The HistoryMakers® presents

ScienceMakers

An Innovative African American Media and Educational Initiative

Toolkit Manual

Volume 3

This material is based upon work supported by the National Science Foundation under Grant No. DRL-0917612. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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The HistoryMakers® ScienceMakers Toolkit

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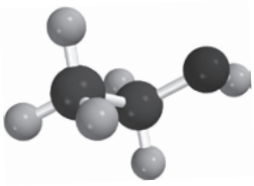

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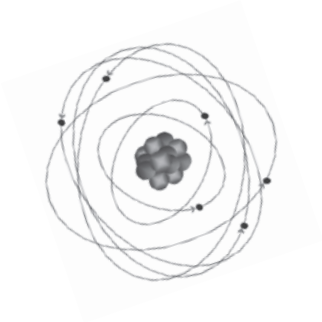

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The HistoryMakers® ScienceMakers Toolkit

Dear *ScienceMakers* Toolkit Users:

In August of 2009, *The HistoryMakers*, the nation's largest African American video oral history archive, was awarded a $2.3 million three-year grant from the National Science Foundation to create *ScienceMakers*, an innovative African American media and education initiative focused on capturing and preserving the stories of African Americans in the STEM (Science, Technology, Engineering and Math) professions. *The HistoryMakers* is a national 501(c)(3) non-profit educational institution founded in 1999 committed to preserving, developing, and providing easy access to an internationally recognized archival collection of thousands of African American video oral histories.

Many are unaware of the contributions of African Americans in the STEM professions. This lack of knowledge adversely affects our youth and their perceptions of the STEM professions. *ScienceMakers* will disseminate the stories of STEM professionals to youth and adult audiences through the internet, public programs, and innovative uses of new technologies. We see the lives of these scientists and their careers as a gateway to greater numbers of youth pursuing STEM careers. We also hope that it will result in an increased interest and awareness of the accomplishments of African American scientists.

This 2012 *ScienceMakers* Toolkit is the third volume of a three-part series of *ScienceMakers* Toolkits. The three volumes of the Toolkit feature 203 scientists. Volume 1 was created in 2009 and profiled thirty-four scientists. Volume 2 was written in 2010 and profiled seventy-three scientists. This Toolkit, Volume 3, was created in 2012 and profiles ninety-six scientists. Like the previous volumes, Volume 3 is also intended to be a career and educational resource. Among its pages, you will find Charles Bolden of NASA, Wanda Austin of the Aerospace Corporation, and Evelyn Granville, the second African American woman to earn her Ph.D. in mathematics. Others include Lonnie Johnson, inventor of the Supersoaker, and Bernard Harris, the first African American astronaut to do a space walk.

Please send all comments, questions, and suggestions to info@thehistorymakers.com.

Thank you for your support of STEM education. We hope you enjoy the ScienceMakers Toolkit. Read on and spread the word!

Sincerely,

Julieanna Richardson
Founder & Executive Director
The HistoryMakers
1900 S. Michigan Avenue
Chicago, Illinois 60616

The HistoryMakers® ScienceMakers Toolkit

Purpose & How to Use This Toolkit

What is STEM?

STEM is an acronym for:
Science
Technology
Engineering
Mathematics

What is the ScienceMakers Mission?

The mission of *The HistoryMakers*' ScienceMakers initiative is to provide youth and adults with:

1. Exposure to successful African American STEM scientists as role models;
2. Increased knowledge about African American contributions to the STEM professions;
3. Increased information on STEM-related careers;
4. Increased awareness of STEM concepts and STEM career opportunities;
5. Improved 21st century learning skills; and
6. Inspiration for lifelong interest in science and in the STEM professions.

What Is A ScienceMaker?

A ScienceMaker is:

- African American by descent.
- A person who by his/her own accomplishments has made significant contributions to research, education, or some other aspect of a STEM discipline.

The Purpose

The ScienceMakers Toolkit is designed to be a resource; it is not a substitute for formal science curriculum, but rather a **career resource and biographical guide to African American scientists**.

How to Use the ScienceMakers Toolkit

There are 96 ScienceMakers featured in this Toolkit. The Toolkit is divided into eight sections including Biology, Chemistry, Computer Science, Engineering, Mathematics, Physics, Space Science, and Administration and Education. Each section contains biographies of leading African American scientists as well as three classroom activities.

At the beginning of the Toolkit, an **Index of Activities** is included, with a list of activities from each section as well as the online resources where the original activity can be found. Activities indicated with "1" are from *ScienceBuddies.org*, a comprehensive resource for science experiments and projects. Those indicated with "2" are from *TeachEngineering.org*, a collaborative project to create a digital library of engineering resources.

The career pages for each section provide information about sub-disciplines of STEM fields as well as an outline of career paths for each field. It also lists specific ScienceMakers by occupation and location. On

each career page are **photographs** related to that STEM field. The photographs are intended to illustrate the STEM field and make the Toolkit more relatable and digestible for a young audience.

ScienceMakers Spotlights highlight each ScienceMaker's life and career. Each Spotlight contains:

- Table
- ScienceMaker Biography
- Science In Action Box
- In His/Her Own Words (in select ScienceMakers Spotlights)
- Discussion Questions
- Glossary

The Table appears at the beginning of each ScienceMakers Spotlight page. It provides basic biographical information on each ScienceMaker.

The Biography provides important information on each ScienceMaker's life and professional development.

The Science In Action Box highlights the scientist's work/field in a way that is accessible and exciting to students. It also shows the importance of the work by relating it to everyday circumstances when applicable.

A number of ScienceMakers Spotlights also feature an **"In His/Her Own Words"** section in which a quote from the scientist is highlighted to provide information about their background, or advice for students who are interested in a scientific career. These quotes are taken from the scientists' presentations at *ScienceMakers* Public Programs around the country.

The Discussion Questions are designed to engage young readers by getting them to think, not only about the ScienceMaker, but about the ScienceMaker's work and its importance. The first question asks students to think about how they would interview the ScienceMaker, incorporating oral history, an important aspect of *The HistoryMakers*' mission. The second question directs students to an online resource where they can learn more about the ScienceMaker's work or an organization within which the ScienceMaker participates. The third and fourth questions are designed to generate group discussion by encouraging creative thinking or asking questions about significance. The fifth and final question asks students to compare the ScienceMaker's career to that of other ScienceMakers in the Toolkit.

The Glossary provides definitions for:

- Scientific disciplines (i.e. electrical engineering)
- Scientific terms (i.e. polymer)
- STEM organizations (i.e. National Science Foundation)
- General vocabulary (i.e. patent, tenured)

Glossary terms are underlined in each biography or Science in Action Box. Definitions, for the most part, are written at a middle to high school level.

The Activities, based on the general field of study, provide hands-on demonstrations that introduce students to new STEM fields. Each activity lists the suggested grade level, the time required, and the approximate cost.

In the back of your *ScienceMakers* Toolkit, you will find:

- ScienceMakers Oral History Guidelines
- ScienceMakers Media Guide
- A list of online resources relating to the material in this Toolkit

The HistoryMakers® ScienceMakers Toolkit

Index of Activities

Section	Activity	Grade Level	Pg.
Biology	Effects of Exercise: Changes in Carbon Dioxide Output[1]	7-10	36
	Liver Stinks[1]	3+	41
	Plants on the Move! Experiments with Phototropism[1]	6-8	44
Chemistry	Balloon Morphing: How Gases Contract and Expand[1]	6-8	89
	Maple Syrup for Pancakes, Waffles and...Crystal Candy?[1]	6-8	94
	Plop, Plop, Fizz Fast: The Effect of Temperature on Reaction Time[1]	4+	97
Computer Science	Artificial Intelligence: Teaching the Computer to Play Tic-Tac-Toe[1]	7-9	122
	Help! What File Format Should I Use to Save My Favorite Photo?[1]	6-8	132
	Quick Draw McPaws: Teaching a Computer Kitty How to Draw Shapes[1]	7-9	136
Engineering	Design, Build and Test Your Own Landfill[2]	5-7	187
	How Does a Hovercraft Work?[1]	K+	197
	Two-Cell Battery[2]	3-5	201
Mathematics	20/20 Vision[2]	3-5	242
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Physics	Building Roller Coasters[2]	7-9	299
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Space Science	Dirty SnowBalls[1]	5-7	342
	Slingshot to the Outer Planets[2]	3-5	347
	Spacecraft Design: Beat the Heat[2]	3-5	353

1. Activities from:

SCIENCE BUDDIES

www.sciencebuddies.org

2. Activities from:

TEACH Engineering Resources for K-12

www.teachengineering.org

The HistoryMakers® ScienceMakers Toolkit

Index of ScienceMaker Birthdays & Birthplaces

By Birth Date

Name	Birth Date	Birthplace
Evelyn Granville	5/1/1924	Washington, D.C.
Rubye Torrey	2/18/1926	Sweetwater, Tennessee
Carl Rouse	7/14/1926	Youngstown, Ohio
James Letton	1933	Paris, Kentucky
Herman Smith	2/9/1933	Fayetteville, North Carolina
John Slaughter	3/16/1934	Topeka, Kansas
Jeannette Brown	5/13/1934	Bronx, New York
Clarence Elder	1935	Georgia
Linnaeus Dorman	6/28/1935	Orangeburg, South Carolina
Gloria Hewitt	10/26/1935	Sumter, South Carolina
Fillmore Freeman	1936	Lexington, Mississippi
Arnold Stancell	11/16/1936	New York, New York
Lucius Walker	1937	Washington, D.C.
Essex Finney	5/16/1937	Powhatan County, Virginia
Gloria Long Anderson	11/5/1938	Altheimer, Arkansas
Percy Pierre	1/3/1939	Welcome, Louisiana
Floyd Williams	9/20/1939	Kansas City, Missouri
DeAnna Banks Beane	1/25/1940	Washington, D.C.
Howard Adams	3/28/1940	Pittsylvania County, Virginia
Donald St. Mary	7/22/1940	Lake Charles, Louisiana
James Donaldson	1941	Madison County, Florida
Wesley Harris	10/29/1941	Richmond, Virginia
Daniel Akins	1942	-
Homer Neal	6/13/1942	Franklin, Kentucky
George Philander	8/25/1942	Calendon, South Africa
Ronald Goldsberry	9/12/1942	Wilmington, Delaware
Barry Johnson	1943	-
Raymond Johnson	6/25/1943	Alice, Texas
James Mitchell	11/16/1943	Durham, North Carolina
Sondra Akins	3/16/1944	Winston-Salem, North Carolina
Georgia Mae Dunston	8/4/1944	Norfolk, Virginia
George Langford	8/24/1944	Roanoke Rapids, North Carolina
Isaiah Blankson	9/28/1945	Cape Coast, Ghana
Walter Hill	8/9/1946	New Brunswick, New Jersey

Charles Bolden	8/19/1946	Columbia, South Carolina
John Hall	9/24/1946	Birmingham, Alabama
Andrea Lawrence	10/6/1946	Asheville, North Carolina
James Johnson	5/27/1947	Annapolis, Maryland
Sylvia Bozeman	8/1/1947	Camp Hill, Alabama
Godfrey Gumbs	9/7/1948	Georgetown, Guyana
Ilesanmi Adesida	1949	Ifon, Ondo, Nigeria
Roscoe Giles	1949	Oakland, California
Jennie Patrick	1/1/1949	Gadsen, Alabama
Matthew George	2/15/1949	Birmingham, Alabama
Legand Burge	8/3/1949	Oklahoma City, Oklahoma
Lonnie Johnson	10/6/1949	Mobile, Alabama
Carlos Handy	10/18/1950	Havana, Cuba
Michael Spencer	3/9/1952	Detroit, Michigan
Albert Crenshaw	3/20/1952	Philadelphia, Pennsylvania
Woodrow Whitlow	12/13/1952	Inkster, Michigan
Steven Richardson	7/22/1953	Brooklyn, New York
Wanda Austin	8/9/1953	New York, New York
William Walden	1954	-
Calvin Howell	12/7/1955	Warrenton, North Carolina
William Massey	1956	Jefferson City, Missouri
Bernard Harris	6/26/1956	Temple, Texas
Fedora Sutton	3/3/1957	St. Joseph, Trinidad, Republic of Trinidad and Tobago
Sharon Neal	1958	-
Gregory Robinson	5/2/1958	Alexandria, Alabama
Peter Delfyett	3/8/1959	Queens, New York
Ketevi Assamagan	3/12/1963	Gabon
Scott Edwards	7/7/1963	Honolulu, Hawaii
Joycelyn Harrison	1964	-
Arlie Petters	2/8/1964	Dangriga, Belize
Gary May	5/17/1964	St. Louis, Missouri
Paul Guèye	7/8/1966	Senegal
Sossina Haile	7/28/1966	Addis Ababa, Ethiopia
Ralph Etienne-Cummings	1967	Victoria, Seychelles
Krishna Foster	1/7/1970	Culver City, California
Ayanna Howard	1/24/1972	Providence, Rhode Island
Trachette Jackson	7/24/1972	-
Idris Assani	-	Niger
Shermane Austin	-	-
Diola Bagayoko	-	-
Sharon Barnes	-	Texas
Roosevelt Calbert	-	Philadelphia, Mississippi
Hattie Carwell	-	Ashland, Virginia

James Curry	-	Oakland, California
William Evans	-	-
Nancy Glenn	-	Charleston, South Carolina
Joseph Gordon	-	Nashville, Tennessee
Albert Green	-	-
Fern Hunt	-	New York, New York
Anthony Joseph	-	-
Julius Jackson	-	-
Walter Lowe	-	North Carolina
Charles McGruder	-	-
Joseph Monroe	-	-
Alfred Msezane	-	South Africa
Sekazi Mtingwa	-	-
James Shoffner	-	-
Cardinal Warde	-	-
Barbara Williams	-	-
Herbert Winful	-	London, England

By Birthplace (sorted by state then city)

Name	Birth Date	Birth State	Birth City
Gregory Robinson	5/2/1958	Alabama	Alexandria
Matthew George	2/15/1949	Alabama	Birmingham
John Hall	9/24/1946	Alabama	Birmingham
Sylvia Bozeman	8/1/1947	Alabama	Camp Hill
Jennie Patrick	1/1/1949	Alabama	Gadsen
Lonnie Johnson	10/6/1949	Alabama	Mobile
Gloria Long Anderson	11/5/1938	Arkansas	Altheimer
Krishna Foster	1/7/1970	California	Culver City
James Curry	-	California	Oakland
Roscoe Giles	1949	California	Oakland
DeAnna Banks Beane	1/25/1940	D.C.	Washington
Evelyn Granville	5/1/1924	D.C.	Washington
Lucius Walker	1937	D.C.	Washington
Ronald Goldsberry	9/12/1942	Delaware	Wilmington
James Donaldson	1941	Florida	Madison County
Clarence Elder	1935	Georgia	-
Scott Edwards	7/7/1963	Hawaii	Honolulu
John Slaughter	3/16/1934	Kansas	Topeka
Homer Neal	6/13/1942	Kentucky	Franklin
James Letton	1933	Kentucky	Paris
Donald St. Mary	7/22/1940	Louisiana	Lake Charles
Percy Pierre	1/3/1939	Louisiana	Welcome
James Johnson	5/27/1947	Maryland	Annapolis
Michael Spencer	3/9/1952	Michigan	Detroit
Woodrow Whitlow	12/13/1952	Michigan	Inkster
Fillmore Freeman	1936	Mississippi	Lexington
Roosevelt Calbert	-	Mississippi	Philadelphia
William Massey	1956	Missouri	Jefferson City
Floyd Williams	9/20/1939	Missouri	Kansas City
Gary May	5/17/1964	Missouri	St. Louis
Walter Hill	8/9/1946	New Jersey	New Brunswick
Jeannette Brown	5/13/1934	New York	Bronx
Steven Richardson	7/22/1953	New York	Brooklyn
Wanda Austin	8/9/1953	New York	New York
Fern Hunt	-	New York	New York
Arnold Stancell	11/16/1936	New York	New York
Peter Delfyett	3/8/1959	New York	Queens
Andrea Lawrence	10/6/1946	North Carolina	Asheville
James Mitchell	11/16/1943	North Carolina	Durham
Herman Smith	2/9/1933	North Carolina	Fayetteville
George Langford	8/24/1944	North Carolina	Roanoke Rapids
Calvin Howell	12/7/1955	North Carolina	Warrenton

Sondra Akins	3/16/1944	North Carolina	Winston-Salem
Walter Lowe	-	North Carolina	-
Carl Rouse	7/14/1926	Ohio	Youngstown
Legand Burge	8/3/1949	Oklahoma	Oklahoma City
Albert Crenshaw	3/20/1952	Pennsylvania	Philadelphia
Ayanna Howard	1/24/1972	Rhode Island	Providence
Nancy Glenn	-	South Carolina	Charleston
Charles Bolden	8/19/1946	South Carolina	Columbia
Linnaeus Dorman	6/28/1935	South Carolina	Orangeburg
Gloria Hewitt	10/26/1935	South Carolina	Sumter
Joseph Gordon	-	Tennessee	Nashville
Rubye Torrey	2/18/1926	Tennessee	Sweetwater
Raymond Johnson	6/25/1943	Texas	Alice
Bernard Harris	6/26/1956	Texas	Temple
Sharon Barnes	-	Texas	-
Hattie Carwell	-	Virginia	Ashland
Georgia Mae Dunston	8/4/1944	Virginia	Norfolk
Howard Adams	3/28/1940	Virginia	Pittsylvania County
Essex Finney	5/16/1937	Virginia	Powhatan County, Virginia
Wesley Harris	10/29/1941	Virginia	Richmond
Daniel Akins	1942	-	-
Shermane Austin	-	-	-
Diola Bagayoko	-	-	-
William Evans	-	-	-
Albert Green	-	-	-
Joycelyn Harrison	1964	-	-
Wendell Hill	-	-	-
Julius Jackson	-	-	-
Trachette Jackson	7/24/1972	-	-
Barry Johnson	1943		
Anthony Joseph	-	-	-
Charles McGruder	-	-	-
Joseph Monroe	-	-	-
Sekazi Mtingwa	-	-	-
Sharon Neal	1958	-	-
James Shoffner	-	-	-
Arthur Thorpe	-	-	-
William Walden	1954	-	-
Cardinal Warde	-	-	-
Barbara Williams	-	-	-

Foreign-born ScienceMakers:

Name	Birthday	Birth Country	Birth City
Arlie Petters	2/8/1964	Belize	Dangriga
Carlos Handy	10/18/1950	Cuba	Havana
Herbert Winful	-	England	London
Sossina Haile	7/28/1966	Ethiopia	Addis Ababa
Ketevi Assamagan	3/12/1963	Gabon	-
Isaiah Blankson	9/28/1945	Ghana	Cape Coast
Godfrey Gumbs	9/7/1948	Guyana	Georgetown
Idris Assani	-	Niger	-
Ilesanmi Adesida	1949	Nigeria	Ifon
Fedora Sutton	3/3/1957	Republic of Trinidad and Tobago	St. Joseph
Paul Guèye	7/8/1966	Senegal	-
Ralph Etienne-Cummings	1967	Seychelles	Victoria
Alfred Msezane	-	South Africa	-
George Philander	8/25/1942	South Africa	Calendon

Biology

Biology literally means "the study of life." This scientific discipline investigates all aspects of living organisms including their growth, anatomy, behavior, origin, evolution, and distribution.

Biologists include all those who look at life, from zoologists, who study animals and their interactions, to biochemists, who research cellular processes involving proteins, hormones, genes, and DNA.

Studying biology teaches you how to observe the world around you, ask questions, hypothesize, gather and analyze information, and solve problems. The work of career biologists is critical in addressing worldwide issues such as human health and the environment.

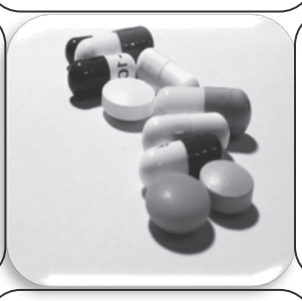
Biological Disciplines

Life Science includes many exciting fields to study and research. Here are just a few…

Microbiology is the study of microbes, organisms that live all around us but cannot be seen without a microscope; for example, bacteria, viruses, and fungi.

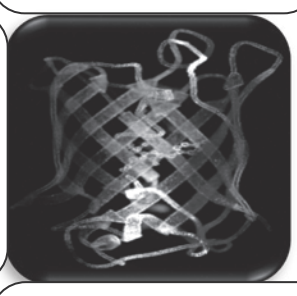
Biochemistry is the study of chemical processes that occur in living organisms, such as how food is broken down to create energy for the body.

Evolutionary biology is the study of how organisms originated from a common ancestor and how they have changed over time.

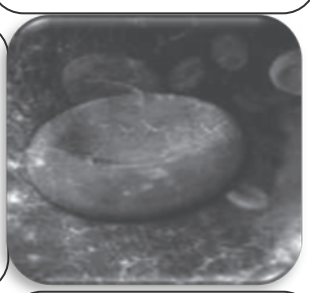


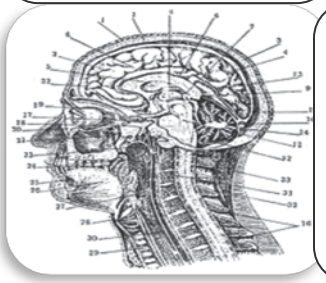
Pharmacology is the study of the uses and effects of drugs, particularly how drugs can be used to treat diseases.

Molecular Biology is the study of the formation, structure, and function of cells and their components, such as proteins and lipids.



Immunology is the study of our body's natural defense against disease, called the immune system. Major components include red and white blood cells, and antibodies.





Neuroscience is the study of how the body transmits and receives signals through the nervous system. Major components of the nervous system include the brain and spinal cord.

Physiology is the science of how living systems function. It includes the chemical and physical processes of organs, cells, and molecules.

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Career Paths in Biology

Biology covers a range of careers in many different areas. Below are just a few jobs open to those with a biology degree. See how each job fits into the larger career paths of Academia, Business & Industry and Healthcare.

Academia

Educators can work in settings such as school classrooms, universities, research labs, nature parks, or museums.

- *Biology Professors* at colleges or universities teach and mentor students and conduct research.
- *Nature Center Educators* design exhibits, lead nature tours, and teach specialized classes.
- *Media Prep Technician*s work in university laboratories to assist graduate students with their research by preparing common chemicals and solutions used in scientific experiments.

Business & Industry

Biologists can work for companies that develop, manufacture, and test new products. They also contribute to the marketing, sales, and public relations departments.

- *Plant Breeders* work at agricultural companies to create new and improved plant varieties such as corn that can grow in dry climates.
- *Food Safety Specialists* work to make sure food products are safe to consume; for example, testing the bacterial content of milk.
- *Biofuels Product Developers* work to create fuels from natural sources such as corn and soybeans instead of fossil fuels which pollute the air.

Healthcare

Biologists can work in hospitals and doctor's offices. They treat patients with illnesses such as AIDS, cancer, diabetes, and heart disease.

- *Pathologists* work in hospital laboratories studying the cause and development of disease.
- *Physical Therapists* treat injuries with exercises and other physical treatments. Some physical therapists work in a nursing home helping stroke patients walk again.
- *Genetic Counselors* work with doctors to help families make choices based on their genetic history (e.g. family history of Alzheimer's, diabetes, or types of cancer). They examine a patient's DNA to look for genes related to certain diseases.

Check Out Our Featured Biologists!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
Albert Crenshaw	Muscle Physiologist	University of Umea	Muscle Pain	19
Georgia Mae Dunston	Microbiologist	Howard University	"Out of Africa" Theory	21
Scott Edwards	Evolutionary Biologist	Harvard University	Bird Evolution	23
Matthew George	Biochemist	Howard University	Mitochondrial DNA	26
Julius Jackson	Microbiologist	Michigan State University	Bacterial Genomes	28
George Langford	Cell Biologist	Syracuse University	Ernest Everett Just	30
Fedora Sutton	Molecular Biologist	South Dakota State University	Plant Timekeeping	32
William Walden	Molecular Biologist	University of Illinois at Chicago	Gene Regulation	34

ScienceMakers Spotlight

Albert Crenshaw

Muscle Physiologist

Birth Date	March 20, 1952
Birth Place	Philadelphia, Pennsylvania
Education	West Virginia University (B.S. 1977)
	University of Umeå, Sweden (Ph.D. 1994)
Awards & Achievements	NASA Laboratory Manager Certificate of Recognition (1990)
	American Scandinavian Foundation Grant (1990)
	Swedish Association for Medical Research Grant (1992 - 1993)

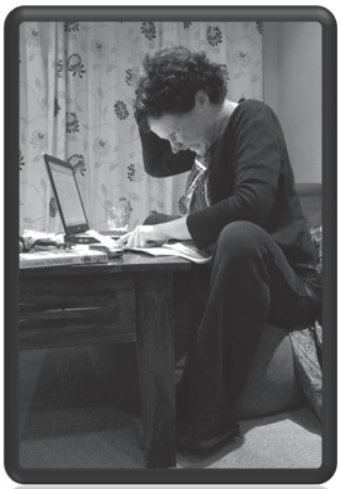
BIOGRAPHY

Albert Crenshaw was the first African American to receive his Ph.D. degree in medical sciences in Sweden. Crenshaw was born in Philadelphia, Pennsylvania on March 20, 1952. His father was a construction worker and his mother a domestic worker. Crenshaw's basketball skills earned him a scholarship to Chowan Junior College where he earned his associate's degree in 1973. He then went on to receive his B.S. degree in biology from West Virginia University in 1977. Crenshaw wanted to pursue a medical career and moved to San Diego, California, to work as a research technician at the University of California, San Diego in an orthopedic research lab. While there, Crenshaw also studied abroad in Gothenburg, Sweden for eight months in a lab exchange program. In 1989, he relocated with the lab to the National Aeronautics and Space Administration (NASA) outside of San Francisco, California. During the year at NASA, he accepted a position as a Ph.D. student again in Sweden, but this time in the town of Umeå where he earned his Ph.D. degree in 1994.

Human Muscle
by 416style @Flickr

Crenshaw's Ph.D. thesis was entitled, *Intramuscular Pressure Techniques for Studying Delayed Onset Muscle Soreness*. This paper built on research that Crenshaw had completed during his time at the orthopedic research lab, where he helped test and modify a method for measuring the fluid pressure between muscle fibers by putting a small tube directly into the muscle. Two years after finishing his Ph.D. degree, Crenshaw accepted a position as an assistant professor of physiology at the Swedish National Institute for Working Life in the Centre for Musculoskeletal Research. In 2000, he became an associate professor at the Centre for Musculoskeletal Research at the University of Gävle in Umeå, Sweden. Throughout his career, Crenshaw has contributed to over fifty scientific articles. Albert Crenshaw resides in Umeå with his wife and two children.

A PAIN IN THE NECK



Neck Pain
by Phil and Pam @Flickr

Ever wonder why your shoulders start to hurt when you are typing at your computer for hours upon hours? Albert Crenshaw's research on muscle physiology helps us understand the physiological mechanism for work-related muscle pain. His work is important because muscle pain can cause people to take extensive sick-leave from work or even retire early. Blood vessels transport oxygen and nutrients to our muscles, so they are essential for proper muscle function. However, when fluid pressure in the muscle increases, blood vessels become constricted, causing delayed onset muscle soreness. This can happen when an adult goes to work in the garden all day for the first time in the spring. The next morning they will be very sore and stiff.

DISCUSSION QUESTIONS

1. If you were to interview Albert Crenshaw, what questions would you ask him?
2. Check out the Kids Health website (http://kidshealth.org/kid/htbw/) and explore the human body. What are three things you learned about muscles?
3. The human muscular system works with the skeletal system to create movement. Can you name three muscles in the human body? What actions do these muscles help you perform?
4. Albert Crenshaw does research on muscle pain. Why is this important and in what ways can it help the working public?
5. How does Albert Crenshaw's career compare to that of other biologists in the Toolkit?

GLOSSARY

Blood Vessels - Tubes in the human body that carry blood to and from the heart

Fluid Pressure - The act of liquids in the body building up in a small space and pushing on the structures around it

Muscle Fibers - Long, thin tubes made up of muscle cells that are bundled together to form a strand; many strands then make up a muscle

Orthopedic - Of or pertaining to the branch of medicine that involves disorders of the spine and joints

Physiology - The study of how an organism functions, internally and externally including the chemical and physical processes of organs, cells, and molecules

Swedish National Institute for Working Life - A research organization that focuses on disorders to the muscles, bones, and joints caused by working conditions

ScienceMakers Spotlight

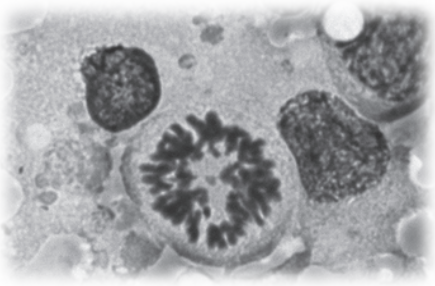
Georgia Mae Dunston

Microbiologist

Birth Date	August 4, 1944
Birth Place	Norfolk, Virginia
Education	Norfolk State University (B.S. 1965)
	Tuskegee University (M.S. 1967)
	University of Michigan (Ph.D. 1972)
Awards & Achievements	Howard University College of Medicine Outstanding Research Award (1990)
	NAACP Science Achievement Award (1990)
	Howard University Graduate School of Arts and Sciences Outstanding Graduate Faculty Member Award (1998)

BIOGRAPHY

Georgia Mae Dunston studies human genetics, particularly in African Americans, in order to answer her childhood question, "Why are people different?" Dunston was born in Norfolk, Virginia on August 4, 1944 to a mother and father who had humble, working-class jobs. Dunston developed an interest in the biology of race and decided to continue her study of biology after graduating from high school. She earned her B.S. degree in biology from Norfolk State University in 1965 and her M.S. degree in biology from Tuskegee University in 1967. Dunston went on to study at the University of Michigan, finishing her Ph.D. degree in human genetics in 1972. She then accepted a position at Howard University Medical Center as an assistant professor.



Cell Division in a Cancer Cell by euthman @Flickr

From 1975 to 1976, Dunston completed a postdoctoral fellowship at the National Cancer Institute where she studied tumor immunology. She later served as a scientist there in an immunodiagnosis lab that was partly funded by the National Institutes of Health (NIH). At Howard, Dunston was appointed director of the human immunogenetics laboratory in 1985. At this time, she focused her research on diseases that are common in the black community as well as genes and immune reactions that are unique to African American populations. From 1991 to 1994, Dunston served as associate director of the Division of Basic Sciences at Howard University Cancer Center. She was promoted to full professor in the Department of Microbiology at Howard in 1993 and became chair of the department in 1998. Inspired by the Human Genome Project, begun in 1990, Dunston focused her attention on the genetic heritage of the African American population. Dunston's work in human genetics and diversity resulted in her founding the National Human Genome Center at Howard in 2001. Georgia Mae Dunston lives in Washington, D.C.

Above Picture of Georgia Mae Dunston from www.andover.edu/About/PAToday/Pages/TheWorldComestoAndover.aspx

SCIENCE IN ACTION

OUT OF AFRICA

Human Origins
by midwestnerd@Flickr

Many scientists believe that modern human life began in East Africa about 100,000 years ago. According to fossil evidence, world populations formed when groups migrated out of Africa to different areas over thousands of years. In recent history, the slave trade interrupted those natural migration patterns, causing many Africans to be suddenly and forcibly displaced to the Americas. As a result, the gene pool of African Americans today is of great interest to geneticists like Georgia Mae Dunston. She conducts research to find out why diseases like prostate cancer and hypertension are more prevalent in the black community. Dunston's ultimate goal is to address the issue of racial and ethnic barriers in the healthcare industry.

DISCUSSION QUESTIONS

1. If you were to interview Georgia Mae Dunston, what questions would you ask her?
2. Check out The University of Utah's genetics website (http://learn.genetics.utah.edu/). What did you learn about genes and DNA?
3. Prostate cancer and hypertension are hereditary diseases that can be inherited from a parent. Can you think of other diseases that are hereditary?
4. Georgia Mae Dunston studies genetics in African American populations. Why is it important to include all races in a human genome study?
5. How does Georgia Mae Dunston's career compare to that of other biologists in the Toolikit?

GLOSSARY

Genes - The functional unit of heredity or inherited characteristics; composed of deoxyribonucleic acid (DNA)

Genetics - The study of inherited characteristics and how they vary between species and within organisms of the same species

Human Genome Project - An international research endeavor to represent the sequence of genes on a chromosome, or map the entire genetic material of the human species

Human Immunogenetics - The study of the human body's natural defense system and how it is affected by inherited characteristics

Immunodiagnosis - The confirmation that someone suffers from a particular disease based on reactions of their immune system

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

Tumor Immunology - The study of the interaction between cancer cells and the human immune system

ScienceMakers Spotlight

Scott Edwards

Evolutionary Biologist

Birth Date	July 7, 1963
Birth Place	Honolulu, Hawaii
Education	Harvard University (B.A. 1986)
	University of California, Berkeley (Ph.D. 1992)
Awards & Achievements	National Evolutionary Synthesis Center Advisory Board Member
	Conservation Genetics and *Molecular Biology and Evolution* Editorial Board Member
	American Association for the Advancement of Science (AAAS) Fellow (2009)

BIOGRAPHY

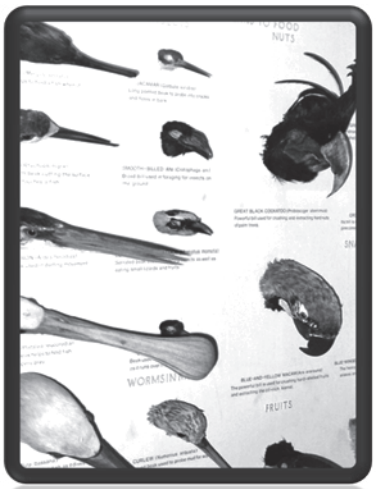
Scott Edwards has worked as an evolutionary biologist in order to answer questions about how animals live and how they change over time. Edwards was born on July 7, 1963 in Honolulu, Hawaii. He grew up in the Bronx, New York, and as a child he was fascinated by plants and animals. Edwards attended Harvard University where he earned his B.A. degree in biology in 1986. During college, Edwards also found time to work at an environmental institute and volunteer at the Smithsonian National Museum of Natural History in Washington, D.C. where he developed an interest in birds. After graduating from Harvard, Edwards studied bird evolution at the University of California, Berkeley where he earned his Ph.D. degree in zoology in 1992. For his research dissertation, Edwards spent ten months in Australia and New Guinea to investigate differences in three groups of songbirds called babblers by comparing their DNA.

White-browed Babbler 1
by aardvaark@Flickr

Edwards then moved to the University of Florida where he received an Alfred P. Sloan postdoctoral fellowship to study bird genetics. In 1994, he became an assistant professor of zoology at the University of Washington, Seattle as well as curator of genetic resources at the University's Burke Museum. In 2003, he served as professor of organismic and evolutionary biology at Harvard University as well as curator of ornithology at the Museum of Comparative Zoology. In 2010, Edwards co-hosted the SyFy television series *Beast Legends*, reconstructing what mythological creatures may have looked like based on first-person accounts, archaeological evidence, and scientific data. He has published over one-hundred scientific research papers. Scott Edwards lives with his wife, Elizabeth Adams. They have two daughters, Kayla and Liana.

SCIENCE IN ACTION

EVOLUTION IN ACTION



Evolution of Beaks to Food
by uncoolbob@Flickr

Ever wonder why an ostrich and a blue jay are so different? Many factors, like changing habitats, can cause new types of birds to develop over long periods of time. The picture on the left shows how bird beaks evolved depending on the food source. Scott Edwards' research focuses on speciation, or how different species of birds came to be. By studying a complete set of DNA from a chicken, Edwards and other scientists want to know what changes are happening at the molecular level when bird species diversify. Bird speciation can also happen at the behavioral level, such as when male or female birds select mates based on preferred characteristics.

IN HIS OWN WORDS

Scott Edwards spoke at the Detroit Science Center for a program with The HistoryMakers on February 17, 2011. Here is a portion of his presentation:

"Just a little bit of background of how I got into science, I grew up in New York City and when I was about six we moved to a part of the Bronx known as Riverdale which was really an interesting place. It was very close to the Hudson River which is a major flyway for migrating birds every spring and a neighbor took me bird watching one morning. Now, you could imagine, I went to an all boys school. In sixth grade, it's not very cool to be a bird watcher. But once I met other scientists, other people interested in natural history and birds, it really encouraged me. Now as a parent, one of my main goals is to get my kids out in the woods, get them off their iPods and into the woods digging in the dirt, looking in the trees. I think we really need to get our kids out because that for me was the big inspiration for becoming a scientist."

DISCUSSION QUESTIONS

1. If you were to interview Scott Edwards, what questions would you ask him?
2. Check out the Discovery Channel website (http://science.discovery.com/interactives/literacy/darwin/darwin.html). What did you learn about evolution from Charles Darwin, the founder of the theory of evolution?
3. DNA is the component of human cells that makes you look different from your classmates. Can you think of physical characteristics like eye color that differ between people?
4. Why is it important for scientists like Scott Edwards to study the evolution of different species?
5. How does Scott Edwards' career compare to that of other biologists in the Toolkit?

GLOSSARY

Curator - A keeper or custodian of a museum or other collection

DNA - Acronym; deoxyribonucleic acid; the genetic material of all living organisms

Evolutionary Biologist - A scientist that studies how organisms have adapted to live in different environments and why organisms of different species look and behave differently

Ornithology - The scientific study of birds

Smithsonian National Museum of Natural History - A natural history museum administered by the Smithsonian Institution, located on the National Mall in Washington, D.C.

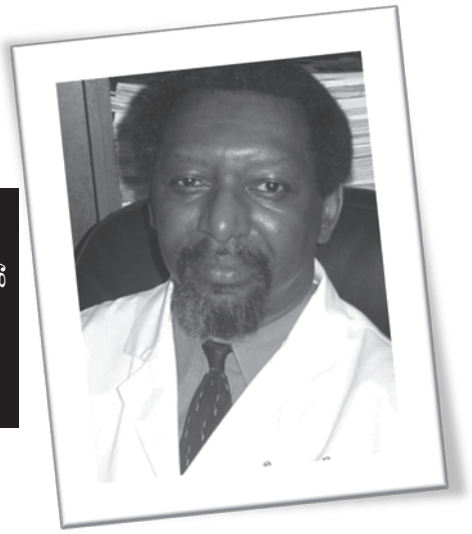
Songbird - A perching bird distinguished by its muscle characteristics

Speciation - The formation of new and distinct species in the course of evolution

ScienceMakers Spotlight

Matthew George

Biochemist

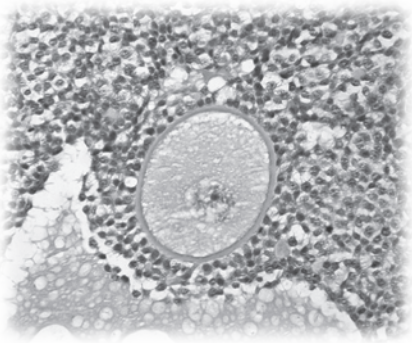


Birth Date	February 15, 1949
Birth Place	Birmingham, Alabama
Education	Wiley College (B.S. 1971)
	Atlanta University (M.S. 1974)
	University of California, Berkeley (Ph.D. 1982)
Awards & Achievements	Smithsonian's Science in American Life exhibit host scientist (1994 - present)
	Howard University Johnetta G. Davis Mentor Award (1994)

BIOGRAPHY

Matthew George's research on mitochondrial DNA earned him a featured spot in the science exhibit, *Science in American Life,* found in the Smithsonian National Museum of American History. George was born on February 15, 1949 in Birmingham, Alabama. After graduating from high school, he earned his B.S. degree in chemistry and biology in 1971 from Wiley College in Marshall, Texas. He then went on to receive his M.S. degree in microbiology and biochemistry in 1974 from Atlanta University (now Clark Atlanta University). In 1982, George earned his Ph.D. degree in biochemistry from the University of California, Berkeley.

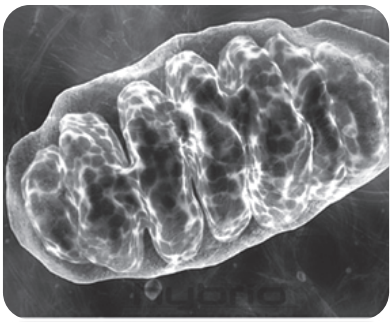
From 1981 to 1984, George studied genetics and biochemistry at the San Diego Zoo and the National Cancer Institute in Frederick, Maryland. His career at Howard University College of Medicine began in 1984 when he became an assistant professor of biochemistry. In 1992, George was promoted to associate professor. George's research focuses on the evolution and interactions of mitochondrial DNA as well as cancer metastasis. He was instrumental in the development of the "Eve hypothesis," a theory that attempts to explain the origin of humankind. George studies the molecular structure and behavior of mitochondrial DNA which traced humans back to a common ancestor that lived in Africa about 200,000 years ago. Between 1995 and 1997, George served as senior scientist on the African Burial Ground Project where he traced 200 year old remains back to West African locations by analyzing DNA from bones. Since 2001, George has served as chair of the Department of Biochemistry and Molecular Biology at Howard University College of Medicine. George has authored numerous scientific research articles and received grant money from prestigious organizations such as the National Institutes of Health (NIH). In addition to his research, George has mentored research students including several prize winners. Matthew George lives in Silver Spring, Maryland, with his wife Yolanda George, an education program director at the American Association for the Advancement of Science (AAAS).



Human Ovary
by euthman @Flickr

SCIENCE IN ACTION

DNA FROM MOTHER



Mitochondria
by biology flashcards @Flickr

You have probably heard about DNA, which contains all of our genetic information. When you were born, 50% percent of your nuclear DNA came from your mother and 50% came from your father. However, there is a structure in our cells called a mitochondrion, which has its own set of DNA. This DNA is special because it is only inherited from the mother. This allows scientists to trace individuals' heritage far back in time to the original location of their ancestors. Using this method, many African Americans have been able to trace their ancestry back to areas of West Africa.

DISCUSSION QUESTIONS

1. If you were to interview Matthew George, what questions would you ask him?
2. Check out *National Geographic*'s human origins website (http://www.nationalgeographic.com/field/projects/human-origins/). What do you find most interesting about the project?
3. Matthew George studied the origin of human kind by looking at mitochondrial DNA. What other types of scientists study human origins?
4. Matthew George conducts cancer research. How can the work of scientists help doctors find a cure for cancer?
5. How does Matthew George's career compare to that of other biologists in the Toolkit?

GLOSSARY

American Association for the Advancement of Science (AAAS) - An international non-profit organization with the stated goals of promoting cooperation between scientists, defending scientific freedom, encouraging scientific responsibility, and supporting scientific education and science

Biochemistry - The study of chemical processes that occur in living organisms such as how food is broken down to create energy for the body

Cancer Metastasis - The development of secondary malignant (diseased) growths at a distance from the primary site of cancer within the body

Genetics - The study of inherited characteristics and how they vary between species and within organisms of the same species

Microbiology - The study of microbes, organisms that live all around us but cannot be seen without a microscope; for example, bacteria, viruses and fungi

Mitochondria - An organelle found in large numbers in most cells, in which the biochemical processes of respiration and energy production occur

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

ScienceMakers Spotlight

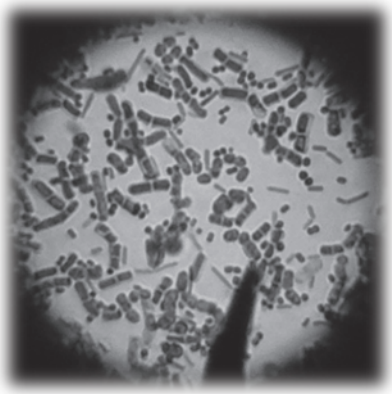
Julius Jackson

Microbiologist

Education	University of Kansas (A.B. 1966, Ph.D. 1969)
Awards & Achievements	William A. Hinton Research Training Award from the American Society for Microbiology (2000)

BIOGRAPHY

Julius Jackson is not only a leader in microbiology research; he also mentors students and directs programs that support students from diverse backgrounds in the scientific fields. He received his A.B. and Ph.D. degrees in microbiology from the University of Kansas in 1966 and 1969, respectively. Following graduation, Jackson completed a National Institutes of Health (NIH) Postdoctoral Fellowship from 1969 to 1971 at Purdue University. Afterwards, he continued to work at Purdue University as a postdoctoral research associate.



Bacteria
by kaibara87 @Flickr

In 1972, Jackson was hired to work at Meharry Medical College in Nashville, Tennessee, where he held a series of positions including chair of the microbiology department. In 1987, he joined the faculty of Michigan State University (MSU) as a professor in the Department of Microbiology and Molecular Genetics and assistant dean in the graduate school. Jackson directs the J-Lab, a research laboratory that uses mathematical and computer models to understand the function of bacterial genes in the cell. He mentors many students in his lab and is an advocate for integrating mathematics into the study of biology. Jackson has published many papers on bacterial genomics and the importance of linking mathematics and biology. As associate dean for Graduate Student Affairs, he directed the Alliance for Graduate Education and the Professoriate (AGEP), a National Science Foundation (NSF)-funded program which recruited and supported doctoral students in the STEM disciplines. He also directed the Committee on Institutional Cooperation (CIC) Summer Research Opportunity Program (SROP). SROP provided research opportunities for students from diverse backgrounds. From 1995 to 1997, he served as director for the Division of Molecular and Cellular Biosciences of the National Science Foundation. Jackson is a fellow of the American Academy of Microbiology and has served on the panels of the National Institutes of Health, National Science Foundation, and the American Society for Microbiology. Julius Jackson works in East Lansing, Michigan.

Above Picture of Julius Jackson from www.msu.edu

SCIENCE IN ACTION

GENOME: A BLUEPRINT FOR AN ORGANISM

Bacteria
by Magoo0311 @Flickr

A blueprint for a house tells the builders about the shape and details of each room. A genome is the blueprint for your body. Genes, made up of DNA, are codes for proteins that are responsible for your appearance and every function in your body. Every cell in your body has a nucleus which contains your whole genome. When you look at a gene under a microsope, you cannot tell what it does in the body. The function of many genes is still unknown. Scientists, like Julius Jackson, study genomes to find out the purpose for each gene. Jackson maps bacterial genomes to see how genes carry out the physiological processes of the organisms.

DISCUSSION QUESTIONS

1. If you were to interview Julius Jackson, what questions would you ask him?
2. Check out Nature's Genome website (http://nature.ca/genome/03/a/03a_e.cfm). How is every organism alike?
3. Humans have 98 % the similarity in DNA as pygmy chimpanzees. Julius Jackson studies bacterial genomes. Do you think humans and bacteria have similar genes? Why or why not?
4. Julius Jackson studies the genes of bacteria. Why is it important to study the function of genes in bacteria?
5. How does Julius Jackson's career compare to that of other biologists in the Toolkit?

GLOSSARY

Bacteria - A single-celled organism with no nucleus; many bacteria cause disease

DNA - Acronym; deoxyribonucleic acid; the genetic material of all living organisms

Genes - The functional unit of heredity or inherited characteristics; composed of deoxyribonucleic acid (DNA)

Genome - The complete set of genes or genetic material present in a cell or organism

Microbiology - The study of microbes, organisms that live all around us but cannot be seen without a microscope; for example, bacteria, viruses, and fungi

Physiological - The functions and processes of an organism

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

ScienceMakers Spotlight

George Langford

Cell Biologist

Birth Date	August 24, 1944
Birth Place	Roanoke Rapids, North Carolina
Education	Fayetteville State University (B.S. 1966)
	Illinois Institute of Technology (M.S. 1969, Ph.D. 1971)
Awards & Achievements	American Society for Cell Biology Ernest Everett Just Lectureship Award (1994)
	University of North Carolina, Chapel Hill SPIRE Distinguished Scholar (2003)
	Illinois Institute of Technology Professional Achievement Award (2009)

BIOGRAPHY

George Langford has held biology faculty positions at several prestigious universities around the United States. He was born on August 26, 1944 in Roanoke Rapids, North Carolina and grew up on a small farm with nine siblings. Langford excelled at math in high school and was fascinated by the shapes and structures found under the microscope. He studied biology at Fayetteville State University and earned his B.S. degree in 1966. Despite the lack of laboratory facilities, Langford had good mentors who persuaded him to attend graduate school. He earned his M.S. degree in 1969 and his Ph.D. degree in 1971, both in cell biology from the Illinois Institute of Technology (IIT). At IIT, Langford developed his research skills and studied nerve and brain cells. He finished his postdoctoral training in 1973 from the cell biology program at the University of Pennsylvania as a National Institutes of Health (NIH) Fellow.

Nerve Cell Pattern by zooboing @Flickr

In 1973, Langford joined the faculty of the University of Massachusetts as a professor of cell biology and conducted research at the Marine Biological Laboratory at Woods Hole, Massachusetts, in 1976. He continued his career in academia, teaching at Howard University in 1977 and the University of North Carolina, Chapel Hill in 1979. Langford's research focused on the nerves of invertebrates as well as cellular motility. He was honored with an appointment to the National Science Foundation (NSF) where he served as director of cell biology from 1988-1989. In 1991, Langford joined the faculty of Dartmouth College as the Ernest Everett Just Chair in Natural Sciences. Between 2005 and 2008, Langford worked at the University of Massachusetts, Amherst as dean of the College of Natural Sciences and Mathematics. In 2008, he was hired to work at Syracuse University as dean of the College of Arts and Sciences. George Langford lives in Syracuse, New York.

Above Picture of George Langford from www.bwfund.org/pages/417/Awards-and-Accolades---July-2009/

SCIENCE IN ACTION

JUST AND LANGFORD: SCIENCE VISIONARIES

Ernest Just
by mbl.edu

George Langford
by mbl.edu

George Langford's career has followed in the footsteps of Dr. Ernest Everett Just, a marine cell biologist born on August 14, 1883. Just completed groundbreaking research in cell biology, discovering that cytoplasm plays a crucial role in fertilization. George Langford's research also investigates marine cell biology within nerve cells of giant squids. He discovered a new system of how proteins are moved within a cell by a myosin-like motor. Langford and Just both spent summers at the Marine Biology Lab in Woods Hole researching cell biology.

DISCUSSION QUESTIONS

1. If you were to interview George Langford, what questions would you ask him? If you were to interview Ernest Everett Just, what questions would you ask him?
2. Check out the Neuroscience for Kids website (http://faculty.washington.edu/chudler/cells.html). Why do you think there are different types of neurons (nerve cells)?
3. What kinds of messages do neurons send to your brain from different parts of your body?
4. Why is it important for scientists like George Langford to study cells even though they are tiny?
5. How does George Langford's career compare to that of other biologists in the Toolkit?

GLOSSARY

Cell - The smallest structural and functional unit of an organism; typically microscopic and consisting of cytoplasm, nucleus, and other organelles

Cytoplasm - The liquid inside the cell; contains various organelles with specialized structures that carry out cellular processes

Fertilization - The joining of the male gamete (sperm) and the female gamete (egg)

Invertebrate - An animal lacking a backbone, such as an arthropod or insect, etc., the invertebrate group comprises 95% of animal species

Marine Biological Laboratory - A laboratoy located in Woods, Hole Massachussets, which hosts year-round research programs in cellular, developmental, and reproductive biology; and molecular biology and evolution.

Motility - The ability to move spontaneously and independently

Myosin - A fibrous protein that forms the contracting fibers of muscle cells and is also involved in motion in other types of cells

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

ScienceMakers Spotlight

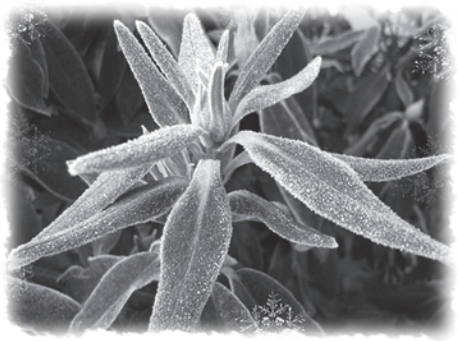
Fedora Sutton

Molecular Biologist

Birth Date	March 3, 1957
Birth Place	St. Joseph, Trinidad, Republic of Trinidad and Tobago
Education	University of Maryland, Baltimore County (B.A. 1982)
	Howard University College of Medicine (Ph.D. 1985)
Awards & Achievements	Howard University Distinguished Ph.D. Alumni Award (1998)
	American Cancer Society award for "Outstanding Service to the Cause of Cancer Control" (2000)
	NSF Certificate of Appreciation for Distinguished Service (2005)

BIOGRAPHY

Fedora Sutton is a molecular biologist who studies the biological processes occurring within plants. She was born on March 3, 1957 and attended elementary, middle, and high school in the Republic of Trinidad and Tobago where she began studying science at an early age. After graduating from high school, Sutton earned her B.A. degree in biochemistry from the University of Maryland, Baltimore County (UMBC) in 1982. She then worked as a technician in the Howard University biochemistry department and received graduate school funding through a research assistantship. Sutton earned her Ph.D. degree in biochemistry and molecular biology from the Howard University College of Medicine in 1985.



Frost on a Plant
by KaCey97007 @Flickr

After earning her Ph.D. degree, Sutton completed postdoctoral research in neurobiology at California Institute of Technology from 1986 to 1987 and the National Institutes of Health (NIH) from 1987 to 1988. During her postdoctoral period, Sutton studied brain function and how organisms respond to their environments. In 1990, Sutton became an assistant professor at South Dakota State University (SDSU). In 1994, she was promoted to associate professor, and since 2001, she has served as full professor in the plant physiology and biochemistry department. When she began her career at SDSU, Sutton switched from studying the biology of the brain to the biology of plants. She looked at plant signaling systems and how plants respond to environmental stressors like frost and drought. She also examined seed dormancy and the timing of sprouting. Sutton wanted to learn enough about plant systems to be able to improve crop production worldwide. She has published countless research articles and received thousands of dollars in funding from SDSU and organizations like the National Science Foundation (NSF). In addition to her research, Sutton also teaches and works in the community. Fedora Sutton works in Brookings, South Dakota. She and her husband have one son.

SCIENCE IN ACTION

PLANT TIMEKEEPING

Cucumber Sprouts
by Plutor @Flickr

How do plants know when to sprout? Can they tell time? Plants rely on abiotic environmental cues such as light, temperature, and moisture. That is why we typically plant in the spring and harvest in the fall, so that plants grow during the warmest time of year. There are certain signals that happen inside the plants' cells. These signals respond to the environment and tell the plant what to do. Scientists, like Fedora Sutton, conduct research to further understand those molecular signals. Armed with this information, scientists can engineer special crops that tolerate very dry weather or very cold weather, making food production in extreme environments more efficient.

DISCUSSION QUESTIONS

1. If you were to interview Fedora Sutton, what questions would you ask her?
2. Check out Delaware State University's Plants for Kids website (http://herbarium.desu.edu/pfk/index.html). Did you learn anything new about plants?
3. Fedora Sutton's research could help farmers around the world? Can you think of three crops grown in the United States that would benefit from Sutton's research and why?
4. Fedora Sutton studies the timing and mechanism of plant processes. Why is it important that plants sprout in time with environmental cues such as amount of light, temperature, and nutrient availability?
5. How does Fedora Sutton's career compare to that of other biologists in the Toolkit?

GLOSSARY

Abiotic - Non-living

Biochemistry - The study of chemical processes that occur in living organisms such as how food is digested to create energy for the body

Cells - The smallest structural and functional unit of an organism; typically microscopic and consisting of cytoplasm and a nucleus

Molecular Biologist - Someone who studies the formation, structure, and function of cells and their components such as proteins and lipids

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Neurobiology - The study of the nervous system including the brain, spinal cord, and nerves; how the body transmits and receives signals through the nervous system

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

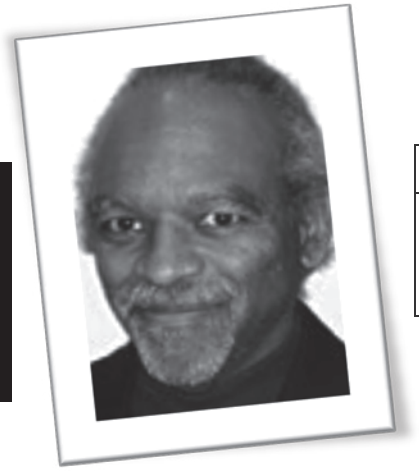
Seed Dormancy - A condition of plant seeds that prevents germinating under optimal environmental conditions

ScienceMakers Spotlight

William Walden

Molecular Biologist

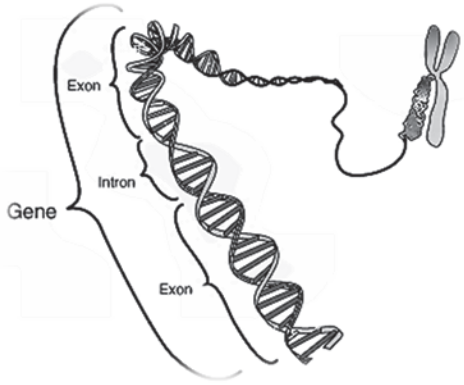
Biology



Birth Year	1954
Education	Morgan State University (B.S.)
	Washington University in St. Louis (Ph.D. 1986)

BIOGRAPHY

William Walden studies gene regulation, the cellular process of the activation of genes. He was born in 1954. Walden received his B.S. degree in biology from Morgan State University and his Ph.D. degree in molecular biology from Washington University in St. Louis in 1986.



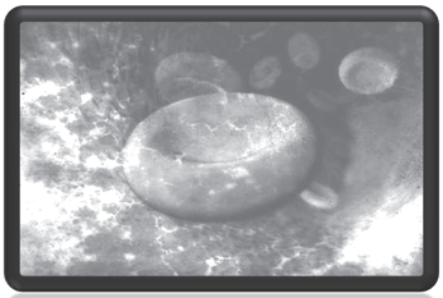
Gene by http://en.wikipedia.org/wiki/File:Gene.png

Walden started his over twenty year career at the University of Illinois, Chicago as an assistant professor in 1987 in the College of Medicine's Department of Microbiology and Immunology. In 1992, he was promoted to associate professor while also starting a five year position as associate department head of the Department of Microbiology and Immunology. Since 2004, he has held the position of full professor and served as the special assistant to the provost for diversity. From 2004 to 2007, he served as the co-chair on the Tenure Committee and from 2006 to 2007, he served as a fellow of the Committee on Institutional Cooperation-Academic Leadership Program which mentors administrators for higher leadership opportunities. Since 2006, Walden has served as director of the Office of Graduate Diversity Programs, which works to increase the number of underrepresented students who successfully earn a Ph.D. degree in the College of Medicine. His research lab studies the role of gene regulation in the control of iron metabolism and how genes control iron transport, storage, and usage. He has also mentored many graduate researchers in his lab. Walden has reviewed grant proposals for the National Science Foundation (NSF), the U.S. Department of Agriculture, and the Illinois Cancer Council. He also reviews material for top scientific journals including, *Science*, *Journal of Biological Chemistry,* and *Journal of Bacteriology*. William Walden works in Chicago, Illinois.

Above Picture of William Walden from www.uic.edu/depts/oaa/waldenbio.html

SCIENCE IN ACTION

GENE REGULATION, AN IMPORTANT ON AND OFF SWITCH



Red blood cell
by Andrew Mason @Flickr

Genes are like codes. When a gene is on, its code gives information to make protein in the cell. However, not all the genes are turned on all the time. If your body produced all of its different proteins at once, they would clog your systems. Gene regulation controls gene activation and also ensures specialized cells, meaning that a muscle cell will only produce muscle protein, and a skin cell will only produce proteins for the skin. The presence or absence of certain hormones and enzymes helps turn genes on or off. William Walden studies the genes that regulate iron use in cells. Iron is important in the body because amongst other things, it is needed to carry oxygen in red blood cells.

DISCUSSION QUESTIONS

1. If you were to interview William Walden, what questions would you ask him?
2. Check out the Kids Health website and learn about genes (http://kidshealth.org/kid/talk/qa/what_is_gene.html#). Write a definition for a gene in your own words.
3. The human growth hormone turns genes on to stimulate growth and cell production. Do you think you have more human growth hormone in your body as a child or an adult? Explain your answer.
4. William Walden studies gene regulation of iron. Why is gene regulation important?
5. How does William Walden's career compare to that of other biologists in the Toolkit?

GLOSSARY

Genes - The functional unit of heredity or inherited characteristics; composed of deoxyribonucleic acid (DNA)

Gene Regulation - The process through which the cell determines when and where genes will be activated and how much gene product, such as protein, will be produced.

Metabolism - The chemical processes that occur within a living organism in order to maintain life

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Tenure - A lifelong appointment to a position not subject to dismissal except under serious circumstances

U.S. Department of Agriculture - A U.S. Government agency that researches and oversees food production, farming, and natural resources

Effects of Exercise: Changes in Carbon Dioxide Output

(www.sciencebuddies.org)

Grade Level: 7 - 10
Time Required: About one week
Cost: $20 - $50

This activity relates to the work of physiologists, like ScienceMaker ***Albert Crenshaw.***

Abstract
Everybody knows that your body needs oxygen to keep going, and that you breathe out carbon dioxide as waste. What happens when you exercise? You've probably noticed that you breathe faster, and your heart beats faster. What triggers your body to respond in this way? How does it "rev up" to keep your muscles going? Here's a project that gives you a peek into the fascinating science of exercise physiology.

Objective
This is a project in human physiology. The goal of this project is to measure changes in carbon dioxide levels in exhaled air before and after physical exercise.

Introduction
The air that you exhale contains carbon dioxide (CO_2), a waste product from the energy-producing biochemical reactions in your cells. You should do background research to find out how your body produces and gets rid of carbon dioxide.

In this project, you will learn a method for measuring the relative amount of carbon dioxide in the air you exhale. You can compare the amount of carbon dioxide you produce when resting and when exercising, both moderately and briskly.

To measure your carbon dioxide output you will be using a colorimetric pH test. pH is a logarithmic measure of the acidity or alkalinity of solutions. pH is the negative logarithm of the hydrogen ion concentration:

$$pH = -\log [H^+] .$$

What this equation means is for each 1-unit change in pH, the hydrogen ion concentration changes ten-fold. Pure water has a neutral pH of 7. pH values lower than 7 are acidic, and pH values higher than 7 are alkaline (basic). The table below has examples of substances with different pH values (Decelles, 2002; Environment Canada, 2002; EPA, date unknown).

Table 1. The pH Scale: Some Examples		
pH Value	H^+ Concentration Relative to Pure Water	Example
0	10 000 000	battery acid
1	1 000 000	sulfuric acid
2	100 000	lemon juice, vinegar
3	10 000	orange juice, soda
4	1 000	tomato juice, acid rain
5	100	black coffee, bananas
6	10	urine, milk
7	1	pure water
8	0.1	sea water, eggs
9	0.01	baking soda
10	0.001	Great Salt Lake, milk of magnesia
11	0.000 1	ammonia solution
12	0.000 01	soapy water
13	0.000 001	bleach, oven cleaner
14	0.000 000 1	liquid drain cleaner

A colorimetric pH test means that the color of the solution changes when the pH changes. Here's how it works. When you add the pH test solution to plain water, it turns blue, or greenish blue, indicating that the pH is near 7. Carbon dioxide is very soluble in water. When it dissolves, CO_2 reacts with water, producing carbonic acid. The pH of the water is shifted from neutral (7) to more acidic (somewhere near 6). Over this range, the pH indicator will change color to yellow. The illustration below shows an example of a pH indicator changing color over this range.

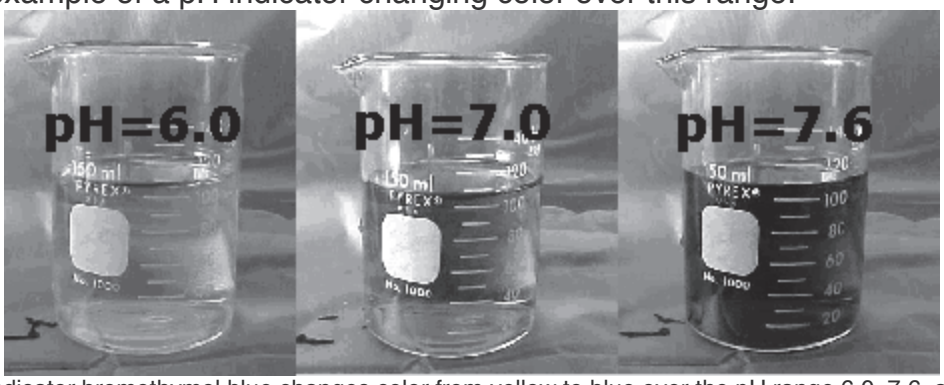


Figure 1. The pH indicator bromothymol blue changes color from yellow to blue over the pH range 6.0–7.6, as illustrated above.

To compare your CO_2 output under different conditions, you will exhale through a tube into a bottle partly filled with the pH indicator solution. The CO_2 that you exhale will dissolve in the water, and gradually acidify it. You'll be able to see the pH indicator change color as this happens. By measuring how long it takes for the pH change to occur, you will have a relative measure of the amount of CO_2 in your breath. The less time it takes for the color change to happen, the more CO_2 there was in your breath.

Terms, Concepts, and Questions to Start Background Research

To do this project, you should do research that enables you to understand the following terms and concepts:

- exercise physiology: find out as much as you can about how the body controls heart rate and breathing during exercise,
- autonomic nervous system,
- terms regarding lung function:

  - tidal volume,
  - vital capacity,
  - total lung capacity.
- terms regarding cardiac function:
  - cardiac output,
  - heart rate,
  - stroke volume.
  - anaerobic
  - aerobic

Questions

- How is oxygen used and carbon dioxide produced in cellular respiration?
- How do cells in the body obtain oxygen and get rid of carbon dioxide?
- How does the body sense and respond to increased cellular respiration rate?

Bibliography

- These sites explain the pH scale:
  - Decelles, P., 2002. "The pH Scale," Virtually Biology Course, Basic Chemistry Concepts, Johnson County Community College [accessed September 19, 2006] http://staff.jccc.net/pdecell/chemistry/phscale.html.
- For information on respiration and exercise, try this website from the Science Museum of Minnesota:
  SMM, 2002. "Habits of the Heart: The Lungs," Science Museum of Minnesota [accessed September 19, 2006] http://www.smm.org/heart/lungs/top.html.
- Here is a good introduction to the physiology of exercise:
  American Physiological Society, 1999. "Background Information" from *The Physiology of Exercise*, American Physiological Society [accessed January 27, 2006]http://www.the-aps.org/education/lot/pdfs/physioex/backgrnd.PDF.
- Shakashiri, B. "Carbon Dioxide," Chemical of the Week, University of Wisconsin [accessed January 26, 2006]http://scifun.chem.wisc.edu/chemweek/CO2/CO2.html.
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- Calabrese, L., 2001. "Volume of human lungs," Elert, G. "The Physics Factbook" [accessed January 27, 2006]: http://hypertextbook.com/facts/2001/LaurenCalabrese.shtml.

Materials and Equipment

To do this experiment you will need the following materials and equipment:

- a freshwater aquarium pH test kit (Tetra brand works well),
- four clear plastic bottles (pint-size water bottles work well),
- water;
- homemade respirometer:
  - one bottle, with cap,
  - plastic tubing (approx. 1 cm internal diameter),
  - modeling clay;

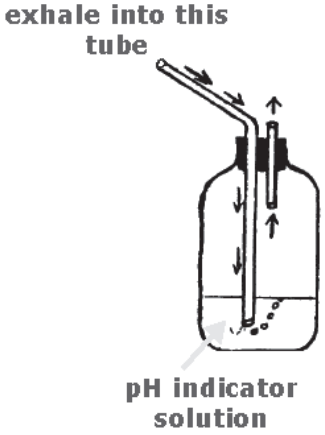

Diagram of respirometer setup. Drill holes in the bottle cap for the tubes to pass through and seal with modeling clay. Pay attention to tube lengths, only the inlet tube should be below surface of liquid.

- aeration setup for de-acidifying pH indicator solution:
  - aquarium pump,
  - tubing,
  - airstone (optional);

- a watch with a second hand or stopwatch,
- a helper to time you.

Experimental Procedure

1. Do your background research to find out about how your body produces and gets rid of carbon dioxide. You should also understand why carbon dioxide makes water more acidic when it dissolves.
2. Fill one of clear plastic bottles nearly to the top with water. (Use distilled water if your tap water has pH < 7.)
3. Add 20-25 drops of the pH test solution, cap the bottle, and mix gently. You should get a nice green or blue color (pH >= 7). If not, try using distilled water.
4. Fill the respirometer a little less than one-third full with diluted pH test solution. Mark the level on the side of the bottle with tape and permanent marker.
5. Fill a second bottle about a quarter full with diluted pH test solution and set it aside as a control for color comparison. Reserve the remaining indicator solution for later.
6. Set up the inlet and outlet tubes of the respirometer as shown in the diagram above.
7. Now you are ready to begin. Your helper should tell you when to start, and mark the time (or start the stopwatch).
8. Do your best to maintain your current, comfortable breathing rate, inhaling through your nose and exhaling from your mouth through the tube.
    a. Don't inhale through the tube! You don't want to suck up the pH indicator solution!
    b. Observe the pH indicator solution for change in color.
9. When the indicator solution in the exhalation bottle has turned yellow, your helper should note the time (or stop the stopwatch). Record the number of seconds it took to change the color of the solution. You may need to practice this process with your partner several times before actual testing to determine the exact color at which to stop the time.
10. Now you need to aerate the pH indicator solution to return it to the starting pH. Remove the cap of the exhalation bottle and aerate the solution using the aquarium aeration pump until the solution matches the original color (compare to your control, it will take 5-10 minutes). [Alternatively, you can pour out the solution into an empty bottle and aerate it there, and pour in the same amount of fresh indicator solution from your reserve. Be careful to fill to the same level as before.]
11. When your respirometer solution is ready again, repeat steps 5–8. Do this until you have at least three measurements at rest (more is better).
12. Next, collect at least three measurements right after exercising moderately (walking at a comfortable pace) or briskly (for example, run in place, raising your knees up high) for 2-3 minutes. See how long it takes you to change the color of the pH indicator, then rest for 10 minutes while you re-aerate the buffer. Then repeat the measurement until you have at least three data points for each condition (more is better).
13. Finally, while at rest, try breathing into (and out of) a paper bag for one minute (or as close to one minute as you can), and then testing your CO_2 output.
14. Average the results for each test condition and compare the results using graphs and tables.
15. How do your results compare to your expectations from your background research? For increasing CO_2 output, how does breathing into a paper bag compare to exercise?

Variations

- **Correlating CO_2 Production with Other Measures.** How does CO_2 output correlate with other measures of increased physical activity such as breaths per minute and pulse rate?
- **Making Your Results More Quantitative.** For a more advanced project, you can actually calculate the amount of CO_2 produced. You can do this by adding a known amount of NaOH to the indicator solution, and calculating how much CO_2 would be required to change the pH to 6. Then, measure how long it takes to acidify the indicator solution. Your measurements will allow

you to calculate an estimate of the CO_2 exhaled per second. Of course, to make this work you will have to work with solutions of known concentration and volume.

- **Effects of Training: Athletes vs. Non-Athletes.** If you wanted to get really ambitious, you could see how conditioning affects CO_2 output. Do conditioned athletes take longer to start producing additional CO_2 with moderate exercise? Do they recover to normal levels faster after exercise?
- **Compare CO2 production after *anaerobic* and *aerobic* exercise.** Compare respirometer results from subjects who run, walk, or bike for 4-7 minutes to those from subjects who do push-ups, lunges, or squats for the same duration.
- For another Science Buddies project on exercise physiology, see: Heart Health: How Does Heart Rate Change with Exercise?.
- For more science project ideas in this area of science, see Human Biology & Health Project Ideas.

Credits
Andrew Olson, Ph.D., Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Zoo_p013.shtml

Sources

- "Investigating CO_2 in Breathing," Bronx High School of Science [accessed January 25, 2006]http://www.bxscience.edu/ourpages/auto/2005/5/26/1117114499842/Investigating%20Carbon%20Dioxide%20in%20Breathing.pdf.
- "How Much Carbon Dioxide Is Produced During Exercise? Teacher's Notes" Faculty of Education, The Chinese University of Hong Kong [accessed January 25, 2006] http://www.fed.cuhk.edu.hk/~johnson/tas/investigation/exercise_teacher.htm.

Liver Stinks

(www.sciencebuddies.org)

Grade Level: 3+
Time Required: A day or less
Cost: $20 or less

This activity relates to the work of molecular biologists, like ScienceMaker ***William Walden.***

Abstract
Sometimes science can be really messy or use pretty disgusting ingredients. That is what it takes to understand how the world works, even if the experiment isn't pretty. Do you like chemical reactions that stink and ooze foamy bubbles? Do you think it sounds fun to make a super gross liver smoothie? Then this is the experiment for you!

Objective
In this experiment, you will extract the enzyme catalase from fresh (or frozen) liver, use it to break down hydrogen peroxide, and test the activity of catalase under different conditions.

Introduction
A chemical reaction is when chemical come together and their molecules interact to form new chemicals. Sometimes chemical reactions happen by themselves. These reactions are usually very fast and spontaneous, and give off energy. Other chemical reactions need energy to happen, and without energy proceed very slowly or not at all.

These types of chemical reactions can be helped to occur more quickly by using enzymes. Enzymes are made out of protein and they speed up the rate of a chemical reaction by acting as a catalyst. A catalyst provides the necessary environment for the chemical reaction to occur, which speeds up the reaction. Certain catalysts work for certain kinds of reactions, in other words each enzyme has a particular type of reaction that it can activate.

Enzymes are proteins, which are molecules that are very large and dynamic. They can be very fussy, and sometimes need to be in certain environments or conditions to work. Some enzymes can be damaged under certain conditions such as heat. A damaged enzyme will no longer work to catalyze a chemical reaction.

One source of enzymes is the liver, which needs to break down many substances in the body. Catalase is one enzyme from liver that breaks down harmful hydrogen peroxide into oxygen gas and water. When this chemical reaction occurs, you can see the oxygen gas bubbles escaping and causing the reaction to foam.

In this experiment, you will use fresh (or frozen) liver as a source of catalase and investigate how the activity of the enzyme can change under certain conditions. What does catalase do? Under which conditions does it work best? Why do we need catalase in our liver?

Terms, Concepts, and Questions to Start Background Research

To do this type of experiment you should know what the following terms mean. Have an adult help you search the internet, or take you to your local library to find out more!

- liver
- protein
- enzyme
- catalase
- hydrogen peroxide
- chemical reaction
- acid
- base

Bibliography

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- Kids Health: The Nemours Foundation. (n.d.). *How the Body Works: Your Liver.* Retrieved July 11, 2010, from http://kidshealth.org/kid/htbw/liver.html

Find out why you should "Love Your Liver" from the folks at Kids Health:

- Kids Health: The Nemours Foundation. (n.d.). *Your Digestive System.* Retrieved June 30, 2010, fromhttp://kidshealth.org/kid/cancer_center/HTBW/digestive_system.html

Learn all about free-radicals, nutrition, antioxidants and the body:

- MadSci Network. (1999, September 27). *Where Does Hydrogen Peroxide come from in the Body?* Retrieved July 26, 2010, fromhttp://www.madsci.org/posts/archives/sep99/938519528.Bc.r.html
- Youngston, Robert. 1994. "The Antioxidant Health Plan." Harper Collins Publishers, U.K

Materials and Equipment

- liver -- either fresh or frozen (Note: If you order fresh liver, be sure to only order a pound or less, not an entire liver. A whole beef liver can weigh 10 lbs!)
- water
- hydrogen peroxide (use a new or recently-purchased bottle for best results.)
- bottle caps
- medicine dropper
- salt (optional)
- boiling pot of water (optional)
- vinegar (optional)
- baking soda (optional

Experimental Procedure

1. Cut the liver into little pieces, about 1–2 centimeters in size. You may need your parents help with this.
2. Place the cubes of liver into a blender and add an equal volume of water.
3. Blend on high speed pulsing when necessary, until the liver is smooth, and no chunks are present. Keep the liver extract in the refrigerator.
4. First, test the activity of untreated liver extract by adding a drop of extract to a bottle cap.
5. Add one drop of hydrogen peroxide. You should see a lot of bubbles!
6. You can record this in a data table and it will be your positive control. Use a scale of 0–5, with 5 representing the "most bubbling" and 0 representing "no bubbling."

Treatments	Bubble
Untreated	5
No liver added	0
Boiled	
Salty	
Acidic	
Basic	

7. Now take different samples of your liver extract and test different conditions on activity, testing a drop of the treated extract each time with hydrogen peroxide.
8. To test the effect of heat, place a small portion of the extract in the microwave in a microwave-safe bowl. Heat covered on high for 20-35 seconds. Test a drop of the treated extract with hydrogen peroxide and record your results in your data table.
9. To test the effect of freezing, freeze a small portion of the extract in the freezer. When the sample is completely frozen, remove it from the freezer and thaw the sample before testing it for enzyme activity. Test a drop of the treated extract with hydrogen peroxide and record your results in your data table.
10. To test the effect of acid, mix the liver with some household vinegar before testing. Test a drop of the treated extract with hydrogen peroxide and record your results in your data table.
11. To test the effect of a base, add some baking soda to your extract before testing. Test a drop of the treated extract with hydrogen peroxide and record your results in your data table.
12. To test the effect of high salt conditions, mix the extract with some table salt. Test a drop of the treated extract with hydrogen peroxide and record your results in your data table.
13. Try experimenting with any other condition you can imagine! Remember to record all of your results in your data table!

Variations

- How does catalase change activity when different amounts of the enzyme or the hydrogen peroxide are present? The hydrogen peroxide is called the "substrate," and sometimes changing the amount of substrate or enzyme will change how the chemical reaction proceeds. This is called "enzyme kinetics." Conduct your own experiment on enzyme kinetics by changing the amount of liver extract and hydrogen peroxide in your reactions. What did you find out?
- Another enzyme, called papain, digests proteins and can be extracted from pineapple. One protein that is fun to use for the experiment is Jello, made out of gelatin. Try a similar type of experiment on the activity of papain.
- The liver contains many enzymes, each important for detoxifying the body. One of the reasons breaking down hydrogen peroxide is important is because if left alone, hydrogen peroxide in the blood can produce free radicals. Free radicals can cause damage to different parts of the body. Test the effect of hydrogen peroxide on different materials around your house, what happens?
- For more science project ideas in this area of science, see Biotechnology Techniques Project Ideas.

Credits

Sara Agee, Ph.D., Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/BioChem_p030.shtml

Plants on the Move! Experiments with Phototropism

(www.sciencebuddies.org)

Grade Level: 6 - 8
Time Required: Several weeks to months
Cost: $50 - $100

This activity relates to the work of plant biologists, like ScienceMaker ***Fedora Sutton.***

Abstract
Plants move—not very quickly compared to animals, but they do move. Their roots grow downward in response to gravity, and their stems grow upward toward the Sun. In this plant biology science fair project, you will investigate how young plants respond through movement to light.

Objective
The objective of this plant biology science fair project is to determine how the amount of light affects a plant's phototropic response.

Introduction
Did you know that plants can move? They do it all the time, but so slowly that we often don't notice it. Plants respond to a number of different cues in their environment with movement. These movements are called **tropisms.** Some examples of tropisms include **gravitropism** (response to gravity), **hydrotropism**(response to water), **thigmotropism** (response to touch), and **phototropism** (response to light). These tropisms are vital to plants' survival. Roots respond to the direction of gravity by growing downward, an example of gravitropism. Roots also grow toward a water source, displaying hydrotropism. The wrapping of a vine's tendrils around a solid support is an example of thigmotropism. You can see lots of examples of phototropism in the plants around you—branches in trees grow toward openings that have the most light, and the stems of young plants bend toward a source of light. In this plant biology science fair project, you will investigate how the amount of light affects the bending of plant stems.

When a seed **germinates,** the roots grow downward, and the stem grows upward. If you expose the growing stems to light from one direction, they start to grow in that direction. In 1809, Swiss botanist Augustin Pyrame de Candolle studied the growth of plants toward a light source and stated that it was caused by an unequal growth on only one part of the plant. Later, in 1880, Charles Darwin (the father of the theory of evolution), discovered that it was actually the tips of the sprouting seedlings that were influenced by the direction of the light source. He discovered that when he covered the tips of growing seedlings, they no longer responded to the light. When he covered the part of the stem below the tip, but not the tip itself, the stems responded normally to light. Examine Figure 1, below.

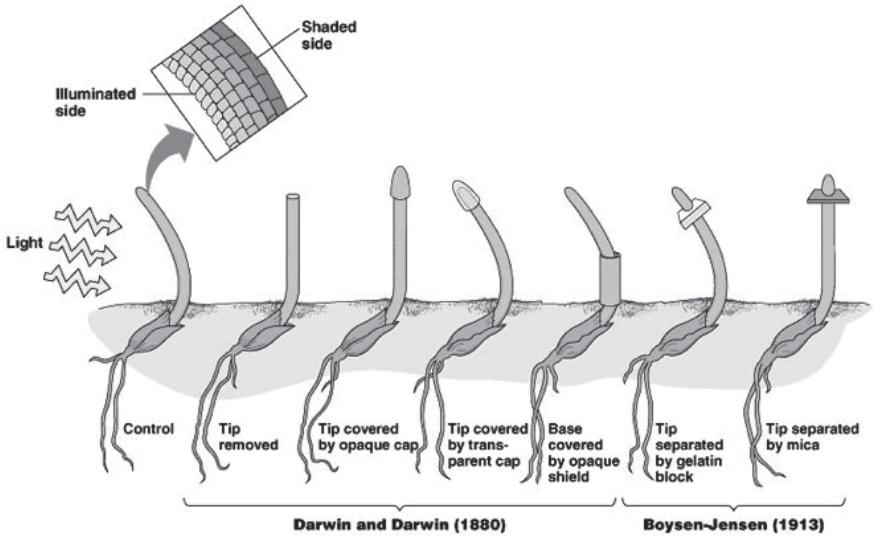

Figure 1. This diagram depicts early experiments with phototropism. Darwin showed that the phototropic response was lost when the tip of the emerging plant was cut off or covered with an opaque cap. Covering the base of the stem did not block phototropic bending. Dutch plant physiologist Boysen-Jensen showed in 1913 that placing a block of gelatin between the tip and the base did not block the response, showing that something was able to diffuse from the tip, through the gel, and into the base. When the tip was separated from the base with a piece of mica, which blocks anything from flowing through, the response is blocked. Note that there is more auxin growth hormone on the shaded side (green color in the small picture insert). (Wikispaces, 2008.)

The Dutch botanist Frits W. Went established a connection between phototropism and a plant hormone, called **auxin,** in the 1920s. He discovered that plants make a chemical in their tips that stimulates growth. Usually this growth hormone spreads evenly around the stem, so the stem grows upward. But if light hits the plant from one direction, the growth hormone is distributed unevenly. In fact, more auxin flows down the "shady" side, causing it to grow faster than the "sunny" side of the plant. This unequal concentration of auxin results in differential growth and the curving of the plant toward the light source.

In summary, the stem bends toward the light because the side of the stem that is *away* from the light grows faster than the side of the stem *facing* the light. This uneven growth pushes the tip toward the light source. The growth of new **plant cells** is stimulated by the plant chemical auxin. The growing stem responds to light from a certain direction by decreasing the amount of auxin on the side of the stem facing the light, relative to the opposite "shady" side. In this plant biology science fair project, you will study how the *amount* of light affects the degree of bending in young plant stems.

Terms, Concepts, and Questions to Start Background Research

- Tropism
- Gravitropism
- Hydrotropism
- Thigmotropism
- Phototropism
- Germination
- Auxin
- Plant cell

Questions

- What did Charles Darwin contribute to our understanding of phototropism?
- Based on your research, what is heliotropism and how is it different from phototropism?
- Based on your research, what effects does auxin have on plant tissue?
- What is the chemical name for auxin?

- Why don't gardeners use natural auxin?

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Materials and Equipment

- Small milk cartons, 1-pint (5, or 15 if you are running all three trials at once); should be thoroughly cleaned and dried before use
    a. You could also use a different kind of box or container if you prefer. The purpose of the container is to block surrounding light from the plant, except for where you place several small holes.
- Permanent marker
- Seeds, radish or lima bean (1 package)
- Potting soil (1 bag)
- Optional: Grow lamp
- Tape, clear
- Aluminum foil
- Hole punch
- Protractor
- Eye dropper
- Top of a shoebox, or a similar item to serve as a tray for the plants (3 if you are running all the trials at once)
- Optional: Lamp
- Lab notebook
- Ruler, metric
- Graph paper

Experimental Procedure

Important Notes Before You Begin

1. Because of the natural variability in plant growth, you may need to adjust this procedure in order to get good results. For example, you may need to expose the plants to light for more or less time than is recommended in the procedure. Adjust the procedure to find the conditions that work best for you.
2. The objective of this science fair project is to expose the plants to different amounts of light, with the light coming from the side, so that the plants will bend toward it. To begin, you'll label the milk cartons 1–5, add soil to them, and then plant four seeds in each carton. *Note:* The plants need to grow for a period of time before being exposed to light. This way, the stems will be growing vertically when they are exposed to light from one side.
3. Ultimately, you will need three trials of this project to make sure your results are consistent. You can either run them one at a time, or run them concurrently.

Preparing the Cartons

1. Using the permanent marker, label the sides of the milk cartons with the numbers 1–5.
2. For carton # 1, cut off the top of the carton with the scissors.
    a. The plants in this carton will grow in normal lighting.
3. For carton # 2, do not make any holes.

a. The plants in this carton should germinate and start to grow, but will be kept in total darkness.

4. For the following cartons, use the hole punch to make holes in one side of each carton, about 6 cm from the bottom. You will need to open the top of the milk carton to make the holes.
    a. Carton #3: One hole
    b. Carton #4: Two holes; should be near each other, but not overlapping
    c. Carton #5: Four holes; should be near each other, in a cluster
5. Be sure to write in your lab notebook the number of holes in each carton, and what each carton's conditions will be once the experiment begins (lighting).
6. Now make some additional holes to allow air into the cartons and excess water to drain out. Punch 10 holes in the bottom of each carton using a pen. Each hole should be about 5 mm in diameter.

Planting the Seeds

1. Put about 3 centimeters (cm) of moist potting soil into each carton. Keep the amount of soil equal in each carton.
2. Moisten the potting soil with water. It should just be moist, not saturated.
3. Put four seeds in each carton. Bury the seeds to a depth of about 1 cm, or follow the directions on the seed package for the recommended depth. Plant all of the seeds at the same depth.
4. Use the permanent marker to put a letter on the side of the carton near each seed so that you can identify them as they grow. For example, label them A, B, C and D, with markings inside the carton.
5. Close cartons 2–5 and seal them with clear tape.
6. Wrap the tops and sides of cartons 2–5 in aluminum foil to block light from reaching the plants. Don't cover the holes in the bottom.
    a. Write the number of the carton onto the aluminum foil with the permanent marker.
7. Record the time and date that the seeds were planted in your lab notebook.

Making Your Observations

1. Check carton #1 each day. Wait until the seeds in carton #1 have germinated and grown about 3 cm. Then begin the exposure to light for the plants in cartons 3–5 (remember, carton #2 stays sealed). *Note:* Start the exposure to light in the morning so that the plants have a full day of light on the first day.
2. Using the scissors, remove the foil only from over the hole in carton #3. Leave the rest of the foil in place to keep the plant in darkness, except for the light from the one hole.
3. Remove the foil only from over the holes in cartons #4 and #5. Leave the rest of the foil in place to keep the plant in darkness, except for the light from the holes.
4. Record the time and date that the plants were exposed to light in your lab notebook.
    a. Use the clear tape to hold the aluminum foil in place around the holes, if desired.
5. Place the cartons in a well-lit room, but out of direct sunlight. Record the time and date in your lab notebook
    a. As an option, you can use a grow lamp as a light source.
    b. Expose the plants to light during the day. Keep them in darkness at night.
    c. Record how long the plants receive light from the holes in the carton.
6. The next morning (day 1), take the all of the cartons to a dimly lit room, open the cartons, and observe the plants.
    a. Use the protractor to measure the angle of the stems. If the protractor is too big to fit into the cartons, use a twist tie to obtain the angle for the stem. Position a twist tie parallel to the base of the stem to be measured. Bend the twist tie to match the angle of the bend in the stem. Use the protractor to record the angle of the twist tie.
    b. Record your observations of the plants from all five cartons in your lab notebook.

   c. As an option, check the plants more often than once per day in the morning. Keep the light exposure to a minimum while taking measurements.
   d. Do not let the soil dry out. If needed, add some water (equal amounts) to each plant, using an eye dropper.
7. Return the cartons to their original states (covered or uncovered), place them in the light again, and allow them to grow for another day.
8. The next morning (day 2), again take the cartons to a dimly lit room, open the cartons and observe the plants. Repeat steps 6–7. *Note:* Remember to treat all of the plants exactly the same. The only difference between the plants in the different cartons should be the amount of light to which they are exposed.
9. Repeat steps 6–7 until you feel you have enough data. Five days worth of data will probably be sufficient, but use your judgment about when to stop the experiment.
10. For each day you collected data on the angles of the plants, graph the angle of the stems vs. the amount of light (the number of holes) to which the plants were exposed.
11. You can graph the data for each plant individually, or graph the average of the angles within a carton.
12. Repeat the entire procedure at least two more times so that you have a minimum of three trials. The different trials can run concurrently. Graph the data for each trial separately.
    - *Note:* The goal is to determine how exposure to different amounts of light affects the growth of the plants. You may need to experiment with the amount of light (the number of holes), the duration of exposure, the height of the holes, or other factors to get a clear result.

Variations

- Keep the number of holes the same and vary the time of light exposure. For example, use a carton with four holes and expose the plant to light for 1/2, 1, 2, 4, and 8 hours per day for three days. What is the minimum amount of time required to observe initial growth toward the light?
- The holes in the carton let in both light and air. It is theoretically possible the air from the holes is affecting the growth of the plants. Alter the procedure to block air (but not light) from entering through the holes.
- Devise a way to determine if the color of the light affects the phototropic effect.
- Try different kinds of lamps. For example, a grow lamp, a fluorescent lamp, and an incandescent lamp.
- Which is more effective for producing the phototropic response: a bright light with a short exposure, or a dim light with a long exposure? For example, try comparing eight holes for 1 hour, and one hole for 8 hours.
- Cut off the tips of the growing stems before you expose them to light. What is the minimum size you need to cut off to block the phototropic response?
- Use a light meter to measure the amount of light to which the plant is exposed. For example, this multimeter has a light meter: Mastech model # MS8229, available from www.amazon.com Graph the stem angle vs. lux.
- Add growth hormone to the cut surfaces of three stems that have had their tops cut off. Place a small piece of gelatin that contains growth hormone (available from a plant nursery) on top of the stem. What if the piece of gelatin with the hormone is placed on an edge of the cut?
- What happens if you put one hole on one side of the carton, and two holes on the opposite side? Or two holes each on opposite sides? Keep the surrounding light uniform.
- For more science project ideas in this area of science, see Plant Biology Project Ideas.

Credits

David Whyte, PhD, Science Buddies
To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/PlantBio_p041.shtml

Chemistry

Chemistry is the science of matter. Chemicals are found everywhere, from the oxygen in the air we breathe to the salt in your food. They can be as close as the dust on the floor or as far away as the matter in distant galaxies.

Chemists study many different types of matter such as the elemental properties of the earth, the chemical make-up of food, the development of drugs and medicine, and the chemistry of human cells.

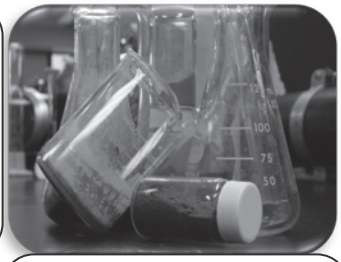
Studying chemistry teaches you how to be organized and efficient. The work of career chemists can be applied in many important worldwide domains such as the food industry, healthcare, and the environment.

Chemistry Disciplines

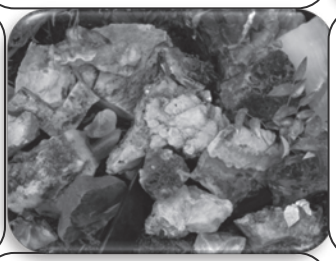
Chemistry includes many exciting fields to study and research. Here are just a few…

Organic Chemistry is the study of carbon containing compounds such as acetic acid (vinegar) and caffeine.

Inorganic Chemistry is the study of compounds, which generally DO NOT contain carbon such as sodium chloride (salt).



Physical Chemistry is the study of the movement and behavior related to the composition and structure of chemical compounds.

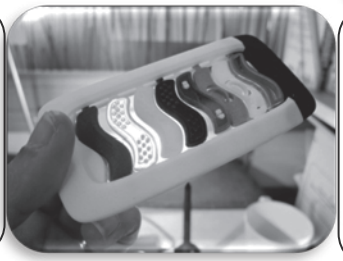


Geochemistry is the study of the chemical composition of the earth and its rocks and minerals.

Analytical Chemistry involves gathering information about the quantity and properties of matter, as well as the processing and communication of that information.

Electrochemistry looks at the chemical properties of electrical phenomena, specifically at the interface of an electron conductor, and an ionic conductor.

Environmental Chemistry is the study of chemical processes occurring in the environment that are impacted by the activity of humans.



Materials Chemistry is the study of the atoms, ions, or molecules that compose a material, as well as its structural and physical properties.

Photo credits from Top Left: p.Gordon@Flickr; mwahlsten@Flickr; gebi!@Flickr; epicollector@Flickr; FritzJ.M@Flickr; jurvetson@Flickr; Massachusetts Dep. Of Environmental Protection@Flicrk; DoNotLick@Flicrk

Career Paths in Chemistry

Chemistry covers a range of careers in many different areas. Below are just a few jobs open to those with a degree in chemistry. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Chemists can work in settings such as school classrooms, universities, research labs, science centers, or museums.

- *Chemistry Professors* at colleges and universities teach and mentor students and conduct research.
- *Supply Room Technicians* work in universities or colleges and are in charge of the safekeeping, handling, and distribution of all chemical supplies. They must adequately train students on how to use chemicals for their laboratory experiments.
- *High School Chemistry Teachers* are usually a student's first exposure to an in-depth study of chemistry. They are responsible for teaching the principals of general chemistry, as well as proper laboratory technique and the steps of the scientific method.

Business & Industry

Chemists can work for companies that develop, manufacture, and test new products in the food and drug industry, for example. They also do consulting work for businesses.

- *Flavor Chemists* work for food companies and create new synthetic flavors in their laboratories. Many snacks and candies have synthetic flavoring that was developed by a chemist.
- *Pharmacists* manufacture and dispense drugs according to doctors' orders. Attention to detail is critical for career pharmacists in order to fill accurate prescriptions.
- *Textile Chemists* study natural and synthetic fibers and use their knowledge of chemistry to create useful materials such as clothing, carpet, and insulation for homes and buildings.

Government

Chemists can work for the government in many different settings such as research labs or the departments of health, energy, sanitation, and defense.

- *Hydrologists* work on interdisciplinary teams studying water with other scientists. They can work as water purification chemists at water treatment plants to ensure that the community has clean drinking water.
- *Hazardous Waste Management Chemists* work in the field or in the lab using analytical chemistry to determine the toxicity of a particular waste material like petroleum from an oil spill.
- *Forensic Chemists* work with the FBI to solve crimes. They analyze chemical evidence from crime scenes like gunshot residue and illegal drugs. They often have to explain their findings in a court of law.

Check Out Our Featured Chemists!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
Daniel Akins	Materials Chemist	City College of New York	Nanomaterials	52
Gloria Long Anderson	Physical Organic Chemist & Educator	Morris Brown College	Fluorine	54
Sharon Barnes	Chemist & Inventor	Dow Chemical Company	Infrared Thermography	56
Jeannette Brown	Organic Chemist & Science Historian	Chemical Heritage Foundation	African American Women Chemists	58
Linnaeus Dorman	Organic Chemist & Inventor	Dow Chemical Company	Prosthetics	61
Krishna Foster	Environmental Chemist	California State University, Los Angeles	Ozone	63
Fillmore Freeman	Organic Chemist	University of California, Irvine	Allicin and Garlic Products	66
Ronald Goldsberry	Chemist & Business Executive	Ford Motor Company	Oxidation and Rust	68
Joseph Gordon	Inorganic Chemist	IBM Almaden Research Center	Phases of Matter	70
John Hall	Atmospheric Chemist	Morehouse College	The Ozone Layer	72
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James Letton	Organic Chemist & Inventor	Procter & Gamble	Fat Substitutes	77
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James Shoffner	Petroleum Chemist	Columbia College; Universal Oil Products Company	Petroleum Chemistry	83
Herman Smith	Medicinal Chemist & Inventor	Up-John Company	HIV Protease Inhibitors	85
Rubye Torrey	Radiation Chemist & Administrator	Tennessee Technological University	Radiation	87

ScienceMakers Spotlight

Daniel Akins

Materials Chemist

Birth Year	1942
Education	Howard University (B.S. 1964)
	University of California, Berkeley (Ph.D. 1968)
Awards & Achievements	City University of New York Faculty Service Award (1999)
	Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring (2000)

BIOGRAPHY

Daniel Akins is a chemist and chemistry professor at the City College of New York (CUNY). He was born in 1942 and graduated from high school in 1960. Akins earned his B.S. degree in chemistry from Howard University in 1964, where he was inducted into Sigma Pi and Sigma Xi honor societies. He received his Ph.D. degree in physical chemistry from the University of California, Berkeley in 1968.

After finishing his education, Akins worked at Florida State University as both a postdoctoral researcher and visiting assistant chemistry professor. In 1970, he became an assistant professor in the chemistry department at the University of South Florida and was promoted to associate professor in 1975. Between 1977 and 1979, Akins served as a visiting program director of the physical chemistry subsection of the dynamics program at the National Science Foundation (NSF). After a brief stint as a senior scientist with the Polaroid Corporation, Akins began his career at City College of New York as a professor of chemistry in 1981. In 1988, he became director of the CUNY Center for Analysis of Structures and Interfaces (CASI). The goals of CASI have been to conduct scientific research and to increase the number of minority students conducting high-level research. Throughout his career, Akins has published numerous scientific research papers. His principal research focus involves the development of new nanomaterials for use in molecular photonic devices (MPDs) and/or chemical sensors. This means he studies the small-scale structure of materials in order to develop better materials for use in different technologies. In addition to his teaching and research, Akins lectures at conferences and universities, both in the United States and abroad. He is a member of several professional organizations, including the American Chemical Society and the Society for Applied Spectroscopy. Daniel Akins lives in Teaneck, New Jersey, with his wife Sondra Akins, an assistant professor of education.

Nanomaterials
by tlahuicef @Flickr

Above Picture of Daniel Akins from www.nanotechnologytoday.blogspot.com/2008_10_01_archive.html

SCIENCE IN ACTION

PUTTING NANOMATERIALS TO GOOD USE

Smoke Detector
by Dottie Mae @Flickr

You may not know it, but you most likely have two chemical sensors in your home right now: your smoke detector and your carbon monoxide detector. A chemical sensor is a device that detects the presence of a chemical and converts it into a signal which can be read by an instrument. If there is a fire, your smoke detector will emit a warning sound telling you to leave your house. Daniel Akins develops nanomaterials for use in chemical sensors. Because nanomaterials are so small and sensitive, it only takes a tiny amount of a chemical to cause a change in the properties of the sensing material and create an alert. Another common chemical sensor is a breathalyzer, which can detect alcohol on a person's breath.

DISCUSSION QUESTIONS

1. If you were to interview Daniel Akins, what questions would you ask him?
2. Check out the Nanotechnology for Kids website (http://www.explainthatstuff.com/nanotechnologyforkids.html). What did you learn about the uses of nanotechnology?
3. Daniel Akins develops nanomaterials for chemical sensors. In what situations are chemical sensors useful?
4. Daniel Akins lectures at conferences and universities. Why is it important for scientists to share knowledge with each other and with the public?
5. How does Daniel Akins' career compare to that of other chemists in the Toolkit?

GLOSSARY

Carbon Monoxide - A colorless, odorless, toxic flammable gas composed of one carbon atom and one oxygen atom

Molecular Photonic Device - An instrument mainly used in the communications industry involving the interactions of photons, particles associated with light, in a solid material

Nanomaterial - A substance that was created on a very small scale; one billionth of a meter

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Physical Chemistry - The study of the movement and behavior related to the composition and structure of chemical compounds

ScienceMakers Spotlight

Gloria Long Anderson

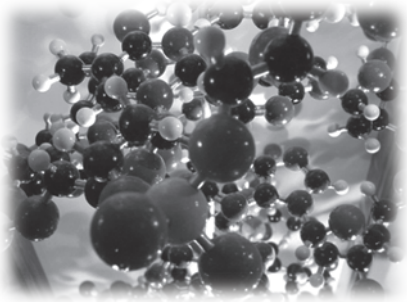
Physical Organic Chemist & Educator

Birth Date	November 5, 1938
Birth Place	Altheimer, Arkansas
Education	Arkansas A&M Normal College (B.S. 1958)
	Atlanta University (M.S. 1960)
	University of Chicago (Ph.D. 1968)
Awards & Achievements	Corporation for Public Broadcasting Board of Directors (appointed by President Richard M. Nixon) (1972)
	Georgia Public Telecommunications Task Force Appointee (1980)

Chemistry

BIOGRAPHY

Gloria Long Anderson is known for being a great mentor and teacher and for her study of the chemical compound, fluorine-19. Anderson was born on November 5, 1938 in Altheimer, Arkansas and her parents encouraged her and her five brothers to pursue an education. After graduating from Atheimer High School in 1954, she attended Arkansas A&M Normal College where she received her B.S. degree in chemistry, graduating at the top of her class in 1958. Anderson then earned her M.S. degree in chemistry from Atlanta University in 1960 under the tutelage of her mentor, Henry C. McBay. Anderson taught chemistry at South Carolina State College and later at Morehouse College before earning her Ph.D. degree in chemistry from the University of Chicago in 1968.



Molecule Model by net_efekt @Flickr

After completing her education, Anderson joined the faculty of Morris Brown College in Atlanta, Georgia as an associate professor and chair of the chemistry department. She also did postdoctoral work at the Georgia Institute of Technology. At Morris Brown, Anderson was promoted to an endowed chair position in 1973. She served as dean of academic affairs from 1984 to 1989 and became the interim president of the college in 1992. Anderson worked tirelessly to improve the scientific programs at Morris Brown College. Through her efforts, the chemistry department grew, the chemistry curriculum was revitalized, and new scientific instrumentation was brought to the campus. Throughout her long career at Morris Brown College, Anderson secured more than $1,000,000 in grants for the college's science programs and faculty. In addition to her work as an educator, Anderson also continued her chemistry research. She focused on the properties of a chemical compound called fluorine-19, which she investigated using an analytical technique called nuclear magnetic resonance (NMR) spectroscopy. Her later research focused on the development of compounds that fight viruses. Gloria Long Anderson lives in Atlanta, Georgia. She has one son.

Above Picture of Gloria Long Anderson from www.asi-org.net

SCIENCE IN ACTION

THE POWER OF FLUORINE

Toothpaste
by wwarby @Flickr

You may have heard of fluoride, which is a form of fluorine and also a component of toothpaste. Fluorine-19 is an isotope, or another form of the element fluorine. Fluorine is a gas which has the chemical symbol F. All isotopes, or forms of a specific element, have equal numbers of protons but different numbers of neutrons. Fluorine (F) has many different isotopes, the most stable of which is fluorine-19. Gloria Long Anderson found Fluorine-19 interesting because of its magnetic properties. It is also used in its own analytical technique called Fluorine-19 NMR spectroscopy, which is used to help determine the structure of other molecules.

DISCUSSION QUESTIONS

1. If you were to interview Gloria Long Anderson, what questions would you ask her?
2. Check out the Chem4Kids website (http://www.chem4kids.com/index.html). Do you think you would enjoy studying chemistry? Why or why not?
3. Fluorine-19 is an isotope, or form, of the element fluorine. Name three other chemical elements and find out if they have a common isotope. If they do, name the isotope.
4. Gloria Long Anderson spent a lot of time and energy improving the chemistry department at Morris Brown College. Why is it important to invest in education?
5. How does Gloria Long Anderson's career compare to that of other chemists in the Toolkit?

GLOSSARY

Endowed - A faculty position at a college or university whose salary comes from a private donation, or gift of money

Fluorine-19 - The most stable isotope of the element fluorine; found naturally on earth in large quantities

Isotopes - Forms of a chemical element that have equal numbers of protons, but different numbers of neutrons in the nucleus

Neutron - A particle with no charge in the nucleus or center of an atom

Nuclear Magnetic Resonance (NMR) Spectroscopy - An analytical technique that is used to determine the structure and composition of chemical compounds by examining the magnetic properties of nuclei

Proton - A positively charged particle in the nucleus or center of an atom

Virus - A tiny body, too small to see with the eye alone, that can only live inside the cells of other organisms; the cause of many illnesses and infections such as the common flu

ScienceMakers Spotlight

Sharon Barnes

Chemist & Inventor

Birth Place	Texas
Education	Baylor University (B.S.)
	University of Phoenix (M.B.A.)
Awards & Achievements	Baylor University Distinguished Black Alumnae (2003)
	Top 75 Most Influential Blacks in Science Award (2004)
	Dow Chemical Company Vice President's Award

BIOGRAPHY

Sharon Barnes is known for her contribution to a patented process for contactless measurement of sample temperature as well as her leadership at Dow Chemical Company. Barnes grew up in a small town in Texas and her mother fueled her love for science during her first experience baking a cake. After graduating from high school, Barnes studied at Baylor University where she graduated with her B.S. degree in biology and chemistry. She later earned her M.B.A. degree from the University of Phoenix.

Baby Thermometer by icethim @Flickr

Barnes began her career in a laboratory conducting chemistry research at Dow Chemical Company. Barnes was a member of a five person team of chemist inventors who, in 1991, invented the device that became a precursor for the thermometers that are now used in the ear canals of babies. When a medical device company purchased the license from Dow, Barnes' invention showed up in baby thermometers around the country. The technology relies on a principal called infrared thermography, which means generating images from heat. In this case, it allows for determining the temperature of a sample without physically touching the sample. Later, Barnes made the switch from being a research chemist to working in the human resources (HR) department at Dow because she wanted to assist employees in the workplace. After applying for a position in HR, Barnes eventually rose to the rank of human resources manager. In addition to her career of more than twenty years at Dow Chemical Company, Barnes is a civic leader both nationally and within her home state of Texas. In 2003, she became the national secretary of the National Organization of Black Chemists and Chemical Engineers (NOBChCE). Barnes earned appointments from Texas Governor Rick Perry and Former Governor George W. Bush to the Health and Human Services Council and Texas Medical Board. She also served two terms on the city council in Lake Jackson, Texas. Sharon Barnes has two children and lives in Freeport, Texas.

Above Picture of Sharon Barnes from www.hhsc.state.tx.us/about_hhsc/council/SB.gif

SCIENCE IN ACTION

TAKING PICTURES WITH HEAT

Thermographic representation of people by opacity @Flickr

Would you like to have a camera that only generated thermal images? Sharon Barnes helped invent a device for baby thermometers using infrared thermography, the same technology that creates thermographic images. Infrared thermography generates images from heat by detecting infrared radiation emitted by heated tissue such as parts of the human body. Temperature measurements from multiple body areas can be used to generate an image of the body in real-time. This technology is used for things like night vision and medical imaging. Advantages include the ability to catch moving targets in real-time and to compare temperatures over a large area.

DISCUSSION QUESTIONS

1. If you were to interview Sharon Barnes, what questions would you ask her?
2. Check out the Marlow Industries website (http://www.marlow.com/thermal-imaging-cameras) and read about how thermal imaging helps firefighters. What are some other uses of thermal imaging?
3. Sharon Barnes invented a device that is used in baby thermometers. How does a normal thermometer work compared to the baby thermometer that Barnes developed?
4. Sharon Barnes switched from research to human resources. What is the role of a human resources department in a company and why is it important?
5. How does Sharon Barnes' career compare to that of other chemists or inventors in the Toolkit?

GLOSSARY

Dow Chemical Company – A company headquartered in Midland, Michigan that specializes in chemical products for the energy, electronics, water, and coatings sectors

George W. Bush - 43rd President of the United States (2001 to 2009) and 46th Governor of Texas (1995 to 2000)

Human Resources - The department of a business or organization that deals with the administration, management, and training of personnel

Infrared Radiation - Electromagnetic energy with wavelengths longer than visible light but shorter than radio waves

Infrared Thermography - The detection of infrared radiation emitted by heated tissue to generate an image

Rick Perry - Governor of Texas (2000 to 2011) at time of printing

ScienceMakers Spotlight

Jeannette Brown

Organic Chemist & Science Historian

Birth Date	May 13, 1934
Birth Place	Bronx, New York
Education	Hunter College (B.S. 1956)
	University of Minnesota (M.S. 1958)
Awards & Achievements	Chemical Heritage Foundation Ullyott Scholar
	The Association of Women in Science (AWIS) award (1990)
	American Chemical Society Fellow (2009)

BIOGRAPHY

Jeannette Brown is known for her dedication to science education and telling the stories of African American chemists. Brown was born in the Bronx, New York on May 13, 1934. At age six, she was inspired by her family doctor to pursue science. Brown graduated from New Dorp High School in 1952 and went on to receive her B.S. degree in chemistry from Hunter College in 1956. She was one of two African Americans in the first class of Hunter's new chemistry program. Brown then earned her M.S. degree in organic chemistry in 1958 from the University of Minnesota as the first African American woman to earn a graduate degree from their chemistry department.

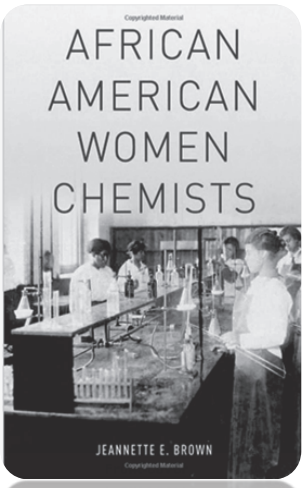
Chemistry By Horia Varlan@Flickr

After graduation, Brown joined CIBA Pharmaceutical Company where she worked on anti-tuberculosis drugs as well as a disease of chickens called coccidiosis. In 1969, she was hired by Merck & Co. Research Laboratories to synthesize compounds for testing as potential new drugs. Brown was appointed chairperson of the Project SEED Committee for the American Chemical Society (ACS) in 1986. She joined the faculty at the New Jersey Institute of Technology (NJIT) in 1993 where she worked as a visiting professor of chemistry and faculty associate. She also helped to write the NJIT Alliance for Minority Participation in Science grant, which was funded by the National Science Foundation (NSF) for two years. Beginning in 1998, Brown also served as the regional director of the New Jersey Statewide System Initiative, where her mission was to improve science education in Essex and Hudson counties. In addition, Brown has also worked for the Chemical Heritage Foundation. In 2010, Brown wrote *African American Women Chemists*, which featured the biographies of twenty-six distinguished chemists including Dr. Marie Daly and Dr. Jennie Patrick, the first African American women to receive their Ph.D. degrees in chemistry and chemical engineering, respectively. Jeannette Brown lives in Hillsborough, New Jersey.

Above Picture of Jeannette Brown from www.amazon.com/Jeannette-E.-Brown/e/B0052XPV4K

SCIENCE IN ACTION

PRESERVING HISTORY



Book Cover from www.amazon.com

If you think studying chemistry means you can only work in a laboratory, check out what Jeannette Brown has done. Brown's book, *African American Women Chemists,* details the experiences of the first black women in chemistry including those who worked in industry, education, and science policy. If you like science, history, and writing, consider a career as an author.

Most of the women in this book were, as the expression is used today, "nerds." They were outstanding students in school. Most were early readers; they learned to go to the library or to read books that their parents owned, and they did this even if their parents were not literate.

- Jeannette Brown

IN HER OWN WORDS

Jeannette Brown was interviewed for the Archives of Women in Science and Engineering at Iowa State University on December 19, 2001.

"We grew up in New York City and my father worked as a superintendent in a house, you know, taking care of, maintaining a house. In the same house there was a doctor, Dr. Logan. He's a famous black, African American physician. And his daughter-she lived there. And his daughter and I used to play together. And one time I guess when I was about six I got very ill. And Dr. Logan took care of me. And so I asked him I said, "How do you get to be a doctor?" And he said, "Well you study science." And I said, "Okay, that doesn't sound like it's hard to do." And so I was going to be a physician when I grew up. And so I knew that I wanted to be a scientist or to study science."

DISCUSSION QUESTIONS

1. If you were to interview Jeannette Brown, what questions would you ask her?
2. Check out the Chemical Heritage Foundation website (http://www.chemheritage.org/discover/chemistry-in-history/people.aspx#h) and find more information Marie Daly. What was the focus of Daly's research?
3. Young Jeannette Brown became interested in chemistry after a conversation with her doctor. If you wanted to know more about careers in science, who would you talk to?
4. Jeannette Brown was the first African American woman to earn her M.S. degree from the University of Minnesota chemistry department. Considering the time period when she earned her degree, what would you do if you were in her shoes?
5. How does Jeannette Brown's career compare with that of other chemists in the Toolkit?

GLOSSARY

Chemical Heritage Foundation - An independent, nonprofit organization, that maintains major collections of instruments, fine art, photographs, papers, and books and hosts conferences and lectures to foster an understanding of chemistry's impact on society

Jennie Patrick - The first African American woman to earn her Ph.D. degree in chemical engineering

Marie Daly - The first African American woman to earn her Ph.D. degree in chemistry

National Science Foundation (NSF) - A United States government agency that supports fundamental research and education in all the non-medical fields of science and engineering

Organic Chemistry - The study of carbon containing compounds such as acetic acid (vinegar) and caffeine

Project SEED - A nonprofit organization, founded in 1963, that partners with schools districts, universities, and corporations and uses mathematics to improve the educational opportunities of urban youth

Tuberculosis - A disease caused by inhaling or ingesting tubercle bacilli bacteria; symptoms include fever and small lesions (usually in the lungs)

ScienceMakers Spotlight

Linnaeus Dorman

Organic Chemist & Inventor

Birth Date	June 28,1935
Birth Place	Orangeburg, South Carolina
Education	Bradley University (B.S. 1956)
	Indiana University (Ph.D. 1961)
Awards & Achievements	National Organization of Black Chemists and Chemical Engineers (NOBCChE)'s Percy C. Julian Award (1992)

BIOGRAPHY

Linnaeus Dorman is known for his inventions in the fields of organic chemistry and biomaterials. Dorman was born on June 28, 1935 in Orangeburg, South Carolina. After graduating from Wilkinson High School, Dorman attended Bradley University in Illinois where he earned his B.S. degree in 1956 in chemistry. In 1957, Dorman became a member of the American Chemical Society (ACS) and remained active with ACS throughout his life. Dorman earned his Ph.D. degree from Indiana University in 1961.

Chemistry
by Milosz1 @Flickr

After completing his studies, Dorman worked as a research chemist at Dow Chemical Company in Midland, Michigan. He published many scientific articles in premier research journals, but Dorman is primarily known for over twenty inventions and patents. Many of Dorman's early patents involve synthesis methods in organic chemistry. In 1985, Dorman invented a chemical compound that acted as an absorbent of formaldehyde in the air. Because formaldehyde is known to be toxic to humans, even small quantities in the air can be harmful when inhaled. In 1992, Dorman invented a calcium phosphate biomaterial that was used in hard tissue prosthetics such as bone prosthetics. He developed a new method to synthesize this material which saved energy and money. From 1992 to 1993, Dorman demonstrated a new process for the controlled release of herbicides. In addition to his work at Dow Chemical Company, Dorman was active in the Midland section of the American Chemical Society, for which he served as secretary. In 1990, he helped host the 22nd Central Regional Meeting of the ACS. In 2000, after his retirement from Dow, Dorman undertook the responsibility of chairing the ACS Minority Affairs Committee. His goal was to increase minority participation in the outreach activities in which the Midland section engaged. Dorman played a major role in initiating the diversity award and the ACS Midland Section Scholarship. Linnaeus Dorman is retired and lives in Michigan.

Above Picture of Linnaeus Dorman from www.chemheritage.org/discover/chemistry-in-history/themes/petrochemistry-and-synthetic-polymers/synthetic-

SCIENCE IN ACTION

ARTIFICIAL BODY PARTS

Dentures
by Williamholling @Flickr

You may have heard of prosthetics, or fake limbs, but did you know that doctors can create replacement bones and teeth? When your baby teeth fall out, your body grows new permanent teeth, but what if one of those gets knocked out while playing hockey? Your dentist can fill the space with an artificial tooth. You may even know someone who wears a complete set of dentures, or fake teeth. In all of these cases, doctors rely on biomaterials, artificial compounds that can be created in a laboratory but are safe to use in the human body. When inventors like Linnaeus Dorman create these materials, they try to mimic natural human body parts.

DISCUSSION QUESTIONS

1. If you were to interview Linnaeus Dorman, what questions would you ask him?
2. Check out the Dow Chemical website (www.dow.com/) and click on “products and services.” Find three products that Dow scientists make. How are the products used to improve everday life?
3. Linnaeus Dorman invented a process for making hard tissue prosthetics like bones. Can you think of parts of the body that can be replaced with prosthetics?
4. Linnaeus Dorman was an active member of the American Chemical Society. Why is it important for scientists to also be involved in educational activities?
5. How does Linnaeus Dorman's career compare to that of other chemists or inventors in the Toolkit?

GLOSSARY

Biomaterial - A synthetic compound used to replace or work alongside living tissue such as in a human knee replacement

Dow Chemical Company - A company headquartered in Midland, Michigan that specializes in chemical products for the energy, electronics, water, and coatings sectors

Formaldehyde - A toxic colorless gas with numerous industrial uses; acts as a building block for many other chemical compounds

Hard Tissue Prosthetics - Artificial materials used to replace or enhance living body parts such as bones, cartilage, or teeth

Organic Chemistry - The study of carbon containing compounds such as acetic acid (vinegar) and caffeine

Synthesis - The process of producing a chemical compound (usually by the union of simpler chemical compounds)

ScienceMakers Spotlight

Krishna Foster

Environmental Chemist

Birth Date	January 7, 1970
Birth Place	Culver City, California
Education	Spelman College (B.S. 1992)
	University of Colorado, Boulder (Ph.D. 1998)
Awards & Achievements	Sophia B. Packard Scholarship (1992)
	California State University, Los Angeles Distinguished Women Award (2007)

BIOGRAPHY

Krishna Foster had the opportunity to study, work, and live in the Arctic Circle in pursuit of her passion for environmental chemistry. Born on January 7, 1970 in Culver City, California, Foster enjoyed exploring nature as a child. During high school, she was an avid cross-country runner. Foster graduated from Helix High School in 1988 and received the National Aeronautics and Space Administration (NASA) Fellowship through the Women in Science and Engineering (WISE) Program that helped finance her education at Spelman College, where she earned her B.S. degree in chemistry in 1992. She became interested in environmental chemistry at the University of Colorado, Boulder, where she earned her Ph.D. degree in 1998.

Mass Spectrometer by nayukim@Flickr

Foster became a postdoctoral researcher at the University of California, Irvine in 1998. In this position, she used mass-spectrometry to see how sea-salt particles affect the ability of the lower-atmosphere to clean itself through oxidation reactions. In 2000, Foster became involved in a project to study surface-level ozone in the atmosphere of the arctic spring. That year, she also accepted a position as an assistant professor at California State University, Los Angeles (Cal State) and was promoted to associate professor in 2006. Her work at Cal State has focused on the effects of sunlight on pollutants in places where air and water meet, like the surface of a lake. Her lab has also developed techniques to study reduced phosphorous oxyanions in natural waters, which could help determine how phosphorous, an essential element in all organisms, might have been initially incorporated into living cells in ancient earth. Foster has served as a mentor to twenty-six high school, undergraduate, and graduate students by providing and guiding research opportunities. Her former students have found success in both academia and industry. Krishna Foster is married to Kwasi Connor and they live in California.

OZONE: HARMFUL OR HELPFUL?

Arctic Glacier
by PolarCruises@Flickr

Krishna Foster traveled all the way to northern Canada to research the effects of sunlight on pollutants at the air-water interface. She discovered that the chemical element bromine plays a role in the destruction of surface-level ozone at sunrise in the arctic. Ozone is a gas made up of three oxygen molecules bonded together. Surface-level ozone is found within 10 miles of the earth's surface. It can be harmful to humans and is the primary component of smog. The ozone layer exists about 30 miles above the earth's surface and protects us from harmful UV rays from the sun.

IN HER OWN WORDS

Krishna Foster was interviewed by The HistoryMakers on April 28, 2011. Here is a portion of her interview:

Like my mother, I enjoyed baking. I remember at [age] ten I was making lemon meringue pies with perky meringue and everything. I would work on making that just right. So I had tendencies towards wet lab chemistry…chemistry and curiosity. One of my childhood phrases is, Why? Why? I always wanted to know why.

DISCUSSION QUESTIONS

1. If you were to interview Krishna Foster, what questions would you ask her?
2. Check out the Science Kids website (http://www.sciencekids.co.nz/sciencefacts/chemistry/oxygen.html). We know that oxygen is a component of ozone, but where else do we find the element oxygen?
3. Phosphorous is an essential element in all organisms, and we need the element oxygen to breathe. Can you name some other chemical elements that are essential for life?
4. Foster studied the way that pollutants and other chemicals interact with the environment. Why is this important?
5. How does Krishna Foster's career compare to that of other chemists in the Toolkit?

GLOSSARY

Bromine - A chemical element that occurs in the oceans as salt; a red liquid with toxic vapors

Environmental Chemistry - The study of chemical processes occurring in the natural world, which are impacted by the activity of humans

Lower Atmosphere - The part of the Earth's sky that is closest to the surface; where weather events occur

Mass spectrometry - An analytical technique that is used to determine the structure and composition of chemical compounds

Oxidation - A chemical reaction in which the atoms of an element lose electrons

Ozone - A colorless gas; the molecule is made up of three atoms of oxygen and exists in the Earth's atmosphere

Reduced Phosphorous Oxyanion - A form of a chemical compound containing the elements phosphorous and oxygen; can serve as a source of nutrients for living organisms in natural waters

ScienceMakers Spotlight

Fillmore Freeman

Organic Chemist

Birth Date	1936
Birth Place	Lexington, Mississippi
Education	Central State College (B.S. 1957)
	Michigan State University (Ph.D. 1962)
Awards & Achievements	Third most highly cited African American chemist according to Oklahoma State University (2002)
	Alexander von Humboldt Foundation Fellow
	Fulbright-Hayes Senior Research Fellow

BIOGRAPHY

Fillmore Freeman is a professor of organic chemistry and has conducted important research on the synthesis and structure of compounds that can fight tumors and viruses. He was born in 1936 in Lexington, Mississippi and graduated from high school in Chicago, Illinois, in 1953. In 1957, Freeman graduated summa cum laude from Central State College in Wilberforce, Ohio, with his B.S. degree and then went on to pursue graduate studies at Michigan State University, where he received his Ph.D. degree in physical organic chemistry in 1962.

Laboratory by RDECOM @Flickr

After a brief stint working with a private firm, Freeman served as a National Institutes of Health (NIH) Fellow at Yale University in 1964. The following year, he became an assistant professor at California State University, Long Beach. During this time, the school expanded its chemistry and biochemistry programs as more and more students became interested in those fields. In 1973, Freeman became a professor of chemistry at the University of California, Irvine where he continued to work for the duration of his professional career. During the 1970's, Freeman traveled to Europe to serve as a visiting professor at the University of Paris and later at the Max Planck Institute of Biophysical Chemistry in Germany. With his background in physical organic chemistry, Freeman has conducted research on a number of topics, including the building blocks, pathways, and reactions of cyclic compounds, or compounds that form a ring shape. In 1991, Freeman was the recipient of a grant from the National Institutes of Health to study the biochemical properties of allicin, a component of garlic. Freeman's work has had a strong emphasis in isolating, researching, and synthesizing compounds with anti-tumor and anti-viral properties. Fillmore Freeman works in Irvine, California.

Above Picture of Fillmore Freeman from faculty.uci.edu

SCIENCE IN ACTION

GARLIC BREATH

Garlic
by mullica @Flickr

Does garlic give us anything besides bad breath? The answer lies in Fillmore Freeman's research! An organic compound called allicin, which is found in crushed garlic, has been found to have both antibiotic activity and anti-diabetes activity when tested in a laboratory. Does it work as medicine in the human body? Fillmore Freeman used an analytical chemistry technique called High Pressure Liquid Chromatography (HPLC) to investigate the behavior of allicin in blood, simulated stomach and intestinal fluids, water, and two other chemical mediums. Freeman discovered that the environment of the human digestive system prevented commercial garlic products from producing allicin.

DISCUSSION QUESTIONS

1. If you were to interview Fillmore Freeman, what questions would you ask him?
2. Check out this Chemical Reaction Video (http://www.youtube.com/watch?v=tE4668aarck). What are the five types of chemical reactions?
3. Garlic is known to contain chemicals that are good for human health. Can you think of other foods that we eat which are good for us? What makes these foods good for us?
4. Freeman investigates the properties of chemical compounds that can fight tumors and viruses in the human body. Why is this important?
5. How does Fillmore Freeman's career compare with that of other chemists in the Toolkit?

GLOSSARY

Allicin - A smelly, oily liquid with antibacterial properties, which is present in garlic

Analytical Chemistry - The gathering of information about the quantity and properties of matter, as well as the processing and communication of that information

High Pressure Liquid Chromatography (HPLC) - A technique in chemistry to separate and identify components of a mixture

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

Organic Chemistry - The study of carbon containing compounds such as acetic acid (vinegar) and caffeine

Physical Organic Chemistry - The study of the movement and physical behavior of organic, carbon containing compounds

Tumor - A mass formed by cancer cells, which replicate more quickly than normal, healthy cells

Virus - A tiny body, too small to see with the eye alone, that can only live inside the cells of other organisms; the cause of many illnesses and infections such as the common flu

Ronald Goldsberry

Chemist & Business Executive

Birth Date	September 12, 1942
Birth Place	Wilmington, Delaware
Education	Central State University (B.S. 1964)
	Michigan State University (Ph.D. 1969)
	Stanford University (M.B.A. 1973)
Awards & Achievements	Industry Week Magazine's Excellence in Management Award (1985)
	Black Enterprise Magazine's Top 25 Black Executives in the U.S. (1988)
	Black Enterprise Magazine's Top 40 Black Executives in the U.S. (1993)

BIOGRAPHY

Ronald Goldsberry used his scientific background to launch himself into a career that culminated in a high-level executive position with the Ford Motor Company. Goldsberry was born on September 12, 1942 in Wilmington, Delaware. He developed an early interest in science and earned his B.S. degree in chemistry from Central State University in 1964. He went on to study organic and physical chemistry at Michigan State University, earning his Ph.D. degree in 1969.

Ford Mustang
by me_ram @Flickr

After a brief period of university teaching and chemistry research, Goldsberry switched to business and enterprise. He earned his M.B.A. degree in 1973 from Stanford University and then worked for a string of Fortune 500 companies beginning with Hewlett Packard and Boston Consulting Group. In 1975, he was hired by the Gulf Oil Corporation where he worked until 1978. Goldsberry then became vice president for business development and planning at the Occidental Chemical Corporation. After that, he was hired by the Parker Chemical Company in Michigan, which treated steel used to build cars. His position as vice president and general manager at Parker exposed Goldsberry to the automotive industry headquartered in nearby Detroit. The decline of the automotive industry at that time caused Parker Chemical Company to be sold to Ford Motor Company in 1983. Ford, however, made Goldsberry president and chief operating officer. He worked hard to improve Parker Chemical Company and ended up doubling its sales. Parker was again sold to a German Company, but Goldsberry stayed with Ford and became general manager of the plastic products division for the Automotive Components Group. In 1990, Goldsberry was appointed executive director of Ford's sales and service strategies. He was promoted to vice president and general manager for customer service in North America in 1994 and later to vice president of global customer service in 1997. Ronald Goldsberry is retired and lives in Bloomfield Hills, Michigan.

Above Picture of Ronald Goldsberry from www.100blackmendetroit.org

SCIENCE IN ACTION

BODY OF STEEL

Rust
by uberculture @Flickr

You probably ride in cars quite often, but have you ever really thought about them? Who builds cars? What are they made from? Ronald Goldsberry began his career in the automotive industry working with Parker Chemical Company, a company that became known for its anti-corrosion process to treat the steel used in car bodies. Corrosion is a type of damage to metals caused by oxidation or a chemical reaction better known as rust. When you leave your bike out in the rain, you may notice the build-up of rust. This can also happen to cars if they are not protected. Rust, or iron oxide, forms when oxygen and iron (steel) combine in the presence of water. Parker Chemical Company developed a process to shield cars from corrosion.

DISCUSSION QUESTIONS

1. If you were to interview Ronald Goldsberry, what questions would you ask him?
2. Check out the CNN website about Fortune 500 companies (http://money.cnn.com/magazines/fortune/fortune500/2011/full_list/). How many of the top 50 do you recognize?
3. Rusting is a very common process that can happen when metal gets wet. Can you name some objects that you have you seen rusting?
4. Ronald Goldsberry worked his way up in the Ford Motor Company. If you wanted to become a top business executive, how would you prepare?
5. How does Ronald Goldsberry's career compare to that of other chemists in the Toolkit?

GLOSSARY

Corrosion - A type of damage to metals caused by a chemical reaction called oxidation

Ford Motor Company - An American automotive corporation based in Michigan that was founded by Henry Ford in the early 20th century

Fortune 500 - An annual list of the five hundred most profitable U.S. industrial corporations

Organic Chemistry - The study of carbon containing compounds such as acetic acid (vinegar) and caffeine

Oxidation - A chemical reaction in which the atoms of an element lose electrons

Physical Chemistry - The study of the movement and physical behavior of chemical compounds

ScienceMakers Spotlight

Joseph Gordon

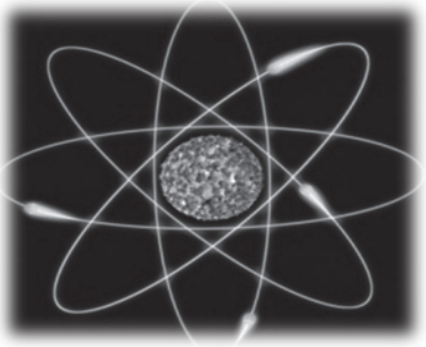
Inorganic Chemist

Birth Place	Nashville, Tennessee
Education	Harvard University (B.S. 1966)
	Massachusetts Institute of Technology (MIT) (Ph.D. 1970)
Awards & Achievements	Historically Black Colleges and Universities (HBCU) Council of Deans Black Engineer of the Year for Outstanding Technical Accomplishment (1990)
	National Organization for the Professional Advancement of Black Chemists and Chemical Engineers Percy Julian Award (1993)

BIOGRAPHY

Joseph Gordon led a research team that made an important discovery related to the structure and behavior of chemical compounds. Gordon was born in Nashville, Tennessee, the son of a homemaker and a physician. After graduating from high school, he studied physics and chemistry at Harvard College (now Harvard University), earning his B.S. degree from there in 1966. Gordon then went on to receive his Ph.D. degree in inorganic chemistry from the Massachusetts Institute of Technology (MIT) in 1970.

In 1975, Gordon joined the staff at the International Business Machines (IBM) Almaden Research Center in San Jose, California. He began as a technical staff manager and supported the office of the laboratory director. Gordon eventually became manager of the Department of Materials for Advanced Technology where he contributed significantly to the fields of materials science and electrochemistry. Gordon conducted research on the atomic structure of chemical compounds and his team was the first to determine how the atomic structure of a solid compound and a liquid compound change when they come in contact with one another. In chemistry, this is called a solid-liquid interface. For example, when a solid substance like quartz crystal, comes into contact with a liquid substance its atomic behavior and structure change. Gordon used many techniques to study the solid-liquid interface including Raman spectroscopy. In 1987, Gordon chaired a conference called the Gordon Conference on Electrochemistry. Throughout his career, he published over seventy-five scientific research articles and he received twelve patents for his discoveries. In addition to his work at IBM's Almaden Research Center, Gordon was a member of several professional societies including the National Organization of Black Chemists and Chemical Engineers (NOBCChE) and the American Physical Society (APS). Joseph Gordon lives with his wife in San Jose, California.



Atom
by Captain Narender @Flickr

Above Picture of Joseph Gordon from domino.research.ibm.com

SCIENCE IN ACTION

WHAT'S THE PHASE?

Boiling Water by jamiesrabbits @Flickr

One of the most basic principles in chemistry is that there are three common phases of matter: solid, liquid, and gas. A solid, like steel, has a definite shape and volume. A liquid, like water, has a definite volume, but takes the shape of its container. A gas, like oxygen, does not have a definite volume or a definite shape. Substances can exist in more than one phase, like when boiling water (liquid) turns into steam (gas). Part of Joseph Gordon's work was examining the structure of compounds in different phases or the structure of a compound as it is changing from one phase to another. He also looked at the boundary or interface between two different substances.

DISCUSSION QUESTIONS

1. If you were to interview Joseph Gordon, what questions would you ask him?
2. Check out the Chem4Kids website (http://www.chem4kids.com/files/matter_states.html) and learn about the phases of matter. What are the four phases of matter? In what state do molecules of matter have the most energy? The least?
3. Joseph Gordon studied the chemistry of different phases of matter. Can you name three substances of each phase: solid, liquid, and gas?
4. Joseph Gordon worked as part of a team of scientists. Why do you think that scientific discoveries often happen through the work of a team of people and why is this important?
5. How does Joseph Gordon's career compare to that of other chemists in the Toolkit?

GLOSSARY

Electrochemistry - The branch of chemistry that deals with the relations between electrical and chemical phenomena

Inorganic Chemistry is the study of compounds, which generally do not contain carbon such as sodium chloride (salt)

International Business Machines Corporation (IBM) - An American technology company that builds and sells computers

Materials Science - The study and development of new types of metals, composites, and plastics

Matter - A substance that has mass and takes up space

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Raman Spectroscopy - A technique used to study the rotation, vibration, and other low-frequency movements of a system

Solid-Liquid Interface - The molecules that are located at the boundary between solid phase and liquid phase; the meeting of a solid substance and a liquid substance

ScienceMakers Spotlight

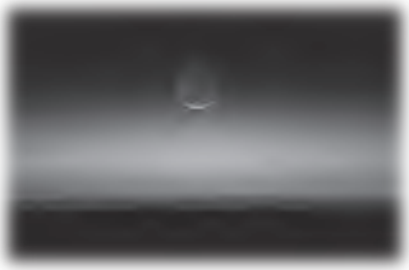
John Hall

Atmospheric Chemist

Birth Date	September 24, 1946
Birth Place	Birmingham, Alabama
Education	Morehouse College (B.S. 1969)
	Harvard University (Ph.D. 1974)
Awards & Achievements	Organized the first delegation of black scientists to China (1982)
	Atlanta Mayor's Advisory Committee for Clean Water (2002)

BIOGRAPHY

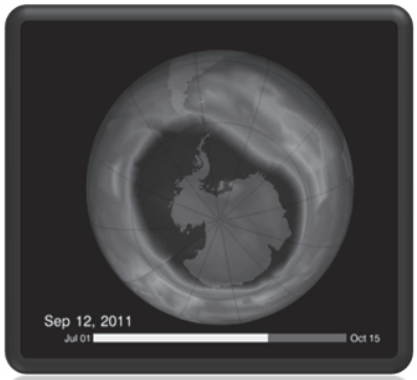
John Hall's career skyrocketed after earning his Ph.D. degree in 1974. His work included investigations for the National Aeronautics and Space Administration (NASA) to find out if space shuttles were causing a hole in the ozone layer. Hall was born on September 24, 1946 and grew up in Atlanta, Georgia, where he attended Henry McNeil Turner High School. He received his B.S. degree in chemistry from Morehouse College in 1969. With a scholarship for continued studies in chemistry, Hall began his graduate studies at Harvard University. He worked with his research advisor, William N. Lipscomb, to better understand the nature of chemical bonds in boranes through electron orbital calculations. They wanted to understand how two parts of a molecule fit together. Lipscomb later earned the Nobel Prize in chemistry for his work on the structure of borane. In 1974, Hall graduated from Harvard University with his Ph.D. degree in theoretical computational chemistry.



Layers of Earth's Atmosphere by NASA Earth Observatory @Flickr

After graduation, Hall worked with Dr. William Guillory under a contract from NASA to develop models of the reaction mechanisms that cause damage to the ozone layer. In 1979, Hall became an associate professor of chemistry at Morehouse College and senior research scientist at the School of Geophysical Sciences at the Georgia Institute of Technology where he continued his research in atmospheric chemistry. Hall found that chlorine nitrate reactions in the atmosphere lead to the depletion of the ozone layer. His later work focused on how pollutants in the air affect human health, particularly low-income populations. He served as the associate vice president for research at The Ohio State University for seven years before returning to Morehouse College in 2001 as chair of the chemistry department. Hall was later named Bruce Raneur Professor of Natural Sciences. He has published numerous academic papers on physical and atmospheric chemistry. John Hall and his wife, Susan Hall, are the founders of Transformational Consultants International, Inc., which specializes in improving workplace productivity and diversity.

THE OZONE: EARTH'S SUNSCREEN



The Hole Over Antartica (in dark grey)-2009 by NASA Goddard Photo and Video @ Flickr

Ozone is a rare gas in the Earth's atmosphere; there are three molecules of ozone for every 10 million air molecules. Despite the small amount, ozone plays an important role in Earth's stratosphere which is often called the ozone layer. The ozone layer is an invisible sunscreen over the Earth protecting us from the sun's harmful UV rays. Due to pollution, there are now large holes in the ozone layer especially over the north and south poles. Nitrogen oxide is a large scale pollutant. It is formed naturally in an electrical storm, but is largely created by pollution from vehicles and power plants. John Hall modeled the chemical reactions that occur when nitrogen oxide and other compounds damage the ozone layer.

IN HIS OWN WORDS

John Hall was interviewed by The HistoryMakers on April 14, 2011. Here is a portion of his interview:

And I read a lot of comic books, particularly the comic books that had to do with science fiction...But they would have these things in them about the international geophysical year and about astronomy and about the universe, and I would read that, and that would be the most interesting part. And then I'd go to the library and I'd check these books out. I remember that one time I went to the library and I had these books on electricity and magnetism and chemistry and stuff. I was like eleven years old. And I went to check them out, and the librarian said, "Can you read these books, are you sure?" And I said, "I think, yeah, I check them out every week."

DISCUSSION QUESTIONS

1. If you were to interview John Hall, what questions would you ask him?
2. Check out this website (http://dnr.wi.gov/org/caer/ce/eek/earth/air/ozonlayr.htm). What are some pollutants that are depleting the ozone layer?
3. John Hall conducted research to determine whether the space shuttles were causing ozone layer depletion. If you could study sources of pollution, which source would you study? Why?
4. Why should you be concerned about the depletion of the ozone layer?
5. How does John Hall's career compare to that of other chemists in the Toolkit?

GLOSSARY

Atmospheric Chemistry - The scientific study of the relationships and interactions of the substances in the gases around the earth

Borane - A chemical compound composed of boron and hydrogen gases

Chlorine Nitrate - An important atmospheric gas that helps to absorb chlorine, which contributes to the depletion of the ozone layer

Electron Orbital - The path of an electron around the nucleus of an atom

Ozone Layer - A region of the upper atmosphere, 10 - 20 miles up, with a high concentration of ozone gas that absorbs ultraviolet radiation from the sun

Theoretical Computational Chemistry - A branch of chemistry that uses principles of computer science to assist in solving chemical problems and seeks to provide theories that explain chemical observations

ScienceMakers Spotlight

Walter Hill

Agronomist

Birth Date	August 9, 1946
Birth Place	New Brunswick, New Jersey
Education	Lake Forest College (B.S. 1968)
	University of Chicago (M.A.T. 1970)
	University of Arizona (M.S. 1973)
	University of Illinois (Ph.D. 1978)
Awards & Achievements	American Society of Agronomy Fellow (1992)
	Chicago Museum of Science and Industry's African American Achiever in Agriculture (1996)
	USDA Group Honor Award for Excellence (1999)

BIOGRAPHY

Walter Hill has combined his agricultural and environmental expertise with his passion for development in order to serve others who are less fortunate. He was born on August 9, 1946 in New Brunswick, New Jersey. Hill attended Lake Forest College near Chicago, Illinois, where he earned his B.S. degree in chemistry in 1968. In 1970, he received his M.A.T. degree from the University of Chicago. Hill graduated with his M.S. degree in soil chemistry from the University of Arizona in 1973 and in 1978, he earned his Ph.D. degree in agronomy and environmental chemistry from the University of Illinois.

Farm by by eamoncurry123@Flickr

Hill began his long career at Tuskegee University in 1978 when he became an assistant professor in the Department of Agricultural Sciences. He was promoted to associate professor and full professor in 1981 and 1984, respectively. In addition to his career at Tuskegee, Hill began working for the United States Department of Agriculture (USDA) in 1986 both as a research director for the Cooperative State Research Program and as an administrator for the Cooperative Extension Program. Also in 1986, Hill became director of the G.W. Carver Agricultural Experiment Station. Hill was appointed dean of the School of Agriculture and Home Economics at Tuskegee University from 1987 to 1996. Since 1996, he has served as dean of the College of Agricultural, Environmental, and Natural Sciences. Hill's research has focused on the sweet potato, which is a model crop for studying food production and sustainable agriculture. He has even investigated the use of the sweet potato on long-term NASA space missions. Hill is interested in teaching and serving others in the fields of agricultural development, nutritional science, environmental resources, and natural sciences like biology and chemistry. He has worked with large agricultural organizations and local farmers to help people utilize their limited resources in productive ways. Walter Hill lives with his wife Jill Harris Hill. They have three sons.

Above Picture of Walter Hill from www.tuskegee.edu

SCIENCE IN ACTION

THE SWEETEST CROP IN SPACE

Sweet Potatoes
by NatalieMaynor @Flickr

What do astronauts eat when they are on a space mission? Walter Hill conducted an experiment to see if sweet potato stem cuttings would grow on a space shuttle in microgravity conditions. He compared stems grown on a space shuttle with those grown on the ground and measured levels of carbon dioxide and oxygen in the air as well as production of sugars like glucose, fructose, and sucrose in the sweet potato stems. Hill discovered that there was a greater accumulation of sugars in the shuttle-grown sweet potato stems, as well as greater root growth. However, there was little difference in cell development. Therefore, sweet potato stem cuttings can be used in space to grow sweet potatoes and feed the flight crew.

DISCUSSION QUESTIONS

1. If you were to interview Walter Hill, what questions would you ask him?
2. Check out the USDA website (www.usda.gov). Would you enjoy studying or working in the field of agriculture. Why or why not?
3. Besides sweet potatoes, what would you recommend for astronauts to eat during a space mission and why?
4. Walter Hill works with underserved communities to improve their agricultural productivity. Why is this important?
5. How does Walter Hill's career compare with that of other chemists in the Toolkit?

GLOSSARY

Agronomy - The study of crop production and soil

Environmental Chemistry - The study of chemical processes occurring in the natural world which are impacted by the activity of humans

Fructose - A sugar found in fruit and honey

Glucose - A simple sugar that is an important energy source in living organisms

Microgravity - Very weak gravity, as in an orbiting spacecraft

Sucrose - A chemical compound that is the primary component of cane or beet sugar

Sustainable Agriculture - Farming methods which increase food production without damaging the environment

United States Department of Agriculture (USDA) - A U.S. Government agency that researches and oversees food production, farming, and natural resources

ScienceMakers Spotlight

James Letton

Organic Chemist & Inventor

Birth Year	1933
Birth Place	Paris, Kentucky
Education	Kentucky State University (B.S. 1955)
	University of Illinois (Ph.D. 1970)
Awards & Achievements	Procter & Gamble Victor Mills Society Member
	National Association of Equal Opportunities in Education Distinguished Alumni (1989)
	National Organization for the Professional Advancement of Black Chemists and Chemical Engineers Percy L. Julian Award (1989)

BIOGRAPHY

James Letton not only followed in the footsteps of famed organic chemist Percy L. Julian, he worked for him at the Julian Laboratory in his first job out of college. Letton was born in 1933 in Paris, Kentucky. He graduated from Kentucky State University with his B.S. degree in 1955. Despite his qualifications, Letton faced racial discrimination and spent two years after college trying to find a job. This was until he learned of Julian Laboratories in Chicago where black chemists were welcomed. Letton worked for Julian Laboratories for over a decade in steroid processing and manufacturing. He left to teach high school science and then earned his Ph.D. degree in chemistry from the University of Illinois in 1970.

Cooking Oil Nutrition Facts by I love butter@ Flickr

After receiving his doctorate, Letton became chairman of the Department of Chemistry at his alma mater, Kentucky State University. In 1975, he left academia for the private sector, working at Procter & Gamble. Letton worked as an organic chemist for the packaged soap division where he developed biodegradable soap agents. He earned his first patent for an enzyme that stabilized Procter & Gamble's brand of laundry detergent. Letton then joined the processing and development team where he worked on fat substitutes including Olestra, which is used in cooking oil or shortening. From this innovative fat substitute, Letton earned a number of patents. From 1979 to 1984, Letton continued to work at Procter & Gamble while serving as president of the Kentucky State University Alumni Association. As a prestigious scientist, Letton has influenced many African Americans to enter into the STEM disciplines. His son, James A. Letton followed in his father's footsteps working as a chemist at Procter & Gamble. His other son, Alan Letton has his Ph.D. degree in chemical engineering and worked at Dow Chemical Company and Sealy before starting his own company. James Letton lives in Cincinnati, Ohio.

Above picture of James Letton from www.pbs.org/wgbh/nova/julian/knew.html

SCIENCE IN ACTION

FOOD FOR THE FUTURE

Pringles Chips
by Charles J Bowley @Flickr

Did you ever wonder how a bag of "light" chips can have half the fat of normal chips or how a diet soda can have zero calories? Diet drinks and "light" foods have synthetic molecules engineered in labs to act the same as sugars or fats, but without calories or cholesterol. In the late 1980s, James Letton developed Olestra, a fat substitute. Olestra is now used in certain types of Light Lays and Light Pringles Chips. Olestra tastes and feels the same as fat but is too large of a molecule to be absorbed in human intestines so it passes through the body undigested. However, this fat substitute is not perfect because it does have some negative side effects such as abdominal cramping.

DISCUSSION QUESTIONS

1. If you were to interview James Letton, what questions would you ask him?
2. Check out the American Chemical Society website (portal.acs.org/portal/Navigate?nodeid=1188) and click on careers Food and Flavor Chemistry. What does a food chemist do? Would you like to be a food chemist, why or why not?
3. James Letton developed food substitutes. Why do people want substitutes for ingredients like fat and sugar?
4. Do you think it is healthier to eat foods with fat and sugar substitutes or eat foods that are all natural? Explain your answer.
5. How does James Letton's career compare to that of other chemists in the Toolkit?

GLOSSARY

Biodegradable - Able to be decomposed by natural processes

Enzyme - A substance produced by a living organism that acts as a catalyst to make a specific biochemical reaction go faster

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Percy L. Julian (1899 –1975) **-** An African American research chemist and a pioneer in the chemical synthesis of medicinal drugs from plants

Procter & Gamble - An American multi-national corporation headquartered in Downtown Cincinnati, Ohio that manufactures a wide range of consumer goods

Steroid - The large class of organic compounds with a characteristic molecular structure containing four rings of carbon atoms; they include many hormones, alkaloids, and vitamins

ScienceMakers Spotlight

Sharon Neal

Analytical Chemist

Birth Year	1958
Education	Spelman College (B.S. 1980)
	Emory University (Ph.D. 1988)
Awards & Achievements	Beckman Young Investigators (1991)
	California State University Lloyd Ferguson Distinguished Lecturer (2005)

BIOGRAPHY

Sharon Neal is a standout in the field of analytical chemistry. She was born in 1958 and received her B.S. degree in chemistry from Spelman College in 1980. After graduation, Neal stayed in Atlanta, Georgia to work as a staff chemist for the Coca Cola Company from 1981 to 1983. She received her Ph.D. degree in chemistry from Emory University in 1988.

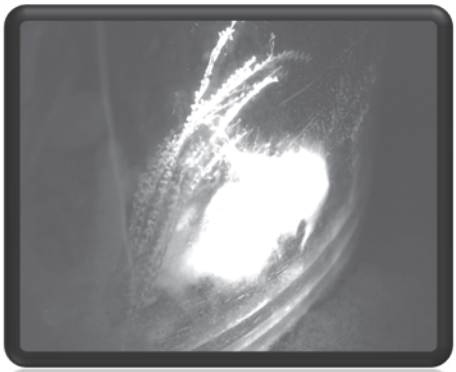
Spectroscopy Machine by UC Davis College of Engineering @Flickr

After obtaining her doctorate, Neal completed postdoctoral research at the University of Washington, Spelman College, and the U.S. Naval Research Laboratory. In 1991, she joined the faculty of the University of California, Riverside as a chemistry professor. Neal went on to work at the University of Delaware in 1998 as an associate professor of chemistry and biochemistry. She has a wide range of research interests including the development and interpretation of multi-dimensional fluorescence methods for analysis of samples, and characterization of intrinsic protein fluorescence. Her laboratory at the University of Delaware studies the dynamic interactions between small molecules and the complex fluids found in biological, environmental, and clinical systems. They use fluorescent probes and spectroscopic instruments to isolate and monitor interactions between small molecules, such as drugs or toxins. Neal has co-authored many books including *Data Analysis for Multidimensional Luminescence* and *Time Domain Filtering of Two-Dimensional Fluorescence Data*. She has numerous papers published in leading journals such as *Analytical Chemistry*, *the Journal of Physical Chemistry, and Analytica Chimica Acta*. Neal has presented at professional conferences and served on several boards including the Oxide Advisory Board. Sharon Neal works in Newark, Delaware.

Above Picture of Sharon Neal from http://www.udel.edu/chem/sneal/sln_rsrch/sln_people.htm

SCIENCE IN ACTION

LET THERE BE LIGHT



Bioluminescent Coral
by NOAA Photo Library @Flickr

Light is a form of energy that is created by other types of energy. For example, incandescent light, like a flame, sunlight, or an electric stove, is created from heat energy. Luminescence is a cold light that is produced at normal temperatures. Luminescence can be created by electrical energy, chemical reactions, and subatomic motions. Fluorescence is luminescence created by ultraviolet radiation and is used in neon light signs. Chemiluminescence has energy supplied by chemical reactions. Glow-in-the-dark plastic tubes sold in amusement parks are examples of chemiluminescence. Another example is bioluminescence, luminescence caused by chemical reactions in living things; fireflies glow by bioluminescence.

DISCUSSION QUESTIONS

1. If you were to interview Sharon Neal, what questions would you ask her?
2. Check out the Lights Alive website (http://www.sdnhm.org/kids/lightsalive/biolum2.html) and learn about bioluminescence. Why do organisms create their own light?
3. How is incandescent light from a flame different from fluorescent light?
4. Sharon Neal uses fluorescence to understand the behavior and interactions of small molecules like drugs and toxins. Why do you think this is important?
5. How does Sharon Neal's career compare to that of other chemists in the Toolkit?

GLOSSARY

Analytical Chemistry - The gathering of information about the quantity and properties of matter, as well as the processing and communication of that information

Fluorescence - Light emitted during absorption of radiation of some other invisible wavelength

Luminescence - Giving off light not caused by heat

Spectroscopy - The branch of science concerned with the investigation and measurement of spectra (a band of colors) produced when matter interacts with or emits electromagnetic radiation

Ultraviolet Radiation - The portion of the electromagnetic spectrum between X-rays and visible light

ScienceMakers Spotlight

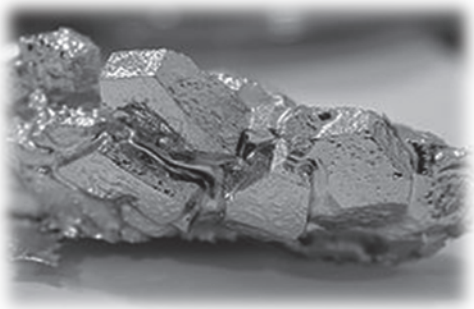
Gregory Robinson

Organometallic Chemist

Birth Date	May 2, 1958
Birth Place	Alexandria, Alabama
Education	Jacksonville State University (B.S. 1980)
	University of Alabama (Ph.D. 1984)
Awards & Achievements	American Chemical Society, Northeastern Georgia, Chemist of the Year Research Award (1998)
	National Organization for the Professional Advancement of Black Chemists and Chemical Engineers Percy L. Julian Award (2004)
	Lamar Dodd Creative Research Award (2010)

BIOGRAPHY

Gregory Robinson has made the successful transition from an elite football player in college, to an award-winning chemist and university professor. He was born on May 2, 1958 in Alexandria, Alabama. Robinson was an exceptional athlete at Alexandria High School, playing baseball, basketball, and football. He attended Jacksonville State University where he took on the challenge of majoring in chemistry and playing college football. In 1980, Robinson was the conference defensive player of the year and received his B.S. degree in chemistry. He went on to receive his Ph.D. degree in chemistry from the University of Alabama in 1984.



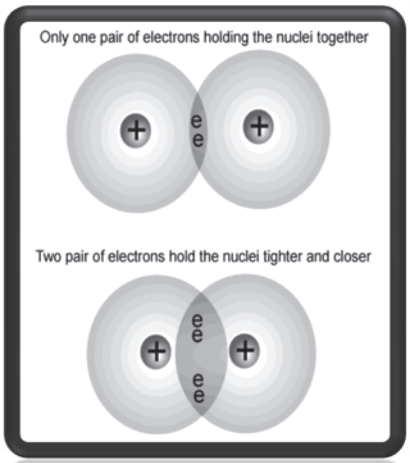
Gallium Crystal
by commons.wikimedia.org/wiki/File

After completing his education, Robinson decided to teach and conduct research at Clemson University. In 1994, he received a fellowship to study at the Technical University in Berlin, Germany. The next year, Robinson left Clemson and joined the faculty at the University of Georgia as a professor of chemistry. In 2005, he was named the Franklin Professor of Chemistry. Robinson's research focuses on organometallic chemistry. This includes compounds which contain chemical bonds between carbon and metallic elements. Robinson also found a way to create unique bond types between certain atoms. For example, he linked two gallium atoms with a triple bond and two silicon atoms with a double bond. Throughout his career, Robinson has published numerous scientific articles. His research work has been featured in top scientific journals including *Science*, *Nature*, and the *Journal of American Chemical Society*. Robinson is a member of several professional societies including the American Chemical Society (ACS) and the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE). Gregory Robinson works in Athens, Georgia.

Above picture of Gregory Robinson from www.creativeresearch.uga.edu

SCIENCE IN ACTION

CHEMICAL BONDS: THE GLUE OF THE UNIVERSE



Single and Double Bonds by ibchem.org

A chemical bond is the force which holds molecules together. There are chemical bonds in water holding hydrogen and oxygen atoms together and bonds in your soda holding millions of aluminum atoms together. How atoms bond depends on the electron configuration. There are two types of bonds, covalent bonds where electrons are shared between the atoms and ionic bonds where an electron is transferred from one atom to another. In a covalent bond, when atoms share two electrons it is a single bond, when they share four electrons it is a double bond and when atoms share six electrons it is a triple bond. Chemists like Gregory Robinson study how to manipulate atoms so they can make new bonds and therefore, new compounds.

DISCUSSION QUESTIONS

1. If you were to interview Gregory Robinson, what questions would you ask him?
2. Check out the American Chemical Society webpage about covalent bonds. (http://www.middleschoolchemistry.com/multimedia/chapter4/lesson4). What can break a covalent bond?
3. Gregory Robinson creates new bonding types in certain kinds of atoms. How is a covalent bond different from an ionic bond?
4. Do you think it was difficult for Gregory Robinson to play football and study chemistry at the same time in college? What challenges did he face and how would you go about overcoming such challenges?
5. How does Gregory Robinson's career compare to that of other chemists in the Toolkit?

GLOSSARY

Chemical Bond - An attraction between atoms that links atoms together forming chemical compounds with two or more atoms; can be covalent or ionic

Covalent Bond - Chemical bonds formed by the sharing of electrons between atoms

Electron Configuration - The arrangement of electrons in an atom

Gallium - A chemical element, with chemical symbol Ga; a soft metal used in making certain kinds of solar cells and semiconductor devices

Ionic Bond - A chemical bond in which one atom loses an electron to form a positive ion and the other atom gains an electron to form a negative ion

Organometallic Chemistry - The study of compounds containing bonds between carbon and a metal

ScienceMakers Spotlight

James Shoffner

Petroleum Chemist

Education	Lincoln University (B.S.)
	DePaul University (M.S.)
	University of Illinois, Chicago (Ph.D.)
Awards & Achievements	American Chemical Society Award for Encouraging Disadvantaged Students into Careers in the Chemical Sciences (2002)
	American Chemical Society 30 Year Councilor (2004)

BIOGRAPHY

James Shoffner was raised on a rural plantation in New Madrid, Missouri in the 1930s. Shoffner's segregated school was open only five months a year; the rest of the time was reserved for growing cotton. He transferred to a boarding school in Kansas City, Missouri where he was first introduced to chemistry and biology. However, Shoffner still had to help in the cotton fields and school for him did not begin until late November. He attended Lincoln University for a year before joining the U.S. Army. After completing his military service, Shoffner returned to college to earn his B.S. degree in chemistry.

American Chemical Society Logo from utdallas.edu

Following graduation, Shoffner worked at the U.S. Post Office before returning to school and earning his M.S. degree in organic chemistry from DePaul University. Shoffner worked at a local paint company before he was hired to work as a carbohydrate researcher at Corn Products. After six years, Shoffner returned to graduate school to pursue a doctoral degree in organic chemistry at the University of Illinois, Chicago. After receiving his Ph.D. degree, Shoffner joined Universal Oil Products Company (UOP) where he spent the next thirty-six years working in petroleum chemistry, specifically studying NMR spectroscopy and additives for plastics. Shoffner started a second career with the American Chemical Society (ACS), becoming active in the Division of Petroleum Chemistry. He held a series of positions in ACS' Chicago Section including serving as a board member and co-chair of Project SEED, a program to help disadvantaged students pursue a career in chemistry. He became a councilor of the ACS in 1974. In 1993, Shoffner retired from Universal Oil Products and joined Columbia College in Chicago as a science professor and science education consultant. In 2006, Shoffner organized the American Chemical Society conference honoring the famed chemist, Percy L. Julian. He was also instrumental in the development of the 2007 PBS NOVA program, *Forgotten Genius,* about the life of Percy L. Julian. James Shoffner lives in Elk Grove, Illinois.

Above Picture of James Shoffner from chicagoacs.net/profiles/shoffner.html

SCIENCE IN ACTION

PETROLEUM: HIDDEN UNDER ROCKS

A U.S. Army Petroleum Specialist by isafmedia @Flickr

Did you know that the fuel in your gasoline tank originated from deposits between rocks under the earth? Petroleum is a major component in gasoline, kerosene, and diesel oil. Petroleum is a liquid mixture of hydrocarbons, meaning that it is made up of compounds with only two elements, hydrogen and carbon. Petroleum was formed 300 million years ago from tiny sea creatures. In time, under great pressure and heat, the sea creatures turned into petroleum. Petroleum must be changed or refined into other products before it can be used. Scientists like James Shoffner study petroleum to find new uses and improve the refining process.

DISCUSSION QUESTIONS

1. If you were to interview James Shoffner, what questions would you ask him?
2. Check out the NOVA's website and read about the life of Percy L. Julian (http://www.pbs.org/wgbh/nova/physics/julian-the-trailblazer.html). How are James Shoffner and Percy L. Julian's lives and career paths similar? How are they different?
3. James Shoffner, had many careers throughout his life. Which of his careers interests you the most? Why?
4. James Shoffner helped disadvantaged students pursue scientific careers. Why is it important to increase the awareness of careers in science?
5. How does James Shoffner's career compare to that of other chemists in the Toolkit?

GLOSSARY

Carbohydrate - An essential structural component of living cells and a source of energy for animals; includes simple sugars with small molecules and large molecular compounds

Nuclear Magnetic Resonance (NMR) Spectroscopy - An analytical technique that is used to determine the structure and composition of chemical compounds by examining the magnetic properties of their nuclei

Organic Chemistry - The study of carbon containing compounds such as acetic acid (vinegar) and caffeine

Percy L. Julian (1899 –1975) **-** An African American research chemist and a pioneer in the chemical synthesis of medicinal drugs from plants

Project SEED- A nonprofit organization, founded in 1963, that partners with schools districts, universities, and corporations and uses mathematics to improve the educational opportunities of urban youth

U.S. Army - A branch of the United States Armed Forces that organizes and trains soldiers for land warfare

ScienceMakers Spotlight

Herman Smith

Medicinal Chemist & Inventor

Birth Date	February 9, 1933
Birth Place	Fayetteville, North Carolina
Education	North Carolina College (B.S. 1954)
	University of California, Berkeley (Ph.D. 1970)

BIOGRAPHY

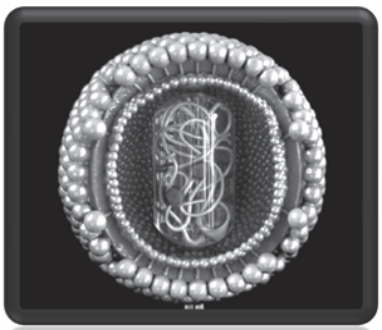
Herman Smith pursued a career in medical chemistry, researching compounds that play an important role in preventing diseases. He was born on February 9, 1933 in Fayetteville, North Carolina. After graduating from high school, Smith attended the North Carolina College (now North Carolina Central University) receiving his B.S. degree in chemistry in 1954. While in college, Smith worked as an orderly at Duke University Hospital.

Pain Medication
by vmiramontes @Flickr

Following graduation, Smith was hired to work at the U.S. Army Chemical Corps as a chemical staff specialist where he also lectured on biological, chemical, and radiological warfare. In 1956, he began working as a research associate for Cornell Medical School. Smith continued his work as a lecturer at Meharry Medical College in Nashville, Tennessee, researching neurotransmitters in the human brain and teaching first year pharmacology students. In 1962, he came to Smith Kline and French Laboratories to research steroids involved with stress, immune reactions, and inflammation. He returned to school to receive his Ph.D. degree in chemistry from the University of California, Berkeley in 1970. Smith then started working for Up-John Company where he would stay for twenty-eight years synthesizing novel compounds for biochemical and medical purposes. Smith patented over seventy new compounds such as HIV protease inhibitors and phosphonates to treat arthritis. His research has led to the understanding of many natural compounds, their role in disease, and their uses in the biochemical and pharmacological fields. Smith retired in 1998 and has remained active serving on the board of directors for numerous community groups in Kalamazoo, Michigan, such as the County Economic Development Board, County Planning Commission, the National Association for the Advancement of Colored People (NAACP), and committees for programs serving at-risk youth. Herman Smith lives in Kalamazoo, Michigan.

SCIENCE IN ACTION

HIV PROTEASE INHIBITORS



HIV Virus
by www.international.ucla.edu

The Human Immunodeficiency Virus (HIV) causes the deadly disease, Acquired Immunodeficiency Syndrome (AIDS). Scientists are still working on a cure for AIDS, although they have developed many drugs targeting HIV to slow the progression of the disease. Herman Smith worked on developing one of the most important class of drugs in fighting the disease, protease inhibitors. HIV replicates itself by inserting its DNA into cells so when the cell copies itself, it also creates a lot more HIV DNA and HIV proteins. In order to become active, the proteins are cut up by the HIV protease, a protein-cutting enzyme. Protease inhibitors block the protease enzyme and therefore, prevent the cell from producing new viruses. Protease inhibitors taken with other HIV drugs can significantly extend the life of a person with HIV.

DISCUSSION QUESTIONS

1. If you were to interview Herman Smith, what questions would you ask him?
2. Check out the Center for Disease Control's information on HIV (http://www.cdc.gov/hiv/). What new information did you learn?
3. Herman Smith researched drugs to treat diseases. If you were a scientist, what disease would you develop a drug for? Why?
4. Herman Smith researches protease inhibitors. Why is it important to find drugs to stop HIV?
5. How does Herman Smith's career compare to that of other chemists in the Toolkit?

GLOSSARY

Arthritis - Painful inflammation and stiffness of the joints

Enzyme - A substance produced by a living organism that acts as a catalyst to make a specific biochemical reaction go faster

HIV Protease Inhibitors - A class of drugs used to treat or prevent infection by the Human Immunodeficiency virus (HIV)

Medicinal Chemistry - The application of chemical principles to create substances to cure disease, treat injuries, and maintain human health

Neurotransmitter - A chemical substance that is released at the end of a nerve fiber and causes the transfer of the impulse to another nerve fiber, a muscle fiber, or some other structure

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Pharmacology - The study of the uses and effects of drugs, particularly how drugs can be used to treat diseases

Phosphonates - Organic compounds that contain a carbon to phosphorous bond

ScienceMakers Spotlight

Rubye Torrey

Radiation Chemist & Administrator

Birth Date	February 18, 1926
Birth Place	Sweetwater, Tennessee
Education	Tennessee State University (B.S. 1946, M.S. 1948)
	Syracuse University (Ph.D. 1968)

BIOGRAPHY

Rubye Torrey has been profiled in many books about scientists due to her unique position as a trailblazing chemist and a high-level administrator. She was born on February 19, 1926 in Sweetwater, Tennessee. As a child, Torrey's grandfather was a strong figure in her life, since her father died when she was an infant. Her grandfather was a farmer and encouraged her interest in nature and science. Torrey attended Swift Memorial Junior College before transferring to Tennessee Agricultural & Industrial State University (now Tennessee State University) where she received her B.S. degree in chemistry in 1946. Torrey received a scholarship, which allowed her to continue her studies at Tennessee State University and earn her M.S. degree in 1948.

Tennessee State University by AlumniRoundup.com

Torrey planned on continuing her education to earn a doctorate degree, but first she wanted to gain work experience. She joined the faculty of Tennessee State University as an assistant professor of chemistry. In 1963, she left to pursue her doctorate degree at Syracuse University where she worked as an instructor in order to pay for her degree. She received her Ph.D. degree in 1968 and was the first African American woman to receive a doctorate degree in chemistry from Syracuse University. In 1970, Torrey completed postdoctoral research at the Brookhaven National Laboratory through a grant from the Atomic Energy Commission where she studied gas formation using mass spectrometry. In 1974, she returned to Tennessee State University where she worked as a professor of chemistry, assistant vice president of research, and chair of the research committee for the College of Arts of Sciences. In 1978, she founded Research Day, a university-wide program to educate students about regional and national research. Torrey left Tennessee State University to join the faculty of Tennessee Technical University as assistant vice president for research. Torrey is a member of the American Association for the Advancement of Science (AAAS), the American Chemical Society (ACS), and Sigma Xi, a scientific research society. Rubye Torrey is retired and lives with her husband, Claude A. Torrey, in Cookville, Tennessee.

Above Picture of Rubeye Torrey from urban-science.blogspot.com/2010/03/right-under-my-nose-dr-rubye-torrey.html

SCIENCE IN ACTION

RADIATION: A HIDDEN HEALTH RISK?

Cellphone
by darkwood67 @Flickr

As technology becomes more integrated into our daily lives, so does the fear of the effects of radiation. Scientists like Rubye Torrey study the chemical and health effects of radiation. Radiation is the process of energy waves passing through space. You can't see it, but there are low levels of radiation around you all the time. Long exposure to high doses of radiation can lead to cancer and brain tumors. A high level of radiation can only happen after an extreme event, like a nuclear power plant meltdown. Cell phones send out radio waves, a form of electromagnetic radiation. Cell phones give off very low levels of radiation, which can have minimal health risks, and scientists are still investigating their long term dangers.

DISCUSSION QUESTIONS

1. If you were to interview Rubye Torrey, what questions would you ask her?
2. Check out BBC Video about Radiation Exposure (http://www.bbc.co.uk/news/health-12722435). When do scientists worry about radiation exposure?
3. Rubye Torrey had a grandfather who fostered her love of science and nature. Discuss someone in your life who encourages you to pursue your interests.
4. Rubye Torrey started Research Day at Tennessee State University where students learned about new and important research. Do some of your own research by reading newspapers or going on the internet. What are important scientific discoveries that are happening today?
5. How does Rubye Torrey's career compare to that of other chemists and administrators in the Toolkit?

GLOSSARY

American Association for the Advancement of Science (AAAS) - An international non-profit organization with the stated goals of promoting cooperation between scientists, defending scientific freedom, encouraging scientific responsibility, and supporting scientific education and science

Brookhaven National Laboratory - A United States national laboratory located in Upton, New York, and was formally established in 1947 at the site of Camp Upton, a former U.S. Army base

Electromagnetic Radiation - A kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously

Mass spectrometry - An analytical technique that is used to determine the structure and composition of chemical compounds

Radiation - The emission of energy as electromagnetic waves or as moving subatomic particles

Balloon Morphing: How Gases Contract and Expand

(www.sciencebuddies.org)

Grade Level: 6 - 8
Time Required: A day or less
Cost: $20 or less

This activity relates to the work of chemists, like ScienceMaker ***Joseph Gordon.***

Abstract
Expanding gases are everywhere, from the kitchen to the cosmos. You've tasted their pleasures every time you've eaten a slice of bread, bitten into a cookie, or sipped a glass of soda. In this chemistry science fair project, you'll capture a gas in a stretchy container you're probably pretty familiar with—a balloon. This will allow you to observe the gas expansion and contraction as the temperature changes.

Objective
To investigate how gases expand and contract with temperature, using latex balloons.

Introduction
Imagine your friend has a cold January birthday and you bundle up and go to the store to buy him a "Happy Birthday" **Mylar®** balloon. You pick out a plump, cheerful balloon and head back to your car. By the time you get home though, you realize that the balloon you picked out isn't so plump anymore. In fact, it's starting to look a bit limp already! Should you take it back to the store? Is it defective? What's going on?

Everything in the world around you is made up of **matter,** including the balloon you just bought *and* what's inside it. Matter comes in four different forms, called **states.** The states, going (generally) from lowest energy to highest energy are **solids, liquids, gases,** and **plasmas.** Gases, like the helium gas inside your balloon, take the shape of the containers that they are in. They spread out so that all the space is filled up evenly with gas **molecules.** The gas molecules are not connected together. They move in a straight line until they bounce into another gas molecule or hit the wall of the container, and then they rebound and continue off in another direction until they hit something else. The combined motion energy of all of the gas molecules in a container is called the **average kinetic energy.**

This average kinetic energy (energy of motion) changes in response to temperature. When the temperature *increases,* the average kinetic energy of the gas molecules also increases. The molecules move faster and have *more frequent* and *harder* **elastic collisions** with the inside of the container. So, when your balloon was in the store, at room temperature, it was plump and full. When the balloon was taken outside into the cold January air, though, the average kinetic energy of the gas molecules was *lowered,* so the elastic collisions of the molecules with the inside wall of the balloon became *less frequent* and *weaker,* making your Mylar balloon saggy.

What do you think would happen if you took a room-temperature balloon and put it inside a car on a hot day? The average kinetic energy of the gas molecules inside would increase, creating more

frequent and forceful collisions with the inside walls of the balloon. The balloon would look very puffy and full, and because Mylar balloons are not stretchy and elastic, the balloon might even burst.

In this chemistry science fair project, you'll investigate these changes in average kinetic energy by using a different kind of balloon—a **latex** balloon, which is able to expand and contract as the force and frequency of the elastic collisions change with temperature.

Terms, Concepts, and Questions to Start Background Research

- Mylar
- Matter
- States (of matter)
- Solid
- Liquid
- Gas
- Plasma
- Molecule
- Average
- Kinetic energy
- Elastic collision
- Latex
- Proportional
- Linear

Questions

- How do gases behave?
- How does temperature affect gas molecules?
- What happens in an elastic collision?

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- EdInformatics.com. (1999). *States of Matter.* Retrieved January 23, 2009, from http://www.edinformatics.com/math_science/states_of_matter.htm

This source discusses what gases are and how they behave:

- Rader, A. (2007). *Looking For a Gas.* Retrieved January 23, 2009, from http://www.chem4kids.com/files/matter_gas.html

This source provides an interactive tool to investigate what happens when gases are heated and cooled:

- BBC. (n.d.). *Gases Around Us.* Retrieved January 23, 2009, from http://www.bbc.co.uk/schools/scienceclips/ages/9_10/gases.shtml

This source discusses elastic and inelastic collisions:

- Nave, C. R. (2005). *Elastic and Inelastic Collisions.* Retrieved January 23, 2009 from http://hyperphysics.phy-astr.gsu.edu/Hbase/elacol.html

This source describes how to turn an expanding balloon into a model of the expanding universe:

- Schlumberger Limited. (2008). *The Expanding Balloon.* Retrieved January 23, 2009, from http://www.seed.slb.com/en/scictr/lab/balloon/index.htm

For help creating graphs, try this website:

- National Center for Education Statistics (n.d.). *Create a Graph.* Retrieved May 23, 2008, from http://nces.ed.gov/nceskids/CreateAGraph/default.aspx

Materials and Equipment

Note: To do this science fair project, you will need to place balloons in areas with three distinctly different temperatures:

1. Room temperature
2. Hot temperature (well above room temperature); for example, under a lamp, outdoors on a hot day, or inside a car on a hot day
3. Cold temperature (well below room temperature); for example, in a freezer, or outdoors on a cold day

- Latex balloons, round rather than oblong (1 package; you will only need 3, but should have extra in case any of them pop).
    - *Note:* Larger balloons allow you to see circumference changes more easily, but if you plan to use a freezer for your cold-temperature trials, your balloon must be able to fit in the freezer when inflated, so a small- to medium-sized balloon is a better choice if your freezer is not very large.
- Marker
- Thermometer with a range that spans the temperatures you will be testing (below freezing to well above room temperature)
- Cloth tape measure with millimeter (mm) markings
- Helper
- Clock
- Lab notebook
- Graph paper

Experimental Procedure

Preparing for the Balloon Tests

1. Blow up one of the balloons until it is quite full, but not close to popping, and tie it off.
2. Mark the balloon with the number 1.
   Measure the circumference of this first balloon with the cloth tape measure, selecting the fullest part of the balloon to measure, as shown in Figure 1 on the right. Hold the tape measure snug on the balloon, but not so tight that the balloon is being squeezed by the tape measure and changing its shape. Record this starting circumference in your lab notebook.
3. Blow up the second balloon so it looks about the size of the first balloon, but don't tie it off yet. Pinch the opening closed between your thumb and finger so the air can't escape. Have your helper measure the circumference of the second balloon, just as you measured the first balloon. Adjust the air in the second balloon until its circumference is within 0.5 cm of the starting circumference of the first balloon, as follows:
    - If the circumference of the second balloon is smaller than the starting circumference of the first balloon, then blow up the second balloon some more.
    - If the circumference of the second balloon is larger than the starting circumference of the first balloon, then let some air out of the second balloon.
5. Tie off the second balloon and mark it with the number 2.
6. repeat step 4 for the third balloon, adjusting the circumference until it is within 0.5 cm of the starting circumference of the first balloon, and then tie it off and mark it with the number 3.
7. Make a data table, like the one shown below.

Figure 1. This drawing shows where to measure the circumference of the balloons.

Circumference Data Table

Temperature (°F)	Balloon 1 Circumference (mm)	Balloon 2 Circumference (mm)	Balloon 3 Circumference (mm)	Average Circumference (mm)	Average Circumference Cubed (mm^3)

Testing Your Balloons at Room Temperature

1. Measure the temperature of the room with the thermometer and record your measurement in the data table.
2. Measure the circumference of each balloon with the tape measure, selecting the fullest part of each balloon to measure, as shown in Figure 1. Hold the tape measure snug on the balloon, but not so tight that the balloon is being squeezed by the tape measure and changing its shape. Record your measurements in the data table.

Testing Your Balloons in the Cold Area

1. Place the thermometer and all three balloons—one at a time, if necessary—in the area where you have chosen to do your cold-temperature testing; such as in the freezer.
2. Wait approximately 1 hour. If you can only put one balloon in at a time, this step will take 3 hours.
3. Remove the balloon(s) from the freezer and immediately measure the circumference(s) and record your measurements in the data table.
4. Record the temperature inside your cold area in the data table.
5. Repeat steps 1–3, if necessary, until all three balloons have been tested in the cold area.

Testing Your Balloons in the Hot Area

1. Wait 20 minutes to allow your balloons to come to room temperature.
2. Place the thermometer and the balloons—one at a time, if necessary—in the area you have chosen to do your hot-temperature testing; such as inside a car on a hot day.
3. Wait approximately 5–10 minutes, or until you can see obvious changes. If you can only put one balloon in the hot area at a time, this step will take up to 30 minutes.
4. Remove the balloon(s) from the hot area and immediately measure the circumference and record your measurements in the data table(s).
5. Record the temperature inside your hot area in the data table.
6. Repeat steps 1–4, if necessary, until all three balloons have been tested.

Analyzing Your Data Table

1. For each temperature, calculate the average circumference and enter your calculations in the data table.
2. For each temperature, cube the average circumference by multiplying the average circumference by itself three times. For example, if the average circumference is 60 mm, then the average circumference cubed is 60 X 60 X 60, or 216,000 mm^3.
3. Plot the temperature on the x-axis (in °F) and the average circumference cubed on the y-axis (in mm^3). You can make the line graph by hand or use a website like http://nces.ed.gov/nceskids/createagraph/default.aspx to make the graph on the computer and print it.

4. Assuming the balloon is a sphere, the volume is proportional to the circumference cubed, meaning there is a linear relationship between volume and circumference if you plot them on a graph. In your graph, is there a linear relationship between the circumference cubed and the temperature? If not, was there a greater change in circumference cubed in going from room temperature to a cooler temperature, or in going from room temperature to a warmer temperature? As the temperature increases, what do you think happens to the space between the gas molecules inside the balloon? What do think happens to the space between the gas molecules inside the balloon as the temperature decreases?

Variations

- Create a balloon model of the expanding universe. Place three small pieces of masking tape at different locations on a lightly inflated balloon that is clamped shut with a clothespin. Make a dot in the center of each piece of tape and have each one represent a different galaxy. Measure the distance between all the galaxies and the circumference of the balloon. Record the distance between all the galaxies and the circumference of the balloon. Blow up the balloon more, clamp it closed again, and repeat your measurements. Repeat this two more times, adding more air each time. In several graphs, plot the circumference of the balloon on the x-axis and the distances between the galaxies on the y-axis.

Credits

Kristin Strong, Science Buddies
Edited by Peter Boretsky, Lockheed Martin

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p077.shtml

☐ Mylar® is a registered trademark of DuPont Teijin Films.

Maple Syrup for Pancakes, Waffles and...Crystal Candy

(www.sciencebuddies.org)

Grade Level: 6 - 8
Time Required: A day or less
Cost: $20 or less

This activity relates to the work of chemists, like ScienceMakers ***Joseph Gordon*** *and* ***James Letton.***

Abstract
Maple syrup is deliciously gooey and great on breakfast foods like pancakes and waffles. But it is has another amazing property. It can form crystals under the right circumstances, and the crystals change in size and shape, depending on temperature. In this science fair project, you will discover how to make crystals out of maple sugar, and study how their growth is affected by temperature.

Objective
The objective of this food science fair project is to investigate how the rate of cooling affects crystal structure.

Introduction
Did you know that there are around 300 different natural flavor compounds in pure maple syrup? Other prominent ingredients are sugar, caramel, and vanilla. Nutty, buttery, floral (honey), cereal, chocolate, and coffee flavors can be found in some syrups! As is the case for most natural products, maple syrups have complex flavor chemistry to delight your senses of taste and smell.

Chemically speaking, maple syrup is a concentrated solution of sugar in water, with many minor flavoring compounds. When it is heated, some of the water evaporates off and the sugar becomes more concentrated. As the heated maple syrup cools, the sugar molecules (the smallest particles of the sugar) form crystals. Unlike the sugar molecules in liquid syrup, which are free to float around, sugar molecules in the heated, concentrated syrup form these crystals, which line up and arrange themselves in an orderly and repetitive pattern. So as the water evaporates, the sugar molecules bump into one another frequently because there are so many of them, so close together. Occasionally, when they bump into each other, the molecules end up sticking together. This slow process is how the crystal "grows."

You might think of a growing crystal as a big block of Legos. Each individual Lego is like a sugar molecule, because it is the smallest "piece" possible. When you add a new Lego piece to the big block, you have to line it up just right so that it will fit in with the pieces that are already there. In the same way, sugar molecules have to align themselves just right in order to become part of the growing crystal.

Crystals can form at different rates; for instance, snowflakes form in seconds, but amethysts and rubies form over years. As you might imagine, the final crystal shape is affected by how fast the molecules adhere to the growing crystal. The slower the rate, the more time each molecule has to get aligned with its neighbors, resulting in a more organized final crystal. In this cooking and food science fair project, you will study how the rate of crystal formation affects crystal shape in maple syrup.

Terms, Concepts, and Questions to Start Background Research

- Solution
- Evaporation
- Concentration
- Molecule
- Crystal
- Sucrose
- Glucose
- Fructose
- Viscous

Questions

- What makes crystals different from other solid materials?
- What are the differences between imitation maple syrup and pure maple syrup?
- What is the definition of the chemical term *precipitation?*
- Why do crystals form after you heat the syrup, but not in unheated syrup?
- Based on your research, list some examples of how the rate of cooling affects crystal growth in different materials.
- What other kinds of food are in the form of crystals?

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- Cornell Sugar Maple Research & Extension Program. (n.d.). *Maple Syrup FAQs.* Retrieved November 12, 2008, from http://maple.dnr.cornell.edu/FAQ.htm

Materials and Equipment

- Small baking pan filled with a thin layer of water and frozen to create a flat sheet of ice
- Pure maple syrup (*not* the imitation syrup)
- Saucepan
- Large spoon
- A second small baking pan at room temperature
- Stopwatch
- Lab notebook
- Ruler
- An adult helper

Experimental Procedure

1. Before you heat the maple syrup, make a sheet of ice by placing a thin layer of water in a baking pan and keeping it in the freezer until it is frozen solid.
2. Once the water in the baking pan is frozen, heat the maple syrup over medium heat in the saucepan, stirring constantly. *Note:* You will need the help of an adult for this part.
3. Bring it to a boil and allow it to cook, uncovered, until it is very thick and viscous. Keep stirring to make sure that it does not burn.
4. Set out the baking pan with the sheet of ice on the countertop.
5. On another flat area of the counter, set out the other room-temperature baking pan.
6. Use your spoon to drop one dollop of the hot, thick maple syrup onto the ice or onto the room-temperature baking pan. You might want to drop the dollop on the frozen baking sheet first, before the ice melts.
7. Do not touch the dollop yet—it will still be really hot!

8. Watch as the maple syrup cools. Use a stopwatch to time how long it takes for crystals to form and solidify on the dollop.
9. Observe the shape and measure the length of the crystals. Use a magnifying glass to get a close look at the crystals.
10. Record your observations about how long it took for the crystals to form and how the rate of cooling affected their size in your lab notebook. Use a data table like the one below. Remember, your notes and observations should be clear enough that someone else could use them to reproduce your results.

Method for Cooling Syrup	Length of Crystals	Time Until First Crystal Visible	Notes
Ice on baking sheet			
Room-temperature baking pan			

11. Repeat steps 6-9 until you have observed at least three dollops on each baking sheet. If your first dollop was on the frozen baking sheet, you might want to drop your next two dollops there, too, before the ice melts. However, if it does start to melt, simply refreeze it and you can continue with your trials on the room-temperature baking sheet.

Variations

- Experiment with the sugar concentration before you put the dollops on ice by heating the solution for different amounts of time. Can you think of some ways to figure out how much you have reduced the volume of the syrup?
- Experiment with cooling the syrup very slowly. For example, allow the syrup to cool in an insulated cup. Are crystals that are made very slowly different than the ones you made earlier?
- What happens if you form the crystals in the refrigerator?
- For another science fair project about sugar, try the Science Buddies science fair project When Science is Sweet: Growing Rock Candy Crystals.
- For more science project ideas in this area of science, see Cooking & Food Science Project Ideas.

Credits

David Whyte, PhD, Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/FoodSci_p044.shtml

Plop, Plop, Fizz Fast: The Effect of Temperature on Reaction Time

(www.sciencebuddies.org)

Grade Level: 4+
Time Required: Several days
Cost: $20 or less

This activity relates to the work of chemists, like ScienceMaker ***Fillmore Freeman.***

Abstract
Alka-Seltzer® tablets fizz furiously when dropped into water. The moment the tablet starts dissolving, a chemical reaction occurs that releases carbon dioxide gas. Can you make Alka-Seltzer® fizz faster or slower by changing the temperature of the water? How big of a difference in the rate of a chemical reaction can temperature make?

Objective
The goal of this project is to measure the effect of temperature on the rate of a chemical reaction.

Introduction
You may have seen a television commercial for Alka-Seltzer tablets, or heard one of their advertising slogans: "Plop, plop, fizz, fizz, oh what a relief it is!®" When you drop the tablets in water, they make a lot of bubbles, like an extra-fizzy soda. And like a soda, the bubbles are carbon dioxide gas (CO_2). However, with Alka-Seltzer®, the CO_2 is produced by a chemical reaction that occurs when the tablets dissolve in water.
The main ingredients of Alka-Seltzer tablets are aspirin, citric acid, and sodium bicarbonate ($NaHCO_3$). When sodium bicarbonate dissolves in water, it dissociates (splits apart) into sodium (Na^+) and bicarbonate (HCO_3^-) ions. The bicarbonate reacts with hydrogen ions (H^+) from the citric acid to form carbon dioxide and water. The reaction is described by the following chemical equation:

$$3HCO_3^- + 3H^+ \rightarrow 3H_2O + 3CO_2$$

So how does temperature come into this? In order for the reaction shown above to occur, the bicarbonate ions have to come into contact with the hydrogen ions. Molecules in a solution are in constant motion, and are constantly colliding with one another. The hydrogen and bicarbonate ions must collide at the right angle and with enough energy for the reaction to occur. The temperature of a solution is a measure of the average motion (kinetic energy) of the molecules in the solution. The higher the temperature, the faster the molecules are moving. What effect do *you* think temperature will have on the speed of the bicarbonate reaction? You can find out for yourself by plopping Alka-Seltzer® tablets into water at different temperatures, and timing how long it takes for the chemical reaction to go to completion.

Terms, Concepts, and Questions to Start Background Research
To do this project, you should do research that enables you to understand the following terms and concepts:

- Molecules
- Temperature
- Reactants

- Products
- Reaction rate

Questions

- Keeping in mind that an increase in temperature reflects an increase in the average molecular motion, how will increased temperature affect the reaction rate?
- What temperature change is required to increase the reaction time by a factor of 2?
- What temperature change is required to decrease the reaction time by a factor of 2?

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Materials and Equipment

To do this experiment you will need the following materials and equipment:

- At least 12 Alka-Seltzer® tablets (if you plan to do additional variations to the project, you'll want to get a larger box)
- Thermometer (good range would be -10°C to 110°C
    - E.g. catalog # WW6332000 from Science Kit & Boreal Lab or catalog #15V1460 from Wards Natural Science
    - Standard kitchen candy thermometer will also work fine
- Clear 12 ounce (355 mL) drinking glass (or larger)
    - **Note:** Use Pyrex glass when working with water heated on the stove or in the microwave)
- Measuring cup
- Masking tape
- Something to stir with (a teaspoon or a chopstick, for example)
- Hot and cold tap water
- Ice
- Stopwatch (you can also use a clock or watch with a second hand)
- A helper
- Lab notebook
- Pencil

Experimental Procedure

1. Do your background research and make sure that you are familiar with the terms, concepts, and questions, above.
2. In this experiment, you will be measuring the time it takes for one Alka-Seltzer® tablet to react completely in water. You will investigate how the reaction time changes with water temperature.
3. You'll use the same glass for repeated trials, so it is convenient to mark the desired water level.
    a. Use the measuring cup to add 8 ounces (236 mL) of water to the glass. (If you're using metric volume units, rounding up to 250 mL is fine.)

   b. Use a piece of masking tape on the outside of the glass to mark the water level. Place the tape with its top edge even with the water level in the glass.
   c. Now you can use the masking tape to fill the glass to the right level for each trial.
4. For observing the reaction, you will use the same volume of water at three different starting temperatures: hot tap water, cold tap water, and ice water.
   a. For the hot and cold tap water, run the water until the temperature stabilizes. Fill the glass with water to the level of the masking tape.
   b. For ice water, fill the glass about half full with ice cubes, then add cold tap water to the level of the masking tape. Stir for a minute or two so that the temperature equilibrates. Once temperature has equilibrated, remove the ice cubes from the water's surface using a spoon or other utensil immediately before adding the Alka-Seltzer tablet.
5. Here is how to measure the reaction time:
   a. Fill the glass with water to the level of the masking tape.
   b. Measure the temperature of the water, and record it in your lab notebook.
   c. Remove the thermometer. (It's not a good idea to use the thermometer as a stirring rod. It might break.)
   d. Have your helper get ready with the stop watch, while you get ready with an Alka-Seltzer® tablet. Have your helper count one–two–three. On three, the helper starts the stop watch and you drop the tablet into the water.
   e. You'll immediately see bubbles of CO_2 streaming out from the tablet.
   f. Stir the water gently and steadily. Use the same stirring method and speed for all of your experimental trials. The tablet will gradually disintegrate. Watch for all of the solid white material from the tablet to disappear.
   g. When the solid material has completely disappeared, and the bubbles have stopped forming, say "Stop!" to have your helper stop the stopwatch.
   h. Record the reaction time in your lab notebook.
   i. Tip: be careful when opening the packets and handling the Alka-Seltzer® tablets. The tablets are thin and brittle, so they break easily. If some of the tablets are whole, and some are broken into many pieces, the separate trials will not be a fair test.
6. For each of the three temperatures, you should repeat the experiment four times, for a total of 12 trials. You can organize your data in a table like the one below.

Condition	Temperature (°C)	Reaction Time (s)				Average Reaction Time (s)
		Trial #1	Trial #2	Trial #3	Trial #4	
Hot Tap Water						
Cold Tap Water						
Ice Water						

7. Calculate the average reaction time for each of the three water temperatures.
8. Make a graph of the average reaction time, in seconds, (y-axis) vs. water temperature, in degrees Celsius (x-axis).
9. How does reaction time change with temperature?

Variations

- More advanced students should also calculate the standard deviation of the reaction times for each temperature.
  - Use the standard deviation to add error bars to your graph.
  - For example, say that the average reaction time for one temperature was 45 seconds, and the standard deviation was 5.2 seconds (these are made-up numbers). You would graph the symbol for the data point at 45 seconds, and then draw short vertical bars

above and below the symbol. Each vertical bar would have a length equivalent to 5.2 seconds.
    - Error bars give your audience a measure of the variance in your data.
- **Adult supervision required.** Is reaction rate predictable over a larger temperature range? Water remains liquid above 0°C and below 100°C. Repeat the experiment at one or more additional high temperatures to find out. Use Pyrex glass for containing heated water, and use appropriate care (e.g. wear hot mitts and safety goggles) when handling hot water.
- Surface area of reactants, see:
- In this experiment you observed the reaction mixture and watched as the tablets dissappeared and formed gas bubbles. For more advanced versions of this experiment, you can build a simple apparatus so that you can measure the volume of the gas produced over time. Because you will be able to collect data at multiple time points, you get information about how the reaction rate changes over time. For more advanced versions of measuring the reaction rate, see the Science Buddies projects:
    - How Fast Does an Alka-Seltzer® Tablet Make Gas?, and
    - Can You Change the Rate of a Chemical Reaction by Changing the Particle Size of the Reactants?.
    - Does changing the particle size of the reactants have as big an effect on reaction time as changing the temperature of the water does? For an experiment that investigates the effect of particle size on the speed of the reaction, see the Science Buddies project Big Pieces or Small Pieces: Which React Faster?
- For more science project ideas in this area of science, see Chemistry Project Ideas.

Credits

Andrew Olson, Ph.D., Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p027.shtml

Sources

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☐ Alka Seltzer® is a registered trademark of Bayer HealthCare LLC.

Computer Science

Computer science is the study of the design, operation, and use of computers. It encompasses the methods and tools involved in the design of computer systems as well as the creation and implementation of algorithms, the rules that a computer program follows.

Computer Scientists study how information is stored and used in computers. This includes studying artificial intelligence (like robots). They also work to improve computer technology and make computers run faster.

Studying computer science requires excellent mathematical skills in order to understand and manipulate computer languages. Computers are becoming increasingly important in our lives at home, at school, and at work, which means computer scientists can find employment almost anywhere.

Computer Science Disciplines

Computer science includes many exciting fields to study and research. Here are just a few…

Artificial Intelligence is the theory and development of computer systems able to perform tasks that normally require human intelligence, such as speech recognition.

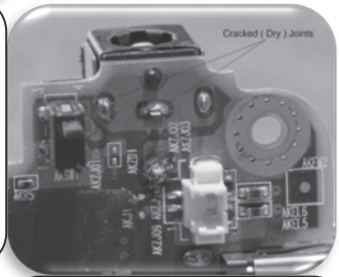
Computer Graphics is the study of digital images and involves creating and manipulating visual data. It is used heavily in the fields of special effects and video games.

Computer Theory involves figuring out what kinds of tasks can be solved using a computer and what resources would be required to do so.

Hardware Engineering is the development of the mechanical, magnetic, electronic, and electrical components that make up a computer system, the parts that you can touch.

Information Theory involves measuring or quantifying information in order to know how much information data can be stored and transmitted at one time.

Programming is the process of writing instructions for a computer to do tasks like mathematical calculations or digital video editing.



Programming Language Theory is the study of computer languages such as, Java, C, and Perl. These languages are used to write computer programs.

Software Engineering is the process of designing high quality software (like *Microsoft Office*) to be affordable, maintainable, and easy to build.

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Career Paths in Computer Science

Computer science covers a range of careers in many different areas. Below are just a few jobs open to those with a computer science degree. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Computer scientists work in settings such as school classrooms, universities, research labs, science centers, and computer labs.

- *Computer Science Professors* at colleges or universities teach and mentor students, and conduct research.
- *University IT Help Desk Workers* assist students with computer issues such as connecting to the internet and computer viruses.
- *Post-Doctoral Researchers* work in university laboratories studying a specific topic in computer science. Researchers can investigate a wide range of subject matter, including image processing and human-computer interactions.

Business & Industry

Computer scientists work in the Information Technology Department of a business or in the computer industry, designing and building hardware and software.

- *Web Developers* create the layout and function of websites using scripts that they write. Scripts are like codes used to add material to a website and different clients require different script languages.
- *Video Game Designers* create video games for consoles like *Wii, Xbox,* and *PlayStation,* as well as for personal computers.
- *Molecular Imaging Software Engineers* design medical equipment that takes pictures of the inside of our bodies. This allows doctors to detect and treat diseases like cancer.

Government

Computer scientists work in a number of government bodies like the military or national research labs in order to keep the United States at the forefront of technology.

- *Network Administrators* are responsible for the creation, upkeep, and repair of computer networks, or all computers that are connected to each other within an organization.
- *Climate Simulation Researchers* work with supercomputers that manage environmental data. Interpretation and analysis of this data contributes to our understanding of the causes and consequences of climate change.
- *U.S. Army Computer Systems Specialists* serve as network administrators for the military. Their jobs are crucial to the safe management and transfer of confidential information.

Check Out Our Featured Computer Scientists!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
Shermane Austin	Climate Computer Scientist	Medgar Evers College - City University of New York	Climate Computer Models	104
Legand Burge	Communications Computer Scientist	Tuskegee University	Voice Recognition Technology	106
Ralph Etienne-Cummings	Computer Scientist & Neuromorphic Engineer	Johns Hopkins University	Artificial Vision	109
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Anthony Joseph	Networking Computer Scientist	University of California, Berkeley	Virus Protection	113
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Joseph Monroe	Computer Programmer	North Carolina A&T State University	Computer Programming Languages	117
George Philander	Atmospheric Scientist & Climatologist	Princeton University	El Niño	119

ScienceMakers Spotlight

Shermane Austin

Climate Computer Scientist

Education	City College of New York (B.S. 1984, M.S. 1985)
	City University of New York (1993)
Awards & Achievements	CUNY Institute of Software Design NYSTAR Award
	NASA IRA Networking Infrastructure Award (1995)
	Hewlett Packard Teaching with Technology Grant (2004)

BIOGRAPHY

Computer Science

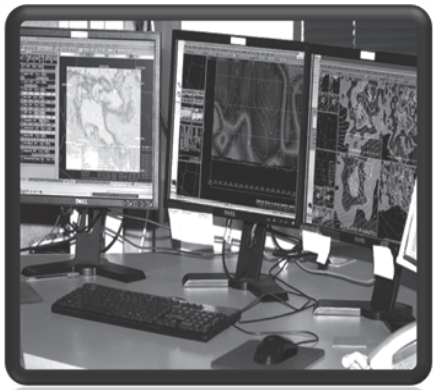
Shermane Austin has used computer technology to gather information about ozone and understand how it is polluting our air. After graduating from high school, Austin attended the City College of New York and earned her B.S. degree in economics in 1984. She earned her M.S. degree in computer science from the same institution a year later. Austin went on to earn her Ph.D. degree from City University of New York in computer science in 1993. After completing her education, Austin became a university research associate at the Institute for Climate and Space Studies, which is part of the National Aeronautics and Space Administration (NASA)*'s* Goddard Institute for Space Studies. She held this position from 1994 to 1996.

Weather Balloon by Alan R. Light

In 2008, Austin started her career as a faculty member at Medgar Evers College - City University of New York. She has taught many undergraduate courses including Introduction to Computing, Robotics, and Internet Programming, as well as several graduate courses. Her education research has focused on developing a space science curriculum, enhancing student diversity, engaging minority students, and using the internet in classroom instruction. Austin served as the principal investigator (PI) and project director for the NASA-funded Minority University Space Interdisciplinary Network (MUSPIN). MUSPIN seeks to expand research and education related to space science and train the next generation of NASA's minority scientists. She also ran the MECSAT high-altitude balloon launch project, which started in 2004 and uses helium-filled balloons to collect tracking and weather data. Austin's primary research interest lies in ozone pollution in the lower troposphere. Austin uses emission spectrometers and monitoring instruments to measure and characterize the ground-level ozone. She has written many scientific papers both in computer science and education. Shermane Austin lives in New York, New York.

SCIENCE IN ACTION

WEATHER AND COMPUTERS



Weather Monitoring Computers
by bill85704@Flickr

How does the weatherman on the morning news know it will rain today? Can he predict the future? Shermane Austin helps to develop intelligent systems (very high-tech computers) that can predict weather patterns by analyzing data from satellites, radar, and upper-air observation. Data, like temperature, pressure, rainfall, wind speed, and cloud cover are put into a computer. Computer scientists create programs and mathematical models that know how to read the data and use the information to predict future atmospheric conditions. So the next time your local weatherman predicts rain, think of the computer scientists who helped to collect that information!

DISCUSSION QUESTIONS

1. If you were to interview Shermane Austin, what questions would you ask her?
2. Check out the Environmental Protection Agency's website on climate change (http://www.epa.gov/climatechange/kids/impacts/index.html). Can you name three types of extreme weather events that can result from a warming planet?
3. Shermane Austin studies ozone with computers. What would you study with a computer?
4. Climate change has come to the attention of the public. Why is computer climate modeling important?
5. How does Shermane Austin's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Spectrometer- A scientific instrument that measures the wavelength and intensity of light emitted by a material

Goddard Institute for Space Studies - NASA laboratory that does basic research in space sciences

Intelligent System - A system such as the human brain or certain computers that have the capacity to learn and respond to changing situations

MECSAT - A project at City University of New York designed to teach students about high altitude balloon launches for atmospheric data collection

Minority University Space Interdisciplinary Network (MUSPIN) - A NASA program that works with minority colleges and universities to train the next generation of NASA scientists and engineers

Ozone - A colorless gas that is made up of three atoms of oxygen and exists in the Earth's atmosphere and troposphere

Principal Investigator (PI) - The lead scientist in a research laboratory or for a specific research project

Troposphere - The closest layer of the Earth's atmosphere; where weather occurs

ScienceMakers Spotlight

Legand Burge

Communications Computer Scientist

Birth Date	August 3, 1949
Birth Place	Oklahoma City, Oklahoma
Education	Oklahoma State University (B.S. 1971, M.S. 1973, Ph.D., 1979)
Awards & Achievements	Retired Colonel for the U.S. Air Force (1999)

BIOGRAPHY

Computer Science

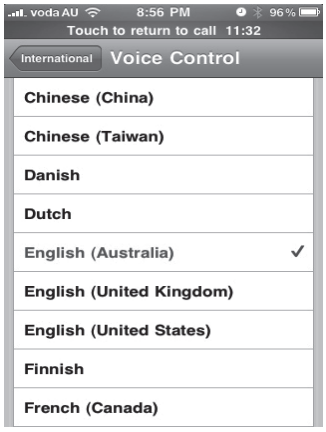
Legand Burge used his electrical engineering expertise in defense of his country, serving in the U.S. Air Force and at the Pentagon. Burge was born in Oklahoma City, Oklahoma on August 3, 1949, the son of an electronics radar technician. An excellent student in math and science, Burge was offered a scholarship to study at Oklahoma State University where he earned his B.S. degree in electrical engineering in 1971. He later earned his M.S. degree in 1973 through the Air Force Institute of Technology Scholars' Program. For the next four years, Burge worked with satellites at the Sunnyvale Air Force Base in California. He went on to earn his Ph.D. degree in electrical engineering in 1979 from Oklahoma State University.

The Pentagon
by gregwest98 @Flickr

Burge's career has focused on information theory, digital signal processing, and communications, with the goal of safely transmitting important military and government information. This became especially important when the United States and the Soviet Union were engaged in a war of intelligence rather than with armed combat. In 1980, Burge began teaching at the Air Force Academy and later at the Air Command and Staff College. Shortly after, he was invited to work at the Pentagon under General Colin Powell's supervision. In 1987, Burge became a lead researcher at the National Security Agency (NSA) and later returned to the Pentagon, working as a cost estimator for the defense secretary. Burge retired from the military in 1999 and joined the faculty at Tuskegee University, becoming dean of the College of Engineering, Architecture, and Physical Sciences. Most recently, Burge worked with his son, Legand Burge, III to operate LL Burge & Associates, an organization that addresses information technology needs. Legand Burge is the father of three adult children: Legand Burge, III, LeAnn Crisp, and Lamuelle Burge, and the step-father of Louis Burge. Legand Burge works in Tuskegee, Alabama.

SCIENCE IN ACTION

VOICE RECOGNITION TECHNOLOGY



Voice Control
by bigyahu@Flickr

How can a machine recognize a human voice? Legand Burge helped to develop computers that can determine the starting and stopping point for each segment of a word. Even words that seem to only have one part, like "hear," actually have at least one break. This technology is used for things like automated phone answering systems that require you to spell your name, give a number, or say "yes" or "no." Some spy movies even demonstrate this technology when a locked door can only be opened by a certain voice. Smart phones have a function called voice control which lets you give commands like, “Call Mom.”

IN HIS OWN WORDS

Legand Burge was interviewed by The HistoryMakers on April 11, 2011. Here is a portion of his interview:

I was thinking one day I would actually go and get a music degree. And the reality came when I heard about how they were doing, musicians like The Temptations and the Supremes and all that, that they would have them perform, but they never would pay 'em… I had a teacher tell me in high school that, “You really ought to get something that's solid. This musician thing is great, but you might not be able to eat much on it. You know, you need to go and be an electrical engineer.”

DISCUSSION QUESTIONS

1. If you were to interview Legand Burge, what questions would you ask him?
2. Check out the National Security Agency's web page on job opportunities for students (http://www.nsa.gov/careers/opportunities_4_u/students/index.shtml). Which jobs interest you the most?
3. Voice recognition technology is used in automated phone systems. How else do you think this technology could be used?
4. Legand Burge worked for the U.S. Secretary of Defense. Why is it important to have smart computer scientists working in national security and defense?
5. How does Legand Burge's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Digital Signal Processing - The transmission and processing of information in the form of a computerized signal

Electrical Engineering - The design, construction, and maintenance of products for electrical and electronic equipment and computer systems

General Colin Powell - The 65th U.S. Secretary of State; a retired four-star general in the U.S. Army

Information Theory - A branch of computer science that involves measuring or quantifying information in order to know how much information data can be stored and transmitted at one time

National Security Agency (NSA) - A U.S. Government Agency that manages and protects U.S. information systems and gathers foreign intelligence information

Pentagon - A U.S. government building with five sides; the headquarters of the United States Department of Defense

U.S. Air Force - A branch of the U.S. Military whose goal is to defend the country by mastering air and space

ScienceMakers Spotlight

Ralph Etienne-Cummings

Computer Scientist & Neuromorphic Engineer

Birth Year	1967
Birth Place	Victoria, Seychelles, East Africa
Education	Lincoln University (B.S. 1988)
	University of Pennsylvania (M.E. 1990, Ph.D. 1994)
Awards & Achievements	National Science Foundation CAREER Award (1996)
	EURASIP Journal of Applied Signal Processing Best Paper Award (2003)
	National Academies of Science Kavli Frontiers in Science Fellow (2007)

BIOGRAPHY

Ralph Etienne-Cummings integrates computers and neuroscience in order to mimic the best that nature has to offer. Etienne-Cummings was born on the island of Seychelles off the East Coast of Africa, in 1967. After graduating high school, Etienne-Cummings earned his B.S. degree in physics from Lincoln University in 1988. Etienne-Cummings went on to receive his M.E. and Ph.D. degrees in electrical engineering from the University of Pennsylvania in 1990 and 1994, respectively.

House Fly Robot
by Samuel Mann@Flickr

Shortly after receiving his Ph.D. degree, Etienne-Cummings was hired as an assistant professor at Southern Illinois University. In 1998, he moved to Maryland where he began teaching as an assistant professor at Johns Hopkins University. From 2002 to 2004, Etienne-Cummings taught at the University of Maryland, College Park as an associate professor while also holding the position of director at the Institute of Neuromorphic Engineering. Since 2005, Etienne-Cummings has held a secondary appointment in computer science, and in 2008, he became a professor of electrical and computer engineering at Johns Hopkins University. Etienne-Cummings' research interests include developing algorithms for biologically inspired robots. Similar algorithms have been used to create a robot vision device that mimics the superior eyesight of a fly, for example. Additionally, while at Johns Hopkins University, Etienne-Cummings sponsored a number of diversity and mentoring programs. In 2004, he served as co-chair of the Diversity Committee, and in 2009, he became a mentor of the school's robotics club. In addition to teaching, Etienne-Cummings has served as a consultant engineer for several technology firms including Nova Sensors, Inc., Innovative Wireless Technologies, Singular Computing, and Panasonic N. American & Corporation. He holds seven patents and has mentored over thirty-five students at the graduate level. Ralph Etienne-Cummings works in Baltimore, Maryland.

Above Picture of Ralph Etienne-Cummings from http://etienne.ece.jhu.edu/etienne/

SCIENCE IN ACTION

ARTIFICIAL VISION

Rubble after the Haiti Earthquake
byuncoolbob@Flickr

In 1993, scientist Carver Mead said, “As engineers, we would be foolish to ignore the lessons of a billion years of evolution.” By this, Mead meant that engineers must use nature’s designs as inspiration for engineering artificial devices. Ralph Etienne-Cummings created a biologically-inspired motion sensor that uses an algorithm, or a set of mathematical instructions, to measure speed, direction, and light. His goal is to improve visual systems for robotics, which can be used in many different situations. Such applications include: visual sensory devices for the blind, vehicles with vision sensors for military use, and vision equipment that can maneuver through post-earthquake rubble in order to search for and rescue survivors.

DISCUSSION QUESTIONS

1. If you were to interview Ralph Etienne-Cummings, what questions would you ask him?
2. Check out the Iguana Robotics, Inc. website (http://www.iguana-robotics.com/research.htm). What are the names of their biomorphic robots. What animals do you think inspired these robots?
3. Ralph Etienne-Cummings works on visual sensory technology. Can you think of other possible uses for his work?
4. Ralph Etienne-Cummings is a neuromorphic engineer, meaning he creates technology based on animal nervous systems. If you were a neuromorphic engineer, what animal's nervous system would you base your technology on? Why?
5. How does Ralph Etienne-Cummings' career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Algorithm - An effective method for solving a problem, such as a calculation or data analysis, using a set of mathematical instructions

Computer Engineering - The design, operation, and use of computers

Consultant - Someone who gives professional advice

Electrical Engineering - The design, construction, and maintenance of products for electrical and electronic equipment and computer systems

Neuromorphic Engineering - The use of human and animal nervous systems as models to design artificial nervous systems in robots

Neuroscience - The study of the nervous system including the brain, spinal cord, and nerves; how the body transmits and receives signals through the nervous system

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention who can prevent others from making, using, or selling the claimed invention

ScienceMakers Spotlight

Roscoe Giles

Computer Scientist

Birth Date	1949
Birth Place	Oakland, California
Education	University of Chicago (B.A. 1970)
	Stanford University (M.S. 1973, Ph.D. 1975)
Awards & Achievements	50 Most Important Blacks in Research Science (2004)
	Computing Research Association (CRA) Award (2000)
	United States Department of Energy's Advanced Scientific Computing Advisory Committee Chair (ASCAC) (2010)

BIOGRAPHY

Roscoe Giles was the first African American to earn his Ph.D. in physics from Stanford University. He was born in 1949 in Oakland, California, and moved to Chicago at age four. Giles graduated from high school in 1966 and earned his B.A. degree in physics at the University of Chicago, graduating with honors in 1970. Continuing his study of physics, he went on to acquire his M.S. and Ph.D. degrees in physics from Stanford University in 1973 and 1975, respectively.

Computer Science Lab by crazytales562 @Flickr

Throughout his career, Giles worked at many prominent institutions such as the Stanford Linear Accelerator Center (SLAC) and the Center for Theoretical Physics at the Massachusetts Institute of Technology (MIT) in 1976. In 1979, he became an assistant professor of physics at MIT and later moved to Boston University in 1985 to teach electrical and computer engineering. While there, he co-directed the Metacenter-Affiliated Resource in the New England Region (MARINER) project in 1995, which was funded by the National Science Foundation (NSF). In 1997, Giles also worked on a project to increase the participation of underrepresented minorities in the computing disciplines. He served as a faculty advisor, mentor for the Minority Engineers Society, and mentor of many high school, undergraduate, and graduate students. His research focuses on parallel computing and other applications of very powerful supercomputers, such as creating simulations of large-scale chemical molecules. Giles also studies micromagnetics and advanced computer architectures, or how computers are built. He is the founder and executive director of the Institute for African American eCulture, which helps to ensure technology resources are equally accesible to all people. Giles also collaborated with NSF on a project called Engaging People in Cyberinfrastructure (EPIC) launched in 2005. The goal of the project was to get more people excited about using computer technology. Roscoe Giles works in Boston, Massachusetts.

Above Picture of Roscoe Giles from www.bu.edu

SCIENCE IN ACTION

SUPERCOMPUTERS

Supercomputer
by Kosheahan @Flickr

Most of you have used a computer, but Roscoe Giles has worked with supercomputers. If you think you're a math whiz, check out these supercomputers that can do billions of calculations per second! During an interview with the *Boston Globe*, Giles explained that a teraflop is a computer speed equal to a trillion operations per second, and a gigaflop is a billion. Your computer at home can only do tens of millions of operations per second. Giles has investigated how supercomputers can be used to solve real-world problems including climate modeling and simulated nuclear weapons testing.

DISCUSSION QUESTIONS

1. If you were to interview Roscoe Giles, what questions would you ask him?
2. Check out the IBM website (http://www.ibm.com/innovation/us/watson/index.html) and read about The Watson Supercomputer. Do you think computers will ever be as complex as human beings?
3. Supercomputers are very complex machines that can solve large problems. What do you usually use a computer for? What problem would you use a supercomputer to solve?
4. Giles strives to create equal access to technology for all people. Why is this important?
5. How does Roscoe Giles' career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Computer Engineering - The study of the design, operation, and use of computers

Electrical Engineering - The design, construction, and maintenance of products primarily for electrical and electronic equipment and computer systems

MARINER Project - A Boston University initiative that offers training programs and opportunities in computational science and internet technology for various partners in academia and industry

Micromagnetics - The study of the forces caused by magnets, measured on a very small scale

National Science Foundation - A United States government agency that supports fundamental research and education in all the non-medical fields of science and engineering

Parallel Computing - The process of many calculations being carried out at the same time on a computer

Stanford Linear Accelerator Center - A facility at Stanford University that houses a particle accelerator, scientific instrument that propels charged atomic particles by increasing their kinetic energy, or energy of motion

Supercomputer - A very powerful computer that is many times more powerful than your average PC

ScienceMakers Spotlight

Anthony Joseph

Computer Scientist

Education	Massachusetts Institute of Technology (B.S. 1988, Ph.D. 1998)
Awards & Achievements	Shell Corporation National Achievement Corporation Scholarship
	Diane McEntyre Award for Excellence in Teaching
	National Science Foundation CAREER Award

BIOGRAPHY

Anthony D. Joseph develops technology that is on the forefront of cyber security and thwarting hackers to keep information safe on mobile and wireless networks. Joseph attended the Massachusetts Institute of Technology (MIT) where he received his B.S. degree in electrical engineering and computer science in 1988. He went on to earn his Ph.D. degree in computer science in 1998 also from MIT. While pursuing his doctorate, Joseph was a member of Frans Kaashoek's Parallel and Distributed Operating Systems laboratory which has researched software systems like computer networks and mobile computing.

Devices on the Same Wireless Network by indyplanets @Flickr

After graduating from MIT, Joseph became a professor of electrical engineering and computer science at the University of California, Berkeley. In 2007, he was appointed to the chancellor's professorship. Joseph also served as director of Intel Research at the University of California, Berkeley. His research focuses on a wide range of computer networking and computer security issues. Joseph has collaborated on many computer-related projects including the Mobile Computer and Networking Conference where he served as program chair in 2003. Joseph was also an editorial board member for *ACM/Kluwer Wireless Networks Journal*, and in 2006, he served as the general chair for the Workshop on Mobile Computing Services. He is also part of the AmpLab Berkeley, which develops technology that makes data accessible to the general public, and the Team for Research in Ubiquitous Secure Technology (TRUST), which researches cyber security. In addition to his research, Joseph has taught computer science classes covering a wide range of topics, such as operating systems, system programming, and computer security. Anthony D. Joseph works in Berkeley, California.

Above Picture of Anthony Joseph from radlab.cs.berkeley.edu/node/74

SCIENCE IN ACTION

VIRUS PROTECTION

Infected Computer
by sbeebe@Flickr

We see computers in science fiction movies that can learn and develop new skills, but did you ever think it was really possible? Computer scientists are now designing computer programs that teach computers to find patterns and learn from rules to develop plans for the future. This is called machine learning. This technology is being applied to computer security to stop invaders who try to steal information through viruses, spam and hacking. Computer scientists design the machine to adapt to a variety of security applications, including spam detection and network intrusion detection. In the future, scientists hope to design a machine that can learn to reject invasions and recognize safe communications.

DISCUSSION QUESTIONS

1. If you were to interview Anthony Joseph, what questions would you ask him?
2. Check out the cyber security website (http://www.staysafeonline.org/) and discuss ways to protect your computer at home and at school.
3. Have you or your family ever had problems with computer security? Describe the problems and how they were resolved.
4. Why is it important to stop viruses and spam from invading computers?
5. How does Anthony Joseph's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Cyber Security - The branch of computer science that develops programs and procedures for information security on computer and networks

Electrical Engineering- The design, construction, and maintenance of products for electrical and electronic equipment and computer systems

Hackers - A person who uses computers to gain unauthorized access to data

Machine Learning - The study of ways by which a program can automatically modify its knowledge and procedures to improve its performance, based on explicit instruction from a human teacher, training examples, its experiences, or experiments generated by the program

Operating Systems - The software that supports a computer's basic functions, such as scheduling tasks, executing applications, and controlling peripherals

Spam - Irrelevant or inappropriate messages sent on the Internet to a large number of recipients

System Programming - The activity of programming a software system

Wireless Network - A network protocol that enables online content to be viewed via wireless devices, such as cell phones and laptop computers

ScienceMakers Spotlight

Andrea Lawrence

Computer Scientist

Birth Date	October 6, 1946
Birth Place	Asheville, North Carolina
Education	Purdue University (B.S. 1970)
	Atlanta University (M.S. 1985)
	Georgia Institute of Technology (Ph.D. 1993)

BIOGRAPHY

Andrea Lawrence is a trailblazer in her field; she was the first African American to receive a Ph.D. in computer science from the Georgia Institute of Technology. Lawrence was born on October 6, 1946 in Asheville, North Carolina. She received her B.S. degree in mathematics from Purdue University in 1970, and earned her M.S. degree in computer science from Atlanta University in 1985. Lawrence began teaching high school mathematics, but switched to teaching college mathematics at Spelman College soon after.

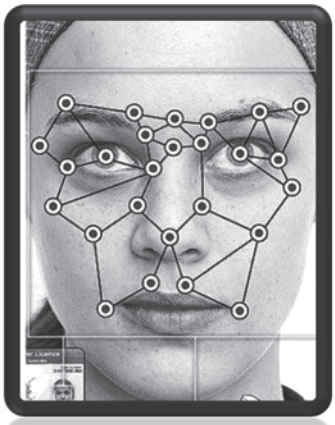
Spellman College
by minoritvrecruitmentonline.com

In 1985, Lawrence began her long career at Spelman College as a lecturer and computer literacy coordinator. In 1986, she was promoted to director of the computer science program and held the position for three years before going back to school to pursue her doctorate. Lawrence obtained her Ph.D. degree from the Georgia Institute of Technology in computer science in 1993. After receiving her doctorate, Lawrence returned to Spelman as an assistant professor in computer science, and in 1996, she became chair of the computer science department. Lawrence has been instrumental in many programs to increase the number of minorities and women involved in scientific disciplines. She served as president of the Association of Departments of Computer Science/Engineering at Minority Institutions (ADMI) and associate director of the National Aeronautics and Space Administration (NASA) WISE (Women in Science and Engineering) Scholars at Spelman College. Lawrence teaches a range of computer science classes including programming languages, computer graphics, artificial intelligence, and human-computer interactions. She also teaches and supervises projects on remote sensing in Antarctica, which uses satellites or aircraft to gather information about Antarctic ice. Her research focuses on human-computer interaction, including using computer animations to teach algorithms. Andrea Lawrence works in Atlanta, Georgia.

Above Picture of Andrea Lawrence from http://nia.ecsu.edu/nrts/2010events/101019cwm/lawrence-bio.html

SCIENCE IN ACTION

IDENTIFYING FACES



Face Recognition
by engineersgarage.com

Since machines were invented, humans have designed them to take on human tasks. Scientists, like Andrea Lawrence, are working to design computer programs that have artificial intelligence. Face recognition is a technology where computers can identify faces. A computer can pick someone's face out of a crowd, extract the face from the rest of the scene, and compare it to a database of stored images. The computer uses distinguishable landmarks on a face, such as the space between the eyes and width of the nose, to positively match a person to a picture in their database. Police departments and airports nationwide are using this technology to identify criminals even if they have changed their name or hair color.

DISCUSSION QUESTIONS

1. If you were to interview Andrea Lawrence, what questions would you ask her?
2. Check out the Artificial Intelligence Lab at MIT (http://videos.howstuffworks.com/mit/2659-artificial-intelligence-lab-at-mit-video.htm). If you could design a robot, what chore would you give it? How would you design it so as to perform the appropriate tasks?
3. Do you think it is a good idea to have computers searching for faces at airports? Why or why not?
4. Andrea Lawrence teaches many computer science courses at Spelman College. Which of the four classes listed in her biography would you be most interested in taking? Why?
5. How does Andrea Lawrence's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Algorithm - An effective method for solving a problem, such as a calculation or data analysis, using a set of mathematical instructions

Artificial Intelligence - The theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages

Programming Language - A language designed for writing computer programs, or instructions for a computer to do certain tasks

Remote Sensing - The scanning of the Earth by satellite or high-flying aircraft in order to obtain information about it

ScienceMakers Spotlight

Joseph Monroe

Computer Programmer

Education	North Carolina A&T State University (B.S. 1962)
	Texas A&M University (M.S. 1967, Ph.D. 1972)
Awards & Achievements	United States Air Force Legion of Merit Service Medal (1974, 1978, 1982)
	United States Department of Defense Superior Service Award - Superior Teaching and Research (1987)
	National Technical Achiever of the Year (1992)

BIOGRAPHY

Joseph Monroe has had a celebrated career teaching computer science to air force pilots and college students. He received his B.S. degree in mathematics, English and French from North Carolina A&T State University in 1962. He earned his M.S degree and his Ph.D. degree in computer science from Texas A&M University in 1967 and 1972, respectively. Joseph Monroe was the second African American in the country to receive his Ph.D. degree in computer science.

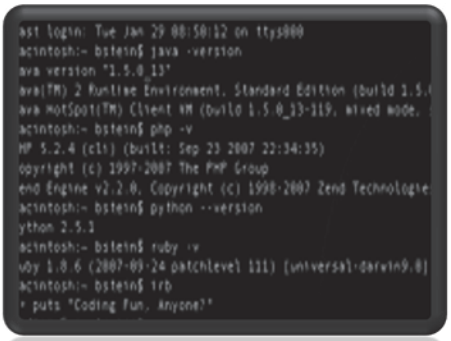
US Air Force Academy Fighter Jet Maneuvers by Beverly&Pack @Flickr

After receiving his doctorate, Monroe was appointed professor of computer science at the United States Air Force Academy. He was the first permanent African American professor at the Academy. From 1978 to1987, he held various positions at the Academy including dean of faculty, chair of the Department of Electrical Engineering, and chair of the Department of Computer Science. In 1987, Monroe joined the faculty of Fayetteville State University, working in administration. In 1991, he returned to his alma mater, North Carolina A&T State University, as the McNair Endowed Chair and professor of computer science. In 2000, he assumed the additional role of dean of the College of Engineering. Under Monroe's leadership, the Departments of Computer Science and Engineering grew in size, increased their funding, and now have the most tenured track African American engineering professors in the nation. Monroe's research focuses on object-oriented programming methods, which support reusing old software to create new computer programs. Monroe was a founding member of the first computer science honor society, Upsilon Pi Epsilon, which is now an international society. Since 2005, he has been on the board of directors for Industries for the Blind and Computing at the National Aeronautics and Space Administration (NASA). In 2009, Monroe retired from North Carolina A&T State University. Joseph Monroe is married to Sally McNair Monroe and they have two sons.

Above Picture of Joseph Monroe from www.ncat.edu

SCIENCE IN ACTION

JAVA: MORE THAN A CUP OF COFFEE



Computer Code from an Internet Webpage by farbfilm @Flickr

Have you ever wanted to write your own computer program? First, you have to know a few vocabulary words. A computer program is an exact set of instructions that tell the computer what to do. A computer program might multiply a set of numbers or play a song from a CD or allow you to surf the internet. In order to write instructions that the computer will understand, programming languages, such as Basic, Java, or Perl need to be used. Next, a compiler translates the instructions so that the computer can execute the program. Computers are extremely fast, performing the long set of instructions in a matter of seconds.

DISCUSSION QUESTIONS

1. If you were to interview Joseph Monroe, what questions would you ask him?
2. Check out the Computer Science Unplugged website (http://csunplugged.com/videos) and watch the video about binary numbers. Explain binary numbers in your own words.
3. If you were to write a computer program, what task would you want it to complete? Explain your answer.
4. Why are computer programs (like Microsoft Word and Internet Explorer) important tools for schools?
5. How does Joseph Monroe's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Alma Mater - The institution or school that a person graduated from

Java - A programming language providing a common base for running applications across a wide variety of computing platforms

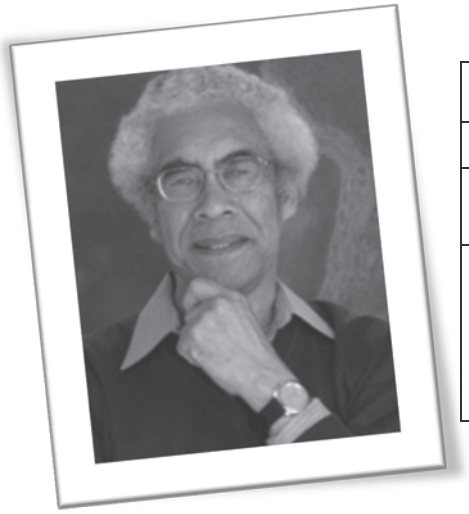
Object-oriented Programming - Creating a computer program that can use and support objects

Tenure - A lifelong appointment to a position not subject to dismissal except under serious circumstances

ScienceMakers Spotlight

George Philander

Atmospheric Scientist & Climatologist



Birth Date	August 25, 1942
Birth Place	Calendon, South Africa.
Education	University of Cape Town (B.S. 1962)
	Harvard University (Ph.D. 1970)
Awards & Achievements	Sverdrup Gold Medal of the America Meteorological Society (1985)
	American Meteorological Society Fellow (1986)
	National Academy of Sciences Member (2004)

BIOGRAPHY

George Philander has gone all over the world to study the interactions between the atmosphere and oceans, which causes some of the world's most extreme weather. Philander was born on August 25, 1942 in Calendon, South Africa. His father was one of the major poets writing in Afrikaans in his generation. However, with the apartheid in South Africa, his family felt threatened and decided to move to New York. Philander had already completed his studies at the University of Cape Town in 1962, with his B.S. degree in applied math and physics. He continued his education at Harvard University in the United States, earning his Ph.D. degree in 1970.

Hurricane over the ocean
by NASA Goddard Photo and Video @Flickr

Shortly after, Philander was hired at Massachusetts Institute of Technology (MIT) on a post-doctoral fellowship in the Department of Meteorology. In 1971, he began work as a research associate in the Geophysical Fluid Dynamics Program at Princeton University. In 1990, he became director of the program in atmospheric and oceanic sciences at Princeton. He served as chair of the Department of Geosciences at Princeton University from 1994 to 2001. Throughout his career, Philander has had the opportunity to make connections internationally, serving as a consultant to the World Meteorological Organization in Geneva, Switzerland and as a visiting professor at the Museum National d'Histoire Naturelle in Paris, France. In 2007, he returned to South Africa where he served as a research professor at the University of Cape Town. Philander researches the connections between the atmosphere and oceans and the effect of climate change on weather. Philander has published over one hundred academic papers, nine chapters in books, and three books on such topics as El Niño and global warming. George Philander has worked for the African Centre for Climate Change and Earth Science at Princeton University since 2007.

SCIENCE IN ACTION

EL NIÑO, HOT AIR OVER HOT WATER

Strong Waves Attributed to El Niño by ingridtaylor@Flickr

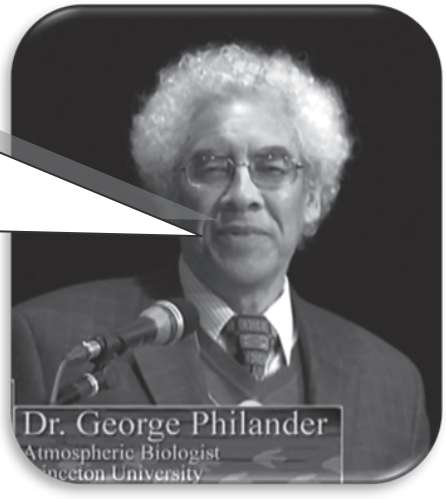
Ever wonder why some years have more extreme weather than others? El Niño is a natural occurrence, which can cause bad storms due to the unstable interactions between the tropical Pacific Ocean and the atmosphere. El Niño is the warm oceanic phase and La Niña is the cold oceanic phase. This climate pattern is often abbreviated to ENSO for El Niño/La Niña-Southern Oscillation. El Niño is characterized by a prolonged difference in Pacific Ocean surface temperatures. It occurs at irregular intervals of two to seven years and lasts nine months to two years. ENSO causes extreme weather such as floods, droughts, and strong hurricanes. There is a strong possibility that global warming is making the ENSO climate pattern more extreme, creating larger storms.

Computer Science

IN HIS OWN WORDS

George Philander spoke at the Detroit Science Center for a program with The HistoryMakers on February 17, 2011. Here is a portion of his presentation:

I would say my main message if you are interested in science is that you got to be interested in looking for patterns and looking for general answers. Some people think it is all about details; it's about learning the names of this bone or that bone. It's looking much more generally ...You can play many wonderful tricks with numbers. Once you know the rules you can apply it to all sorts of other things. You can apply it to weather, to climate, all sorts of issues.



DISCUSSION QUESTIONS

1. If you were to interview George Philander, what questions would you ask him?
2. Check out the Office of Oceanic and Atmospheric Research (http://www.oar.noaa.gov/k12/html/elnino2.html) and learn about El Niño. What information did you find the most interesting?
3. George Philander worked at the World Meteorological Institute. How do scientists predict weather patterns?
4. George Philander has studied climate change. Why is this important?
5. How does George Philander's career compare to that of other computer scientists in the Toolkit?

GLOSSARY

Afrikaans - A language of southern Africa, derived from the form of Dutch brought to the Cape by Protestant settlers in the 17th century; an official language of South Africa

Apartheid - A policy or system of segregation or discrimination on grounds of race in South Africa between 1948 and 1994

El Niño - An irregular and complex series of climatic changes characterized by warm nutrient-poor water off northern Peru and Ecuador, typically in late December

Meteorology - The study of the processes and phenomena of the atmosphere as a means of forecasting the weather

Artificial Intelligence: Teaching the Computer to Play Tic-Tac-Toe

(www.sciencebuddies.org)

Grade Level: 7 - 9
Time Required: About one week
Cost: $20 or less

*This activity relates to the work of computer programmers, like ScienceMakers **Joseph Monroe** and **Anthony Joseph**.*

Abstract
This is a more challenging JavaScript project: can you write a program that can play Tic-Tac-Toe? You'll have to figure out a way to translate the game strategy into a computer algorithm. The project will show you how to create a working Tic-Tac-Toe board on a webpage. Your challenge will be to show the computer how to play. Just think: you'll be creating artificial intelligence!

Objective
The goal of this project is to write a JavaScript program that plays Tic-Tac-Toe. This project will take you through the steps of creating the interface for the game. You will need to take it from there and write the algorithms to create a computer opponent.

Introduction
This is an example of an intermediate programming project. You will be writing a program that allows you to play a game of Tic-Tac-Toe against the computer.

To do this project, you should already be comfortable with creating basic HTML files using a text editor. You should also be familiar with creating HTML form elements, and having them interact with JavaScript functions. If you have not done any JavaScript programming before, we suggest you start with a simpler project (available at www.sciencebuddies.org), like Forms and Functions: Writing a Simple Calculator Program with JavaScript or ABC's of Programming: Writing a Simple 'Alphabetizer' with JavaScript.

The Introduction will help you get started, in a step-by-step manner. If you follow the steps in the Introduction, you can gradually build up a webpage that you can use to play Tic-Tac-Toe with a friend. The experience you gain from building the two-player game will help you when you take on the challenge of programming the computer to play against you.

Here are the steps covered in the Introduction. First you will learn how to write an HTML file (webpage) that represents a Tic-Tac-Toe board. Next you will learn how to make your webpage respond to mouse clicks on the Tic-Tac-Toe board using JavaScript. Then you will learn how to update the text values of HTML elements on the fly. You will also learn how to program Tic-Tac-Toe knowledge into your program to detect when the game has been won or ended in a draw. At this point, you'll have a webpage that you can use to play Tic-Tac-Toe with a friend.

The challenge we leave you with for your project is to write the algorithms so that the computer can be your opponent instead. Can you create a computer opponent that always gives you opportunities to win? Can you improve that opponent so that it plays strongly but sometimes gives you an opportunity to win? Finally, we all know that it is possible to play a perfect game of Tic-Tac-Toe that results in a draw. Can you write an AI player that never loses?

The important HTML elements used in this project are:

SCRIPT	The <SCRIPT> element is used to begin and end a section of JavaScript code.
INPUT	The <INPUT> element can be used to create buttons. Buttons will represent the squares of our Tic-Tac-Toe board in this lesson.
P	The <P> element is used to create paragraphs. We will use this element to create a space that tells the user what is going on in the game.
	This element stands for "non-breaking space." It is used in HTML to place a space on the webpage where no line-break can occur. We will use non-breaking spaces to represent empty squares on the Tic-Tac-Toe board.

The important JavaScript objects, functions, and keywords used in this project are:

Var	The var keyword is used to declare a variable in JavaScript. A variable is a piece of data in JavaScript that can be changed and compared to other variables.
function	The function keyword is used to declare the beginning of a function. A function is a reusable piece of code that performs a specific purpose. In this project you will use functions to do things such as: place an X or an O on the game board, or check to see if someone has won the game, or to start a new game after one has finished.
== , !=	The operators "is equal to" (==) and "is not equal to" (!=) are used to compare values in JavaScript. There are also comparison operators for "less than" (<), "less than or equal to" (<=), "greater than" (>), and "greater than or equal to" (>=). The result of using a comparison operator is either true or false. Comparison operators are used in if statements and for loops to control program execution (see next two entries).
if...else	An if statement is a conditional statement. It is used to control the flow of the program using simple true/false expressions. For example, you might have a variable to indicate whose turn it is (X or O). When there is a mouse click on a blank square, you can use an if statement to check the value of the turn variable so you know whether to mark the square with an X or an O.
for	The for keyword is used to loop through a section of code a number of times. In this project we will use loops to check each value on the game board.

Making a JavaScript Tic-Tac-Toe Board

1. **Laying out the game board.** In this project, the game board is made up of buttons. There are 3 rows that each have 3 button across. Each button represents a square on the Tic-Tac-Toe board. The HTML code necessary to lay this out is easy. To do this, we use the HTML <INPUT> tag. The input tag must have a type. In our case the type is "BUTTON".

```
<INPUT TYPE="BUTTON" ID="0_0" VALUE="   ">
<INPUT TYPE="BUTTON" ID="1_0" VALUE="   ">
<INPUT TYPE="BUTTON" ID="2_0" VALUE="   ">
<BR>
<INPUT TYPE="BUTTON" ID="0_1" VALUE="   ">
<INPUT TYPE="BUTTON" ID="1_1" VALUE="   ">
<INPUT TYPE="BUTTON" ID="2_1" VALUE="   ">
```

```
<BR>
<INPUT TYPE="BUTTON" ID="0_2" VALUE="   ">
<INPUT TYPE="BUTTON" ID="1_2" VALUE="   ">
<INPUT TYPE="BUTTON" ID="2_2" VALUE="   ">
<BR>
```

Notice that each input has an "ID" and a "VALUE." The VALUE is displayed on the face of the button. At the start of the game, the buttons are blank. The ID can be used to tell which button was pressed. We will also use the ID to change individual buttons to show an X or an O.

2. **"Catching" mouse clicks.** In order to make the Tic-Tac-Toe game interactive you will need to know when the user clicks on a button. JavaScript provides an easy way to do this. <INPUT> tags can have an ONCLICK attribute that you can use to call JavaScript code whenever the button is clicked. This must be added to each button on our board like so:

```
<INPUT TYPE="BUTTON" ID="0_0" VALUE=" " ONCLICK="alert('Hi, you clicked me!');">
```

Now you will know whenever a player clicks on a button. The next step is putting the right value into the box. After that, we'll tackle alternative turns!

3. **Setting the value of a square.** The first step in making the Tic-Tac-Toe game work is setting the value of a square when it is clicked. Each of the squares will work in the same way. Because the click response is common to all of the squares, you should write one piece of code that can be used by any square when it is clicked. To do this you need to create a JavaScript function. At the top of your HTML file (in the <HEAD> section) add a <SCRIPT> tag so you can write JavaScript code, like this:

```
<SCRIPT TYPE="TEXT/JAVASCRIPT">
</SCRIPT>
```

Now you can write JavaScript code inside the script section. Let's start by creating the function we will call whenever a button is clicked:

```
function squareclicked(square)
// squareclicked is a function that is called whenever a button is clicked.
{
}
```

These four lines create a function that will do nothing. The first line is a comment. It summarizes what the function does. The function is named "squareclicked," and it has one argument, "square." The argument will be used to tell the function which button has been clicked. This means you need to update your buttons to call the squareclicked() function:

```
<INPUT TYPE="BUTTON" ID="0_0" VALUE=" " ONCLICK="squareclicked(this);">
```

Notice how "this" is being sent whenever we call the squareclicked() function. When you put "this" inside an onclick attribute it represents the <INPUT> that the onclick attribute is created in. This means that whenever a button is clicked it will call the squareclicked() function and pass itself to the function. This will enable you to set the value of the square. Now update the squareclicked() function to set the value of the button:

```
function squareclicked(square)
// squareclicked is a function that is called whenever a button is clicked.
{
  square.value = 'X';
}
```

Jackpot! Now whenever a button is clicked it gets the value 'X'. The next step is to put the right value in the square based on whose turn it is.

4. **Alternating turns.** In order to alternate turns and place the right value in the square that is clicked we will need to keep track of whose turn it is. You can do this by creating a "global" variable (a global variable can be accessed from any function) in the JavaScript section outside of the squareclicked() function, like this:

```
<SCRIPT TYPE="TEXT/JAVASCRIPT">
var xTurn = true;

function squareclicked(square)
// squareclicked is a function that is called whenever a button is clicked.
{
 ... code here ...
}
<script>
```

5. **Using the xTurn variable.** The next step is to use the xTurn variable in the squareclicked() function to put the right marker (X or O) onto the board, depending on whose turn it is. After marking the square, the function should switch whose turn it is.

```
function squareclicked(square)
// squareclicked is a function that is called whenever a button is clicked.
{
 var value = square.value;
 if(value != 'X' && value != 'O')
 {
   if(xTurn)
   {
      square.value = 'X';
      xTurn = false;
   }
   else
      {
         square.value = 'O';
         xTurn = true;
      }
 }
   else
      alert('That square has already been played.');
}
```

This function will mark squares and switch turns appropriately. Notice how the outer if ... else statements prevent a square from being chosen more than once. The inner if ... else statements check the xTurn variable, mark the square with the correct market, and switch the xTurn variable to the next player.

It would be really nice if we could tell the players whose turn it is, though. Let's add a status bar.

6. **Adding a status bar.** To add a status bar we will need to add a section near the bottom of our HTML page (above the </body> tag):

```
<P ID="status">X's turn</P>
```

The "ID" attribute is very important because it will allow us to change the value of the status bar later! Update the squareclicked function to use the status bar:

```
function squareclicked(square)
// squareclicked is a function that is called whenever a button is clicked.
{
 var status = document.getElementById('status');
 var value = square.value;
 if(value != 'X' && value != 'O')
 {
   if(xTurn)
   {
     square.value = 'X';
     xTurn = false;
     status.innerHTML = 'O\'s turn';
   }
   else
     {
       square.value = 'O';
       xTurn = true;
       status.innerHTML = 'X\'s turn';
     }
 }
   else
     alert('That square has already been played.');
}
```

7. **Starting a new game.** The last thing we need to do in order to have a functioning Tic-Tac-Toe board is give the players a way to start a new game. You can add a button to do this:

```
<INPUT TYPE="BUTTON" ID="NEWGAME" VALUE="New Game" ONCLICK="newgame();">
```

This button calls the function "newgame()," which we haven't written yet. The newgame() function must reset everything that is necessary to start the game anew:

```
function newgame()
{
  var status = document.getElementById('status');

  xTurn = true;
  status.innerHTML = 'X\'s turn';

  for(var x = 0; x < 3; x++)
  {
    for(var y = 0; y < 3; y++)
    {
      document.getElementById(x + '_' + y).value = ' ';
    }
  }
}
```

Checking for the End of the Game

You have now successfully made a program that lets two players play a game of Tic-Tac-Toe. You can make this game better by detecting when the game has ended (win, lose or draw). To do this we need to do several things.

1. First we need to create a global variable to keep track of whether or not the game is over:

   ```
   var gameOver = false;
   ```

2. Next we need to keep track of how many moves have been made. If 9 moves have been made and nobody has won then we know all of the spaces on the board have been filled, and we have a tie. We'll create a global variable to keep track of the number of moves that have been made:

   ```
   var numMoves = 0;
   ```

3. Now you can write a function that checks to see if a player has won. Call it checkWin(). The checkWin function will determine if a player has won by checking every row, every column, and both diagonals to see if any of them are made up entirely of X's or O's. The function will return a value of either "true" or "false" indicating whether or not someone has won:

   ```
   function checkWin()
   {
    var status = document.getElementById('status');
    var val0;
    var val1;
    var val2;

    // check columns
    for(var y = 0; y < 3; y++)
    {
      val0 = document.getElementById('0_'+y).value;
      val1 = document.getElementById('1_'+y).value;
      val2 = document.getElementById('2_'+y).value;
      if(val0 == 'X' && val1 == 'X' && val2 == 'X')
      {
        status.innerHTML = "X WINS!";
        return true;
      }
      else if(val0 == 'O' && val1 == 'O' && val2 == 'O')
      {
        status.innerHTML = "O WINS!";
        return true;
      }
    }

    // check rows
    for(var x = 0; x < 3; x++)
    {
      val0 = document.getElementById(x + '_0').value;
      val1 = document.getElementById(x + '_1').value;
      val2 = document.getElementById(x + '_2').value;
      if(val0 == 'X' && val1 == 'X' && val2 == 'X')
      {
        status.innerHTML = "X WINS!";
   ```

```
    return true;
  }
  else if(val0 == 'O' && val1 == 'O' && val2 == 'O')
  {
    status.innerHTML = "O WINS!";
    return true;
  }
}

// check top left to lower right diagonal
val0 = document.getElementById('0_0').value;
val1 = document.getElementById('1_1').value;
val2 = document.getElementById('2_2').value;
if(val0 == 'X' && val1 == 'X' && val2 == 'X')
{
  status.innerHTML = "X WINS!";
  return true;
}
else if(val0 == 'O' && val1 == 'O' && val2 == 'O')
{
  status.innerHTML = "O WINS!";
  return true;
}

// check lower left to top right diagonal
val0 = document.getElementById('2_0').value;
val1 = document.getElementById('1_1').value;
val2 = document.getElementById('0_2').value;
if(val0 == 'X' && val1 == 'X' && val2 == 'X')
{
  status.innerHTML = "X WINS!";
return true;
}
else if(val0 == 'O' && val1 == 'O' && val2 == 'O')
{
  status.innerHTML = "O WINS!";
  return true;
}

// no winner yet  return false;
}
```

4. We also need to incorporate the gameOver variable, the numMoves variable, and the checkWin() function into the newGame() function and the squareclicked()function. The newGame() function needs to set gameOver = false, and numMoves = 0:

```
numMoves = 0;
gameOver = false;
```

5. The squareclicked() function will need three updates.
    a. You will need to check at the beginning of the squareClicked function to see if the game is over (so the players can't make moves after the game is over):

```
 if(gameOver)
 {
```

```
        alert("The game is already over.");
        return;
      }
```

b. You will need to increment numMoves each time a player takes a turn:

```
      if(xTurn)
      {
        numMoves++;
        square.value = 'X';
        xTurn = false;
        status.innerHTML = 'O\'s turn';
      }
      else
      {
        numMoves++;
        square.value = 'O';
        xTurn = true;
        status.innerHTML = 'X\'s turn';
      }
```

c. You will need to check at the bottom of the squareClicked function (after a move has been made) to see if there is a winner or a tie:

```
      var winner = checkWin();
      if(!winner)
      {
        //check to see if there is a tie
        if(numMoves == 9)
          status.innerHTML = 'Tie Game!';
      }
      else
        gameOver = true;
```

Creating a Computer Opponent

Now that you have created a working game of Tic-Tac-Toe for two players wouldn't it be nice to have someone to play against? How about playing against the computer? This requires artificial intelligence to the game. What is involved in adding artificial intelligence? Check out the Experimental Procedure section!

Terms, Concepts, and Questions to Start Background Research

To do this project, you should do research that enables you to understand the following terms and concepts:

- HTML concepts:
  - start tags and end tags,
  - comments,
  - the <HEAD> section,
  - the <SCRIPT> section,
  - the <BODY> section,
  - the <FORM> section,
  - the <INPUT> tag,
- JavaScript concepts:
  - functions,
  - variables,
  - objects,
  - events,
- general programming concepts:

- reserved words,
- control statements (e.g., if...else statements, for loops),
- recursion,
- artificial intelligence.

Questions:

- How do you program a button in an HTML form to call a JavaScript function?
- How do you pass information from an HTML form to a JavaScript function using a variable?
- How do you program a JavaScript function to display information in an HTML form?

Bibliography

- HTML Forms reference:
  W3C, 1999. "Forms in HTML Documents, HTML 4.01 Specification" World Wide Web Consortium (Massachusetts Institute of Technology, Institut National de Recherche en Informatique et en Automatique, Keio University) [accessed June 6, 2006] http://www.w3.org/TR/REC-html40/interact/forms.html.
- A list of reserved words in JavaScript (you cannot use these words for function or variable names in your program, because they are reserved for the programming language itself):
  JavaScript Kit, 2006. "JavaScript Reserved Words," JavaScript Kit [accessed June 6, 2006] http://www.JavaScriptkit.com/jsref/reserved.shtml.
- A JavaScript reference:
  Netscape Communications Corporation, 1999. "JavaScript Guide," [accessed June 6, 2006] http://wp.netscape.com/eng/mozilla/3.0/handbook/javascript/.
- If you get interested and start doing a lot of programming, you may want to try using a text editor that is a little more sophisticated than Notepad. An editor designed for programming can help with formatting, so that your code is more readable, but still produce plain text files. This type of editor can also do "syntax highlighting" (e.g., automatic color-coding of HTML) which can help you to find errors. Here is a free programmer's editor that you can try:
  Kang, I., 2003. "Crimson Editor," [accessed June 6, 2006] http://www.crimsoneditor.com/.
- You can find a step-by-step JavaScript tutorial at the link below. If you need help with the JavaScript concepts covered in this project, this tutorial should help:
  Webteacher Software, 2006. "JavaScript Tutorial for the Total Non-Programmer," Webteacher Software, LLC. [accessed June 6, 2006]http://www.webteacher.com/javascript/index.html.
- This webpage by Matt Gemmell describes what programming actually is:
  Gemmell, M., 2002. "Introduction to Programming," Matt Gemmell, Scotland Software [accessed June 6, 2006]http://www.scotlandsoftware.com/articles/programming/.

Materials and Equipment

To do this experiment you will need the following materials and equipment:

- computer with Web browser (e.g., Firefox or Internet Explorer),
- text editing program (e.g., Notepad or Crimson Editor).

Experimental Procedure

The Introduction took you through the steps to create a working Tic-Tac-Toe game that you could play with a friend. The next step is to program the computer to play the game in place of one player. You'll be adding a simple form of *artificial intelligence* (AI) to your program! What is involved in adding AI to the program? Several things:

1. The computer must know when it is has the turn to move.
   a. Your program can keep track of this with another global variable:

```
var computerTurn = false; // true/false variable to keep track of the turn
```

    b. Whenever a move is made, you can switch the value of the computerTurn variable, like this:
    computerTurn = !computerTurn
2. There must be code in place to make a move! You can use a code snippet like the one below, but where should you put it? You should be able to figure this out on your own!

```
if(computerTurn)
{
  makeComputerMove();
}
```

3. How will the computer determine where to place its X or O? In other words, what will go into the "makeComputerMove()" function? You'll have to think about Tic-Tac-Toe strategy, and try to reduce it to a series of steps that you can write in a program. For example, the computer could mark the first empty spot it finds, or it could choose a random empty spot, or it could look for places where the opponent has 2 in a row in order to block, or it could look for places where it has 2 in a row so it could win. It could also be a mix of all of the above! This is entirely up to you but it's easy to see that some methods will produce a better computer opponent than others.
4. Whatever strategy you choose you will most likely have to loop through all the squares. The code in the checkWin() function should help you figure out what to do.
5. It's a good idea to follow the method used in the Introduction. Start out with something simple, get it working, and then refine it. As you improve your program, remember save your previous version, and re-name the file before making radical changes. That way, you can always go back to a working version.
6. Can you create a computer opponent that always gives you opportunities to win? Can you improve that opponent so that it plays strongly but sometimes gives you an opportunity to win?
7. When you have a working computer opponent, make a prediction about how well the computer's strategy will work. Test your prediction by playing a few dozen games against the computer, and record the results of each game. How did your prediction hold up? How can you improve the computer's performance? Refine the program and try again!

Variations

- Once you've created one computer opponent, why not try having the computer play against itself? Have the program run in a loop, with input from the HTML form to set the number of games. The program should also keep track of the results. You can give the two players different strategies. Predict which strategy will be stronger, and test your prediction by having the computer play a few hundred games against itself. Try this for several different strategies.
- We all know that it is possible to play a perfect game of Tic-Tac-Toe, so that the result is always a draw. Can you write an AI player that never loses?
- **Advanced.** The most complex and powerful AI game opponents will use a technique called *recursion*. Recursion is when you write a function that calls itself again in certain cases. This would be used by the AI player to evaluate the outcome of moves that it could make in the future. By doing this the AI player can "look ahead" to make a better decision about what moves to play.
- For more science project ideas in this area of science, see Video & Computer Games Project Ideas.

Credits

By Adam Schepis, Software Engineer
Edited by Andrew Olson, Ph.D., Science Buddies
To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Games_p014.shtml

Help! What File Format Should I Use to Save My Favorite Photo?

(www.sciencebuddies.org)

Grade Level: 6 - 8
Time Required: A day or less
Cost: $20 or less

This activity relates to the work of computer programmers and computer teachers like, ***Roscoe Giles*** *and* ***Andrea Lawrence.***

Abstract
Jpeg, bmp, gif, tiff…do these just look like words that you and your friends might make up for your own secret language? They are actually just a few of the file formats (which means "types") that you can use to save your favorite photo on your computer. But does it matter which one you use? Try this simple science fair project to find out and you'll never choose the wrong one again!

Objective
In this science fair project, you will test if saving an image file in a different format will change the file size**.**

Introduction
What do *you* do with digital images? Email photos from a digital camera or send them from your cell phone to friends? Scan and store your best drawings? Submit fan art to Club Penguin? Post to a family blog, website, or Facebook page? Look at a webpage with a gallery of pictures of your favorite actress? In the United States, almost everyone sees or uses digital images on a daily basis, but what exactly *is* a digital image file? A digital image file is just like any other computer file containing information. Examples of other digital files you might use without even knowing it include the file that stores your highest score in a computer game (usually this is something the game goes and looks up in the file without even asking you), or the word processing file containing the latest report you typed and saved for school. For digital images, and all other types of documents, information is stored as a file of a certain size, depending upon how much information is in the image. For instance, imagine you have a folder for a class project. If you have to write a 2–3 page report, the folder won't need to be very thick, right? But imagine you've got to turn in a project with a long report, several images, and a bunch of graphs. The folder to hold it all would need to be bigger. The information on a computer is stored as bits, and the size of the file is measured in bytes (pronounced just like a "bite" of food). So the more bits of information you have in your image file, the more bytes of space the file will be. The bits of information in an *image* file include things like which colors to use, how many colors to use, where to put pixels (which are the smallest parts of an image) of color, how many pixels to use, and how big the image is.

All of this information is stored in the file when you save it so that you can open it and use it later. When you save an image file on your computer, the program will have you choose a format in which to save it. Here are a few of the most common file formats used by most image editing programs:

- JPEG (Joint Photographic Experts Group, pronounced jay-peg)

- TIFF (Tagged Image File Format, pronounced as it looks)
- PNG (Portable Network Graphics, pronounced by reading each letter individually)
- GIF (Graphic Interchange Format, pronounced as it looks)
- BMP (Bit Mapped, pronounced by reading each letter individually)

If the information in the image is the same, then why are there so many different file formats? Well, the information in a file is stored using code (a set of instructions for the computer). The data is encoded in a different way, depending upon the format you choose to save it in. When you open the file, the program reads the code to know how to put the data back together and give you your image. But back to why we need different ways of writing the data into code. One reason is that different image editing programs have different sets of codes that they can open and interpret (understand). So, perhaps program A can read JPEGs, but program B can only read BMPs. If your file was saved in a format that your image editing program can't "read," you might not be able to open it! Another reason for different file formats is that different codes have different complexities (levels of difficulty) and take up different amounts of space on your computer. Some codes are very complex, so they take a lot of processing to interpret, and thus, result in larger file sizes. This can be a problem if you want to email your photo to a friend—it could take a long time for him or her to download and view it. On the other hand, a more simple code that would give a smaller file size, allowing for fast download and viewing, might also oversimplify your data, leading to data loss and poor image quality.
What does this all mean when you save your photos? It means you need to match the file format you choose with the way you want to use it. Are you going to email it to a friend, print it out, or put in on a website? If you're e-mailing just *one* photo to a friend, it might not matter how large the file is—chances are, with today's Internet, they can download it pretty quickly. But what if you send all *60* pictures from your latest vacation? Nobody wants to sit in front of their computer and wait 10 minutes or more for all those photos to download! This is a case where smaller file sizes, and thus a faster download, matters. On the other hand, a picture whose information has been reduced so that the file size is very small might not look good if it is take printed on their computer or taken to a photo store and printed as a large picture to frame. So if you get lucky enough to run into your favorite movie actor at the airport and take a picture with him, saving that photo in *some* file formats might be a bad idea if you plan on hanging a large version of it on your bedroom wall! In this science fair project, you will investigate the link between image file format and file size. After changing the format of the image you choose, what will happen to the file size?

Terms, Concepts, and Questions to Start Background Research
To do this science fair project, you should know what the following terms mean. Have an adult help you search the internet, or take you to your local library to find out more!

- Bit
- Byte
- Pixel
- Image file format (JPEG, TIFF, PNG, GIF, BMP, etc.)
- Code
- File size (measured in megabytes, mB)

Questions

- Does changing the file type change the image?
- Are different file types suited for different uses?
- Which file types are best for printing photos? Posting them on websites? Sending them by email?

Bibliography

- Wikipedia Contributors. (2006, April 17). Graphics file format summary. *Wikipedia: The Free Encyclopedia.* Retrieved April 17, 2006, from http://en.wikipedia.org/w/index.php?title=Graphics_file_format_summary&oldid=48844609
- Murray, J.D., and van Ryper, W. 1996. *Encyclopedia of Graphics File Formats*, Second Edition. Sebastopol, Calif.: O'Reilly.
- Miano, J. 1999. *Compressed Image File Formats: JPEG, PNG, GIF, XBM, BMP*. Boston: Addison-Wesley Professional.

Materials and Equipment

- Computer
- Image editing program; if you don't have one installed on your computer, several free ones are available for download on the Internet, including IrfanView, for Windows only, or GIMP for Windows or Mac. Be sure you have permission to download a program to your computer before you do so.
- Adult helper
- Your favorite digital photo
- Lab notebook

Experimental Procedure

1. If you are unfamiliar with how to use all the controls on your computer, ask an adult for help. Choose a digital image to use for your science fair project. Save a copy of the photo in a new folder on your desktop, labeled *Image File Experiment,* so it will be easy to find.
2. Open your image editing software. Any image editor will work for this science fair project, although be aware that the number of options you will have for saving your photo with different image file formats may vary.
3. From the menu bar, select "File" and then "Open" by clicking with your mouse.
4. In the browser window, select the new folder you made for your photo on your desktop, labeled *Image File Experiment.* You should see your picture in the folder. Click on the file name to select your picture and click "OK" or "Choose" (depending upon the software and computer you are using).
5. You should see your photo open in a new window of your image editing program.
6. Now you are ready to save several versions of your file, each as a different type of file. You should first make a data table in your lab notebook, like the one below, in which to keep track of your results:

Trial	**File Name**	File Format	File Size (MB)
#1			
#2			
#3			
#4			

7. From the menu bar, select "File" and then "Save As" by clicking with your mouse.
8. In the browser window, find and select the new folder you made on the desktop, labeled *Image File Experiment,* as the destination for your newly saved photos.
9. In the "Save As" dialog box, there will be a place where you can type in a new name to save the new image as. You should change the name of the file; for example, you might change a file named "Puppy" to "Puppy1", "Puppy2", "Puppy3", etc.

10. In the "Save As" dialog box, there will also be a place where you can select the file format you wish to save the new image as. Choose one of the file formats from the list (TIFF, JPEG, GIFF, BMP, EPS, PICT, etc.) and click "OK," "Choose," or "Select," depending upon your program.
11. Another dialog box will appear, offering a selection of different settings for the type of image file format you have selected. For this science fair project, keep all of these options as the pre-selected default settings. Leave them as they are and do not change anything, then click "OK." (See the Variations section for a more advanced project about changing these settings to optimize your images for different purposes.)
12. The image should now be saved as a new file with a new file format. Write the name of the file and the format of the file in your data table.
13. Repeat steps 7–12, choosing a new and different file format each time you save the photo.
14. After you have saved your photo in several different file formats, close all of your open images and your image editing program.
15. Open the desktop file manager and select the folder you created in which to save your photos—the one labeled *Image File Experiment.*
16. In this folder, you probably see a list of the file names, but you need to know more details. Select “View” from the menu bar and you might see options such as “thumbnails,” “list,” and “details.” Click on “Details” (or whatever is comparable, depending on your computer). You should now see a list of all of the photos you have saved, along with some other listed information about each file (like the date it was created). In a column to the right, you should see a column labeled "Size" (which means the size of the file). Write the information from this column in your data table, next to the corresponding file name.
17. Make a graph of your results. Which file format resulted in the largest file? The smallest file? Were there any file formats that were very similar in size? Can you make recommendations for how or when to use each type of file?

Variations

- In this science fair project, you used the default settings for saving your photo in each of the different file formats. For a more advanced project, you can experiment with the different settings for each file format to *optimize* the settings. How would you change the settings to make a good photographic quality print? How would you change the settings for a website photo? How about for sending a quick email?
- Try opening the files in another image editing program. Do the images open properly? Which files are cross-compatible? Which files are not? Which file format is the best choice for sharing images with people who use different imaging software than you do?
- Do you have a Mac or a PC? Do you use Windows or Linux? Sometimes the file format of an image file is not compatible if transferred across different *platforms.* If you have access to different computers that run on different platforms, you can test the different image file types for cross-platform compatibility. Which files are most compatible? Which file types are the most specialized?
- How does changing the file type change the quality of the data? You can enlarge each photo saved in each file type and see which ones retain the most data. Will each type of file allow you to enlarge the photo while still looking good?
- There are three main types of color profiles used for printing images: RGB, CMYK and B&W. Try changing the color profile of each type of image to see if it supports all three color profiles. Does the image still look good? Which color profile is the most difficult?

Credits

Sara Agee, PhD, Science Buddies
To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/CompSci_p020.shtml

Quick Draw McPaws: Teaching a Computer Kitty How to Draw Shapes

(www.sciencebuddies.org)

Grade Level: 7 - 9
Time Required: About one week
Cost: $20 or less

This activity relates to the work of computer scientists and computer programmers, like ScienceMakers ***Andrea Lawrence*** *and* ***Joseph Monroe.***

Abstract
Have you ever played a computer game in which a cartoon character, like a dog or a cat, moves or turns when you click on it? Have you ever wondered how characters know how far to move or how far to turn? In this computer science project, you will learn how with a simple (and free) program called Scratch, which will let you write your own computer program that tells a cartoon kitty how to draw shapes.

Objective
To determine how to draw different two-dimensional shapes using the computer language Scratch.

Introduction
What are your favorite things to draw? Pets? Trees? Flowers? Rainbows? One of the tricks that artists use when they plan a new drawing is to break down objects into smaller parts and shapes. So the ears on a cat break down into triangles. Or the beak on a bird breaks down into a cone. Shapes like circles, ovals, squares, triangles, hexagons, octagons, cylinders, and cones are the basic building blocks of any drawing.

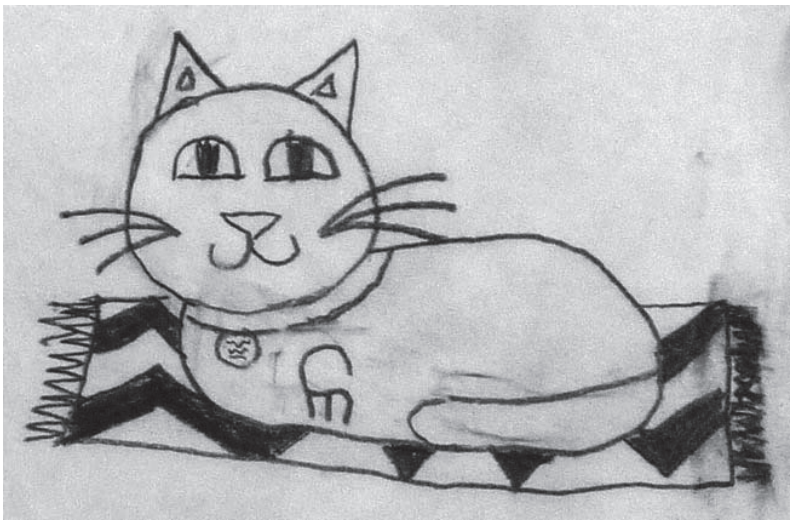


Figure 1. In this drawing of a cat you can find many shapes, like the triangles in the ears, nose, and rug; the circles in the head and collar; the half-circles in the eyes; the oval in the body; and the rectangle in the rug.

If you look at the simplest two-dimensional (flat) shapes, shown below, you can see that some of them have angles. An angle is where a line makes a sharp turn. You can measure how sharp the turn is by using a tool called a protractor. A protractor has little marks on it, just like a ruler, but instead of measuring inches or centimeters, a protractor measures angles in degrees.

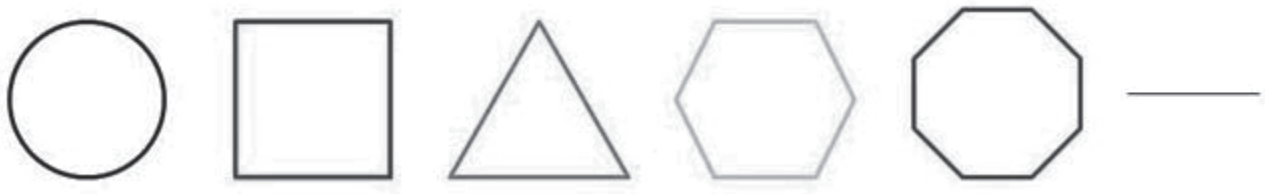


Figure 2. These are simple two-dimensional shapes: A circle, square, triangle, hexagon, octagon, and a line.

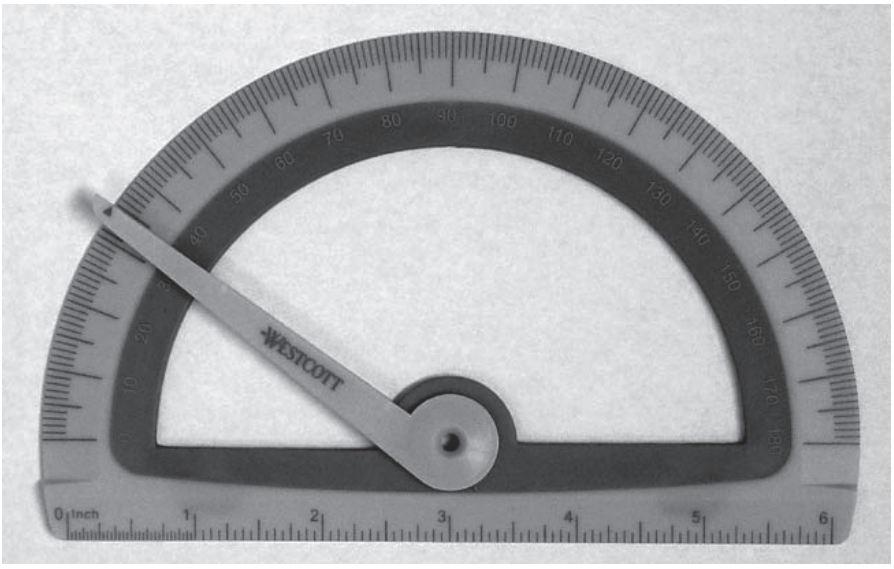
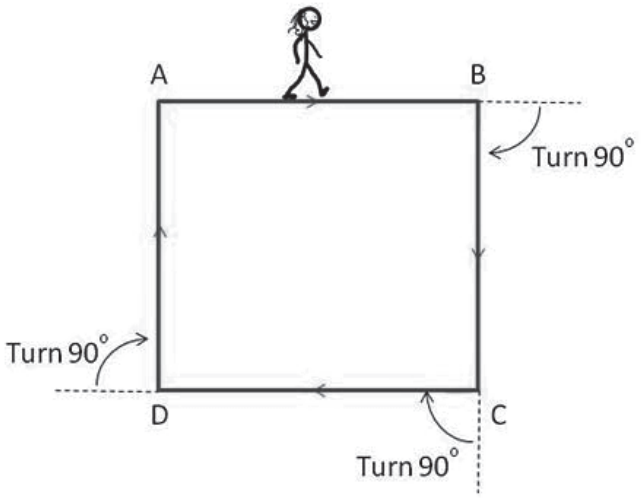
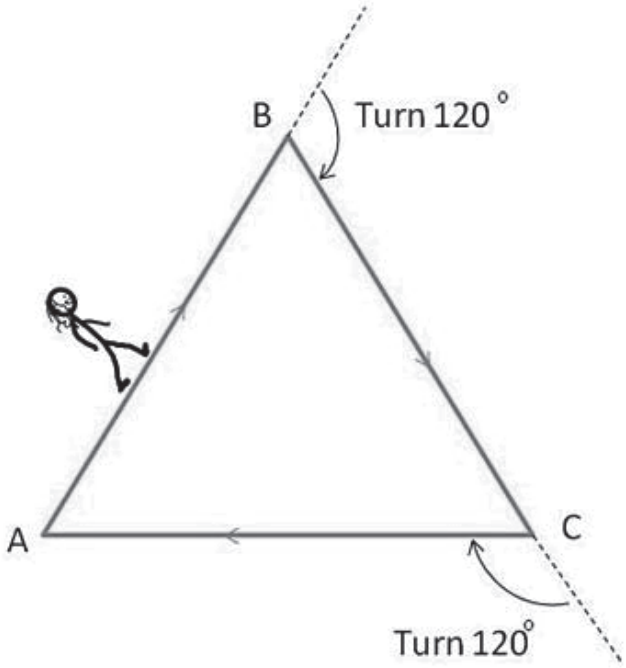


Figure 3. This is the math tool called a protractor that is used to measure the angles in two-dimensional shapes. The protractor in this example is measuring 35 degrees.

Pretend that you want to teach a friend how to draw a square. You decide to walk the path of a square on the floor so that you can show the friend what she has to do. You can see below that to draw a square, you would start walking at point A, travel to point B, and then turn (or rotate) 90 degrees, so that you can reach point C. Then you turn 90 degrees again to get to point D. Finally, you walk some more until you come back to point A.



Now suppose your friend tells you that she wants to learn how to draw a triangle, so you show her that path, too. To draw a triangle, you start at Point A, travel to Point B, and then have to turn *very* far—120 degrees—so that you can continue on the path to Point C. Then you have to turn 120 degrees again, so that you can come back to Point A.



In this computer science project, you are going to teach a *kitty* how to draw. The kitty is a cartoon character who is just a beginning artist. She doesn't even know how to draw shapes, like a triangle, yet. You'll help her by writing a simple **computer program**—a set of instructions for the computer. The computer program will tell her how to move so that she can draw her first shapes and get her start becoming a great artist!

Terms, Concepts, and Questions to Start Background Research

- Angle
- Protractor
- Degree
- Computer program

Questions

- What does an artist do first when he or she wants to draw something?
- What does a protractor help you measure?
- If you wanted to draw a big shape in the sand or in the snow with your feet, how would you move your body to do it?
- Why do cartoon characters on a computer need a computer program?

Bibliography

Watch this video to learn about angles:

- Khan Academy. (2010). Introduction to Angles. Retrieved March 23, 2010, from http://khanexercises.appspot.com/video?v=2439OIVBgPg

Visit this interactive website to learn how to use a protractor to measure angles:

- Robinson, M. (2000). Protractor. Retrieved March 23, 2010, from http://www.amblesideprimary.com/ambleweb/mentalmaths/protractor.html

These resources will introduce you to Scratch:

- Scratch Team, MIT. (n.d.). Scratch. Retrieved March 23, 2010, from http://scratch.mit.edu/
- Scratch Team, MIT. (n.d.). Getting Started with Scratch, v1.4. Retrieved March 23, 2010, from http://info.scratch.mit.edu/sites/infoscratch.media.mit.edu/docs/ScratchGettingStartedv14.pdf

Materials and Equipment

- Personal computer with Internet access and the computer program Scratch installed; see the Experimental Procedure for details on installing Scratch for free.
- Adult helper
- Protractor
- Lab notebook

Experimental Procedure

Installing and Getting Started with Scratch

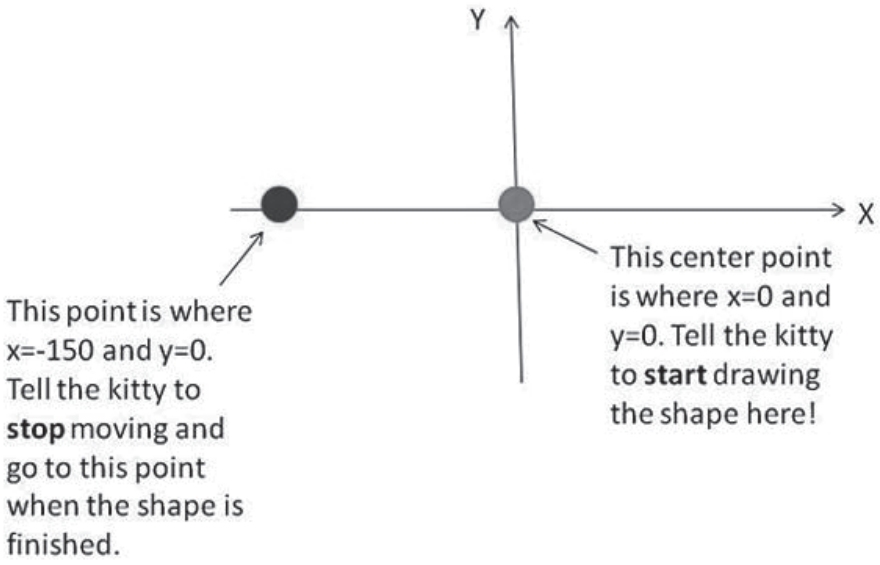
1. To start this science fair project, you should go to the Scratch download page at scratch.mit.edu/download and have an adult help you follow the instructions there to download and install Scratch for free. If you need help installing it, read the Science Buddies Installing & Getting Started with Scratch page. This short guide will familiarize you with Scratch.
2. If this is your first time using Scratch or if you need a refresher, read the Science Buddies Scratch User Guide.
3. When you first start up Scratch, you'll see your artist cat come up on the screen. Meow! It's time to program Kitty so that she can draw shapes.
4. If you want to change the way Kitty looks before you start, read the Variations section, below the Experimental Procedure, to find out how.

Writing Instructions for the Kitty

1. The first thing Kitty needs to learn is *when* to start drawing. It's a little bit like when you run a race and someone says, "1, 2, 3…go!" You need to tell Kitty when to go. Find the symbol with the green flag (think of how green traffic lights mean *go*) under the Control category, and drag it to the center panel.

2. Now Kitty must erase any previous drawings so that she can start out with a fresh page. It's kind of like getting a fresh sheet of paper with no marks on it. Go to the Pen category and get the Clear element and snap it onto the flag. The Clear element clears the page.

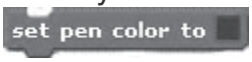
3. The next thing you need to tell Kitty is *where* to start drawing her shapes. The center of the screen where Kitty will be drawing has the **coordinates** x=0 and y=0. This is a good place to start drawing, but if you want to tell her to choose a different spot, feel free to do so, using the instructions below.



To tell Kitty to go to the starting point (indicated by the green circle, above) and start drawing, you need to find the Go To instruction under the Motion category, which looks like this:

Drag this Go To element to the center panel and snap it onto the "Clear" element. Be sure to enter a 0 for x and a 0 for y, if those numbers are not already there and if those are the coordinates at which you want Kitty to start.

4. It's time to choose a *color* for Kitty's pen. Go to the Pen category and find the element that says "Set Pen Color to…" and is followed by a colored block (*not* the one followed by a white space for a number to be typed in). Drag it over to the center panel and snap it on to your "Go To x:__ y:__" element. Click on the color that you want for Kitty's pen.



5. Now Kitty has a pretty pen, but you have to tell her to use it! Go to the Pen category, and find the element called "Pen Down" and snap it to the bottom of your growing chain of computer language commands (called *blocks*). This will tell Kitty to put her pen down on the page.

6. Now it gets exciting. It's time for Kitty to learn how to draw her first shapes. Remember from the Introduction how you taught your friend to draw a square and a triangle using steps and angles? Go to the Motion category and take a look at the elements that begin with "Move" and "Turn."

That's *exactly* what you did when you walked the path of the square and the triangle—you moved and turned, moved and turned, moved and turned, over and over again until you completed the shape. So you know you're going to need those two elements in your list of instructions.

- Move the "Move" and "Turn" elements to the center panel and type in some starting values, like 60 steps and 90 degrees, just to get started. You will change these values during your testing.

But how do you make Kitty do something over and over again? That's where the Control category can help you. Look at the "Repeat" element. Any instructions you put *inside* the repeat element will be repeated again and again!

- Move the "Repeat" element to the center panel and type in a starting value of 20 (indicating to repeat 20 times). You will change this value during your testing.

Arrange the "Move," "Turn," and "Repeat" elements in a way that you think will make Kitty draw shapes. *Hint:* Notice the white space between the "Repeat" element's golden shape—do you think that will help you use this block? You can stuff as many blocks inside there as you want and they will all be repeated the number of times that you have set.

7. It's not time to test just yet. First, you need to make Kitty put the pen away and move herself out of the way after she is done drawing, so that you can see what shape she has made. Go back to the Pen category and drag over the Pen Up element, which means "Take your pen off the paper, Kitty!"

8. To get her to move out of the way, you want to move her to a coordinate that is away from her drawing, like the red circle shown in the graph several steps above. Use the "Go To x:__y:__" element in the Motion category again to get her to move out of the way.

Enter -150 for the x-coordinate, and 0 for the y-coordinate. Feel free to choose a different ending location.

9. Finally, you want Kitty to look at her masterpiece, not up in the sky or down at the ground. Choose the "Point in Direction…" element from the Motion category to get her to look right. Leave the number as is, reading 90 (which means 90 degrees).

Testing Your Computer Program

1. Now that your program is written, you need to test it and adjust it to get Kitty to draw certain shapes. It's time to experiment. To start running the program, just click the green flag above the white screen where you see Kitty.
2. What happened? Did she draw a shape? What shape is it? Experiment with the values in the "Move," "Turn," and "Repeat" elements to see what shapes you can get her to draw. Create a data table in your lab notebook, like the one below, so that you can remember what different values do in your program. If you need help with your program, read the Science Buddies Troubleshooting a Program in Scratch page.

Scratch Testing Data Table

Number of repeats	Number of steps	Turn in degrees	Shape Kitty drew	Comments on the shape, such as its size, or whether it went off the page
20	60	90		

3. Get Kitty to draw all the basic shapes, like a line, a triangle, a square, a hexagon, an octagon, and a circle. The circle is an interesting challenge, because there are no angles, so you will have to make very small turns and get a shape that *approximates* a circle. Once you've completed it, would you say it's a very good approximation? Does it look like a circle to you?
    a. Use a protractor to measure the amount of turn needed to draw each shape. For example, to draw a square, you need to turn 90 degrees. To draw a triangle, you might want to try having Kitty turn 120 degrees. These are values to test (one at a time) in your computer program. If you don't know how to use a protractor, see the link to instructions in the Bibliography, above.
    b. Can you get Kitty to draw different sizes of shapes, such as a small triangle, a medium-sized triangle, and a big triangle?
    c. Can you make Kitty draw slow and fast?
    d. How does the "Repeat" element affect how long Kitty draws?
    e. How does the "Steps" element affect the size of the shape?
    f. How does the "Turn" element affect the type of shape?

Variations

- Would you like to change the way Kitty looks? Click on the Looks category for all sorts of fun things to try.
    - There are two elements called "Change Color Effect By…" and "Set Color Effect to…" Experiment with those to see what happens to Kitty. Can you make Kitty turn pink with one of these blocks?
    - *Note:* When you are experimenting with how something looks, it is best to add the "Clear Graphics Effects" element near the top of the chain of blocks, so that you can start with a fresh, new look each time you click on the green flag.
    - Once you understand what these blocks do for the word *Color,* click on the word "Color" in each element and you can see even more exciting things to try, like changing "Fisheye," "Whirl," "Pixelate," "Mosaic," "Brightness," and "Ghost." Experiment again to see what each of those does. Is there one you like best? Is there a block that has the power to turn one kitty into many kittens?
    - Another way to change Kitty's look is with the "Switch to Costume" element. You first have to go to the center panel and click on the Costume tab. Then, either draw something yourself with the tools there, or *import* (bring in) something that you want to change Kitty into, like a puppy or a fish from one of the folders that you see, like the Animals or Fantasy folders.
    - And, just for fun, you can always make Kitty say something at the end of her drawing, like "Ta Da!" or "Where did Kitty go?" (if she has changed into a different animal). The "Say" elements allow you to have Kitty say whatever you wish.
- If you can teach Kitty how to draw *equilateral* shapes (shapes that have sides that are the same length), can you teach her how to draw shapes with sides of different lengths, like a rectangle?
- When you were testing your program, did Kitty draw some unusual shapes that look like flowers? Or beautiful lace? Can you make Kitty color in the flowers by changing the pen size? Can you make Kitty draw a whole flower garden? Make sure she draws herself some catnip!
- For more science project ideas in this area of science, see Computer Science Project Ideas.

Credits

Kristin Strong, Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/CompSci_p035.shtml

Engineering

Engineering is the practical application of scientific principles and knowledge to everyday problems, often in commercial and industrial settings. It is concerned with the design, building, and use of engines, machines, materials, and structures.

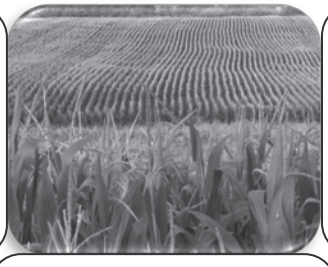
Engineering is a diverse and in-demand field with engineers employed in almost every part of the economy. Their role is crucial to society, which is why President Obama wants to train 10,000 new engineers each year. Engineers create solutions for the problems we face, from civil engineers who build bridges and dams to mechanical engineers who design engines, motors, and machines.

Studying engineering will teach you how to identify a problem, design a solution, test the design, and make improvements. Engineering has provided the tools, technologies, and conveniences that shape our modern life, including the bus you take to school, the projector in your classroom, and the microwave that heats your snack after school.

Engineering Disciplines

Engineering includes many exciting fields to study and research, here are just a few…

Agricultural Engineering is focused on developing technologies to improve agricultural productivity and create renewable energy sources and sustainable products.



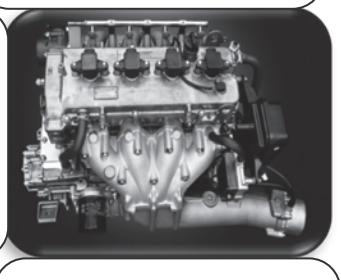
Bioengineering is an interdisciplinary field developing new technologies such as prosthetic limbs, biomechanics, and molecular modeling.

Chemical Engineering is the transformation of raw materials into substances that are useful to humans, such as petroleum refined into gasoline or kerosene.

Civil engineering is the design and construction of our nation's infrastructure including brides, buildings, highways, dams, canals, and locks.

Electrical Engineering is the design, construction, and maintenance of products primarily for electrical and electronic equipment and computer systems.

Mechanical Engineering is the study of the design, construction, and operation of machinery.



Materials Science and Engineering is the development of new types of metals alloys, composites, and plastics. Existing materials are also adapted for new uses.

Nuclear Engineering is the development of instruments, processes, and systems used in the creation or derivatives of nuclear energy, such as in power plants.

Photo credits from Top Left: fishhawk @Flickr, GollyGforce @Flickr.buggolo @Flickr, dimhap @Flickr, Yamahawatercraft @Flickr, polymer808 @Flickr, hige-daruma @Flickr

Career Paths in Engineering

Engineering covers a range of careers in many different areas. Below are just a few jobs open to those with a degree in engineering. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Engineers work in settings such as school classrooms, universities, research labs, science centers, or museums.

- *Engineering Professors* at colleges and universities teach and mentor students, and conduct research to further their field.
- *Engineering Teachers* teach students about basic engineering concepts. Due to the high demand of engineers, this is an increasingly popular subject to teach in elementary and high school.
- *Research Scientists* work at research institutes and universities developing new technologies that are on the cutting edge of research, such as artificial intelligence and robots.

Business & Industry

Engineers work for companies that research, develop, manufacture and test new products and technologies.

- *Roller Coaster Engineers* design rides for theme parks that maximize physical forces to make the most extreme and thrilling experience possible.
- *Biomedical Engineers* work at technology companies to design prosthetic limbs, micro-implants, and medical equipment, such as MRIs and X-ray machines.
- *Optical Engineers* design equipment that utilizes the properties of light including instruments, such as lenses and microscopes. They also design products that use lasers, such as optical disc systems (CDs and DVDs).

Government

Engineers work in many government departments designing public infrastructure, improving how systems are operated, and developing new technologies.

- *Environmental Engineers* create waste management systems that treat chemical, biological, and thermal waste. They also develop machines that purify air and desalinate water, making seawater safe to drink by taking out the salt.
- *Structural Engineers* design and analyze buildings, towers, tunnels, and offshore structures such as oil platforms.
- *General Engineers* are also businesspeople who manage budgets and projects. A general engineer at the Department of Defense would manage contracts and test the safety of machines like helicopters and tanks.

Check Out Our Featured Engineers!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
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Peter Delfytett	Electrical Engineer	University of Central Florida	Diodes	148
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Herbert Winful	Electrical Engineer & Laser Expert	University of Michigan	Lasers	185

ScienceMakers Spotlight

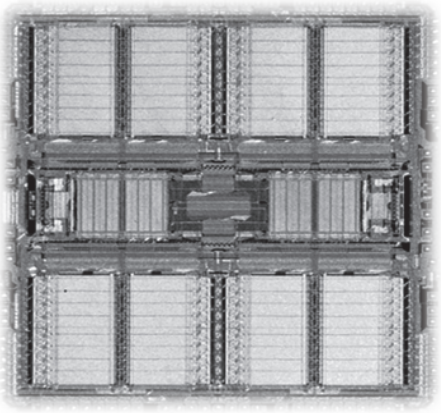
Ilesanmi Adesida

Electrical Engineer

Birth Year	1949
Birth Place	Ifon, Ondo, Nigeria, Africa
Education	University of California, Berkeley (B.S. 1974, M.S. 1975, Ph.D. 1979)
Awards & Achievements	Micro and Nano Engineering Conference Best Paper Award (1996)
	University of Illinois Oakley-Kunde Award for Excellence in Undergraduate Education

BIOGRAPHY

Ilesanmi Adesida comes from the African country of Nigeria and made a successful career for himself as an electrical engineer at the University of Illinois, Urbana-Champaign. Adesida was born in 1949 in Ifon, Ondo, Nigeria and later became an American citizen. After graduating from high school, Adesida decided to continue his education. He received his B.S. degree in electrical engineering from the University of California, Berkeley in 1974, his M.S. degree in 1975, and his Ph.D. degree in 1979.



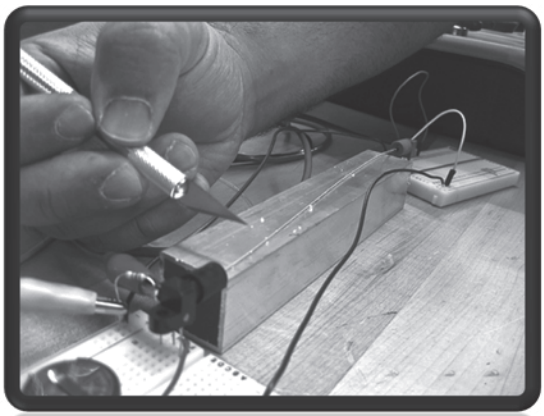
Silicon Circuit
by Ross Elliott @Flickr

After earning his Ph.D. degree, Adesida served as a research associate at Cornell University from 1979 to 1984. He then returned to Africa to accept a position as the head of the electrical engineering department at Abubakar Tafawa Belewa University in Bauchi, Nigeria. In 1987, Adesida returned to the United States to start his career at the University of Illinois, Urbana-Champaign as a professor of electrical and computer engineering. He changed teaching topics in 2001, becoming a professor of materials science and engineering at the same institution, and in 2005, Adesida accepted the position of dean of the College of Engineering. From 1987 to 2010, Adesida mentored nineteen postdoctoral fellows and awarded thirty-four Ph.D. degrees to his students. He also supervised many undergraduate research projects. While highly regarded for his teaching, Adesida has also been equally recognized for his research. He works with semiconductors, which are materials that can control an electrical current, as well as other nanomaterials. This technology can be used in cell phones, long-distance voice and data transfer, and deep-space communications. Adesida's particular contributions include a special technique that is used to construct nanomaterials. He has authored over 250 scientific papers and several book chapters. Ilesanmi Adesida works in Urbana, Illinois.

Above Picture of Ilesanmi Adesida from www.ece.illinois.edu/directory/profile.asp?iadesida

SCIENCE IN ACTION

LONG DISTANCE PHONE CALLS



Testing a Fiber Optic Cable
by Morgan Sutherland @Flickr

When you call your grandmother in Arizona, how does your voice signal reach her? The majority of long-distance communication travels on fiber optic cables. Ilesanmi Adebesi works to develop more efficient devices and circuits to make sure that your voice reaches your grandmother at an extremely high speed. Optical fibers are long, thin strands of glass that are only as thick as a single human hair. These fibers are grouped in bundles called optical cables and are used to transmit light signals over long distances. When the signals arrive at the other end, they are decoded and sent to your grandmother's telephone.

DISCUSSION QUESTIONS

1. If you were to interview Ilesanmi Adesida, what questions would you ask him?
2. Check out the How Stuff Works website (http://communication.howstuffworks.com/fiber-optic-communications/fiber-optic.htm). When you make a long-distance telephone call, how does your voice reach the person you are calling?
3. Engineering is the use of science to solve real world problems such as building bridges. Can you think of other examples where engineering is used?
4. Ilesanmi Adesida taught and mentored students in addition to conducting research. Why is that important?
5. How does Ilesanmi Adesida's career compare to that of other engineers in the Toolkit?

GLOSSARY

Computer Engineering - The design, operation, and use of computers

Electrical Engineering - The design, construction, and maintenance of products for electrical and electronic equipment and computer systems

Fiber Optic Cable - A thin strand of glass or plastic that carries light along its length

Materials Science - The study and development of new types of metals, composites, and plastics

Nanomaterials - A substance that was created on a very small scale; one billionth of a meter

Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

ScienceMakers Spotlight

Peter Delfyett

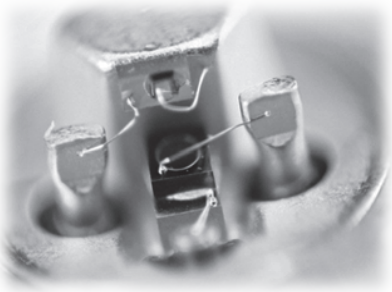
Electrical Engineer

Birth Date	March 8, 1959
Birth Place	Queens, New York
Education	City College of New York (B.E. 1981)
	University of Rochester (M.S. 1983)
	City University of New York (Ph.D. 1988)
Awards & Achievements	University of Central Florida Pegasus Award (2002)
	Science Spectrum Outstanding Black Professional in Science (2005)
	American Physical Society Edward Bouchet Award (2010)

BIOGRAPHY

Peter Delfyett is known for his leadership of the National Society of Black Physicists (NSBP) as well as his research at the University of Central Florida. Delfyett was born in Queens, New York on March 8, 1959. After graduating from high school, Delfyett attended the City College of New York where he earned his B.E. degree in electrical engineering in 1981. He went on to earn his M.S. degree in electrical engineering from the University of Rochester in 1983. In 1988, Delfyett completed his studies with his Ph.D. degree from the City University of New York.

Engineering



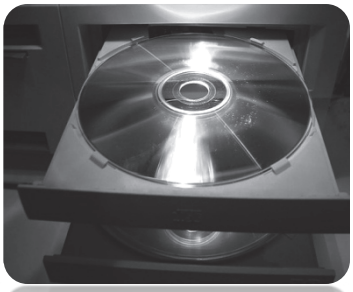
Laser Diode by Dave Lindblom @Flickr

After finishing his education, Delfyett joined the technical staff at Bell Laboratories where he developed the world's fastest semiconductor diode laser. He also invented a clocking network for high speed digital switches, which is like a computer that connects digitally encoded messages in the telephone network allowing for multiple users to communicate. In 1993, Delfyett was hired by the University of Central Florida's School of Optics in the Center for Research and Education in Optics and Lasers (CREOL). He rose to the position of professor of optics and is also a trustee chair. His research interests include signal processing and optics among others. Delfyett developed an optical communication link that can produce twenty independent wavelength channels. His development also allows for super fast analog to digital conversion. Throughout his career, Delfyett published over 200 scientific research articles and has been awarded twelve patents. In addition to his research and development, Delfyett also serves the physics community. He is a board member of the Orlando Science Center and a member of the Bellcore Teacher's Institute where he teaches proper science instruction methods for children. He also serves as an editor for two scientific journals by the Institute of Electrical and Electronics Engineers (IEEE). Peter Delfyett lives with his wife in Geneva, Florida.

Above Picture of Peter Delfyett from www.creol.ucf.edu/People/Details.aspx?PeopleID=296

SCIENCE IN ACTION

WHAT IS A DIODE?



CD drive
by aussigall @Flickr

When you are working on a science project at your computer, you are using more diodes than you know. The CD-ROM drive needs a diode to read the CD that you put in it, the music CD player requires a diode, and the laser printer that you use to print your report requires a diode. So what is a diode? It basically serves as a one-way street for electricity, only allowing the current to flow in one direction. Peter Delfyett helped to develop a superfast semiconductor laser diode, which generates optical pulses, or pulses of light instead of electricity. This faster signal makes electronic devices work more efficiently.

DISCUSSION QUESTIONS

1. If you were to interview Peter Delfyett, what questions would you ask him?
2. Check out the Science for Kids website (http://www.pbs.org/transistor/science/info/diodes.html). Why is it important that diodes only let electricity flow one way?
3. Peter Delfyett studies electronics. What kinds of electronics that utilize diodes do you use on a day to day basis?
4. Digital signals represent a technological improvement over analog signals. Why is it important for the U.S. to stay on top of technological advances?
5. How does Peter Delfyett's career compare to that of other engineers in the Toolkit?

GLOSSARY

Analog - Relating to or using signals or information represented by a continuously variable physical quantity such as spatial position or voltage

Bell Laboratories - The research and development organization of Alcatel-Lucent and previously of the American Telephone & Telegraph Company (AT&T); also known as Bell Labs and formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories

Diode - A device in electronics with two terminals, typically allowing the flow of electricity in one direction only

Electrical Engineering - The design, construction, and maintenance of products for electrical and electronic equipment and computer systems

Optics - The branch of physics that involves the behavior and properties of light

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Semiconductor Diode Laser - A device that produces radiation energy when electrical current passes through it

Signal Processing - The transmission of information; can be in the form of a digital signal

ScienceMakers Spotlight

Clarence Elder

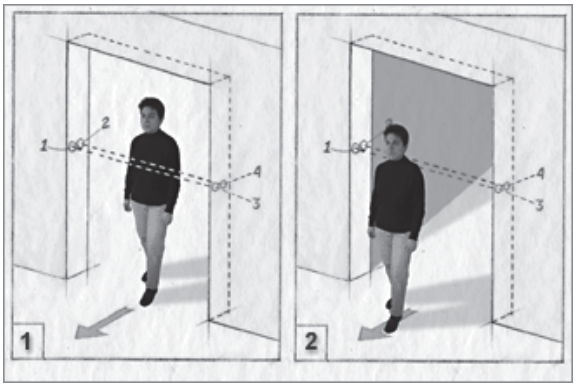
Engineer & Inventor

Birth Year	1935
Birth Place	Georgia
Education	Morgan State College (B.S. 1956)
Awards & Achievements	New York International Patent Exhibition Outstanding Achievement in Electronics Award (1969)

BIOGRAPHY

Clarence Elder is an engineer and inventor known for developing a system to reduce energy use in homes. Elder was born in 1935 in Georgia. After graduating from high school, Elder attended Morgan State College (now Morgan State University) where he graduated with his B.S. degree in 1956.

Elder is credited with many patents including his 1971 Sweepstake Programmer. This invention is a coin operated game apparatus in which the player tries to match graphics or numbers that are selected by a chance mechanism. After inserting a token into the machine, the player has a chance to try and match one or two additional graphics or numbers with the original. In 1973, Elder received a patent for his Random Unit Generator Amusement Device, which is also a game. In that case, the player observes a series of quickly moving graphics or numbers and has to stop the machine so that a certain design is displayed. The objective is to match the machine's random selections to pre-selected choices by the player. Elder's most significant patent came in 1976 for the "Occustat." The occustat is an energy monitoring control system for rooms. The system was created to reduce the energy use of homes. It works by aiming a beam of light across entrances to buildings and rooms to see if anyone enters. When the building or room is empty, controls for light, heat, or cooling are reduced. The “Occustat" was shown to lower energy use by 30%. It became widely used in office buildings, schools, and hotels around the world. Elder also founded the research and development firm Elder Systems, Incorporated, located in Baltimore, Maryland. Throughout his career, Elder received twelve U.S. and foreign patents for his inventions in the field of electronics. Clarence Elder lives in Baltimore, Maryland.



Occustat
by http://web.mit.edu/invent/iow/elder.html

Above Picture of Clarence Elder from www.onmy.com/haynie/new_page_12.htm

THE ORIGINAL GREEN REVOLUTION

Energy Saving Lightbulb
by Muffet @Flickr

Did you know that inventors, engineers, and scientists are constantly working to help our environment? They create improved technology that produces less waste and reduces energy use by humans. Some examples include compact fluorescent light bulbs (the curly ones), low flow toilets (the kind with two flush buttons), and hybrid cars, which use a combination of gasoline and electricity. Clarence Elder's "Occustat" invention represents an early success in reducing human energy use. The green revolution has become a widespread movement to save our environment. You can do things like turn off lights when you leave a room or leave the bathroom faucet off while you are brushing your teeth.

DISCUSSION QUESTIONS

1. If you were to interview Clarence Elder, what questions would you ask him?
2. Check out the Energy Quest website (http://www.energyquest.ca.gov/saving_energy/index.html). What are three ways that you can save energy around your house?
3. Clarence Elder's "Occustat" works because a light beam detects people entering or leaving a room. What other technology can you think of that uses sensors to detect something?
4. Coal is a fossil fuel, or a non-renewable energy source. Hydropower, or waterpower, is a renewable energy source. Can you name some other renewable and non-renewable energy sources?
5. How does Clarence Elder's career compare to that of other engineers in the Toolkit?

GLOSSARY

Fluorescent Light Bulb - Uses 20-40% less electricity than a regular light bulb and can last up to twenty times longer

Low-Flow Toilet - A toilet that is designed to use less water than a regular toilet; uses 1.6 gallons instead of 3.6 gallons

Occustat - An energy monitoring system which reduces energy use in rooms that are unoccupied

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

ScienceMakers Spotlight

Essex Finney

Agricultural Engineer & Administrator

Birth Date	May 16, 1937
Birth Place	Powhatan County, Virginia
Education	Virginia Polytechnic Institute (B.S. 1959)
	Pennsylvania State University (M.S. 1960)
	Michigan State University (Ph.D. 1963)
Awards & Achievements	Penn State University Outstanding Engineering Alumnus Award (1985)
	American Society of Agricultural Engineers Fellow

BIOGRAPHY

Essex Finney was an outstanding leader in the U.S. Department of Agriculture (USDA), and he served as a science consultant to Presidents Jimmy Carter and Ronald Reagan. Finney was born in Powhatan County, Virginia on May 16, 1937. As a child, he worked on his family farm growing tobacco, wheat, corn, and hay as well as raising cattle, pigs, chickens, and horses. Finney became interested in agricultural engineering when his family acquired a tractor. After graduating from Pocahontas High School in 1954, he earned his B.S. degree in 1959 from Virginia Polytechnic Institute. Finney went on to earn his M.S. degree in 1960 from Pennsylvania State University, and in 1963, he was the first African American to receive his Ph.D. degree from the Department of Agricultural Engineering at Michigan State University. Between 1963 and 1965, Finney served as an officer in the U.S. Military.

Tractor
by Pamelainob @Flickr

In 1965, Finney accepted a position with the USDA's Beltsville Agricultural Research Center (BARC) in the instrumentation research laboratory. He worked on methods to sort agricultural products and measure their quality. Finney was appointed assistant director of the center in 1977 and became director in 1989. For one year in this period, Finney served as associate director of the Agricultural Research Service (ARS) twelve-state North Atlantic Area. In addition, from 1980 to 1981, he was a senior policy analyst in the Office of the Science Advisor to the President. Finney went to work at the USDA Headquarters in Washington, D.C. in 1992 where he served as the associate administrator for the ARS. Finney then worked with the USDA until his retirement in 1995. In addition to his administrative duties, Finney also conducted research. His early research included investigating methods of drying cereal grains like wheat, rice, and barley, and his later research focused on techniques and instruments that measure food quality. Essex Finney lives in Maryland.

Above Picture of Essex Finney from www.vtmagazine.vt.edu/fall97/feature1.html

SCIENCE IN ACTION

WHERE DOES OUR FOOD COME FROM?

Vegetables
by David ... @Flickr

When you go to the grocery store, you may buy a box of rice or a half dozen tomatoes from a big bin, but did you ever wonder where that food comes from? The U.S. Department of Agriculture is a government organization that helps farm products get from the farms to our grocery store shelves. They also help farmers develop the best ways to grow food and raise animals. At one point in his career, Essex Finney did research on cereal grain drying, which prevents the build-up of insects, mites, mold, and fungi. It allows the grains to be stored for longer periods of time before spoilage occurs.

DISCUSSION QUESTIONS

1. If you were to interview Essex Finney, what questions would you ask him?
2. Check out the USDA website (www.usda.gov/). What did you discover about healthy eating?
3. Corn and wheat are two common agricultural products grown in the U.S. that are refined and used in many different products. Name ten products that are from refined from either corn or wheat. (Check the boxes on the food you eat, be creative!)
4. Farming is a very difficult job. Why is it important to have an organization like the U.S. Department of Agriculture?
5. How does Essex Finney's Career compare to that of other engineers in the Toolkit?

GLOSSARY

Agricultural Engineering - A branch of engineering that focuses on developing technologies to improve agricultural productivity and create renewable energy sources and sustainable products

Consultant - Someone who gives professional advice

Jimmy Carter (1924 -) - The 39th President of the United States (1977–1981); Recipient of the Nobel Peace Prize in 2002

Ronald Reagan (1911 - 2004) - The 40th President of the United States (1981–1989); 33rd Governor of California (1967–1975)

U.S. Department of Agriculture (USDA) - A U.S. Government agency that researches and oversees food production, farming, and natural resources

ScienceMakers Spotlight

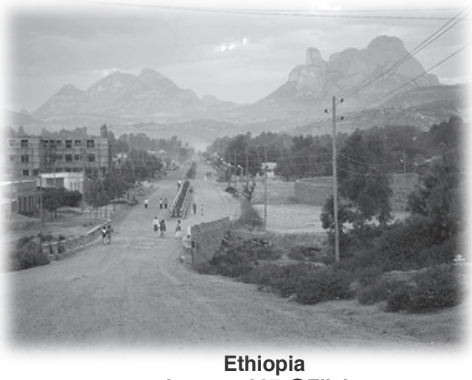
Sossina Haile

Chemical Engineer & Materials Scientist

Birth Date	July 28, 1966
Birth Place	Addis Ababa, Ethiopia, East Africa
Education	Massachusetts Institute of Technology (B.S. 1986, Ph.D. 1992)
	University of California, Berkeley (M.S. 1988)
Awards & Achievements	National Science Foundation National Young Investigator Award (1994-1999)
	Newsweek Magazine's "12 people to watch" (2008)
	American Institute of Chemists' Chemical Pioneer Award (2010)

BIOGRAPHY

Sossina Haile is a pioneer in the field of fuel cells. Her research could lead to a more efficient and inexpensive energy source that would help meet the world's growing energy needs. Haile is no stranger to being a trailblazer. She was born on July 28, 1966 in Addis Ababa, Ethiopia in East Africa, but her family left during an uprising in 1976. After graduating high school, Haile attended Massachusetts Institute of Technology (MIT) where she received her B.S. degree in materials science and engineering in 1986. She went on to receive her M.S. degree from the University of California, Berkeley in 1988 and her Ph.D. degree from MIT in 1992. A Fulbright Fellowship along with a Humboldt Fellowship allowed her to study at the Max Planck Institute in Germany.



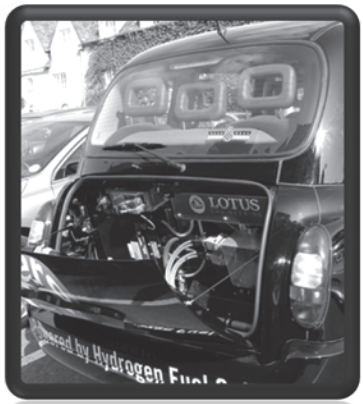
Ethiopia
by pogo667 @Flickr

In 1993, Haile became assistant professor of materials science and engineering at the University of Washington, Seattle. She joined the faculty at the California Institute of Technology in 1996. Her research group investigates ionic conduction, or the flow of charged particles in solid materials, which can be used to make batteries and fuel cells. In the 1990s, Haile fabricated the first solid-acid fuel cell in her lab, regarded as a gateway to more powerful, commercial cells. In comparison to other fuel cells, Haile's process is unique for its creation of efficient yet inexpensive energy. In 2003, two of her former graduate students created Superprotonic, a company that develops fuel cell technology, with Haile as their advisor. Throughout her career, Haile has received recognition for her work with fuel cells and for developing new ways of using solar energy to make fuels like hydrogen and methane. Haile has also worked on the process of water splitting and has published over 120 research papers. Sossina Haile lives with her two sons in southern California.

Above Picture of Sossina Haile from http://addis.caltech.edu/

SCIENCE IN ACTION

FUEL CELLS AS CLEAN ENERGY



Fuel Cell Taxi
by The Ewan@Flickr

Sossina Haile is a trailblazer in the development of fuels cells. Fuel cells are a super clean energy source, meaning they create very little pollution. They use chemical energy as their energy source like a combustion engine in a car. A combustion engine can be messy and inefficient, but a fuel cell is not. This is because a fuel cell converts chemical energy directly into electrical energy like a battery. Therefore, a fuel cell is a highly efficient, low emission energy source. It will be an important clean energy resource in the future, and maybe someday you will drive a fuel cell car like the one seen here!

DISCUSSION QUESTIONS

1. If you were to interview Sossina Haile, what questions would you ask her?
2. Check out the Toyota Kids website (http://www.toyota.co.jp/en/kids/eco/fchv.html). Why are they making cars with fuel cells?
3. How does car exhaust contribute to pollution problems?
4. What can you do in your daily life to help protect the environment?
5. How does Sossina Haile's career compare to that of other engineers in the Toolkit?

GLOSSARY

Chemical Energy - Energy released from a substance, or absorbed in the formation of a chemical compound during a chemical reaction

Combustion Engine - An engine that works when a mixture of gasoline and air is compressed to ignite a spark and create heat energy

Fuel Cell - A cell producing an electric current directly from a chemical reaction

Ionic Conduction - Electrical conduction of a solid due to the displacement of ions within the crystal structure

Materials Science - The study and development of new types of metals, composites, and plastics

Solid-acid - A solid that is a cross between a salt and an acid

Superprotonic - An energy technology company established to market and commercialize the innovative solid acid fuel cell (SAFC)

Water splitting - The general term for a chemical reaction in which water is separated into oxygen and hydrogen

ScienceMakers Spotlight

Joycelyn Harrison

Aerospace Engineer & Inventor

Birth Year	1964
Education	Spelman College (B.A. 1987)
	Georgia Institute of Technology (B.S. 1987, M.S. 1989, Ph.D. 1993)
Awards & Achievements	NASA Exceptional Achievement Medal (2000)
	NASA Outstanding Leadership Medal (2006)
	H.J.E. Reid Award for Most Outstanding Langley Research Center Technical Publication (2010)

BIOGRAPHY

Joycelyn Harrison has a number of patents under her name for materials that can be used in the aerospace industry. Harrison was born in 1964 and after graduating from high school, she decided to attend Spelman College where she received her B.S. degree in chemistry in 1987. She then went on later that year to earn her second B.S. degree in chemical engineering from the Georgia Institute of Technology. Harrison remained at Georgia Tech as a graduate student and completed her M.S. and Ph.D. degrees in chemical engineering in 1989 and 1993, respectively.

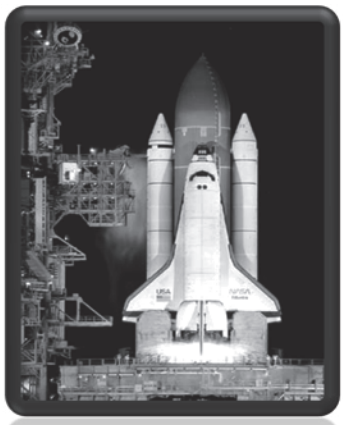
Satellite
by NASA Goddard@Flickr

In 1994, Harrison worked at the Advanced Materials and Processing Branch (AMPB) of the National Aeronautics and Space Administration (NASA) Langley Research Center in Hampton, Virginia. While at Langley, Harrison researched piezoelectric materials, a class of polymers that can become deformed when exposed to an electric current and conversely, they can generate an electric current when they become deformed due to an outside force. These materials have been used in car air bag sensors, computer disk drives, and electric guitars. Harrison also participated on the Thin-Layer Composite-Unimorph Piezoelectric Driver and Sensor (THUNDER) project. The THUNDER team worked to improve the durability, energy efficiency, and production costs of piezoelectric materials. In 1999, Harrison became chief of AMPB, which required her to supervise more than forty research scientists who were studying materials development. Harrison's personal achievements include a number of patents for piezoelectric substrates that she invented between 1999 and 2008. Her inventions have applications both in the aerospace industry for the repair of satellites and the commercial sector for improvements in devices, such as robots, heart pumps, and audio speakers. In 2009, Harrison became the manager of the Low Density Materials Program at the Air Force Office of Scientific Research where she developed lighter and stronger materials for aircraft. Joycelyn Harrison lives in Arlington, Virginia.

Above Picture of Joycelyn Harrison from prince.org/msg/105/261625

SCIENCE IN ACTION

SPACE VEHICLES



Space Shuttle
by cosmobc@Flickr

NASA scientists like Joycelyn Harrison are always looking for ways to make their spacecraft lighter and stronger. This involves using new and innovative materials such as carbon nanotubes. A carbon nanotube consists of a very thin sheet of carbon atoms that are arranged in a tight honeycomb structure. The sheet is then rolled up into a hollow tube. Harrison seeks new arrangements of nanotubes in three dimensional structures which will produce lower density materials for use in the aerospace industry. The more efficient space travel becomes, the more likely it would be to send the average citizen on a vacation to the moon.

DISCUSSION QUESTIONS

1. If you were to interview Joycelyn Harrison, what questions would you ask her?
2. Check out the NASA Langley website (http://www.nasa.gov/centers/langley/home/index.html). What types of projects do you find most interesting?
3. If efficient aerospace materials ever allow for vacation space travel, where would you go and why?
4. Why is it important to use light and strong materials when constructing spacecraft? What conditions do you think spacecraft materials must be able to withstand?
5. How does Joycelyn Harrison's career compare to that of other engineers in the Toolkit?

GLOSSARY

Aerospace Industry - All companies or individuals involved in the design, construction, and science of aircraft and spacecraft

Carbon Nanotube - A small hollow tube made from a one-atom-thick flat sheet of densely packed carbon atoms; used in the construction of electronic devices

Chemical Engineering - The transformation of raw materials into substances that are useful to humans, such as petroleum refined into gasoline or kerosene

Langley Research Center - The oldest of NASA's field centers, located in Hampton, Virginia

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using or selling the claimed invention

Piezoelectric Materials - A substance that can produce mechanical motion when exposed to an electric current and generate an electric charge when subjected to stress

Polymers - Any of numerous natural and synthetic compounds consisting of up to millions of repeated linked units, each a relatively light and simple molecule

ScienceMakers Spotlight

Ayanna Howard

Electrical Engineer & Robotics Expert

Birth Date	January 24, 1972
Birth Place	Providence, Rhode Island
Education	Brown University (B.S. 1993)
	University of Southern California (M.S. 1994, B.S. 1999)
	Claremont Graduate University (M.B.A. 2005)
Awards & Achievements	Jet Propulsion Laboratory's Lew Allen Award for Excellence in Research (2001)
	Institute of Electrical and Electronic Engineers Early Career Award in Robotics and Automation (2005)
	National Society of Black Engineers Janice Lampkin Educator Award (2009)

BIOGRAPHY

Ayanna Howard grew up watching the 'Bionic Woman' television show knowing she wanted to be a robotics engineer. Howard was born on January 24, 1972 in Providence, Rhode Island. After graduating from John Muir High School in Pasadena, California, Howard earned her B.S. degree in engineering from Brown University in 1993. She continued her studies and received her M.S. and Ph.D. degrees in engineering from the University of Southern California in 1994 and 1999, respectively.

Playing With Robots

Throughout her education at the University of Southern California, Howard worked at the National Aeronautics and Space Administration (NASA)'s Jet Propulsion Laboratory in Pasadena, California where she helped design the Mars Rover. She held a number of positions working with the organization until 2005, including computer scientist, information systems engineer, robotics researcher, and senior robotics researcher. Howard continued her education at Claremont Graduate University earning her M.B.A. degree in 2005. That same year, Howard was offered a position at the Georgia Institute of Technology, where she started her own laboratory while working as an associate professor in the School of Electrical and Computer Engineering. Her research group, the Human-Automation Systems (HumAnS) Lab, focused on how to enhance the autonomy of robots, or make them more human-like, by giving them perception and reasoning abilities. Howard's work in robotics and engineering has earned her considerable attention. In 2008, her SnoMote robots were internationally recognized for their ability to study the impact of climate change in such remote areas as the Antarctic ice shelves. Her lab also worked on intelligent robots for assistive healthcare and therapy. Throughout her career, Howard has published over 100 academic papers. Ayanna Howard is married to Jose Torres. She has one son and two stepsons.

SCIENCE IN ACTION

ROBOTS AND CLIMATE CHANGE

Ayanna Howard With SnoMotes

Want to know what the weather is like today? Ask a robot! The SnoMote is a remote-controlled snowmobile that can navigate itself around ice and snow. The SnoMote was funded by NASA to help scientists collect data in the Artic, one of the world's most extreme environments. The robots work as a team monitoring an area. They have sensors to navigate the terrain autonomously, or without human guidance while measuring humidity, temperature, and wind speed. The plan is to deploy a team of forty SnoMotes (each costing $10,000) to collect data about climate change models. This data can be used to predict the weather as well as the speed at which the polar ice caps and ice shelves are melting.

IN HER OWN WORDS

Ayanna Howard spoke at The Detroit Science Center for a program with The HistoryMakers on February 17, 2011. A student asked her, "What are important qualities of an engineer?" Here is Ayanna Howard's answer:

"One quality that is very important is passion. As a scientist, you need to have passion for what you're doing because not everything works all the time. And so if you don't have passion typically you might say it didn't work...maybe I'm not meant for this. And so having a passion and a desire to keep moving forward is really key number one. And of course, you have to like math and science."

DISCUSSION QUESTIONS

1. If you were to interview Ayanna Howard, what questions would you ask her?
2. Check out Carnegie Mellon's Robotics Academy website (http://www.education.rec.ri.cmu.edu/content/educators/index.htm). What kind of robot would design? Why?
3. Check out the Mars Rover website (http://marsrover.nasa.gov/). What kind of data are the scientists collecting from Mars?
4. Do you think it is a good idea to have completely autonomous robots who think for themselves without human input? Why or why not?
5. How does Ayanna Howard's career compare to that of other engineers in the Toolkit?

GLOSSARY

Autonomy - Independence or independent thought, such as a robot thinking for itself without human input

Climate Change - A long-term change in the earth's climate, especially a change due to an increase in the average atmospheric temperature

Human-Automation Systems (HumAnS) Lab - A research laboratory at the Georgia Institute of Technology that researches and develops technology to mimic human intelligence in robots

Mars Rover - Any of a number of small unmanned remote-controlled vehicles sent to the planet Mars to do scientific research

NASA's Jet Propulsion Laboratory - The leading U.S. center for robotic exploration of the solar system; conducts major programs in space-based Earth sciences and astronomy

SnoMote - Robots that can intelligently work together to navigate around ice and snow by classifying microscopic fissures in the icy terrain

ScienceMakers Spotlight

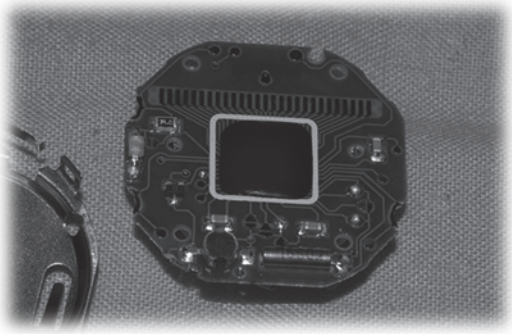
Barry Johnson

Metallurgical Engineer & Materials Scientist

Birth Year	1943
Education	Villanova University (B.M.E.)
	Carnegie Mellon University (M.S., Ph.D. 1970**)**
	Arizona State College
Awards & Achievements	National Black Engineer of the Year Award for Professional Achievement (1994)
	Germany's Fraunhofer Society Member (1999)
	J. Stanley Morehouse Memorial Award (2000)

BIOGRAPHY

Barry Johnson has been on the forefront of semiconductor development. Johnson was born in 1943 and raised in Philadelphia, Pennsylvania. After graduating from high school, he went on to receive his B.M.E. degree from Villanova University. He earned advanced degrees in metallurgical engineering and materials science from Carnegie Mellon University, his M.S. degree and his Ph.D. degree in 1970. Johnson also obtained his degree in advanced business administration from Arizona State College.



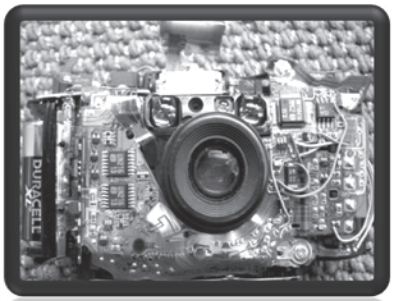
Circuitry of a Motorola Watch by Gray Marchiori-Simpson@Flickr

Johnson has had a long career in research, development, and education. Johnson then joined Motorola in 1976. By 1982, he was the director of technology and planning for the electronic materials division of Motorola Semiconductors Products, Inc. In 1984, Johnson left to join the faculty at the University of Arizona as a professor of electrical and computer engineering. After four years, Johnson returned to work in industry as the senior research fellow in the super-conductivity center at E.I. Dupont de Nemours & Co. In 1994, Johnson joined Motorola, Inc. as vice president and director of Core Technologies. His research and development interests included semiconductors and circuit systems in electronic devices. In 2000, Johnson became the senior vice president and chief technology officer of Honeywell International, Inc. Two years later, he returned to his alma mater, Villanova University, as dean of the Department of Engineering. He retired from the position in 2006. Johnson began serving on the board of directors for Rockwell Automation in 2005, a company that develops technology for industrial automation. Throughout his career, Johnson was awarded several patents, mostly pertaining to his work in electronics engineering. Johnson has also contributed many scientific articles and received many awards for his research, innovation, and teaching. Barry Johnson lives in Pennsylvania.

Above Picture of Barry Johnson from www.rockwellautomation.com

SCIENCE IN ACTION

SEMICONDUCTORS IN EVERDAY LIFE



Circuitry of an Olympus Camera
by jurvetson@Flickr

Every substance in the world can be categorized by how well it conducts electricity. Materials like glass and plastic cannot carry an electrical current and are called insulators. Materials that hold electrical charge readily like copper are called conductors. Substances that can carry a current, but not as readily as conductors are called semiconductors. Semiconductors like silicon can be used as switches to control the amount of electricity flowing through a current. They can be used to perform calculations and are the foundation of every device with a computer chip. Engineers like Barry Johnson are constantly developing semiconductor technology to make electronic devices smaller and faster.

DISCUSSION QUESTIONS

1. If you were to interview Barry Johnson, what questions would you ask him?
2. Check out the NDT Resource website (www.ndt-ed.org/EducationResources/HighSchool/Electricity/hs_elec_index.htm). Give one example of both a conductor and insulator that are not listed above.
3. Metallurgy is the study of metals such as iron and copper. Can you think of other metals?
4. Name three electronics that you use every day that have semiconductors. What role do they play in your life?
5. How does Barry Johnson's career compare to that of other engineers in the Toolkit?

GLOSSARY

Alma Mater - The institution or school from which a person graduated

Circuit - A device that acts as a pathway for electrical current to flow

Honeywell International, Inc. - A Fortune 100 company that manufactures technology for safety, security, and energy needs

Industrial Automation - The use of computer and electronic technology to manufacture goods, reducing the need for human input

Materials Science - The study and development of new types of metals, composites, and plastics

Metallurgical Engineering - The branch of engineering that involves the manipulation and study of metals such as iron or copper

Motorola - An American telecommunications, data communications, and technology company

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using or selling the claimed invention

Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

ScienceMakers Spotlight

James Johnson

Environmental & Civil Engineer

Birth Date	May 27, 1947
Birth Place	Annapolis, Maryland
Education	Howard University (B.S. 1969)
	University of Illinois (M.S. 1970)
	University of Delaware (Ph.D. 1982)
Awards & Achivements	A Tribute to Women of Color's Men of Courage Award (1999)
	Water Environment Federation Gordon Maskew Fair Distinguished Educator Award (2008)
	National Society of Black Engineers, D.C. Chapter Lifetime Achievement Award (2009)

BIOGRAPHY

James Johnson is an environmental engineer who has dedicated his life to the treatment and disposal of hazardous waste. Born on May 27, 1947 in Annapolis, Maryland, Johnson earned his B.S. degree in civil engineering from Howard University. He received his M.S. degree in sanitary engineering in 1970 from the University of Illinois and earned his Ph.D. degree in civil and environmental engineering in 1982 from the University of Delaware.

Litter on a Beach
by epSos.de@ Flickr

After completing his graduate studies, Johnson began working as chair of the Department of Civil Engineering at his alma mater, Howard University. He taught undergraduate and graduate courses in environmental engineering including hazardous waste management, treatment, and disposal. He also studied the effect of humic acids, contaminated soil, and explosive waste. From 1989 to 2002, Johnson served as associate director of the Great Lakes and Mid-Atlantic Hazardous Substance Research Center. In 1996, Johnson was named dean of Howard University's College of Engineering, Architecture, and Computer Sciences, he became the Samuel P. Massie Professor of Civil Engineering in 2005, and in 2009, he became a professor emeritus of civil engineering. He was appointed chair of the National Advisory Council for Environmental Policy and Technology (NACEPT) by the U.S. Environmental Protection Agency (EPA) in 2010. Johnson was the first African American to chair this independent committee for the Agency. He also served as chair of the U.S. EPA's Board of Scientific Counselors. Johnson has published over sixty academic papers and co-edited two books including one on hazardous waste. James Johnson works in Washington, D.C.

Above Picture of James Johnson from cresp.org

SCIENCE IN ACTION

HUMIC ACID AT WORK BENEATH YOUR FEET

Plants Growing in Rich Soil
by Magic Madzik @Flickr

You step on humic acid every day. It is a primary component of soil. Humic acid is also found in streams and ocean water. James Johnson researches the structure of humic acid to understand how it interacts with other molecules. Humic acid is produced by the decomposition of organic material by bacteria. Humic acid and fulvic acid (a type of humic acid) are used in agriculture to improve soil quality and increase plant growth. They are also used as a nutritional supplement for humans. Fulvic acid and humic acid make up 30-50% of the dissolved organic material in water systems.

DISCUSSION QUESTIONS

1. If you were to interview James Johnson, what questions would you ask him?
2. Check out the EPA website (http://www.epa.gov/osw/hazard/). What are some examples of hazardous waste? How are they disposed?
3. Humic acid is a component of soil. Collect three soil samples, at your school, your home, and your local park. How are they different, and why?
4. With technology and industry advancing every day, why is it important to develop methods of waste control?
5. How does James Johnson's career compare to that of other engineers in the Toolkit?

GLOSSARY

Alma Mater - The institution or school from which a person graduated

Civil Engineering - The design and construction of our nation's infrastructure including bridges, buildings, highways, dams, canals, and locks

Environmental Engineering - The application of scientific and engineering principals to improve our natural world

Explosive Waste - Material that is chemically or energetically unstable, and at any moment, can cause the release of heat or a change in pressure, leading to an explosion

Humic Acid - A dark brown substance that is the primary component of soil; produced when soil bacteria decompose dead organic matter like dried leaves and fallen tree branches

Sanitary Engineering - The application of engineering methods to improve human community sanitation systems through the removal and disposal of human waste and supply of safe water

U.S. Environmental Protection Agency (USEPA) - A U.S. Government agency whose goal is to monitor and safeguard human health and our natural surroundings

ScienceMakers Spotlight

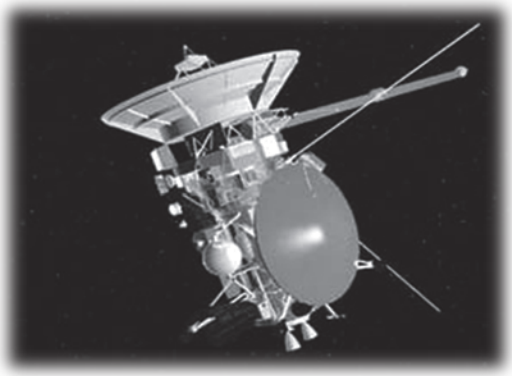
Lonnie Johnson

Engineer & Inventor

Birth Date	October 6, 1949
Birth Place	Mobile, Alabama
Education	Tuskegee University (B.S. 1973, M.S. 1975)
Awards & Achievements	Air Force Commendation Medal
	Inducted into the Inventor Hall of Fame (2000)
	Popular Mechanics Top 10 New World-Changing Inventions of the Year (2010)

BIOGRAPHY

Lonnie Johnson is not only the inventor of the world's most powerful and popular water gun, the Super Soaker; he has also developed technology for spacecraft and solar cells. Johnson was born on October 6, 1949 in Mobile, Alabama. He loved to invent things as a child like his own go-kart powered by a lawn mower motor. In high school, Johnson won first place at a regional science competition with a robot made from junkyard scraps. He entered Tuskegee University on a mathematics scholarship and received his B.S. degree in mechanical engineering in 1973 and his M.S. degree in nuclear engineering in 1975.



Artist's Drawing of the Cassini Probe by Cornell SPIF@Flickr

Following graduation, Johnson joined the United States Air Force where he worked for the Air Force Weapons Laboratory in New Mexico. In 1973, he joined NASA's Jet Propulsion Laboratory as a senior systems analyst where he worked on the Galileo Mission to Jupiter. Johnson returned to the military in 1982 to work at the Strategic Air Command Facility in Nebraska and on Edwards Air Force Base in California. In 1987, he returned to the Jet Propulsion Laboratory where he worked on the Mars Observer Project and the Cassini robot probe that flew to Saturn. Johnson started his own engineering firm in 1989, which licensed the Super Soaker invention. The idea for the Super Soaker came to Johnson in 1982 when he was tinkering in his home trying to create an environmentally friendly heat pump. In 1991, the Super Soaker generated over $200 million in profits. Johnson has over 100 patents in his name. Johnson also started two companies focused on innovative energy technology. Excellatron Solid State, LLC develops new technology for rechargeable batteries and Johnson Electro-Mechanical Systems (JEMS) developed a new type of solar cell, which has received national acclaim. Lonnie Johnson lives and works in Atlanta, Georgia.

Above Picture of Lonnie Johnson from www.black-inventor.com/Lonnie-G-Johnson.asp

SCIENCE IN ACTION

ENERGY FROM THE SUN

Johnson With JTEC
by www.greenlaunches.com/

The Sun is an almost endless source of energy that with the right technology can be converted into electricity to power the planet. The Johnson-Thermal Electrochemical Convertor System (JTEC) is a generator with no moving parts. JTEC creates pressure gradients just like a generator. Instead of that pressure powering a wheel, JTEC forces ions through a thin wall to generate electricity from heat. The unit is started by a jolt of electricity, causing hydrogen to circulate between two fuel cell assemblies. One assembly is heated by the sun and one assembly lets the heat out into the air. This process produces an electrical current and thus, a renewable energy source!

DISCUSSION QUESTIONS

1. If you were to interview Lonnie Johnson, what questions would you ask him?
2. Check out Invent Now Website (http://www.inventnow.org/). What would you invent?
3. Solar panels, like the Johnson-Thermal Electrochemical Convertor System, are a renewable energy source. Can you name other renewable or non-renewable energy sources?
4. Why is renewable energy important for our future?
5. How does Lonnie Johnson's career compare to that of other engineers in the Toolkit?

GLOSSARY

Cassini Robot Probe - A satellite that was sent to Saturn to gather information about the planet

Fuel Cell - A device that produces an electric current directly from a chemical reaction

Galileo Mission to Jupiter - An initiative that sent two spacecraft to Jupiter in order to learn more about its atmosphere and moons

Generator - An instrument that converts mechanical energy into electricity

Ion - An atom or a molecule that has either a positive or negative charge due to the loss or gain of an electron

Mars Observer Project - An initiative that sent a spacecraft to Mars, to collect high-resolution images of the planet

NASA's Jet Propulsion Laboratory - A federally funded research and development center whose primary focus is the scientific study of the solar system, including exploration of the planets with satellites or robots

United States Air Force - A branch of the U.S. Military whose goal is to defend the country by mastering air and space

ScienceMakers Spotlight

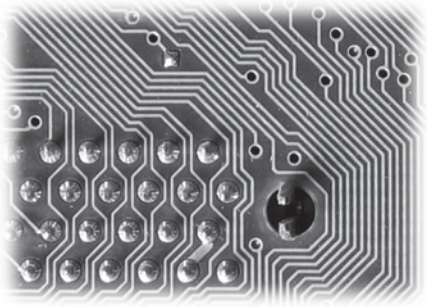
Gary May

Electrical & Computer Engineer

Birth Date	May 17, 1964
Birth Place	St. Louis, Missouri
Education	Georgia Institute of Technology (B.S. 1985)
	University of California, Berkeley (M.S. 1987, Ph.D. 1991)
Awards & Achievements	National Commission for Co-Op Educator Hall of Fame (2007)
	American Association for the Advancement of Science Fellow (2009)
	Outstanding Alumni Award from University of California, Berkley (2010)

BIOGRAPHY

Gary May is the dean of engineering at the Georgia Institute of Technology where he provides leadership to over 400 faculty and 12,000 students. He also finds time to pursue his research in integrated circuits. May was born on May 17, 1964 in St. Louis, Missouri. In high school, he developed his passion for engineering while attending the Develop Engineering Students summer program. May attended the Georgia Institute of Technology where he received his B.S. degree in electrical engineering in 1985. During college, he worked in software development and aerospace mechanics for McDonnell-Douglas Corporation. May received his M.S. degree and his Ph.D. degree in electrical engineering and computer science from the University of California, Berkeley in 1987 and 1991, respectively.

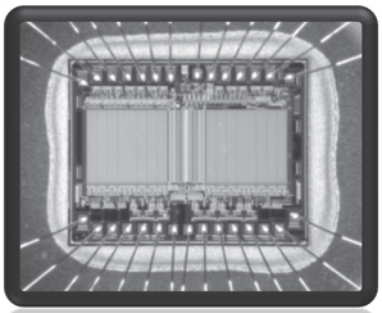


Circuit Board
by guapan @Flickr

In 1991, May returned to Georgia Tech as an assistant professor of electrical and computer engineering, beginning his long career as an educator, researcher and administrator. In 2000, May became a full professor and two years later, he became executive assistant to the president of Georgia Tech where his duties included serving as a liaison between Georgia Tech administration and faculty. In 2005, May was appointed the Steve W. Chaddick School Chair of the School of Electrical and Computer Engineering, and in 2011, he was promoted to dean of the College of Engineering. May's research involves integrated circuits, which are used in artificial intelligence and machine sensors. May founded the Summer Undergraduate Research in Engineering/Science (SURE) program with a grant from the National Science Foundation (NSF). May is also the creator and director of Facilitating Academic Careers in Engineering and Science (FACES) which utilized a $10 million grant from NSF to double the number of African American Ph.D. students at Georgia Tech. He has authored over 200 papers and has given numerous presentations in the area of integrated circuit computer manufacturing. Gary May works in Atlanta, Georgia.

SCIENCE IN ACTION

INTEGRATED CIRCUITS: THE HEART OF THE FUTURE



Integrated Circuit
by pasukaru76 @Flickr

The first computers built in the 1940s were the size of a small room and could only solve certain types of math problems. Now, computers can fit in the palm of your hand and run large complicated programs. This is made possible by semiconductor integrated circuits which are the heart of the multi-trillion dollar electronics industry. An integrated circuit is a miniaturized electrical circuit with transistors and wires all on one tiny square silicon chip. The chip is built up in layers. Each layer has a particular pattern on top of silicon and then alternating different masks of silicon. One chip the size of a centimeter can hold millions of transistors. Companies can now make millions of integrated chips in a few seconds.

DISCUSSION QUESTIONS

1. If you were to interview Gary May, what questions would you ask him?
2. Check out the How Stuff Works website (http://www.howstuffworks.com/diode.htm) to learn about semiconductors. Name one new thing that you learned.
3. There is a Silicon Valley, California; Silicon Valley, India; and a Silicon Border, Mexico. Why do these locations have similar names? What do they produce there?
4. Gary May has developed integrated circuit technology that is found in computers and many electronics. How have integrated circuits changed our society from the 1980s to today?
5. How does Gary May's career compare to that of other engineers in the Toolkit?

GLOSSARY

Artificial Intelligence - The theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages

Electrical Engineering - The design, construction, and maintenance of products primarily for electrical and electronic equipment and computer systems

Integrated Circuit - A miniaturized electrical circuit

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

Silicon Chip - Electronic equipment consisting of a small crystal of a silicon semiconductor constructed to carry out a number of electronic functions in an integrated circuit

Software - The programs and other operating information used by a computer, such as Microsoft Office

Transistor - A small electronic instrument containing a semiconductor and having at least three connections to external circuits; used as a building block in electronic devices

ScienceMakers Spotlight

James Mitchell

Chemical Engineer & Materials Scientist

Birth Date	November 16, 1943
Birth Place	Durham, North Carolina
Education	North Carolina A&T State University (B.S. 1965)
	Iowa State University (Ph.D. 1970)
Awards & Achievements	Percy L. Julian Research Award (1989)
	Black Engineer of the Year (1993)
	NSBE Lifetime Achievement in Industry Award (1999)

BIOGRAPHY

James Mitchell grew up in a single parent home where money was a constant problem. Mitchell resolved to change his circumstances from a young age and earn a doctoral degree. He was born on November 16, 1943 in Durham, North Carolina. Mitchell chose to study chemistry because it had consistent logical principles. He graduated from North Carolina A&T State University in 1965 with his B.S. degree in chemistry. Mitchell went on to receive his Ph.D. degree from Iowa State University in chemistry in 1970. Mitchell was particularly interested in analytical chemistry, which involves determining the composition of matter. At Iowa State, his research focused on using new materials to isolate rare chemical elements from different mixtures.

Bell Laboratories by kugelfish @Flickr

Mitchell accepted a position at Bell Laboratories as a member of the technical staff. Mitchell joined the team that developed optical wave guides, which are glass-like fibers used to carry light flashes over long distances. These waves can be used in telecommunications and carry more information than radio waves in the same amount of time. Mitchell's focus was to remove any impurities in the core chemicals. Mitchell excelled at Bell Laboratories, becoming head of the Inorganic Analytical Group in 1972 and head of the process and chemical engineering research department in 1994. Under Mitchell's leadership, the department contributed many cutting edge technologies and became a world renowned research organization. Mitchell's research focuses on trace analysis, finding what small fraction of a certain chemical makes up a larger compound or material. He later became director of the Materials Processing Research Laboratory, and in 2001, was named vice president of Communications Material Research Laboratory. Mitchell left industry in 2002 to become a professor in the Department of Chemical Engineering at Howard University where he served as director of the nanomaterials and nanoscales research centers. In 2010, he became dean of the College of Engineering. James Mitchell lives with his wife in Washington, D.C.

Above Photo of James Mitchell by: http://hucrest.howard.edu/Mitchell.htm

SCIENCE IN ACTION

NEW USES FOR ORGANIC MATERIALS

Elephant Grass
bv V. Bali @Flickr

Elephant grass is a tall grass that grows in the savannas of Africa along lakes and rivers where the soil is rich. It gets its name because it is the favorite food of elephants. Farmers use the grass to feed their animals. Scientists like James Mitchell are now studying different uses for elephant grass, such as an ingredient in pills and tablets. To do this, they isolate microcrystalline cellulose (MCC) from the grass. Cellulose is the most abundant organic compound on earth and is the main component of cell walls. MCC improves how compounds stick to each other and stabilizes foams, gels, starches, and mixtures of liquids. It can replace fats and is an ingredient in vitamin and drug tablets.

DISCUSSION QUESTIONS

1. If you were to interview James Mitchell, what questions would you ask him?
2. Check out the Bell Laboratories website (http://www.alcatel-lucent.com/wps/portal/belllabs) where James Mitchell worked. What technologies are they developing that interest you the most? Why?
3. Elephant grass has many uses including biofuels. Corn is used as biofuel as well, what other uses does corn have besides in food?
4. James Mitchell developed technology to purify materials as well as air and water. Why is this important?
5. How does James Mitchell's career compare to that of other engineers in the Toolkit?

GLOSSARY

Analytical Chemistry - The gathering of information about the quantity and properties of matter, as well as the processing and communication of that information

Bell Laboratories - The research and development organization of Alcatel-Lucent and previously of the American Telephone & Telegraph Company (AT&T); also known as Bell Labs and formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories

Cellulose - An insoluble substance that is the main constituent of plant cell walls and of vegetable fibers such as cotton

Industry - Economic activity concerned with the processing of raw materials, developing new products or technology, and manufacturing goods in factories

Nanomaterial - A substance that was created on a very small scale; one billionth of a meter

Optical - Having to do with sight, especially in relation to the behavior and properties of light

Trace Analysis - The determination of each component of a material or compound, even those in very small quantities

ScienceMakers Spotlight

Jennie Patrick

Chemical Engineer

Birth Date	January 1, 1949
Birth Place	Gadsen, Alabama
Education	University of California, Berkeley (B.S. 1973)
	Massachusetts Institute of Technology (Ph.D. 1979)
Awards & Achievements	Outstanding Women in Science and Engineering Award (1980)
	American Institute of Chemical Engineers Williams W. Grimes Award (2000)

BIOGRAPHY

Jennie Patrick was the first African American woman to earn her Ph.D. degree in chemical engineering, and she went on to have an illustrious career working at a number of different companies and universities. She was born on January 1, 1949 in Gadsen, Alabama, as one of five children in a working class family. In 1964, she was among the first generation of black students to integrate Gadsen High School. Patrick attended Tuskegee University, majoring in chemistry. At the end of her freshman year, the university started a new major: chemical engineering. Unfortunately the program quickly shut down and Patrick withdrew from Tuskegee University. She was accepted at the University of California, Berkeley, but transfer students could not receive scholarships, so Patrick had to take a year off to earn money for school. She graduated with her B.S. degree in chemical engineering in 1973. She pursued her graduate studies at Massachusetts Institute of Technology (MIT), earning her Ph.D. degree in 1979.

MIT Campus
by Extrudedaluminiu @Flickr

After finishing her education, Patrick joined the faculty of the General Electric Research Center as a staff engineer, researching fluid extraction technology. In 1983, she became the project manager at Phillip Morris Research Facility heading the supercritical extraction technology program. Patrick became the research department manager at Rohm and Haas Company in 1985 where she continued her research in supercritical extraction and expanded to polymer science and emission technology. In 1990, she was hired as assistant to the executive vice president at Southern Company Services. In 1993, Patrick returned to Tuskegee University as the 3M Eminent Scholar. She left Tuskegee in 1997 to become a senior consultant for Raytheon Engineers & Constructors. Patrick has worked as a consultant for Education & Environmental Solutions since 2000. Due to her accomplishments, she has been profiled in many magazines and books including *Ebony Magazine* and *US Black Engineer*. Jennie Patrick lives in Peachtree City, Georgia.

SCIENCE IN ACTION

TAKING OUT THE FAT

Reduced Fat Dairy
by thedalogs @Flickr

Chemical engineers like Jennie Patrick have come up with a solution on how to make foods with less fat. Supercritical Fluid Extraction (SFE) is the process of separating one component from another using supercritical fluid to remove the unwanted component or collect a desired substance. Carbon dioxide is the most common supercritical fluid. Due to the increase in the number of cases of obesity and high cholesterol in recent years, there is a need to reduce the high cholesterol and fat in foods like meats and dairy products. Supercritical carbon dioxide can remove cholesterol from many food products including meat.

DISCUSSION QUESTIONS

1. If you were to interview Jennie Patrick, what questions would you ask her?
2. Check out the Let's Move website (http://www.letsmove.gov/kids). What steps do you already take to be healthy in your own life? What steps could you add to your daily schedule to be even healthier?
3. Supercritical fluid extraction can extract fat and cholesterol from food. What other substances would you extract from food or drinks? Why?
4. Jennie Patrick developed supercritical fluid extraction. Why is this technology important?
5. How does Jennie Patrick's career compare to that of other engineers in the Toolkit?

GLOSSARY

Emission - The production and discharge of something, especially gas or radiation

Polymer - Any of numerous natural and synthetic compounds consisting of up to millions of repeated linked units, each a relatively light and simple molecule

Supercritical Fluid - Any substance at a temperature and pressure above its critical point, where the boundaries between the phases of matter (example: gas, liquid) cease to exist

Supercritical Extraction - The process of separating one component from another using supercritical fluid to remove the unwanted component or collect a desired product

ScienceMakers Spotlight

Percy Pierre

Electrical Engineer

Birth Date	January 3, 1939
Birth Place	Welcome, Louisiana
Education	University of Notre Dame (B.S. 1961, M.S. 1963)
	Johns Hopkins University (Ph.D. 1967)
Awards & Achievements	U.S. Navy Superior Public Service Award (1993)
	National Society of Black Engineers Golden Torch Award (2003)
	American Association for the Advancement of Science Lifetime Mentor Award (2008)

BIOGRAPHY

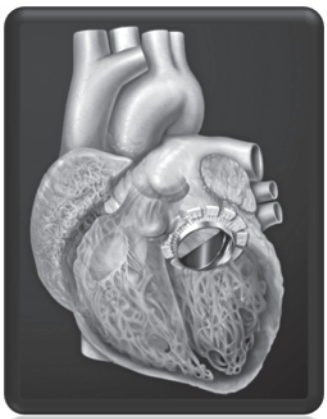
Percy Pierre is a pioneer in his field; the first African American in the country to earn a Ph.D. in electrical engineering. He was born on January 3, 1939 in Welcome, Louisiana. Pierre graduated from St. Augustine High School in New Orleans, Louisiana. He attended the University of Notre Dame where he earned degrees in electrical engineering; his B.S. degree in 1961 and his M.S. degree in 1963. Pierre received his Ph.D. degree in electrical engineering from Johns Hopkins University in 1967.

Michigan State University Campus by betsyweber @Flickr

After graduation, he began a series of successful posts in government and higher education. In 1969, he was selected to serve as a White House Fellow and Deputy to the Assistant to the President for Urban Affairs. In 1971, he joined the faculty of Howard University as dean of the School of Engineering. Pierre introduced new engineering programs to the school, such as a master's program in computer science and a doctoral program in electrical engineering. In 1977, he left Howard University to serve as assistant secretary to the U.S. Army for research, development, and acquisition where he managed a $12 billion budget. Pierre started his own consulting business, Percy A. and Associates in 1983. He served as president of Prairie View A&M University from 1983 to 1989 and was professor of electrical engineering from 1989 to 1990. He came to Michigan State University in 1990 as vice president for research and graduate studies and also as professor of electrical engineering. At Michigan State University, Pierre created programs to increase the financial support and mentoring opportunities available for minority graduate engineering students. Pierre received many awards and served on many boards, including the National Security Advisory Board and the Defense Science Board. Percy Pierre is married to Olga A. Markham, and they have two daughters.

SCIENCE IN ACTION

USING SIGNAL PROCESSING TO DETECT A BROKEN HEART



Artificial Valve in the Heart
by Patrick J. Lynch @Flickr

How do you detect a broken heart? Percy A. Pierre's work potentially has an answer. His research concerns mathematical modeling of random signals, such as electric and acoustic signals. Analyzing these signals has applications across many different fields including oil exploration, military surveillance, and medical implant devices.

The heart has four valves, which continually open and close to allow blood to be pumped through its four chambers. When a valve becomes diseased, the flow of the blood through the heart decreases. The diseased valve can be replaced with an artificial valve, significantly extending the life of the patient. Artificial valves can also wear down and need to be replaced. Acoustic signal processing can be used to listen to the heart, and detect whether the valve is working properly or if the valve needs to be replaced.

DISCUSSION QUESTIONS

1. If you were to interview Percy Pierre, what questions would you ask him?
2. Check out the Lawrence Livermore Laboratory's website (https://www.llnl.gov/str/Clark.html). What other acoustic signal research is being done?
3. Military surveillance and medical devices are being designed to process sound signals. What are some devices that interpret voice signals?
4. President Obama and Percy Pierre are trying to increase the number of engineers in the United States. Why are engineers so important to our society?
5. How does Percy Pierre's career compare to that of other engineers in the Toolkit?

GLOSSARY

Acoustic - Relating to sound

Mathematical Modeling - A description of a system using mathematical language

Signal Processing - Signal processing is an area of electrical engineering and applied mathematics that deals with operations on or analysis of signals

Valve (heart) - A passageway in the heart to control the one-way flow of blood

ScienceMakers Spotlight

John Slaughter

Electrical Engineer

Birth Date	March 16, 1934
Birth Place	Topeka, Kansas
Education	Kansas State University (B.S. 1956)
	University of California, Los Angeles (M.S. 1961)
	University of California, San Diego (Ph.D. 1971)
Awards & Achievements	Martin Luther King, Jr. National Award (1997)
	National Academy of Engineering Arthur M. Bueche Award (2004)
	Benjamin Banneker Lifetime Achievement Award (2008)

BIOGRAPHY

John Slaughter is known for his leadership as assistant director of the National Science Foundation (NSF). He was born on March 16, 1934 in Topeka, Kansas. Slaughter knew from a young age that he wanted to become an engineer. He received support from his parents, and although his teachers pushed him towards a vocational profession, Slaughter was determined to seek a higher education in engineering. He taught himself how to repair radios and started his own radio repair business. Slaughter attended Washburn University in his hometown where he used his radio business profits to pay for tuition. After two years, Slaughter transferred to Kansas State University where he received his B.S. degree in electrical engineering in 1956.

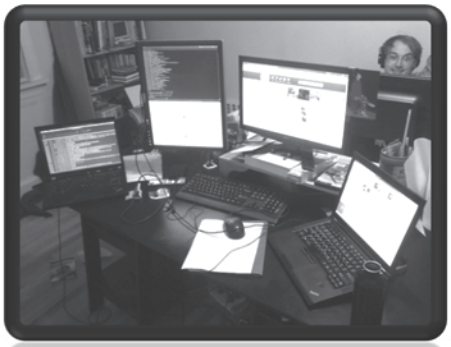
National Science Foundation Logo by nsf.gov

Slaughter moved to San Diego and was hired at General Dynamics Corporation, a large aerospace company. In 1960, Slaughter began working for the Naval Electronics Laboratory, conducting research on electronic control systems. He worked there for the next fifteen years, while pursuing his graduate studies part-time. In 1961, he received his M.S. degree from the University of California, Los Angeles and in 1971, Slaughter received his Ph.D. degree in engineering physics from the University of California, San Diego. In 1975, Slaughter left the Naval Electronics Laboratory to join the faculty of the University of Washington as the director of the Applied Physics Laboratory and professor of electrical engineering. In 1977, he became assistant director for astronomical, atmospheric, earth, and ocean sciences at the National Science Foundation (NSF) and he was promoted to director in 1980. He returned to academia as president of the University of Maryland in 1982 and president of Occidental College in 1988. In 2010, Slaughter joined the faculty of the University of Southern California as professor of education and engineering. He is a member of the National Academy of Engineering (NAE) and was a member of the President's Council of Advisors on Science and Technology from 2006 to 2008. John Slaughter is married to Ida Bernice Slaughter and they have two children.

Above picture of John Slaughter from www.thebannekerinstitute.org/resources/featured-scientist/jon-slaughter/

SCIENCE IN ACTION

ALGORITHIM: A MATHEMATICAL RECIPE



Computers
by isforintsects@Flickr

When you hear the word algorithm, do you stop listening because you do not think you will understand? Do not let the big word turn you off; algorithms are basically a list of clear instructions of how to make calculations or solve a problem. A simple algorithm can be used to find the largest number in an unsorted list. A cooking recipe is one kind of algorithm; a computer program is an elaborate algorithm, giving the computer instructions for what to do. The best computer programs are "simple and elegant" meaning they give the best instructions in the least amount of steps. John Slaughter has developed computer algorithms for system optimization, the process of making a computer run more efficiently.

DISCUSSION QUESTIONS

1. If you were to interview John Slaughter, what questions would you ask him?
2. Check out the How Stuff Works website and learn about algorithms (http://computer.howstuffworks.com/question717.htm). What is an algorithm you would use to pick up a friend from the airport?
3. An algorithm is a set of instructions on how to solve a problem. Besides a recipe, when else do you follow a set of instructions?
4. John Slaughter started his own radio repair shop to pay for college. Why is it important to be self-motivated when it comes to education?
5. How does John Slaughter's career compare to that of other engineers in the Toolkit?

GLOSSARY

Algorithm - An effective method for solving a problem, such as a calculation or data analysis, using a set of mathematical instructions

Control System - A device or set of devices to manage, command, direct, or regulate the behavior of other devices or systems

Engineering Physics - The study of the combined disciplines of engineering, mathematics, and physics

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Naval Electronics Laboratory - The laboratory's goals were to find the solution of any problem in the field of electronics, in connection with the design, procurement, testing, installation, and maintenance of electronic equipment for the U.S. Navy; now part of Space and Naval Warfare Systems Center in San Diego

System Optimization - The process of making a computer run more efficiently

ScienceMakers Spotlight

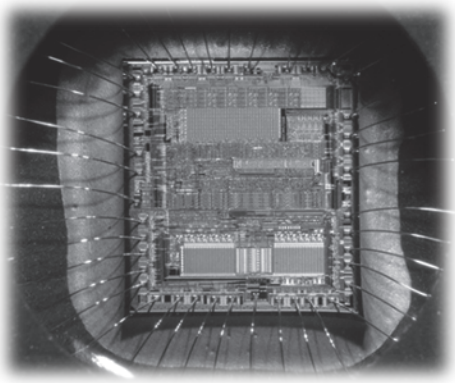
Michael Spencer

Electrical & Chemical Engineer

Birth Date	March 9, 1952
Birth Place	Detroit, Michigan
Education	Cornell University (B.S. 1974, M.S. 1975 and Ph.D. 1981)
Awards & Achievements	Presidential Young Investigator Award (1985)
	NASA Certificate of Recognition (1992)
	QEM Giants of Science Award (1996)

BIOGRAPHY

Michael Spencer spends his days focused on engineering projects, starting with a breakfast full of brainstorming at 4:00 a.m. Spencer was born on March 9, 1952 in Detroit, Michigan. He grew up in Washington, D.C. and travelled to Ithaca, New York, to study at Cornell University. He earned his B.S. degree in 1974 and his M.S. degree in 1975. Spencer worked at Bell Laboratories from 1974 to 1977 before returning to Cornell to receive his Ph.D. degree in electrical engineering in 1981.

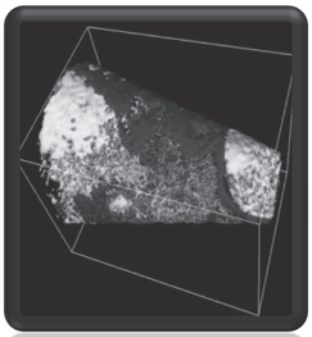


Microcontroller (small computer) by yellowcloud @Flickr

Spencer joined the faculty of Howard University as an assistant professor in 1984. Spencer founded the Materials Science Center for Excellence in 1984 and served as its director for the entirety of his career at Howard. The center provided research opportunities for faculty and staff to study specific semiconductors and their applications to electronics. Spencer was promoted to full professor of engineering in 1998. During this time, Spencer also worked as a visiting scientist at the National Aeronautics and Space Administration (NASA)'s JET Propulsion Laboratory. In 1999, he returned to Cornell University as professor of electrical engineering. He served as associate dean of research and graduate studies for the College of Engineering from 2002 to 2008. Spencer has directed the Wide Bandgap Laboratory where he researched semiconductor materials like Silicon Carbide (SiC) and Gallium Nitride (GaN), as well as two dimensional semiconductors like graphene. Spencer served as one of the directors for the National Science Foundation (NSF) Nano-Fabrication Network, a group of directors working together to manipulate matter on the atomic level. He co-founded Widetronix, a company that builds low power long life batteries. Spencer has written over 130 publications concerning semiconductors and has also co-authored five U.S. patents. Michael Spencer lives in Ithaca, New York.

SCIENCE IN ACTION

NANOTECHNOLOGY



Computer Image of a Drill Bit by jurvetson @ Flickr

A nanometer is a unit of measurement like inches, miles, and meters. It is one billionth of a meter. A meter is thirty-nine inches. That means you can see something the size of a nanometer only with a very powerful microscope. A water molecule is less than a nanometer. A typical bacteria or germ is about 1,000 nanometers. A hair is 100,000 nanometers. Your computer has switches that are 100 nanometers wide. Materials on the nanometer or atomic scale are considered cutting edge technology called nanotechnology. They can be used in a variety of different fields including medicine, electronics, and biomaterials.

DISCUSSION QUESTIONS

1. If you were to interview Michael Spencer, what questions would you ask him?
2. Check out the Nanooze website (http://www.nanooze.org) and learn about nanotechnology. What application of nanotechnology do you think will be most important in the future? Why?
3. Michael Spencer develops semiconductors which are crucial to almost all electronics. Do you think your life would be different without semiconductors? Why or why not?
4. Graphene is shaped like a honeycomb, and it is extremely thin and strong. Why do you think the honeycomb shape is beneficial for its strength?
5. How does Michael Spencer's career compare to that of other engineers in the Toolkit?

GLOSSARY

Bell Laboratories - The research and development organization of Alcatel-Lucent and previously of the American Telephone & Telegraph Company (AT&T); also known as Bell Labs and formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories

Gallium Nitride - A semiconductor made up of gallium and nitrogen

Graphene - A one-atom-thick flat sheet of carbon atoms that is densely packed in a honeycomb shape

JET Propulsion Laboratory - A federally funded research and development center whose primary focus is the scientific study of the solar system, including exploration of the planets with automated probes, such as a satellite or robot

Nano-Fabrication - The design and manufacture of devices with dimensions measured in nanometers; one nanometer is a billionth of a meter

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

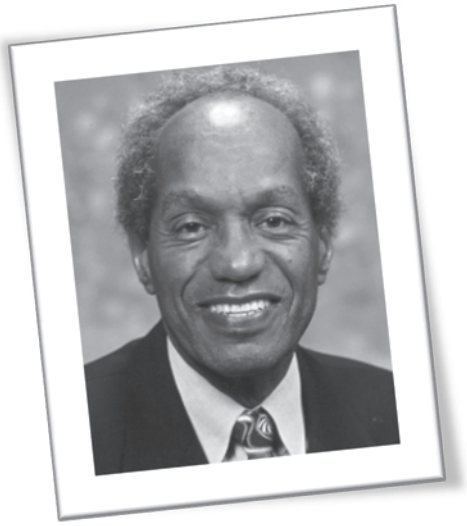
Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

Silicon Carbide - A semiconductor made of silicon and carbon

ScienceMakers Spotlight

Arnold Stancell

Chemical Engineer



Birth Date	November 16, 1936
Birth Place	New York, New York
Education	City College of New York (B.S. 1958)
	Massachusetts Institute of Technology (Ph.D. 1962)
Awards & Achievements	Career Achievement Award of City College of New York (1993)
	AIChE National Award in Chemical Engineering (1997)
	Presidential Appointee to the National Science Board (2011)

BIOGRAPHY

Arnold Stancell has completed many firsts in his life; he was the first African American to earn his Ph.D. degree in engineering, to become a tenured professor at Massachusetts Institute of Technology (MIT), and to work as a senior oil executive. Stancell was born on November 16, 1936 in the Harlem neighborhood of New York, New York. He lived with his single mother and focused on his education. He passed competitive exams to get into high school and graduated with honors from the City College of New York, earning his B.S. degree in chemical engineering in 1958. Stancell was awarded a graduate fellowship from MIT and received his Ph.D. degree in chemical engineering in 1962.

Oil exploration in Egypt by aballant38 @Flickr

After graduation, Stancell worked at Mobil Oil from 1962 to 1970, researching new chemical and plastic products. During this time, he invented nine innovative processes for making plastics. In 1970, Stancell took a leave of absence from Mobil Oil to teach at MIT. He started a research program focused on ionized gas (plasma) reactions. In 1972, Stancell turned down a tenured professorship position at MIT to return to Mobil Oil as manager of Mobil Chemical Planning. He continued to excel at Mobil, becoming vice president of Mobil Plastics and in 1986, vice president of Mobil Europe Marketing and Refining. In 1989, he became vice president of International Exploration and Production and was responsible for finding and developing oil and natural gas reserves in Europe, the Middle East, and Australia. Stancell negotiated and launched an $18 billion natural gas production deal between Mobil and Qatar, a small nation in the Middle East. In 1993, he retired from Mobil after a 31-year career and joined the faculty of the Georgia Institute of Technology in 1994 as professor of chemical engineering. In 2004, Stancell became Turner Professor Emeritus and later retired from Georgia Tech. Stancell consulted and advised the United States Department of Interior after the British Petroleum (BP) Oil spill in 2010. Arnold Stancell lives in Greenwich, Connecticut.

SCIENCE IN ACTION

OFF SHORE OIL DRILLING AND THE BRITISH PETROLEUM (BP) OIL SPILL

Oil Rig
by ST33VO @Flickr

Not all oil can be found on land or in shallow water. Offshore oil drilling goes deep under the ocean floor to tap oil reserves. Offshore drilling is a significant percentage of oil reserves, but it is also dangerous. The BP Oil Spill was the largest marine oil spill in history. Over the course of three months in 2010, 5 million barrels of oil leaked into the Gulf of Mexico from the damaged offshore well before it was capped. After the spill, Stancell and five other engineers presented a report to President Obama of short-term steps to improve offshore drilling. These steps included providing multiple backups for the blowout preventor, which had failed during BP's Deepwater Horizon explosion and ingraining safety procedures into the company's culture.

DISCUSSION QUESTIONS

1. If you were to interview Arnold Stancell, what questions would you ask him?
2. Check out the Energy Story website (http://www.energyquest.ca.gov/story/chapter08.html). What is the origin of Fossil Fuels?
3. Oil is a fossil fuel. Name two benefits and two disadvantages of using fossil fuels.
4. The BP Oil Spill devastated the coastal environment of the Gulf of Mexico. Do you think we should continue using offshore drilling as a source of oil in the United States? Why or why not?
5. How does Arnold Stancell's career compare to that of other engineers in the Toolkit?

GLOSSARY

Blowout Preventer - A large, specialized valve used to seal, control, and monitor oil and gas wells

Ionized Gas (Plasma) - Gas whose atoms have lost or gained electrons, causing them to be electrically charged

Tenure - A lifelong appointment to a position not subject to dismissal except under serious circumstances

Offshore Drilling - Oil drilling deep under the ocean floor at a distance away from the shore

ScienceMakers Spotlight

Lucius Walker

Mechanical Engineer & University Administrator

Birth Date	1937
Birth Place	Washington, D.C.
Education	Howard University (B.S. 1957)
	Carnegie Institute of Technology (M.S. 1958, Ph.D. 1966)
Awards & Achievements	Black Engineer of the Year Award for Higher Education (1988)
	New York Academy of Science Member
	Ralph R. Teetor Award

BIOGRAPHY

Lucius Walker was such a bright child that he entered college at the age of fifteen. Born in 1937, Walker was a Ford Foundation early admission student to Morehouse College in 1952. In 1954, he transferred to Howard University to study engineering. Walker graduated with his B.S. degree in mechanical engineering in 1957. He continued his studies at Carnegie Institute of Technology (now Carnegie Mellon University), earning his M.S. degree in 1958 and his Ph.D. degree in 1966.

Howard University by Kevin Coles @Flickr

In 1972, Walker joined the efforts to increase the number of minority students in engineering. He co-founded and directed the Engineering Coalition of Schools for Excellence in Education and Leadership. Funded by the National Science Foundation (NSF), this project was designed to initiate collaboration between seven major engineering schools in order to promote equal opportunity in engineering for minority youth. Walker also co-founded the organization, Advancing Minorities' Interest in Engineering, which was a collaboration between industry, government organizations, and historically black engineering colleges. Walker taught at both Carnegie Mellon University (CMU) and the University of Massachusetts, but the majority of his career was spent at Howard University. He served as both assistant and associate dean of the School of Engineering and chairman of the Department of Mechanical Engineering. In 1976, Walker became acting dean of the School of Engineering and in 1978, he was appointed dean. Throughout his career, Walker also worked for General Electric, Exxon, Ford Motor Company, and Harry Diamond Laboratories. He published many scientific research articles covering topics like transportation systems analysis, fluid mechanics, and bioengineering. Walker also conducted aerodynamics research using airplane models as testers. Lucius Walker retired as dean in 2002, but he serves as professor emeritus at Howard University. Lucius Walker has two children and six grandchildren.

Above Picture of Lucius Walker from www.howard.edu

SCIENCE IN ACTION

FLUIDS IN MOTION

Hydraulic Jack
by nSeika @Flickr

When you hear the word fluid, you probably think of a liquid like water. In physics and engineering, the term fluid means any substance with no fixed shape, such as a liquid or a gas. Studying fluid mechanics helped engineers create mechanical marvels such as the hydraulic press. When your auto mechanic changes a flat tire on your car, he probably uses a hydraulic jack, which lifts the car off the ground. The jack uses the movement of a fluid (oil) to create lifting power. A plunger-like pump called a piston pushes the oil into a cylinder, which transfers the force to a second cylinder connected by an oil-filled pipe.

DISCUSSION QUESTIONS

1. If you were to interview Lucius Walker, what questions would you ask him?
2. Check out the HowStuffWorks website (http://science.howstuffworks.com/transport/engines-equipment/hydraulic.htm). What other machines use hydraulics?
3. If you were a mechanical engineer, what type of vehicle would you be most interested in working on and why?
4. Lucius Walker served in Howard University's School of Engineering for forty-four years. Why is it important that African Americans be represented in the engineering fields?
5. How does Lucius Walker's career compare to that of other engineers in the Toolkit?

GLOSSARY

Aerodynamics - The study of the properties of moving air, and especially of the interaction between the air and solid bodies moving through it

Bioengineering - An interdisciplinary field developing new technologies such as prosthetic limbs, biomechanics, and molecular modeling

Fluid Mechanics - The study of the movement and behavior of fluids

Hydraulic Press - An instrument that generates a force when a piston forces fluid into a cylinder and that movement is transferred to a second cylinder; used in machines, such as a hydraulic car jack

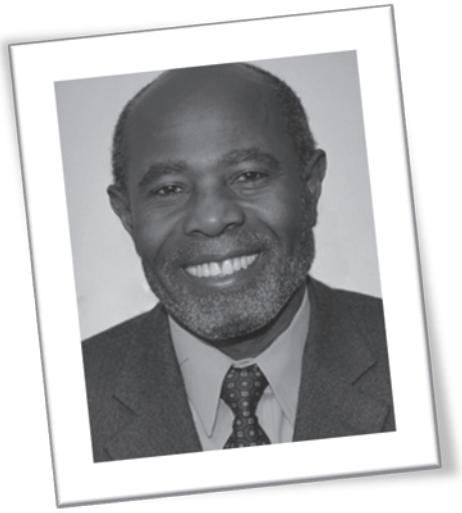
Mechanical Engineering - The study of the design, construction, and operation of machinery

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

ScienceMakers Spotlight

Cardinal Warde

Electrical Engineer & Inventor



Education	Stevens Institute of Technology (B.Sc. 1969)
	Yale University (M.Phil. 1971, Ph.D. 1974)
Awards & Achievements	Stevens Institute Renaissance Science and Engineering Award (1996)
	Harrison College- Queens College Personal Achievement Award

BIOGRAPHY

Cardinal Warde is known for being a world renowned inventor and a leading expert on optical information processing. Warde grew up in Barbados, a small Caribbean island. In high school, he turned his father's vacant carpenter's shop into a chemistry and physics laboratory. In 1965, Warde came to the United States to study at Stevens Institute of Technology where he received his B.Sc. degree in physics in 1969. He continued to study physics at Yale University, receiving his M.Phil degree in 1971 and his Ph.D. degree in 1974. During his Ph.D. research, Warde developed a passion for optical engineering and designed a new type of interferometer, a device that measures the length of waves near absolute zero temperatures.

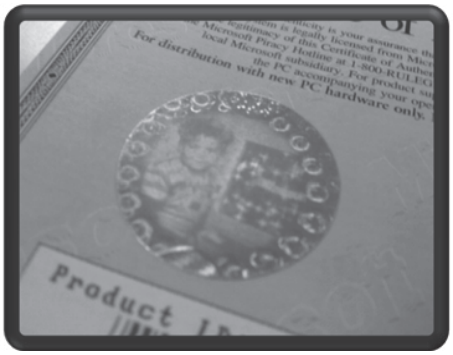
Digital Camera Screen by Will Folsum @Flickr

Following graduation, Warde joined the faculty of Massachusetts Institute of Technology (MIT) as an assistant professor in the electrical engineering department. He worked with a group of faculty members developing optical communication devices, which worked well in severe weather. He also developed holography technology. Warde has written over one hundred papers on optical devices, materials, and systems and has ten patents on various optical devices. He has invented several types of spatial light modulators and light shutters. Warde has also worked on developing optical neural-network co-processers that could give the next generation of computers a basic brain-like processing system. In 1982, he founded Opron Systems, Inc. a technology company that develops novel electro-optic displays, and in 1999, he co-founded Radiant Images, Inc. a company that develops crystal microdisplays for digital camera view finders. Warde has served as a consultant for Caribbean governments and lectured at government meetings about the importance of technology and education in economic development. He also mentors high school students, encouraging them to pursue careers in the STEM fields as part of the Network Program of the New England Board of Higher Education. Cardinal Warde works in Cambridge, Massachusetts.

Above picture of Cardinal Warde from eecsfacweb.mit.edu/facpages/warde.html

SCIENCE IN ACTION

HOLOGRAMS: MORE THAN A TRICK OF LIGHT



Microsoft Hologram
Product by McGrigg @Flickr

Have you ever looked at an image and it changed when you moved your head? You were probably looking at a hologram. Cardinal Warde is an expert on many optical materials including holograms. Holograms are three-dimensional images formed by interference of light beams from a laser or other solid light source. To capture a hologram, a solid beam of light from a laser is reflected on an object. This light is overlapped by a second reference beam on film. A hologram creates a true three-dimensional image, and when you move your head, you can see three different perspectives. Holograms are difficult to forge or copy. Therefore, they are used to prove that an item is authentic, such as on driver's licenses, passports, and all types of currency.

DISCUSSION QUESTIONS

1. If you were to interview Cardinal Warde, what questions would you ask him?
2. Check out the How Stuff Works Website and learn about holograms. (http://science.howstuffworks.com/hologram.htm). Why do you need to make a hologram?
3. Why are holograms used on objects that need to be secure such as currency, drivers' licenses, and passports?
4. Cardinal Warde is an inventor of optical materials. What materials do you use every day that use optical technology?
5. How does Cardinal Warde's career compare to that of other engineers in the Toolkit?

GLOSSARY

Absolute Zero - The lowest temperature that is theoretically possible, at which the motion of particles that constitutes heat would be minimal (- 459.67 degrees Fahrenheit)

Electro-optics - A branch of technology involving components, devices, and systems, which operates by modifying the optical properties of a material by an electric field

Holography - The study of holograms, three-dimensional images formed by the interference of light beams from a laser or other coherent light sources

Interferometer - Any measuring instrument that uses interference patterns to make accurate measurements of waves

Optical - Having to do with sight, especially in relation to the behavior and properties of light

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Spatial Light Modulator (SLM) - An object that alters the shape or position of a beam of light

Wave - A repeating disturbance or movement that transfers energy through matter or space

ScienceMakers Spotlight

Herbert Winful

Electrical Engineer & Laser Expert

Birth Place	London, England
Education	Massachusetts Institute of Technology (B.S. 1975)
	University of Southern California (M.S. 1977, Ph.D. 1981)
Awards & Achievements	Presidential Young Investigator (1987)
	University of Michigan College of Engineering Teaching Excellence Award (1990)
	Amoco/ University Faculty Teaching Award (1993)

BIOGRAPHY

Herbert Winful, a pioneer in the field of optics, grew up fascinated with lasers. He dreamt of inventing an X-ray laser. Born in London, England and raised in Cape Coast, Ghana in West Africa, Winful came to the United States to study. He received his B.S. degree in electrical engineering from Massachusetts Institute of Technology (MIT) in 1975. He received his M.S. degree and his Ph.D. degree from the University of Southern California in 1977 and 1981, respectively.

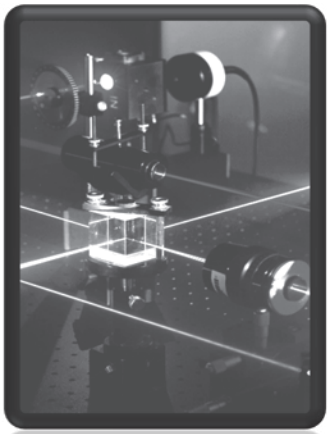
Fiber Optics
by qwrrty @Flickr

From 1980 to 1986, Winful was a principal member of the technical staff at GTE Laboratories (now Verizon Technology Laboratories), a leading technology company in fiber optics. In 1987, he joined the faculty of the University of Michigan as an associate professor in the Department of Electrical Engineering and Computer Science. In 1992, Winful was promoted to full professor and awarded the Arthur F. Thurnau Professorship. His research focused on laser physics and nonlinear optics, specifically how a laser beam is so intense it can change the way light reflects. Winful is well known for developing a new theorem that answered a seventy-five year old question about how electrons tunnel through barriers. At the University of Michigan, he has taught classes on electrical circuits, nonlinear optics, and fiber optics. Winful has also taught at universities in China, Italy, France, and Ghana. As a leader in the field of laser science, he was awarded two patents involving optical technology and has published over 120 articles. Winful is a member of several prestigious professional societies including the American Physical Society (APS), the Institute of Electrical and Electronics Engineers (IEEE), and the Optical Society of America (OSA). He also has a passion for music and spends his spare time playing the piano and composing new music. Herbert Winful works in Ann Arbor, Michigan.

Above Picture of Herbert Winful from math.buffalo.edu

SCIENCE IN ACTION

LASERS: A POWERFUL TOOL



Lasers
by Official U.S. Navy Imagery @Flickr

The first working laser was produced in 1960, and now it is an important part of modern technology, used to correct vision, print text, remove unwanted hair, and assist with targeting in military applications. A laser amplifies or strengthens light waves making for a well defined beam of light. Lasers can be powerful enough to cut through metal or even cause a nuclear reaction. They can also be used with greater precision to perform the same functions as a scalpel in surgeries. They send and receive information, for example reading the information on a CD or reading bar codes in stores and supermarkets. A single laser can send thousands of phone conversations at the same time.

DISCUSSION QUESTIONS

1. If you were to interview Herbert Winful, what questions would you ask him?
2. Check out the NASA's laser website (http://spaceplace.nasa.gov/laser/). How are lasers different than natural light?
3. Lasers are a powerful and extremely useful tool, but they can also be extremely dangerous. Give some examples of how lasers can be harmful.
4. As a child, Herbert Winful wanted to develop an X-ray laser. Can you make a prediction for a new and important use of lasers in the future?
5. How does Herbert Winful's career compare to that of other engineers in the Toolkit?

GLOSSARY

Fiber Optics - The transmission of light signals through glass fibers

Laser - A device that generates an intense beam of light that is one bright color

Nonlinear - Not following a straight line or in more than one dimension

Optics - The branch of physics that involves the behavior and properties of light

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Design, Build and Test Your Own Landfill

(www.teachengineering.org)

Grade Level: 5 - 7
Time Required: 60 minutes
Cost: $2 per group
Group Size: 4

Contributed by: TeachEngineering.org — Resources for K-12

This activity relates to the work of civil engineers and environmental engineers, like ScienceMaker ***James Johnson.***

Summary
Students design and build model landfills using materials similar to those used by engineers for full-scale landfills. Their completed small-size landfills are "rained" on and subjected to other erosion processes. The goal is to create landfills that hold the most garbage, minimize the cost to build and keep trash and contaminated water inside the landfill to prevent it from causing environmental damage. Teams create designs within given budgets, test the landfills' performance, and graph and compare designs for capacity, cost and performance.

The trash that people throw away gets put in landfills that are designed and built by engineers.
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Engineering Connection
Engineers design landfills to contain waste from many types of anthropogenic (human-generated) sources. The garbage comes from many places, including household trash cans, worn-out tires, sludge from wastewater treatment plants, old couches, and scrap metal. The main challenge for engineers is to keep the waste materials from being a health hazard. Also, because of economic constraints, landfills must be as small as possible while holding the most amount of waste material possible. Engineers work with regulators to design landfills that are suitable for hazardous and non-hazardous waste.

Pre-Requisite Knowledge
A basic understanding of what water (and, hence, leachate) does and does not flow through. Specifically, water flows very slowly through clay so clay is a good material for a landfill liner system.

Learning Objectives
After this activity, students should be able to:

- Describe a landfill and its purpose.
- Explain the alternatives to dumping human-made garbage in landfills and ways to decrease the amount of waste that ends up in landfills.
- Describe how landfills can be hazardous for the environment if they are not well engineered.

- Describe the kinds of materials make good liner systems for landfills.
- Explain what it means to optimize something.

Materials List

Each group needs:

- clear plastic tub (~12-in long × 6-in wide × 5-in deep) (~30-cm x 15-cm x 13-cm) with about 1 inch (2.54 cm) of sand in the bottom
- clay (~750 cm3), this clay does not need to be the high-quality type used for modeling; clayey or silty soil from your backyard works fine
- sand (~1500 cm3) (available at home and garden stores)
- gravel (~100 cm3) (available at home and garden stores)
- ~15 cotton balls
- (optional) tiny houses and buildings (such as Monopoly game houses and hotels), or any other simple representation to simulate the presence of a town sitting on the sand base
- Roles and Optimization Worksheet
- Budget Worksheet

Note: The amounts of clay, gravel and sand are approximate (based on experience with teaching the activity), but because students can choose how much of each type of material they want to use, it is helpful to have a bit extra on hand.

For the entire class to share:

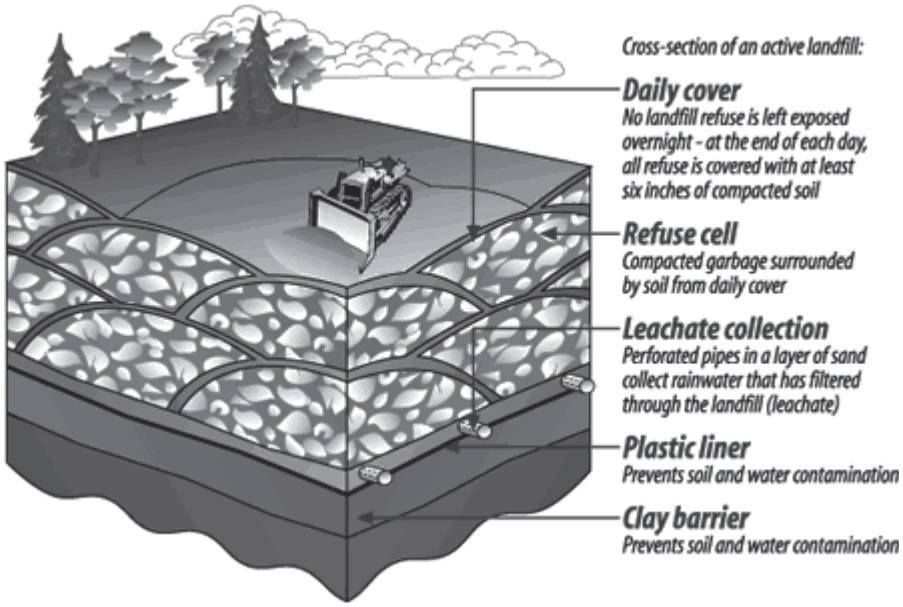
- food coloring
- clear plastic tub in which to mix together food coloring, water and cotton balls ("garbage")
- (optional) gloves or spoon to "mix" the garbage
- strips of plastic garbage bags, to simulate geosynthetics used in landfills
- toothpicks
- straws
- popsicle sticks
- small, paper "Dixie" cups (~85 ml size), to measure and distribute clay, gravel and sand
- access to water
- watering can, water bottle or other "rain storm" device
- (optional) electric fan, to simulate the erosion force of wind
- (optional) graph paper

Introduction/Motivation

The people living in the US make about 250 million tons of trash every single year! (EPA, 2009) And, about 300 million people live in the US. So, that works out to about 4½ pounds of trash generated per person — every single day!

How much of this garbage do you think gets recycled and composted? Only about one-third of this trash gets recycled or composted, which means that on average, you make three pounds of trash every day that we have to put somewhere (and the US makes 470 tons of trash every day).

Where do you think we should put this trash? Can we just dump it out in a field? Why not? What if the dump or landfill is near a lake or a river? Groundwater that is stored in aquifers is always flowing. People use wells to bring groundwater up from the aquifers to drink. We must keep dirty water that comes from the landfill (leachate) from getting into the groundwater, otherwise we can make people sick.



Example composition of a modern landfill.
Copyright © King County, WA
http://your.kingcounty.gov/dnr/kidsweb/images/landfill_diagram.gif

So what should be put underneath all the trash in the landfill? How about once the landfill is finished? Should we cover the landfill or leave it open to the air? What should we cover it with? Erosion can affect your landfill if you are not careful. Landfills must be designed well enough to withstand erosion from rain, wind or even earthquakes. Let's make some models and learn what works best.

Vocabulary/Definitions

anthropogenic:	Created by people or caused by human activity.
aquifer:	An underground layer of permeable rock, sand, gravel or soil that contains or conducts groundwater. The pore spaces in aquifers are filled with water and are interconnected, so that water flows through them. Source of water for springs and wells.
geosynthetic:	Human-made materials for earth systems (such as landfills, dams, roads and retaining walls).
landfill:	An engineered site used to dispose of garbage by burying it.
leachate:	Contaminated water that seeps out of landfills. Often contains high amounts of organic matter and toxic chemicals.
liner system:	The technical term for the layers of materials (such as clay and geosynthetics) that protect landfills from erosion, and keep trash and leachate from escaping from landfills.
impermeable:	A material characteristic that does not allow a fluid (such as water) to flow through it.
optimize:	To make a system as good or functional as possible.
requirement:	What a particular product, system or service should do. A necessary attribute, capability, characteristic, quality or limitation. In engineering, sets of requirements are inputs into the design stages of product development.

Procedure

Before the Activity

- Gather materials and make copies of the Roles and Optimization Worksheet and Budget Worksheet.
- Prepare for each group a tub with a bottom sand layer to serve as a landscape upon which to build a landfill (see Figure 1). Set up a town using small houses (or other materials) to

represent a population using the groundwater (for drinking, cooking, cleaning, gardening, recreation, etc.).

- Prepare the "garbage" by mixing cotton balls, food coloring and water (see Figure 1).

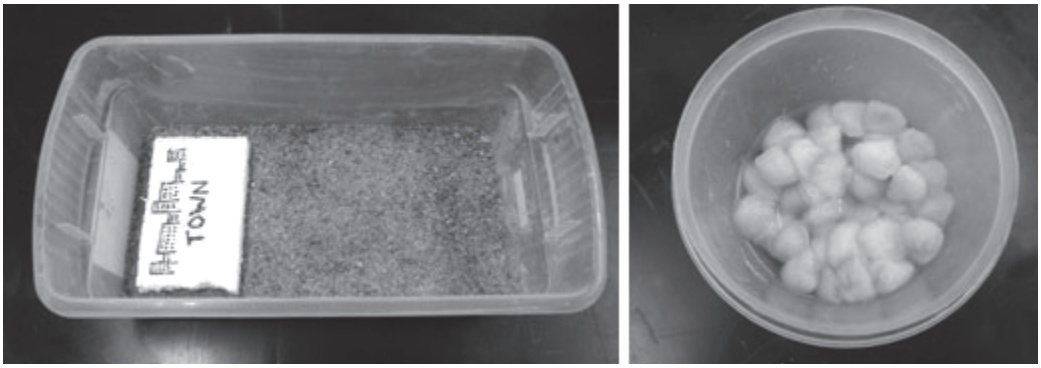


Figure 1. In advance, prepare boxes with a base sand layer and a representation of a town, as well as the pre-mixed "garbage."

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With the Students: Create Model Landfills

1. Divide the class into groups of four students each. Hand out the Roles and Optimization Worksheets.
2. Assign each group member one of four team roles (or let the students decide amongst themselves). Have them indicate on their worksheets who is responsible for each role.
   - Project engineer: The project engineer is the project leader. This person is in charge of final decisions. S/he listens to all of the engineers and helps to decide the best idea. S/he makes sure the landfill gets built on schedule.
   - Design engineer: The design engineer plans how the landfill will work and look. This person is in charge of picking materials and deciding how the landfill should be built. S/he works with the budget office (when picking materials) and construction engineer (when deciding how to build the landfill).
   - Construction engineer: The construction engineer builds the landfill. This person gets the plans about how to build the landfill from the design engineer. If the landfill design must be fixed, s/he talks to the budget office about getting more or different materials.
   - Budget office: The budget office makes sure that the project spends the least amount of money possible. This person helps the design engineer pick materials. S/he is in charge of filling out the budget worksheet, doing the calculations, and keeping track of how much money has been spent. You cannot go over budget!!
3. Introduce the project objectives to the students: Each group must design a landfill that 1) can hold the most garbage, 2) minimizes the cost, while making sure that, 3) the landfill is able to contain the waste during a rainstorm without allowing leachate to get to the town. As you do this, just like engineers, you will be following the steps of the engineering design process: understand the need, brainstorm different designs, select a design, plan, create, test, analyze and improve.
4. Hand out the budget worksheets to the "budget office" students in each group and talk with them about the different materials.
5. Have the "design engineer" students draw out his/her team's landfill design and complete the budget worksheet.
6. Sign-off on the engineering landfill designs and budget worksheets for each group.
7. Have students bring both their approved (signed) designs and completed budgets to the "supply shop" to get their supplies.

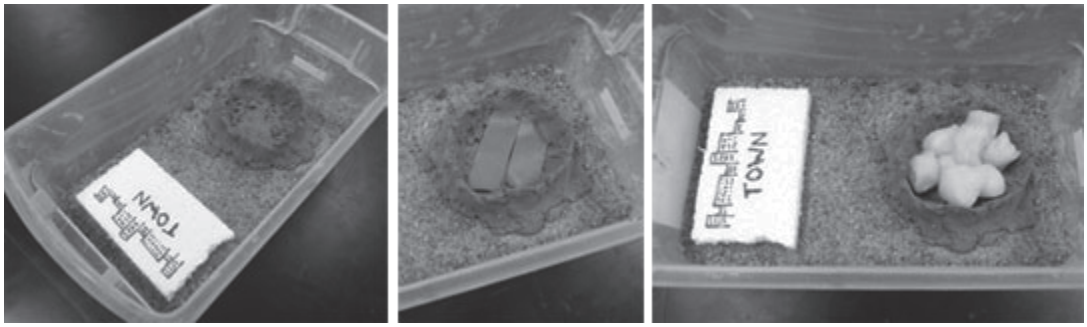

Figure 2. To make their model landfills, have students construct their base liner systems and fill with garbage.
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8. Have students construct the base liner systems for their model landfills (see Figure 2). The goal is to keep water from getting out of the landfill. Therefore, materials such as clay and geosynthetics are good choices, because water cannot flow through them easily. (Basically, the liner should look like a clay bowl or box. Of course, not all teams will choose this path — so you may see Popsicle sticks, toothpicks, etc., at this stage. The word "system" is used because students can use a combination of materials to make base liners [however, because of the budget constraint, they cannot afford to buy many things].) Remember to save some funds to purchase materials to build your top cap (to put on after the garbage is inserted). A landfill without a top is no good for anybody!
9. Fill the landfill with "garbage" (see Figure 2) making sure not to let the food coloring seep out into the area around the landfill before construction is completed. Count how many cotton balls you put in. Have the Project Engineer tell you how many to put in.
10. Have students record the quantity of garbage cotton balls that their landfills can hold on the worksheet.
11. Give students time to finish constructing the top cap liner systems for their landfills (see Figure 3). The purpose of the top cap is to keep the rain out of the landfill. Therefore, like the bottom liner system, it should be made of materials water cannot flow through. Additionally, some protection (such as gravel) can be placed on top to keep rainwater and sunlight from eroding away the liner.

Figure 3. Have students construct top cap liner systems using clay and gravel. Then test the model landfills with "rainstorms."
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With the Students: Test Landfill Performance

1. Create "rainstorms" by pouring water on the model landfills (see Figure 3).
2. Use a pencil or Popsicle stick to dig into the sand outside of the landfill and near the town to look for any seeping food coloring (leachate) (see Figure 4). Make multiple soils tests.
3. Repeat the rainstorm, if desired.
4. (optional) Apply other erosion forces to the model landfill, such as wind or earthquakes.

Figure 4. Does it work? Test the model for any landfill leakage.
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5. Have students document on their worksheets the performance of their landfills (how much garbage it held, how much it cost and whether or not it leaked).
6. Once students have recorded the garbage capacity, cost and performance, have them present their designs to the class. See the embedded assessment "Design Presentations" questions in the Assessment section.

With the Students: Design Comparison

1. Create a table that compiles data (amount of garbage, cost and performance) from each group.
2. Present the data on large, colorful posters.

- Make a line graph of the amount of garbage each landfill held.
- Make a line graph of the cost of each landfill.
- Make a line graph of the performance of each landfill (rate as pass/fail or on a 1-to-5 scale).

3. Discuss the differences between presenting data in graphs as opposed to tables.
4. Lead a class discussion that compares and analyzes all group data, and explores the concept of optimization. Use the post-activity assessment questions provided in the Assessment section. Determine which landfill is most optimal.

Safety Issues

If using a fan to simulate wind, watch that students are not too near to the landfill model that dirt blows into their eyes.

Assessment

Pre-Activity Assessment

Brainstorming: Engage the students in open discussion as a class. Remind them that no idea or suggestion is "silly." All ideas should be respectfully heard. Ask the students:

- What can we do with garbage that does not get recycled or composted? (Answer: Put it in landfills.)
- How might we decrease the amount of trash that gets put in landfills? (Possible answers: Do a better job recycling, use less packaging, reuse more things, do more composting, burn our waste, use fewer things [buy fewer clothes, toys, products, etc.].)
- What materials do we want to use to use to keep garbage "juice" (leachate) from flowing out of our landfills? (Possible answers: Impermeable materials, low-permeability materials, clay.)

Activity Embedded Assessment

Activity Worksheets: Have student teams complete the Roles and Optimization Worksheet and Budget Worksheet. Gauge their understanding of the subject matter by observing their use of the worksheets.

Design Presentations: Have groups present descriptions of the model landfills they designed and created, addressing the following questions:

- Did your landfill keep the town safe? Why or why not?
- What was the most effective part of your design?
- What was the least effective part of your design?
- How did the different materials perform?

Post-Activity Assessment

Optimization Discussion: Lead a class discussion asking students the following questions:

- What does optimization mean? (Answer: For any given engineering challenge, many possible design solutions exist. In engineering, optimization means finding the best solution, which is usually a compromise among several often conflicting requirements [such as cost, capacity, performance, etc.].)
- Which group had the most optimal design (most garbage, least cost and best performance)?
- What were some characteristics of good vs. bad designs?

Activity Extensions

Give students more time and different project constraints to redesign and rebuild their landfill models. For example, change the price of the materials and see how that affects the landfill designs. Or, require each landfill to hold at least a certain amount of trash (cotton balls). Or, have the class collectively make a new design that incorporates the best aspects of all the designs, as well as improvements suggested through testing.

Activity Scaling

- For lower grades, give a far more specific design with more constraints. For example, only allow the use of clay. See which group can use the least amount of clay to hold the most trash. Walk the students through the activity step-by-step. Build the bottom liner as a class. Help each group to make sure they are successful.
- For upper grades, put a tracer in the "garbage" and do chemical testing of the water seeping out of the landfill. For example, one simple tracer to measure for is pH. Lemon juice has a low pH and can be measured with litmus paper. Then have students discuss how to clean up the acidic leak (such as by adding a material with a higher pH, such a baking soda).
- Vary the activity to suit the class and available supplies. Perhaps leave the material choices more open ended, and/or add the idea of removing leachate from the landfill (using straws, turkey basters, etc.). Have teams design and build the best model landfill possible.

Additional Multimedia Support

Look online for example diagrams of how engineers have designed landfills. *Suggestions:*
http://www.mackinac.org/media/images/2007/ms2007-01-12a.jpg
http://your.kingcounty.gov/dnr/kidsweb/images/landfill_diagram.gif
http://herbarium.usu.edu/fungi/funfacts/Landfilldone.jpg
http://www.virginiaplaces.org/waste/graphics/landfilllayers.gif
http://earth911.com/wp-content/uploads/2009/03/landfill3-300x228.gif
http://www.pollutionissues.com/images/paz_02_img0144.jpg
http://www.a2gov.org/government/publicservices/fieldoperations/solidwasteunit/PublishingImages/layers-labeled.jpg

Review the steps of the engineering design process at
http://www.teachengineering.org/engrdesignprocess.php

References

Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008. Published November 2009. US Environmental Protection Agency. Accessed December 16, 2010. (source of statistics) http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2008rpt.pdf

Solid Waste and Recycling (The Cedar Hills Regional Landfill). Updated August 16, 2000. Natural Resources Kids Page, King County, WA. Accessed January 4, 2011. http://your.kingcounty.gov/dnr/kidsweb/landfill.htm

Contributors

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Group name: _____ **Date:** _____

Engineering Roles

Project Engineer

Name(s): _____

The project engineer is the project leader. This person is in charge of final decisions. S/he listens to all of the engineers and helps to decide on the best idea. S/he makes sure the landfill gets built on schedule.

Design Engineer

Name(s): _____

The design engineer plans how the landfill will work and look. This person is in charge of picking materials and deciding how the landfill should be built. S/he works with the budget office (when picking materials) and construction engineer (when deciding how to build the landfill).

Construction Engineer

Name(s): _____

The construction engineer builds the landfill. This person gets the plans about how to build the landfill from the design engineer. If the landfill design must be fixed, s/he talks to the budget office about getting more or different materials.

Budget Office

Name(s): _____

The budget office makes sure that the project spends the least amount of money possible. This person helps the design engineer pick materials. S/he is in charge of filling out the budget worksheet, doing the calculations, and keeping track of how much money has been spent. You cannot go over budget!!!

Landfill Performance

How much garbage did your landfill hold? _____

How much did your landfill cost? _____

Did your landfill leak? _____

Group names _____

_____

_____

_____

Budget Worksheet: Materials and Cost of Landfill

Your group has been given a budget of **$1,000.** Keep a record of the materials that you purchase. Record the amount of each material that you buy in the "quantity" column.
To find the total cost for that material, multiply the quantity by the unit cost.
To find the total cost of the model landfill, tally the total costs of each building material.
Make sure to write in pencil, because you may need to buy more materials as you build!

Building Material	**Quantity** (how many?)	**Unit Cost** (price for 1)	**Cost** quantity × unit cost
1 cup of gravel		**$75**	
1 cup of sand		**$100**	
1 cup of clay		**$100**	
5 strips of geosynthetic (black plastic)		**$400**	
1 small straw		**$125**	
5 toothpicks		**$150**	
1 popsicle stick		**$125**	
		Total Cost:	

Notes:

How does a Hovercraft Work?

(www.sciencebuddies.org)

Grade Level: K+
Time Required: A day or less
Cost: $20 or less

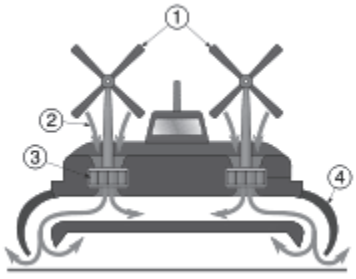
This activity relates to the work of aerospace engineers and mechanical engineers, like ScienceMakers ***Jocelyn Harrison*** *and* ***Lucius Walker.***

Abstract
Have you ever ridden on a hovercraft? It is like gliding on a cushion of air! Make your own mini hovercraft in this experiment to test how hovercrafts work.

Objective
In this experiment you will test if different volumes of air will cause a balloon powered hovercraft to travel for longer periods of time.

Introduction
A hovercraft is a vehicle that glides over a smooth surface by hovering upon an air cushion. Because of this, a hovercraft is also called an Air-Cushion Vehicle or ACV. The hovercraft creates vents of air, which are trapped beneath the vehicle by a curtain surrounding the base. These currents of air can create an air cushion on any smooth surface, land or water! Since a hovercraft can travel upon the surface of water, it is also called an amphibious vehicle. Here is a picture of a modern hovercraft and a diagram showing how the air vents create the air cushion (Wikipedia, 2007):

This image shows a modern style hovercraft which carries passengers over the surface of the water. (Wikipedia, 2007)



This image shows how the air vents moving through the hovercraft create the air cushion below the craft for movement: 1) propellers, 2) air currents, 3) fan, and 4) flexible skirt. (Wikipedia, 2007)

How does the air cushion beneath the hovercraft allow the vehicle to glide to freely? The key to the ease of movement is reducing friction. Vents of slowly moving, low-pressure air are ejected downwards against the surface close below it creating the air cushion. The air is trapped beneath the

hovercraft by a flexible skirt, also called the curtain. The trapped air cushion greatly reduces the friction of the vehicle, allowing it to glide freely upon the smooth surface below.
In this experiment, you will build your own mini hovercraft using a CD, recycled bottle, and a balloon. You will use balloons of different sizes to test if more air will cause the hovercraft to travel for longer periods of time. A large balloon will provide a larger volume of air, and a small balloon will provide a smaller volume of air. Will a larger balloon make the hovercraft travel longer than a smaller balloon?

Terms, Concepts, and Questions to Start Background Research
To do this type of experiment you should know what the following terms mean. Have an adult help you search the Internet, or take you to your local library to find out more!

- Hovercraft
- Friction
- Air cushion
- Volume

Questions

- How does a hovercraft work?
- How does the flow of air reduce friction of the hovercraft in motion?
- Is the volume of air in a balloon powered hovercraft important for how long it can hover?

Bibliography

- Read this Wikipedia article to understand how a hovercraft works:
  Wikipedia contributors, 2007. "Hovercraft," *Wikipedia, The Free Encyclopedia* [accessed October 6, 2007] http://en.wikipedia.org/w/index.php?title=Hovercraft&oldid=164570589
- There are many designs for balloon hovercrafts, here are three design sources for this project:
  - Questacon, 2007. "CD Balloon Hovercraft," Questacon, The National Science and Technology Centre: Canberra, Australia. [accessed October 6, 2007] http://www.questacon.edu.au/html/squad_activities/forces_cd_hovercraft.html
  - CUED, n.d. "Balloon Hovercraft," Cambridge University Engineering Department (CUED), UK. [accessed October 6, 2007]http://www.eng.cam.ac.uk/outreach/CUEDresources/HoverMagic/instructions_balloons.pdf
  - MAKE, 2006. "Balloon Hovercrafts: Made!" MAKE Magazine. [accessed October 6, 2007]http://www.makezine.com/blog/archive/2006/10/balloon_hovercr.html
- Ready to scale up? Here are two designs for building a large hovercraft you can ride on:
  - Beaty, Bill, 1997. "Science Fair Project: Ultra-Simple Hovercraft can lift several adults!" Science Hobbyist: Seattle, WA. [accessed October 6, 2007]http://amasci.com/amateur/hovercft.html
  - Twofoos.com, 2005. "The DIY Hovercraft," Twofoos.com [accessed October 6, 2007] http://www.twofoos.com/hacks/hovercraft.html

Materials and Equipment

- Pop-top cap from a recycled plastic drinking bottle
- An old CD
- Craft glue
- Balloons of different sizes (small, medium, and large)
- Balloon pump (optional)
- Stopwatch
- Large flat surface for testing the hovercraft

Experimental Procedure

1. First you will construct the base of the hovercraft, so gather your supplies and prepare a craft space.
2. Remove a pop-up lid from a plastic drinking bottle.
3. Close the pop-top lid so that air cannot escape, and glue the base so the lid covers the hole in the center of the CD.
4. Allow the glue to dry completely. (Optional: You can make several of these if you like.)
5. Your complete design (with balloon attached) will look like this (Questacon, 2007):

6. Next you will test the hovercraft with your balloons of different sizes. Choose a very small balloon, a medium-sized balloon, and a large balloon for this part of the experiment
7. Blow up a balloon and pinch the neck so that no air can escape.
8. Stretch the neck of the balloon over the pop-top.
9. Place the CD hovercraft on a flat surface and prepare your timer.
10. Start your timer, open the pop top lid, and push the hovercraft. Stop the timer when the hovercraft stops hovering.
11. For each balloon you should do at least five timed trials. Record the time in seconds (s) for each trial in a data table:

Trial	Small Balloon	Medium Balloon	Large Balloon
#1			
#2			
#3			
#4			
#5			
TOTAL			
AVERAGE			

12. Calculate the average hover time in seconds for each sized balloon. Do this calculation by adding together the times of all five trials, and then dividing your answer by five.

13. Make a graph of your data. Make a scale of the "Average Hover Time in Seconds (s)" on the left side (y-axis) of the graph. Draw a bar for each balloon size up to the corresponding value, and be sure to label your columns.
14. Analyze your data and make your conclusions. Did you notice any trends? Which hovercraft hovered for the longest period of time? Why do you think this happened?

Variations

- You can also measure the volume of air inside each balloon to have a more quantitative test of the hovercraft. You can measure the volume of air in the balloon two ways:
    - Water displacement method - Dunk the filled balloon in a large metric measuring container . Subtract the initial water height from the final water height, and the answer will be equal to the volume of the balloon.
    - Air displacement method - Fill a large graduated cylinder with water in a large tub of water. Turn the cylinder bottom up and lift so that you can see the measurements, but keeping the opening of the cylinder under water so that the water will not escape. Place the pinched opening of the balloon near the opening of the cylinder and release the balloon so that the air travels up into the cylinder. When the balloon is finished draining air, record the volume of air trapped in the cylinder.
    - Geometric method (gives an estimate) - You can measure the circumference of the balloon, and estimate the volume of the balloon based on the formula for the volume of a sphere.
- Try testing the hovercraft on different surfaces. Which type of surface works best?
- What other hovercraft designs can you try? Can you scale up this design to make a larger hovercraft? Can you use the action of a hovercraft for any practical purpose, or to solve a problem?
- For more science project ideas in this area of science, see Aerodynamics & Hydrodynamics Project Ideas.

Credits

Sara Agee, Ph.D., Science Buddies

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Aero_p033.shtml

Two-Cell Battery

(www.teachengineering.org)

Grade Level: 3 - 5
Time Required: 60 minutes
Cost: $3.50 per group
Group Size: 3

Contributed by: TeachEngineering.org — Resources for K-12

This activity relates to the work of civil engineers and material scientists, like ScienceMakers ***Sossina Haile and Lonnie Johnson.***

Summary

Students build their own two-cell batteries. They also determine which electrolyte solution is best suited for making a battery.

Engineering Connection

For some engineers, designing amazing batteries is their specialty. Electrical engineers continually conduct research to improve the efficiency of rechargeable batteries that are used in laptops, cell phones, digital cameras and electric cars. Some engineers are developing extremely tiny batteries that are smaller than the width of a human hair. These batteries provide power for microelectromechanical systems (MEMS) located in devices for specialized use in the medical and aerospace industries.

Learning Objectives

After this activity, students should be able to:

- Describe the energy transformations that take place when a battery is connected in a circuit.
- Explain that an electrolyte is needed for a battery to produce current electricity.
- Construct and interpret a graph of current produced by a battery as a function of electrolyte concentration.

Materials List

Each group needs:

- 2 pieces aluminum foil: 8 in x 12 in (20 cm x 30 cm)
- 2 wide-mouth glass jars (must be able to hold at least 150 ml)
- 2 small paper cups (such as Dixie cups), cut at ¾ in from the cup bottom, or 2 plastic caps from milk jugs
- 3 pieces (one: 12 in [30 cm] and two: 31.5 in [80 cm]) of non-insulated copper wire (gauge AWG 20) (available at most hardware stores); a total of 75 in (200 cm) per group. Or, if you have insulated wire, it will work if you strip the insulation off the ends.
- masking tape
- wire cutters
- marking pens

- 1 Two-Cell Battery Worksheet

For a Battery Testing Station for the entire class to share:

- containers for the electrolyte solutions (must be able to hold at least 150 ml); wide-mouth glass jars work well
- electrolyte solutions (make in advance with water and vinegar, citrus juice [such as lemon] or salt; see Procedure section)
- a few graduated cylinders (10-25 ml) or liquid measuring cups or jars with volumes marked on the side
- 3 pairs of safety glasses or goggles
- 1 DC ammeter (to measure current in amperes) (available at most hardware or electronics shops)
- paper towels

For a Cleaning Station for the entire class to share:

- water and sink, or, if no drain is available, a large empty container to collect the used electrolyte solutions
- (optional) paper towels

Introduction/Motivation

(Before starting the activity, ask students to brainstorm.) From where does electricity come? (Possible ideas: A wall outlet, power plant, photovoltaic/solar cells, batteries, etc. If no student mentions a battery, ask them the next question.) Do you think electricity can come from a battery? (Answer: Yes) Have you ever wondered what is inside of a battery? How do engineers decide what liquid or paste to use in this can full of chemicals?

What is inside a battery that helps produce current electricity? (Possible ideas: Chemicals, paste or a bunch of electrons.) Well, inside a battery there are two metal plates or posts called electrodes where chemical reactions take place and produce electrons. Also inside is a solution called an electrolyte, which allows charge to move in the solution and balances the movement of electrons. During today's activity you will create your own two-cell batteries and learn how engineers determine what type of electrolyte is best to use in a batteries!

(Show students a battery.) Have you ever looked closely at a battery and seen a small number with the letter "V" next to it? What does the letter represent? (Answer: Volts). During today's activity, you will learn how to determine the number of volts a battery produces.

(Remind students.) Remember when we learned about atoms? Atoms are made of smaller parts called protons, neutrons and electrons. The electrons carry a negative electric charge, move from atom to atom, and create current electricity.

How many different applications can you think of that use batteries? (Listen to student ideas.) How do you think that engineers might be involved with batteries? (Listen to student ideas.) Well, engineers design all the types of batteries that we use every day. Some engineers conduct research to improve the efficiency of rechargeable batteries. Other engineers work to improve rechargeable lithium batteries that are used for laptops, digital cameras and electric cars so they last longer and are able to be re-charged for additional cycles. Other engineers also are developing an extremely small battery to power microelectromechanical systems (MEMS). MEMS devices, which are used in medical and aerospace industries, are smaller than the width of a human hair. That's a small battery!

Vocabulary/Definitions

ammeter: An instrument that measures electric current in amperes.
cations: An ion or group of ions having a positive charge and characteristically moving toward the negative electrode in electrolysis.
electrolyte: A material that dissolves in water, producing a solution that conducts electricity.
ion: An atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons.

Procedure

Background

A typical wet-cell battery has two terminals, a liquid electrolyte and two electrodes, called the anode and the cathode.

During this activity students make their own two-cell batteries with aluminum and copper electrodes immersed in a prepared electrolyte solution. We use two cells connected in series (one after the other) to make this battery because the voltage produced by each cell is so low; connecting the two cells in series doubles the voltage produced.

In each cell, the aluminum foil serves as the anode. The aluminum foil oxidizes, producing aluminum cations (Al3+) that go into the solution and leave the aluminum electrode with excess electrons. These electrons move through the foil in container A, up to the copper wire (which is connected to the ammeter), and through the ammeter to the coiled copper wire in container B.

In each cell, the copper wire is the cathode. Electrons combine with copper cations in the solution and form elemental copper. The same oxidation process takes place at the aluminum anode in container B as was described for container A. Therefore, there is a movement of electrons from the foil in container B through the copper wire to the coiled wire in container A. Again, these electrons combine with the copper cations in the solution in container A. The electrolyte in both cells serves to balance the movement of electrons by providing ions. Each cell produces a voltage of about 2 V, so the total voltage for the battery is about 4 V.

Before the Activity

- Cut two 8 in x 12 in (20 cm x 30 cm) pieces of aluminum foil for each team.
- Cut one 12 in (30 cm) piece and two 31.5 in (80 cm) pieces of wire for each team. Note that insulated wire can be used, as long as it is stripped at the ends.
- Decide which electrolytes to use. (Suggestion: For a class of 27 students working in nine teams of three students each, use three different electrolytes [vinegar, citrus juice, salt] in three different strengths [weak, medium, strong].)
- Prepare the electrolyte solutions, making about 400 mL of each solution. Make sure to label them. The whole class can use the same type of solution at different strengths, or different teams can have different types of solutions at a range of strengths (see examples below):
    - Weak solution: 5 ml (~1 teaspoon) of [vinegar or citrus juice or salt] for every 100 ml water
    - Medium solution: 15 ml (~1 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water
    - Strong solution: 40 ml (~2.5 tablespoon) of [vinegar or citrus juice or salt] for every 100 ml water
- If the number of teams is not a multiple of three (one team will use the weak solution, one will use the medium solution, and one will use the strong solution), prepare more electrolyte solutions for the remaining teams, making them incrementally stronger.

- Prepare a Battery Testing Station for the entire class to use: 3 pairs of goggles, a DC ammeter, graduated cylinders, all the containers of prepared electrolyte and paper towels.
- Set up a Cleaning Station.
- Make copies of the Two-Cell Battery Worksheet, one per team.

With the Students

Have each team construct their two-cell batteries at desks. After all the teams have finished, have the class gather around the battery testing station to observe what happens when electrolyte is added to each team's battery.

Constructing the Battery

1. Put a piece of tape on each glass container. Label one container A and the other B.
2. Have students roll each piece of foil so the long side of the roll is about 12 in (30 cm). Crumple about 1/4 of one end on each roll.
3. Place one aluminum foil roll in each container, placing the crumpled end on the bottom of the container. Carefully flatten the rolled part of the foil against the side of each container.
4. Place a paper cup bottom (or milk cap) on top of the crumpled foil in each container; the aluminum foil column should go up and around the side of the paper cup (or milk cap) (see Figure 1).
5. Carefully wind one end of the 12 in (30 cm) piece of copper wire around the top of the foil roll in container A. Make a couple winds with the wire to get a good connection. Leave the other end of the wire free.

Figure 1. The aluminum foil column (anode) crumpled at the bottom and covered by a paper cup bottom.
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6. Coil about 22-24 in (55-60 cm) of the 31.5 in (80 cm) piece of wire into a ball. Place this ball on top of the paper cup bottom in container B. Make sure the copper wire is not touching the aluminum foil.
7. Coil about 22-24 in (55-60 cm) of the second 31.5 in (80 cm) piece of wire into a ball. Place this ball on top of the paper cup bottom in container A. Make sure the copper wire is not touching the aluminum foil.
8. Carefully wind the free end of the third piece of copper wire (the 31.5 in wire in container A) around the top of the foil roll in container B. Again, make a couple winds with the wire to get a good connection.

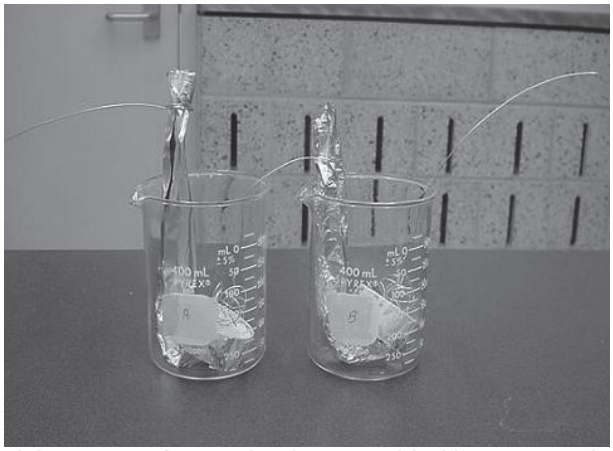

Figure 2. Activity set up: A completely assembled battery ready for testing.
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Testing the Battery. Repeat steps 9-15 for each team.

9. Have students wear goggles when they test their batteries.
10. Connect the free end of the wire from container A to one of the ammeter connections.
11. Connect the free end of the wire from container B to the other ammeter connection.
12. Obtain an electrolyte solution. Pour about 50 ml of the electrolyte solution into container A and about 50 ml of the same solution into container B. The solution should cover the wire coils in both containers completely; if not, carefully add more of the solution.
13. Measure the current produced by the battery using a DC ammeter. Have one student from each team record the electrolyte concentration and current.

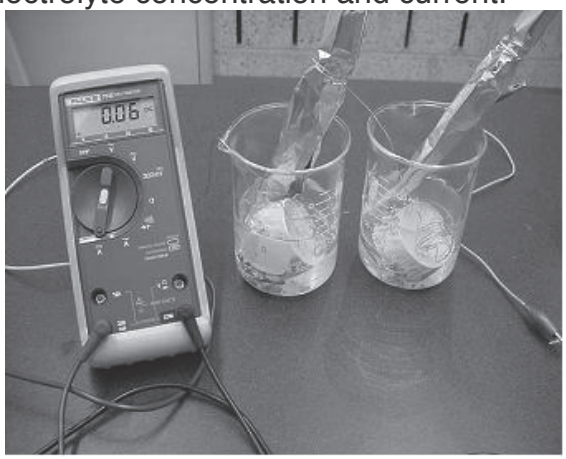

Figure 3. The current generated by an approximate 4mL/100mL solution of lemon juice. Disconnect the wires from the ammeter.
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14. Disconnect the wires from the ammeter
15. Pour the electrolyte solution back into its correct source container.
16. After all the students have tested their batteries, have each team disassemble their batteries. Have one member of each team take their materials to the Cleaning Station. Students should gently rinse containers A and B with a small amount of water. Pour this water in the sink or into a container provided for this purpose.
17. Have teams report the electrolyte concentration and current produced by their batteries on the board.
18. In teams, have students complete the Two-Cell Battery Worksheet.

19. As a math exercise, using the chart on the Two-Cell Battery Worksheet, have students construct graphs of current as a function of concentration and use the graphs to predict what the current might be at intermediate electrolyte concentrations.

Safety Issues

- Require students to wear safety goggles at the Battery Testing Station, in case any electrolyte splashes.
- Watch that students do not play with the copper wire, so they do not cut themselves or others.

Troubleshooting Tips

Make sure students do not touch the copper wire and the aluminum foil. If the copper wire and aluminum foil contact each other, it produces a short circuit (which is a low-resistance connection established by accident between two points in an electric circuit, causing the current to flow through the area of low resistance [aluminum to copper wire] and bypass the intended circuit [the solution]). If a short circuit is created, students will not get any current reading (0.00 A) or will not obtain an accurate current reading on the DC ammeter for the solution.

Be sure to prepare enough electrolyte solution. Some containers may need up to 200 mL of solution, depending on their size.

Assessment

Pre-Activity Assessment

Brainstorming: In small groups, have students engage in open discussion. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Encourage wild ideas and discourage criticism of any ideas. Ask the students:

- From where does electricity come? (Possible answers: A wall outlet, power plant, photovoltaic/solar cells, batteries, etc.)
- What is inside batteries that helps produce current electricity? (Possible answers: Chemicals, paste, or a bunch of electrons.)

Activity Embedded Assessment

Question/Answer: Ask students questions and have them raise their hands to respond. Write answers on the board and discuss as a class.

- What causes the needle to move on a DC ammeter? (Answer: Chemical energy in the battery is converted to electrical energy in the copper wire, which causes the needle to move on a DC ammeter.)

Worksheet/Pairs Check: Have one student from each team record on the board the electrolyte concentration and current while using the DC ammeter. Have students work in groups to answer questions on the Two-Cell Battery Worksheet. After student teams finish their worksheets, have them compare answers with a peer group, giving all students time to finish their worksheets.

Post-Activity Assessment

Question/Answer: Ask students questions and have them raise their hands to respond. Write answers on the board and discuss as a class. Ask the students:

- Explain the role of the aluminum foil and copper wire in the battery circuit. (Answer: Copper and aluminum are the electrodes in the battery. Chemical reactions take place at the electrodes producing electrons that move through the wires.)
- Was there an ammeter reading for the battery before you added electrolyte? (Answer: No. There is no ammeter reading for the battery until you add the electrolyte.)

- Which electrolyte solution produced the highest current reading? (Note: This depends on which electrolytes you use and on their concentration. Using a strong salt solution should give the highest current. A strong vinegar solution produces the next highest current.)
- Why do we need an electrolyte in a battery? (Answer: The electrolyte allows charge to move in the solution balancing the movement of electrons.)

Activity Extensions

After students have taken their last reading, have them add a teaspoon of baking soda (a base) to a container with an acidic solution. Have them record what happens to the ammeter reading.

Connect several batteries together in series using wires with alligator clips. How many batteries does it take to light a #40 light bulb?

Activity Scaling

- For lower grades, conduct the activity as described, but do not complete the worksheet. Instead, have students measure and record the battery current for each electrolyte using a DC ammeter. Then, have them explain which electrolyte concentration produces a battery with the highest current.
- For higher grades, have students measure current using a DC ammeter, complete the worksheet, and create graphs of current as a function of electrolyte concentration. Use the graph to predict the current at intermediate electrolyte concentrations. Ask students to draw conclusions about how the current produced by a battery depends on the concentration of the electrolyte in the battery.

References

Making a "Wet Cell" Battery, Grade 9 Lesson Plan, Renewable Energy, The Infinite Power of Texas, accessed March 2004. http://www.infinitepower.org/pdf/18-Lesson-Plan.pdf

Contributors

University of Colorado Boulder: Xochitl Zamora Thompson, Sabre Duren, Joe Friedrichsen, Daria Kotys-Schwartz, Malinda Schaefer Zarske, Denise W. Carlson (This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.)

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Team Name: _____ **Date:** _____

Two-Cell Battery Worksheet

1. In the space below, draw a sketch of your two-cell battery circuit. Label each cell of the battery, the aluminum anode and copper cathode in each cell, and the direction that electrons move in the circuit.

2. Complete the following chart using information from all the teams in your class.

Solution #	Electrolyte	Concentration	DC Ammeter Reading

3. Which solution produced the lowest current? Why?

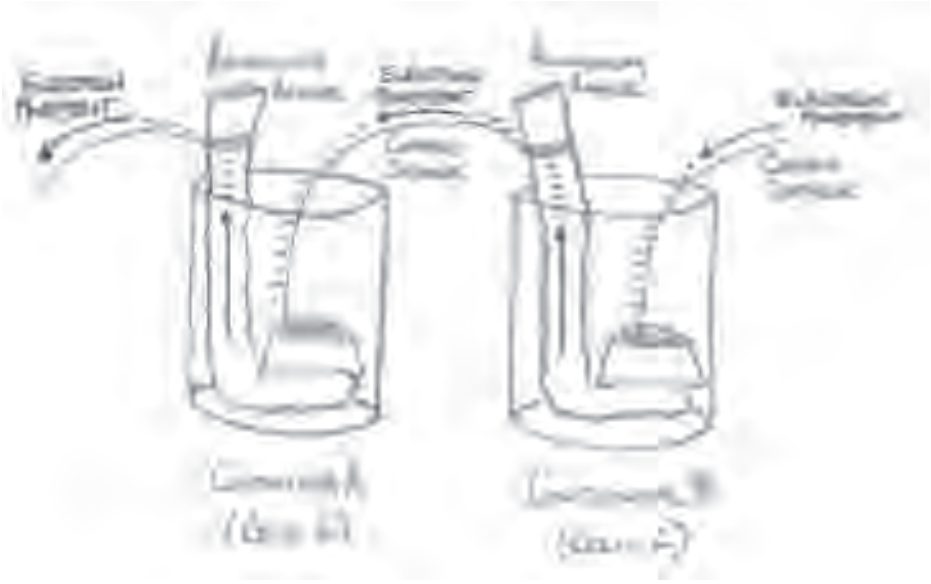
4. Which solution produced the highest current? Why?

5. Which solution made the best battery?

Team Name: _____ **Date:** _____

Two-Cell Battery Worksheet Answers

1. In the space below, draw a sketch of your two-cell battery circuit. Label each cell of the battery, the aluminum anode and copper cathode in each cell, and the direction that electrons move in the circuit.



2. Complete the following chart using information from all the teams in your class.

Below are some examples; other solutions can be used.

Solution #	Electrolyte	Concentration	DC Ammeter Reading
1	Water/Vinegar	5mL / 100mL solution of vinegar	-0.06 A
2	Water/Vinegar	25mL / 100mL solution of vinegar	-0.11 A
3	Water/Lemon Juice	5mL / 100mL solution of lemon juice	0.06 A
4	Water/Lemon Juice	15mL / 100mL solution of lemon juice	0.03 A

3. Which solution produced the lowest current? Why?

   15mL / 100mL solution of lemon juice

   This answer depends on which electrolytes you use and on their concentration. In this case, the lemon juice produced the lowest current because it had the lowest concentration of electrolytes.

4. Which solution produced the highest current? Why?

   25mL / 100mL solution of vinegar

   This answer depends on which electrolytes you use and on their concentration. In this case, the vinegar solution produced the highest current because it had the highest concentration of electrolytes.

5. Which solution made the best battery?

In this case, the Water/Vinegar solution made the best battery because it had the highest concentration of electrolytes. However, if the electrolyte concentrations are the same in each solution, the best battery will be made by the substance that can completely ionize (dissociate into ions) in water. In this case, a water/salt solution (strong electrolyte) will produce the highest current, followed by water/vinegar (weak electrolyte), and then water/citrus juice (weak electrolyte).

Note: All ionic compounds are strong electrolytes. Some acids and bases are strong electrolytes; many others are weak. Most other molecules are non-electrolytes.

Mathematics

Mathematics comes from the Greek word, μαθηματική (*mathēmatikē) and* means learning or knowledge. This scientific discipline investigates patterns and is the study of quantities, structures, and space. Mathematics uses rational arguments called proofs to explain solutions to problems instead of physical experiments like the natural sciences.

Mathematicians can study a diverse range of topics, from urban planners who develop cities to theoretical mathematicians who study abstract mathematical principles and develop new formulas. Mathematicians approach a problem logically and use formulas to explain relationships and make conjectures on how the world works**.**

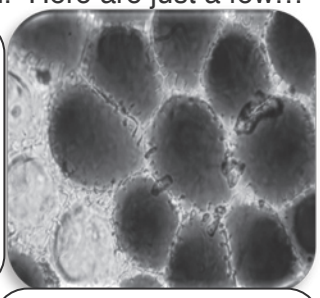
Studying mathematics helps the mind to reason and organize complicated problems into clear and logical steps. Mathematics can be applied to all other scientific fields and is also used across business and industry.

Mathematical Disciplines

Mathematics includes many exciting fields to study and research. Here are just a few…

Actuarial Science is a combination of math and statistics to assess risk in the finance and insurance fields.

Biomathematics is the interdisciplinary field that applies mathematical techniques to quantify biological processes.



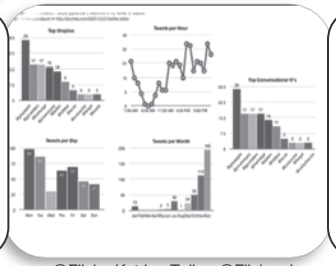
Cryptography uses mathematical techniques to insure secure communication; for example, protecting your bank information at the ATM machine.

Finance is the study of marketing and managing money through accounts in business. Models are made to predict the behavior of financial markets.

Game Theory is a mathematical method for analyzing calculated situations such as sports where a person's success is based upon the choices of others.

Operations Research is an interdisciplinary field that is focused on making the best decision to address problems, such as maximizing profits or minimizing costs.

Number Theory is the study of prime numbers as well as properties of integers.



Statistics involves the collection, organization, analysis, and interpretation of data from surveys and experiments.

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Career Paths in Mathematics

Mathematics covers a range of careers in many different areas. Below are just a few jobs open to those with a mathematics degree. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Mathematicians can work in settings such as schools, universities, and science centers.

- *Mathematics Professor*s work at a colleges and universities teaching and mentoring students, and conducting research. The Mathematics field can be broken down into two broad fields:
    1. *Theoretical Mathematicians* develop new principles and recognize new relationships between existing principles of mathematics.
    2. *Applied Mathematicians* use mathematical theory to solve real world problems.
- *High School Math Teachers* teach students about the foundations of math such as geometry, statistics, algebra, and calculus.

Business & Industry

Mathematicians work to make companies more efficient by improving systems and optimizing profits. They also build models to analyze financial markets, calculate costs, and predict trends in business.

- *Actuaries* manage risk in businesses by evaluating the likelihood of events and calculating the cost of different outcomes. They also assess the security of financial systems.
- *Air Traffic Controllers* coordinate the movement of air traffic to ensure that planes stay a safe distance apart. Their immediate concern is safety, but controllers also must direct planes and manage air traffic to minimize delays.
- *Foreign Exchange Traders* buy and sell currencies in different foreign exchange markets, taking into account factors that influence local economies and values of different currencies.

Government

Mathematicians design and analyze complex algorithms and work with difficult cryptographic problems. The National Security Agency (NSA) is the country's leading single employer of mathematicians.

- *Cryptoanalysts* design processes to solve problems and analyze secret coding systems for military, political, or law enforcement agencies. They also help protect people's privacy and keep hackers out of important computer systems.
- *Statisticians* gather and interpret data about all aspects of human populations through tools such as the U.S. Census.
- *Urban Planners* develop plans for land and growth of communities. They recommend locations for roads, businesses, and schools. They also forecast the future needs of the community.

Check Out Our Featured Mathematicians!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
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ScienceMakers Spotlight

Idris Assani

Theoretical Mathematician

Birth Place	Niger, West Africa
Education	University Paris Dauphine (M.S. 1981)
	University Paris 6 (Ph.D. 3eme Cycle 1981, Ph.D. Sciences 1986)
Awards & Achievements	National Science Foundation Research Grant (1990 to 1997)
	University of North Carolina "Favorite Faculty" Teaching Award (1996)

BIOGRAPHY

Idris Assani was the first black mathematics professor at the University of North Carolina, Chapel Hill. Assani was born in Niger, West Africa and grew up in Benin, West Africa. He later moved to France to pursue his education. Assani earned his M.S. degree from the University Paris Dauphine in 1981. He went on to receive his Ph.D. 3eme Cycle in 1981 and his Ph.D. Science in 1986 from University Paris 6. After receiving an invitation from the University of North Carolina, Assani came to the United States in 1988 with very little knowledge of the country and its culture.

Math
by trindade.joao@Flickr

Shortly after his arrival at the University of North Carolina mathematics department, Assani was recognized by the American Mathematical Society (AMS) Council for his work and mathematical abilities. In 1995, after a long legal battle to verify his qualifications as a foreign national, he finally was promoted to associate professor with tenure. As part of the legal settlement, Assani applied for promotion to full professor just one year later. On July 1, 1996, he achieved the rank of full professor. Assani wanted the university to benefit from his struggle, so he worked to increase the number of black graduate students in the math department. In addition to teaching and mentoring students, Assani conducted research and published many scientific papers. His research topics include Ergodic Theory and Dynamical Systems. The latter includes mathematical representations whose values change over time. The human heartbeat is an example of such a system. Ergodic theory has to do with predicting the behavior of a system by averaging every possible position that the system can take. It is often used in statistical thermodynamics, which mathematically examines the conversion of heat to energy. Assani has published many scientific papers and one book. Idris Assani lives in Chapel Hill, North Carolina.

Above Picture of Idris Assani from /math.unc.edu/people/images/copy_of_faculty/idrisassani.jpg/image_mini

SCIENCE IN ACTION

MATHEMATICAL MODELING

Clock Pendulum
by Krow10 @Flickr

Can a clock pendulum be represented by a mathematical model even though it doesn't move in a line? Idris Assani researches a concept called dynamical systems, which includes models of non-linear mathematical patterns such as the flow of water through a pipe, certain chemical reactions, human heart rhythms, and the swing of a clock. Dynamical systems can even be used to model the movements of players on a soccer field or the coordination between different parts of the leg while kicking the ball. All of these movements can be represented with mathematical rules that describe the position of a point in a geometric space at a given time.

DISCUSSION QUESTIONS

1. If you were to interview Idris Assani, what questions would you ask him?
2. Check out the PBS kids website (http://pbskids.org/cyberchase/find-it/math-and-sports/). What are three ways that math and sports collide?
3. The human heart beat is a dynamical system because its movement changes with time; it increases during exercise and decreases when a person is at rest. Can you think of three other patterns of movement that might be described by a dynamical system model?
4. Why is it important to predict with mathematical models how quickly a chemical reaction, such as fire burning, will take place?
5. How does Idris Assani's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Dynamical Systems - A mathematical representation of movement in which the value of the variable changes over time according to a fixed rule

Ergodic Theory - The branch of mathematics that predicts the behavior of dynamical systems

Ph.D. 3eme Cycle - A higher education degree in the French system; the third cycle refers to the Ph.D. degree as opposed to the B.S. or M.S. degrees

Ph.D. Science - A higher education degree in the French system which specifies the science discipline

Statistical Thermodynamics - The application of probability theory to the study of energy conversion between heat and mechanical work

Tenure - A lifelong appointment to a position not subject to dismissal except under serious circumstances

ScienceMakers Spotlight

Sylvia Bozeman

Mathematician & Educator

Birth Date	August 1, 1947
Birth Place	Camp Hill, Alabama
Education	Alabama A&M University (B.S. 1968)
	Vanderbilt University (M.S. 1970)
	Emory University (Ph.D. 1980)
Awards & Achievements	White House Initiative Faculty Award for Excellence in Science and Technology (1988)
	Tenneco United Negro College Fund Award for Excellence in Teaching (1988)
	American Association for the Advancement of Science Mentor Award (2008)

BIOGRAPHY

Sylvia Bozeman is known for her commitment to increasing the number of African American women with Ph.D. degrees in mathematics. She was born in Camp Hill, Alabama on August 1, 1947 and attended segregated schools growing up. Encouragement from her parents and a high school teacher led Bozeman to earn her B.S. degree in mathematics from Alabama A&M University in 1968. She received her M.S. degree from Vanderbilt University in 1970. At Vanderbuilt, Bozeman realized that her white classmates were better prepared in linear algebra during their college years.

After working briefly at Vanderbilt and Tennessee State University, Bozeman joined the faculty at Spelman College in 1994 while her husband was on the faculty at Morehouse College, also in Atlanta. At that time, Spelman was in the midst of building a strong mathematics program under the guidance of mathematician and chemist, Dr. Shirley McBay and mathematician, Dr. Etta Falconer. In 1976, Bozeman took a leave of absence to continue her education, earning her Ph.D. degree from Emory University in 1980. She returned to Spelman as an assistant professor in 1980 and was promoted to associate professor and full professor in 1984 and 1991, respectively. Bozeman's dedication to science and math education at Spelman contributed to the college earning a reputation as one of the best undergraduate mathematics programs in the country. In 1993, Bozeman began oversight of a $3 million grant to start a Center for Scientific Applications of Mathematics, which has focused on the practical and broad uses of mathematics. Bozeman co-directed the national program, Enhancing Diversity in Graduate Education (EDGE) from 1998 to 2011, a program that she co-founded to assist women in earning doctorate degrees in mathematics. In 1997, she was elected governor of the Southeastern section of the Mathematical Association of America (MAA), the first African American to be a section governor. Sylvia Bozeman lives in Atlanta with her husband. They have a son and a daughter.

Mathematics
by ptwo @Flickr

Above Picture of Sylvia Bozeman from www.aaas.org/aboutaaas/awards/mentor/mentor2008.shtml

SCIENCE IN ACTION

3-D VISION

Lawnmower Robot
by AuburnAlumniAssociation @Flickr

Robots and other visual navigation systems must be able to recognize three-dimensional shapes, such as cylinders and spheres, just like humans can. Since computers and machines do not have brains, scientists must provide instructions to the machines for them to do certain tasks. Those instructions came in the form of a mathematical algorithm, which Sylvia Bozeman helped to develop in 1989. Given range data, meaning how far away certain objects are, her algorithm can be used to identify lines and edges and determine the three-dimensional shape of an object. Bozeman conducted research on this technology that is used today in computerized visual systems, such as those in the land-rover robots studying the rocky, unpredictable surface of Mars.

DISCUSSION QUESTIONS

1. If you were to interview Sylvia Bozeman, what questions would you ask her?
2. Check out the Math is Fun website (http://www.mathsisfun.com/), recommended by the American Mathematical Society. How can doing math puzzles and games help strengthen your brain?
3. An algorithm is like a mathematical formula. Have you used any mathematical formulas in your classes at school?
4. Sylvia Bozeman helped increase the number of African American women in math through her work at Spelman College. Why is it important to bring women into a traditionally male-dominated field?
5. How does Sylvia Bozeman's career compare to that of other mathematicians or educators in the Toolkit?

GLOSSARY

Algorithm - An effective method for solving a problem, such as a calculation or data analysis, using a set of mathematical instructions

Etta Falconer (1933 - 2002) - Late Callaway Professor of Mathematics and Associate Provost for Science Programs and Policy at Spelman College; Sylvia Bozeman's mentor for over twenty-five years

Linear Algebra - A branch of mathematics concerned with vectors (a quantity with a number and a direction) and linear equations whose graphs represent a straight line

Shirley McBay (1935 -) - A ScienceMaker and educator who worked at Spelman College and the National Science Foundation (NSF) to improve the quality of mathematics and chemistry education

ScienceMakers Spotlight

James Curry

Applied Mathematician

Birth Place	Oakland, California
Education	University of California, Berkeley (B.S. 1970, M.S. 1971, Ph.D. 1976)

BIOGRAPHY

James Curry has used computer models to understand complex systems including weather patterns and mathematical equations. He was born in Oakland, California and became interested in mathematics after seeing fascinating symbols and equations in a physics book at age twelve. Curry was determined to learn calculus and understand the language of mathematics, and he received a lot of support from a high school math teacher. Curry also became interested in computers after working with one that was donated to his high school. After graduating from high school, Curry attended the University of California, Berkeley where he earned his B.S. degree in 1970. He went on to receive his M.S. and Ph.D. degrees in 1971 and 1976, respectively.

Equation
by Victorrochajr @Flickr

Curry conducted postdoctoral research at the National Center for Atmospheric Research in Boulder, Colorado, and it was there that he first encountered a supercomputer, a computer thousands of times more powerful than a desktop computer. Curry joined the faculty at the University of Colorado, Boulder after completing his postdoctoral research. He received money from the National Science Foundation (NSF) as part of a Minority Research Initiation grant. Curry used the money to fund his research project on computers. He investigated the role of computers in helping people to understand complicated topics like weather monitoring and mathematics theory. Curry's research focused on developing ways to solve nonlinear equations using a computer. A nonlinear equation is one whose graph does not make a straight line. He worked with scientists who study the ocean and atmosphere and helped them to answer questions about their work using mathematics and computers. Curry was promoted to full professor of mathematics at the University of Colorado, Boulder, and he became the associate director of the program in applied mathematics. James Curry works in Boulder, Colorado.

Above Picture of James Curry from www.math.buffalo.edu/mad/PEEPS/curry_jamesh.html

SCIENCE IN ACTION

MOTION IN THE OCEAN

Waves
by Mikebaird @Flickr

When you go to the beach, do the waves hit you at a steady pace or is it random? How can this be measured? Oceanographers often use equations to study the movement of water in the oceans. They may need to predict wave patterns in order for ships to sail safely. Sometimes ocean scientists also want to know in what direction a current of warm water will travel. There is also an equation that tells scientists how much carbon dioxide from the air is dissolving into our oceans. James Curry has used his mathematics and computer skills to solve equations that are interesting to oceanic and atmospheric scientists.

DISCUSSION QUESTIONS

1. If you were to interview James Curry, what questions would you ask him?
2. Visit the Vector Kids website (http://www.vectorkids.com/vkvariable.htm) and practice solving equations. This is similar to what James Curry does, but he uses computers.
3. Predicting ocean wave patterns can help ships to know which route to take. Who else might benefit from knowing how rough the waves will be?
4. James Curry studies the use of computers to understand complicated topics. Why is this important?
5. How does James Curry's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Calculus - A branch of mathematics that involves rates of change such as accelerations, curves, and slopes

Carbon Dioxide - A gas in the atmosphere made up of one carbon atom and two oxygen atoms

Current - A body of water or air moving in a definite direction

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Nonlinear Equations - An equation whose graph does not make a straight line

Oceanographer - A scientist who studies the physical and biological aspects of the Earth's oceans

Supercomputer - A computer that is many times more powerful than an average PC; used for very large calculations and data analysis like weather and climate modeling

ScienceMakers Spotlight

James Donaldson

Mathematician & University Administrator

Birth Year	1941
Birth Place	Madison County, Florida
Education	Lincoln University (A.B. 1961)
	University of Illinois (M.S. 1963, Ph.D. 1965)
Awards & Achievements	Lincoln University Alumni Achievement Award (1986)
	National Institute of Science Memorial Lecturer (1989)

BIOGRAPHY

James Donaldson is known for his leadership as dean of Howard University's College of Arts and Sciences, the largest college in the university. Donaldson was born in a rural setting in Madison County, Florida in 1941. His uncle supplemented his rural schoolhouse education by teaching him math, as well as how to read and write at a young age. After graduating from high school, Donaldson attended Lincoln University in Pennsylvania where he earned his A.B. degree in mathematics in 1961. He then went to the University of Illinois where he earned his M.S. and Ph.D. degrees in mathematics in 1963 and 1965, respectively.

Howard University by Kevin Coles @Flickr

After finishing his studies, Donaldson became an assistant professor of mathematics at Howard University in 1965. The following year, he moved to the University of Illinois, his alma mater, where he also served as an assistant professor. In 1969, Donaldson went to work at the University of New Mexico as an associate professor of mathematics. He returned to Howard in 1971, becoming chairman of the mathematics department, a position he held until 1990. During that time, Donaldson helped to develop the first Ph.D. degree-granting mathematics program at a historically black college or university (HBCU). He also held visiting professorships in New York and Italy. In 1995, he served as a member of the strategic planning initiative at Howard University and co-chaired the Core Curriculum Committee where he worked on mathematics curriculum development. Based on his leadership abilities, Donaldson was selected to be dean of the College of Arts and Sciences in 1999. Donaldson also served as the vice president of the board of trustees at Lincoln University. His research interest in mathematics involves differential equations. In addition to his administrative duties, Donaldson published over fifty research articles and served as a consultant for the National Research Council, the National Science Foundation (NSF), and the D.C. Public School System. James Donaldson works in Washington, D.C.

Above Picture of James Donaldson from www.coas.howard.edu/deans_biography.html

SCIENCE IN ACTION

HISTORICALLY BLACK COLLEGES AND UNIVERSITIES

Graduates
by stevendepolo @Flickr

James Donaldson is a dean at Howard University, the Historically Black College or University (HBCU) that started the first Ph.D. degree-granting mathematics program in the country. The United States' HBCUs were founded primarily after the American Civil War with the intention of serving the black community, but today the percentage of non-black student enrollments is increasing. There are over one hundred HBCUs in the country spread through about half of the states. Lincoln University, where James Donaldson earned his first degree, is an HBCU. Others include Tuskegee University, Spelman College, and North Carolina A&T State University.

DISCUSSION QUESTIONS

1. If you were to interview James Donaldson, what questions would you ask him?
2. James Donaldson earned his A.B. degree and now works at an HBCU. What do you think are some of the benefits of such schools?
3. Check out the mathematics lessons in this document (http://college.cengage.com/mathematics/larson/calculus_applied/6e/shared/appendices/appdx_c_sec_04.pdf). What are some real world situations that use differential equations?
4. James Donaldson's leadership abilities earned him a position as a dean at Howard University. What do you think are the qualities of a good leader and why are leaders important in a school setting?
5. How does James Donaldson's career compare to that of other mathematicians or administrators in the Toolkit?

GLOSSARY

Alma Mater - The institution or school from which a person graduated

American Civil War - The war between the northern U.S. states (usually known as the Union) and the Confederate states of the South between 1861 and 1865

Consultant - Someone who gives professional advice

Curriculum - The subjects comprising a course of study in a school or college

Differential Equation - A mathematical equation that describe the relationship between an unknown function and its derivative, which is a measure of the function's rate of change; an example of a differential equation is the equation representing the velocity of a ball when it is thrown up in the air

Historically Black Colleges and Universities (HBCUs) - A group of over one hundred higher education institutions in the United States that were established to serve the black community

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

ScienceMakers Spotlight

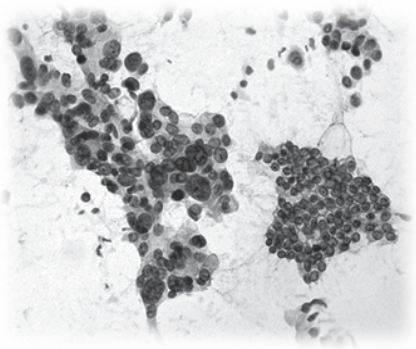
Nancy Glenn

Statistician

Birth Place	Charleston, South Carolina
Education	University of South Carolina (B.S. 1987, M.S. 1995)
	Rice University (Ph.D. 2002)

BIOGRAPHY

Nancy Glenn was the first African American to graduate with her Ph.D. in statistics from Rice University. Glenn was born in Charleston, South Carolina. After graduating from high school, Glenn attended the University of South Carolina where she earned her B.S. degree in mathematics in 1987. She continued her studies at the University of South Carolina and earned her M.S. degree in statistics in 1995. In 2002, Glenn earned her Ph.D. degree in statistics from Rice University in Houston, Texas. Her Ph.D. dissertation was about robust empirical likelihood, which is a statistical method of estimating a quantitative value.



Cancer Cells Vs. Normal Cells by euthman @Flickr

After finishing her studies, Glenn became an assistant professor in the Department of Statistics at her alma mater, the University of South Carolina. In 2006, she conducted research in the field of bioinformatics and contributed to several scientific research articles. One article examined the statistical patterns of cancer cell lines and another investigated the future of data analysis in evolutionary genomics, which is the study of how organisms' DNA changes during evolution. Glenn remained at the University of South Carolina until 2007 when she was hired as an assistant professor in the Department of Mathematical Sciences at Texas Southern University in Houston, Texas. Throughout her career, Glenn published many scientific articles, and she participated in several activities outside of her teaching career. Glenn was the Houston representative of the American Statistical Association, and she also served as a reviewer for several mathematical publications such as the *Journal of the American Statistical Association* and the *Journal of Probability and Statistical Science*. In her role as an educator, Glenn teaches and mentors many undergraduate and graduate students. Nancy Glenn works in Houston, Texas.

Above Picture of Nancy Glenn from www.math.buffalo.edu/mad/PEEPS/glenn_nancy.html

SCIENCE IN ACTION

STATISTICS AND DATA

Height Measurement
by Official U.S. Navy Imagery @Flickr

Usually when you do any kind of scientific experiment, you end up with data. Data are a set of values for something that you are trying to measure, such as the height of a plant, the rate of bacterial growth, or the speed at which a vehicle accelerates. Statisticians, like Nancy Glenn, analyze quantitative information in different ways. The most basic statistical analyses include taking the mean (average), median (middle value), and mode (range) of a set of values. Imagine you are comparing the heights of girls and boys in your class. First you would measure all girls and all boys, and take the average (mean) of each group. Then, by comparing those two values, you can conclude generally who is taller, the boys or the girls.

DISCUSSION QUESTIONS

1. If you were to interview Nancy Glenn, what questions would you ask her?
2. Check out Mapstats website for kids (http://www.fedstats.gov/kids/mapstats/). What statistics did you learn about the population and people of the United States?
3. A person's numerical height and weight are considered quantitative information. Can you think of two other ways that a person can be described quantitatively?
4. Nancy Glenn participated in activities outside of teaching. What have you learned from this Toolkit so far about what a university professor does?
5. How does Nancy Glenn's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Alma Mater - The institution or school from which a person graduated

Bioinformatics - The use of mathematics to solve problems of living systems such as the human body; often uses computers

Cancer Cell - Cells, or organism building blocks, that do not replicate like normal healthy cells; the growth of cancer cells is not tightly regulated leading to the buildup of diseased cells

DNA - Acronym; deoxyribonucleic acid; the genetic material of all living organisms

Evolutionary Genomics - The study of how organisms' DNA changes during evolution

Quantitative - Usually numerical values that tell us about an object or a system; A person's height would be quantitative, but the color of their shirt would be qualitative information

Statistics - A branch of mathematics which involves the collection, organization, analysis, and interpretation of data from surveys and experiments

ScienceMakers Spotlight

Evelyn Granville

Mathematician & Educator

Birth Date	May 1, 1924
Birth Place	Washington, D.C.
Education	Smith College (B.S. 1945)
	Yale University (M.S. 1946, Ph.D. 1949)
Awards & Achievements	2nd African American woman to earn her Ph.D. in mathematics (1949)

BIOGRAPHY

Evelyn Granville grew up during the Great Depression and she viewed mathematics and education as a means of opening doors and creating opportunity. Born on May 1, 1924 in Washington, D.C., Granville attended a segregated high school where she excelled in math. She decided to study math at Smith College in Massachusetts at the encouragement of her high school teacher. She earned a full scholarship and also worked at the National Bureau of Standards (now called the National Institute of Standards and Technology (NIST)) during the summers. Granville earned her B.S. degree in mathematics in 1945. She went on to earn her M.S. and Ph.D. degrees in mathematics and theoretical physics from Yale University in 1946 and 1949, respectively.

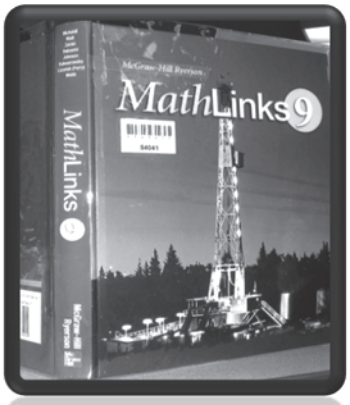
Ballistic Missile by U.S. Missile Defense Agency @Flickr

Granville's first job was as a part-time research assistant, but the next year, she was hired as an associate professor at Fisk University. She stayed at Fisk until 1952, when she took a job as a mathematician at the National Bureau of Standards in Washington, D.C. Her research group used math to investigate the workings of ballistic missiles, those that travel long distances to reach a specific target. Granville became interested in using computers to solve problems in science. Beginning in the mid 1950s, she worked for several different technology companies, including International Business Machines Corporation (IBM), Space Technology Laboratories, and North American Aviation (NAA). She returned to IBM in 1963 where she did research in trajectory analysis for NASA's Apollo Program. In 1967, Granville joined the faculty at California State University, Los Angeles, and also began a career in mathematics education and teacher training, during which time she co-wrote a math textbook for elementary school teachers. In 1985, after moving to Texas, Granville joined the faculty of Texas College. She then became a professor at the University of Texas, Tyler. Evelyn Granville lives in Texas.

Above Picture of Evelyn Granville from www.math.buffalo.edu/mad/PIX/granvilleevelyn-margemurray.jpg

SCIENCE IN ACTION

MATHEMATICS MADE EASY



Math Textbook
by Enokson @Flickr

When you open your math textbook, do you think about who wrote it? Scientific knowledge is extremely important, but so is the ability to communicate that knowledge to young people or non-scientists. Evelyn Granville was very good at explaining complex mathematical ideas in a way that is easy to understand. She used her skills to educate teachers about proper math instruction for kids and she even wrote a textbook for elementary school teachers. If you like science and communication, you may consider a career in science writing or education where you take complex scientific language and make it exciting and understandable to the public.

DISCUSSION QUESTIONS

1. If you were to interview Evelyn Granville, what questions would you ask her?
2. Check out the website for the National Institute of Standards and Technology (http://www.nist.gov/index.html). What kinds of work are done there?
3. Evelyn Granville worked on ballistic missiles at the National Bureau of Standards. Can you think of other defense-related research in which scientists participate?
4. Towards the end of her career, Evelyn Granville trained elementary school math teachers. What do you think makes a good math teacher?
5. How does Evelyn Granville's career compare to that of other mathematicians or educators in the Toolkit?

GLOSSARY

Ballistic Missile - A weapon often used in war that travels long distances to reach a specific target

Great Depression - A global economic decline that took place during the 1930s, where money lost value and unemployment rose by 25%

International Business Machines Corporation (IBM) - An American technology company that builds and sells computers

National Institute of Standards and Technology (NIST) - A U.S. Government agency that works with industry to develop and apply technology, measurements, and standards

North American Aviation (NAA) - An American company that built aircraft such as planes and space shuttles; now part of the Boeing Company

Theoretical Physics - The use of mathematical models and concepts of physics to explain and predict natural occurrences

Trajectory Analysis - Gathering information about the path of a projectile such as a ball thrown or a rocket ship launched

ScienceMakers Spotlight

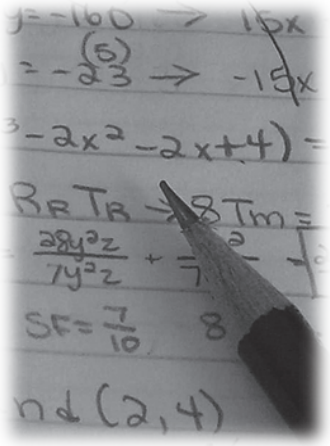
Gloria Conyers Hewitt

Mathematician

Birth Date	October 26, 1935
Birth Place	Sumter, South Carolina
Education	Fisk University (B.S. 1956)
	University of Washington, Seattle (M.S. 1960, Ph.D. 1962)
Awards & Achievements	Executive Council of Pi Mu Epsilon (national mathematics honorary society) (1972 to 1975)
	Mathematical Association of America Board of Governors (1995)

BIOGRAPHY

Gloria Conyers Hewitt was the fourth African American woman ever to earn her Ph.D. degree in mathematics. Hewitt was born on October 26, 1935 in Sumter, South Carolina. After graduating from high school, she was encouraged by her parents to attend college. Hewitt earned her B.S. degree in mathematics from Fisk University in 1956. She took to calculus during a Christmas break in college when she solved a complicated word problem after two weeks of work. Hewitt went on to earn her M.S. and Ph.D. degrees in mathematics from the University of Washington, Seattle in 1960 and 1962, respectively. Her thesis was called *Direct and Inverse Limits of Abstract Algebras.*



Algebra
by .raindrops.@Flickr

After earning her Ph.D. degree, Hewitt became an assistant professor at the University of Montana and was promoted to associate professor in 1966. In 1972, Hewitt earned the rank of full professor of mathematics. Between 1980 and 1981, she went on sabbatical at the Case Institute of Case Western Reserve University in order to conduct research. After experiencing an initial lack of respect from her white male colleagues at the University of Montana, Hewitt was able to show that her mathematical ability was more important than her race and sex in gaining recognition. She was named associate chair of the Department of Mathematical Science in 1993 and became chair two years later. Hewitt's research interests consisted of abstract algebras, including algebraic topology, group theory, and Noetherian Rings. In addition to her research, Hewitt is committed to increasing the number of minority students in mathematics. In 1992, she conducted a survey for the National Association of Mathematicians to gather statistics on the status and numbers of black mathematics graduate students. Gloria Conyers Hewitt lives in Missoula, Montana.

Above Picture of Gloria Conyers Hewitt from www.math.buffalo.edu/mad/PEEPS/hewitt_gloriac.html

SCIENCE IN ACTION

MATH GAMES

Rubik's Cube
by jekert gwapo@Flickr

Many common games and puzzles, like the Rubik's Cube, have foundations in mathematics. To solve a Rubik's Cube, you must arrange the square so that each side is one color. What does this have to do with mathematics? The solution is based on one of Gloria Hewitt's research topics called group theory, which is the algebraic study of transformations and symmetry. In other words, it examines ways that you can turn, rotate, or stretch one pattern back onto itself. By counting all possible twists and flips for each square, you can create mathematical formulas to help you find the solution. Trying to solve the cube by making random moves could take years!

DISCUSSION QUESTIONS

1. If you were to interview Gloria Conyers Hewitt, what questions would you ask her?
2. Check out the American Mathematical Society's website (http://www.ams.org/home/page). What did you find most interesting?
3. The Rubik's Cube is a popular puzzle. Can you think of other games or puzzles that exercise your mathematics skills?
4. Young Gloria Conyers Hewitt worked on one math problem for two weeks. Why is it important to never give up?
5. How does Gloria Conyers Hewitt's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Abstract Algebra - A branch of mathematics that involves the study of algebraic structures, such as rings, groups, and fields

Algebraic Topology - A branch of mathematics which uses tools from abstract algebra to study spaces which are formed by a set of points and satisfy a set of rules (topological space)

Calculus - A branch of mathematics that involves rates of change such as accelerations, curves, and slopes

Group Theory - In mathematics, the study of groups, or a mathematical set in which each element has an inverse; the algebraic study of transformations and symmetry

Noetherian Rings - Rings whose ideal conditions are not too large; expressed by a finiteness condition

Sabbatical - A period of paid leave for a college professor during which time they may travel or study

ScienceMakers Spotlight

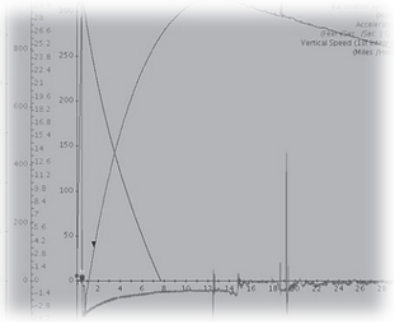
Fern Hunt

Applied Mathematician & Computer Scientist

Birth Place	New York, New York
Education	Bryn Mawr College (A.B.)
	New York University Courant Institute of Mathematics (M.S., Ph.D. 1978)
Awards & Achievements	National Science Foundation Career Advancement Award (1989 -1990)
	Arthur S. Flemming Award for Outstanding Federal Service (2000)
	Chicago Museum of Science and Industry Modern Leonardo Selection (2006)

BIOGRAPHY

Fern Hunt is a top research mathematician at the National Institute of Standards and Technology (NIST). She was born in New York, New York and after graduating from high school, she went to college at the encouragement of her mother. Hunt earned her A.B. degree in mathematics from Bryn Mawr College and then entered New York University's Courant Institute of Mathematics where she earned her M.S. degree. In 1978, Hunt received her Ph.D. degree in mathematics, also from the Courant Institute.



Mathematical Modeling by jurvetson @Flickr

Hunt started working in academia, first at the University of Utah. She later accepted a position in Howard University's mathematics department as an assistant professor. From 1981 to 1982, Hunt worked in the mathematical biology laboratory at the National Institutes of Health (NIH). She served as a consultant for the National Bureau of Standards between 1986 and 1991. In 1993, Hunt left Howard to start her career at the National Institute of Standards and Technology in the computing and applied mathematics laboratory. Hunt is interested in applied probability and dynamical systems, which are mathematical models that describe different kinds of movement. She also worked on modeling the Barkhausen Effect, a mathematical principal that is used to describe the materials composing the black strip on ATM cards. Hunt also conducted research in biomathematics to look at genetic variation and patterns in bacteria. Throughout her career, Hunt has received grant funding to conduct research and she has written numerous scientific articles. In addition to her work at the National Institute of Standards and Technology, Hunt is active in the scientific and local communities. She is involved with several professional mathematical societies and has served as a consultant for organizations like the U.S. Department of Energy (DOE). Fern Hunt works in Gaithersburg, Maryland.

Above Picture of Fern Hunt from www.thebannekerinstitute.org/resources/featured-scientist/fern-y-hunt/

SCIENCE IN ACTION

WHAT'S IN THE STRIP?

Debit Card by MoneyBlogNews @Flickr

Have you ever wondered how a swipe card works? All credit and debit cards have magnetic black strips that are "read" by a machine in order to process your payment. These strips are made of iron-based particles and each particle is actually a very small magnet, only about 20 millionths of an inch long. If the strip becomes dirty, bent, scratched, or exposed to another magnet, it may not work properly. There is a mathematical principle called the Barkhausen Effect, which is used to characterize the behavior of iron-based magnets that are used in magnetic strips. As part of her research, Fern Hunt created a mathematical model of the Barkhausen Effect.

DISCUSSION QUESTIONS

1. If you were to interview Fern Hunt, what questions would you ask her?
2. Check out the National High Magnetic Field Laboratory Website (http://www.magnet.fsu.edu/education/tutorials/java/barkhausen/index.html) and learn about the Barkhausen Effect using the interactive tutorial. What happens when you remove the iron core? Why do you think this happens?
3. Fern Hunt has done mathematical modeling of bacterial genetics. What else do you think can be modeled mathematically?
4. The National Institute of Standards and Technology helps industrial organizations around the country use new technologies. Why is it important to use technology?
5. How does Fern Hunt's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Barkhausen Effect - The specific reaction of an iron-based magnet when the magnetizing force applied to it is changed

Consultant - Someone who gives professional advice

Dynamical System - A mathematical representation of movement in which the value of the variable changes over time according to a fixed rule

National Institute of Standards and Technology (NIST) - A U.S. Government agency that works with industry to develop and apply technology, measurements, and standards

National Institutes of Health (NIH) - An agency in the Department of Health and Human Services whose mission is to employ science in the pursuit of knowledge to improve human health; the principal biomedical research agency of the federal government

Probability - The branch of mathematics that deals with quantities having random distributions

U.S. Department of Energy (DOE) - A U.S. Government agency that researches and oversees energy technology, energy conservation, and nuclear weapons

ScienceMakers Spotlight

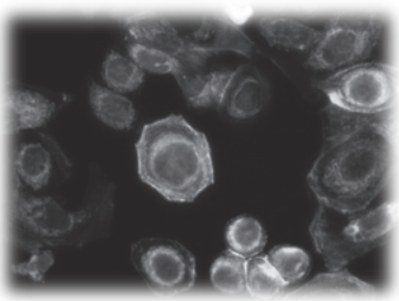
Trachette Jackson

Biomathematician

Birth Date	July 24, 1972
Education	Arizona State University (B.S. 1994)
	University of Washington (M.S. 1996, Ph.D. 1998)
Awards & Achievements	Alfred P. Sloan Research Fellowship in Mathematics (2003)
	James S. McDonnell 21st Century Scientist Award (2005)
	Blackwell Tapia Prize (2010)

BIOGRAPHY

Trachette Jackson graduated from a large public high school with a goal: to be the first person in her family to attend college. She is now a full professor of mathematics, the first African American female to have that title at the University of Michigan. Trachette Jackson was born on July 24, 1972. In high school, Jackson spent her summers at a math-science honors program at Arizona State University where she developed her passion for mathematics. In 1994, Jackson received her B.S. degree in mathematics from Arizona State University. She earned her M.S. and Ph.D. degrees from the University of Washington in 1996 and 1998, respectively.

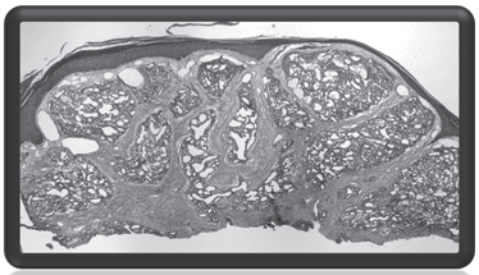


Breast Cancer Cells by GE Healthcare @Flickr

After completing her education, Jackson became an assistant professor at the University of Michigan. She was promoted to full professor eight years later. Jackson's interdisciplinary research in mathematical oncology is applying math to the study of cancer. The main focus of Jackson's research is combining mathematical modeling and in vivo tumor vascularization to gain deeper understanding of tumor growth and the vascular structure of molecular, cellular, and tissue levels. Jackson co-founded and co-directs the Mathematics Biology Research Group (MBRG). The group organizes lectures, conferences, and workshops for graduate students and postdoctoral researchers among other activities. She is also the co-principal investigator of the National Science Foundation (NSF)-funded University of Michigan SUBMERGE Program (Supplying Undergraduate Biology and Mathematics Education Research Group Experiences). It is an interdisciplinary program in math and biology that exposes undergraduates to experimental biology within mathematical modeling and gives exposure to quantitative analysis in biology courses. They also provide mentoring for the undergraduates using teams of faculty in each field. Jackson has published numerous papers on the subject of mathematical oncology and her work has received international attention. Trachette Jackson is married with two sons.

SCIENCE IN ACTION

APPLYING MATH TO FIGHT CANCER



Capillaries Inside a Tumor
by euthman @Flickr

If you were a scientist, how could you tell if a tumor was cancerous? Angiogenesis is the process of new blood vessels growing from pre-existing vessels. This is a normal and necessary process for growth and development. It also contributes to the healing of cuts and wounds. However, angiogenesis is also a fundamental step in a dormant tumor becoming a cancerous one. Jackson studies the progression of angiogenesis by quantifying the effect of different factors on capillary (tiny blood vessels) growth. She creates mathematical models to help decide which drugs would be best in clinical cancer trials.

DISCUSSION QUESTIONS

1. If you were to interview Trachette Jackson, what questions would you ask her?
2. Check out the Inside Cancer Website (http://www.insidecancer.org/). How does cancer begin in the human body?
3. Trachette Jackson applies mathematics to cancer research. Pick another field and describe how math is used, such as sports or business.
4. Trachette Jackson researches tumor growth, why is this important?
5. How does Trachette Jackson's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Angiogenesis - The development of new blood vessels

In Vivo - Experimentation or processes occurring within a living organism

Mathematical Modeling - A description of a system using mathematical language

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Principal Investigator (PI) - The lead scientist in a research laboratory or for a specific research project

Quantitative Analysis - Chemical analysis to determine the amounts of each element in the substance

Vascular - Containing vessels that carry or circulate fluids, such as blood, lymph, or sap, through the body of an animal or plant

Vascularization - The formation of vessels, especially blood vessels

ScienceMakers Spotlight

Raymond Johnson

Mathematician

Birth Date	June 25, 1943
Birth Place	Alice, Texas
Education	University of Texas (B.A. 1963)
	Rice University (Ph.D. 1969)
Awards & Achievements	Distinguished Minority Faculty (1986)
	AAAS Lifetime Mentor Award (2007)

BIOGRAPHY

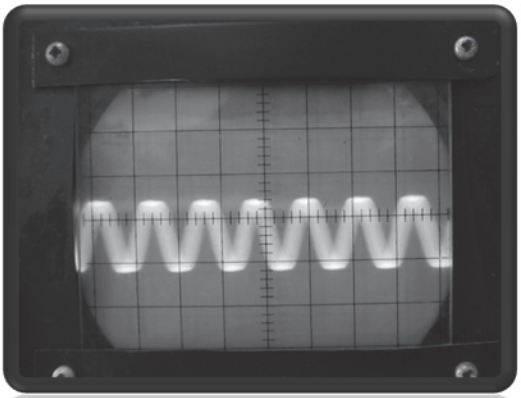
Raymond Johnson led the way for minority scientists by breaking through barriers and serving as a mentor. He was born on June 25, 1943 in Alice, Texas. Johnson attended a two room schoolhouse because the nearby grade school was segregated. In high school, Johnson excelled in mathematics and he majored in mathematics at the University of Texas where he received his B.A. degree in 1963. Johnson was the first African American to be admitted to Rice University. Two alumni sued the university to stop Johnson's entrance, but within the year, Rice University won the case and Johnson became a student, graduating with his Ph.D. degree in mathematics in 1969.

Rice University
by EFLON @Flickr

After college, Johnson started his forty year career at the University of Maryland beginning as an assistant professor in 1966. He was the first African American professor in the mathematics department. Johnson briefly left the University of Maryland to teach at Howard University, but then returned in 1978. Johnson was also a visiting professor at McMaster University from 1983 to 1984. Johnson served as chair of the graduate studies department at the University of Maryland from 1987 to 1990. As chair, he founded several programs to eliminate barriers for minority students and help increase the number of minorities and women in the Ph.D. program in mathematics. He was promoted to chair of the mathematics department in 1991, a position he held for five years. In 2009, Johnson returned to Rice University to serve as a visiting professor. Johnson has conducted research on harmonic analysis, the study of overlapping waves. He has contributed to over twenty-five publications on mathematics research. Raymond Johnson works in Houston, Texas.

SCIENCE IN ACTION

WAVES: MORE THAN YOU THINK



High Pitch Sound Wave
by tjmwatson @Flickr

What do you think of when you hear the word "wave;" A wave on a beach? A microwave? A radio wave? When Raymond Johnson hears the word wave, he probably thinks of harmonic analysis, the branch of mathematics that studies the representation of functions or signals as overlapping waves. A wave is a repeating disturbance or movement that transfers energy through matter or space. Both light and sound travel as waves. Waves have mathematical properties that can be analyzed to understand the motion of the wave. Harmonic analysis can be used to understand engineering concepts, as well as analysis of sound and image signals.

DISCUSSION QUESTIONS

1. If you were to interview Raymond Johnson, what questions would you ask him?
2. Check out the Physics Classroom website (http://www.physicsclassroom.com/class/waves/u10l1a.cfm) and learn about waves. What are some types of waves?
3. Is a sound wave faster than a light wave? Explain your answer and then do some research to see if you were correct.
4. Why do you think it is important to study waves?
5. How does Raymond Johnson's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Function - A mathematical relationship such that each element of a given set is associated with an element of another set

Harmonic Analysis - The branch of mathematics that involves the representation of functions or signals as overlapping waves

Wave - A repeating disturbance or movement that transfers energy through matter or space

ScienceMakers Spotlight

William Massey

Applied Mathematician

Birth Year	1956
Birth Place	Jefferson City, Missouri
Education	Princeton University (B.S. 1977)
	Stanford University (Ph.D. 1981)
Awards & Achievements	National Association for Mathematics Service Award (1996)
	W. Lincoln Hawkins Mentoring Excellence Award at Bell Laboratories (1997)
	Blackwell -Tapia Prize (2006)

BIOGRAPHY

William Massey is known for his leadership and innovation in modeling and designing our modern communications system. He was born in 1956 in Jefferson City, Missouri. Massey's parents were both educators and his mother encouraged his love of math from a young age by creating math-related games for him. Massey continued to excel at mathematics, taking geometry and trigonometry classes at a St. Louis public high school. He attended Princeton University where he earned his A.B. degree in mathematics in 1977. Massey went on to receive his Ph.D. degree in mathematics from Stanford University in 1981. As a graduate student, Massey participated in the prestigious Cooperative Research Fellowship Program (CRFP) at Bell Laboratories which paid for his doctoral degree. His fellowship at Bell Laboratories introduced him to the world of applied mathematics and the mathematics behind communication systems called queuing theory.

Library Shelves by barbourians @Flickr

Massey's interest in the applied mathematics turned into a full time position at Bell Laboratories in 1981. Bell Laboratories was a major industrial research center in communications, and a large number of high-achieving African American scientists worked there. Massey became the first CRFP fellow to become a mentor for the fellowship program and wrote seven research publications with minority fellows. In 2001, he left Bell Laboratories after a twenty year career to work as the Edwin S. Wilsey Professor in the Department of Operations at Princeton University. Massey is a leading researcher in the field of queuing theory and in 2005, was the second most cited African American mathematician in the world according to *Journal of Blacks in Higher Education*. William Massey has presented at many conferences, served on the executive board of the National Association for Mathematics, and founded the annual Conference for African American Researchers in Mathematical Science. William Massey works in Princeton, New Jersey.

Above Picture of William Massey from www.princeton.edu/~wmassey/

SCIENCE IN ACTION

THE MATH BEHIND WAITING IN LINE

You Tube Website by Majento @Flickr

Queuing theory is a key mathematical theory tool used to solve many problems in the area of communications services. It can be applied to internet services like YouTube. Queuing theory is so important that the success of a wireless telephone provider could hinge on how well a company utilizes it. It is the mathematical description of waiting in lines. Queuing estimates the number of people who need a certain service and whether their collective demands will be met by available resources over a given period. This means that companies use queuing theory to predict which times will be busier or slower and to make sure there are enough resources.

DISCUSSION QUESTIONS

1. If you were to interview William Massey, what questions would you ask him?
2. Check out the Real Trees website (http://www.realtrees4kids.org/ninetwelve/supply.htm). Why is it important for businesses to think of supply and demand?
3. What time of day do you think the demand for websites like YouTube is greatest? Why?
4. Why do you think it is important for companies to use the queuing theory to predict how many people will use their services?
5. How does William Massey's career path compare to other mathematicians in the Toolkit?

GLOSSARY

Bell Laboratories - The research and development organization of Alcatel-Lucent and previously of the American Telephone & Telegraph Company (AT&T); also known as Bell Labs and formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories

Cited - Quoted from a book, author, or paper, especially a scholarly work

Journal of Blacks in Higher Education - A professional journal whose goal is to provide racial statistics on an institution-by-institution basis, which appears to have considerable competitive force in persuading American colleges and universities to more fully integrate their campuses

Queuing Theory - The branch of mathematics that estimates the number of people who need a certain service and whether their collective demands will be met by available resources over a given period

ScienceMakers Spotlight

Arlie Petters

Mathematician

Birth Date	February 8, 1964
Birth Place	Dangriga, Belize
Education	Hunter College (B.S./M.A. 1986)
	Massachusetts of Institute of Technology (Ph.D. 1991)
Awards & Achievements	Hunter College Hall of Fame (1998)
	Blackwell-Tapia Prize in the Mathematical Sciences (2004)
	Membership in the Most Excellent Order of the British Empire by the Queen of England (2008)

BIOGRAPHY

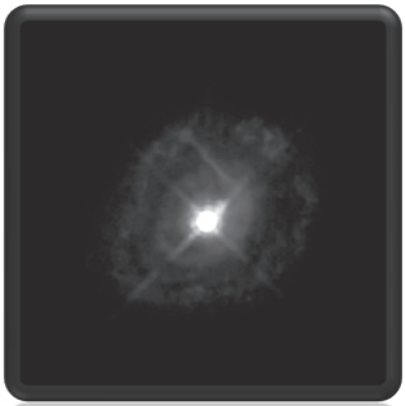
Arlie Petters is a modern day renaissance man with a triple appointment to the departments of mathematics, physics, and finance at Duke University. Petters was born on February 8, 1964 in Dangriga, Belize. As a child, he lived with his grandparents, and was captivated by the mystery of the skies. In 1979, Petters left Belize to live with his mother in the United States. After graduating from Canarsie High School in Brooklyn, Petters enrolled at Hunter College. Family problems left Petters homeless, but he received a Minority Access to Research Careers Fellowship that allowed him to stay in school. In 1986, Petters graduated with his B.A/M.A. interdisciplinary degrees in mathematics and physics. He continued his dual concentration in math and physics at the Massachusetts Institute of Technology (MIT), earning his Ph.D. degree in 1991.

Galaxy of Stars
by NASA Goddard Photo and Video @ Flickr

Following graduation, Petters became an instructor of pure math at MIT. In 1993, Petters joined the faculty of Princeton University as an assistant professor of mathematics. Five years later, Petters left Princeton for Duke University where he served as the William and Sue Gross Associate Professor. In 2003, he became a full professor, the first African American at Duke University to receive tenure. In 2009, Petters received a triple appointment to the departments of mathematics, physics, and business administration. Petters' research has focused on gravitational lensing, which is gravity's effect on light. He also teaches his students about science and technology entrepreneurship in developing countries like Belize. In 2005, Petters founded the Petters Research Institute to train Belizean students in the STEM disciplines. Since 2010, Petters has served as chairman on the Council of Science Advisors to the Prime Minister of Belize. Arlie Petters lives in Durham, North Carolina, but he visits his native Belize often.

SCIENCE IN ACTION

LIGHT'S JOURNEY FROM THE SUN



Black Hole in Space
by NASA Goddard Photo and Video @Flickr

After the sun, the nearest star is 4.2 light years or 40 trillion kilometers away. When you look up at that star in the night sky, it took 4.2 years for that light to reach the Earth. What forces affect the light on its long journey to Earth? Arlie Petters' research explores this question by studying gravity's effect on light. On a light's long journey, it can be bent by the gravity of a billion stars or deflected by a black hole whose gravity is so intense it bends passing light rays like a lens. An example similar to this on Earth is how light is deflected and focused when passing through water in a swimming pool.

DISCUSSION QUESTIONS

1. If you were to interview Arlie Petters, what questions would you ask him?
2. Check out the Jet Propulsion Laboratory's website (imagine.gsfc.nasa.gov/docs/features/news/grav_lens.html) to learn about gravitational lensing. What is the most interesting thing you learned?
3. Would you enjoy living in a world without gravity? Why or why not?
4. Arlie Petters studies gravitational lensing, which is important for our understanding of how lenses work. Can you think of three objects that use lenses?
5. How does Arlie Petters' career compare to that of other mathematicians?

GLOSSARY

Black Hole - A region of space with a gravitational field so strong that nothing can escape from it

Entrepreneurship - The process of undertaking innovative projects in business as well as organizing and managing those projects

Gravity - The force that attracts a body toward the center of the Earth or toward any other physical body having mass

Gravitational Lensing - The effect of gravity on light

Lens - A piece of glass or other clear substance with curved sides for concentrating or dispersing light rays

Tenure - A lifelong appointment to a position not subject to dismissal except under serious circumstances

ScienceMakers Spotlight

Donald St. Mary

Applied Mathematician

Birth Date	July 22, 1940
Birth Place	Lake Charles, Louisiana
Education	McNeese State College (B.S. 1962)
	University of Kansas (M.A. 1964)
	University of Nebraska (Ph.D. 1968)
Awards & Achievements	Third Annual Celebration of Black Scholarship Distinguished Scholar (1993)

BIOGRAPHY

Donald St. Mary has spent his long career in mathematics not only researching differential equations, but helping to increase the accessibility of STEM fields for minority students. He was born on July 22, 1940 in Lake Charles, Louisiana. In college, St. Mary pursued mathematics, receiving his B.S. degree from McNeese State College in 1962, his M.A. degree from the University of Kansas in 1964, and his Ph.D. degree from the University of Nebraska in 1968.

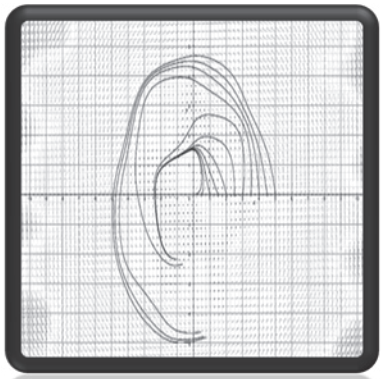
University of Massachusetts Amherst by jayhay312 @Flickr

Following his graduation in 1968, St. Mary joined the faculty of the University of Massachusetts, Amherst as an assistant professor in the mathematics department. He was promoted to associate professor in 1975, became full professor in 1983, and was appointed head of the Department of Mathematics and Statistics in 1994. St. Mary also served as a visiting professor at the University of Oklahoma in 1975 and at Yale University in 1989. He worked as a research associate for the Navy Summer Faculty Research Program, and from 1983 to 1987, he was a consultant for the Naval Underwater Systems Center. St. Mary's research focused on numerical analysis, differential equations, and underwater acoustics. During his over thirty years at the University of Massachusetts, he was very involved in university committees including the Multicultural Advisory Board and the Minority Graduate Student Recruitment Committee. St. Mary taught a wide range of courses from remedial mathematics to graduate level courses on applied mathematics. He created the Science Enrichment Program, a summer program for high school students designed to deepen their understanding of the sciences. He has presented his work at many conferences, including a presentation entitled, *Experiences of the Black Scientist*. Donald St. Mary lives in Amherst, Massachusetts.

Above Picture of Donald St. Mary from www.math.umass.edu/Directory/personal.html?email=stmary

SCIENCE IN ACTION

DIFFERENTIAL EQUATIONS



Drawing of a Differential Equation
by Ethan Hein @Flickr

An equation is a math sentence stating that the two sides are equal. For example, in the equation, x + 5 = 7, the only value for x is 2 because the two sides of the equation have to be equal. There are many different equations and each has a different way to solve it. The same applies for differential equations, which Donald St. Mary has studied. A differential equation is a mathematical equation for an unknown function. They are important in engineering, physics, and economics. Differential equations are often used when one quantity in the equation is constant and one quantity is variable, or changes depending on the situation. If you throw a ball in the air, the force of gravity remains the same, but the speed of the ball changes. Thus, it can be expressed as a differential equation.

DISCUSSION QUESTIONS

1. If you were to interview Donald St. Mary, what questions would you ask him?
2. Check out the Real World Applications of Mathematics video (http://www.youtube.com/watch?v=NFgfRAg7v-c). What are some applications of mathematics?
3. Donald St. Mary created programs to involve more minority students in the sciences. Write a short speech for a program for high school students on why becoming a mathematician would be a great career choice.
4. Donald St. Mary was very involved in university committees and conferences. Why do you think it is important for scientists to be involved in committees, panels, and conferences?
5. How does Donald St. Mary's career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Applied Mathematics - The use of mathematical principals to solve real world problems in the physical, biological, and sociological world

Differential Equation - A mathematical equation that describes the relationship between an unknown function and its derivative, which is a measure of the function's rate of change; an example of a differential equation is the equation representing the velocity of a ball when it is thrown up in the air

Numerical Analysis - The branch of mathematics that deals with the development and use of numerical methods for solving problems

Underwater Acoustics - The study of sound and the waves that make up sound in water

ScienceMakers Spotlight

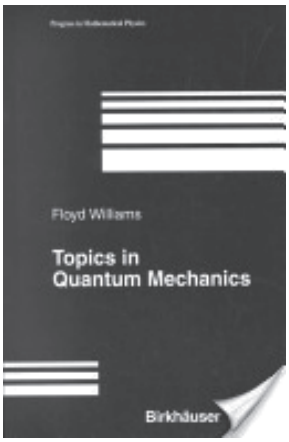
Floyd Williams

Mathematical Physicist

Birth Date	September 20, 1939
Birth Place	Kansas City, Missouri
Education	Lincoln University (B.Sc. 1962)
	Washington University (M.Sc. 1965, Ph.D. 1972)

BIOGRAPHY

Floyd Williams is known for his leadership in lie theory, an advanced mathematical theory concerning symmetry. Williams was born on September 20, 1939 in Kansas City, Missouri. In high school, he excelled in music, but mathematics was his worst subject. Williams did not think of going to college until his last week of high school when he was offered a music scholarship to Lincoln University. At Lincoln, Williams became interested in relativity, which drew him to study mathematics. He received his B.Sc. degree in mathematics in 1962. He went on to receive advanced degrees in mathematics from Washington University in St. Louis: his M.Sc. degree in 1965 and his Ph.D. degree in 1972.



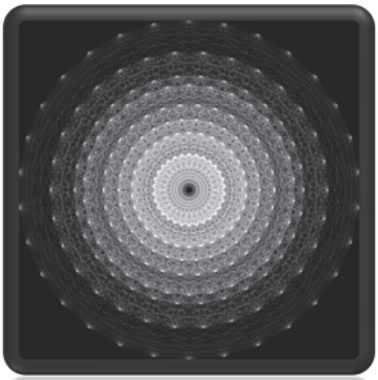
Floyd Williams' Book from booklens.com

From 1972 to 1975, Williams worked as a lecturer and instructor at Massachusetts Institute of Technology (MIT) as well as an associate instructor at the University of California, Irvine. In 1975, he joined the faculty of the University of Massachusetts, Amherst as an assistant professor. In 1978, Williams was promoted to associate professor and since 1984, he has been a full professor. In 1983, Williams received a National Science Foundation (NSF)-funded grant to continue his research in lie theory. Williams is internationally known for his research in lie theory and mathematical physics. He has served as a visiting professor at a number of universities across the United States and around the world including the State University of New York, Stoneybrook; Sophia University in Tokyo, Japan; the State Technical University in St. Petersburg, Russia; and the Institute of Theoretical Physics in San Paolo, Brazil. Since 2005, Williams has served as a professor emeritus at the University of Massachusetts, Amherst. He has published forty papers and four books including *Topics in Quantum Mechanics* and *Mathematical Methods in Physics*. Floyd Williams works in Amherst, Massachusetts.

Above Picture of Floyd Williams from math.umass.edu

SCIENCE IN ACTION

LIE GROUPS: THE BASIS FOR THE THEORY OF EVERYTHING?



Lie Group
by jared @Flickr

The entire universe can be described mathematically. Scientists are seeking one large mathematical theory to explain how everything works and how all forces are connected. Mathematicians like Floyd Williams study lie groups, a mathematical shape, which is a collection of circles twisting around each other in a specific pattern. The simplest lie group is a circle. To the left is an E8 Lee group where 248 circles twist around each other. Mathematicians and theoretical physicists are still developing theories, but the E8 lie group may serve as a model of how all the forces in the universe interrelate, from subatomic forces to gravitational forces.

DISCUSSION QUESTIONS

1. If you were to interview Floyd Williams, what questions would you ask him?
2. Check out the Science Channel Theory of Everything Video (http://science.discovery.com/videos/through-the-wormhole-2-theory-of-everything.html). Give two examples of mathematical patterns or shapes you can find in nature.
3. Floyd Williams studies mathematical physics. How are the field of mathematics and physics interrelated?
4. Mathematicians like Floyd Williams use mathematics to study physics and the workings of the universe. Why is this important?
5. How does Floyd Williams' career compare to that of other mathematicians in the Toolkit?

GLOSSARY

Lie Group - A mathematical shape which is a collection of circles twisting around each other in a specific pattern

Lie Theory - Advanced mathematics that deals with symmetry

Mathematical Physics - The development of mathematical methods, which can be applied to problems in physics

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Relativity - Either of two theories developed by Albert Einstein, the special theory of relativity, which requires that the laws of physics shall be the same as seen by any two different observers in uniform relative motion, and the general theory of relativity which considers observers with relative acceleration and leads to a theory of gravitation

Quantum Mechanics - The branch of mechanics that deals with the mathematical description of the motion and interaction of subatomic particles

20/20 Vision

(www.teachengineering.org)

Grade Level: 3 - 5
Time Required: 50 minutes
Cost: None
Group Size: 2

Contributed by: TeachEngineering.org — Resources for K-12

*This activity relates to the work of mathematicians and statisticians, like ScienceMakers **Sylvia Bozeman** and **Nancy Glenn**.*

Summary
Students determine their own eyesight and calculate what a good average eyesight value for the class would be. They learn about technologies to enhance eyesight and how engineers play an important role in the development of these technologies.

Engineering Connection
Engineers have created eye devices for people that have vision difficulties, including glasses and LASIK (Laser-Assisted In Situ Keratomileusis) eye surgery equipment. Electrical engineers have used their understanding of the eye to create a microchip that can be implanted into the back of the eye. The microchip works as a light sensor for people whose natural light sensor does not work.

Learning Objectives
After this activity, students should be able to:

- Describe vision.
- Explain how vision is measured.
- List several technologies designed by engineers to adjust/enhance vision.

Materials List
Each group needs:

- calculator
- 2 copies of the 20/20 Worksheet

Introduction/Motivation
Our eyes are an important part of our nervous system. What do we do with our eyes? We see the world around us! Why do we have two eyes? Well, two eyes help us see a larger area than just one eye. Each of our eyes sees an object from slightly different angles, allowing our brain to fit two images together to make a 3-D image in our head. These 3-D images help us judge the distance we are from the object. Does everybody see the same? Well, everybody's eyes have lenses that change shape when we focus on something. The lenses become rounder when we look at something close up and flatter when we look at something that is far away. However, not all eyes focus light rays exactly the same. How your eyes see something is called *vision*.

What does it mean to have 20/20 vision? Do you know? Having 20/20 vision means that when you stand 20 feet away from the chalkboard, you can see what the "average" person sees. If you have 20/40 vision, it means that you can only read the letters that someone with 20/20 or "normal" vision would read standing 40 feet away. This means that you actually have to be closer to the chalkboard to read it. Can you guess what having 20/100 vision means? It means that if you were standing 20 feet from the chalkboard you would see what an average person standing 100 feet away would see. You can also have vision that is better than average. If you had 20/10 vision, you would be able to stand 20 feet from the chalkboard and see what an average person sees when they stand 10 feet away from the chart. A hawk's vision is eight times better than a human's — that would be almost 20/2 vision!

The eye itself is a ball made up of three layers. The outside layer is made of two parts, the *clear cornea* (directly at the front of the eye) and the *white sclera* (gives the eyeball its shape). Beneath the outside layer is the middle layer, called the *iris*. The iris controls how much light enters the eye. It dilates to let more light in through the pupil and contracts to let in less light. The iris is pigmented and is what gives the eye its color.

In an attempt to see at 20/20, some people use glasses or contact lenses. There are also some technologies that have been developed with engineers to try and correct vision. One form of this is LASIK surgery. LASIK stands for "Laser-Assisted In Situ Keratomileusis" and is a procedure that permanently changes the shape of the cornea (the clear part on the front of the eye) by using a laser. The top surface of the cornea is cut and rolled back revealing the middle section of the cornea. A laser is used to vaporize a portion of the middle section, and the flap is then returned to its normal location over the eye. This allows the eye to change shape closer to the way an eye would in someone with 20/20 vision.

Today, we are going to learn what our own vision is. We are also going to look at the average vision of our entire class, and think about how engineers design technologies with vision in mind.

Procedure

Before the Activity

- Print out the Eye Chart
- Affix Eye Chart to the wall of the classroom, and mark a place on the floor that is 20 feet from the chart.
- Make enough copies of the 20/20 Worksheet for each student

With the Students

1. Ask students what they think 20/20 vision means. Help them brainstorm ideas.
2. Explain to the students that their job as engineers today will be to determine the average or "normal" eyesight for their class and then design a technology that has the class eyesight average in mind. The average will be done by recording the vision of everybody in the class.
3. Have students take turns standing at the 20-foot mark and identifying the smallest row on the eye chart that they can read with their right eye (cover up the left eye), then the left eye (cover up the right eye), then with both eyes together. The small number to the left of the row represents the denominator of the fraction. For example, if the last readable row has a 30 next to it, their vision would be 20/30. Note: If someone has glasses, they can try this experiment with their glasses both on and off.
4. Once each student has measurements for both of their eyes, have them find the average of the two eyes together on their worksheet. (Students can also compare this to the vision of both individual eyes. The results may or may not be the same.)
5. Next, give each student the data for each person in the class. (Note: copy the master sheet, put it up on a transparency, or write results on the board.) 6. Have the students calculate the

class average and write a paragraph explaining why they think designs could be based on the class average vision data.

6. Have students share their answer with a neighbor and then see if the class can come to a consensus.
7. With a neighbor, have the students brainstorm and sketch (if time) a new technology for the class that is based on the vision data. Tell the students that they are designing an electronic message board for the teacher to put up homework reminders, upcoming events for the school, and important class news. Have the students think about the average vision of the class, and use that to decide what the message board will look like and where in the classroom it should be placed. Have students share their ideas with the rest of the class.

Troubleshooting Tips

If you do not have 20 feet to work with, you can have students read the chart from 10 feet and then convert the fraction to 20 feet. For example, 10/40 would be 20/80.

Consider having one person record all of the data on the board or overhead for the rest of the class.

You may want to suggest to students ways of finding a "normal" value for the class. The mean (the average), median (the value in the exact middle of the data set), and mode (the most often occurring measurement) are good places to start.

Assessment

Pre-Activity Assessment

Discussion Questions: Solicit, integrate and summarize student responses. Ask the students:

- Why do we have two eyes instead of one?
- What is 20/20 vision?

Activity Embedded Assessment

Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Voting: Ask a true/false question and have students vote by holding thumbs up for true and thumbs down for false. Count the number of true and false and write the number on the board. Give the right answer.

- True or False: Vision is how someone sees something. (Answer: True)
- True or False: Everybody's eyes have lenses that change shape when we focus on something. (Answer: True, the lenses of our eyes become rounder when we look at something close up and flatter when we look at something that is far away.)
- True or False: The "average" person can see 20/30 vision (Answer: False, the average person sees with 20/20 vision.)
- True or False: The only way to correct vision is with glasses. (Answer: False, there are also some technologies that have been developed with engineers to try and correct vision, including LASIK eye surgery.)

Post-Activity Assessment

Class Presentation: Have the student groups present their electronic message board design to the rest of the class. Ask them to discuss why they chose the design they did and where they would place the message board in the classroom.

Informal Discussion: Solicit, integrate and summarize student responses.

- Ask the students to discuss why understanding vision and how the eye works is important to engineers.

Activity Extensions

Not all animals have 20/20 vision. For example, hawks see 8 times better than humans and a frog's eye has a special set of cells that responds to motion instead of light. Have students research how different animals "see."

Have students investigate the difference between nearsightedness and farsightedness.
Have students answer the question, "Is eating carrots good for your eyesight?" (Yes, it can be because carrots contain vitamin A, which is used to make pigments in the light-sensitive cells of the eye!)

Have students calculate their vision if the average is based on 100/100 vision. This would be accomplished by multiplying the fraction by another fraction to get the numerator to 100. For example, if a person has 20/40 vision, they would multiply that number by 5/5 to get 100/200.

References

International Society for the Enhancement of Eyesight, January 28, 2005 http://www.i-see.org/ - accessed May 30, 2006.

Contributors

University of Colorado Boulder: Joe Freidrichsen, Denali Lander, Malinda Schaefer Zarske, Janet Yowell (This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.)

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Names: _____ **Date:** _____

20/20 Worksheet

1) The vision in my left eye is : 20/_____(row number)

2) The vision in your right eye is : 20/_____ (row number)

3) Adding my answer from 1 with my answer from 2 gives me:
   20 + 20 = _____

4) Dividing the answer in 3 by two gives me: 40 ÷ 2 = _____
   This is my average eyesight for both eyes.

5) Is there a difference between your answers in number 4 and numbers 1 and 2? Why or why not?

_____

_____

_____

Record the average eyesight for everyone in the class in the chart below:

Person	Both Eyes	Person	Both Eyes
1	20/	18	20/
2	20/	19	20/
3	20/	20	20/
4	20/	21	20/
5	20/	22	20/
6	20/	23	20/
7	20/	24	20/
8	20/	25	20/
9	20/	26	20/
10	20/	27	20/
11	20/	28	20/
12	20/	29	20/
13	20/	30	20/
14	20/	31	20/
15	20/	32	20/
16	20/	33	20/
17	20/	34	20/

1) Using the vision data for the class, what is the average or “normal” vision?

_____

2) Why do you think new technologies for your classroom should be based on the class average for eyesight?

_____

_____

_____

3) You are an engineer who is designing an electronic message board in the classroom for the teacher to use for homework reminders, upcoming events for the school, and important class news. Using the average eyesight data for the class, brainstorm and design what the message board will look like and where in the classroom it should be placed. Draw a picture of your design in the space below.

20/20 Vision Activity – Eye Chart

Using a Snellen Eye Chart

The chart is usually read while standing at a distance of 20 feet. Acuity is represented as a fraction, with the distance at which you are standing being the numerator (top part of fraction), and the normal maximum legible viewing distance ("Distance" on the chart below) as the denominator (bottom of fraction). So if, at 20 feet, you can read the letters on the row marked “40,” this means you have visual acuity of 20/40 or better: 1/2 normal. From 10 feet, if the smallest letters you could read were on the “40” line, this would give you an acuity of 10/40: 1/4 normal. If you are nearsighted, your vision will become more normal the closer you stand to the chart.

Make your own eye chart!

For those enterprising souls out there who would like to laser print or draw by hand their own eye chart, or if you would like to verify that your printout is of the correct proportions, here are the specs:

Distance (feet)	70	60	50	40	30	20	15	10	7	4
letter ht (mm)	31	27	22	18	13	9	7	4	3	2
letter ht (pt)	88	76	63	50	38	25	19	13	9	5
font size (pt)	152	130	108	87	65	43	33	21	15	9

Interpreting the chart

“Distance” in the above table refers to the furthest distance from the chart at which a normal eye is able to read the letter. On a Snellen eye chart, row’s letters of a given size have the corresponding distance number next to them. Thus, row of 18mm letters is marked “40.” The font must be Courier (or Courier Bold) in order for the "font size" in points to correspond to the indicated letter height. Courier Bold is the PostScript font that most closely approximates the official Snellen letters.

Note: the top of the second page of the eye chart will need to be taped to the bottom of the first page of the eye chart (at the dotted line). Be sure to cover the dotted line with your paper.

Source: International Society for the Enhancement of Eyesight, January 28, 2005, http://www.i-see.org/, accessed May 30, 2006.

Tape here ↑

20 R X J B T I F P A

15 I R G H J D S E U O Q X

10 H N M K L D R T Y E W I O Q P R E

7 F D R T K S W Q I V D H K I U T X S B K D F E

4 B O F C P T E B L F B E Z C O P E

Classroom Triangles

(www.teachengineering.org)

Grade Level: 7 - 9
Time Required: 50 minutes
Cost: None
Group Size: 2

Contributed by: TeachEngineering.org — Resources K-12

*This activity relates to the work of mathematicians, like Sciencemaker **Arlie Petters**.*

Summary
Students use bearing measurements to triangulate and determine objects' locations. Working in teams of two or three, students must put on their investigative hats as they take bearing measurements to specified landmarks in their classroom (or other rooms in the school) from a "mystery location." With the extension activity, students are challenged with creating their own maps of the classroom or other school location and comparing it with their classmates' efforts.

Engineering Connection
Engineers use triangulation technology for many applications. For example, triangulation calculations are used for shape reconstruction of 3D geographic objects such as aquifers, ocean currents and weather fronts. Triangulation calculations are used in medical devices to detect heart rhythm disorders. Triangulation is also used in manufacturing or prototyping processes that create solid objects of polymer materials from the information provided on computer drawings.

Learning Objectives
After this activity, students should be able to:

- Describe how to use a compass to do triangulation and determine their location,
- Identify the intersection of two points,
- Determine a landmark on a map
- Explain the relationship between triangulation technology and other fields of study (such as mathematics)

Materials List
Each student needs:

- 1 copy of the Classroom Triangles Worksheet
- pencil
- graph paper
- ruler
- compass (students may share if necessary)
- tape measure (students may share if necessary)

Introduction/Motivation

You have a problem — you think. You know where "something" is, but you do not know where YOU are. So, how can you even begin to determine your location if you do not have a clue as to your whereabouts? You can use triangulation to determine your location. Triangulation is based on finding an unknown location using angle measurements to two known locations. Mathematically, the two known positions define the two vertices (and length of the one side) of a triangle, and the two bearing measurements define two of the angles of the triangle. To get a clearer picture of this process, assume you know where your home is, you know where the movie theatre is, but you do not know how to describe where your school is located. Luckily, you have a compass and a map. You can take a bearing measurement from the school to the cross streets nearest your home and the movie theatre, triangulate the two and determine the location of your school. If you can draw a straight line, then finding your school's location is as simple as 1,2,3!

If you are not lost, for what other reasons would you need to know about and how to take bearing measurements for the purpose of triangulation? Mountaineers, for example, need to know this information so that they may safely hike in the mountains and not get lost or put themselves in danger. Engineers use bearings to determine where to build roads, lay underground wires and pipes and construct bridges and dams. This activity teaches you how to take a bearing measure and apply triangulation to determine locations in the classroom. Afterwards, you should be able to use a map and a compass to determine many unknown locations.

Procedure

Before the Activity

- Take 3-4 bearing measurements to objects in the classroom from one location (important that you do this before your students begin this activity). Take three bearing measurements of each object from one "mystery" location that the students will try to figure out.
- Create a classroom map. On a piece of graph paper create a scale that maps one square of the paper to a reasonable length in the classroom. You can use a tape measure, or if there are square tiles on the floor, you can count tiles and fractions of a tile.
- Determine the direction to magnetic north in your classroom. Pick the wall that is most directly to the north as "classroom north." You should orient your classroom map so that the walls closest to north-south are on the left and right sides, and the closest to east-west walls are on the top and bottom. Draw a pseudo magnetic declination indication on your class map that shows which way magnetic north points with respect to your classroom north.
- Draw the outline of the room on the paper, and mark several fixed landmarks that are easy to sight. You can use things like the edge of a desk, the doorknob, a specific shelf of a bookshelf or the edge of the chalkboard. Alternatively you could hang up "markers" on the walls as your landmarks. Make sure that the landmarks are correctly placed on the classroom map, and make two or more copies for each team.
- Practice taking a bearing measurement from one location in the classroom to each of the landmarks, making the "declination" adjustment and figuring out where you are. Be sure to keep at least one "clean" copy of the classroom map, as you will be giving each student a copy. It is advised to make a teacher's copy which shows the bearings.

With the Students

1. Hand out a copy of the classroom map that you created.
2. Illustrate on the chalk/white board how to draw a bearing line on the map through the landmark and how to find the intersection of two bearing lines. Identify the x, y (horizontal and vertical) coordinates of the intersection, and show them the location in the classroom from where the measurements were taken. Have the students explain in their own words how to take a bearing.

3. Give the class the bearing measurements that you made from an interesting point in the classroom to three landmarks. Have the students work in teams of two or three to figure out the location using triangulation.
4. Hand out the Classroom Triangles Worksheet to each student.
5. Now have them use a compass to take their own bearing measurements to classroom landmarks, and mark their location on the worksheet. They can check their answers using a tape measure or by counting floor tiles.
6. Discuss the results of the activity. Ask students what they learned. Did they have trouble finding two or three bearings? Ask the students how they decided which landmarks to use. How did this affect their results? (Answer: If the landmarks are almost along the same line, you do not get very reliable results. If the landmarks are at close to 90 degrees apart, you get the best results.) If they sited to three landmarks, how big was their triangle that bounded their position?

Troubleshooting Tips
When you draw the classroom map, make sure to leave space between the walls and the edge of the paper. If the classroom is very skewed relative to north, it might be very confusing to take accurate bearing measurements.

Also when drawing the classroom map, select objects that are roughly at waist to chest level so that the students can easily take accurate bearing measurements. Use things like the edge of a desk, a specific shelf of bookshelf, the doorknob, or the edge of the chalkboard.

Assessment
Pre-Activity Assessment
Activity Review: With students, review activity topic and discuss findings as a class.
Review how to take a bearing. Pass out compasses to each student (or pair of students) and go over the steps of how to take a bearing, using the front of the classroom or the teacher's desk.
Have students volunteer to explain how to take a bearing in their own words.

Activity Embedded Assessment
Worksheet: Have the students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment
Pairs Check: After students finish working individually on worksheets, have them compare answers with a peer, giving all students time to finish the worksheet. Have them check for location accuracy using their compass and the known bearings.

Discussion/Questions: Ask the students and discuss as a class:
- What did you learn?
- Did you have trouble finding a location using two or three bearings?
- How did you decide which landmarks to use? How did this affect your results? (Answer: If the landmarks are almost along the same line, you do not get very reliable results. If the landmarks are at close to 90 degrees apart, you get the best results.)
- If you sited to three landmarks, how big was your triangle that bounded the position?

Hunt for Red October: Tell students about the movie "The Hunt for Red October." In this movie the submarine loses power to its navigation equipment. Using a map, one crew member gives the captain some bearings and distances to get them through a dangerous ravine. The crew member has to get his bearings just right or the submarine will crash. For this activity, have the students create their own

dangerous ravine trail map and write instructions for how someone could navigate through it. For example, if using graph paper, 1 block could equal 1 mile. The student's directions might read "First, go N40 for 6 blocks" and so on. Have the students exchange maps and see if they can follow each other's directions and make it through the ravine.

Activity Extensions
Working in teams of two, have students create a classroom map. On a piece of graph paper, have them create a scale that maps one square of the paper to a reasonable length in the classroom. They can use a tape measure, or if there are square tiles on the floor, have them count tiles and fractions of a tile. Have students indicate north on their maps and the location of different classroom objects and take the bearing measurement from specific locations. Students should compare maps with other teams and discuss their observations/measurements as a class.

Activity Scaling
For lower grades, have students work in groups to complete the worksheet.
For upper grades, have students work alone to complete the worksheet.

Contributors
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(This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.)

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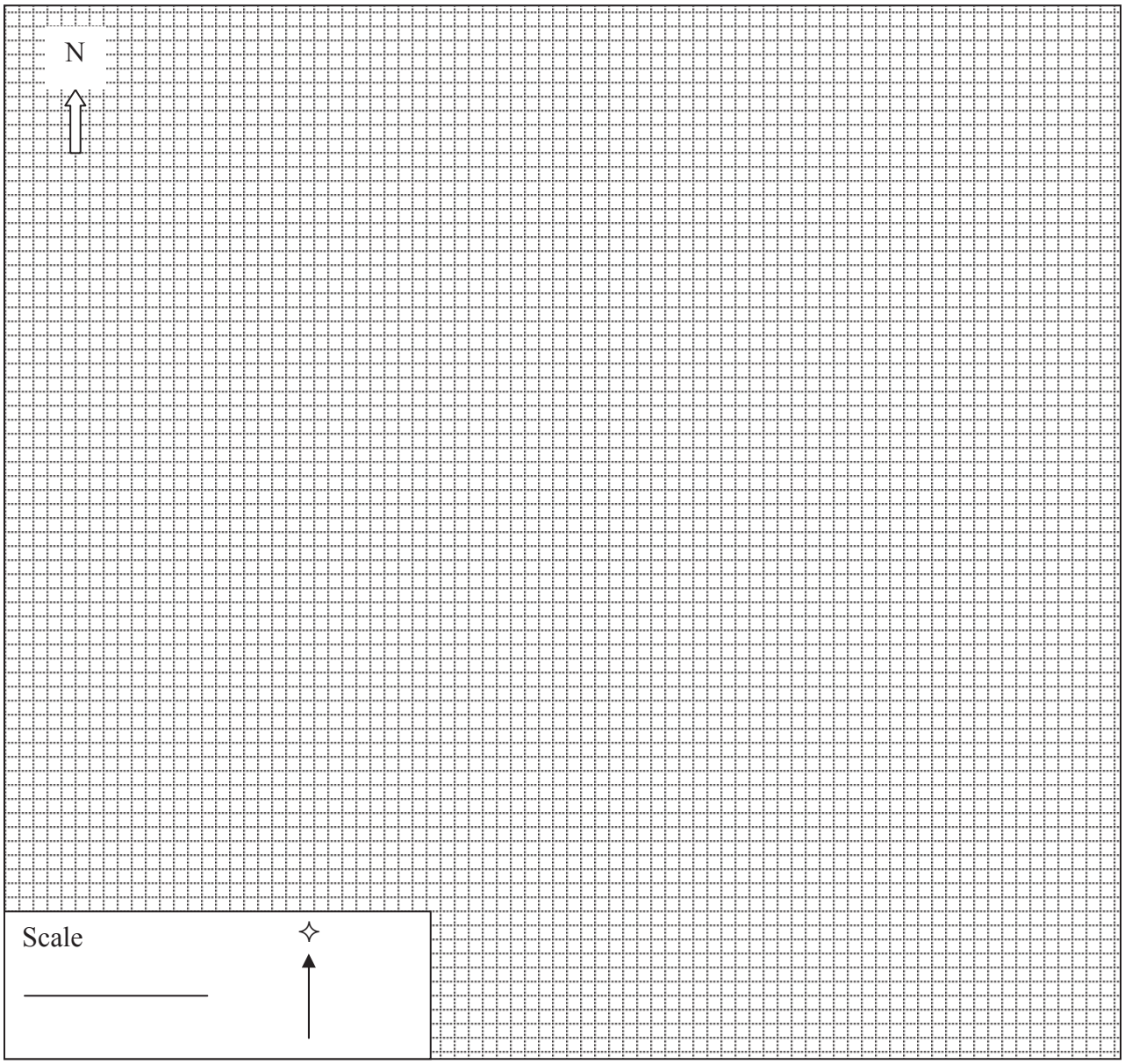
Name: _____ **Date:** _____

Classroom Triangles – Worksheet



Landmark 1_____Bearing_____Corrected bearing_____

Landmark 2_____Bearing_____Corrected bearing_____

Landmark 3_____Bearing_____Corrected bearing_____

Unknown location coordinates x =_____y =_____

Unknown location name _____

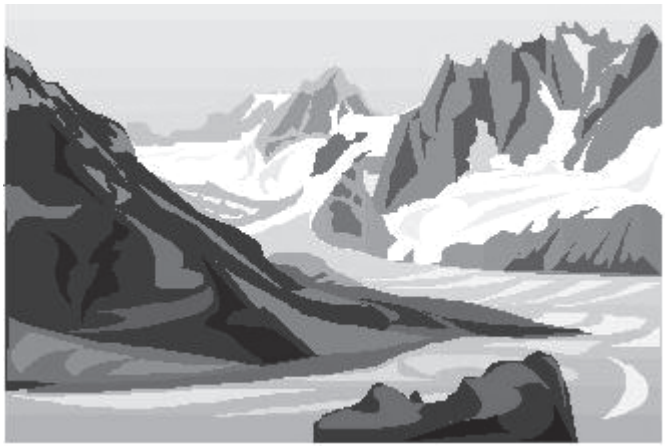
Trig River

(www.teachengineering.org)

Grade Level: 7 - 9
Time Required: 45 minutes
Cost: None
Group Size: 2

Contributed by: TeachEngineering.org — Resources for K-12

This activity relates to the work of mathematicians, like ScienceMakers ***Raymond Johnson and Arlie Petters****.*



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Summary
Students learn about and use a right triangle to determine the width of a "pretend" river. Working in teams, they estimate of the width of the river, measure it and compare their results with classmates.

Engineering Connection
Sometimes engineers cannot directly measure an object's size or distance because it would take too much time, or it is physically impossible (a tape measure to find the distance from the Earth to Pluto?). Instead of actually measuring a size or distance, engineers use trigonometry and other mathematical relationships to estimate it very accurately.

After this activity, students should be able to:

- Use right triangle trigonometry and angle measurements to calculate distances.
- Convert from US customary to metric units.
- Perform averaging and comparison of numbers.
- Explain how engineers use trigonometry and other mathematical relationships to estimate distances.

Materials List

Each group should have:

- A copy of the Trig River Worksheet
- A protractor (or printed copy of the attached Paper Half Protractor)
- 1 piece of string (6-inch long). Any long, very thin items could be substituted, such as spaghetti noodle, pipe cleaner, etc.
- pencil
- tape measure or meter stick (groups can share)

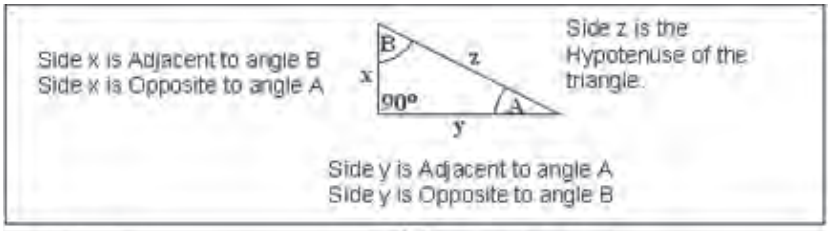
Introduction/Motivation

Is it possible to determine the width of a river without crossing it? (Answer: It is possible to come very close to determining the width of a river of any size, using triangles.) The same principle used to determine the width of a river can be applied to other situations, including determining the height of a hill, a tree or a building. The simple geometric shape that makes this all possible is the triangle. During this activity, you will learn how to use triangles to determine the width of a river.

Procedure

Background

Trigonometry is a branch of mathematics dealing with relationships between the angles and sides of triangles. The three basic trigonometric relations that we are concerned with in this activity are: sine, cosine, and tangent (abbreviated as sin, cos, and tan). They are the ratios of the lengths of two sides of a particular triangle. The type of triangle that is most useful to mathematics is a right triangle, which has one angle equal to 90º. By definition, the 90º-angle is made by two lines that are perpendicular to each other (like the corner of a square), and a sloping line connecting the two perpendicular lines makes the third side of the triangle. This sloping line is called the hypotenuse, and the name comes from the Greek hypo (meaning under) and teinein (meaning to stretch). It is easiest to show this visually:



For Angle A:

$$\sin(A) = \frac{\text{Opposite}}{\text{Hypotenuse}} = \frac{x}{z}$$

$$\cos(A) = \frac{\text{Adjacent}}{\text{Hypotenuse}} = \frac{y}{z}$$

$$\tan(A) = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{x}{y}$$

For Angle B:

$$\sin(B) = \frac{\text{Opposite}}{\text{Hypotenuse}} = \frac{y}{z}$$

$$\cos(B) = \frac{\text{Adjacent}}{\text{Hypotenuse}} = \frac{x}{z}$$

$$\tan(B) = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{y}{x}$$

The letters SOH CAH TOA can help students remember which sides go with which functions (Sine = Opposite / Hypotenuse, etc.). Mnemonics may help 6-8th graders memorize the relations: "Some Old Hag Caught A Hippie Tripping On Art" or "Some Oaf Happily Cut A Hole Through Our Apartment."

Before the Activity

1. Print out enough Trig River Worksheets for each student and the Paper Half Protractors, if enough protrators are not available for students to use/share.

2. Determine whether to conduct the activity indoors or outside.
3. Prepare or choose objects that can be used as markers and shore boundaries.

With the Students

Is it possible to determine the width of a river without crossing it? (Allow discussion and entertain any creative ideas: walk through the river, throw a rope across, use stepping-stones, etc. Then state that this river that does not allow solutions those solutions because it is too deep, the current is too swift, it is too wide, you do not have that tool, etc.) If a student knows about using triangles, have them explain as much as they can or introduce the idea and give a quick review of a right triangle — drawing and labeling it on the board.

Define a "river" for the students. For example, if working inside, rearrange desks to form the two "banks" of the river (with space for students to work on each "shore"). If working outside, choose a spot with two widely spaced (2-5 meters) and roughly parallel lines to define the "river" banks. For example, a wide sidewalk, two lines on a football field, or a strip of grass with straight edges. If a small "river" is being measured, have the students measure in centimeters, if a larger "river" is being used, have the students measure in meters. Because these are ratios of distance, the result at the end should have the same unit (meters, centimeters, etc.) used to make the initial measurement.

1. On one side of the river (as close to the middle of that side as possible, set an object that will be the Far Edge Marker. Normally this represents a tree right at the edge of the opposite side of the river.
2. Directly across from the marker, place a Zero Edge Marker (see Figure 1). All the students should be on this side of the river.
3. Lay the measuring tape along the "zero edge bank" with one end at the Zero Edge Marker and place a piece of tape every ½ meter on the river edge of the desks. Repeat this in the other direction (see Figure 1).
4. Give each student a worksheet.
5. Each student should make an estimate of how wide the river is and record it on the back of their worksheet (anywhere on the paper is acceptable).
6. Each group will work from a different tape mark. When both students of a group are at their disignated mark and have written on their worksheet the distance their tape is from the Zero Edge Marker, give each group a protractor.

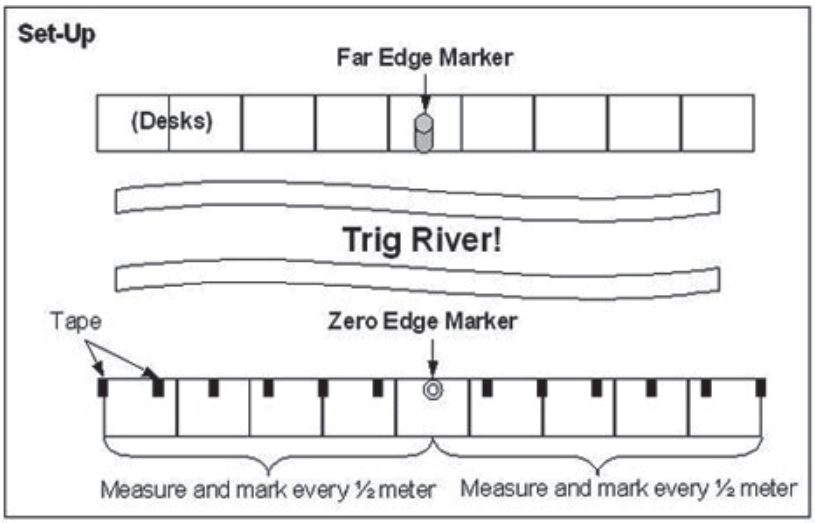


Figure 1. Set-up for angle measurement.

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7. Lay the protractor with the center point on the middle of the tape and the zero angle pointing toward the Zero Edge Marker (see Figure 2).

8. One student will hold the protractor in place while the other places one end of the string on the center point of the protractor and aims the other end at the Far Edge Marker. Read the angle the string passes over on the protractor (counting up from zero; this should not be more than 90 degrees), and record it on the worksheet. While the students do this, the teacher can measure the actual distance between the two markers; do not reveal the distance yet.
9. Partners switch jobs and record a second measurement on their worksheet.
10. Complete the worksheet calculations. (Leave the desks and markers in place.)
11. Have students compare their estimate of the river width to the actual measurement. How close was their estimate?
12. Have the students use both metric and English units to measure the distance from the zero marker. Compare the two results at the end.

Question and Answer #1: Were students who were closer to the zero marker more or less accurate than those further away? (Answer: Students close to the zero marker should be less accurate because the values of the tangents of angles close to 90° become large quickly and a small error in the angle measurement results in a large distance error. Note that the same problem would be seen as the measured angle approached zero degrees, but a student would have to be infinitely far away for that.)

Question and Answer #2: Could this measuring method be used in the wilderness if you did not have a calculator or Trig Tables? (Answer: It is not easy to memorize the tangent values for all angles but one value is very easy to remember: tan(45). Have the students find this value and then explain why they get a simple answer.)

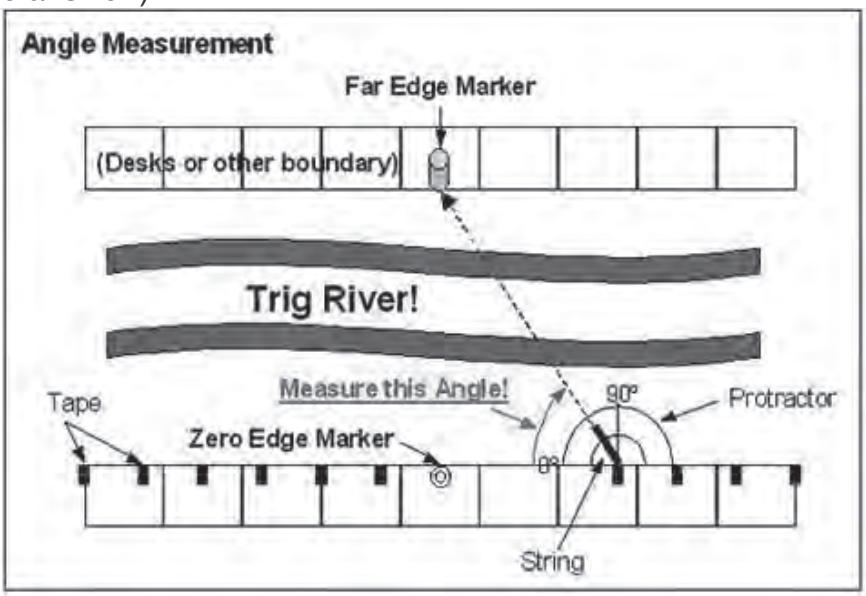

Figure 2. Angle measurement.

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Safety Issues

- Have students use caution not to bump heads when grouping up on taped marks; they may have to take turns if their tape marks are too close for a group of students.
- To avoid tripping over desk legs, students should be reminded to move carefully between the "banks" of the imaginary river.

Troubleshooting Tips

Students may get confused on the trigonometry involved in this activity. After all of the students have tried to figure out the distance across the river, choose one of the tape marks and have the class walk through the activity together for reinforcement.

Assessment

Pre-Activity Assessment

Discussion Question: Solicit, integrate and summarize student responses.
Is it possible to determine the width of a river without crossing it? (Allow discussion and entertain any creative ideas: walk through the river, throw a rope across, use stepping-stones, etc. Then state that this river does not allow those solutions because it is too deep, the current is too swift, it is too wide, you do not have that tool, etc.) See "With the Students" in the Procedure section.
Prediction: Have the students estimate how wide the river is and record predictions on the board.

Activity Embedded Assessment

Worksheet: Have the students complete the activity worksheet, Trig Calculations; review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Question/Answer: ask the students and discuss as a class:
Were students closer to the zero marker more or less accurate than those further away? (Answer: Students close to the zero marker should be less accurate because the values of the tangents of angles close to 90º become large quickly and a small error in the angle measurement results in a large distance error. Note that the same problem would be seen as the measured angle approached zero degrees, but a student would have to be infinitely far away for that.)
Could this method be used in the wilderness if you did not have a calculator or Trig Tables? (Answer: It is not easy to memorize the tangent values for all angles but one value is very easy to remember: tan(45). Have the students find this value and then explain why they get a simple answer.)

Activity Extensions

Using the following website, have students complete the navigation example using trigonometry: http://www.staff.vu.edu.au/mcaonline/units/trig/ratios.html.

Activity Scaling

- For lower grades, conduct the activity without step #12 in the Procedure section.
- For upper grades, have students determine the difference between their river estimate and the actual value. Then as a class, plot all the differences (in estimated vs. actual values) vs. the distances from the zero marker. Do the estimates become more or less accurate when measured near or far from the zero marker? Is there an optimal distance from the zero marker that minimizes the error?

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Contributors

University of Colorado Boulder: Jean Parks, Denise W. Carlson (This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.)

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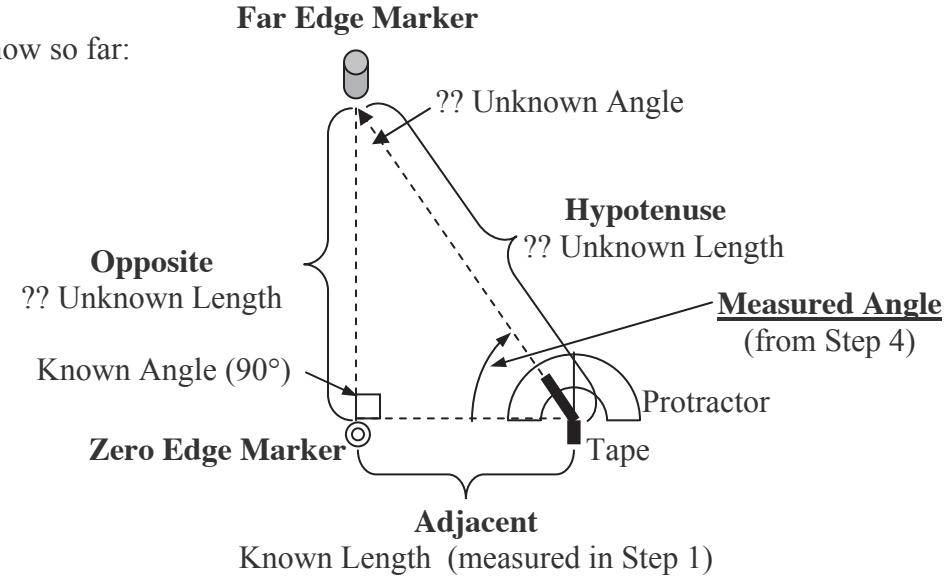
Name: _____ Date: _____

Trig River Worksheet

1. Your distance from the Zero Edge Marker: _____
2. 1st pencil angle measured on the protractor: _____ (degrees)
3. 2nd pencil angle measured on the protractor: _____ (degrees)
4. Find the *average* of these two angle measurements by adding them together and dividing by 2:

   (1st Angle) _____ + (2nd Angle) _____ = _____ ÷ 2 = _____ (degrees)

What we know so far:



We know the length of the side *Adjacent* to the measured angle, but we do not know the length of the side *Opposite* the angle or the length of the *Hypotenuse*.

5. Which of the trigonometric functions use the side we know and the side we want to know in our "river"?

   Circle one: **Sin = Opp / Hyp** **Cos= Adj / Hyp** **Tan= Opp / Adj**

6. What is the Tan of your measured angle (use a calculator or chart)? _____
7. Now you have one unknown in your equation, and you can solve it!

   Length of Adjacent Side x Tan value of your angle = Length of Opposite Side!

   _____ x _____ = ?

   Write your answer here: _____ .

Congratulations, you are a math wizard! Now you know the width of the Trig River!

Mathematics

Physics

Physics is the study of the nature and properties of matter and energy. It encompasses concepts such as forces, electricity, and pressure. Physics is made up of topics as large as the universe and as small as elementary particles like quarks and electrons.

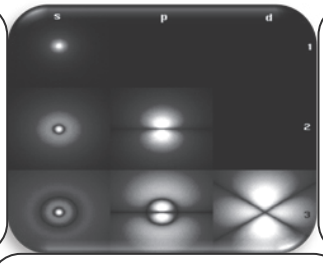
Physicists' ideas have led to many inventions from rocket ships to cell phones to microwaves. Physicists study a variety of topics related to matter and energy, including gravitational forces, optics, and magnetic fields.

Studying Physics teaches you to problem solve and think abstractly. It helps you to understand the basic forces that affect your everyday life, such as how electricity powers your computer and how gravitational pull keeps you on the ground.

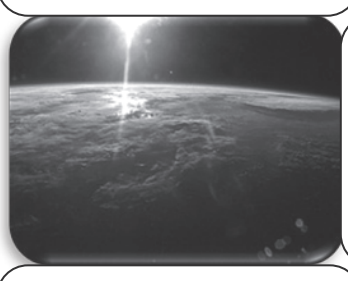
Physics Disciplines

Physics includes many exciting fields to study and research, below are just a few…

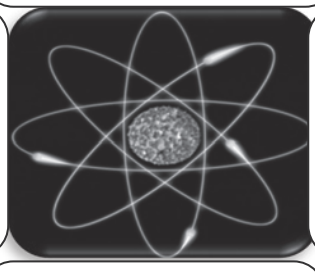
Atomic Physics is the study of atoms, especially the electrons surrounding the nucleus. It is focused on the movement of electrons and how their arrangement changes.



Condensed matter involves the physical properties of matter such as solids and liquids, states of matter in which molecules are more tightly packed than gases.



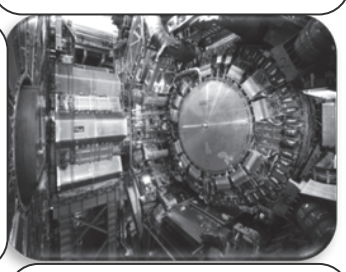
Geophysics is the study of the physics of the Earth. This includes its movement and the forces acting upon on the Earth, such as gravity and magnetic fields.



Nuclear physics is the study of the forces present in the atomic nuclei, the interactions between the atom's building blocks, and its applications to nuclear power.

Optics involves the behavior and properties of light. This includes how light interacts with matter and the construction of instruments to detect or utilize light.

Particle physics is the study of the small, basic elements of matter such as quarks and electrons and the forces acting among them.



Theoretical Physics uses mathematical models and concepts of physics to explain and predict natural occurrences.

Thermodynamics is the study of radiation and heat. It involves the relationships between temperature, volume, and pressure variables.

Photo credits from Top Left: Ethan Hein@flickr, DStarbuck@Flickr. Masterjack.roger@Flickr , Captain Narender@Flckr, Nauvasca@Flickr, Luke Hayfield Photography@Flickr, ianmunroe@flickr

Career Paths in Physics

Physics covers a range of careers in many different areas. Below are just a few jobs open to those with a degree in physics. See how each job fits into the larger career paths of Academia, Business & Industry, and Government

Academia

Physicists work in settings such as school classrooms, universities, research labs, science centers, and museums.

- *Physics Professors* at colleges and universities teach and mentor students and conduct research to further their field.
- *Physics Teachers* teach students in elementary school and high school. They introduce students to the basic concepts and laws of physics such as forces, gravity, weight, and pressure.
- *Research Scientists* work at research institutes developing new technologies and studying concepts such as electromagnetic fields and the rate the universe is expanding.

Business & Industry

Physicists work for companies that research, develop, manufacture, and test new products and technologies.

- *Radiation Protection Administrators* develop policies and asses radiation programs for technology companies. Radiation is a byproduct of many electronic devices and high levels of radiation can cause diseases such as cancer.
- *Medical Physicists* develop technologies, such as Magnetic Resonance Imaging (MRI) and radiation therapy, to detect and treat diseases like cancer.
- *Research and Development Physicists* apply their knowledge of physics to the development and improvement of consumer products, such as microwaves and televisions.

Government

Physicists work at research institutes, such as Argonne National Laboratory and Fermi Laboratory. They conduct research or serve as consultants for agencies such as the Department of Defense.

- *High Energy Particle Physicist*s work at particle accelerator labs studying what happens to charged particles at high speeds. This is often done to simulate the Big Bang Theory which explains how the universe was started with just a few particles.
- *Aircraft Instructors* teach United States Air Force pilots not only how to fly but about aerodynamics and the forces acting on an airplane.
- *Renewable Energy Developers* works to develop and improve renewable energy sources, such as solar, wind, and hydroelectric power from dams.

Check Out Our Featured Physicists!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
Ketevi Assamagan	Nuclear and Particle Physicist	Brookhaven National Laboratory	Particle Accelerators	265
Diola Bagayoko	Theoretical Physicist & Educator	Southern University, Baton Rouge	Minority Science Education	267
Hattie Carwell	Health Physicist	U.S. Department of Energy (DOE); National Technical Association	Energy Use	269
William Evans	Materials Scientist	Lawrence Livermore National Laboratory	Diamonds	271
Albert Green	Physicist & Business Executive	Kent Displays, Inc.	Liquid Crystal Displays (LCDs)	273
Paul Guèye	Nuclear Physicist	Hampton University	Cancer Treatment	275
Godfrey Gumbs	Nanophysicst	Hunter College - CUNY	Graphene	277
Carlos Handy	Physicist	Texas Southern University; Clark-Atlanta University	Wavelets	279
Wendell Hill	Optical Physicist	University of Maryland	Electromagnetic Radiation	281
Calvin Howell	Nuclear Physicist	Duke University	National Security Technology	283
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Alfred Msezane	Physicist	Clark Atlanta University	Electrons	287
Sekazi Mtingwa	Particle Physicist	Fermi National Accelerator Laboratory; Massachusetts Institute of Technology	Particle Accelerators	289
Homer Neal	High Energy Particle Physicist	University of Michigan	Large Hadron Colliders	291
Stephen Richardson	Physicist	Howard University; Naval Research Laboratory	Semiconductors	293
Carl Rouse	Astrophysicist	Lawrence Livermore National Laboratory; Rouse Research, Inc	Layers of the Sun	295
Arthur Thorpe	Solid State Physicist	Howard University	Superconductors	297

ScienceMakers Spotlight

Ketevi Assamagan

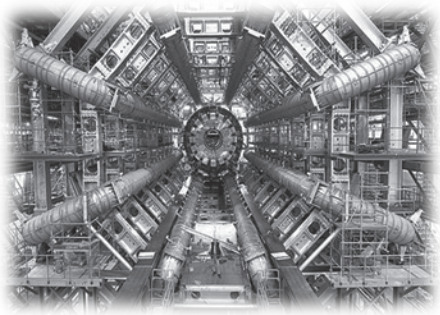
Nuclear & Particle Physicist

Birth Date	March 12, 1963
Birth Place	Gabon, West Africa
Education	University of Benin (Togo) (B.S. 1985)
	Ball State University (M.S. 1989)
	University of Virginia (Ph.D. 1995)
Awards & Achievements	Brookhaven National Laboratory Outstanding Mentor Award (2002)
	ATLAS Experiment Convenorship Award (2008)
	Brookhaven National Laboratory's ATLAS Experiment Primary Contact Person (2010)

BIOGRAPHY

Ketevi Assamagan has worked on the cutting edge of physics research both in Geneva, Switzerland, and for the U.S. Department of Energy (DOE). Assamagan was born on March 12, 1963 in the West African nation of Gabon. After graduating from high school, Assamagan attended the University of Benin in Togo, West Africa, where he earned his B.S. degree in 1985. He continued his education in the United States, earning his M.S. degree from Ball State University in 1989. Assamagan earned his Ph.D. degree in nuclear and particle physics from the University of Virginia in 1995.

After earning his Ph.D. degree, Assamagan became a postdoctoral research associate in the Jefferson Lab at Hampton University. There, he worked on a project called the spectrometer wire chamber, which helped gather information about light. Assamagan developed a system for the rotation and angular position of the spectrometer, which contributed to its data collection of certain properties of light. Assamagan remained at Hampton until 1998, when he took a position as a research associate at the European Center for Nuclear Research (CERN) in Geneva, Switzerland. From 1998 to 2001, Assamagan worked with CERN's particle accelerator to find the Higgs Boson, a large elementary particle whose existence has not yet been proven. It is thought to play a role in how other elementary particles get their masses. In 2001, Assamagan was hired by the U.S. Department of Energy's Brookhaven National Laboratory where he works on the ATLAS Project. The project hopes to detect new elementary particles using CERN's Particle accelerator. Assamagan has also supervised and mentored both graduate and undergraduate students. Additionally, he helped to organize the African School of Fundamental Physics, an educational workshop funded in part by Brookhaven National Laboratory. The workshop is intended to give students around the world and in Africa the resources and support that they need to be internationally competitive physicists. Ketevi Assamagan works in New York.

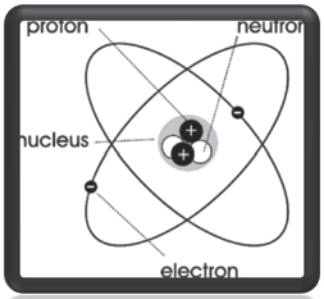


Large Hadron Collider by Image Editor @Flickr

Above Picture of Ketevi Assamagan from www.linkedin.com/pub/ketevi-assamagan/4/832/483

SCIENCE IN ACTION

ATOM SMASHERS



Particles
by lednichenkoolga @Flickr

Why are particle physicists sometimes called atom smashers? Particle physicists like Ketevi Assamagan work with particle accelerators, which are large machines that are designed to propel atomic particles in hopes of smashing them into smaller pieces. You may have heard of protons, neutrons, and electrons, but did you know that particle accelerators have helped scientists to discover smaller particles like fermions, quarks, leptons, and bosons? Atom smashing contributes to our understanding of the structure of matter, which is what our universe is composed of.

DISCUSSION QUESTIONS

1. If you were to interview Ketevi Assamagan, what questions would you ask him?
2. Check out the Particle Adventure website (http://particleadventure.org/). Can you find out what three elementary particles make up an atom?
3. Check out the U.S. Department of Energy website (http://energy.gov/). Would you like to work for this government agency?
4. Matter is any substance that has mass and takes up space. Why is it important that scientists and the public understand the particles that make up matter?
5. How does Ketevi Assamagan's career compare to that of other physicists in the Toolkit?

GLOSSARY

Elementary Particle - A particle that is smaller and less complex than an atom; what all matter is made of

European Center for Nuclear Research (CERN) - The world's largest particle physics laboratory located in Geneva, Switzerland where you can find the Large Hadron Collider, a particle accelerator that is 27 km in circumference

Higgs Boson - The Higgs Boson is a hypothetical elementary particle, no particles are yet known

Matter - A substance that has mass and takes up space

Nuclear Physics - The study of the forces present in the nucleus of an atom; the interactions between the atom's building blocks and its applications to nuclear power

Particle Accelerator - A scientific instrument that propels charged atomic particles by increasing their kinetic energy, or energy of motion

Particle Physics - The study of the small, basic elements of matter such as quarks and electrons and the forces acting among them

Spectrometer - A scientific instrument that measures the wavelength and intensity of light emitted by a material

U.S. Department of Energy (DOE) - A U.S. Government agency that researches and oversees energy technology, energy conservation, and nuclear weapons

ScienceMakers Spotlight

Diola Bagayoko

Theoretical Physicist & Educator

Education	Ecole Normale Superieure (B.S. 1973)
	Lehigh University (M.S. 1978)
	Louisiana State University (Ph.D. 1983)
Awards & Achievements	Louisiana Governor's Award for Excellence in Educational Reform (1993)
	U.S. Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring (1996)
	American Association for the Advancement of Science (AAAS) Mentor Award for Lifetime Achievement (2009)

BIOGRAPHY

Diola Bagayoko is well known for his extensive work in the field of science education, mentoring, and administration. Bagayoko earned his B.S. degree in chemistry and physics from the Ecole Normale Superieure (ENSup) in Mali, West Africa in 1973. Prior to that, he received formal training in the theory and practice of teaching and learning from ENSup. During his undergraduate education, Bagayoko also taught high school physics and chemistry in Sikasso, Mali, West Africa. In 1978, Bagayoko received his M.S. degree in solid state physics from Lehigh University, and in 1983, he earned his Ph.D. degree in theoretical solid state physics from Louisiana State University.

Science Students from 2011 ScienceMakers Public Program

After earning his Ph.D. degree, Bagayoko served as a physics lecturer at the University of Benghazi in Libya, North Africa. In 1984, Bagayoko became an assistant professor of physics at Southern University in Baton Rouge, Louisiana. He was promoted to associate professor in 1989. In 1990-91, Bagayoko established the nationally recognized Timbuktu Academy in Baton Rouge, using experience gained through his years of mentoring. The Timbuktu Academy is a program and resource center based at Southern University that offers pre-college and undergraduate students a chance to pursue scientific fields. Funding comes from the Office of Naval Research, the Department of the Navy, and the National Science Foundation (NSF), among others. Bagayoko has also served as director of the academy since its inception. In 1999, Bagayoko was promoted to distinguished professor of physics and beginning in 2002, he also served as adjunct professor of mathematics and science education. In addition to his teaching and mentoring, Bagayoko worked as a consultant for several organizations, including the Southern Regional Education Board (SREB) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Bagayoko has published over eighty scientific research articles on condensed matter physics and properties of metals, as well as over fifty papers concerning science education. Diola Bagayoko works in Baton Rouge, Louisiana, with his wife, who is also on the faculty at Southern University.

Above Picture of Diola Bagayoko from www. afrisciheroes.wordpress.com/tag/diola-bagayoko/

SCIENCE IN ACTION

MINORITY SCIENCE EDUCATION

Science Classroom
from 2011 ScienceMakers Public Program

According to the National Center for Education Statistics, during the 2008 - 2009 school year, there were more than 67,000 Ph.D. degrees granted in the United States. Just over 11, 000 of those went to minority students. This discrepancy is especially true of students in scientific fields. Fortunately, scientists and educators like Diola Bagayoko, are working hard to close that gap by promoting science education for minority students. His Timbuktu Academy reaches over 5,000 pre-college and undergraduate students and their parents per year. 93% of Timbuktu scholars are African American. In 2002, the Academy won the U.S. Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring.

DISCUSSION QUESTIONS

1. If you were to interview Diola Bagayoko, what questions would you ask him?
2. Check out The National Center for Education Statistics (http://nces.ed.gov/). What else did you learn about education in the United States?
3. Diola Bagayoko studied physics but dedicates much of his time to promoting science education. If you could enroll at his Timbuktu Academy, what would you study and why?
4. Diola Bagayoko has the ability to reach out to students not only academically, but on a personal level as well. Why is it important to have a mentor or teacher that you feel comfortable talking to?
5. How does Diola Bagayoko's career compare with that of other physicists in the Toolkit?

GLOSSARY

Condensed Matter Physics - The scientific study of the properties of solids, liquids, and other forms of matter in which atoms or particles are highly concentrated

Consultant - Someone who gives provisional advice

National Center For Education Statistics - A government agency that is responsible for collecting and analyzing data on education in the United States

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Solid State Physics - A branch of physics that involves the study of rigid matter, or solids, through various analytical methods

United Nations Educational, Scientific, and Cultural Organization (UNESCO) - A United Nations agency established in 1945 to promote the exchange of information, ideas, and culture

ScienceMakers Spotlight

Hattie Carwell

Health Physicist

Birth Place	Ashland, Virginia
Education	Bennett College for Women (B.S. 1971)
	Rutgers University (M.S. 1971)
Awards & Achievements	Bennett College Alumnae Achievement Award (1996)
	National Technical Association Outstanding Women in Science Award (1998)
	Benjamin Banneker Legacy Award (2007)

BIOGRAPHY

Hattie Carwell worked as a health physicist and group leader at the U.S. Department of Energy (DOE). Carwell grew up in a nurturing black community in Ashland, Virginia, which encouraged her interest in science. After graduating from high school in 1966, Carwell continued her studies at Bennett College for Women. She earned her B.S. degree in biology and chemistry in 1971. Carwell then received her M.S. degree in health physics from Rutgers State University of New Jersey. In 1991, she received an honorary doctorate from Bennett College.

Department of Energy Seal by DonkeyHotey @Flickr

In 1972, Carwell started her long career as a health physicist with the U.S. Department of Energy. From 1980 to 1985, she went on leave to Vienna, Austria, where she served as a nuclear safeguards inspector and group leader at the International Atomic Energy Agency. Some of Carwell's special assignments at the DOE included environmental surveying and waste management. In 1990, she became a program manager for high energy and nuclear programs with the DOE San Francisco Operations Office. She then became a senior facility operations engineer at the Berkeley Site Office in 1992. In 1994, Carwell was promoted to operations lead at the Berkeley Site Office, a position which she held until 2006. She became a senior physical scientist before retiring in 2008. In 2011, Carwell served as president of the National Technical Association. Throughout her career, Carwell has written numerous research articles and two books including, *Blacks in Science: Astrophysicist to Zoologist*. She also co-founded the Museum of African American Technology (MAAT) in Oakland, California. In addition to her work at the Department of Energy, Carwell spent much of her free time engaged in efforts to make science and engineering accessible to the community by organizing science fairs and writing science articles for the local newspaper. Carwell has also participated in outreach efforts in Africa where she worked to make Ghanaian villagers more self-sufficient. Hattie Carwell lives in Oakland, California.

Above Picture of Hattie Carwell from www.lbl.gov/Publications/Currents/Archive/Mar-18-2005.html

SCIENCE IN ACTION

ENERGY USE AND YOU

Wind Energy
by janie.hernandez55 @Flickr

Every day you use energy. Everything from riding on the school bus to washing your clothes to turning on the lights uses energy. Hattie Carwell worked for a government agency called the U.S. Department of Energy (DOE) that manages and supports our energy needs, making sure that we are using clean energy technology. The Department of Energy also keeps statistics on how much energy we use. For example, in 2009, each person in Illinois used 296 million BTUs of energy. A BTU is a unit of energy and equals approximately the amount of energy needed to heat 0.1198 gallons of water from 39°F to 40°F. One of Carwell's duties in the DOE was waste management, which can help with conserving energy.

DISCUSSION QUESTIONS

1. If you were to interview Hattie Carwell, what questions would you ask her?
2. Check out the U.S. Department of Energy website (http://energy.gov/maps/2009-energy-consumption-person) Find out the average energy consumption for your state. Then, compare your state's energy use to another state. Which state consumes more energy on average? Why do you think this is?
3. Hattie Carwell worked for the U.S. Department of Energy. Can you think of some of the times during the day that you use energy? How can you minimize the amount of energy you use?
4. Hattie Carwell has done outreach work in Africa, helping villagers become more self-sufficient. Why is this important?
5. How does Hattie Carwell's career compare to that of other physicists in the Toolkit?

GLOSSARY

BTU - Acronym; British Thermal Unit; a measure of energy that equals approximately the amount of energy needed to heat about 0.1198 gallons of water, from 39°F to 40°F

Health Physicist - A scientist who provides technical and safety information about how to handle materials used in facilities working with radiation energy

National Technical Association - A professional association of scientists and engineers, committed to ensuring that minorities, women, and youth have the skills needed for a technological workforce

U.S. Department of Energy (DOE) - A U.S. Government agency that researches and oversees energy technology, energy conservation, and nuclear weapons

ScienceMakers Spotlight

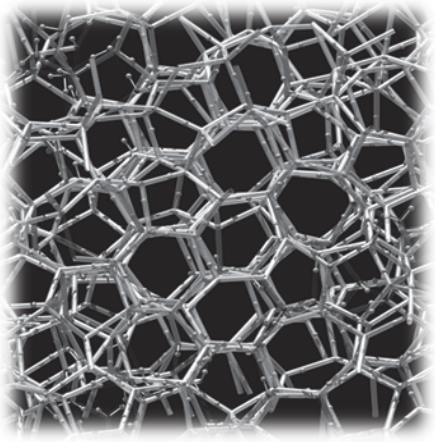
William Evans

Materials Scientist

Education	California Institute of Technology (B.S.)
	Harvard University (M.S., Ph.D.)
Awards & Achievements	Tau Beta Pi Honors Society

BIOGRAPHY

William Evans is a group leader of the high pressure physics group at the well-known Lawrence Livermore National Laboratory (LLNL). After graduating from high school, Evans attended the California Institute of Technology (Cal Tech) where he earned his B.S. degree in physics. He then went on to study at Harvard University, earning his M.S. degree and his Ph.D. degree in applied physics.



Physical Structure by vitroid@Flickr

In 1995, Evans began working at the Lawrence Livermore National Laboratory as a staff scientist. In 2008, he was promoted to group leader of the high pressure physics group at LLNL. The Lawrence Livermore National Laboratory is located in California and has a goal of ensuring the United States' nuclear, international, domestic, energy, and environmental security. LLNL scientists in multiple disciplines like biology, chemistry, and physics are using applied science and technology to solve world problems. Although Evans received his education in physics, his work at LLNL encompasses aspects of physics, chemistry, and materials science. He conducts research on ultra high-pressure diamond anvils, Raman spectroscopy, and X-ray scattering among other things. All of these research topics help Evans to understand the behavior of materials under high temperature and pressure conditions. For example, he and a team of LLNL scientists built an anvil, or pressure device, using flattened diamonds as the pressure surface. These diamond anvils allowed Evans to find out what happens to other materials as they get "squashed" by the diamonds. Evans has published numerous scientific research articles and is a member of several professional societies, including the American Physical Society (APS) and the American Chemical Society (ACS). Evans also serves the community by judging science fairs. William Evans works in Livermore, California.

Above Photo of William Evans from www.linkedin.com/in/wjevans

SCIENCE IN ACTION

DIAMONDS: MORE THAN JUST JEWELRY

Diamond
by jurvetson @Flickr

You have probably seen diamond rings and bracelets in jewelry shops, but did you know that diamonds are also used in science? William Evans and his team at LLNL use diamond anvils to apply pressure to other materials in order to study their physical and chemical properties. The diamond "squashing" surfaces are an important part of the anvil device because diamonds are the hardest known solids on Earth and they can withstand very high pressure. First, the tip of a diamond is polished down to a flat surface, and a small sample of material to be studied is placed between two flat diamonds. Pressure is applied, and changes in the material's structure and behavior are recorded.

DISCUSSION QUESTIONS

1. If you were to interview William Evans, what questions would you ask him?
2. Check out the Lawrence Livermore National Laboratory website (https://www.llnl.gov/). What kinds of security initiatives are happening at LLNL?
3. Diamonds are the hardest known solids on Earth. What other materials can you think of that are extremely hard?
4. At the Lawrence Livermore National Laboratory, different types of scientists work together on the same problem. Why is it important to have different perspectives when doing scientific research?
5. How does William Evans' career compare with that of other physicists in the Toolkit?

GLOSSARY

Diamond Anvil - A device that applies pressure to small samples in order to test the structure and behavior changes of the sample material

Lawrence Livermore National Laboratory (LLNL) - A science and technology laboratory located in California whose goal is to ensure United States national security

Raman Spectroscopy - A technique used to study the rotation, vibration, and other low-frequency movements of a system

X-Ray Scattering - A technique used to study the structure, chemical composition, and physical properties of materials

ScienceMakers Spotlight

Albert Green

Physicist & Business Executive

Education	The University of Chicago (B.S.)
	Stanford University (Ph.D.)
Awards & Achievements	Black Engineer of the Year Award Most Promising Scientist (1997)
	Smart Business Magazine's Innovation in Business Award (2011)

BIOGRAPHY

Albert Green has held several positions in top scientific companies including CEO of Kent Displays, Inc. Green earned his B.S. degree in physics from the University of Chicago and went on to earn his Ph.D. degree in physics from Stanford University. In addition to his education in physics, Green participated in the Executive Training Summer School at Massachusetts Institute of Technology's (MIT) Sloan School of Business Administration.

LCD Screen by JVCAmerica @Flickr

After finishing his education, Green was hired at a company called Science Applications International Corporation (SAIC). He held several positions including senior scientist, program manager, and business unit chief manager. Eventually, he became vice president and division manager of SAIC. This position allowed him to work closely with another company, Kent Displays, and together they developed a new flexible display technology called *Reflex*. After thirteen years with SAIC, Green joined the team at Kent Displays, becoming their CEO in 2007. He also serves on the board of directors. Under Green's leadership, Kent Displays shifted its focus from scientific research to product manufacturing. One product that was launched under Green's guidance is the Boogie Board LCD Writing Tablet (2010). Kent Displays has the world's only roll-to-roll Liquid Crystal Display (LCD) production line, which began in 2008. It is considered a green technology because it produces very little waste byproduct. Throughout his career, Green received more than twenty-five patents for products and processes involving displays, photonic systems, and advanced materials. In addition to his leadership of Kent Displays, Green also shares his knowledge of science and business with the world community. Green served as an advisor to President Barack Obama's Export Council and often contributed to U.S. Department of Commerce functions. Green also serves the community as a board of directors member for several organizations and as an adjunct professor at Kent State University. Albert Green works in Ohio.

Above Picture of Albert Green from www.kentdisplays.com

SCIENCE IN ACTION

IS THERE LIQUID IN YOUR ALARM CLOCK?

LCD Clock Display
by chrisdlugosz @Flickr

Many products that you use every day have liquid crystal display screens. Does this mean that there is liquid and crystals in the screen? A liquid crystal is a substance that is neither liquid nor solid but somewhere in between. Each LCD display is composed of a sheet of liquid crystals and other layers like glass and electrodes. Albert Green is the head of a company that manufactures LCD screens. This technology is useful because it creates lightweight compact screens that do not consume a lot of power. LCD technology has recently become very popular, and since 2008, the majority of televisions sold are equipped with LCD screens.

DISCUSSION QUESTIONS

1. If you were to interview Albert Green, what questions would you ask him?
2. Check out the HowStuffWorks website (http://www.howstuffworks.com/lcd.htm). What did you learn about Liquid Crystal Display?
3. Albert Green's company makes liquid crystal display screens. Do you have any electronics in your home or school that use LCD screens?
4. Albert Green promotes environmentally friendly technology. Why is this important?
5. How does Albert Green's career compare to that of other physicists in the Toolkit?

GLOSSARY

Barack Obama - 44th president of the United States and the first African American to hold the office

Electrode - A conductor through which electricity enters or leaves an object, substance, or region

Liquid Crystal Display - An electronic visual display in which an electric current is applied to a liquid crystal layer

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using, or selling the claimed invention

Photonic System - The application of electromagnetic energy whose basic unit is the photon

ScienceMakers Spotlight

Paul Guèye

Nuclear Physicist

Birth Date	July 8, 1966
Birth Place	Senegal, West Africa
Education	University of Cheikh Anta Diop (Senegal) (B.S. 1987, M.S. 1990)
	University of Clermont-Ferrand (France) (Ph.D. 1994)
Awards & Achievements	#1 Academic Student in his master's (M.S.) class
	1st Senegalese to earn a Ph.D. degree in nuclear/high energy physics
	Only reference thesis comparing electrons and positrons data for Coulomb and dispersive corrections required for nuclear physics
	President Elect of the National Society of Black Physicists (2011)

BIOGRAPHY

Paul Guèye is known for his work in nuclear and high energy physics at the French Energy Atomic Commission as well as his Ph.D. thesis experiment, conducted at the Jefferson Lab in Virginia.

Particle Accelerator by Bananimal @Flickr

Guèye was born in Senegal, West Africa on July 8, 1966. After graduating from high school, Guèye attended the University of Cheikh Anta Diop in Senegal. He received his B.S. degree in 1987 and his M.S. degree in 1990 in physics and chemistry. Guèye went on to earn his Ph.D. degree in nuclear physics from the University of Clermont-Ferrand in France in 1994.

In 1995, Guèye joined the physics department at Hampton University where he participated in the Jefferson Lab's first physics experiments. Guèye developed an interest in the study of matter. He created theoretical models and scientific instruments to study a particle called the strange quark. In 2001, Guèye became the head of the brachytherapy research and development group of the medical physics graduate program at Hampton. In that position, he received patents for a new technique to measure the dose (amount of radiation) given to a patient. His development can help doctors treat cancer and heart disease. Guèye has also conducted research in accelerator physics in order to determine the behavior and composition of the particles that make up matter. He leads an effort to construct a low energy particle accelerator at Hampton. Guèye uses the Geant4 Toolkit, a scientific instrument that simulates the interaction of particles with matter. In addition to his research, Guèye co-supervised the first African American female Ph.D. students in nuclear physics and medical physics at Hampton. In 2008, he organized the *Fifty Years of Women in Medical Physics Symposium* as part of the American Association of Physicists in Medicine (AAPM). Guèye also worked with the National Aeronautics and Space Administration (NASA) to improve knowledge of radiation interaction with matter. Additionally, he has co-led an international collaboration to develop a large research facility for Africa. Paul Guèye works in Hampton, Virginia.

Above Picture of Paul Guèye from science.hamptonu.edu/physics/faculty/gueye.cfm

SCIENCE IN ACTION

CANCER TREATMENT

Radiation Therapy Machine
by Sam Blackman @Flickr

You may have heard about nuclear disasters such as the 2011 flooding in Japan that was caused by an earthquake and tsunami, which damaged a nuclear power plant and released dangerous radiation. Radiation, however, can also be used as a medical tool to stop cancer cells from spreading for example. Cancer cells, unlike healthy cells, replicate abnormally and can lead to tumors. Doctors can use a treatment called proton therapy in which an external beam of protons is aimed at the tumor site, almost like a laser beam. The protons damage the DNA of the cancer cells, killing them, or at least preventing them from spreading. Paul Guèye conducts research in the use of proton therapy.

DISCUSSION QUESTIONS

1. If you were to interview Paul Guèye, what questions would you ask him?
2. Check out the American Association of Physicists in Medicine website (http://www.aapm.org/medical_physicist/default.asp), and read about what medical physicists do. Would you enjoy being a medical physicist? Why or why not?
3. Physics can be applied to the field of medicine, for example cancer treatment. What other types of science are involved in the medical field?
4. Why is it important for scientists like Paul Guèye to study the particles that make up matter?
5. How does Paul Guèye's career compare to that of other physicists in the Toolkit?

GLOSSARY

Brachytherapy - A type of cancer treatment that uses an internal radioactive source to target the cancer cells

Cancer Cells - Cells, or organism building blocks, that do not replicate like normal healthy cells

DNA - Acronym; deoxyribonucleic acid; the genetic material of all living organisms

Matter - A substance that has mass and takes up space

Nuclear Physics - The study of the forces present in the nucleus of an atom; the interactions between the atom's building blocks and its applications to nuclear power

Particle Accelerator - A scientific instrument that propels charged atomic particles by increasing their kinetic energy, or energy of motion

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention and has the privilege of stopping others from making, using or selling the claimed invention

Radiation - The emission of energy as electromagnetic waves or as moving subatomic particles

Strange Quark - A particle with a mass 988 times that of an electron and an electric charge of -1/3

ScienceMakers Spotlight

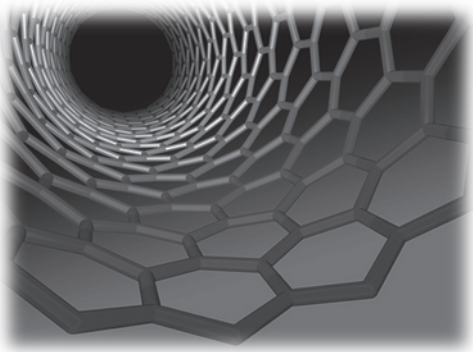
Godfrey Gumbs

Nanophysicist

Birth Date	September 7, 1948
Birth Place	Georgetown, Guyana
Education	Trinity College, Cambridge University (B.A. 1971)
	University of Toronto (M.S. 1973, Ph.D. 1978)
Awards & Achievements	American Physical Society Fellow
	American Physical Society Bouchet Award (2005)
	Institute of Physics (U.K.) Fellow

BIOGRAPHY

Godfrey Gumbs was born in Guyana, South America, educated in the United Kingdom and Canada, and has worked as a physicist and professor of physics in the United States. Gumbs was born on September 7, 1948 in Georgetown, Guyana. After graduating from high school, he received a scholarship to attend Trinity College, Cambridge University in 1968. He earned his B.A. degree in applied mathematics in 1971. Gumbs went on to earn his M.S. and Ph.D. degrees in theoretical condensed matter physics from the University of Toronto in 1973 and 1978, respectively.



Carbon Nanotube
by ghutchis@Flickr

From 1978 to 1982, Gumbs served as a research associate at the National Research Council of Canada in Ottawa. Then, from 1982 to 1989, he worked as a Canada University fellow where he was both an assistant and associate professor. As a fellow, Gumbs worked at the University of Lethbridge in Alberta, Canada. In 1992, he was hired by Hunter College, City University of New York and appointed the Chianta-Stoll Chair and distinguished professor. Gumbs' research interests in theoretical condensed matter physics include electronic and optical properties of mesoscopic systems, which are between the size of an individual atom and a micrometer. He also works with semiconductors and carbon nanotubes, which are composed of a material called graphene. These tubes have applications in cell phones and other technology. Gumbs' research also contributes to the construction of transistors, which are used in most electronic devices. Gumbs has published numerous scientific research articles and also works to increase minority participation in science through his teaching and mentoring. Godfrey Gumbs lives in New York, New York.

SCIENCE IN ACTION

GRAPHENE: MIRACLE MATERIAL

Smart Phones
by Dru Bloomfield@Flickr

What if you could fold up your smart phone and store it behind your ear? Electronic devices like a flat screen television or a smart phone rely on materials that transfer information. In 2010, a team of scientists won the Nobel Prize in Physics for the isolation of graphene, a super material that may make electronics even smaller, lighter, faster, and more flexible. Godfrey Gumbs continued to study the properties of graphene, which consists of a single layer of massless carbon atoms. Because of its massless properties, graphene demonstrates high mobility, which leads to the exceptionally rapid transfer of information. Graphene is also extremely strong. It would take an elephant, balanced on a pencil, to break through a sheet of graphene the thickness of Saran Wrap.

DISCUSSION QUESTIONS

1. If you were to interview Godfrey Gumbs, what questions would you ask him?
2. Check out Chem 4 Kids website (http://www.chem4kids.com/files/elements/006_where.html). In addition to the material graphene, where else can carbon be found?
3. If you had a sheet of super strong graphene, what would you use it for?
4. Godfrey Gumbs studies condensed matter physics to examine the properties and uses of different materials. What can scientists do with that knowledge?
5. How does Godfrey Gumbs' career compare with that of other physicists in the Toolkit?

GLOSSARY

Applied Mathematics - The use of mathematical principles to solve real world problems in the physical, biological, and sociological world

Carbon Nanotube - A small hollow tube that is made out of graphene and is used in the construction of electronic devices

Condensed Matter Physics - The branch of physics involving the properties of solids, liquids, and other forms of matter in which atoms or particles are highly concentrated

Graphene - A one-atom-thick flat sheet of carbon atoms that is densely packed in a honeycomb shape

Mesoscopic - A measure of size that is between an individual atom and a micrometer

Optical - Having to do with sight, especially in relation to the behavior and properties of light

Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

Transistors - A small electronic instrument containing a semiconductor and having at least three connections to external circuits; used as a building block in electronic devices

ScienceMaker Spotlight

Carlos Handy

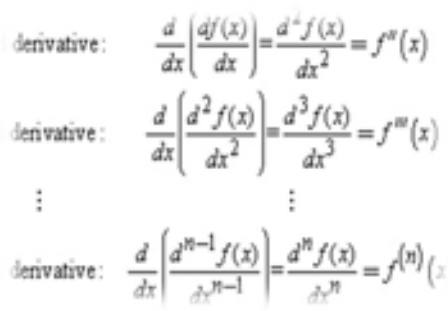
Physicist

Birth Date	October 18, 1950
Birth Place	Havana, Cuba
Education	Columbia College, New York (B.A. 1972)
	Columbia University (M.A. 1975, Ph.D. 1978)
Awards & Achievements	Bell Laboratories Cooperative Research Fellow (1972)
	NSF Creativity Extension Award (1988)

BIOGRAPHY

Carlos Handy is known for his development of an unprecedented computational physics technique called the Eigenvalue Moment Method (EMM). Handy was born in Havana, Cuba, on October 18, 1950 to a Cuban mother and an American father. Growing up in New York City, Handy attended George Washington High School where he was a top math student. In 1972, Handy earned his B.A. degree in physics from Columbia College in New York. He then continued his studies at Columbia University, earning his M.A. degree in physics in 1975 and his Ph.D. degree in theoretical physics in 1978.

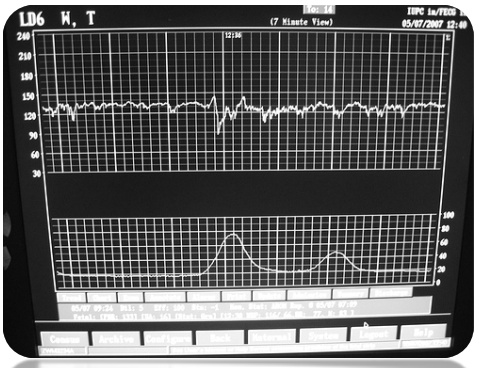
From 1978 to 1981, Handy worked as a postdoctoral research associate at Los Alamos National Laboratory focusing on the use of moment representations to relate large scale to local scale features of strong coupling problems. A related approach to this led to Wavelet analysis, as developed by others (i.e. Grossman, Morlet, and Daubechies). In 1983, Handy was hired by Atlanta University (now Clark-Atlanta University) as an associate professor of physics. During his time there, he received grant money from the National Science Foundation (NSF), which led to his discovery of the Eigenvalue Moment Method (EMM) technique. The EMM technique is a method for calculating ground state energy. It innovatively combined three different methods in quantum physics. Since original discovery of the EMM method in the 1980s, researchers have developed more sophisticated versions of EMM now referred to as Semidefinite programming (SDP) analysis (in the 1990s). Handy was the first to exploit these types of computational procedures in physics. A second grant allowed Handy to develop alternative computational schemes for the EMM in 1991. He also created and co-directed the Center for Theoretical Studies of Physical Systems, a research and student mentoring center. Throughout his career, Handy published numerous research articles. In 2005, Handy left Clark-Atlanta University and became head of the physics department at Texas Southern University where he assumed full responsibility for the development of the physics program. His professional concerns include the need for modern facilities in physics education as well as students' early mastery of calculus. Carlos Handy works in Houston, Texas.



Calculus by lednichenkoolga @Flickr

SCIENCE IN ACTION

WHY WAVELETS?



Heart Monitor Wavelets
by tiarescott @ Flickr

When you hear the word wave, you may think of a wave in the ocean or a heat wave during the summer. In physics, the word wave refers to a repeating disturbance or movement that transfers energy through matter or space. Waves are all around us even though you cannot see them. Carlos Handy studied multi-scale physics formulations fundamentally tied to wavelets as a postdoctoral researcher. A wavelet is a special kind of wave or oscillation that is of finite length, oscillates between positive and negative values, and decays to zero at infinity. It must also satisfy some precise mathematical properties pertaining to the nature of these oscillations (perhaps similar to those recorded on a heart monitor). Wavelets are indispensable in signal processing and image/signal compression.

DISCUSSION QUESTIONS

1. If you were to interview Carlos Handy, what questions would you ask him?
2. Check out the Physics4Kids website (http://www.physics4kids.com/files/mod_quantum.html). What did you learn about quantum physics?
3. Carlos Handy studied wavelet related methods as a postdoctoral researcher. Can you think of anything living or non-living that moves in a wave-like pattern?
4. Carlos Handy was an ambitious high school student who taught himself calculus. Why is it important to have motivation and drive in school?
5. How does Carlos Handy's career compare with that of other physicists in the Toolkit?

GLOSSARY

Coupling - an interaction between different properties of a system, such as a group of atoms or nuclei, or between two or more systems

Eigenvalue Moment Method (EMM) - An energy calculation technique that uses principals of quantum physics, mathematics, and optimization theory (linear programming)

Ground State - The lowest energy state of an atom, molecule, particle, etc.

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Signal Processing - The transmission of information; can be in the form of a digital signal

Theoretical Physics - A branch of physics that uses mathematical models and concepts of physics to explain and predict natural occurrences

Wavelet - A wave-like oscillation that starts and ends at an amplitude of zero

ScienceMakers Spotlight

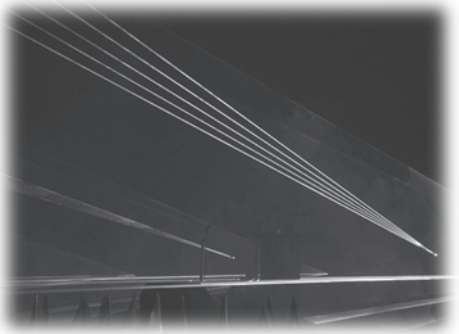
Wendell Hill

Optical Physicist

Education	University of California, Irvine (B.A. 1974)
	Stanford University (M.S.1976, Ph.D. 1980)
Awards & Achievements	NSF Presidential Young Investigator (1985-1990)
	Sigma Xi Distinguished Lecturer (2001)

BIOGRAPHY

Wendell Hill is known for being a prestigious physics professor and researcher at the University of Maryland. Hill received his B.A. degree in physics from the University of California, Irvine in 1974. He received an International Business Machines Corporation (IBM) graduate fellowship to pursue his master's degree. He obtained advanced degrees in physics from Stanford University: his M.S. degree in 1976 and his Ph.D. degree in 1980.



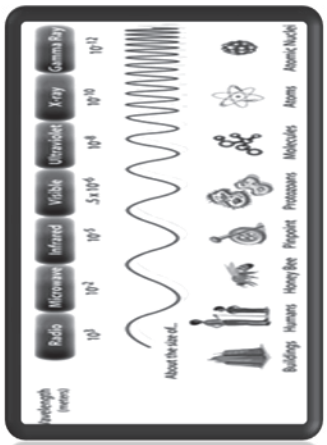
Lasers
by Quassaam @Flickr

Following graduation, Hill worked as a postdoctoral fellow at the National Institute of Standards & Technology (NIST) and from 1982 to 1987, he continued to work for NIST as a visiting scientist. In 1982, he joined the faculty of the University of Maryland Institute for Physical Science and Technology (IPST) as an assistant research scientist. In 1986, he became an assistant professor; in 1990, an associate professor; and in 1996, a full professor. Since 1999, Hill has directed the Laboratory for Atomic, Molecular & Optical Science, and Engineering. The research lab investigates two areas: ultra-cold studies, specifically atom optics; and ultra-fast studies, specifically the interaction of electromagnetic radiation with atoms and molecules using lasers. Hill has served as a visiting scientist at the Université de Paris, Orsay in France and as a visiting scholar at the Instituto Venezalano de Investigaciones in Venezuela. He has served as a fellow for a number of prestigious professional societies including the American Physical Society (APS), the National Society of Black Physicists (NSBP) and the Optical Society of America (OSA). Hill has also served on the executive committee of the APS Division of Laser Science and the APS committee of minorities. He has also chaired the National Academy of Sciences Committee on Atomic Molecular and Optical Science. He has written a number of scientific articles on subjects including lasers, radiation physics, and spectroscopy. Wendell Hill works in College Park, Maryland.

Above Picture of Wendell Hill from umdphysics.umd.edu/people/faculty/150-hill.html

SCIENCE IN ACTION

ELECTROMAGNETIC RADIATION: WAVES OF ENERGY



Visible Light Spectrum by NASAGlobalAstro @Flickr

Humans can only see a small part of the electromagnetic radiation spectrum in the form of visible light. The electromagnetic spectrum includes gamma rays, X-rays, ultraviolet light, visible light, infrared light, television waves, and radio waves. Electromagnetic radiation has properties of both particles and waves. Particles have mass and take up space. Waves have no mass and yet carry energy as they travel through space. By measuring the wavelength, scientists separate the different types of radiation into categories. Each category has different properties. For example, infrared is heat radiation and X-rays can penetrate solid objects. Studying the interaction between matter and electromagnetic radiation allows scientists, like Wendell Hill, to understand the structure of electrons in an atom.

DISCUSSION QUESTIONS

1. If you were to interview Wendell Hill, what questions would you ask him?
2. Check out the NASA Kids website (http://science.hq.nasa.gov/kids/imagers/ems/waves3.html) and learn about electromagnetic radiation. Which type of radiation has the longest wavelength and how long is it? What type of radiation has the shortest wavelength?
3. X-rays, microwaves, and radio waves are three types of electromagnetic radiation. Choose one type of electromagnetic radiation and explain how you use it in your everyday life.
4. Wendell Hill uses electromagnetic radiation to understand the interactions of electrons. Why is this important?
5. How does Wendell Hill's career compare to that of other physicists in the Toolkit?

GLOSSARY

Atom Optics - The area of physics which deals with beams of cold, slowly moving neutral atoms, as a special case of a particle beam

Electromagnetic Radiation - A kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously

International Business Machines Corporation (IBM) - An American technology company that builds and sells computers

Lasers - A device that generates an intense beam of light that is one bright color

National Institute of Standards and Technology (NIST) - A U.S. Government agency that works with industry to develop and apply technology, measurements, and standards

Radiation - The emission of energy as electromagnetic waves or as moving subatomic particles

Spectroscopy - The branch of science concerned with the investigation and measurement of spectra (a band of colors) produced when matter interacts with or emits electromagnetic radiation

ScienceMakers Spotlight

Calvin Howell

Nuclear Physicist

Birth Date	December 7, 1955
Birth Place	Warrenton, North Carolina
Education	Davidson College (B.S. 1978)
	Duke University (Ph.D. 1984)
Awards & Achievements	North Carolina board of Science and Technology Young Investigator (1989)
	American Physical Society (APS) Fellow (2006)
	Samuel DuBois Cook Award for Service at Duke University (2008)

BIOGRAPHY

Calvin Howell is known for his commitment to the field of nuclear physics as director of the Triangle Universities Nuclear Laboratory (TUNL). He was born on December 7, 1955 in Warrenton, North Carolina. After graduating from high school, Howell earned his B.S. degree in physics from Davidson College in 1978. He then went to Duke University where he received his Ph.D. degree in 1984 with a specialty in experimental nuclear physics.

Calvin Howell in His Laboratory

After finishing his education, Howell conducted postdoctoral research at TUNL for one year, serving as an instructor and research associate. In 1985, he joined the faculty at Duke University as an assistant professor of physics. Howell was promoted to associate professor in 1992 and full professor in 2001. Also in 2001, Howell was hired as deputy director of the Triangle Universities Nuclear Laboratory, a position he held until 2006 when he became the director of TUNL. In addition to his positions at Duke University and TUNL, Howell held many visiting positions including nuclear physics program director at the National Science Foundation (NSF), visiting scientist at the Stanford Linear Accelerator Center (SLAC), and visiting scientist at the Los Alamos National Laboratory. Howell's research interests in experimental nuclear physics include explosive nucleosynthesis, which describes the cosmic formation of atoms like during the Big Bang. Howell has also studied carbon and nitrogen build-up in plants using radioactive isotopes of those elements. He and his colleagues from Duke were involved in a study of national security to identify suspicious materials on cargo ships. Howell has co-authored more than 110 research articles in scientific journals. In addition to his teaching and research, Howell serves the physics community through numerous board and committee memberships. He also participates in activities to promote academic opportunities for minority students. Between 2001 and 2005, Howell served as academic coordinator for the Minority Medical Education Program at Duke University. Calvin Howell works in Durham, North Carolina.

SCIENCE IN ACTION

A MATTER OF NATIONAL SECURITY

Cargo Ship
by Andy Siitonen @Flickr

Have you ever had your fingerprints taken? Police use fingerprints to identify crime suspects, because each person's fingerprints are different. Physicists from North Carolina have identified "fingerprints" or unique markers of nuclear materials. One of those markers, Calvin Howell noted, is a distinct energy pattern based on a material's nuclear structure. Howell leads the Duke University group that is studying the energy patterns of potentially harmful materials like weapons. These materials are being brought into ports by cargo ships. Terrorists often try to smuggle explosives or radioactive materials in with other cargo, but this new technology is sensitive enough to detect these hidden materials.

DISCUSSION QUESTIONS

1. If you were to interview Calvin Howell, what questions would you ask him?
2. Check out Duke University's TUNL website (http://www.tunl.duke.edu/). What kinds of projects are being done there?
3. Calvin Howell is a nuclear physicist whose work extends into many scientific fields. Which of his research topics do you find most interesting?
4. Calvin Howell and other Duke University scientists conduct research that may help identify harmful material on cargo ships. Why is this important to national security?
5. How does Calvin Howell's career compare to that of other physicists in the Toolkit?

GLOSSARY

Big Bang - The theory that the universe originated from a high density and temperature explosion of a small volume of matter between 10 billion and 20 billion years ago

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Nuclear Physics - The study of the forces present in the atomic nuclei; the interactions between the atom's building blocks and its applications to nuclear power

Nuclear Structure - The make-up of sub-atomic particles and composition of the nucleus; each chemical element has a unique structure

Radioactive Isotope - A form of a chemical element that emits radiation energy and has an equal number of protons but different numbers of neutrons in the nucleus

Stanford Linear Accelerator Center (SLAC) - A facility at Stanford University that houses a particle accelerator, scientific instrument that propels charged atomic particles by increasing their kinetic energy, or energy of motion

ScienceMakers Spotlight

Walter Lowe

Applied Physicist

Birth Place	North Carolina
Education	North Carolina A&T State University (B.S.)
	Stanford University (Ph.D. 1983)
Awards & Achievements	U.S. Department of Energy Grant ($9.2 million)

BIOGRAPHY

Walter Lowe was a pioneer in the field of physics and led a team that created the first movie of materials changing on the atomic level. He was raised in North Carolina and attended North Carolina A&T State University, where he graduated with his B.S. degree in physics. He went on to receive his Ph.D. degree in condensed matter physics from Stanford University in 1983. His dissertation focused on synchrotron radiation, which is electromagnetic radiation released by extremely fast-moving charged particles.

Argonne National Laboratory by DiscoverDupage @Flickr

Following graduation, Lowe joined the faculty of Howard University as a professor of physics. His research focused on using X-rays to study new materials. Lowe also studied condensed matter physics, the study of matter, such as liquid or solids where the atoms are closely packed. In 2001, Lowe secured a $9.2 million dollar grant from the U.S. Department of Energy (DOE) for Howard University to complete collaborative research with The University of Michigan and Lucent Technologies/Bell Laboratories. The collaborative work took place at Argonne National Laboratory's Advanced Photon Source (APS), and Lowe served as director of this project called the Michigan-Howard-Lucent Technologies Collaborative Access Research Team (MHATT-CAT). An APS is a research X-ray machine the size of a football stadium. At Argonne, Lowe's team produced one of the first recorded movies of structural changes occurring on the atomic level. Lowe was appointed science advisor to the Photon Sciences Directorate at Argonne National Laboratory, responsible for community outreach and development. He has served on many committees including the U.S. Department of Energy's Basic Energy Sources Advisory Committee. Lowe's brother is Calvin Lowe, vice president of research and development for the National Aerospace Corporation. Walter Lowe works in Washington, D.C.

SCIENCE IN ACTION

ARGONNE LABORATORY: RESEARCHING FOR THE FUTURE

Aerial view of the Advanced PhotonSource by www.aps.anl.gov @Flickr

If you live in Northeast Illinois near Chicago, then you can go on a field trip to the Argonne National Laboratory! The laboratory covers 1,500 wooded acres, but the cool stuff happens within the laboratory. A popular stop on Argonne field trips is the Advanced Photon Source (APS), which produces the most brilliant X-ray beams in the Western Hemisphere. More than 3,500 scientists and engineers from all over the world, including Walter Lowe, have conducted research at the APS. The National Laboratory has completed some pretty exciting projects, including the first town lit only by nuclear energy. Other projects include a nuclear submarine reactor and biochips that detect and identify toxic chemical and biological agents.

DISCUSSION QUESTIONS

1. If you were to interview Walter Lowe, what questions would you ask him?
2. Check out the Argonne National Laboratory website (www.anl.gov/). Would you like to work at Argonne National Laboratory? If so, in what position?
3. Condensed Matter Physics is a big name for the study of matter such as liquids and solids. Name three liquids and solids that you encounter every day.
4. Walter Lowe studies materials on the atomic level. Why do you think it is important to study atoms?
5. How does Walter Lowe's career compare to that of other physicists in the Toolkit?

GLOSSARY

Argonne National Laboratory -The first science and engineering research national laboratory in the United States, which conducts basic science research in energy storage, environmental sustainability, and national security

Bell Laboratories - The research and development organization of Alcatel-Lucent and previously of the American Telephone & Telegraph Company (AT&T); also known as Bell Labs and formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories

Condensed Matter Physics - The branch of physics involving the properties of solids, liquids, and other forms of matter in which atoms or particles are highly concentrated

Electromagnetic Radiation - A kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously

Synchrotron Radiation - Electromagnetic radiation released by charged particles that are moving at speeds close to that of light on lines made by magnetic force fields

U.S. Department of Energy (DOE) - A U.S. Government agency that researches and oversees energy technology, energy conservation, and nuclear weapons

ScienceMakers Spotlight

Alfred Msezane

Physicist

Birth Place	South Africa
Education	University of South Africa (B.Sc. 1964)
	University of Saskatchewan (M.Sc. 1968)
	University of Western Ontario (Ph.D. 1973)
Awards & Achievements	World Service Scholarship (1965)
	Honorary Doctorate Degree from the University of South Hare, South Africa (1998)
	Edward Bouchet Award of the American Physics Society (1999)

BIOGRAPHY

Alfred Msezane studies the shape and behavior of one of the most fundamental particles, the electron. He was born in South Africa and received his B.Sc. degree in physics from the University of South Africa in 1964. Msezane travelled to Canada to study physics at the University of Saskatchewan where he received his M.Sc. degree in 1968. Msezane returned to South Africa for a year to conduct research at the Nuclear Physics Research Unit of Witwaterstrand University. He received his Ph.D. degree in physics from the University of Western Ontario in 1973.

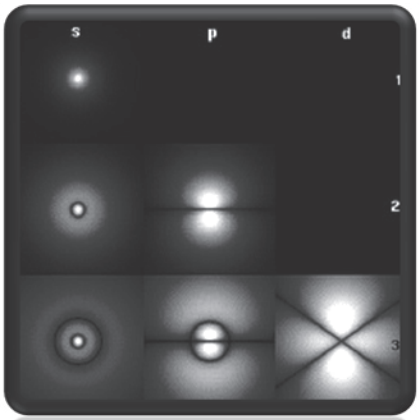
Electron Microscope by AMagill @ Flickr

Msezane started his long career as a teacher at the University of New Brunswick in 1973 and became a physics instructor in 1976. He came to the United States to complete his postdoctoral research at the Georgia State University in 1974. From 1978 to 1980, he served as a visiting professor at Louisiana State University. In 1980, Msezane joined the faculty of Morehouse College as an assistant professor of physics. He left Morehouse College in 1983 to become a professor at Atlanta University and served as chair of the physics department from 1986 to 1989. In 1988, Atlanta University merged with Clark University to become Clark Atlanta University. Msezane is the founder and director of the Center for Theoretical Studies of Physical Systems (CTSPS) at Clark Atlanta University. The center researches mathematical physics theory, solid matter, and image processing. Msezane's research includes electron interaction with matter and electron configuration within the atom. He has published over 260 research papers and is a member of several professional societies, including the American Physical Society (APS) and the National Society of Black Physicists (NSBP). Alfred Msezane works in Atlanta, Georgia.

Above Picture of Alfred Msezane from www.math.buffalo.edu/mad/physics/msezane_alfredz.html

SCIENCE IN ACTION

ELECTRONS: AN INVISIBLE INGREDIENT IN THE UNIVERSE



Electrons Orbitals
by Ethan Hein @ Flickr

Have you ever looked at a picture from a wide angle and then slowly moved in closer and closer until you saw the tiny dots that make up the picture? If you had a powerful electron microscope, you could zoom in on atoms which make up the whole universe. Electrons are the negatively charged particles of atoms and form a cloud that surrounds the center of the atom. They move so quickly that it is impossible to predict where they will be at a specific moment, but scientists discovered specific areas or orbitals where electrons are likely to be. Electrons are important in how atoms react and connect with other atoms. They also power all of our appliances through electricity.

DISCUSSION QUESTIONS

1. If you were to interview Alfred Msezane, what questions would you ask him?
2. Check out the Chem 4 Kids's website (http://www.chem4kids.com/files/atom_electron.html) and learn about electrons. How do electrons create electricity?
3. Why do you think physicists like Alfred Msezane study electrons?
4. An electron microscope allows scientists to see very tiny particles. What would you like to look at through a microscope?
5. How does Alfred Msezane's career compare to that of other physicists in the Toolkit?

GLOSSARY

Electron - The smallest particle in an atom; it carries a negative electric charge

Electron Configuration - The arrangement of electrons in the nucleus

Electron Microscope - A microscope with high magnification and resolution, employing electron beams in place of light and using electron lenses

Image Processing - The analysis and manipulation of a computer image, esp. in order to improve its quality

Matter - A substance that has mass and takes up space

ScienceMakers Spotlight

Sekazi Mtingwa

Particle Physicist

Education	Massachusetts Institute of Technology (B.S. 1971)
	Princeton University (M.A., Ph.D. 1976)
Awards & Achievements	U.S. Department of Energy's Nuclear Energy Research Advisory Committee (1998 to 2008)

BIOGRAPHY

Sekazi Mtingwa was born Michael Von Sawyer, but changed his name during college to reflect his respect for African culture. During grade school, classmates called him a mad scientist because of his passion for science. Mtingwa attended Henry McNeal Turner High School in Atlanta, Georgia, and his senior biology project won first place in the state science fair. He received his B.S. degree in physics and mathematics in 1971 from Massachusetts Institute of Technology (MIT). Mtingwa accepted a Ford Foundation fellowship to attend Princeton University where he earned his M.A. and Ph.D. degrees in physics in 1976.

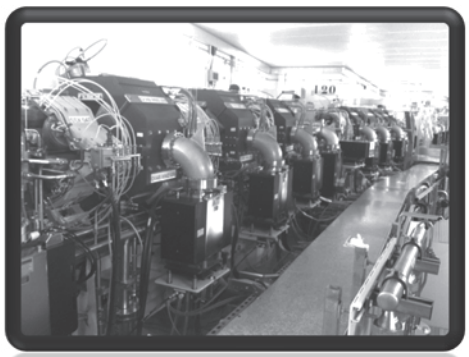
Fermi National Laboratory by Linda N. @Flickr

Following completion of his graduate studies, Mtingwa joined the faculty of the University of Rochester as a research associate and assistant professor. In 1978, he became a postdoctoral fellow at the University of Maryland. In 1980, Mtingwa joined the staff at Fermi National Accelerator Laboratory studying antiproton particles and particle beam dynamics. Mtingwa continued his physics research at Argonne National Laboratory in 1988. He returned to academia in 1991 in order to positively impact minority students as chair and professor at North Carolina A&T's physics department. In 2001, he became the Martin Luther King, Jr. Visiting Professor of Physics at MIT, and in 2003, he joined Harvard University's physics department as a visiting professor. In 2006, he returned again to MIT as senior lecturer in the Office of the Dean for Undergraduate Studies and directed MIT's Office of Minority Education's Tutoring Services. Mtingwa's mission has been to show students how physics is both relevant and exciting. He travels extensively in Africa developing science and technology programs and is on the board of directors of the African Laser Center. Mtingwa has many hidden talents as well; he has a black belt in Taekwondo and speaks four languages. Sekazi Mtingwa is married to Estella Johnson and they have two daughters.

Above picture of Sekazi Mtingwa from www.sais-jhu.edu/centers/geei/prpnuclear.htm

SCIENCE IN ACTION

SMASHING ATOMS



Particle Accelerator
by Matt From London @Flickr

How do you study the structure of an atom? Physicists have discovered that one of the best ways is to accelerate atoms and watch them smash together at near light speeds. To make atoms travel at high speeds, a large electric field is created by a huge magnet. The magnet pushes the atoms along in stream of particles called a beam. Two beams of particles are crossed with each other causing the atoms to collide. Physicists collect data from the collision and study the particles created. Mtingwa has worked in calculating intrabeam scattering where collisions happen in three dimensions causing the beam to grow.

DISCUSSION QUESTIONS

1. If you were to interview Sekazi Mtingwa, what questions would you ask him?
2. Check out the Particle Adventure website (http://www.particleadventure.org/accel_design.html). What are the two types of accelerators?
3. Would you like to work at a particle accelerator laboratory? Why or why not?
4. Sekazi Mtingwa works to develop scientific programs and infrastructure. Why do you think it is important to build particle accelerators and laser centers?
5. How does Sekazi Mtingwa's career compare to that of other physicists in the Toolkit?

GLOSSARY

Antiproton Particles - A particle that has the same mass but an equal and opposite charge of a proton; Antiprotons are stable, but they are typically short-lived since any collision with a proton will cause both particles to be destroyed in a burst of energy

Argonne National Laboratory - The first science and engineering research national laboratory in the United States which conducts basic science research in energy storage, environmental sustainability, and national security

Dynamics - The branch of mechanics concerned with the motion of bodies under the action of forces

Fermi National Accelerator Laboratory - A U.S. Department of Energy national laboratory specializing in high-energy particle physics; has the world's second largest particle accelerator

Intrabeam Scattering - The occurrence in a particle accelerator where collisions happen in three dimensions and cause the beam to grow

ScienceMakers Spotlight

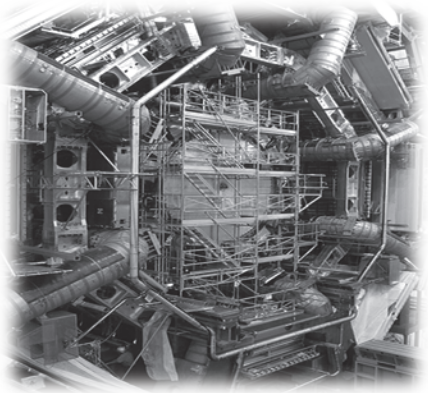
Homer Neal

High Energy Particle Physicist

Birth Date	June 13, 1942
Birth Place	Franklin, Kentucky
Education	Indiana University (B.S. 1961)
	University of Michigan (Ph.D. 1966)
Awards & Achievements	Guggenheim Fellowship (1980)
	Indiana University Distinguished Alumni Service Award (1994)
	Edward A. Bouchet Award (2003)

BIOGRAPHY

Homer Neal has studied elementary particles and helped to develop the CERN Large Hardron Collider. He was born on June 13, 1942 in Franklin, Kentucky. As a child, Neal pursued an interest in amateur radio and built his own radio set; these were the foundations for his lifelong interest in science. He received his B.S. degree in physics in 1961 from Indiana University and went on to earn his Ph.D. degree in physics from the University of Michigan in 1966.



CERN Large Hadron Collider by Guistino @Flickr

After receiving his doctorate degree, Neal joined the faculty of Indiana University as a professor in the physics department. In 1976, he became the dean for research and graduate development at Indiana University. Neal then left Indiana University to serve as the provost at the State University of New York in 1981. He returned to the University of Michigan in 1987 as the chair of the physics department. In 1993, Neal became vice president for research at the University of Michigan and was interim president of the University of Michigan in 1998. His research has focused on high energy physics. Neal became director of the University of Michigan ATLAS project which conducts research at CERN, the European Laboratory for Particle Physics. In 1995, he was part of the DZERO collaboration at the University of Michigan, which discovered the top quark. Neal's role in the project was designing, implementing, and analyzing the data from the Incryostat Detector, which detects particles like quarks. Neal is on the board of directors of the Ford Motor Company where he chairs the Committee on Environmental and Public Policy. He has served on the board of directors for the Argonne National Laboratory and Fermi National Accelerator Laboratory. His work has taken him to research institutes in China, Denmark, and Switzerland. He is also the regent and executive committee member of the Smithsonian Institute. Homer Neal is married to Donna J. Daniels and they have two children.

Above Picture of Homer Neal from www.lsa.umich.edu/physics/directory/faculty/ci.nealhomer_ci.detail

SCIENCE IN ACTION

ALMOST AS FAST AS THE SPEED OF LIGHT

Inside the Large Hadron Collider
by simone.cortesi @Flickr

Superman now has competition in the Large Hadron Collider that can send particles at nearly the speed of light. This sounds like the vision of a mad scientist in a comic book, but particle accelerators are producing real results that tell us about the basic particles of an atom and what might have created the Big Bang Explosion. The Big Bang Theory is the leading scientific theory of how the universe was created billions of years ago. Particle accelerators, like the Large Hadron Collider, are used to simulate the Big Bang Theory to understand the basic origins and foundations of the universe. In the future, the high energy collisions could also produce black holes, dark matter, and perhaps even particles we have not seen before.

DISCUSSION QUESTIONS

1. If you were to interview Homer Neal, what questions would you ask him?
2. Check out the Particle Adventure (www.particleadventure.org/accel.html). What two problems do particle accelerators solve?
3. Homer Neal travels across the world studying particle acceleration. Would you like to be a particle physicist? Explain your answer.
4. Particle accelerators cost billions of dollars to build. Do you think this is a worthwhile use of the money? Why or why not?
5. How does Homer Neal's career compare to that of other physicists in the Toolkit?

GLOSSARY

Argonne National Laboratory - The first science and engineering research national laboratory in the United States where basic science research is conducted on energy storage, environmental sustainability, and national security

CERN - The world's largest particle physics laboratory located in Geneva, Switzerland where you can find the **Large Hadron Collider**, a particle accelerator that is 27 km in circumference

Fermi National Accelerator Laboratory - A U.S. Department of Energy (DOE) national laboratory specializing in high-energy particle physics; has the world's second largest particle accelerator

High Energy Physics (Particle Physics) - The study of the small, basic elements of matter such as quarks and electrons and the forces acting among them

Top Quark - One of several elementary particles; a major building block of all matter that cannot be broken down into smaller components

ScienceMakers Spotlight

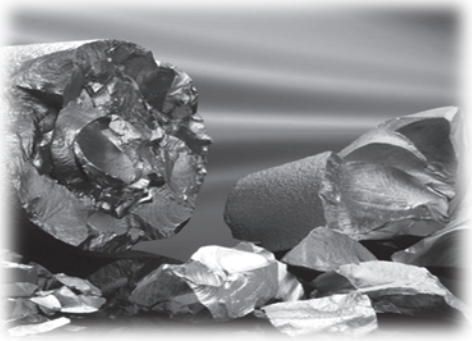
Steven Richardson

Physicist

Birth Date	July 22, 1953
Birth Place	Brooklyn, New York
Education	The Ohio State University (M.S. 1981, Ph.D. 1983)
Awards & Achievements	National Science Foundation (NSF) Career Advancement Award (1992)
	Distinguished *Sigma Xi* National Lecturer (1997,1998)
	Distinguished Summer Faculty Fellow at the Center for Computational Materials Science of the Naval Research Laboratory in Washington, D.C (2011)

BIOGRAPHY

Steven Richardson was born on July 22, 1953 in Brooklyn, New York. His father was a subway conductor and his mother, a nurse; they both stressed the importance of education. Richardson excelled in academics, so he pursued his interests in literature, science, and mathematics at Brooklyn Preparatory High School. He attended Columbia University where he studied chemistry on a National Achievement Scholarship. He received advanced degrees from The Ohio State University: his M.S. degree in physics in 1981 and his Ph.D. degree in theoretical condensed matter physics in 1983. During his graduate studies, he was an International Business Machines (IBM) Minority Graduate Fellow and a Xerox Graduate Fellow. At Xerox, he discovered a new semiconductor surface, which he included in his Ph.D. dissertation.

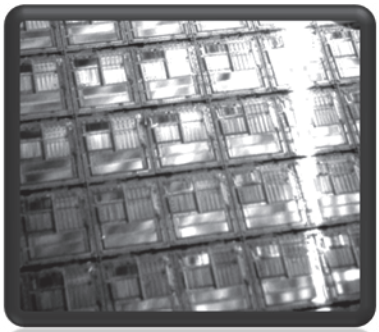


Raw Silicon Material
by Saginaw Future @Flickr

Following graduation, Richardson was a Chancellor's Distinguished Postdoctoral Fellow at the University of California, Berkeley and in 1985, he was a Ford Foundation Postdoctoral Fellow at Lawrence Berkeley National Laboratory. In 1986, Richardson was hired to work at Eastman Kodak Company as a senior research scientist. From 1987 to 1988, he took a temporary leave from Kodak to serve as program director for the National Science Foundation (NSF) Condensed Matter Theory Program. In 1989, he joined the Department of Electrical and Computer Engineering at Howard University as an associate professor and associate director of the Materials Science Research Center of Excellence. In 1995, he was promoted to full professor. Since 1997, Richardson has served as a visiting scientist at the Naval Research Laboratory. Richardson's research utilized supercomputers to calculate the structural, electronic, and vibrational properties of molecules; this technology has the ability to predict the properties of a variety of different molecules and materials. His research has been supported by many public institutions including, the Office of Naval Research, the U.S. Department of Energy (DOE), and the National Science Foundation. Steven Richardson works in Washington, D.C.

SCIENCE IN ACTION

SEMICONDUCTORS: FINDING THE RIGHT AMOUNT OF FLOW



A Silicon Wafer
by JamesIrwin @Flickr

Steven Richardson studies semiconductors. Semiconductors, such as silicon and gallium, are materials that conduct electricity poorly because their crystal lattice structure is bound very tightly. Only a few free electrons can move from atom to atom, leading to a very weak electric current. Adding impurities to semiconductors, a process called doping, can either improve or weaken this electrical current. Impurities such as arsenic and phosphorus increase the flow of electrons but impurities such as aluminum and boron decrease it. The ability to control the flow of electricity through semiconductors has made them an extremely important material in technology, especially electronics.

DISCUSSION QUESTIONS

1. If you were to interview Steven Richardson, what questions would you ask him?
2. Check out this video about the *Texas Instruments* Silicon Chip (http://www.youtube.com/watch?v=X9Z3D_o8m5s /). Why is a silicon chip so important?
3. Why is a semiconductor like silicon used to make a chip instead of metals like iron or copper?
4. Steven Richardson researches molecules using a supercomputer. Would you like to do this type of research? Why or why not?
5. How does Steven Richardson's career compare to that of other physicists in the Toolkit?

GLOSSARY

Condensed Matter Physics - The branch of physics involving the properties of solids, liquids, and other forms of matter in which atoms or particles are highly concentrated

Crystal Lattice - An exact organization of atoms in a solid substance that allows for a specific place for every molecule or atom

Dissertation - A long essay on a particular subject, especially one written as a requirement for a Ph.D. degree

Lawrence Berkeley National Laboratory (LBNL) - A U.S. Department of Energy (DOE) national laboratory conducting unclassified scientific research across a wide range of scientific disciplines

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Semiconductor - A material that is neither a good conductor nor a good insulator of electricity such as silicon, boron, and carbon

Supercomputer - A computer that is many times more powerful than an average PC; used for very large calculations and data analysis like weather and climate modeling

U.S. Department of Energy (DOE) - A U.S. Government agency that researches and oversees energy technology, energy conservation, and nuclear weapons

ScienceMakers Spotlight

Carl Rouse

Astrophysicist

Birth Date	July 14, 1926
Birth Place	Youngstown, Ohio
Education	Case Institute of Technology (B.S. 1951)
	California Institute of Technology (M.S. 1954, Ph.D. 1956)
Awards & Achievements	Case Institute Physics Prize for Excellent Grades (1951)

BIOGRAPHY

Carl Rouse is internationally known for his work in solar physics and astrophysics; he found new ways to study the sun and challenged known theories at the time. Rouse was born on July 14, 1926 in Youngstown, Ohio, and grew up in a busy neighborhood next to large steel mill factories. He was introduced to science by building model airplanes and helping his father repair cars. A good student, Rouse graduated from high school one semester early in 1944, and enlisted in the United States Army, where he was encouraged to study engineering at Howard University, Pennsylvania State University, and New York University. Honorably discharged in 1946, Rouse created engineering drawings before enrolling at Case Institute of Technology where he received his B.S degree in physics in 1951. Rouse then went on to receive his M.S. degree in 1954 and his Ph.D. degree in physics in 1956 from the California Institute of Technology.

Corona of the Sun During a Solar Eclipse by NASA Goddard Photo and Video @Flickr

Rouse knew he wanted to spend his time in research, so rather than teach at a college, he worked at an airplane company before transferring to the Lawrence Livermore National Laboratory in 1957. Rouse worked on the effect of the atomic bomb, studying how its explosion can change a solid, like iron, into a gas in less than a second. He developed a new way to measure helium in the sun's atmosphere, which challenged the conventional theory about the interior of the sun. In 1968, he moved to the General Atomic Laboratory where he studied applications of atomic energy including nuclear shielding. Rouse also used the company's supercomputer for his own research on the sun's atmosphere. In 1992, he founded Rouse Research, Inc., a private company in Del Mar, California. Carl Rouse has three adult children: Cecilia, Carolyn, and Forest Rouse.

SCIENCE IN ACTION

HIDDEN LAYERS OF THE SUN

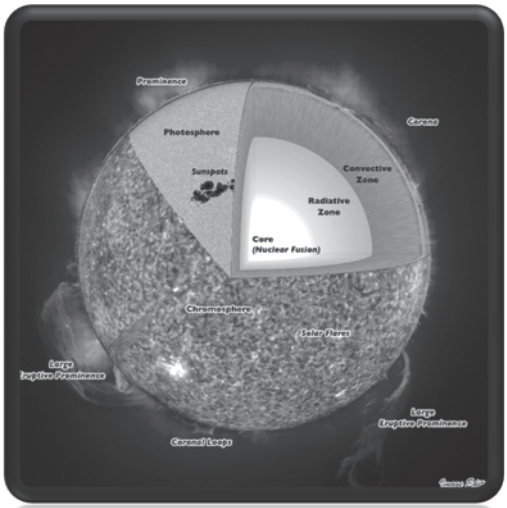


Diagram of the Sun
by Image Editor @Flickr

Did you know the sun has layers? The outer layers of the sun make up its atmosphere. The sun has the same chemical elements as the Earth, but it is so hot that all of them are in a gaseous state. There is no real surface to the sun. Gases just come closer together and become denser towards the Sun's center. We can measure the mass of the sun, its radius, and how brightly it shines. Carl Rouse created a new model of the sun because the standard model at the time did not reflect the known quantities. He used additional observations to create his unique model, including helioseismology, the study of listening to the sun's sound waves.

DISCUSSION QUESTIONS

1. If you were to interview Carl Rouse, what questions would you ask him?
2. Check out NASA's information about the sun (http://imagine.gsfc.nasa.gov/docs/science/know_l1/sun.html). What are the names of the layers of the sun?
3. Do you think the sun weighs more than the Earth? Make a guess and explain your reason. Then do some research to find out if you were right.
4. Why do you think it is important to study phenomena in outer space like the sun's atmosphere?
5. How does Carl Rouse's career compare with that of other physicists in the Toolkit?

GLOSSARY

Astrophysics - The study of the physics of stars, galaxies, and the interstellar medium

Atomic Energy - The energy released by a nuclear reaction

Helioseismology - The study of listening to the sun's sound waves

Helium - One of the lightest gases; used to fill balloons

Lawrence Livermore National Laboratory (LLNL) - A scientific research laboratory with the principal responsibility of ensuring the safety, security, and reliability of the nation's nuclear weapons

Nuclear Shielding - The development of materials to effectively shield humans and other living organisms from the effects of nuclear reactions

Supercomputer - A very powerful computer that is many times more powerful than your average computer; used for very large calculations and data analysis like weather and climate modeling

ScienceMakers Spotlight

Arthur Thorpe

Solid State Physicist

Education	Howard University (B.S. 1954, M.S. 1959, Ph.D. 1964)

BIOGRAPHY

Arthur Thorpe has had a significant presence in the physics department of Howard University for the last fifty years, first as a student, then as a professor, researcher, and mentor. Thorpe attended Howard University where he received his B.S. degree in 1954, his M.S. degree in 1959 and his Ph.D. degree in 1964.

Howard University by Kevin Coles @Flickr

After completing his graduate studies, Thorpe joined the faculty of Howard University as an assistant professor of research in the Department of Physics. From 1969 to 1971, he served as the assistant dean of the graduate school. In 1971, he was promoted to full professor of physics and served as chairman of the physics department until 1979. Thorpe directed the Cooperative Physics Program funded by the U.S. Office of Education from 1974 to 1980. In 1993, he became the director of the National Aeronautics and Space Administration (NASA)-funded Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA) at Howard University. The center emphasized the training of African Americans in the space-based sciences and engineering. Thorpe recruited many students for the center. His research involved the study of solid state physics, the evaluation of superconducting materials for space application, and enhancing high-temperature superconductors. Thorpe has mentored many students who have gone on to lead successful careers in physics. During part of his long career at Howard, Thorpe commuted from North Carolina to Washington, D.C. by flying his own airplane. He would spend his whole day in the physics department teaching, researching, and working with students. Thorpe has written over ninety-three publications in major scientific journals such as the *Journal of Geophysical Research*, the *Journal of Radiation Effects,* and the *Journal of Bioinorganic Chemistry*. Arthur Thorpe works in Washington, D.C.

SCIENCE IN ACTION

SUPERCONDUCTORS: A LEVITATING PHENOMENON

Shanghai Maglev Train
by olekvi @Flickr

Normal conductors, such as copper wires, have resistance meaning that atoms in the wire impede the flow of electricity. Today 6% to 7% of electricity gets lost on the way to consumers, in part due to resistance. Superconductors require no power to move an electric current and allow electricity to flow through them without resistance. The only problem is that superconductors work only under extremely cold temperatures around -234 °C. Scientists like Arthur Thorpe research superconductors so that they function in warmer temperatures. Superconductors can also levitate in the air above a magnet. This phenomena is being used today in some types of Maglev Trains. These high-speed trains are powered by magnets and can travel at over 300 mph.

DISCUSSION QUESTIONS

1. If you were to interview Arthur Thorpe, what questions would you ask him?
2. Check out the Extreme Engineering Video about Maglev Trains (http://dsc.discovery.com/videos/extreme-engineering-season-1-shorts-maglev-train.html). Why does the train have no friction?
3. Arthur Thorpe was the director of the Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA). How are atmospheres on other planets different from Earth? Why does Earth's atmosphere support life and other planets do not?
4. Arthur Thorpe has developed superconductor technology. How do you think superconductors will be used in the future?
5. How does Arthur Thorpe's career compare to that of other physicists in the Toolkit?

GLOSSARY

Maglev Train - A type of high-speed train that runs on magnets supported by a magnetic field generated around the track

Resistance - A material's opposition to the flow of electric current

Solid State Physics - A branch of physics that involves the study of rigid matter, or solids, through various analytical methods

Superconductor - A type of solid material whose electrical resistance drops to zero, freely allowing the flow of electricity when cooled below a certain temperature

Building Roller Coasters

(www.teachengineering.org)

Grade Level: 7 - 9
Time Required: 2 hours
Cost: $10 per group
Group Size: 4

Contributed by: TeachEngineering.org — Resources for K-12

*This activity relates to the work of physicists and physics teachers, like ScienceMaker **Diola Bagayoko**.*

This is an example of a possible student-built marble rollercoaster.
Copyright © Engineering K-PhD Program, Duke University

Summary

Students build their own roller coasters using pipe insulation and marbles, and then analyze them using principles of physics. They examine conversions between kinetic and potential energy and frictional effects to design roller coasters that are completely driven by gravity. A class competition is then held to determine the most innovative and successful roller coasters.

Engineering Connection

During the design of their roller coasters, students encounter many of the issues that actual roller coaster engineers encounter. In order to build a working roller coaster, students must recognize the constraints placed on their design and the design of real roller coasters by basic laws of physics. Their ability to understand and work with these constraints is paramount to the success of their roller coasters.

Pre-Requisite Knowledge

Students need basic prior knowledge about forces, particularly gravity and friction, as well as some familiarity with kinetic and potential energy. They should also know Newton's Second Law of Motion and understand basic concepts of motion, such as position, velocity, and acceleration. The "Physics of Roller Coasters" lesson should be covered prior to the activity.

Learning Objectives

After this activity, students should be able to:

- Explain why it is important for an engineer to know how a roller coaster works.
- Explain in physics terms how their roller coaster works.
- Discuss the effects of gravity and friction in the context of their roller coaster designs.
- Use the principle of conservation of energy to explain the layout of roller coasters.
- Identify points in a roller coaster track at which the car has maximum kinetic energy and maximum potential energy.
- Identify points in a roller coaster track where the car experiences more or less than one g-force.
- Identify points in a roller coaster track where the car accelerates and decelerates.

Materials List

Each group needs

- 1 two-meter (6-foot) long foam tube (1/2" pipe insulation) cut in half lengthwise (one side of the tube should be perforated already; use a pair of scissors or utility knife to cut through this perforation and the other side of the tube to form two halves, so one tube works for two groups)
- 1 glass marble
- 1 wooden marble
- 1 steel marble
- 1 paper cup
- 1 roll of masking tape
- 1 set of markers, crayons, or pencils
- 1 blank sheet of paper
- stopwatch

Introduction/Motivation

During today's activity, you are going to design your own roller coasters using foam tubes and marbles. I'd like for you to start by drawing your roller coaster on paper before actually building it. Along with your drawing, you will also need to name your roller coaster and make a sign for it. [At this point, show the students photographs of some real roller coasters to remind them of the possibilities for their own coasters. Some examples are available at http://www.ultimaterollercoaster.com/coasters/pictures/.]

Remember what you've already learned when designing your roller coasters. The first hill has to be the highest point or the roller coaster won't work. If a car isn't moving fast enough at the top of a loop it will fall off the track. And lastly, you need to make friction between the car and the track as small as you can so the cars can move fast enough to make it through the whole track.

Give each student a copy of the scoring rubric for the class competition. Then let them break up into groups and start designing their roller coasters on paper. Look over their drawings to ensure that their proposed designs are physically possible. If not, point out those aspects of the roller coaster they may want to rethink and allow them the opportunity to iterate their designs. Students will earn points for each type of marble that successfully completes their track and lands safely in the cup. The glass marble simulates a normal car while the wooden marble and the steel marble represent an empty car and a full car, respectively.

Vocabulary/Definitions

force:	A force is any push or pull.
gravity:	Gravity is a force which draws any two objects toward one another.
speed:	Speed is how fast an object moves and is equal to the distance that object travels divided by the time it takes.

velocity: Velocity is a combination of speed and the direction in which an object travels.
critical velocity: Critical velocity is the speed needed at the top of a loop for a car to make it through the loop without falling off the track.
acceleration: How quickly an object speeds up, slows down, or changes direction; equal to change in velocity divided by time.
friction: Friction is a force caused by rubbing between two objects.
potential energy: Potential energy is energy stored by an object ready to be used (in this lesson, we will use gravitational potential energy, which is directly related to the height of an object and its mass).
kinetic energy: Kinetic energy is the energy of an object in motion, which is directly related to its velocity and its mass.
gravitational constant: The gravitational constant is the acceleration caused by Earth's gravity at sea level and is equal to 9.81 m/s^2 (32.2 ft/s^2).
g-force: Also known as a gravitational force, a g-force is equal to the force exerted on an object by Earth's gravity at sea level.

Procedure

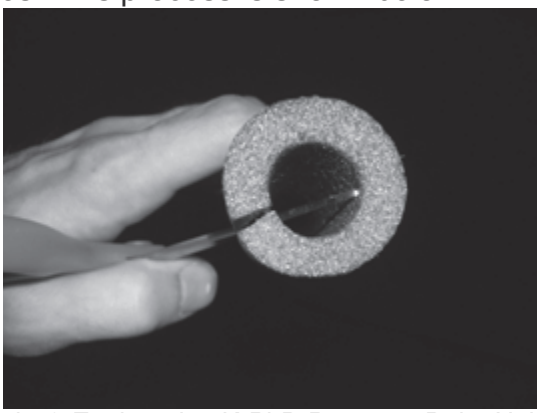
Background

Students must understand a few concepts in order to build and analyze their roller coasters.

- The top of the first hill must be the highest point on the roller coaster.
- Cars move fastest at the bottoms of hills and slowest at the tops of hills.
- Friction will convert useful energy into heat and must be minimized.
- G-forces greater than one occur at the bottoms of hills and g-forces less than one occur at the tops of hills.
- Cars must have a certain velocity at the top of loops to avoid falling.

Before the Activity

- Acquire one tube for each group along with three glass marbles, a wooden marble, a roll of masking tape, and a plastic cup.
- Cut each of the tubes in half so each group receives 1 length of tube cut in half lengthwise. One side of the tube should be perforated already. You can use a pair of scissors or utility knife to cut through the other side of the tube to form two halves, and each group should receive one of these halves. This process is shown below.



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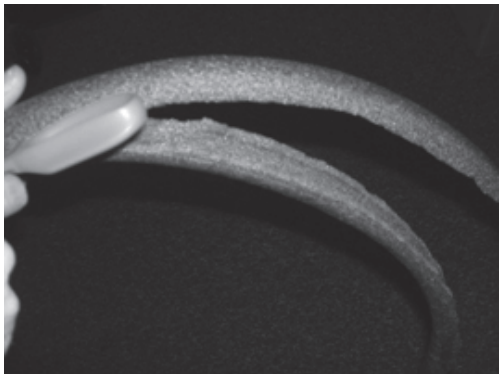

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- Make copies of the worksheet and the scoring rubric for each student or each group of students.
- If there is additional time, the TeachEngineering Lesson "Time for Design" outlines the engineering design process. Utilizing this process while building their roller coasters helps students learn exactly how roller coaster engineers solve problems.

With the Students

- Divide the class into groups of 3-4 students each.
- Have students draw their roller coaster on paper, name it, and make a sign for it. This may take up to 30 minutes.
- Give students the foam tube, masking tape, and cup and let them build their roller coasters using classroom materials. Students should be able to build their first design in 10 minutes or less. The cup should be used to catch the marble at the end of the track.
- Give the students marbles so they are able to test their roller coasters and make any necessary changes. This is the most time-consuming step and students may need up to 45 minutes to redesign their tracks.
- Hand out a stopwatch to each group and give them time to complete the worksheet, in which they determine certain specifications of their roller coasters.
- Have each group present its roller coaster to the class and then use the rubric to help test the roller coasters for the class competition.

Safety Issues

Make sure that students don't swallow the marbles or throw them at one another. Slipping on marbles that are on the floor could also pose a problem. Have students immediately pick up any marbles that fall to the floor.

Troubleshooting Tips

If students have difficulty getting their roller coasters to work …

- They need to make sure that the highest point of the roller coaster is at the beginning.
- They may need to reduce friction by checking that the track is wide enough for the marbles to pass.
- Any deformation in the track occurring when marbles are rolled down the track results in a loss of energy as well, so it is important to make the roller coaster as stable as possible by taping it to supports at several points. Textbooks, walls, desks, chairs, and shelves all make great supports.

Assessment

Activity Embedded Assessment

Check that each group understands how and why their roller coaster works (if it works). If a roller coaster is not working, ask students what they think the problem is. See if they can explain problems such as "It's not high enough" or "The marbles rub too much" in physics terms such as "It doesn't have enough potential energy because it's not high enough," or "The friction between the marble and the track is too great."

Post-Activity Assessment

Ask each student or each group of students to complete the Roller Coaster Specifications Worksheet, (included on the next page) which asks them to identify some critical points of the roller coaster as well as other specifications such as height and the number of loops and turns.

Activity Scaling

- For higher grades, introduce equations for potential and kinetic energy and have students calculate both forms of energy and verify the Law of Conservation of Energy. Loops can also be explored along with the concept of critical velocity. The starting height of a roller coaster necessary to complete a loop of a given height can also be found.
- For lower grade levels, conduct the lesson without most of the physics exploration behind it. Students can build their own roller coasters and discover for themselves many of the concepts that are discussed in detail at higher grade levels (such as energy conservation, friction, and gravity), and they may also be capable of understanding some basic explanations of friction and gravity.

Contributors

Engineering K-Ph.D. Program, Pratt School of Engineering, Duke University: Scott Liddle (This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.)

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Roller Coaster Scoring Rubric

Creativity Points

Points are awarded for each of the following items included in a group's roller coaster.

Every 50 cm of height	1 point
90º turn	1 point
180º turn	2 points
270º turn	3 points
Loop	3 points
Corkscrew	4 points

Performance Points

Points are awarded for each type of marble that successfully completes the roller coaster and lands in the paper cup.

Wooden marble	3 points
Glass marble	3 points
Steel marble	3 points

Group Members

_____

_____

_____

_____

Roller Coaster Worksheet

Roller Coaster Name: _____

Draw a sketch of your roller coaster in the space below:

Height in cm: _____
# of Loops: _____
# of Corkscrews: _____
# of Turns _____

- Place a 1 next to a point on your roller coaster where the cars *accelerate*.
- Place a 2 at a point on your roller coaster where the cars *decelerate*.
- Place a 3 next to the point where cars have the greatest *potential* energy.
- Place a 4 next to the point where cars have the greatest *kinetic* energy.
- Place a 5 at a point where the rider experiences a g-force *greater than 1 g.*
- Place a 6 at a point where the rider experiences a g-forge *less than 1 g.*

Magnetic Attraction

(www.teachengineering.org)

Grade Level: 3 - 5
Time Required: 60 minutes
Cost: 2.50 per group
Group Size: 2

Contributed by: TeachEngineering.org — Resources for K-12

*This activity relates to the work of physicists, like ScienceMaker **Arthur Thorpe**.*

Summary
Students complete a series of six short investigations involving magnets to learn more about their properties. Students also discuss engineering uses for magnets and brainstorm examples of magnets in use in their everyday lives.

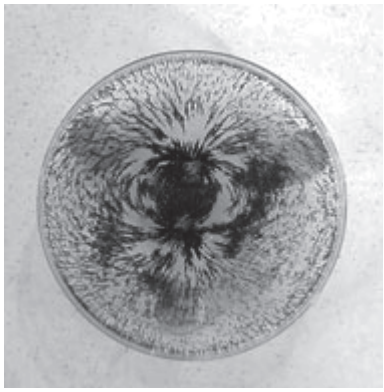

Figure 1. Pattern of iron filings caused by a bar magnet.
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Engineering Connection
While engineers use magnets many purposes, one important use is information storage, or "magnetic memory." We see this everyday in credit cards, VCRs, cassette tapes, computers and zip disks. Magnets are also used in motors and acoustics. Engineers apply their understanding of magnetic fields to design satellites that withstand the effects of the earth's strong magnetic field, which can affect a satellite's orientation around the planet and disrupt sensitive electronics. Engineers design magnetic resonance imaging (MRI) techniques to create computerized images of internal human body tissues using the nuclear magnetic resonance of atoms in the body with the application of radio waves.

Learning Objectives
After this activity, students should be able to:

- Describe some basic properties of magnets.
- Explain that magnets have two different poles that attract or repel other magnets or objects.
- List several devices that engineers have designed using magnets.
- List everyday devices that use magnets.

Materials List
Each group needs:

- Magnetic Attraction Station Worksheet
- Magnetic Attraction Station Instruction Sheet (or, print out one sheet, cut it up and place portions at each station.

Set up the following stations for use by the entire class:
Station 1: Ring Magnets

- 2-4 ring magnets (magnets available at most hardware stores)

- 1 pencil

Station 2: Magnetic Separation
- ½ teaspoon (2.5 grams) sugar
- 1 teaspoon (5 grams) iron filings (available at hardware stores)
- 1 cup (.24 liter) water
- 2 beakers

Station 3: Magnetic Pole Identification
- 1 large bar magnet
- 1 small bar magnet
- 1 orienteering compass
- masking tape

Station 4: Magnetic Loops
- 1 piece thin Plexiglas or a Petri dish
- 4 small items of identical height (corks or blocks), to securely prop up the Plexiglas or Petri dish
- a few differently-shaped magnets (For example, bar, ring or u-shaped magnets)
- a small container of iron filings.

Station 5: Magnetic Prediction
- 1-2 bar magnets
- several test objects, such as corks, erasers, paper clips, coins, cloth, aluminum foil, plastic pen, mechanical pencil graphite, ceramic, Popsicle sticks, etc.

Station 6: Make Your Own Magnet
- 2 bar magnets
- 2 nails (made of zinc, iron or steel, but not aluminum)
- 10-20 paper clips

Introduction/Motivation

Magnets are fun to play with! Today we're going to have the chance to try many different magnet activities. First, what do you know about magnets? Can you name the properties of magnets? Here are some magnet properties: (List them on the board.)
- All magnets have a north pole (N) and a south pole (S).
- Opposite magnet poles attract each other whereas like poles repel or push each other away.
- Magnets have invisible magnetic fields around them (the space around the magnet where the magnet's forces can be felt).
- Some materials can become magnetized by rubbing them in one direction with a magnet or by placing them near a strong magnet.
- Heating, dropping or hammering a magnet decreases its strength and may demagnetize it.

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Did you know that engineers use magnets to make many things, including speakers? That's right the speakers in your stereo or your parents' cars have magnets in them that help them produce sound waves. Engineers also use magnets in many other devices such as motors, television sets, and magnetic information storage in a computer or on a credit card. This magnetic memory storage process records movies on VCR tapes and saves information to a computer. Without engineers, you might not be able to watch your favorite movie, listen to your favorite song, or save photographs onto a computer hard drive!

Engineers must understand everything about the properties of magnets, including how the earth's magnetic field works. Yes, the planet we live on has one gigantic magnetic field. Engineers who work with satellites learn how the magnetic field works so they can get satellites into space. Biomedical engineers design ways to make computer images of the inside of your body using the magnetic fields of atoms in the body, called an MRI (magnetic resonance imaging). Many other types of engineers — if they work with motors — also must understand magnets.

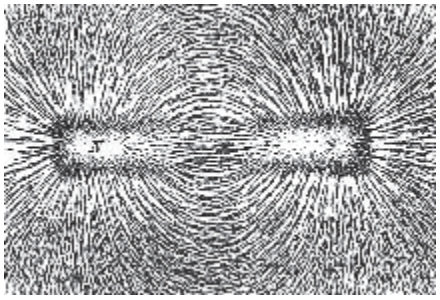
Now that we've talked a little about magnets, who wants to use what we know about magnets and try some activities? There are six different magnet activities for you to try today. Make sure to take your worksheet with you (one per team) and fill it out as you go through the stations.

Vocabulary/Definitions

attract:	To cause to draw near by physical force.
engineer:	A person who applies her/his understanding of science and mathematics to create things for the benefit of humanity and our planet. This includes the design, manufacture and operation of efficient and economical structures, machines, products, processes and systems.
magnet:	Something that attracts iron and generates a magnetic field.
magnetic field:	The portion of space around a magnet where the magnetic forces of the object can be detected.
magnetic memory storage:	Using magnets to store information. For example, computer hard drives, flash drives, floppy drives, zip drives.
Magnetic pole:	One of the two ends of a magnet where the magnetic field is most intense.
repel:	To push back or away by a force.

Procedure

Background



Magnetic lines of force of a bar magnet are shown by iron filings on paper. Note the north and south poles.
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http://en.wikipedia.org/wiki/File:Magnet0873.png

A magnet is an object that attracts ferrous objects and has a magnetic field. A ferrous object is one that contains some amount of iron. Ferrous metals include steel and alloys of iron with other metals, including stainless steel. A magnetic field is the space surrounding a magnet where magnetic forces are exerted on ferrous objects. For example, if an iron nail was placed near a bar magnet, the nail would experience a magnetic force. However, once the nail was removed, the bar magnet's magnetic field would continue to exist. The direction of the magnetic field at any point is in the same direction as the magnetic force at that point.
One of the most common types of magnets is a bar magnet. It is a long uniform rectangle with a north pole on one end and a south pole on the other. The ends are called "north pole" and "south pole" because a magnet that is free to pivot around a vertical axis always points in a north-south direction. This can be seen on a compass. The end that points in the north direction is called the north pole of the magnet and the end that points in the south direction is called the south pole of the magnet. Like ends of a magnet repel each other and unlike poles attract each other.

Before the Activity

- Make copies of the Magnetic Attraction Station Worksheet, one for each student pair, and the Magnetic Attraction Station Instruction Sheet. Either make enough copies to give each team a copy of the full instruction sheet, or cut up one copy of the instruction sheet to post portions at each station.
- Gather materials and assemble a station for each of the magnet demonstrations.
- At Station 1: Ring Magnets, place 2-4 ring magnets and a pencil.
- At Station 2: Magnetic Separation, mix ½ teaspoon (2.5 g) of sugar with ½ teaspoon (2.5 g) of iron filings in a beaker. Place ½ teaspoon (2.5 g) of iron filings in a second beaker with 1 cup (.24 l) of water.
- At Station 3: Magnetic Pole Identification, place 1 large bar magnet, 1 small bar magnet and a compass. Use masking tape to label the poles 1 and 2, making sure to cover any existing N or S pole identification on the bar magnet.

- At Station 4: Magnetic Loops, create a small elevated surface or table by placing a piece of thin Plexiglas on top of four items of identical height (such as corks or blocks). Place a few differently-shaped magnets nearby, along with a small container of iron filings.
- At Station 5: Magnetic Prediction, place a variety of test objects (see Materials List for ideas) along with one or two magnets.
- At Station 6: Make Your Own Magnet, place 2 rectangular magnets, 2 nails, and a small pile of paper clips.

With the Students

1. Divide the class into teams of two students each. Pass out the worksheet, one per team. Pass out a station instruction sheet to each team, or provide instructions at each station.
2. Have the student pairs work through the stations, filling out their worksheet as they go.
3. Station 1: Ring Magnets — Put two ring magnets on the pencil so that the magnets repel each other (see Figure 2). Hold the bottom ring and move it up and down along the pencil. What happens? Next, hold one ring between your thumb and forefinger. Hang the second ring on the first ring edge to edge. Can you make the second ring travel round the first ring in a circle?
4. Station 2: Magnetic Separation — Use a magnet to remove iron filings from the mixtures in the beakers. Why can you separate the mixtures with a magnet?
5. Station 3: Magnetic Pole Identification — Use the small magnet or a compass to determine which pole of the large magnet is the N pole and which is the S pole. Which is the N pole of the large magnet, pole 1 or 2?

Figure 2. Experimenting with ring magnets.
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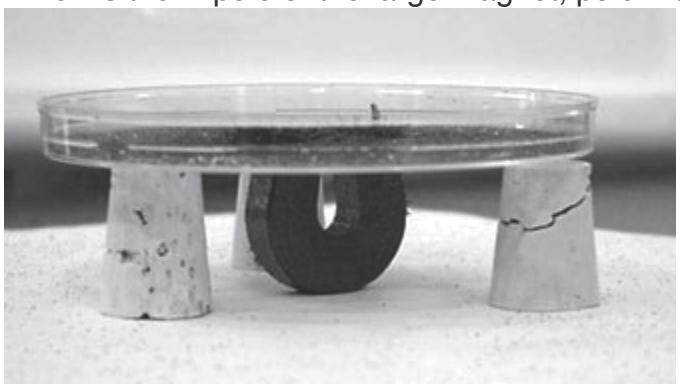

Figure 3. Station 4 set-up using a Petri dish, corks and a u-shaped magnet.
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6. Station 4: Magnetic Loops — Put a magnet under the Petri dish (or Plexiglas) (see Figure 3). Sprinkle some iron filings on the surface of Petri dish. What shapes and patterns do the iron filings make? Try this with magnets of different shapes and sizes. Do they make different shapes? (See Figure 1 for an example of what the filings might look like.)
7. Station 5: Magnetic Prediction — Which objects do you think will be attracted to the magnet? Touch the magnet to each of the items. Which objects stick to the magnet? Which do not? What do the objects that are attracted to the magnet have in common?
8. Station 6: Make Your Own Magnet — Rub the magnet against a nail (in one direction only) to magnetize it. How many paper clips can you pick up with the nail (see Figure 4)? Demagnetize the nail. How do you know it's demagnetized? Now magnetize the nail again. How can you make the nail a stronger magnet using only the materials at the station? How can you test your idea? Demagnetize the nail when you're finished.

Troubleshooting Tips

For the iron filings station, supply magnets that are pre-wrapped in paper towels to assure the iron filings will not stick to the magnets.

To magnetize a nail, students must stroke it in one direction only. Before they leave the station, remind them to demagnetize the nail by hitting it against the tabletop.

It may take some finesse to sprinkle the iron filings on the plastic surface to show the magnetic loops. Practice in advance to be able to help students who have trouble.

Figure 4. A magnetized nail attracts smaller nails and paperclips.
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Assessment

Pre-Activity Assessment

Class Definition: Have students develop a class definition for a *magnet*. Write the definition on the board. Lead them towards an explanation that involves anything that creates a magnetic field, or that attracts or repels other objects such as iron or steel.

Activity Embedded Assessment

Worksheet/Pairs Check: To start the activity, hand out the Magnetic Attraction Worksheet, having students work in pairs to visit each station and complete the worksheet. Have the students check each other's answers.

Prediction: Ask students predict the outcome of the activity before the activity is performed.

- For the Station 5: Magnetic Attraction, ask students to predict on their worksheet which objects will be attracted to the magnet.

Class Discussion: Lead a class discussion and ask the students:

- How can you use a compass to test the poles of a magnet? (Answer: The red [or north] arrow of the compass will point to the north pole of the magnet and the white [or south] arrow of the compass will point to the south pole of the magnet.)
- What did the iron filings do when you held the magnet underneath them? (Answer: The iron filings traced out the invisible magnetic field around the magnet.)
- What were some of the objects around the room that were magnetic? Where were some of the objects that were not magnetic? (Answers may vary.)
- What are some of the devices that engineers have created that use magnets? (Answers may vary).

Post-Activity Assessment

One and Done: Ask students to think of examples of: 1) uses for magnets around their homes, 2) objects that contain magnets and 3) items that contain magnetic memory storage. Have them raise their hands (or indicate thumbs up) when they have an example. Call on students at random to state their answer (either a use or an object). Have students put their hands down once they have contributed an answer. No repeat answers permitted. (Possible example uses: To post papers to the refrigerator, to store information, to find [or hold] pins and needles. Possible example objects that contain magnets: Refrigerator, hair dryer, appliances, anything with a motor. Possible example items that contain magnetic memory storage: Credit card, VCR tape, cassette tape, computer hard drive, zip disk, flash drive, floppy disk.)

Informal Engineering Discussion: Engage students in a discussion to gauge their understanding of the subject. Ask the students:

- Engineers use magnets when designing information storage devices for computers, including hard drives and flash drives. They use strong magnets to read or write information to these devices. Why might you need to be careful with magnets around credit cards, VCR tapes, cassette tapes, zip disks, and floppy disks? (Answer: Magnets can not only read and write information on these items; they can also erase the data or information stored on them.)

- Engineers design ways to recycle thrown-away materials. How could magnets be used to sort recyclable materials? (Example: Magnets are used to separate steel cans from other [non-metal] trash. Refer to what they learned at Station 5: Magnetic Prediction.)

Activity Extensions

Silly Magnetic Pictures: Laminate an image of the face a person (maybe the teacher). Have students place the laminated sheet on top of four blocks. Pour a small amount of iron filings on top of the image. Using a bar magnet underneath the picture, have the students move the filings to create hair, a beard, a mustache or eyebrows on the image.

Construct a series circuit with two batteries, one bulb and a switch. Have the students use a compass to investigate the magnetic field of a current-carrying wire.

Activity Scaling

- For lower grades, conduct the test stations as group demonstrations or at students' desks while they follow along with the teacher.
- For an upper grades math extension, make a graph showing the number of times the nail was stroked with the magnet and the strength the nail's magnetic field (how many paper clips the magnetized nail could attract). Have students use their graph to predict the number of paper clips the nail could pick up if it were stroked an intermediate number of times.

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Space Radiation Analysis Group. Last updated March 4, 2005. Johnson Space Center, NASA. Accessed April 26, 2006. http://srag-nt.jsc.nasa.gov/

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Station Instruction Sheet

Station 1: Ring Magnets
Put two ring magnets on the pencil so that the magnets repel each other. Hold the bottom ring and move it up and down along the pencil. What happens?

Next, hold one ring between your thumb and forefinger. Hang the second ring on the first ring edge to edge. Can you make the second ring travel round the first ring in a circle?

Station 2: Magnetic Separation
Use a magnet to remove iron filings from the mixtures in the beakers.

How does this work? Why can you separate the mixtures using a magnet?

Station 3: Magnetic Pole Identification
Use the small magnet or a compass to determine which pole of the large magnet is the N pole and which is the S pole.

Which is the N pole of the large magnet, pole 1 or 2?

Station 4: Magnetic Loops
Put a magnet under the Petri dish or Plexiglas. Sprinkle some iron filings on the plastic surface. What shapes do the iron filings make?

Try this with magnets of different shapes and sizes. Do they make different shapes?

Draw a picture showing the shape of the magnetic fields for two different magnets.

Station 5: Magnetic Prediction
Which objects do you think will be attracted to the magnet?

Before you test the objects, list them in the worksheet table, and predict which you think will be attracted to the magnet.

Then, test each object by touching the magnet to it. Which objects stick to the magnet? Which do not? Record your results in the worksheet table.

What do the objects that are attracted to the magnet have in common?

Station 6: Make Your Own Magnet
Pick up the nail, knock it against the table top and touch its point to a paper clip. Does the nail behave like a magnet, or not?

Next, rub the magnet against the nail to magnetize the nail. Make sure to rub it in only one direction (not back and forth). Now, how many paper clips can you pick up with the nail?

Demagnetize the nail by knocking it against the table top. How do you know it is demagnetized?

Now magnetize the nail again. How can you make the nail a stronger magnet using only the materials at the station? How can you test your idea?

Remember to demagnetize the nail before you move to the next station.

Team Name: _____ Date: _____

Names: _____ and _____

Magnetic Attraction Station Worksheet

Station 1: Ring Magnets

Draw a picture of the two ring magnets on the pencil. What happens when you move the lower ring magnet?

Station 2: Magnetic Separation

Why can you separate the mixtures using a magnet?

Station 3: Magnetic Pole Identification

Which is the N pole of the large bar magnet, pole 1 or 2?

Station 4: Magnetic Loops

Draw a picture below showing the shape of the magnetic fields for two different magnets.

Station 5: Magnetic Prediction
Before you test the objects:

- List in the table below all the objects you are testing.
- If you predict an object will be attracted to the magnet, write YES in the Prediction column. Otherwise, write NO in the Prediction column.

After you test each object:

- If the object is strongly attracted to the magnet write STRONG in the Result column.
- If the object is weakly attracted to the magnet, write WEAK in the Result column.
- If it is not attracted to the magnet at all, write NO in the Result column.

Test Object	Attraction Prediction	Result
	Yes or No	Strong, Weak or No

Station 6: Make Your Own Magnet
How many paper clips did you pick up with the nail the first time you magnetized it?

How can you tell when the nail is demagnetized?

How can you make the nail a stronger magnet using only the materials at the station? Describe how you would test your idea.

Team Name: _____ **Date:** _____

Names: _____ **and** _____

Magnetic Attraction Station Worksheet Answers

Station 1: Ring Magnets
Draw a picture of the two ring magnets on the pencil. What happens when you move the lower ring magnet?

The upper magnet moves with the lower magnet.

Station 2: Magnetic Separation
Why can you separate the mixtures using a magnet?

As long as one of the materials is magnetic and the other is not, the magnetic material will be removed by the magnet, leaving the other material behind.

Station 3: Magnetic Pole Identification
Which is the N pole of the large bar magnet, pole 1 or 2?

The N pole is the one to which the S pole of the compass or other magnet is attracted.

Station 4: Magnetic Loops
Draw a picture below showing the shape of the magnetic fields for two different magnets.

Answers will vary and should look like the shapes the iron filings make.

Station 5: Magnetic Prediction
Before you test the objects:

- List in the table below all the objects you are testing.
- If you predict an object will be attracted to the magnet, write YES in the Prediction column. Otherwise, write NO in the Prediction column.

After you test each object:

- If the object is strongly attracted to the magnet write STRONG in the Result column.
- If the object is weakly attracted to the magnet, write WEAK in the Result column.
- If it is not attracted to the magnet at all, write NO in the Result column.

Test Object	Attraction Prediction Yes or No	Result Strong, Weak or No
Answers vary according to the provided test materials; check individually. In general, metal objects (except non-ferrous metals such as aluminum) will register a strong or weak attraction, and non-metal objects will register no attraction.		

Station 6: Make Your Own Magnet
How many paper clips did you pick up with the nail the first time you magnetized it?

Answers may vary.

How can you tell when the nail is demagnetized?

A de-magnetized nail will no longer pick up paper clips.

How can you make the nail a stronger magnet using only the materials at the station? Describe how you would test your idea.

Answers may vary; check individually. For example, using the permanent magnet, stroke the nail more. Test to see how many paper clips it picks up. Be careful not to accidentally de-magnetize the nail.

The Biomechanics of Pitching

(www.sciencebuddies.org)

Grade Level: 6 - 8
Time Required: Several days
Cost: $20 - $50

This activity relates to the work of physicists, like ScienceMaker ***Steven Richardson.***

Abstract
What do Nolan Ryan, Mark Wohlers, Armando Benitez, and Roger Clemens have in common? These men are all major league baseball pitchers who have pitched baseballs at 100 miles per hour or greater! What does it take to throw a baseball this fast? Does it come down to having the biggest muscles? Can a ball thrown this fast also be accurate? In this sports science fair project, you will learn about the biomechanics of pitching. Investigate how body position and physics interact to produce fast pitching, and find out if you have the skill and speed to become a major league baseball pitcher.

Objective
To determine how body position affects baseball speed.

Introduction
Baseball is widely known as America's favorite game and pastime. It's fun to watch two teams pit their skill and strategy against each other. There are many factors that affect the score and which team wins the game. The teams need to hit the ball, field the ball, and run fast. One of the most important factors is good pitching. If the pitcher is not in top form, then the opposing team has more chances to hit the ball, get on base, and score.

Figure 1. This image shows a baseball game in progress at Wrigley Field in Chicago, Illinois. (Wikipedia, 2004.)

Pitching a ball quickly and accurately is complicated. It is dependent on how the pitcher controls and uses his or her body to eject the ball from his or her hand. **Biomechanics** is the study of the human body in motion. Biomechanists apply principles from mechanics and engineering to study the forces that act on the body and the effects they produce. A pitcher needs to understand how to use his or her body and become familiar with all of its possible positions in order to pitch a ball as fast as he or she can. In fact, pitchers can get injured if they don't know how to use their bodies properly.

The American Sports Medicine Institute has separated the act of pitching into six phases. It is important for the pitcher to properly perform each step in order to prevent injury. These six phases are as follows:

1. Windup: The windup phase begins when the pitcher steps back with the front foot, balances on the back foot, and picks the front leg up. The windup phase ends when the front leg is at its maximum height and the two hands begin to separate.
2. Stride: During the **stride** phase, a pitcher moves the front foot toward home plate as the two arms swing down and apart from each other. The stride phase ends when the front foot touches the mound.
3. Arm cocking: During the arm-cocking phase, the **pelvis** and then upper body **rotate** to face home plate as the throwing arm externally rotates at the shoulder. The arm-cocking phase ends when the shoulder reaches its maximum external rotation.
4. Arm acceleration: The phase from the instant of maximum shoulder external rotation until ball release is arm **acceleration.**
5. Arm deceleration: The phase from ball release until the arm stops internally rotating is defined as the arm **deceleration.**
6. Follow-through: Follow-through begins with maximum shoulder internal rotation and ends when the pitcher regains a balanced position.

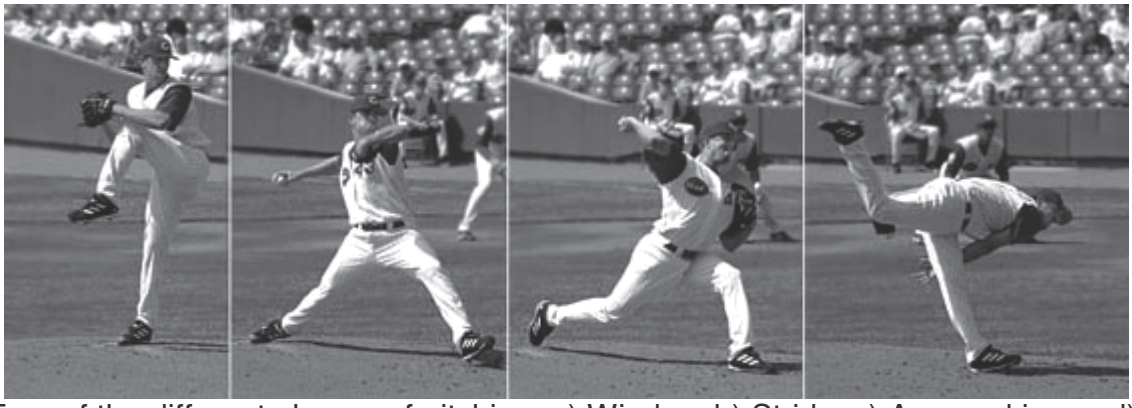


Figure 2. Four of the different phases of pitching: a) Windup, b) Stride, c) Arm cocking and) Follow-through. (wikiHow, 2004.)

Pitching puts a great amount of stress on the throwing arm, especially at the elbow and arm. During pitching, there are both external and internal **forces** acting on the body. External forces include **gravitational** force and the ball's **resistive** force. Internal forces include how each part of the arm (the hand, the wrist, the elbow) act against each other. There is a lot of physics that describes the motion of the throwing arm.

In this sports science fair project, you will experiment with the biomechanics of pitching. You will determine if the stride step and the length of the stride affect the **speed** of a pitch. Remember to warm up your arm prior to starting this science fair project, and stop pitching if your arm starts to hurt. You don't want to get injured as you perform your project. Have your coach or an adult standing by to help, if necessary. Batter up!

Terms, Concepts, and Questions to Start Background Research

- Biomechanics
- Stride
- Pelvis
- Rotate
- Acceleration
- Deceleration
- Force
- Gravity
- Resistance
- Speed

Questions

- What are the different parts of the arm? Is it just the arm that throws, or are different parts of the body involved in throwing?
- What are two joints in the arm that can be injured due to poor pitching? What can happen to these joints?
- What are the biomechanics of other sports, such as golf, soccer, or football?

Bibliography

The following website shows the different phases of pitching and provides more information about pitching:

- American Sports Medicine Institute (n.d.). *Biomechanics of Throwing.* Retrieved January 28, 2009 from http://www.asmi.org/sportsmed/pitching/pitch-biomech.html

For help creating graphs, try this website:

- National Center for Education Statistics. (n.d.). Create a Graph. Retrieved November 12, 2008, from http://nces.ed.gov/nceskids/CreateAGraph/default.aspx

Materials and Equipment

- Clothesline
- Bed sheet, choose a color that contrasts with the color of the baseball.
- Permanent marker
- Clothespins (6)
- Tape measure
- Adult volunteer to use the camcorder
- Camcorder
- Baseball
- Pitching volunteers (3). Your volunteers should have experience throwing a ball.
- Lab notebook
- Graph paper

Experimental Procedure

Preparing the Setup

Note: You should not perform this science fair project on a breezy or windy day.

1. Read the operating instructions of the camcorder you are using. Make sure that the adult who will operate it understands how to work the camcorder, how the timer works, and how to replay a recording in slow motion.
2. At your test location, find two poles or two trees to which you can tie a clothesline. Make sure that the clothesline is securely tied and nowhere near any windows or other breakable objects.
3. Using the permanent marker, draw a large "X" in the middle of the bed sheet. The "X" should be about 2 feet tall.

4. Attach the bed sheet to the clothesline, lengthwise, with the six clothespins. The ends of the bed sheet should touch the ground.
5. Measure a spot 40 feet away from the sheet with your tape measure. This is the position from where you will be throwing the ball. If this distance is too far and you don't think that you will be able to hit the sheet, then move forward to a distance from where you will be able to hit the sheet. Record the distance in your lab notebook.
6. Have your adult volunteer find a safe location from where to record your pitching with the camcorder. The camcorder should be positioned so that the pitcher and the sheet are both in the shot; in other words, the adult volunteer should not pan the camera from the pitcher to the sheet. Be sure the volunteer records each pitcher's entire throw, until the ball is released from the hand. Make sure that the camcorder timer is on.

Figure 3. This pitcher is getting ready to pitch the ball with no stride.

Performing the Trials

1. Exercise your arm in preparation for pitching. You should never start any kind of exercise without warming up properly. Pitch the ball with a comfortable and normal stride forward. Try to get an idea of how long your normal stride is.
2. Have your adult volunteer start the camcorder. Do this first pitch just with your arm and no stride forward. Now aim for the "X" and throw the ball at the sheet.
3. Now pitch the ball with a stride that is the length of your normal and comfortable stride length. Make sure that the volunteer is recording (with the timer on) your pitching and the ball hitting the sheet each time.
4. Repeat steps 2–3 of this section two additional times each. If the ball fails to hit the sheet during any of the trials you will have to redo that trial.
5. Repeat step 5 in the previous section and steps 1–4 of this section with each of your pitching volunteers.
6. Now review the recordings in slow motion for each volunteer. Note the start time and end time for each pitch. The start time is when you can see that the ball has left the volunteer's hand. The end time is when the ball hits the sheet. You can see the sheet start to billow and move when the ball hits the sheet. Record the data in your lab notebook in a data table like the one shown below.

Distance to Sheet =

	Trial	Start Time	End Time	Pitch Time = End Time - Start Time	Speed = $\frac{\text{Pitch Distance}}{\text{Pitch Time}}$	
No Stride						Average speed =
Stride						Average speed =

Analyzing Your Data

1. Once you have collected the data for all of the volunteers, it is time to analyze it. First, calculate the *pitch time,* which is the difference between the start time and the end time, for each trial, of each stride position for each volunteer. This is the time it takes to leave the hand and hit the target. The less time it takes to pitch the ball, the faster the speed of the ball. Record the calculations in your data table.
2. The speed of the ball is calculated by dividing the distance between the pitcher and the target by the pitch time. If you would like to learn more about calculating speed, check out the following Science Buddies project: Speed Quest. Calculate the average speed for no stride and then again for stride.
3. Graph the average speed data. If you would like to learn more about graphing or would like to do your graphs online, try the following website: nces.ed.gov/nceskids/CreateAGraph/default.aspx. Label the x-axis with the following labels: *No Stride* and *Stride.* Label the y-axis *Average Pitching Speed.* Plot the data for all of your volunteers. Can you see a pattern? Is there a difference between striding and not striding?

Variations

- Does striding affect accuracy? Is it easier to hit a target when you stride forward? Do the experiment and find out!
- How does the pitcher's height and weight affect speed? Does it make a difference? Collect 10 volunteers of varying heights and weights and do the experiment.
- What happens if your stride length is longer than your normal and comfortable stride length? Does this affect the speed of the pitch or how you control the ball?
- Kinematics is the branch of mechanics that describes the motion of objects without consideration of the circumstances leading to the motion. Can you see the difference in the motion of the arm between striding and not striding? You can investigate this by taping reflective tape to the joints of the pitching arm and videotaping the pitching.
- For more science project ideas in this area of science, see Sports Science Project Ideas.

Credits

Michelle Maranowski, PhD, Science Buddies
The author would like to thank Mr. Jack Duffy for testing this project.

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Sports_p053.shtml

Space Science

Space Science is a broad term that encompasses all scientific fields concerned with everything outside of the Earth's atmosphere. It is a highly interdisciplinary group of sciences with heavy influence from physics and engineering.

Space Science includes two large scientific fields: astronomy and astronautics. **Astronomy** is the study of the bodies and phenomena that make up the universe, such as galaxies, stars, planets, and asteroids. **Astronautics** is the science and engineering of spacecraft. Space scientists can be astronauts, aerospace engineers, and astrophysicists.

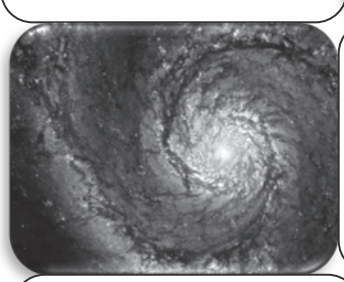
Studying space science teaches you to explore unchartered territory and create innovative tools and technologies. A space scientist is a highly creative, ambitious team player with a probing mind and a sense of daring.

Space Science Disciplines

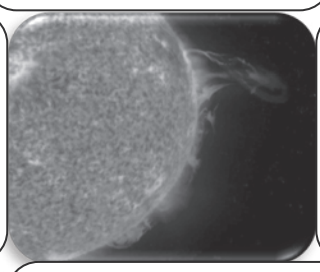
Space Science includes many exciting fields to study and research, here are just a few…

Aerospace Engineering is the design, construction, and science of aircraft and spacecraft.

Astrophysics is the study of physics in outer space including the astrodynamics of extraterrestrial objects like asteroids and comets.

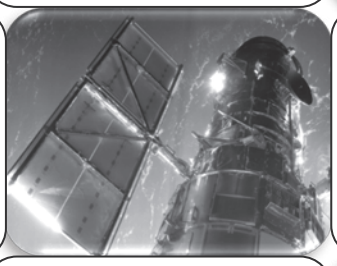


Cosmology is the study of the largest structures of the universe. It is focused on questions about the universe's formation and evolution.

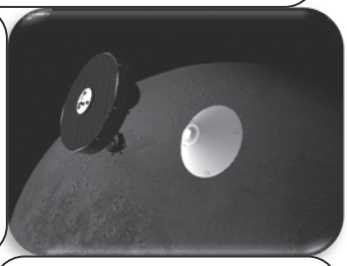


Heliophysics is the study of the sun and heliosphere, the bubble around the sun created by solar wind. Solar wind can travel at over one million km/hour.

Observational Astronomy is a field dedicated to the collection of data and measurements of celestial bodies.



Planetary Science is the study of planets, in particular those in our Solar System. It involves the processes that form the planets and their compositions.



Space Medicine is the practice of medicine on astronauts in outer space. This discipline is focused on extending the time period astronauts can live in space.

Spacecraft Propulsion, is the study of how spacecrafts are launched, change orbits, and navigate space.

Photo credits from Top Left: FlyingSinger @Flickr, Bill Ingalls @Flickr, dsleeter_2000 @Flickr, NASA Goddard Photo and Video @Flickr, NASA Goddard Photo and Video Hubble @Flickr, FlyingSinger @Flickr, John Grunsfeld @Flickr, cosmobc @Flickr

Career Paths in Space Science

Space Science covers a range of careers in many different areas. Below are just a few jobs open to those with a degree in one of the space sciences such as astronomy or astronautics. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Space Scientists can work in settings such as school classrooms, universities, research labs, planetariums, science centers, or museums.

- *Astronomy Professors* at colleges and universities teach and mentor students and conduct research to further their field.
- *Space Center Educators* teach students about the universe, astronautical engineering, and space travel. Some educators work at space camps where students do hands-on activities such as flight simulators.
- *Astronaut Corps Trainers* are expert mechanical engineers, medical doctors, and astrophysicists. They teach astronauts how to operate equipment and simulate space travel, as well as prepare them for any circumstances that may occur in space.

Business & Industry

Space Scientists work for companies that develop, manufacture, and test new products designed specifically for space, such as satellites. They also work in commercial space travel.

- *Aerospace Engineers* design, construct, and test aircraft, missiles, satellites, and spacecraft.
- *Satellite Communication Engineers* design, implement, and support customer networks over both terrestrial and satellite infrastructure, which includes both cellular and wireless communications.
- *Commercial Astronauts* are trained to command, pilot, or serve as crew members of privately funded spacecraft. The developing commercial space industry would bring tourists as well as scientists into outer space.

Government

National Aeronautics and Space Administration (NASA) is the world's leader in space and aeronautics. Their goal is to pioneer the future in space exploration and aeronautics research.

- *Food Technology Specialists* develop new processes and products such as dehydrated food that will allow astronauts to feed themselves on short and long space missions.
- *Planetary geologists* study the terrain of other planets through images and technology that collect data like the Mars Rover. They also study rocks and terrain here on Earth.
- *Mechanical Engineers* develop new technologies for instruments used in satellites and on ground-based missions. These instruments collect data about the atmospheric and climate conditions in space and on other planets.

Check Out Our Featured Space Scientists!

ScienceMakers	Occupation	Workplace	Topics of Science in Action Boxes	Pg.
Wanda Austin	Aerospace Engineer & Engineering Executive	The Aerospace Corporation	Space Debris	324
Isaiah Blankson	Aerospace Engineer & Inventor	National Aeronautics and Space Administration (NASA) Glenn Research Center	Aircraft Engines	327
Charles Bolden	Astronaut & National Aeronautics and Space Administration (NASA) Administrator	National Aeronautics and Space Administration (NASA) Headquarters	The Hubble Telescope	329
Bernard Harris	Astronaut & Medical Doctor	National Aeronautics and Space Administration; The Harris Foundation	Space Exploration	331
Wesley Harris	Aerospace Engineer	Massachusetts Institute of Technology	Aerodynamics	334
Charles McGruder	Astronomer	Western Kentucky University	Life on Other Planets	336
Woodrow Whitlow	Aeronautical & Astronautical Engineer	NASA Headquarters	Aeroelasticity	338
Barbara A. Williams	Astronomer	University of Delaware	Radio Waves	340

ScienceMakers Spotlight

Wanda Austin

Aerospace Engineer & Engineering Executive

Birth Date	August 9, 1953
Birth Place	New York, New York
Education	Franklin and Marshall College (B.S. 1975)
	University of Pittsburgh (M.S. 1977)
	University of Southern California (Ph.D. 1988)
Awards & Achievements	Women in Technology International Hall of Fame Inductee (2007)
	President Obama's Review of Human Spaceflight Plans Committee Member (2009)
	Black Engineer of the Year (2009)

BIOGRAPHY

Wanda Austin grew up in the Bronx, New York, and worked hard to develop her love for mathematics. Her hard work paid off because Austin became the president and CEO of the Aerospace Corporation, one of the most prominent research facilities in the world. Austin was born on August 9, 1953 in New York, New York and her parents, a barber and a nurse, encouraged her interest in math. After graduating from Bronx High School of Science in 1971, Austin received a scholarship to attend Franklin and Marshall College where she earned her B.S. degree in mathematics in 1975. Austin earned her M.S. degrees in mathematics and systems engineering from the University of Pittsburgh in 1977. Austin then worked at Rockwell International assisting in the development of missiles used in war planes.

Satellite
by damien_m_in_japan @Flickr

In 1979, Austin began her career with The Aerospace Corporation, a non-profit research and development center with strong ties to the United States' National Security, Space, and Communications programs. Austin received money from the Aerospace Corporation to continue her education, and she earned her Ph.D. degree from the University of Southern California in 1988. During her studies, Austin also worked for the United States Air Force Satellite Communication Systems, where she was promoted to manager in 1991. She helped to create a system of communications satellites for the U.S. Military, which allowed them to safely transmit important information. Austin became the general manager of the Electronic Systems Division of The Aerospace Corporation in 1997. Within three years, she rose to senior vice president of the National Systems Group. In 2008, Austin was unanimously selected by the Aerospace Corporation board of trustees to become the president and CEO of the organization. Austin and her husband Wade have two adult sons.

SCIENCE IN ACTION

SATELLITE OR SPACE JUNK?

Satellite
by BobMacInnes @Flickr

You have probably heard the word “satellite,” but what is a satellite? It can be any object, natural or manmade, that revolves around another object, in this case, the Earth. There are thousands of satellites that currently orbit the Earth, but scientists like Wanda Austin have to differentiate between useful satellites and "space junk," nonfunctioning manmade material which also orbits the earth. Space junk, or space debris, can come from used rocket boosters, nuts and bolts from space station construction, discarded items from astronauts, and pieces of exploded spacecraft. Some scientists are developing special spacecraft with giant nets to scoop up the space junk and dispose of it.

IN HER OWN WORDS

Wanda Austin was interviewed by The HistoryMakers on April 25, 2011. Here is a portion of her interview:

I thought of myself as going to college. I don't think mathematician per se. But again because to me that was just normal. It was sort of like well of course I can do those math problems, that's no big deal. You know my mother [Helen McCallum Lewis Pompey] would take me to the grocery store and I could tell her to within five cents what the grocery bill would be. Because it was just something, again that I had an affinity for. Didn't seem strange to me, it's just one of those things where you say of course everybody can do that, right? But I didn't think, I don't think it was formalized in my mind as being a mathematician 'til I was in college.

DISCUSSION QUESTIONS

1. If you were to interview Wanda Austin, what questions would you ask her?
2. Check out the website for The Aerospace Corporation, (http://www.aero.org/). What other work is done there?
3. Some scientists are developing special spacecraft with giant nets to get rid of space junk. Can you think of other possible ways to clean up the space just outside the earth's atmosphere?
4. Austin worked on communication satellites for the U.S. Military. Why is this important?
5. How does Wanda Austin's career compare with that of other space scientists in the Toolkit?

GLOSSARY

Aerospace Corporation - A private company associated with the U.S. Air Force whose main purpose is to conduct scientific research in support of the U.S. Government

CEO - Chief Executive Officer*;* the leader in charge of operating the company; may appoint other managers (including a president)

Communications Satellite - A manmade object that orbits the Earth and transmits signals to and from Earth

National Systems Group - A division of the Aerospace Corporation that uses systems engineering to support space programs of the National Reconnaissance Office, a U.S. Government intelligence agency

Rockwell International - An American manufacturing company in the latter half of the 20th century, involved in aircraft, the space industry, both defense-oriented and commercial electronics, and automotive and truck components among other things

Space Debris - Manmade material orbiting the earth that no longer serves a purpose, such as old rocket parts

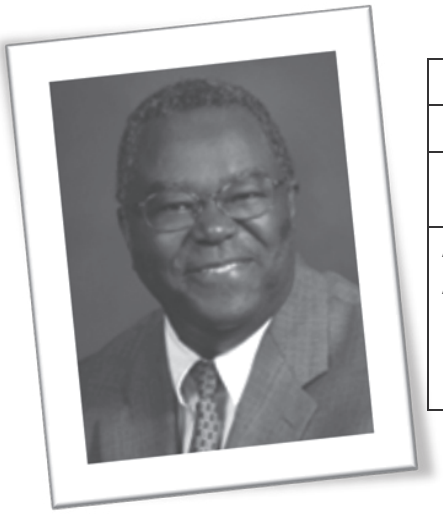
Systems Engineering - A branch of engineering that involves the design and management of complex engineering projects

United States Air Force - A branch of the U.S. Military whose goal is to defend the country by mastering air and space

ScienceMakers Spotlight

Isaiah Blankson

Aerospace Engineer & Inventor

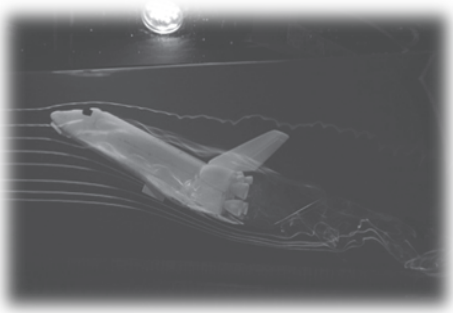


Birth Date	September 28, 1945
Birth Place	Cape Coast, Ghana, West Africa
Education	Massachusetts Institute of Technology (B.S. 1969, M.S. 1970, Ph.D. 1973)
Awards & Achievements	Black Engineer of the Year Award (2005)
	Black Scientist of the Year Award (2006)
	Presidential Rank Award of Meritorious Senior Executive (2006)

BIOGRAPHY

Isaiah Blankson is well known for his work with high-speed propulsion at the National Aeronautics and Space Administration (NASA) Glenn Research Center. He was born on September 28, 1945 in Cape Coast, Ghana, a country in West Africa. After graduating from high school, Blankson pursued his education at Massachusetts Institute of Technology (MIT). He earned his B.S., M.S., and Ph.D. degrees in 1969, 1970, and 1973, from the Department of Aeronautics and Astronautics at MIT. His Ph.D. thesis was on hypersonic aerodynamics and propulsion, which means he studied super high speed aircraft.

Blankson worked as an aerospace research scientist for several organizations before beginning his career at NASA as a hypersonics program manager in 1988. There, he was in charge of planning, directing, reviewing, and managing an annual budget of $28 million. In 2000, Blankson was promoted to senior scientist/technologist in the Research and Technology Directorate at NASA Glenn Research Center in Cleveland, Ohio. Blankson has studied missile and aircraft flight by investigating the flow of gas around the aircraft or missile. Aerodynamics is the way air moves around things, for example, how the air behaves when the wing of an airplane passes through it. Blankson specifically examined electromagnetic fields that are involved in flows. His research also targeted a new type of imaging called passive millimeter-wave imaging, which includes full-body scanning at airport security. During his time with NASA, Blankson has made important contributions to high-speed propulsion technology including several engine patents. One such patent was the Exoskeletal Engine Concept. Additionally, Blankson contributes to preparing the next generation of scientists and engineers at universities like Hampton University, North Carolina A&T State University, and the University of Maryland. Isaiah Blankson lives with his wife Marsha in Solon, Ohio.



Shuttle Aerodynamics by .RGB @Flickr

Above Picture of Isaiah Blankson from rt.grc.nasa.gov

SCIENCE IN ACTION

WHAT MAKES VEHICLES MOVE?

Airplane
by viZZZual.com @Flickr

Every vehicle, from the bus you ride to school, to the airplane that takes you on vacation, has an engine. Standard airplane turbine engines work by combustion, a process in which chemical energy from fuel is combined with oxygen in compressed air to create mechanical energy. Isaiah Blankson helped invent a new aircraft engine technology called the Exoskeletal Engine Concept, which is safer, more efficient, and more versatile than the standard gas turbine engine. The Exoskeletal Engine Concept is better because it is composed of stronger materials that last longer without degrading. It is also very heat resistant, so keeping the engine cool is not a problem.

DISCUSSION QUESTIONS

1. If you were to interview Isaiah Blankson, what questions would you ask him?
2. Check out NASA's website on aerodynamics (http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html). What did you learn about aerodynamics after exploring the website?
3. Isaiah Blankson is an inventor just like the inventor of the light bulb. Can you think of other inventions that have made your life easier?
4. Isaiah Blankson studies ways to improve high-speed aircraft, like a space shuttle. Why is it important for the U.S. to be on the cutting-edge of aerospace technology?
5. How does Isaiah Blankson's career compare with that of other space scientists in the Toolkit?

GLOSSARY

Combustion - A process by which chemical energy from fuel is combined with oxygen in compressed air to create mechanical energy

Electromagnetic Field - A force that results from an electric charge in motion; contains both electric and magnetic components

Exoskeletal Engine Concept - Aircraft engine technology that is stronger and more efficient than the standard gas turbine engine

Hypersonic Aerodynamics - The study of gas flow around solid objects such as aircraft at super high speeds

NASA Glenn Research Center - A NASA field office in Cleveland, Ohio, that focuses on the design of aeronautical technology for space flight

Passive Millimeter-Wave Imaging - A technology that differentiates between the millimeter wave emissions that are given off by human skin and the lower energy emissions of inanimate objects; used in airport security full-body scanners

Patent - A declaration issued by a government agency that declares someone the inventor of a new invention with the privilege of stopping others from making, using, or selling the claimed invention

ScienceMakers Spotlight

Charles Bolden

Astronaut & NASA Administrator

Birth Date	August 19, 1946
Birth Place	Columbia, South Carolina
Education	U.S. Naval Academy (B.S. 1968)
	University of Southern California (M.S. 1977)
Awards & Achievements	NASA Exceptional Service Awards (1988, '89, '91)
	U.S. Marine Corps Defense Superior Service Medal and Distinguished Flying Cross
	U.S. Astronaut Hall of Fame Inductee (2006)

BIOGRAPHY

Charles Bolden became the first African American to hold the position of National Aeronautics and Space Administration (NASA) Administrator, the highest position at NASA. Bolden was born on August 19, 1946 in Columbia, South Carolina and as a child, he dreamed of joining the U.S. Navy. After graduating from high school in 1964, Bolden received a congressional appointment to study at the U.S. Naval Academy. He earned his B.S. degree in electrical science in 1968 and was commissioned as second lieutenant in the U.S. Marine Corps. Bolden chose flying over ground combat, becoming a naval aviator after finishing flight school in 1970. He flew in more than one hundred combat missions during the Vietnam War. After the war, Bolden earned his M.S. degree in systems management from the University of Southern California in 1977.

Space Shuttle Atlantis Liftoff by Official U.S. Navy Imagery@Flickr

In 1978, Bolden became a test pilot at the Naval Air Test Center, and the next year, he was accepted into the NASA Space Program. Bolden piloted space shuttles, *Columbia* (1986) and *Discovery* (1990), the latter of which deployed the Hubble Space Telescope. In the wake of the 1986 Challenger disaster, Bolden became the chief of the safety division at NASA. Bolden also served as mission commander for space shuttles *Atlantis* (1992) and *Discovery* (1994), spending a total of 680 hours in space during his four flights. In 1994, Bolden returned to active duty in the U.S. Marine Corps as deputy commandant of midshipmen at the U.S. Naval Academy. He served in Operation Desert Thunder in Kuwait in 1998. In 2002, Bolden was promoted to major general, the highest post an African American has had in the U.S. Marine Corps. He retired from the U.S. Marine Corps in 2003 and served as president of the American PureTex Water Corporation. In 2009, President Barack Obama appointed Bolden NASA Administrator. Charles Bolden and his wife Alexis Walker have two children.

Above Picture of Charles Bolden from www.nasa.gov

SCIENCE IN ACTION

POWERFUL TELESCOPE

Hubble Telescope
by cliff1066 @Flickr

Have you ever wanted to travel in space? In 1990, Charles Bolden piloted the space shuttle *Discovery*. The journey lasted five days, and its primary mission was to deploy the Hubble Telescope, which orbits the earth every ninety-seven minutes at 353 miles above our atmosphere. The telescope provides high quality images of space. Bolden talks about the sheer power of the telescope, explaining that if he stood on the moon with a nickel in his hand, he could read from the Earth the words, 'In God We Trust.' The Hubble Telescope needs electricity to operate, but since there are no electrical outlets in space, it relies on power from the sun through solar cells similar to those used on the Earth's surface.

DISCUSSION QUESTIONS

1. If you were to interview Charles Bolden, what questions would you ask him?
2. Check out NASA's website (http://sm3a.gsfc.nasa.gov/classrm2.html#buzz). What did you learn about the Hubble Telescope?
3. As chief of the NASA Safety Division, Charles Bolden ensured space flight safety by making sure the equipment was working. Can you think of other ways to ensure a safe space journey?
4. Charles Bolden is the head of NASA. Why is it important for the U.S. to have a space program?
5. How does Charles Bolden's career compare to that of other space scientists in the Toolkit?

GLOSSARY

Barack Obama - 44th president of the United States and the first African American to hold the office

Challenger Disaster - A failed 1986 U.S. Space Shuttle launch that resulted in the deaths of all seven astronauts on board; the failure was due to a malfunction in one of the rocket boosters

Hubble Space Telescope - A scientific instrument, deployed in April 1990, that orbits the earth at 353 miles in altitude and provides images of space that are not obstructed by the atmosphere

Operation Desert Thunder (1998) - A U.S. Military mission in response to threats by Iraqi President Sadaam Hussein to shoot down U.S. planes and disregard a U.S. established no-fly zone

Systems Management - The field of study related to the operation of information technology (such as computers) and other systems; provides the skills necessary to take the lead on projects and ensure a smooth process and finish

U.S. Marine Corps - A branch of the U.S. Armed Forces composed of troops that operate on land and on water

U.S. Navy - A branch of the U.S. Armed Forces that maintains, trains, and equips combat-ready forces who operate primarily on water

Vietnam War - A military conflict during the years 1954 to 1975 between the Chinese- supported Communist forces of North Vietnam and the U.S.-supported forces of South Vietnam

ScienceMakers Spotlight

Bernard Harris

Astronaut & Medical Doctor

Birth Date	June 26, 1956
Birth Place	Temple, Texas
Education	University of Houston (B.S. 1978)
	Texas Tech University Health Science Center of Medicine (M.D. 1982)
	Mayo Clinic (Residency, 1985)
	University of Houston (M.B.A.)
Awards & Achievements	American College of Physicians Fellow
	Ronald E. McNair Foundation *Challenger* Award (1996)
	Horatio Alger Award (2000)

BIOGRAPHY

In 1969, when Bernard Harris watched the first landing on the moon, he set his sights on space exploration. Harris was born in Temple, Texas on June 26, 1956. During his youth, Harris lived on the Navajo reservations of Arizona and New Mexico. In high school, Harris decided he wanted to be a medical doctor. He attended the University of Houston, earning his B.S. degree in biology in 1978. Harris continued his education at Texas Tech University Health Science Center of Medicine and received his M.D. degree in 1982. He then completed his residency in internal medicine at the Mayo Clinic in Rochester, Minnesota.

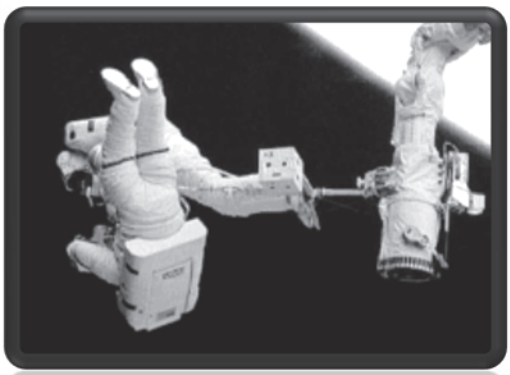
Space Shuttle Launch
by Matthew Simantov @ Flickr

Never forgetting his aspirations to become an astronaut, Harris followed a career path that would enable him to realize this dream. Upon completing his residency, Harris pursued research opportunities at Ames Research Center and later the Lyndon B. Johnson Space Center. In 1990, Harris joined the elite training group, National Aeronautics and Space Administration (NASA) Astronaut Corps. Following the completion of intensive training in 1993, Harris joined the Space Shuttle *Columbia* as a mission specialist. Two years later, he made history as the first African American to walk in space, where he and crew member Michael Foale tested the temperature resilience of their spacesuits. Following his career in astronautics, Harris became an entrepreneur in 1996, working as vice president of Spacehab Inc., which was focused on commercializing space exploration. Bernard Harris founded The Harris Foundation in 1998, which works to empower minorities and economically and socially disadvantaged individuals by supporting education and health initiatives. After earning his M.B.A. degree from the University of Houston, Clear Lake, Harris became executive director of Versalius Ventures in 2001. He also had a middle school named after him in 2006. Bernard Harris lives in Houston, Texas.

Above Picture of Bernard Harris from www.yourhoustonnews.com

SCIENCE IN ACTION

SPACE EXPLORATION



Bernard Harris Space Walk
from www.aaregistry.org/historic_events/view/first-african-american-walks-space

Bernard Harris went on two space missions during his career as an astronaut. On the Space Shuttle *Columbia* in 1993, Harris investigated the effect of zero gravity on the human body. He developed in-flight medical and exercise devices to extend an astronaut's time in space. The Space Shuttle *Columbia* orbited the earth every ninety minutes and Harris saw a sunrise or sunset every forty-five minutes. On his second mission in 1995, Harris was the payload commander which means he was in charge of the science laboratory on the space shuttle. That mission was the first meeting with the Russian Space Station *Mir*. You can read about Bernard Harris's inspirational journey in his autobiography, *Dream Walker*.

IN HIS OWN WORDS

The HistoryMakers honored the accomplishments of Bernard Harris in a televised program taped on March 15, 2011. Here is a portion of the program:

Let me share the details of getting into space and how interesting that can be...The shuttle vehicle weighs five million pounds in order to get that vehicle into space we have to light five engines... that produces a thrust of 7 1/2 million pounds and with that pushing against the ground we go in the opposite direction in a hurry. It only takes 8 1/2 minutes to get to space...getting there is exciting...I remember on my first mission we got up there the main engines cut off and we went from being pushed back in our seat at three times our weight to zero gravity in a split second. I turned to the commander and went wow, that was cool.

DISCUSSION QUESTIONS

1. If you were to interview Bernard Harris, what questions would you ask him?
2. Check out the Physics4Kids website (http://www.physics4kids.com/files/motion_gravity.html). Why is gravity important to life on earth?
3. The Bernard Harris Space Camp is a free summer program for students interested in math and science. Check out their website (http://www.theharrisfoundation.org/sitecontent/565/summer-science-camp/category/457/education.aspx) If you went to space camp, what aspect of space science (space medicine, planets, space shuttle engineering) would you be interested in learning? Why?
4. Bernard Harris worked on finding ways for humans to spend long periods of time in the zero gravity of space. How might this change the future of space exploration?
5. How does Bernard Harris's career compare with that of other space scientists in the Toolkit?

GLOSSARY

Ames Research Center - One of NASA's ten major field centers; located in California's Silicon Valley

Astronautics - The science and engineering of spacecraft

Lyndon B. Johnson Space Center - NASA's center for human spaceflight training, research, and flight control

Mayo Clinic - A nonprofit worldwide leader in medical care, research, and education located in Rochester, Minnesota

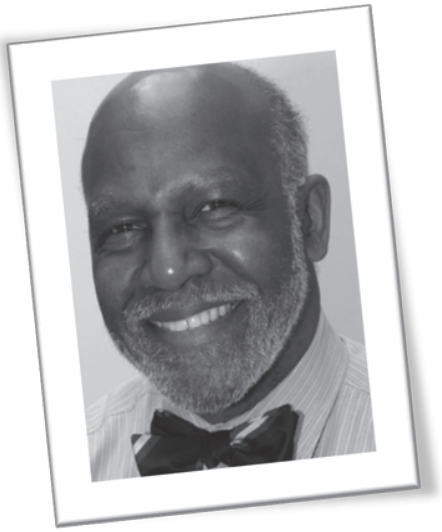
NASA Astronaut Corps - The unit of the United States National Aeronautics and Space Administration (NASA) that selects, trains, and provides astronauts as crew members for U.S. and international space missions

Residency - The period in a doctor's medical training during which he or she gets practical experience with real patients

ScienceMakers Spotlight

Wesley Harris

Aerospace Engineer



Birth Date	October 29, 1941
Birth Place	Richmond, Virginia
Education	University of Virginia, Charlottesville (B.S. 1964)
	Princeton University (M.A. 1966, Ph.D. 1968)
Awards & Achievements	Massachusetts Institute of Technology Irwin Sizer Award, 1979
	The University of Virginia Engineering Foundation's Engineering Achievement Award (1994)
	NASA's Outstanding Leadership Award (1994)

BIOGRAPHY

Wesley Harris loved airplanes as a child and spent his days building model planes. As an adult, he went on to head the National Aeronautics and Space Administration (NASA) Office of Aeronautics where he researched the fluid dynamics of airplanes. Harris was born on October 29, 1941 in Richmond, Virginia. His parents worked in Richmond's tobacco factories and encouraged him to pursue an education. He attended Armstrong High School and with the launch of the first satellite Sputnik, Harris knew the opportunities in the aerospace field would increase. Harris received his B.S. degree in aeronautical engineering in 1964 from the University of Virginia, Charlottesville. He received his M.A. degree in 1966 and his Ph.D. degree in 1968, both in aerospace and mechanical sciences from Princeton University.

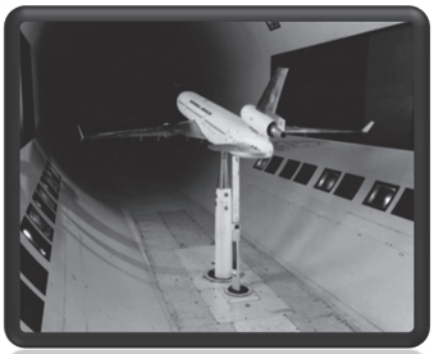
Global Hawk Plane
by NASA Goddard Photo and Video
@Flickr

After completing his graduate studies, Harris joined the faculty of the University of Virginia as an assistant professor of aerospace engineering. In 1972, he left to join the faculty of Massachusetts Institute of Technology (MIT) as an associate professor of aeronautics, astronautics, and ocean engineering. In 1975, Harris founded MIT's Office of Minority Education. From 1979 to 1980, he took a leave of absence from MIT to work at NASA Headquarters as a program manager in the Office of Aeronautical and Space Technology where he developed computational techniques to solve high-speed air movement problems. In 1985, Harris served as dean of the School of Engineering at the University of Connecticut where he spearheaded the establishment of an environmental research center. In 1993, Harris accepted a position as associate administrator for aeronautics at NASA Headquarters where he directed many innovative projects, such as the development of unpiloted vehicles. In 1995, he returned to MIT as the Martin Luther King, Jr. Visiting Professor. Harris became head of MIT's Department of Aeronautics and Astronautics in 2003 and has served as associate provost for faculty equity since 2008. Wesley Harris works in Cambridge, Massachusetts.

Above Picture of Wesley Harris from web.mit.edu/newsoffice/2003/harris-0514.html

SCIENCE IN ACTION

AIR IS SUCH A DRAG



Model Airplane in a Wind Tunnel
by http://windtunnels.arc.nasa.gov/

Would you rather swim a race with all your clothes on or in a swim suit? The obvious answer is a swim suit because there is resistance or drag as you swim. Drag is a mechanical force caused by the difference in velocity between the solid object and the fluid (liquid or gas) it moves in. Drag pulls in the opposite direction that the object is moving in. So when you run, drag pushes against you and slows you down. Speed increases the effect of drag, so in airplanes or space shuttles, which can go 17,500 mph, drag can really make a difference. At NASA, aerodynamics scientists such as Wesley Harris have used wind tunnels to test forces, such as drag that affect an aircraft.

DISCUSSION QUESTIONS

1. If you were to interview Wesley Harris, what questions would you ask him?
2. Check out the NASA Video about Fluid Dynamics (http://www.youtube.com/watch?v=sQ-kEz9Im2UI). What are some examples of drag?
3. Would you like to work as an aerospace engineer like Wesley Harris? Why or why not?
4. Why is it important to increase drag in spacecraft?
5. How does Wesley Harris' career compare to that of other space scientists in the Toolkit?

GLOSSARY

Aeronautical Engineering - The branch of engineering that involves the design, construction, and science of aircraft and spacecraft

Aerodynamics - The study of the properties of moving air and especially of the interaction between the air and solid bodies moving through it

Drag - A mechanical force caused by the difference in velocity between the solid object and the fluid (liquid or gas) it moves in

Fluid Dynamics - A sub-discipline of fluid mechanics that deals with fluid flow and the science of fluid in motion

Velocity - The speed of something in a given direction

ScienceMakers Spotlight

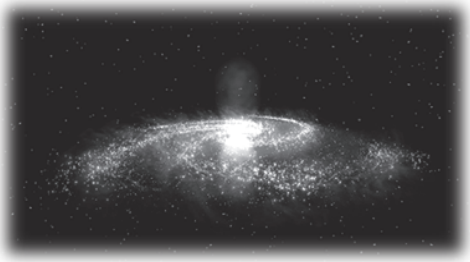
Charles McGruder

Astronomer

Education	California Institute of Technology (B.S. 1965)
	University of Heidelberg, Germany

BIOGRAPHY

Charles McGruder was the second African American undergraduate student to attend California Institute of Technology. He graduated from high school in Bristol, Pennsylvania; and continued his studies at Cal Tech in 1961. At that time, McGruder was the only African American undergraduate student. When he graduated with his B.S. degree in astronomy in 1965, there was only one other African American to follow in McGruder's footsteps, Joseph Rhodes. McGruder received his Ph.D. degree in astronomy from the University of Heidelberg in Germany.



Giant Gamma Ray Bubbles in the Milky Way by NASA Goddard Photo and Video @Flickr

Following graduation, McGruder worked at Fisk University, Vanderbilt University, and the University of Nigeria before he was hired to work at Western Kentucky University as a professor. McGruder served as head of the Department of Physics and Astronomy from 1993 to 2002. He also served as the president of the National Society of Black Physicists (NSBP) from 2000 to 2002. In 2005, McGruder was appointed to the National Research Council's Committee on Astronomy and Astrophysics. The group's goal was to make progress in astronomy, provide counsel to the federal government on how to plan programs, and assess government institutes like the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA). McGruder is the director of Team Experience in Astronomy for Minorities. His research at Western Kentucky University focused on extrasolar planets, gamma ray bursts, and a worldwide network of fully robotic imaging telescopes. McGruder has been very active in astronomy internationally, working on a bid to bring the Square Kilometer Array (SKA) radio telescope to South Africa. It would be the world's largest technological device and bring 1000 radio dishes to South Africa. McGruder also appeared in the 2009 documentary, *Hubble's Diverse Universe*. Charles McGruder works in Bowling Green, Kentucky.

Above Picture of Charles McGruder from physics.wku.edu

SCIENCE IN ACTION

LIFE ON OTHER PLANETS

Planet With Comet Like-Tail
by NASA Goddard Photo and Video
@Flickr

Man has long looked up at the stars and pondered whether or not there is life on other planets. With modern technology, scientists finally have an answer to that question. An extrasolar planet is a planet outside the earth's solar system. The extrasolar planets we have found so far are giants, like Jupiter and Saturn. However, some are a part of solar systems similar to ours, which may have smaller planets that support life. NASA has started a series of missions to find and explore new worlds. The Kepler Mission is a spacecraft equipped with an observatory to seek out habitable planets orbiting other stars. Later missions will measure the distances to stars, characterize hundreds of planets the size of Earth to look for similarities, and launch a telescope a hundred times stronger than the Hubble Space Telescope.

DISCUSSION QUESTIONS

1. If you were to interview Charles McGruder, what questions would you ask him?
2. Go to NASA's Planet Quest website (http://planetquest.jpl.nasa.gov/) and research extrasolar planets. What planet do you find the most intersting?
3. Would you want to research extrasolar planets like Charles McGruder? Why or why not?
4. Do you think it is important to study astronomy and learn about space? Why or why not?
5. How does Charles McGruder's career compare to that of other space scientists in the Toolkit?

GLOSSARY

Astronomy - The study of the bodies and phenomena that make up the universe such as galaxies, stars, planets, and asteroids

Extrasolar - Outside the Earth's solar system

Gamma Ray Bursts - Flashes of gamma rays (a form of radiation energy) that result from explosions in distant galaxies

Hubble Space Telescope - A scientific instrument, deployed in April 1990, that orbits the earth at 353 miles up and provides images of space that are not obstructed by the atmosphere

Kepler Mission - A spacecraft equipped with an observatory to seek out habitable planets orbiting other stars

National Research Council - A private, non-profit institution that seeks to improve government decision making and public policy, increase public understanding, and promote knowledge in matters involving science, engineering, technology, and health

Radio Telescope - An instrument used to detect radio emissions from the sky, whether from natural celestial objects or from artificial satellites

ScienceMakers Spotlight

Woodrow Whitlow

Aeronautical & Astronautical Engineer

Birth Date	December 13, 1952
Birth Place	Inkster, Michigan
Education	Massachusetts Institute of Technology (B.S. 1974, M.S. 1975, Ph.D. 1979)
Awards & Achievements	U.S. Black Engineer of the Year in Government (1989)
	Career Communications Group Scientist of the Year (2007)
	The American Institute of Aeronautics and Astronautics Fellow (2010)

BIOGRAPHY

Woodrow Whitlow has had a meteoric rise through the ranks of the National Aeronautics and Space Administration (NASA) to become a senior administrator, but it all started with a telescope in eighth grade and a fascination with the skies. Whitlow was born on December 13, 1952 in Inkster, Michigan. He received his B.S., M.S., and Ph.D. degrees in aeronautics and astronautics at Massachusetts Institute of Technology (MIT) in 1974, 1975, and 1979, respectively.

Launch at Kennedy Space Center by Undertow851 @Flicker

Whitlow's long career with the National Aeronautics and Space Administration (NASA) began in 1979, when he was hired as a research scientist at the NASA Langley Research Center in Hampton, Virginia. At Langley, he specialized in fluid dynamics, aerodynamics, and aeroelasticity. He rose quickly to become a senior research scientist. He also headed various specialty branches in astrophysics and aeronautics. In 1994, Whitlow became the Director of the Critical Technologies Division in the Office of Aeronautics at NASA Headquarters in Washington, D.C. He then moved to the NASA John H. Glenn Research Center at Lewis Field in Cleveland, Ohio, in 1998 where he served as the director of research and technology, among other positions. Whitlow served as director of the NASA John F. Kennedy Space Center in 2003. He set policies and held duties in the processing of spacecraft and the launching of vehicles. In 2005, he was appointed director of the NASA Glenn Research Center where he was responsible for organizing and overseeing mission-related activities at the Center. In 2010, NASA Administrator Charles Bolden named Whitlow the Associate Administrator for Mission Support at NASA Headquarters. Throughout his career, Whitlow has written nearly forty technical papers, most in the areas of fluid dynamics and aeroelasticity. Whitlow and his wife have two daughters and two granddaughters.

Above Picture of Woodrow Whitlow from www.nasa.gov/centers/glenn/about/bios/whitlowbio.html

SCIENCE IN ACTION

ENGINEERING SPACE SHUTTLES

Space Shuttle Transport
by Ted Van Pelt @Flickr

Ever wonder why a flag can flutter in a stiff breeze or a twig can shake in fast flowing water? This phenomenon is called aeroelasticity, the interaction between three forces: inertia, elasticity, and aerodynamic forces. Aeroelasticity must be considered in designing an airplane because it is impossible to construct an airplane wing that will not move when it is in flight. It is related to flutter, the potentially dangerous occurrence when air currents interact with the vibration of an aircraft causing rapid motion of the aircraft. Thus, NASA scientists need to study aeroelasticity to prevent as much flutter as possible in the space shuttles they design.

DISCUSSION QUESTIONS

1. If you were to interview Woodrow Whitlow, what questions would you ask him?
2. Check out NASA's Kennedy Space Center website (www.ksc.nasa.gov/) where Woodrow Whitlow worked. What projects or missions interest you the most? Why?
3. Woodrow Whitlow worked for NASA, finding ways to prevent aeroelasticity and flutter in an aircraft. Have you been in an airplane when there is turbulence? Why is it important to design airplanes that prevent as much flutter as possible?
4. Do you think NASA is an important program for America's future? Why or why not?
5. How does Woodrow Whitlow's career compare to that of other space scientists in the Toolkit?

GLOSSARY

Aerodynamics - The study of the properties of moving air and especially of the interaction between the air and solid bodies moving through it

Aeroelasticity - The science of the interaction between aerodynamic forces and nonrigid structures

Fluid Dynamics - A sub-discipline of fluid mechanics that deals with fluid flow and the science of fluid in motion

Flutter - Undesired wavering in a part of an aircraft under stress

Inertia - The resistance of an object to a change in its motion

NASA Glenn Research Center - A NASA field office in Cleveland, Ohio that focuses on the design of aeronautical technology for space flight

NASA John F. Kennedy Space Center - The NASA installation that has been the launch site for every United States human space flight since 1968

NASA Langley Research Center - The oldest of NASA's field centers, located in Hampton, Virginia

ScienceMakers Spotlight

Barbara Williams

Astronomer

Education	University of North Carolina, Greensboro (B.S.)
	University of Maryland, College Park (M.S./ Ph.D. 1981)
Awards & Achievements	Outstanding Young Woman of America (1986)

BIOGRAPHY

Barbara Williams used radio waves to create images of galaxies and other celestial bodies. She is known as the first African American woman astrophysicist. Williams received her B.A. degree in physics from the University of North Carolina, Greensboro. She earned her M.S. and Ph.D. degrees in 1981, both in radio astronomy, from the University of Maryland, College Park. As a result, Barbara Williams was the first African American woman to receive her Ph.D. degree in astronomy.

Compact Group of Galaxies by HubbleColor @Flickr

After receiving her Ph.D. degree, Williams served as a research associate at the National Radio Astronomy Observatory. She completed a postdoctoral fellowship in astronomy at the University of North Carolina, Chapel Hill. In 1986, she joined the Department of Physics and Astronomy at the University of Delaware. Williams was promoted to associate professor in 1992. In 1994, Williams became the acting associate chair of the Department of Physics and Astronomy. She has published many scientific papers in the area of radio observations of compact groups of galaxies. Radio waves can penetrate through gas in outer space, as well as through dust and planetary atmospheres, providing a much clearer picture of stars and galaxies. Williams has also worked and researched at many institutions across the United States. She worked at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center as a NASA-American Society for Engineering Education (ASEE) Summer Faculty Fellow in 1987 and a National Research Council Senior Fellow in 1996. Williams served as a visiting professor at Princeton University in 1991 in the Department of Astrophysical Science. She was also a visiting professor at Florida A&M University. Williams has presented at many conferences and is a charter fellow of the National Society of Black Physicists (NSBP). Barbara Williams lives in Newark, Delaware.

Above Picture of Barbara Williams from web.physics.udel.edu/about/directory/faculty/barbara-williams

SCIENCE IN ACTION

RADIO WAVES: MAPPING SPACE

Satellite
by speedysteph01@Flickr

You use radio waves every day when listening to your radio, watching TV, or using your cell phone. Radio waves are a form of electromagnetic radiation, just like visible light you see with your eyes. Barbara Williams uses radio waves to create images of outer space. Telescopes can detect electromagnetic submissions from the ground and space. Thermal radio waves are produced by the motion of charged objects as small as molecules and atoms. The more heat energy contained within an object, the more electromagnetic radiation it releases. Each type of atom creates a different wavelength of radiation. A radio telescope has antennas to collect the radio waves, an amplifier to boost the weaker radio signals, and a recorder to keep a record of the signal.

DISCUSSION QUESTIONS

1. If you were to interview Barbara Williams, what questions would you ask her?
2. Check out the Australia Telescope website (http://outreach.atnf.csiro.au/education/everyone/radio-astronomy/). What are some different types of electromagnetic radiation?
3. How do you use the different types of electromagnetic radiation in your everyday life?
4. Barbara Williams uses radio telescopes to study distant galaxies. Do you think it is important to study stars in far away galaxies. Why or why not?
5. How does Barbara Williams' career compare to that of other space scientists in the Toolkit?

GLOSSARY

Electromagnetic Radiation - A kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously

Goddard Space Flight Center - NASA's first major scientific laboratory devoted entirely to the exploration of space with responsibilities, including the design and construction of new scientific and application satellites, as well as tracking and communication with existing satellites

Radio Wave - An electromagnetic wave which is used for long-distance communication

Thermal - Of or relating to heat

Dirty Snowball: How a Comet's Size Affects How Fast it Melts

(www.sciencebuddies.org)

Grade Level: 5 - 7
Time Required: 60 minutes
Cost: $2.00

This activity relates to the work of astronomers, like ScienceMaker ***Charles McGruder.***

Abstract
Comets—big lumps of rock, ice, and frozen gases that orbit the Sun—are among the most amazing heavenly objects seen in the night sky. The glowing tail behind the comet's nucleus inspires wonder. But did you know that a comet's tail is evidence that it's melting? As a comet passes by the Sun on its orbital path, it starts to melt. But do bigger comets melt faster than smaller comets? In this astronomy science project, you will investigate how the size of the comet affects the rate at which it melts and by how much.

Objective
To model comets using ice forms and determine how weight affects the rate of melting.

Introduction
A comet streaking across the sky, its tail stretching behind, is an amazing sight. Because comets are not visible all the time, they are usually special and even spectacular for people on Earth. In olden times, comets were considered as both good and bad omens. But what is a comet? Where do comets come from? And what is a comet made of?

A comet is basically a "dirty snowball" of dust and sometimes rock, frozen water, and frozen gases like ammonia, methane, carbon monoxide, and carbon dioxide. Comets travel in an orbit; a short orbital-period comet is one that takes 200 years or less to go around the Sun, and a long orbital-period comet takes more than 200 years—often thousands or even millions of years. Halley's Comet is a short orbital-period comet that can be seen from Earth every 75 to 76 years. Comet Hale-Bopp, which was visible to the naked eye for 18 months spanning 1996 and 1997, is a long orbital-period comet that won't be visible from Earth again for several thousand years. Short orbital-period comets are thought to originate from the Kuiper Belt, while long orbital-period comets are believed to be from the Oort Cloud. The Kuiper Belt lies beyond the planet Neptune (between 30 astronomical units [AU] and 55 AU from the Sun), and the Oort Cloud, which is thought to be a spherical cloud surrounding the solar system, lies about 50,000 AU from the Sun. Objects in the Oort Cloud are made up of frozen water, frozen ammonia, and frozen methane.

Comets are made up of a nucleus, a coma, and a tail, as shown in Figure 1 below. A comet's nucleus can range from hundreds of meters to tens of kilometers across.

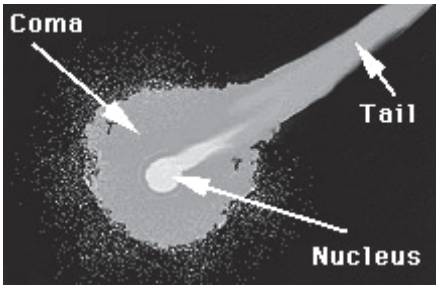


Figure 1. This simple diagram shows the different parts of a comet. (HEASARC, n.d.)

Occasionally, the gravitational influence of one of the outer planets or, in the case of the Oort Cloud, the gravitational influence of nearby stars, causes a comet to enter an elliptical orbit that carries it closer to the sun. The nucleus is volatile because it is made up of unstable matter that evaporates easily. As the comet orbits closer to the Sun, solar radiation—the energy that the sun gives out—begins to melt the nucleus and causes the volatile material and dust to come out. (We also feel solar radiation, in the form of sunlight, on our skin.) The dust surrounds the nucleus to form the coma. Solar winds push the melted material away from the nucleus, causing the tail to form. Some comas can be nearly a million kilometers wide while tails can be more than 100 million kilometers long. Later, when the comet moves away from the Sun to the outer solar system and beyond, the coma and tail disappear and the nucleus remains frozen. Figure 2 below shows a comet as seen through a telescope. Sometimes, we can see comets from Earth without telescopes when they pass close to the Sun because their tails and comae reflect sunlight.

Figure 2. This color image of Comet C/2001 Q4 (NEAT) was taken at the WIYN 0.9-meter telescope at Kitt Peak National Observatory near Tucson, Ariz., on May 7, 2004. It is a composite picture, assembled by combining images taken through blue, green, and red filters. (T. Rector [University of Alaska Anchorage], Z. Levay and L. Frattare [Space Telescope Science Institute], and WIYN/NOAO/AURA/NSF)

As a comet travels towards the Sun, how does it melt? Do bigger comets melt faster than smaller comets? In this astronomy science project, you will model comets of different sizes and then use a hair dryer as a heat source (to mimic the Sun and other "warm" planetary objects) to determine how the size of a comet affects melting.

Terms, Concepts, and Questions to Start Background Research

- Orbital periods (short and long)
- Kuiper Belt
- Astronomical units
- Oort Cloud
- Nucleus
- Coma
- Tail
- Elliptical orbit
- Volatile
- EvaporateSolar radiation
- Solar wind
- Sublimation

Questions

- How long is an astronomical unit?
- How long is a light year?
- How many astronomical units are in a light year?
- What causes comets to move out from the Oort Cloud?

- What are some other examples of short orbital-period and long orbital period comets?
- What is the lifespan of a comet? Do they last forever?
- What is the cycle of comet Hale-Bopp in years? When will it be seen from Earth again?
- What is the source of the Perseid meteor showers?

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Materials and Equipment

- Balloons (1 package)
- Butcher's twine, cotton (1 roll)
- Scissors
- Volunteer to help make the comets
- Baking sheet
- Hair dryer
- Small pot
- Kitchen timer
- Lab notebook
- Ruler

You will also need to purchase, or borrow from your science teacher, these pieces of laboratory equipment. Or, with a little bit of problem-solving, you may find a way to rig up your own way of hanging the comets rather than using the support stand and ring clamp.

- Graduated cylinder, 100 milliliter (1). This can be purchased online at www.scientificsonline.com, Item # 3037525-GRP
- Support stand (1). Can be purchased online at www.scientificsonline.com, Item # 6308003
- Ring clamp (1). Can be purchased online at www.scientificsonline.com, Item # 6308504

Disclaimer: Science Buddies occasionally provides information (such as part numbers, supplier names, and supplier weblinks) to assist our users in locating specialty items for individual projects. The information is provided solely as a convenience to our users. We do our best to make sure that part numbers and descriptions are accurate when first listed. However, since part numbers do change as items are obsoleted or improved, please send us an email if you run across any parts that are no longer available. We also do our best to make sure that any listed supplier provides prompt, courteous service. Science Buddies receives no consideration, financial or otherwise, from suppliers for these listings. (The sole exception is any Amazon.com or Barnes&Noble.com link.) If you have any comments (positive or negative) related to purchases you've made for science fair projects from recommendations on our site, please let us know. Write to us at scibuddy@sciencebuddies.org.

Experimental Procedure

Making the Comets

1. Take six balloons, stretch them out and confirm that there are no holes in them. For this project, you will make three large comets and three small comets.
2. Cut twelve lengths of butcher's twine that are each 12 inches long. Push one end of a string as far as it can go into a balloon. Repeat this with the other five balloons.
3. Fill the graduated cylinder with 100 milliliters (ml) of water. Ask your volunteer for help. Carefully pour the water into the balloon. Repeat two more times so that you have 300 ml of water in the balloon. Then, fill the graduated cylinder with 50 ml of water and pour that into the balloon, for a total of 350 ml of water in the balloon. Tie the end of the balloon with an additional piece of string, making sure that no water can leak out, and place it on the baking pan.
4. Repeat step 3 two more times so that you have three balloons filled with 350 ml of water. These will be the large comets.
5. Repeat steps 3 and 4 with the remaining balloons, except fill them with only 250 ml of water, to make a total of three small comets.
6. Place the baking pan with the six balloons (comets) in the freezer and wait until the water in the balloons is completely frozen.

Testing the Comets

1. Make a table in your lab notebook, like the one shown below, so that you can record data.

Comet	Trial	Amount of Water Melted into Pot (in Milliliters)
Large (350 ml)	1	
	2	
	3	
Small (250 ml)	1	
	2	
	3	

Table 1. Milliliters of melted water for large and small comets

2. It is important to do at least three trials of the experiment so that you know that your results are accurate and repeatable.
3. Put together the support stand and attach the ring clamp to the post. Place the pot underneath and directly below the ring clamp.
4. Plug in the hair dryer.
5. Remove one of the large comets from the freezer. Carefully untie and remove the balloon so that you have just the ice and the hanging string left.
6. Tie the loose end of the string to the ring clamp so that the comet hangs directly over the pan.
7. Set the timer for two minutes. Turn the dryer on high heat and then hold it 2 inches away from the comet for two minutes. Use a ruler to figure out how far away two inches is.
8. Once 2 minutes have elapsed, turn off the hair dryer and set it aside. Pour the water from the pan into the graduated cylinder and measure how much water melted from the large comet. Record the data in your lab notebook.
9. Take the comet off the ring and discard it.
10. Repeat steps 5 through 9 with the two other large comets. Record the data in your lab notebook.
11. Now repeat steps 5 through 10 with the three small comets. Record the data in your lab notebook.

Analyzing Your Data

1. Now for both sizes of comets, average the amount of liquid melted over the three trials and also figure the average percentage of melted water in terms of the total amount of water for both comet sizes. Record your data in a table like the one shown below.

Comet	Average Amount of Water Melted into Pot (ml)	Percentage Comet Melted (%)
Large (350 ml)		
Small (250 ml)		

Table 2. Average amount of water melted in large and small comets and its percentage in terms of the total amount of water

2. To calculate an average, add the numbers of the three trials and then divide by three. Equation 1 shows how to calculate an average.

Equation 1.

$$\text{Average} = \frac{X1 + X2 + X3}{3}$$

X1= The amount of water melted into pot, trial 1
X2= The amount of water melted into pot, trial 2
X3= The amount of water melted into pot, trial 3

3. Now calculate the percent melted for each comet size. Divide the average amount of water that melted into the pot by the amount that was in the comet originally, either 350 ml or 250 ml, and then multiply by 100. Equation 2 shows how to calculate the percentage the comet melted.

Equation 2.

$$\text{Percentage Comet Melted (\%)} = \frac{\text{Average Amount of Water Melted}}{\text{Amount of Water in Comet}} \times 100$$

Amount of Water in Comet= 350 ml or 250 ml

4. Based on the data in your tables, which comet melts the most and the fastest? What did you learn from this project?

Variations

- How long does it take for each size of comet to completely melt? How big is the difference in time?
- Make your comets more realistic. Try this comet recipe. Add a given number of small rocks and a consistent, measurable, and identical quantity of sand to each of the comets before freezing and proceed with the experiment. How do these more realistic comets sublimate and how does size affect the sublimation?
- For more science project ideas in this area of science, see Astronomy Project Ideas.

Credits

Michelle Maranowski, PhD, Science Buddies

This project is based on one of the Science Buddies – Lick Observatory Astronomy Contest winning projects: Boulos, Bassam N. (2011). "Comets"

To access this activity online, go to:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Astro_p035.shtml

Slingshot to the Outer Planets

(www.teachengineering.org)

Grade Level: 3 - 5
Time Required: 50 minutes
Cost: $15 per group
Group Size: 5

Contributed by: TeachEngineering.org — Resources for K-12

*This activity relates to the work of aerospace engineers, like ScienceMaker **Isaiah Blankson**.*

Summary
Students are introduced to the engineering challenges involved with interplanetary space travel. In particular, they learn about the gravity assist or "slingshot" maneuver often used by engineers to send spacecraft to the outer planets. Using magnets and ball bearings to simulate a planetary flyby, students investigate what factors influence the deflection angle of a gravity assist maneuver.

Engineering Connection
Since the discoveries of Jupiter, Saturn, Uranus and Neptune, humans have become increasingly intrigued with these planets located so far from Earth. Until recently, scientists and engineers relied on telescopes to observe and understand the outer planets. Today, engineers use large rockets to send satellites deep into space to probe the unknown. However, since rocket fuel is costly and heavy, engineers invent creative ways, such as the gravity assist or "slingshot" maneuver, to propel their spacecraft to greater distances.

Pre-Req Knowledge
A familiarity with the concepts of kinetic and potential energy, and work.

Learning Objectives
After this activity, students should be able to:

- Describe why spacecraft need so much energy to travel to and explore the outer planets.
- Explain what the gravity assist or "slingshot" effect is and how engineers use this technique to launch spacecraft greater distances.

Materials List
Each group needs:

- 10-inch (25-cm) square, 1-inch (2.54-cm) thick piece of transparent Plexiglas to serve as a baseboard (available at hardware stores)
- 4 small wooden pieces or books to serve as corner supports for the Plexiglas baseboard
- 1 strong magnet (available at hardware stores)
- 2-3 steel ball bearings (various sizes, 1/18-inch and larger; available at hardware stores, auto parts stores, bicycle shops)
- 2 pieces of angle aluminum, a right-angle V cross-section 6-10-inches (15-25-cm) long (available at hardware stores)

- 1 large magnetic ball (this may be difficult to find at some hardware stores; magnetic tennis balls are available online at http://www.stevespanglerscience.com/product/1312)
- Trajectory Deflection Worksheet

Introduction/Motivation

Have you ever wondered how engineers send satellites and probes out to faraway planets like Jupiter and Saturn so they can discover more about them? Actually, sending satellites to the outer planets is a complicated process. To help understand this process, think of what it's like on our planet Earth: If you want to send an object very high into the sky, you must give it a lot of energy. You can throw it really hard or use something to help launch it. But either way, lots of energy is required because the object must overcome the Earth's gravity in order to go higher and higher. The same idea applies to interplanetary travel, but instead of overcoming Earth's gravitational field, a satellite must overcome the pull of the Sun's gravity in order to rise higher and higher. Typically, a satellite gets this great amount of energy by being attached to a large rocket that pushes it at very high speeds out to its intended destination. However, rocket fuel is expensive and engineers always want to save on fuel requirements whenever possible, so they are always looking for alternative ways to propel spacecraft. One source of energy is actually the planets themselves. Since the planets orbit the Sun at incredible speeds, they have a tremendous amount of kinetic energy (not to mention potential energy due to their distance from the Sun). Engineers recently discovered how to take some of this energy from the planets and transfer it to the spacecraft as a way to speed its journey to its planned destination. This technique is called the *gravity assist maneuver*, also known as the "slingshot" effect. This maneuver is commonly used for spacecraft heading for the outer planets, like Jupiter, Saturn, Uranus and Neptune, because so much energy is required to overcome the Sun's gravitational pull to get that far away. Without this maneuver, spacecraft visiting the outer planets would take far too long to get there and use way too much fuel.

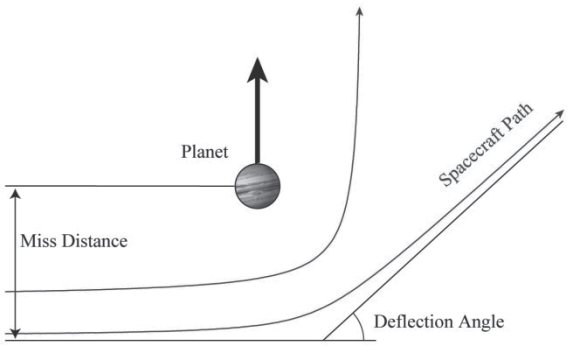

Figure 1. Trajectories of different flyby maneuvers.
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The key to the gravity-assist (or slingshot) maneuver is to pass the spacecraft pretty close to a moving planet so that it enters that planet's gravitational field. As the spacecraft approaches the planet, the planet's gravitational pull begins to bend or change the spacecraft's path. Even though the spacecraft's speed (relative to the planet) remains unchanged, its speed relative to the Sun becomes faster. The amount of energy gained depends on several things, including the distance by which the spacecraft misses the planet, the approach speed of the spacecraft, and the masses of the spacecraft and planet (see Figure 1).

The slingshot technique has been used by many spacecraft such as Voyager 1 and the Cassini Probe. Voyager 1 performed slingshot maneuvers around both Jupiter and Saturn in 1979 to escape our solar system and explore interstellar space. The Cassini probe used multiple gravity assist maneuvers when it passed by Venus twice, then Earth, and finally Jupiter on its way to Saturn (see Figure 2). This path greatly reduced the amount of rocket fuel needed to send Cassini to explore

Saturn. Also, the Ulysses probe used this technique not to gain energy but to change its path so that the poles of the Sun could be studied.

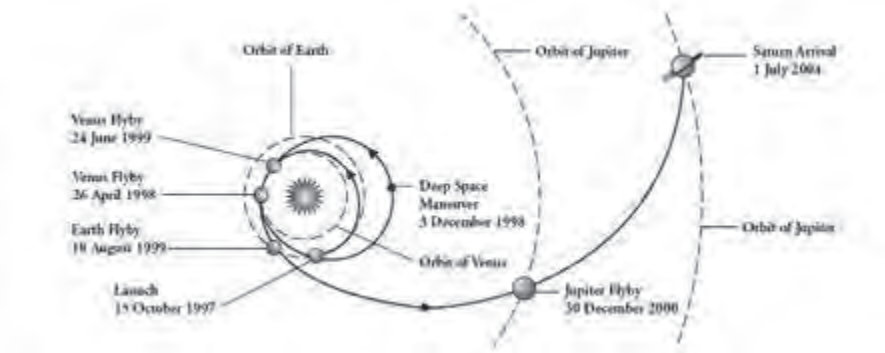

Figure 2. The cruise phase of Cassini-Huygens' route to Saturn is shown, with major planetary flyby maneuver milestones during more than six years indicated by their dates.
Copyright © Planetary Billiards Activity, JPL, NASA, http://saturn.jpl.nasa.gov/education/pdfs/Planetary_Billiards.pdf

To understand how the slingshot effect works, we are going to work in engineering teams to determine how we want to launch our spacecraft to get to the outer planets. We will use a ball bearing to represent our spacecraft and a magnet to represent the gravitational field of the planet. We will set up a model to help us predict the path of our spacecraft during different launches. First, we will roll the ball bearing close to the magnet and observe how its path is changed by the magnetic field. This shows us the change in the path of the ball — the same as when a spacecraft approaches a planet. Several factors affect the angle of the spacecraft's path after it passes near a planet — called the *deflection angle*. You will test to find out what factors change the path and deflection angle. For example, perhaps the size of the ball (spacecraft), the speed of the ball as it approaches the planet or the size of the magnet (planet).

Vocabulary/Definitions

energy: A measure of the ability to do work. For example, to lift an object against gravity or drag it against friction.
engineer: A person who applies her/his understanding of science and mathematics to creating things for the benefit of humanity and our world.
gravity assist maneuver: A spaceflight technique in which the gravitational field of a planet is used to increase the speed and alter the path of a spacecraft without using fuel.
kinetic energy: The energy of motion.
launch window: The time period during which a spacecraft must be launched to achieve its given mission course.
potential energy: The energy of position, or stored energy.
work: The energy it takes to move an object some distance.

Procedure

Before the Activity

- Gather materials and make copies of the Trajectory Deflection Worksheet.
- Free up enough classroom desktop, tabletop or floor space to lay down a baseboard for each group, propped up under each corner (see Figure 3). Or, conduct the activity outside or in the gym.

With the Students

1. Divide the class into teams of five or six students each. Each student in the group will get a chance to test different spacecraft travel paths.
2. Pass out a worksheet to each group and review it with the class.

3. Distribute materials (except the large magnetic ball and second piece of angle aluminum) to each group.
4. Guided by the worksheet, have students start testing which factors affect the path of their spacecraft magnet. Direct students to place the magnet under the middle of the baseboard and use the angle aluminum to guide the steel balls toward the magnet, as shown in Figure 3.

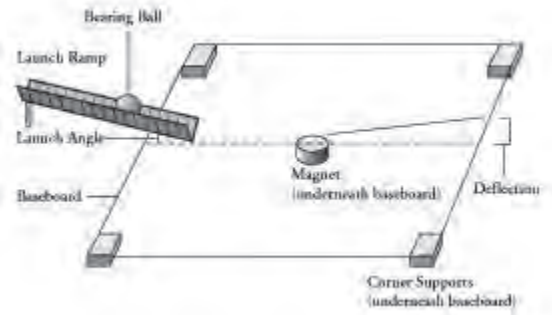

Figure 3. Activity set-up for demonstrating the slingshot maneuver via magnetism-governed flybys of steel balls. An inclined launch ramp guides a steel ball towards a magnet.
Copyright © Planetary Billiards, JPL, NASA, http://saturn.jpl.nasa.gov/education/pdfs/Planetary_Billiards.pdf

5. After trying several tests, give each team a large magnetic ball and another piece of angle aluminum so that they can simulate an actual planet flyby. Place the large magnetic ball on a second launch ramp and set it in motion. Have students experiment with timing. When should the spacecraft be launched so that it increases it maximum velocity without actually "hitting" the moving planet?
6. As a class, discuss the test results. Observation points: Students should have observed that the mass of the ball (spacecraft), initial speed of the ball (spacecraft), mass of the magnet (planet), and the miss distance were all contributing factors that affect the spacecraft's path as it performs a gravity assist maneuver around a planet. In addition, students should have discovered that if the ball is passed in front of a moving planet, the overall velocity is reduced, whereas if the ball is passed behind a moving planet, the overall velocity is increased.
7. Conclude by asking the post-activity questions provided in the Assessment section.

Safety Issues

- If Neodymium magnets are used, practice caution because they are extremely powerful. For this activity, these magnets should not be used without a protective covering.

Troubleshooting Tips

Since they are easy to lose, get a few extra ball bearings and magnetic balls.

Assessment

Pre-Activity Assessment

Prediction: Have students predict activity outcomes by asking:

- Do you think it is possible for a planet to give some of its energy to a spacecraft? If so, how is this possible?

Activity Embedded Assessment

Group Questions: During the activity, have teams predict the performance of their spacecraft during different testing scenarios:

- What factors affect the path of the spacecraft? Why? (Answers: The mass of the spacecraft, the mass of the planet, the approach velocity of the spacecraft, and the approach distance all affect the final spacecraft path.)

Post-Activity Assessment

Discussion Question: Solicit, integrate and summarize student responses.

- Why is it necessary for engineers to use the flyby technique to reach the outer planets? (Answer: Since the outer planets are so far from the Sun, it takes a lot of energy to overcome the pulling force of the Sun to reach them. A creative solution is to use the flyby technique as an energy source, instead of rocket fuel.)
- If the spacecraft takes energy from the planet, does that mean the planet slows down? (Answer: Technically yes. However, because the planet is much larger than the passing spacecraft, the energy lost to the planet is very small compared to its total energy. A good example is when a bug hits a school bus, head on. Technically speaking, the school bus loses energy due to the collision, but it cannot even feel it.)

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Trajectory Deflection Worksheet

Conduct the following experiments to find out which factors affects the path of the spacecraft during a planetary flyby.

1. Use different-sized spacecraft (ball bearings) to fly past the planet (magnet). Does this change the path of the spacecraft? _____

2. Change the initial speed of the spacecraft by raising the launch ramp. Does this change the path of the spacecraft? _____

3. Try using a different-sized planet (magnet). Does this change the path of the spacecraft? _____

4. Try moving the launch ramp away from the planet. Does this change the trajectory of the spacecraft? _____

Which items from above would your engineering team use to design a launch for a spacecraft trying to get to the outer planets? (Example: Spacecraft size, spacecraft initial velocity, planet size, distance of launch from the planet.)

_____

_____

_____

_____

_____

_____

Spacecraft Design: Beat the Heat

(www.teachengineering.org)

Grade Level: 3 - 5
Time Required: 50 minutes
Cost: $5 per group
Group Size: 2

Contributed by: TeachEngineering.org —Resources for K-12

This activity relates to the work of astronautical engineers, like ScienceMaker ***Woodrow Whitlow.***

Summary

To understand the challenges of satellite construction, student teams design and create model spacecraft to protect vital components from the harsh conditions found on Mercury and Venus. They use slices of butter in plastic eggs to represent the internal data collection components of the spacecraft. To discover the strengths and weaknesses of their designs, they test their unique thermal protection systems in a planet simulation test box that provides higher temperature and pressure conditions.

Engineering Connection

To continue the exciting ventures of space exploration, engineers design and create instruments, satellites and spacecraft and send them to the unknown areas of the universe to gather information about places that are too far and too dangerous for people to go. These creations return to Earth important information about local conditions, so we can learn more. Building these instruments and spacecraft is anything but routine; teams of engineers with a variety of specialties construct these devices to withstand the extreme conditions they might encounter.

Pre-Requisite Knowledge

A basic introduction to Mercury and Venus and their characteristics is helpful, such as TeachEngineering's Solar System unit lesson 3, Mercury and Venus. It may also be helpful to provide a brief review of heat transfer concepts, including conduction, convection and radiation.

Learning Objectives

After this activity, students should be able to:

- Discuss why it is important to study other planets and discover more about our solar system.
- Describe the engineering challenges associated with sending a spacecraft to either Mercury or Venus.
- Explain how engineers protect spacecraft from the harsh conditions found on Mercury and Venus.

Materials List

For the test box:

- 1 thin piece of transparent Plexiglas for testing window (available at hardware stores)

- 1 medium-sized cardboard box, such as a copier paper box
- hairdryer
- duct or packaging tape
- paper towels or plastic liner, to catch drips in the bottom of the box

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Each group needs:

- 1 thin square pat of butter
- plastic egg, or another small closed plastic container to represent a space capsule or probe

For the entire class to share:

- scissors
- masking tape
- glue
- construction paper
- aluminum foil
- toothpicks
- assortment of balsa wood, fabric and cardboard pieces
- assortment of Styrofoam cups
- thermometer to measure inside test box temperature
- oven mitt to remove warmed space capsule form the test box
- watch or clock for timing

Introduction/Motivation

For the past 60 years, humankind has explored and studied the solar system beyond its own planet Earth. Recently these investigations have been performed by satellites designed to go to other planets and send back information about the conditions found on other worlds. Many of these missions require the satellite to collect data on a planet's temperature, atmosphere and soil composition. By carrying out these explorations, we satisfy our desire to answer questions about the unknown, and we begin to better understand our universe and how it works. In addition, we can learn more about our own planet, Earth, by comparing the conditions found on other planets.

While many planets have been studied in detail since the launch of the first satellite in 1957, Mercury and Venus are two planets that are especially difficult to study and, as a result, are more unknown to us. In fact, only one satellite has ever flown to Mercury — Mariner 10 in 1974 — and only half of Mercury's surface has been mapped. Also, although eight Soviet Venera spacecraft have landed on Venus, none have survived longer than about two hours in the harsh Venusian conditions!

So why are these two planets so difficult to study? It is mostly because of their locations. Remember that Mercury and Venus are the two planets closest to the Sun, so their surfaces are extremely hot! Mercury has an average temperature of 800 ^{o}F (430 ^{o}C) during the day while Venus has an average of 900 ^{o}F (480 ^{o}C). Did you notice, even though Venus is twice as far from the Sun as Mercury, its average temperature is much hotter than Mercury's average? This is because Venus is surrounded

by a thick atmosphere composed of carbon dioxide that creates a greenhouse effect. This means that it traps the heat and does not let it dissipate back into space.
In addition to the extremely hot temperatures, sending satellites to these planets requires a large amount of energy to slow them down as they approach the planets. As satellites get closer and closer to the Sun, they begin to speed up, just as an object speeds when dropped from a tall height on Earth. If the satellites did not have rocket engines to slow them down, they would zoom right past the planet and continue orbiting the Sun.

So how do engineers design a spacecraft to overcome these problems? This is the question you will answer today by creating a spacecraft design for a planet such as Venus and Mercury. On Venus, the temperatures are high enough to melt lead and the atmospheric pressure is 90 times that on Earth! Of the eight spacecraft that landed on Venus, four of them managed to take photographs (six, altogether) of the terrain surrounding their landing site because windows made of diamonds protected the camera lenses. Certainly, if we want to send a space probe to another planet, we would like it to last longer than two hours. So, engineers are continually testing ideas to make spacecraft able to survive harsh conditions that exist on planets such as Mercury and Venus.

Vocabulary/Definitions

engineer: A person who applies her/his understanding of science and mathematics to creating things for the benefit of humanity and our world.

greenhouse effect: A process that traps heat inside the atmosphere due to solar radiation travelling through the atmosphere and heat radiation unable to pass out of the atmosphere due to atmospheric carbon dioxide and other gases.

spacecraft: A vehicle designed for travel or operation in space beyond the Earth's atmosphere or in orbit around the Earth.

thermal protection system: The part of a spacecraft that protects it from very hot external temperatures.

Procedure

Before the Activity

- Gather materials.
- Construct a planet simulation test box. Choose a box size that can easily fit three or four student spacecraft, each containing a probe or space capsule, at a time. Replace one side with a thin piece of transparent Plexiglas (use duct or packaging tape to secure it). Make the following cuts into the box: a round hold to accommodate a hairdryer nozzle (to heat the inside air and increase the inside air pressure), a small round hold to permit insertion of a thermometer (to take the inside air temperature), a small hole or vent opening to keep too much pressure from building up, and a flap big enough to permit temporary access to easily move the spacecraft in and out (see Figure 1). As an alternative, use a toaster oven set at a very low temperature.

Figure 1. Example planet simulation test box.
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With the Students - Step 1: Design

1. Present the student challenge: Today your engineering team is challenged to design a spacecraft that can resist the harsh conditions found on planets such as Mercury and Venus. The longer your spacecraft survives the harsh conditions of the planet, the more time we have to collect information and data about the planet. Use your knowledge about the conditions found on Mercury and Venus to design a thermal protection system for a probe that will be sent there. This spacecraft must be carefully designed to protect the sensitive devices — such as a camera, antenna and sensors — that collect planet data. All the teams will test their designs to determine which design works best and why.
2. As a class, brainstorm ideas about how to best protect the precious spacecraft components from the hazardous planet conditions; namely the high temperatures and high pressures of Venus. (See the ideas provided in the activity embedded assessment portion of the Assessment section.)
3. Present the construction materials from which students may choose. Explain that after they have finished their design and are ready to build, each team will be given a slice of butter and a plastic egg. The butter represents the vital components of the spacecraft and the test box represents the harsh conditions found on Mercury or Venus. Their goal is to use the materials to design and create a thermal protection system to protect the butter from the very hot and high pressure conditions in the planet simulation test box.
4. Divide the class into teams of two or three students each. Direct the groups to choose an idea from the class brainstorming activity to use in the design of their spacecraft.
5. Ask each team to draw a sketch of how their spacecraft will look using the given materials.

With the Students - Step 2: Build

6. Give each group a pat of butter and a plastic egg. Instruct them to place the butter inside the egg (representing a probe or space capsule) and build their spacecraft and thermal protection system to protect the butter when it's in the test box. Remember, the butter represents the vital components of the spacecraft and the test box represents the harsh conditions found on Mercury or Venus.
7. Give students some time to create their spacecraft with the given materials.

With the Students - Step 3: Test

8. Lay a plastic liner or paper towel in the bottom of the test box to collect any leaking melted butter.
9. Place several teams' spacecraft into the test box and use the hairdryer to raise the temperature and, if possible, the pressure inside the test box.
10. Have students use the thermometer to read the increasing temperature inside the test box.
11. Check the spacecraft after 2 minutes, 4 minutes, etc. Repeat the planetary simulation test with the next set of spacecraft. The spacecraft whose butter lasts the longest without melting is the best because it kept the precious cargo (butter) safest longest.
12. Observation notes: Before the end of the activity, students should realize that the butter is best protected if it does not touch the walls of its spacecraft. While waiting, explain to students that this is because the hot atmosphere begins to heat up the spacecraft walls first, then, if the butter touches the walls it begins to melt the butter by conduction. Instead, if the butter is suspended inside the capsule by string or toothpicks, the heat must conduct through the air to raise the temperature of the butter. This takes longer since air is a poor conductor and hence, the butter does not melt as fast.
13. To conclude, lead a class discussion, comparing teams' spacecraft results and discuss what materials and designs worked best to protect the butter from melting. See post-activity questions and activities in the Assessment section.

Safety Issues

- Use an oven mitt or make sure the space capsules have cooled before removing them from the test box.

Troubleshooting Tips

As an alternative to the test box, use a toaster oven set at a low temperature, being careful to not melt the plastic eggs.

Assessment

Pre-Activity Assessment

Prediction: Ask the students:

- Which planet do you think is the hottest in the solar system? (Answer: Venus. Even though Mercury is closer to the Sun, Venus' dense atmosphere traps heat and raises the surface temperature to nearly 1300^{o}F [700 ^{o}C].)

Activity Embedded Assessment

Brainstorming: As part of the activity, lead a class brainstorm session to come up with creative ideas for how engineers might build a spacecraft so that it protects its vital internal components. How can we incorporate what we know about heat transfer (conduction, convection, radiation) to protect the interior from heat? (Possible answers: Build large radiators that absorb most of the heat instead of the interior components. Insulate the spacecraft with Styrofoam so that heat cannot penetrate inside. Put the spacecraft in a really cold part of the room just before placing it in the test box. Protect the internal components by not having them touch the space capsule walls.)

Prediction: As a class, examine each batch of spacecraft before they go into the test box. Ask the students:

- Which of these models do you predict will best protect the probe's internal data collection components (butter) from the heat and pressure on the planet (inside the box)? (Answers will vary.)

Post-Activity Assessment

Discussion Question: Solicit, integrate, and summarize student responses.

- How long did it take for your spacecraft to malfunction (that is, for the butter to melt)?
- Which spacecraft protected its internal components the best and why?
- How might you re-engineer your design so it lasts (protects the butter from melting) longer?

Re-Engineering: Ask students how they could improve their spacecraft design to work better, and have them sketch or test their ideas.

Activity Extensions

Ask students to research the longest time a spacecraft has survived on the surface of Venus. (Answer: Venera 13 survived for approximately 127 minutes before its signal was lost.)
Engineers design instruments and devices to gather information about places that are too difficult or dangerous for people to go. What if you could not go in your basement, house, backyard, school or classroom for some reason? How do we collect data from deep in an ocean, volcano or space? How would you design something to go in without you and gather information so that you could tell the conditions inside? (Ideas: Robots with cameras and sensors, tiny camera on stick to slide in doors or windows, mirror to reflect images, telescopes, probes for oceans, volcanoes and space.) Assign students to write a paragraph describing an existing tool or device, and another paragraph to describe another tool or device that does not exist, but that an engineer could create.

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Contributors

University of Colorado Boulder: Jake Lewis, Malinda Schaefer Zarske, Denise W. Carlson (This material is based upon work supported by the National Science Foundation under award numbers DUE 0226322 and DUE 0532709. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author[s] and do not necessarily reflect the views of the National Science Foundation

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Science Administration & Education

Administration and education encompasses many careers that scientists have had outside of a laboratory or industrial setting. Many STEM professionals are career business administrators or educators.

Administrators and educators work for organizations like the American Association for the Advancement of Science (AAAS), whose goal is to promote the value of science and science education, or the National Science Foundation (NSF), which funds many scientific initiatives and research projects across the United States.

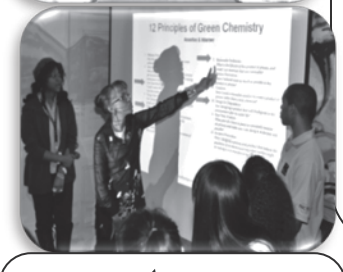
Studying to be an administrator or educator teaches you how to answer big questions about the course of STEM and STEM education. One of the major issues that the United States is trying to address right now is how to increase the number of minority students entering STEM fields.

Administrators & Educators At Work

Schools

Universities

Science Administrators and Educators apply their scientific backgrounds to careers in a variety of different settings, such as schools, universities, museums, or the government. Administrators and educators often complete their higher education in fields like business, education, law, administration, or management. Career administrators and educators are often at the forefront of making policies for their individual organizations or for science in the United States as a whole.



Museums

Government

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Career Paths in Administration & Education

Administration and Education covers a range of careers in many different areas. Below are just a few possible jobs. See how each job fits into the larger career paths of Academia, Business & Industry, and Government.

Academia

Educators and administrators work in settings such as schools, universities, and science centers or museums.

- *Science Museum Directors* are in charge of preserving the museum's collection. They decide how to manage and present the artifacts and how to direct the educational initiatives of the museum.
- *University Deans* are senior academic administrators at the college level. They direct the academic affairs of individual science departments including coursework, instruction, research, and student life.
- *High School Science Department Heads* are in charge of how science is taught at their school. They serve as the liaison between their school's teachers and the science education policy makers from the school district and beyond.

Business & Industry

Educators or administrators work for companies that develop, manufacture, and test new products. They also work for businesses as consultants.

- *Company Presidents* work for corporations that manufacture products like drugs, laboratory equipment, chemicals, or food. They oversee production as well as marketing, sales, and business relationships.
- *Science Text Book Publishers* are responsible for writing and updating the content in science textbooks to make sure that they include the latest scientific information.
- *Science News Writers* educate the public about current events in science. They work for the newspaper and magazine industry and can transform dense scientific writing into something that lay people can understand and enjoy.

Government

Educators and Administrators work as political advisors for organizations like the National Science Foundation (NSF) and the Department of Education.

- *NSF Director* provides leadership and direction to the National Science Foundation, which is responsible for funding research and education activities that develop and advance scientific knowledge
- *The U.S. Secretary of Education* is the head of the U.S. Department of Education. They enforce federal discrimination laws, make policies, and manage funding, as well as collect data on the achievement of America's schools.
- *USAID Workers* often work in developing countries in order to improve their infrastructure in sectors like agriculture and science education.

Check Out Our Featured Administrators/Educators!

ScienceMakers	Occupation	Workplace	Topics in Science in Action Boxes	Pg.
Howard Adams	Mentor & Consultant	National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM); H.G.Adams and Associates	Consultants and Mentors	362
Sondra Akins	Science Educator & Chemist	Englewood Public Schools (New Jersey); William Peterson University	Science Teaching	364
DeAnna Banks Beane	Science Educator & Administrator	Association of Science and Technology Centers	Science Museums	366
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ScienceMakers Spotlight

Howard Adams

Mentor & Consultant

Birth Date	March 28, 1940
Birth Place	Pittsylvania County, Virginia
Education	Norfolk State University (B.S., 1964)
	Virginia State University (M.S. 1969)
	Syracuse University (Ph.D. 1978)
Awards & Achievements	American Society of Engineering Education Centennial Medallion (1993)
	Presidential Award for Excellence in Science, Mathematics, Engineering, and Mentoring (1996)
	Distinguished Alumni Award from the National Association for Equal Opportunity in Higher Education (2004)

BIOGRAPHY

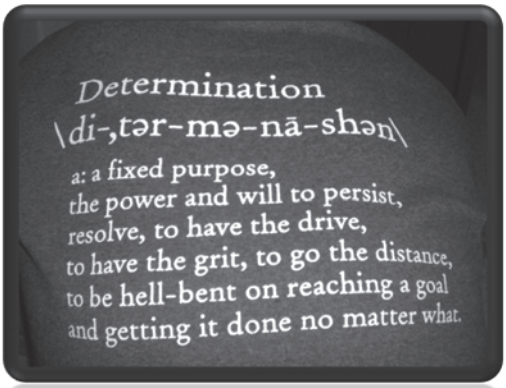
Howard Adams is known for his mentorship of minorities in science. Adams was born in Pittsylvania County, Virginia on March 28, 1940. As a child, he helped his father on the family farm growing tobacco, wheat, and corn. During high school, Adams worked as a kitchen helper at the Greyhound bus station in Danville, Virginia. After graduating from high school in 1958, Adams left home and worked as a cook in New Jersey for one year before returning to Virginia to study biology at Norfolk State University. Adams participated in many student groups, serving as Cadet Captain in the ROTC Military Science Program, president of the sophomore and senior classes, president of the biology club, and vice president of the student government association. He received his B.S. degree in biology from Norfolk State University in 1964, his M.S. degree from Virginia State University in 1969, and his Ph.D. degree in higher education administration from Syracuse University in 1978.

Graduation Hat Toss
by _naveen_ @Flickr

From 1970 to 1973, Adams served as Norfolk State University's first director of alumni affairs, and the next year, he was nominated vice president for student affairs. In 1978, he accepted the position of executive director of the National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM). Adams' goal was to provide graduate fellowships in engineering and science to top students from underprivileged communities. In 1995, Adams created the consulting company, H.G. Adams & Associates, Inc. He also wrote or co-authored over fifteen self-help guides and handbooks including, *Negotiating the Graduate School Process: A Guide for Minority Students* (1985). Howard Adams is a proud husband to wife, Eloise Christine Davis. They have one daughter, Stephanie Glen Adams.

Above Picture of Howard Adams from vimeo.com/channels/233969#14859141

CONSULTANTS AND MENTORS



Determination
by Dana Lookadoo - Yo! Yo! SEO@Flickr

Is there someone in your life who you consider a mentor? Mentoring and consulting make up a very important business that helps organizations develop and empower their employees by establishing training programs, providing motivational speaking, and giving general advice. Howard Adams provides such services for universities, businesses, and other organizations. He also works with students to help them perform better in school. As a motivational speaker, Adams talks about topics like leadership, success, empowerment, and goal setting. He has spoken at over 500 colleges and universities.

DISCUSSION QUESTIONS

1. If you were to interview Howard Adams, what questions would you ask him?
2. Check out the U.S. News website on science graduate schools (http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-science-schools). Which schools have a strong reputation in your field of interest?
3. Howard Adams is a mentor. Talk about someone in your life that you look up to for advice.
4. Howard Adams encourages minority students to pursue graduate degrees in science. Why is this important?
5. How does Howard Adams' career compare to that of other educators in the Toolkit?

GLOSSARY

Alumni - A person who graduated from a mentioned school

Consulting - Giving professional advice; advising

National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) - An organization that works to increase minority participation in the sciences, especially at the graduate degree level

ROTC - Acronym; Reserve Officers' Training Corps; a program for training American high school and college students to be officers in the U.S. Armed Forces

ScienceMakers Spotlight

Sondra Akins

Science Educator & Chemist

Birth Date	March 16, 1944
Birth Place	Winston-Salem, North Carolina
Education	University of California, Berkeley (B.S. 1967)
	Florida State University (M.S. 1970)
	Columbia University (Ed.D. 1993)
Awards & Achievements	Sigma Xi Society of Ramapo College of New Jersey Award for Dedication to Science Teaching (1998)
	National Science Education Leadership Association Exemplary Science Nomination

BIOGRAPHY

Sondra Akins is a chemist and science educator who has had a successful teaching and administrative career at various schools. Akins was born on March 16, 1944 in Winston-Salem, North Carolina and she became interested in chemistry by the time she graduated from Atkins High School in 1962. Akins earned her B.S. degree in chemistry from the University of California, Berkeley in 1967 and her M.S. degree in chemistry with a minor in higher education from Florida State University in 1970. In 1993, she received her Ed.D. degree in science education from Columbia University.

School Classroom by alamobasement @Flickr

After earning her master's degree, Akins taught physical science at Greco Jr. High School in Tampa, Florida. Between 1971 and 1974, she taught chemistry at St. Petersburg Community College. She left St. Petersburg in 1974 to teach at Hillsborough Community College where she rose to the rank of associate professor. In 1977, she taught at Northern Virginia Community College, and in 1979, Akins worked as an honors physics teacher in Lexington Massachusetts Public Schools. She also spent two years as an industrial hygienist at an information technology company from 1981 to 1983. Akins began her long career with the Englewood Public School District in Englewood, New Jersey, in 1983 where she started as a science and mathematics teacher. In 1988, she became the director of mathematics, science, and technology. In this position, Akins trained teachers, developed the course work or curriculum for science classes, and made sure that students were learning from their teachers. She taught again between 1995 and 1997 and served as a high school principal for one year in 1997. From 1998 to 2001, Akins was a staff developer for Englewood Public Schools where she served as a mentor, giving advice to teachers. She also promoted research-based teaching (RBT). Since 2001, Akins has been an assistant professor in the Department of Secondary and Middle School Education at William Peterson University. Sondra Akins lives with her husband Daniel Akins, a chemist, in Teaneck, New Jersey.

Above Picture of Sondra Akins from: www.aaas.org/aboutaaas/awards/mentor/mentor2008.shtml

SCIENCE IN ACTION

TEACHING HOW TO TEACH

Science Lesson
from 2011 ScienceMakers Public Program

You may think that your science teachers have all the answers, but the truth is, teachers are continually receiving training to sharpen their skills and learn innovative approaches to their job, just as in any other profession. Sondra Akins works to improve science teaching, and in 2008, she presented her ideas at the American Chemical Society National Meeting. According to Akins, successful science education means: *having a supply of diverse and qualified teachers, students learning through inquiry and experiments, students presenting their own work, students understanding connections between science and technology, students learning about careers in science, and students learning about the contributions to science by minorities.*

DISCUSSION QUESTIONS

1. If you were to interview Sondra Akins, what questions would you ask her?
2. Sondra Akins works in curriculum development. If you were to develop your own mini science course for ten-year olds, what topics would you include?
3. Sondra Akins has taught science at the high school and college levels. If you were a science teacher, what grade would you want to teach and why?
4. Sondra Akins gained experience teaching and mentoring at many different schools. Why is it important to have a broad and diverse perspective on science education?
5. How does Sondra Akins' career compare to that of other educators in the Toolkit?

GLOSSARY

Curriculum - The subjects comprising a course of study in a school or college

Industrial Hygienist - An educated professional with training and experience to anticipate, recognize, evaluate, and develop controls for health hazards presented by the workplace

Research-Based Teaching (RBT) - Instruction strategies that teachers can use to meet the needs of students; applying research to decision making

ScienceMakers Spotlight

DeAnna Banks Beane

Science Educator & Administrator

Birth Date	January 25, 1940
Birth Place	Washington, D.C.
Education	Howard University (B.S. 1962)
	Rutgers University (M.Ed. 1973)

BIOGRAPHY

DeAnna Banks Beane is nationally known for her dedication to the improvement of science education for minority and low income youth. Beane was born in Washington, D.C. on January 25, 1940. She became interested in science and nature as a child, and after graduating from high school, Beane attended Howard University where she earned her B.S. degree in zoology in 1962. Originally intending to go to medical school, Beane realized that she could better share her passion for science by becoming an educator. She received her M.Ed. degree from Rutgers University in 1973.

Science Students from 2011ScienceMakers Public Program

Between 1966 and 1981, Beane taught at a New Jersey middle school, as well as at schools for pregnant teens in three cities. She also worked extensively with issues of racial equality in education. From 1983 to 1985, she worked for the Mid-Atlantic Center for Race Equity. Beane became interested in the issue of equity in science education and the juncture between formal classroom education and informal science education. In 1985, she became the director of education for the National Urban Coalition where she developed and directed a national program to increase minority involvement in science, technology, and math. After a brief period of independent consulting for elementary and middle school math programs, Beane joined the Association of Science-Technology Centers, Inc. (ASTC) in 1991. She spent ten years directing ASTC's national initiative YouthALIVE! (Youth Achievement through Learning, Involvement, Volunteering, and Employment). YouthALIVE brought youth development programs to science centers around the country, giving them the skills necessary to support the developmental and educational needs of ten to eighteen year olds. In 2001, Beane was promoted to director of partnerships for learning at ASTC. Throughout her career, she published many articles, several books, and served as co-editor for the April 2005 issue of *Curator: The Museum Journal*. DeAnna Banks Beane works in Washington, D.C.

A TRIP TO THE MUSEUM

Science Museum
by coolinsights @Flickr

Do you like visiting science museums? How about zoos, planetariums, and aquariums? The goal of science centers is to raise awareness of STEM issues and create scientific interest and knowledge for the public. DeAnna Banks Beane works for the Association of Science-Technology Centers, Inc., which is an organization founded in 1973 that links 600 science centers in forty countries around the world. ASTC helps science centers and museums to share ideas with each other, so that children and family visitors will learn about science and also have fun. ASTC also makes sure that science centers and museums are represented in the government and can receive funding to create interesting new exhibits.

DISCUSSION QUESTIONS

1. If you were to interview DeAnna Banks Beane, what questions would you ask her?
2. Check out the website for the Museum of Science and Industry (MSI) in Chicago (http://www.msichicago.org/). Which exhibit do you find most interesting and why?
3. Cities around the world like New York, Atlanta, London, and Shanghai have wonderful science museums. If you could visit any science center or museum in the world, which one would you choose and why?
4. Just like the students in your classroom communicate and share ideas, science centers around the world talk to each other, with the help of organizations like ASTC. Why is this important?
5. How does DeAnna Banks Beane's career compare to that of other educators in the Toolkit?

GLOSSARY

Association for Science-Technology Centers, Inc. (ASTC) - A non-profit organization founded in 1973 that fosters communication between science centers worldwide to further their common goals

Consulting - Giving professional advice; advising

National Urban Coalition - A non-profit minority community-based organization, founded in 1986, that focuses on community development in sectors like public safety and education

ScienceMakers Spotlight

Roosevelt Calbert

Science Administrator

Birth Place	Philadelphia, Mississippi
Education	Jackson State University (B.S.)
	University of Michigan (M.A.)
	University of Kansas (M.S. 1969, Ph.D. 1971)
Awards & Achievements	Jackson State University Presidential Citation Award (1986)
	National Science Foundation Director's Equal Opportunity Achievement Award (1986)
	Senior Executive Service Performance Award (1994)

BIOGRAPHY

Roosevelt Calbert is known for his leadership as part of the National Science Foundation (NSF) and for his education of minority students. Calbert is a native of Philadelphia, Mississippi. After graduating from high school, Calbert attended Jackson State University, where he earned his B.S. degree. He also received his M.A. degree in education from the University of Michigan and then attended the University of Kansas to study plasma physics. Calbert earned his M.S. degree in 1969 and his Ph.D. degree in 1971 from the University of Kansas.

Science Education from 2011 ScienceMakers Public Program

Early in his career, Calbert served as director of the Cooperative Academic Planning (CAP) Program at the Institute for Services to Education where he studied curriculum change in black colleges as well as academic planning and evaluation. In 1975, Calbert began his long career with the National Science Foundation, joining NSF's Directorate for Science and Engineering Education. Calbert held many positions over his twenty-four year career with NSF, including senior program analyst, agency representative for the White House Initiative of Historically Black Colleges and Universities (HBCUs), and, most recently, division director of human resource development. Calbert's role at NSF was based on his commitment to improving educational opportunities for minority students. He established several programs that are geared toward science, engineering, and mathematics education for underrepresented students. In 1992, he became a member of the Senior Executive Service, which is an executive leadership group composed of U.S. Government employees. In addition to his work at NSF, Calbert has worked on the faculty at both Alcorn State University and Alabama State University. He published numerous academic articles and presented at professional conferences. Roosevelt Calbert is retired and lives in Reston, Virginia, with his wife. He has four children and six grandchildren.

Above Picture of Roosevelt Calbert from www.math.buffalo.edu/mad/physics/calbert

SCIENCE IN ACTION

NATIONAL SCIENCE FOUNDATION

***ScienceMakers* is a NSF-funded grant. The grant has funded public programs nation-wide like this one at the Detroit Science Center with ScienceMaker, Ayanna Howard.**

Many of the scientists in this book have, at some point in their lives, been involved with or funded by the National Science Foundation (NSF). As a U.S. Government agency, NSF supports scientific research and programs by giving grant money to qualified people and organizations who have good ideas. In order to get money for a research project or program, you have to write a grant proposal and explain your ideas to the people in charge at NSF. NSF gives grants for pure scientific research and also for science education programs similar to those in which Roosevelt Calbert was involved. The Toolkit you are reading right now is part of an NSF-funded educational project called *ScienceMakers: African Americans and Scientific Innovation.*

DISCUSSION QUESTIONS

1. If you were to interview Roosevelt Calbert, what questions would you ask him?
2. Check out the NSF website (http://www.nsf.gov/). Do you think you would enjoy working for this organization like Roosevelt Calbert did?
3. The National Science Foundation gives grant money to support science projects. If you could get money from NSF, what kind of project would you do?
4. Roosevelt Calbert dedicated his life to improving science education opportunities for minorities. What do you think are important factors in a quality education?
5. How does Roosevelt Calbert's career compare to that of other administrators in the Toolkit?

GLOSSARY

Curriculum - The subjects comprising a course of study in a school or college

Grant Proposal - A formal proposal submitted to a government or civilian entity that outlines a proposed project, shows budgetary requirements, and requests monetary assistance in the form of a grant

National Science Foundation (NSF) - A United States government agency that supports research and education in all the non-medical fields of science and engineering

Plasma Physics - The branch of physics that involves material in plasma phase, which is separate from the solid, liquid, and gas phases

Senior Executive Service - A group composed of U.S. Government employees who possess leadership and executive skills; charged with leading the continuing transformation of government