GROWING LAB GIRLS

A Free Resource for Grades 9-12 Teachers in English Language Arts, Science, Mathematics, and Engineering

talkSTEM
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Created by

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About the Contributors

This toolkit was developed as a collaborative project coordinated by the talk**STEM** organization. Based in Dallas, Texas, talk**STEM** is a 501(c)3 organization and a diverse community actively engaged in STEM learning and teaching. Our marquis program is the walk**STEM** tour, a customized experience created and coordinated by talk**STEM** that connects the real world to STEM. Learn more about us by visiting our website www.talkstem.org or emailing our Director and Founder, Koshi Dhingra at koshi@talkstem.org.

The following individuals participated in creating this toolkit:

Maisa Correa De Oliveira is a doctoral candidate in the Department of Biological Sciences at the Center of Drug Discovery, Design and Delivery, Southern Methodist University. She earned her B.Sc. in Biological Sciences from Mackenzie Presbyterian University, in Sao Paolo, Brazil. Her research focuses on establishing a high expression system for the human P-glycoprotein and Breast Cancer Resistance Protein (BCRP) for later biochemical evaluation of in silico identified potential P-gp and BCRP inhibitors.

Koshi Dhingra, Ed.D. is the Founder and Director of talk**STEM**. She has a doctorate in science education from Teachers College, Columbia University, and has years of experience teaching at the middle and high school levels, as well as teaching in teacher education programs. Most recently, she served as a director of the Science and Engineering Education Center at the University of Texas at Dallas.

Jonathan Edquid is Program Manager for talk**STEM**. A science educator with experience in the Houston and Garland independent school districts, he is also formerly of the National Math + Science Initiative, where he developed and presented science and math teacher training at the elementary and middle grades levels. Jonathan also served as STEM Curriculum Designer for the Dallas Arboretum, where he created and revised Classroom, Outreach, and Afterschool programs.

Wanda Gass worked for Texas Instruments for 31 years where she was elected TI Fellow and IEEE (Institute of Electrical and Electronics Engineers) Fellow. In 2012, she became Director of Summer Camps for Young Women and in February 2014 became President of Design Connect Create. Wanda received her B.S. in Electrical Engineering from Rice University and M.S. in Biomedical Engineering from Duke University.

Mala Mahendroo, PhD, is a Professor in the Department of Obstetrics and Gynecology and Member of the Green Center for Reproductive Biological Sciences at the University of Texas Southwestern Medical Center. Her postdoctoral work was supported by fellowships from the National Institutes of Health, The Lalor Foundation, and the Burroughs Wellcome Foundation.

Dustin Miller is Director of Education at the Dallas Arboretum and Botanical Garden. With a MA in Anthropology, Dustin strives to build cultural connections with informal science resources. In addition to his role at the Dallas Arboretum, Dustin currently serves as President of the Informal Science Education Association of Texas.

We are grateful to the following people for judging the Making It Personal (writing) contest and My Plant (photography) contests:

Carolyn Armbruster is the Founder and Director of Artful Thinking DFW. Ms. Armbruster earned an MAT in Museum Education from George Washington University.

Anna Kuchment is a staff science writer at **The Dallas Morning News** and a contributing editor at Scientific American. She started her career in New York City, where she graduated from the Columbia University Graduate School of Journalism, spent 14 years as a staff reporter, writer and editor at **Newsweek** magazine and then became a senior editor at **Scientific American**. Her work has been recognized by the National Association of Science Writers, the Society for Features Journalism, and the American Geophysical Union. Her first book, **The Forgotten Cure,** about the race to develop new antibiotics from old-world medicines, was published in 2011 by Copernicus Books.

Preface

Inspired by Dr. Jahren's interviews and memoir, ***Lab Girl***, this toolkit has been created to provide powerful messages about the universal relevance of science to each and every one of us. We present a peek into the unique experiences of 3 other women scientists and an opportunity for students to examine their personal relationships with science. We hope that this resource will serve as a toolkit for grades 9-12 teachers who want to deepen the conversation with the young women in their English, Science, Mathematics, and Engineering classes.

We want young women to know that they are all scientists. We want them to understand science is an umbrella term for a diverse range of human activity, that scientific inquiry involves taking risks and collaborating with many groups of people. We want them to view science as an exciting set of ways of looking at the world around us.

This toolkit consists of a menu of activities related to English Language Arts, Science, and Engineering. There are 5 sections: What is Science?, Lab Girls, Plants, Communicating Science through Social Media, and Photography and Writing Contests. Grappling with data is an integral part of what scientists do, and part of this toolkit offers students the opportunity to work with real world data derived from 2 Dallas-based women scientists. Additionally, with the cooperation of the Dallas Arboretum, the plant section allows students to work with real world horticultural data that they would otherwise not have access to. We hope that teachers will use the menu options throughout the school year. Our goal is to get girls to think more deeply about the nature of science, reflect on themselves as scientists, and express their science-related ideas and questions. We want them to understand that science is a process of inquiry and not a search for the "right" answer. Science is a constant search for meaning and we invite students to participate in this effort by grappling with real data that current scientists have gathered and are working with.

"You are now a scientist. People will tell you that you have to know math to be a scientist, or physics, or chemistry. They're wrong….What comes first is a question, and you're already there….. It's not nearly as involved as people make it out to be."

From ***Lab Girl***, p. 4

Student Contests

There are two contests described in this toolkit sponsored by talkSTEM. We invite teachers to submit their students' writing and photographs by email. We hope teachers use these contests as opportunities to generate some excitement around class assignments. You can email student submissions to info@talkstem.org. Check the talkSTEM website for current deadlines. Please include student name, age, grade, and school. **These entries will be judged by a staff science writer for the Dallas Morning News and Artful Thinking, DFW**. Winning entries will be celebrated and recognized on talkSTEM.org and our social media platforms.

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What is Science?

A. Changing the Conversation about Science & Scientists

Ask students to consider these four messages:

1. "Science makes a world of difference,"
2. "Scientists are creative problem-solvers,"
3. "Scientists help shape the future," and
4. "Science is essential to our health, happiness, and safety."

Ask students to discuss these statements in pairs or groups of three and then individually select the statement that resonates most with them. Create a personal story using the statement that you connect most with. In your story, describe an event, a person, or a group that exemplifies the message you have selected.

Activity adapted from Committee on Public Understanding of Engineering Messages, & Engineering, N. A. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. National Academies Press.

B. Career Motivations

Have students brainstorm in small groups of 2-4 students about what may motivate them when choosing a career. Provide post-its and examples such as family role models or pay. Ask each group to come up with a minimum number of items that would motivate them (say, 6-10). Have them write each item on a separate post it.

Then on the board, draw four quadrants and put these categories in them:

1. Social Impact
2. Extrinsic
3. Intrinsic
4. Prestige

Explain what each of the four categories mean. Social Impact refers to the idea that one's career helps people and society. Extrinsic factors refer to things like pay and job security and intrinsic factors refer to an inner love or drive that causes one to do a certain task because of the specific satisfaction that comes directly from doing that task be it cooking, playing the piano, etc. Prestige refers to external recognition which may or may not be accompanied by a high pay.

Ask each group to discuss which quadrants their post-its will go in and then invite them to put their post its up. Facilitate a whole group discussion on the various factors the class has come up with.

Students can be asked to write a reflection on their thinking about what motivates them to consider particular careers and why.

Activity adapted from Committee on Public Understanding of Engineering Messages, & Engineering, N. A. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. National Academies Press.

C. Taking Risks and Iteration

The riskiest part is learning what a true scientist is and then taking the first shaky steps down that path, which will become a road, which will become a highway, which will maybe someday lead you home. A true scientist doesn't perform prescribed experiments; she develops her own and thus generates wholly new knowledge. (***Lab Girl***, p. 66)

For every activity and lab that you have students do, talk for a few minutes about risk-taking and the role it plays in that investigation. You can even ask them to include a few sentences on their reflection on the risks they took and the ways they iterated on the activity (or that they would like to iterate on the activity if time constraints prevented them). The important characteristic of risk taking needs to be developed over time. Students need to identify themselves as risk-takers in the scientific arena in order for them to persevere and find joy in their scientific explorations.

I. Engineering Design Challenges

Have enough materials for the groups to do this exercise two times so that they can improve on their own group's idea or use an idea from another group that was successful and improve on that idea.

Choose from one of the five challenges:

1. SPAGHETTI TOWER
   A. OBJECTIVE: To create the tallest free-standing structure from 30 pieces of spaghetti, 1 meter of masking tape, and1 meter of string that will support a single marshmallow.
   B. TIME: 20 minutes
   C. MATERIALS per group of 2 -3 students: 30 pieces of spaghetti, 1 meter of tape, 1 meter of string, 1 pair of scissors, 1 medium sized marshmallow
   D. Directions: Students are given the materials; they have 20 minutes to construct the tallest free-standing structure that will support the marshmallow. They may use all or as little of the materials given. The marshmallow must be placed on top of the structure and measurements will be taken from the bottom of the structure to the marshmallow. Students are not allowed to rotate tables so it stands taller, tape the structure to the tables, floor, etc. Group with the tallest free standing structure gets a prize or trip to the treasure box!
2. PAPER TABLE
   A. OBJECTIVE: To design and build their table out of paper
   B. TIME: 15 minutes
   C. MATERIALS per group: 3 pieces of newspaper, 24 " of masking tape, 8.5 x 11" cardboard sheet, ruler, scissors
   D. DIRECTIONS: Each group has 15 minutes to. It must be 8 inches high and be able to hold a ream of paper. You may not tape the newspaper to the table or to the cardboard. You may not fold or bend the cardboard in any way. Use the first 5 minutes to brainstorm what you plan to build and select on design idea. Use 5 minutes to build your table and then test your design. Use the last 5 minutes to modify and improve your design. The team that can support the most weight will win.
   E. DISCUSSION: After the competition ask about the roles of the team members.
      1. How many ideas did you come up with?
      2. How did you decide which idea to use?
      3. Why did the design that won work better than the other designs?
      4. What would you do differently if you could build another table?
3. BALLOON ROCKETS
   A. OBJECTIVE: Create a balloon rocket that will travel straight upward toward the ceiling.
   B. TIME: 20 – 30 minutes

C. MATERIALS: 2 Balloons, 4 straws, 1 pair of scissors, tape, 3 rubber bands, 4 paper clips, 4 notes cards
D. DIRECTIONS: Students are given the various materials in a large zip-lock baggie. They then have 15 minutes to create a balloon rocket. They may use all or as little of the materials as they want. After time is called they then share out about their design. The balloon rocket cannot be hooked to any string for a zip-line. There may be some groups who are successful but some who may not be. Once they share out, you can give them another 8 minutes to redesign their rocket and see if they can get it to work.

4. ALUMINUM BOAT
   A. OBJECTIVE: Each team will construct a boat out of a piece of aluminum foil.
   B. TIME: 10 minutes
   C. MATERIALS: 3 10cm x 10cm pieces of foil, pennies, timer
   D. DIRECTIONS: The boats will be loaded with pennies. The winning boat holds the most pennies. The boat must remain afloat for 5 seconds after the last penny has been placed aboard and may not touch the sides of the water container. Teams will be given 2 pieces of foil so that they can refine their original design on their second attempt.
5. EGG DROP
   A. OBJECTIVE: Use provided materials and your knowledge of forces, impulse and momentum to create a container that will protect a raw egg when dropped from a given height.
   B. MATERIAL: cotton, balloons, paper, tape, glue, string, popsicle sticks, rice, soda cans, and bubble wrap as decided by the instructor based upon the height.

II. Iteration

Science and engineering share the same principle of iteration - building and improving upon previous designs. Dr. Jahren describes how she and her lab manager, Bill, went through multiple prototypes of a device that would be “able to scrub nitrous oxide out of the gases released during the detonation of a homemade explosive” and divert the gases to a mass spectrometer for analysis. Describe a time when you designed and created something iteratively.

D. Science at Home and Role Models

Here is an excerpt from an interview with Dr. Jahren in **Time** magazine by Siobhan O'Connor (May, 2016):

> TIME: You say at one point in the book that if you were going to continue to do science every day, you wouldn't be like any other woman you know. Did you never have female role models in science?
>
> Hope Jahren: Not that I can remember. I had women in my life that I looked up to and they were successful and happy and they accomplished different things. I remember thinking 'I am a scientist and if I spend my life in a lab, I will never get to have those things.' That felt like a loss. I am also fiercely proud of the fact that science is practiced in the home. It's how you cook or measure fabric for curtains. My mother was as much of a scientist as my father [who taught science at a community college] but she didn't have the same chances. So I never did think of myself not as a scientist. The funny thing is, that's been great for my work. I don't work in order to prove myself to an institution. So I have to think 'Why am I doing this?' 'What am I getting out of this?' The system of awards that you're supposed to chase, I never presumed those were open to me. So the only thing I wanted was one more day in the lab. And it's still all I want.

1. List some ways in which you practice science at home.
2. Using Jahren's broad definition of what counts as science, who are your female role models in science? Why do these women inspire you?

Lab Girls

The following stories and activities center on the work and careers of women scientists: Nobel Laureate Barbara McClintock, Southern Methodist University PhD candidate Maisa Correa De Oliveira, and UT Southwestern Professor Mala Mahendroo. All these scientists grapple with data that they gather to extract meaning. The goal is always to tell and to retell the story addressed in their research questions.

A. Barbara McClintock

Evelyn Fox Keller's biography of Nobel Laureate Barbara McClintock, **A Feeling for the Organism**, is a great read. Barbara McClintock's research on corn genetics in the 1940s and 50s led to the discovery of transposons or jumping genes. For this work, she remains the only American woman to win an unshared Nobel Prize (Physiology or Medicine in 1983).

The following are quotes from the biography of Barbara McClintock, **A Feeling for the Organism**. Choose one or more and discuss in light of your own personal experiences.

1. Good science cannot proceed without a deep emotional investment on the part of the scientist. It is that emotional investment that provides the motivating force for the endless hours of intense, often grueling labor.
2. It never occurred to me that there was going to be any stumbling block. Not that I had the answer, but [I had] the joy of going at it. When you have that joy, you do the right experiments. You let the material tell you where to go, and it tells you at every step what the next has to be because you're integrating with an overall brand new pattern in mind. (When asked how she could have worked for two years without knowing the outcome.)
3. Things are much more marvelous than the scientific method allows us to conceive.
4. [Plants] are fantastically beyond our wildest expectations.

B. Maisa Correa De Oliveira

Doctoral candidate in the Department of Biological Sciences at Southern Methodist University

Microorganisms have always fascinated me. How is it possible that such small and simple organisms could adapt themselves so well to so many environment. The estimation number of bacteria on earth would be around 5 x 10 to the 30th power (that would something like a 5 with 30 zeroes after it). There are bacteria inside us right now. A study from last year reported that the estimated total number of bacteria in a 70 kg man would be around 3.8 x 10^13 (see reference*). Bacteria are extraordinary survivors that can live on extreme temperatures, toxic environment, they can even survive on their dormant state through centuries before start to growth again. Usually we think about bacteria as bad guys because we related them to several diseases, but a great proportion of bacteria are beneficial. For example, what makes our planet not be a huge trash can of every single organism that already had lived before us is the work of the soil bacteria that drive the process of decomposition of this dead material, returning to the environment all the building blocks necessary to feed or build a new organism. Now talking about the ones that living inside us, the flora within the guts of human are what make digestion possible, so they are actually helping us to survive. Cows are not able to digest grass to obtain the nutrients they need, one of their four chamber of their stomach - the rumen - is a large fermentation compartment where bacteria and other microorganisms break down food. Isn't that cool?

Another amazing feature of bacteria is the ability to uptake small fragments of DNA from different sources. It could be exchanged from another bacterium, or even from bacteria that release their cell content after death. This simple feature can provide to the bacteria a great advantage, it could provide for instance, resistance to antibiotics. This DNA are usually circular and we call them plasmids. We can take advantage of the bacteria because of this. We can manage to insert a DNA of our interest and make bacteria produce what we want. And more, since bacteria can also grow fast (it means replicate) they can produce a lot of what we want in very short time. Here is how I manage to use bacteria in my work with drug discovery in cancer therapy.

Reference: *Revised Estimates for the Number of Human and Bacteria Cells in the Body Ron Sender1 , Shai Fuchs2*, Ron Milo1
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4991899/pdf/pbio.1002533.pdf

Maisa's Research Question:

What does it take to increase effectiveness of chemotherapy drugs for cancer patients?

ZOOMING OUT: WHAT IS THE BIG PICTURE?

A common issue that cancer patients undergoing chemotherapy face is that the medication stops being effective. We say the tumor cells have developed resistance to the treatment and will be resistant not only to the specific drug that was being used but a wide range of them. The main cause of the problem is that the tumor cell membranes express a family of protein transporters whose job it is to export toxins, which could include chemotherapeutic drugs, out of the cell. Imagine shooting more and more bullets against the enemy but to no avail because the enemy has a superb bullet proof wall. P-glycoprotein (P-gp) is the most common member of this family of protein transporters.

The goal of my research is to make human P-gp. Once I have done this, I will test the activity of this protein meaning I hope to measure the speed at which P-gp works to pump out toxins. Following this, I will add inhibitors and measure the effects so that I can figure out how much I can reduce the activity of P-gp.

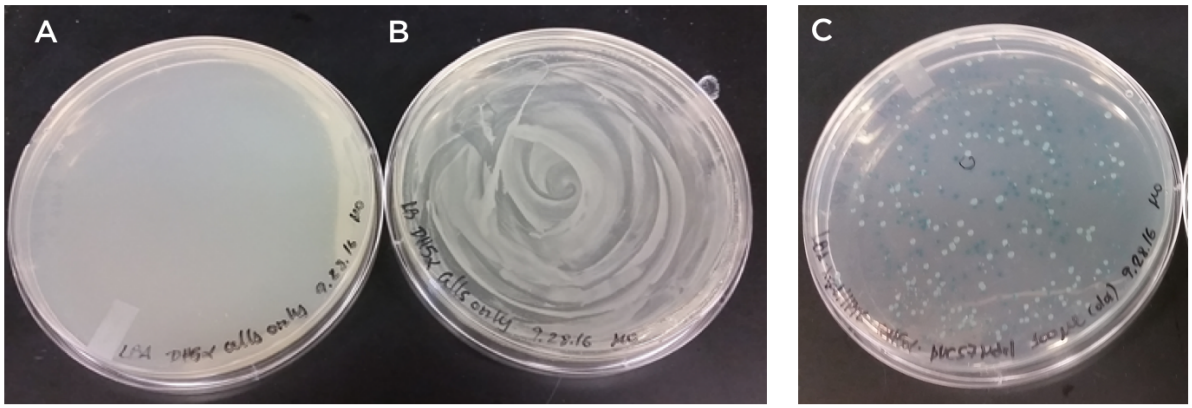
ZOOMING IN: CLONING HUMAN P-GP IN BACTERIA

Here are some of my experimental results in which I enlist the help of some bacteria to produce a good quantity of human P-gp and then I check to make sure that I have isolated this protein:

First step – Remember when I told you I could insert a small fragment of DNA on bacteria to make them produce what I want? What I wanted was to produce a large amount of the P-glycoprotein DNA sequence. I wanted to make the bacteria – *Escherichia coli* (*E. coli*) - to make more copies of this DNA for my latter experiments. So first I designed a plasmid containing human P-gp DNA and another sequence that would give resistance to the antibiotic Ampicillin. Then I wanted to insert this plasmid on *E. coli*, a procedure called transformation. I needed to get just the *E. coli* cells that were transformed successfully. In other words, the ones that now carry the DNA that express the human P-gp. The reason I used *E. coli* bacteria is that these cells reproduce rapidly and will help me make a lot of the P-gp in a short time. Remember, though, that I cannot see the DNA so I need to find a trick to tell me if the human DNA coding for P-gp is in the bacterial cell. Combining the human P-gp DNA with easily available DNA which results in ampicillin resistance (this is a

commonly used technique) would be the way to make me see which cell I should select.

Initially I prepare some special plates containing agar and the nutrients necessary for bacterial growth. I some plates I added ampicillin and in others I did not (in photos a and b in the diagram below). I used some of the bacterial cells that had not been exposed to the plasmid and applied them to these plates. In diagram A the plate contain ampicillin while in diagram b does not. They are important control plates from my transformation. Next, I had the transformed bacteria (the ones that could contain the plasmid DNA) and I wanted to make sure that I was isolating only those cells that had successfully incorporated the plasmid DNA, so I applied the cells in a plate with ampicillin. I selected the colonies possibly containing the DNA of my interest. I said possibly because I need an extra step to double check if the DNA is there...



A) Plate prepared with nutritive medium (LB) + ampicillin (A): *E. coli* cells applied to this plate as a negative control of the growth - no growth observed.
B) Plate prepared with nutritive medium (LB): E. coli cells applied to the plate as a positive control of the growth - bacteria grow as a lawn
C) Plate prepared with nutritive medium (LB) + ampicillin (A): E. coli cells transformed with plasmid pUC57-MDR1 subsites2 (P-gp) were applied to this plate. Experimental plate, only the cells containing the plasmids would growth - White colonies are the ones that contains our Plasmid with P-gp DNA. Two of these colonies were picked to test if P-gp DNA is there.

Second Step - The DNA sequencing seems like a mystery but it is really nice that we found ways where we could really see it. I needed to break down the cell to get access to the DNA. Once the cell is open I can get access to the cell content, including the DNA. Then I used gel electrophoresis to identify the kind of DNA I have. Agarose gel electrophoresis is a method scientists use to separate molecules based on their size and electrical charge in a matrix of agarose set on a box called an electrophoresis chamber. Biomolecules are

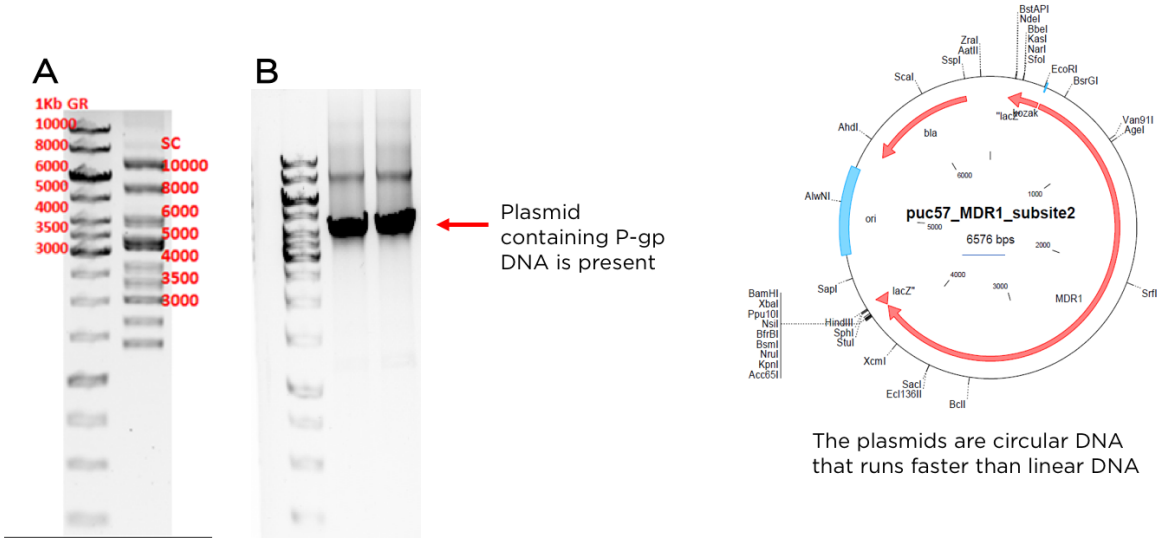
separated by applying an electric field to move the charged molecules through the agarose gel. First, I insert the sample into little pockets called wells within the gel. The DNA molecules have negative charges so they move toward the positively charged electrode on the electrophoresis chamber. The DNA exists in linear form, like our genomic DNA and also circular forms like the plasmids I designed for transformation. The latter form has an interesting feature called supercoiling. Imagine that you have an elastic band. Then you can start to wrap it around itself. This is exactly how the plasmid DNA would do. The greater the number of turns the DNA molecule makes, the more supercoiled it is as a result of which it gets more compact. So the supercoiled DNA runs faster compared to other forms in a gel electrophoresis experiment. You can read about this here: https://biology.stackexchange.com/questions/39242/why-does-supercoiled-dna-run-faster

When plasmid DNA is isolated and run on an agarose gel, I usually observe 2, 3 or even 4 or more bands. I am always hoping that the majority of the isolated DNA will be supercoiled DNA, because I would know I did not damage the DNA while I was breaking the cells to get it, but other forms can also crop up. How these forms will show up on an agarose gel (in terms of relative migration speeds) is shown in the diagram below.

http://bitesizebio.com/13524/how-to-identify-supercoils-nicks-and-circles-in-plasmid-preps/

In Figures A and B, you can see the bands I saw when I compared supercoiled DNA with a known linear marker called GR. All this work was done so I can “see” what really is invisible. Bacterial transformation and gel electrophoresis are merely tools that can help me identify and isolate the gene that codes for human P-gp. If I can produce a lot of this protein, I will make some assays to check how active it is and then check new compounds that could stop P-gp to work. If I am successful in stop or decrease it activity that would increase the effectiveness of Chemotherapeutic drugs since the protein would not pump the medication out anymore.

DNA gel screening – plasmid prep



Only plasmid DNA can be seen on the gels.
A) Comparison of Gene Ruler (GR) 1 Kb DNA ladder and Supercoiled (SC) DNA ladder. **B) On both samples,** there is a thinner band between 6000 and 8000 bps that would be in the correct place if the plasmid was a linear DNA. Here in figure a we have a comparison between the GR ladder with a supercoiled (circular) DNA ladder (SC). The correct size of plasmid should be 6576 bps, so should be above 6000 bps and this means between 4000 and 5000 bps on linear GR ladder. On Lane 1: 1 Kb GR DNA ladder; Lane 2: plasmid pUC57-MDR1-subsites2 (6576 bps) found on colony 1; Lane 3: plasmid pUC57-MDR1-subsites2 (6576 bps) found on colony 2.

Figure A: DNA markers contain fragments of DNA of known size, so we can use them to compare the size with our DNA. On the figure 'a' there are two different DNA markers, GR is a linear DNA marker while SC is a supercoiled circular DNA marker. As you can see, circular DNA at 10,000bps is in between 6,000 and 8,000 bps in comparison with GR linear marker. That's because supercoiled DNA (that would be well packed) runs faster on the gel than linear DNA.

Figure B: there is only the GR linear marker to be compared with our samples, that's why figure 'a' is here, so we know where we supposed to expect our Plasmid supercoiled DNA to be. So the 6576 bps (base pairs) circular plasmid should be around 4000-5000 bps on GR linear marker.

Read through Maisa's story and discuss the following questions:

A. In her photographs of her agar plates in which she is culturing transformed *E. coli*, she refers to positive and negative controls. Explain fully the purpose behind each of the 3 plates. Describe 2-3 other situations in your everyday life or in a scientific investigation at school in which you have used positive and negative controls.

B. List the various ways in which Maisa's work is connected to work done by other researchers. As two examples, she uses techniques such as bacterial transformation and gene markers. Both of these have been developed by other scientists. Also, list some other researchers you can imagine being interested in knowing about Maisa's findings. What could they be studying?

C. Write a letter to Maisa in which you share any interests you may have in the area of cancer research and specific questions about her research. Your teacher can send selected letters to Maisa. You can write a letter individually, as a small group or as a class.

D. Look up some other ways in which the technique of bacterial transformation is helpful in biological research.

E. Read the short article: https://biology.stackexchange.com/questions/39242/why-does-percoiled-dna-run-faster. Explain the differences between supercoiled, linear, nicked, and circular single-stranded DNA. Why do these different forms of DNA result in bands in different locations during gel electrophoresis?

F. If you have done a lab at school involving gel electrophoresis, growing bacteria on agar plates for any reason, bacterial transformation, or anything that Maisa's experimental data reminds you of, write a paragraph in which you summarize what you did and how you felt while doing the lab. Reflect on what you remember and the wonderings, confusions, discoveries, connections, feelings, and new questions you recall.

C. Professor Mala Mahendroo

Professor in the Department of Obstetrics and Gynecology and Member of the Green Center for Reproductive Biological Sciences at the University of Texas Southwestern Medical Center

Mala Mahendroo is a Professor in the Department of Obstetrics and Gynecology at UT Southwestern Medical School in Dallas. She has had a research lab there for 17 years and currently has 6 lab members working with her. She describes being a scientist as an opportunity to go on a scavenger hunt every day. Like a scavenger hunt, one clue leads to the next and you get to learn something new every day. It is so fun to be challenged and make new discoveries. In particular she has also enjoyed the opportunities that science brings to meet and interact with people from many countries and to collaborate on cervix projects with researchers who have a different expertise such as obstetricians and mechanical engineers. When she is not in the lab, Dr. Mahendroo loves to spend time with her two college-aged daughters, travel, hike, cook and read.

In the following passage, Dr. Mahendroo describes her lab's work to understand the mechanisms of cervical ripening and its connection to preterm labor.

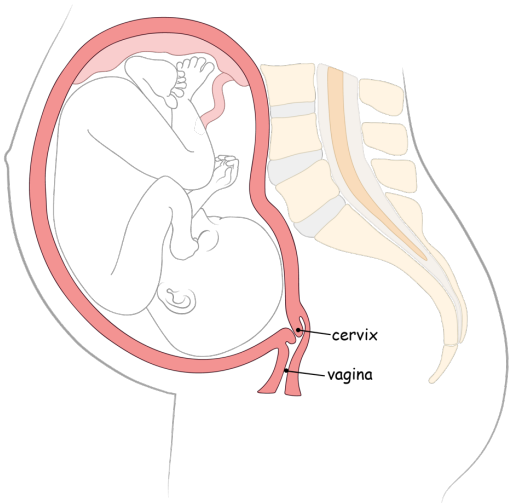


Figure 1 During pregnancy the baby develops in the uterus, and the cervix, located at the base of the uterus, remains rigid and closed.

ZOOMING OUT

The growth and development of a healthy baby that is well-equipped to survive outside the womb requires a pregnancy that lasts 38-40 weeks. During this time the baby is housed in the uterus, which provides just the right environment for the baby to grow and develop. The uterus is a muscle which at the end of pregnancy begins to contract to push the baby out of the birth canal. At the base of the uterus just inside the vagina is a structure called the cervix (Fig 1). During pregnancy the cervix is tightly shut and stiff to keep the baby in the uterus, and by the end of pregnancy the cervix is transformed to a soft and flexible structure to open and allow birth to occur. To give you an idea of the amazing change the cervix undergoes, its consistency during pregnancy is similar to the

cartilage on the bridge of your nose and by the end of pregnancy has a consistency that is similar to your lips.

The focus of my research is to try and understand how the cervix goes from stiff and rigid to soft and compliant. Our goal is to understand how the cervix remodels in normal pregnancy and figure out what causes the cervix to remodel too early in some pregnancies. **Why is this important?** Because sometimes the cervix opens up earlier that 38-40 weeks of pregnancy and this can lead to the mom going into labor too early and the baby being born before it is fully developed and ready to survive in the real world! The problem is called preterm labor. In the United States 1 in every 10 babies is born preterm. Some of these babies may not survive while others survive but have health problems that could last their entire lives.

We use the mouse as a model system for our studies. **Why use the mouse?** Because 1) we can't ethically collect cervix from pregnant women, 2) the mouse has a relatively short pregnancy (19 days) so we can easily monitor changes through pregnancy, 3) the process of cervical remodeling is similar (but not identical) to the human, and 4) we can create mice with a genetic modifications (we call them gene knockouts, KO) which is a useful tool to learn about the function of a specific gene.

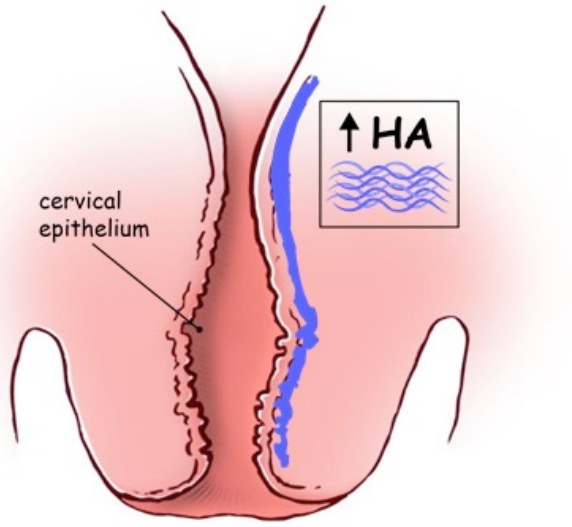


Figure 2 Diagram of cervix with arrow pointing to the epithelium. Note that the synthesis of hyaluronic acid (HA) is increased in epithelium at the end of pregnancy in women and mice (HA indicated in blue).

ZOOMING IN

Science requires one to play detective and ask a lot of "**What, Why and How**" questions. One example from research in my lab is our longstanding interest in a molecule called hyaluronic acid (HA). HA is molecule with functions that include keeping our skin hydrated (it is probably an ingredient in your face moisturizer), allowing cells in our body to move to the right place and in keeping our joints and some tissues lubricated or flexible. Interestingly, the synthesis of HA is increased in the cervix towards the end of pregnancy in women and mice (Fig 2). **But why?** Since HA in other tissues helps to keep

tissue hydrated and flexible, *we **hypothesized** the increased synthesis of HA is critical for the transition of the cervix to a soft and compliant structure in preparation for birth. We tested our hypothesis by asking the following question*:

What happens when the cervix can't make HA at the end of pregnancy?

To answer this question we created mice that were missing the genes required to make HA. I will refer to this as the HA gene knockout mice. We anticipated if HA was important that pregnant HA knockout females may have difficulties during the birth process. As seen from the table, the mice lacking HA gave birth on gestation day 19 just like the normal wild type mice. We were so disappointed! **Based on this finding was our hypothesis correct?**

Table 1 Summary of birth timing in normal and HA KO mice

	Delivered on time (number of mice)
Normal mice	100% (12/12)
HA KO mice	100% (10/10)

In addition to monitoring birth, we searched for other clues that may help us understand what HA was doing in the pregnant cervix. We dissected the cervix from gestation day 18 wild type and HA knockout mice and looked at the cells in the cervix under a microscope. We were surprised to see that the epithelial cells appeared disorganized in the HA KO as compared to the wild type mice (Figure 3). This was something unanticipated and gave us hope that the loss of HA in the cervix may affect cervical function. Epithelial cells line the cervix (Fig 2) and play an important role in immune protection against harmful bacteria that during pregnancy can ascend from the vagina into the uterus to cause preterm birth. This observation led to another question.

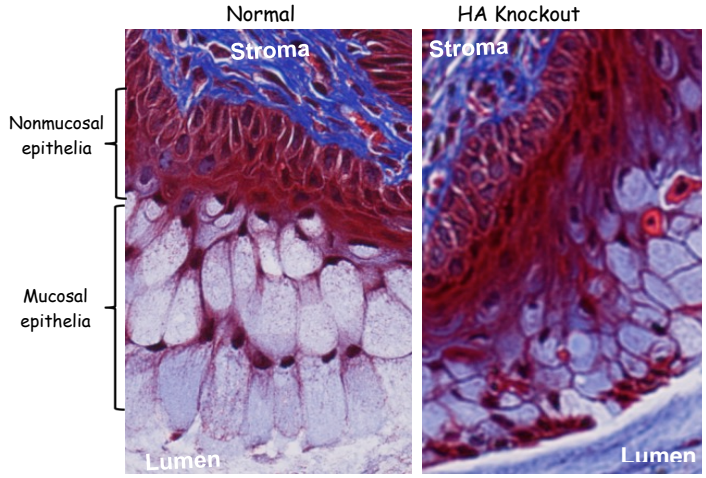


Figure 3 The cervical epithelia from a normal (left panel) and HA knockout (right panel) mouse one day before birth on day 18 of pregnancy. Note the abnormal and disorganized mucosal epithelia in the HA knockout mouse compared to

How may the disruption in the cervical epithelial cells impact the ability of the HA KO mice to deal with an ascending infection during pregnancy?

To answer this question we applied an equal number of *E. coli* bacteria into the vagina of a gestation day 15 HA KO and wild type mouse and then monitored the mice to see if they would deliver preterm (within 48 hours after we applied the *E. coli*) or if they would deliver at term (gestation day 19). As seen in Figure 4, 27% of WT mice delivered preterm but 92% of the HA KO mice delivered preterm. We were amazed and very excited by these differences! From this observation we concluded that the disrupted epithelia in the HA KO mice leads to in reduced ability for immune-protection against ascending infection-induced preterm birth.

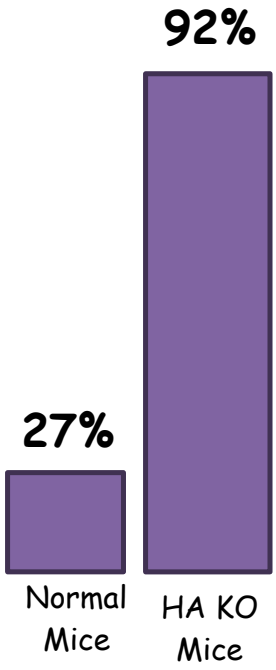


Figure 4 Summary of preterm birth rates in normal and HA KO mice with vaginal exposure to bacteria on gestation day 15. Preterm birth occurred within 48 hours after exposure.

These findings have led us to conclude the HA plays an important role in ensuring that the cervical epithelia are well organized and able to provide a physical and immunological barrier against ascending infection. We were very proud to make this exciting new discovery! As is the norm is scientific discovery, these insights have led to more questions. Below I provide 2 ongoing questions that my lab is hoping to answer based on current research in the lab. This includes:

Why is the epithelial barrier function lost when the cells don't make HA?

How may levels of HA become reduced in women and contribute to preterm birth?

Read through Dr. Mahendroo's story and answer the following questions.

1. If the data table in Table 1 had looked like Table 2, what would Dr. Mahendroo's lab conclude about the role of HA in normal pregnancy?
2. Can you redraw bar graph in Figure 4 to present data that would allow Dr. Mahendroo to conclude that the disrupted epithelia in the HA knockout does not impact preterm birth resulting from an ascending infection?

Table 2 Summary of birth timing in normal and HA KO mice

	Delivered on time (number of mice)
Normal mice	100% (12/12)
HA KO mice	30% (3/10)

3. What other questions come to mind that relate to Professor Mahendroo's work. Consider both the zooming out, background info as well as the zooming in, more specific information. Try to find out by doing some quick research on the internet as to whether these questions are being addressed in any ongoing research.
4. Professor Mahendroo describes how observation of the organization of epithelial cells led her lab to come up with new questions. Describe an occasion when your observations have led to new questions both in science/engineering classes as well as outside the classroom.
5. Summarize in your own words the specifics (zooming in) aspect of Professor Mahendroo's current research work when it comes to understanding preterm labor.

The March of Dimes is a non-profit organization that works to end premature births and other problems faced by babies. In this short video, created by the March of Dimes, Dr. Mahendroo and others describe their feelings for their work. Watch the video and respond to the questions that follow.

http://bit.ly/15MODUTSW

1. What is the rationale for the creation of the network of researchers described in the video created by the March of Dimes?
2. As you listen to the questions and perspectives of each of the researchers interviewed, make a note of them. What is your reaction to each of these perspectives? What do you hope these researchers will learn and accomplish over time?

Plants are Alive

*No risk is more terrifying than that taken by the first root. A lucky root will eventually find water, but its first job is to anchor - to anchor an embryo and forever end its mobile phase, however passive that mobility was….Everything is risked in that one moment when the first cells (the "hypocotyl") advance from the seed coat….The gamble is everything, and losing means death. The odds are more than a million to one against success. (**Lab Girl**, p. 52)*

A. Trial Gardens

The Dallas Arboretum and Botanical Gardens is more than a beautiful spot to connect with nature; horticultural research is occurring there everyday! The following information comes from their website and explains what the trial gardens are.

http://www.dallasplanttrials.org/page/About-Dallas-Arboretum-Plant-Trials

In north Texas, we have many environmental challenges that make selecting the "right" plants crucial to successful gardening. Although most catalogs and books give good descriptions about a plant's requirements, many of these descriptions are based on growing experience in northern states. Here in Dallas, we have weather conditions that force us to choose plants that have extra fortitude. Our winters can be mild, but we may experience sudden sharp drops in temperature; plants must tolerate periods of either too much rain, or no rain at all; and no one can forget about our extreme temperature conditions in the summer. We ask a lot of our ornamental plants!

The Trial Gardens at the Dallas Arboretum were created for the purpose of expanding our research efforts and providing information to the public. The main focus of the plant testing program is to grow and evaluate many different plants in the drastic climate of the Metroplex and North Central Texas, and develop new plant selections. Information generated from these trials is provided to commercial plant producers, retailers, and home gardeners.

The following is actual data from the trial garden for different varieties of pansy. The plants are graded on a scale of 0-4, with 0 being death/disappearance of the plant and 4 being ideal specimen. Examine the data and answer the questions that follow.

Series	Leaf Color & Quality	Plant Vigor	Flower/Stalk Display	Flowering Uniformity
Inspire DeluXXe Deep Blue	4	3	3	3
Inspire DeluXXe Deep Blue	3	3	3	2
Inspire DeluXXe Deep Blue	3	3	3	2
Inspire DeluXXe Deep Blue	3	3	3	2
Inspire DeluXXe Deep Blue	4	3	4	3
Inspire DeluXXe Deep Blue	4	2	3	2
Inspire DeluXXe Deep Blue	4	2	3	3
Inspire DeluXXe Deep Blue	4	3	3	3
Inspire DeluXXe Denim	4	3	3	2
Inspire DeluXXe Denim	3	3	3	2
Inspire DeluXXe Denim	3	3	3	3
Inspire DeluXXe Denim	4	3	4	3
Inspire DeluXXe Denim	4	3	3	4
Inspire DeluXXe Denim	4	2	3	2
Inspire DeluXXe Denim	4	2	3	2
Inspire DeluXXe Denim	4	3	3	3
Inspire DeluXXe Ocean	4	3	3	3
Inspire DeluXXe Ocean	3	3	3	3
Inspire DeluXXe Ocean	3	3	3	3
Inspire DeluXXe Ocean	3	3	4	4
Inspire DeluXXe Ocean	3	3	3	4
Inspire DeluXXe Ocean	4	2	3	2
Inspire DeluXXe Ocean	4	2	3	2
Inspire DeluXXe Ocean	4	3	3	2
Inspire DeluXXe Red Blotch	4	3	3	2
Inspire DeluXXe Red Blotch	3	3	3	2
Inspire DeluXXe Red Blotch	3	3	3	2
Inspire DeluXXe Red Blotch	3	3	3	2
Inspire DeluXXe Red Blotch	3	4	3	2
Inspire DeluXXe Red Blotch	4	2	3	2
Inspire DeluXXe Red Blotch	4	2	3	2

1. For each observed characteristic, which variety was closest to the ideal specimen?
2. Which variety was the most ideal overall? How did you determine this?

3. What type of graph should be used to summarize this data? Why? Create this graph.
4. Observe some flowering plants near your school, in your neighborhood, or elsewhere. What are some characteristics you would be interested in collecting information about other than the ones listed in the previous chart (Dallas Arboretum Trial Data)? How would you devise a way for several other people to gather data using your criteria? In other words, create a scale with range from 0-4 (as the horticulturists at the Dallas Arboretum did) and describe how your fellow researchers could use your scale to gather data over time.

B. Germination Activity

As a modification to a standard germination lab activity, have students work in pairs to come up with a way to find out what the germination rate of the seeds you will be giving them. Have them come up with an outline of a procedure and check in with another group to compare their strategy. Then have a discussion on group ideas for the experimental procedure. Approve the procedure that all agree makes the most sense.

C. Reflecting on Your Relationship with Science and with Plants

Watch this 6min interview with Dr. Jahren:

https://www.youtube.com/watch?v=UJa8dzBAhmY

A. Create a representation of a tree that you remember from some part of your life. It could be a piece of writing, a picture or other representation. Express the ways the tree made you feel, helped you, and some of the times in your life that you remember the tree being part of your experience.
B. When do you feel you “belong” to science? (This could be in or beyond the classroom.) What would help you feel like you belonged to the spaces in which science is learned or done?

Communicating Using Social Media

A. #ManicureMonday

Below is an excerpt of a column from **USA Today**, Feb, 2014:

What Manicures, Science Have in Common by Laura Vanderkam

Like many people on Twitter, Hope Jahren likes to share small details of her life with her followers. So when she broke a nail while working in the geobiology lab she runs at the University of Hawaii-Manoa last November, she jokingly tweeted about her lab #manicure — only to see Twitter autofill another hashtag: #ManicureMonday.

In this conversation, she discovered that Seventeen magazine invited girls to post pictures of their polished digits. Jahren had an idea. Why not encourage scientists to use #ManicureMonday to post pictures of their hands doing science? She tweeted: "Purpose of #ManicureMonday is to contrast real #Science hands against what @seventeenmag says our hands should look like. All nails welcome."

"I had no designs that it should spread beyond me," she tells me. It did. On Nov. 18, her feed filled with photos of hands gripping beakers, measuring fossils, or in Jahren's case, holding ferns.

Though the original intent might have been to inform the fashion magazine world that what hands do is more important than what they look like, over many Mondays, participants showed something more interesting: "Women scientists' hands are like every other woman's hands," Jahren says.

Photo after photo showed that you can be a scientist and have cool nails. You can do serious work and enjoy girlie things. This isn't a contradiction — and in the ongoing conversation about women in science, it's a message girls need to see..... Sarah Hörst, an astronomy and astrophysics post-doc at the University of Colorado-Boulder (who will be joining the planetary science faculty at Johns Hopkins this fall), participated in #ManicureMonday.

"I often post pictures from the lab in which you can see my hands," Hörst says. "People have commented at various times about my nail color or the fact that I had a nice manicure, so it wasn't much different to throw the hashtag at the end of pictures that I post normally." She works with solvents in her lab, but has found that UV cured nail polish holds up well. "I like to have pretty nails and

cute shoes and makeup and dresses, etc., and I do care about the way I look," she says. "But I am also very serious about my science, and these two things are not incompatible."

One week, Hörst went further with #ManicureMonday. She painted planets and other solar system objects on her nails. Each tweet had a themed picture — like her Mars nail with a model of the Mars Rover — and links to more information. She fielded lots of questions from astronomy enthusiasts. It's unclear whether any manicure-loving girls will now picture the glamorous Hörst when they think of a scientist, but they might.

"It used to be the only way the public saw scientists was through TV or movies, and that provides a very biased picture," she says. "But social media allows us to work to change that." With 4,000-plus followers, Hörst knows that many people "can name a living female scientist, and that's a big deal to me."

Have students work in groups of 3 or 4:

A. What would your nails look like if you were to post a picture of your hands for a #ManicureMonday post? What would your real #Science hands be doing?
B. Come up with a social media campaign that would showcase what girls at your school do that makes them scientists.

B. Hashtags

Below is an excerpt from a short article about Dr. Jahren by Karen Shook from **Times Higher Education**, May 2016:

While scientists have always known that they are funny, quirky, interesting, varied, adventurous individuals, does Jahren believe that social media has helped the rest of the world find out?

“Twitter is an excellent resource for people who want to know about the daily life of the scientist, and to get a glimpse of the authentic informal personalities of the scientists themselves. Scrolling the hashtag #scicomm is a great place to start.”

Have students work in pairs to explore these hashtags:

#ManicureMonday

#Science

#scicomm

A. For each hashtag, have students select 2-3 posts and images they found to be the most interesting and share.
B. Come up with some ideas for a new hashtag relating to girls doing science as part of their everyday life that would catch on amongst teens.

Photography and Writing Contests

A. My Plant Photography Contest

Take a picture of any parts of a plant - roots, leaves, wood, knots, flowers, fruit or other. Choose a phrase or sentence from Jahren's book as a caption for your picture (please include page number). Write a sentence explaining why you chose that phrase as your caption.

Email entries to info@talkstem.org. Be sure to include your name, age, email address, school, grade, and teacher name. Your entry will be judged on these criteria:

1. quality and originality of your photo
2. relevance of the quote you selected to your photo
3. Your personal reaction to the quote you selected (one sentence only)

Winners will be celebrated and recognized on talkSTEM.org and social media platforms.

Entries will be judged by Artful Thinking, DFW.

B. Making It Personal Science Writing Contest

Here's an excerpt from ***Lab Girl*** in which Dr. Jahren describes some lab work she did:

> When I got to the x-ray diffraction laboratory, I placed a glass sample slide onto the countertop, covered it in fixating epoxy, and sprinkled it with powder from the ground hackberry pit. I placed the slide into the diffraction machine and oriented everything carefully, and then activated the x-ray source. After lining up the strip chart, I said a silent prayer that its unobservable inkwell was full enough to last the entirety of the run, and then I settled in to watch and wait. (p. 70)

Please watch this 5 min video: http://bigthink.com/videos/hope-jahren-on-the-personalization-of-science-writing

Write about a science investigation or lab that you did in a class. Make it personal. Express what you did and why, your thinking as you were doing it,

your experience, your wonderings, confusions, new questions and connections to other parts of your life.

Email entries to info@talkstem.org. Be sure to include your name, age, email address, school, grade, and teacher name. Your entry will be judged on these criteria:

1. Originality
2. Evidence of connection to substantive science concept and/or activity
3. Language and mechanics

Entries will be judged by a staff science writer from the **Dallas Morning News** who is also an editor for **Scientific American**.

Word limit: 1,000 words (double-spaced)

Winning entries will be celebrated and recognized on talkSTEM.org and social media platforms.

Standards Alignment Supplement

A. What is Science?

Course	Level	TEKS
English	7	7.15A, 7.16, 7.18, 7.28
	8	8.15A, 8.16, 8.18, 8.28
	E1	E.14, E.15, E.26
	E2	E2.14, E2.15, E2.26
	E3	E3.9A, E.14, E3.26
	E4	E4.9A, E4.14, E4.26
Math	7	7.1A, 7.1C
	8	8.1A, 8.1C
	ALG 1	A.1A, A.1C
	GEO	G.1A, G.1C
	ALG 2	A2.1A, A2.1C
	MATH MODELS	M.1A, M.1C
	PRECAL	P.1A, P.1C

Course	Level	CCSS
English	7	7.15A, 7.16, 7.18, 7.28
	8	8.15A, 8.16, 8.18, 8.28
	9-10	E.14, E.15, E.26
	11-12	E2.14, E2.15, E2.26

Course	Level	CCSS
Math	7	MP4, MP5**
	8	
	ALG 1	
	GEO	
	ALG 2	
	MATH MODELS	
	PRECAL	

B. Lab Girls

Course	Level	TEKS
English	7	7.7, 7.10A, 7.10B, 7.12A, 7.15, 7.16, 7.17B, 7.17C, 7.22, 7.23, 7.25, 7.28
	8	8.7, 8.10A, 8.10B, 8.12A, 8.15, 8.16, 8,17B, 8.17C, 8.22, 8.23, 8.25, 8.28
	E1	E1.6, E1.9, E1.14, E1.15B, E1.20, E1. 21, E1.22, E1.23, E1.26
	E2	E2.6, E2.9, E2.14, E2.15B, E2.20, E2. 21, E2.22, E2.23, E2.26
	E3	E3.6, E3.9, E3.14, E3.15B, E3.20, E3. 21, E3.22, E3.23, E3.26
	E4	E4.6, E4.9, E4.14, E4.15B, E4.20, E4. 21, E4.22, E4.23, E4.26
Science	7	7.2B, 7.2D, 7.2E
	8	8.2B, 8.2D, 8.2E
	BIO	B.2E, B.4B, B.5C
Math	7	7.4D
	8	8.2C

Course	Level	CCSS
English	7	RI.7.1, RI.7.2, RI.7.3, W.7.2, W.7.3, W.7.4, W.7.7, SL.7.1, SL.7.2, RST.6-8.1, RST.6-8.2, RST.6-8.7, RST.6-8.9, RST.6-8.10
	8	RI.8.1, RI.8.2, RI.8.3, W.8.2, W.8.3, W.8.4, W.8.7, SL.8.1, RST.6-8.1, RST.6-8.2, RST.6-8.7, RST.6-8.9, RST.6-8.10
	9-10	RI.9-10.1, RI.9-10.2, W.9-10.2, W.9-10.3, W.9-10.4, W.9-10.7, SL.9-10.1, RST.9-10.1, RST.9-10.2, RST.9-10.7, RST.9-10.9, RST.9-10.10
	11-12	RI.11-12.1, RI.11-12.2, W.11-12.2, W.11-12.3, W.11-12.4, W.11-12.7, SL.11-12.1, RST.11-12.1, RST.11-12.2, RST.11-12.7, RST.11-12.9, RST.11-12.10
Math	7	7.RP.A.3
	8	8.EE.A.4

C. Plants are Alive

Course	Level	TEKS
English	7	7.1, 7.10, 7.16, 7.17, 7.17D, 7.28
	8	8.1, 8.10, 8.16, 8.17, 8.17D, 8.28
	E1	E1.9, E1.14, E1.15B, E1.15D, E1.26
	E2	E2.9, E2.14, E2.15B, E2.15D, E2.26
	E3	E3.9, E3.14, E3.15B, E3.15D, E3.26
	E4	E4.9, E4.14, E4.15B, E4.15D, E4.26
Science	7	7.2A, 7.2B, 7.2C, 7.2D, 7.2E,
	8	8.2A, 8.2B, 8.2C, 8.2D, 8.2E, 8.3D
	BIO	B.2E, B.2F, B.2G, B.2H
Math	7	7.1D
	8	8.1D

Course	Level	CCSS
English	7	W.7.2, W.7.3, W.7.4, SL.7.1, WHST.6-8.2, WHST.6-8.4, WHST.6-8.9, WHST.6-8.10
	8	W.8.2, W.8.3, W.8.4, SL.8.1, WHST.6-8.2, WHST.6-8.4, WHST.6-8.9, WHST.6-8.10
	9-10	W.9-10.2, W.9-10.3, W.9-10.4, SL.9-10.1, WHST.9-10.2, WHST.9-10.4, WHST.9-10.9, WHST.9-10.10
	11-12	W.11-12.2, W.11-12.3, W.11-12.4, SL.11-12.1, WHST.11-12.2, WHST.11-12.4, WHST.11-12.9, WHST.11-12.10
Math	7	MP6**
	8	

D. Communicating Using Social Media

Course	Level	TEKS
English	7	7.1, 7.7, 7.16, 7.17D, 7.22B, 7.23, 7.24, 7.25, 7.28
	8	8.1, 8.7, 8.16, 8.17D, 8.22B, 8.23, 8.24, 8.25, 8.28
	E1	E1.6, E1.14, E1.15D, E1.21, E1.22, E1.23, E1.26
	E2	E2.6, E2.14, E2.15D, E2.21, E2.22, E2.23, E2.26
	E3	E3.6, E3.14, E3.15D, E3.21, E3.22, E3.23, E3.26
	E4	E4.6, E4.14, E4.15D, E3.21, E4.22, E4.23, E4.26

Course	Level	CCSS
English	7	W.7.2, W.7.3, W.7.4, W.7.6, W.7.7, W.7.8, SL.7.1, SL.7.5
	8	W.8.2, W.8.3, W.8.4, W.8.6, W.8.7, W.8.8, SL.8.1, SL.8.5
	9-10	W.9-10.2, W.9-10.3, W.9-10.4, W.9-10.6, W.9-10.7, W.9-10.8, SL.9-10.1, SL.9-10.5
	11-12	W.11-12.2, W.11-12.3, W.11-12.4, W.11-12.6, W.11-12.7, W.11-12.8, SL.11-12.1, SL.11-12.5

E. Photography and Writing Contests

Course	Level	TEKS
English	7	7.7, 7.13A, 7.15, 7.16
	8	8.7, 8.13B, 8.15, 8.16,
	E1	E1.6, E1.12B, E1.14A
	E2	E2.6, E2.12B, E2.14A
	E3	E3.6, E3.12B, E3.14A
	E4	E4.6, E4.12B, E4.14A
Science	7	7.2
	8	8.2
	BIO	B.2

Course	Level	CCSS
English	7	W.7.3, W.7.4
	8	W.8.3, W.8.4
	9-10	W.9-10.3, W.9-10.4
	11-12	W.11-12.3, W.11-12.4

* Standard 1 from the TEKS is the same for all K-12 Mathematics Courses

** The Mathematical Process Standards are the same for all K-12 Mathematics Courses

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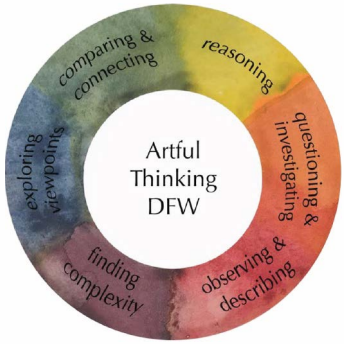

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