High School Biofabrication Storyline - Activity Sheet

Lesson 1 – Anchoring Phenomenon, Initial Modeling, & Driving Question Board
45 Minutes

This Lesson presents two potential videos that acquaint students with the life-changing circumstances that occur with organ loss. In the two scenarios, young girls (one famous and one quite young) describe how they managed the lost function of their kidneys. One uses dialysis, and the other receives a transplant to stay alive! Students watch one or both videos and consider "Kidneys, Need 'em or not?" Students may not fully understand their vital function in maintaining health or homeostasis. After students view the videos, they contribute are asked to model what they know about human kidney function, and with post-its, add in their questions or wonderings about kidneys and kidney disease.

Materials:
- Whiteboards or paper for student-generated models
- Post-it Notes with poster paper or use a technological tool like JamBoard to generate a "Driving Question Board." The DQB will be used to record student questions and wonderings about the videos and kidney function**.** Only one question or wondering should be posted on each post-it!
- A large enough screen for students to view the video(s) as a class or share the links for students to watch them independently/remotely.

Science Background: This anchoring phenomenon provides an opportunity for students to learn about the dilemma faced when an organ has failed. The focus is on the loss of kidneys; organs that are familiar to students. The kidneys are a component of the urinary system and help to eliminate waste, and they also work within the circulatory system to filter blood. This can be a great opening phenomenon for a unit focused on homeostasis, genetics, and/or the pluripotency of stem cells. We purposely streamlined this unit for high school teachers to implement and adjust it within their current curriculum, thus accomplishing a more complete storyline with additional phenomena to support the Science and Engineering Practices such as research in defining problems, designing investigations, analyzing data, and communicating outcomes.

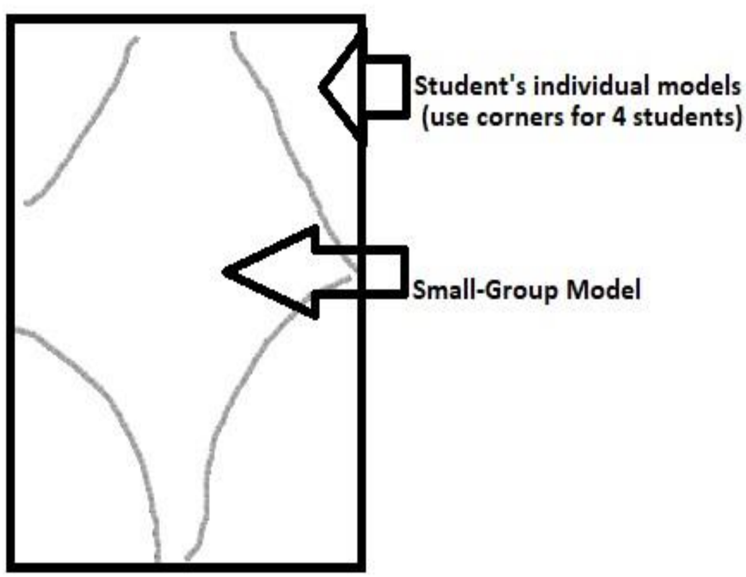
Vocabulary: Dialysis, Homeostasis

What Students Figure Out? Students usually know about kidneys and that they are part of the urinary system. The videos as an anchoring phenomenon motivate a variety of questions and wonderings, such as:

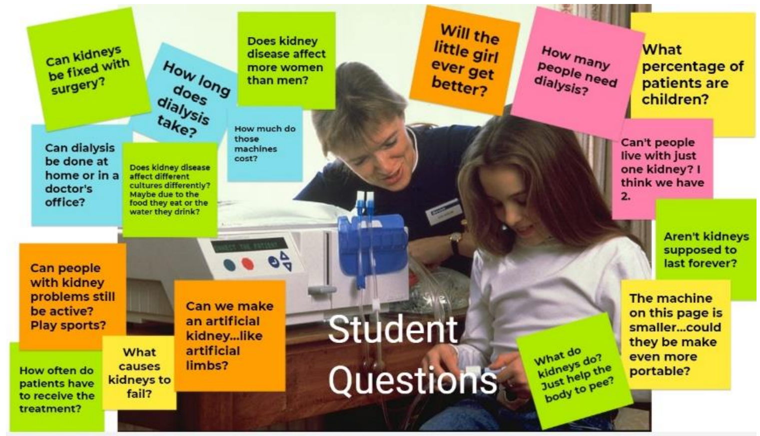
- Why do some people get kidney diseases while others do not?
- Is kidney disease hereditary?
- Can kidneys be repaired?
- What do kidneys have to do with blood?
- Can you live without kidneys?
- What is their role in the body?
- Do all animals have kidneys?
- Does the donation of a kidney hurt the donor?
- *Please add any additional questions students might wonder about?*

Differentiation: The initial modeling should encourage all students to draw how they think a kidney functions. This assists students who may not have the words to describe their thinking. In developing a small group model, students will need to discuss their thinking with their peers as they try to develop a small group consensus about kidney functioning. This provides opportunities for students to question and ask for clarification in a small group setting and can assist language learners.

Two phenomena are given but one might sufficiently motivate student thinking and questioning. The instructor can choose to use one video or both. The instructor should give students post-it notes to record their wonderings as they watch the videos or have students talk with their partners or in small groups about their questions as they develop models. Think-pair-share styled interactions assist ELL learners, students that need more thinking time, and encourage those who sometimes act too quickly to think more deeply.



Lesson Progression: The instructor might present the student question “Kidneys, Need ‘em or not?” to begin and presents the video(s). Prompt students to use their post-it notes for questions or wonderings as they watch the videos. Then, ask students to create a model that explains what they understand about how kidneys work in the human body. If a large whiteboard or sheet of paper is given to each group, students can make small drawings in the corners to begin getting their ideas out. Then the center part can be used to convene the groups thinking into a small group model that they agree upon.



The individual models provide opportunities for students to learn from each other and to further question their own or others' understanding. They also serve as a base for teachers to develop instructional activities (formative assessment). Students are encouraged to use their post-it notes to record additional questions or wonderings (one question per note). Encourage students to have at least two-three each, which can deepen the conversations and the learning. Using the term "wonderings" motivates students' curiosity at almost any age. It invites them to participate without judgment. It is important for all ideas to be shared and respected. This is again, encouraging students to go public with their thinking.

A Driving Question Board (DQB) is developed from the student questions. Students post their questions and wonderings publicly. They may find others have similar questions or that another group had questions they hadn't thought of. Some teachers might suggest categories for the questions, student groups might suggest categories before posting begins, or once posted, the notes can be reorganized into categories that need further investigation. By moving about a classroom and listening into conversations, the instructor can also interject possible categories from the conversations they overheard and guide categories towards planned areas for investigations. For example:

- I heard several groups debating how kidneys work and about their structure. So do we have questions in this area? About kidney structure & function?
- Another group was discussing a human body system, do we have any questions about the system or systems the kidney is connected to?

Teachers can also think aloud to encourage students' ideas and thinking. Here are potential questions we heard in our field tests.

- Both videos involve young people. Do older people also contract kidney disease?
- Are there patterns as to who gets kidney disease? Does it affect some countries more than others?
- Does a person's diet have anything to do with kidney disease?
- Can males also have kidney issues?
- What causes kidney failure?
- Could I develop kidney problems? How would I know? What are the symptoms?
- How do Doctors detect kidney issues?

Supporting Resources:

- Selena Gomez Kidney Story – video
- Diary of a Dialysis Kid - video

You can find many online videos about kidney disease and dialysis; students will also add in examples from their own families and friends. Also see links within the narrative.

Lesson 2 – How do kidneys help to maintain life?
45 Minutes-Lab investigation
45 Minutes - Adjusting small group models & building a class consensus model

This Lesson assists students in learning more about the kidneys' function in the body. The lab activity was slightly adapted from lab investigations normally used in General Biology courses at the high school level. This traditional lab is heavy with front-loaded information and direction. We suggest having students make the solution and then predict how they think the ingredients within the dialysis tubing will change. The intent of this investigation is to understand what dialysis and kidneys do on a broader scale. The activity becomes more meaningful when students realize the importance of how semipermeable membranes work in this process but also throughout the human body. A simulation of transfer across a semipermeable membrane (designed by NH students) assists students in "seeing" how this process works at the molecular level or teachers might choose a more physical representation of the dialysis process (see class simulation below). These activities share a partial model that further students' experience with structure and function

Materials: Lab Instruction Sheet for Students – these traditional labs can be heavy with vocab and front-loaded info. Encourage your students with simulations that they can maneuver and then give them the basic recipe and have them predict how the components will change.

Osmosis and Inquiry-based Kidney Simulation
https://www.carolina.com/teacher-resources/Interactive/developing-and-analyzing-urine-samples-as-a-model-of-kidney-function/tr41615.tr

Alt: Videos Illustrating Similar Osmosis & Diffusion using Dialysis Tubing
https://www.youtube.com/watch?v=Ji1wetFngLo
https://www.youtube.com/watch?v=Xxp6oponwkg

Lecture/Demonstration/Simulation of Kidney Function
https://www.biointeractive.org/classroom-resources/kidney-function

Examples of a Class Simulation:
https://thescienceteacher.co.uk/wp-content/uploads/2018/08/Modelling-kidney-function.pptx

Diffusion - simulation: ttps://phet.colorado.edu/en/simulations/membrane-channels/activities

NH Students Simulator: https://eaglesoftworks.github.io/Diffusion/

Science Background: The functions of semipermeable membranes are important to many cellular and organ interactions. Through a focus on the kidney as just one example, structure & function as a cross-cutting concept can be further emphasized. Additionally, synthetic semipermeable membranes are used in desalination and other water filtration needs. Students may raise these as analogous to the dialysis tubing or these examples could be used as assessments of student understanding. Cells and cellular organelles are surrounded by semipermeable membranes.

Vocabulary: Dialysis, Homeostasis, Dialysate, Active/Passive Transport, Semi-permeable membrane, Osmosis, Diffusion

What Students Figure Out? The activities provide a broad understanding of how kidneys' membranes "filter" wastes from the body. One student suggested that "at airports, TSA agents are like semipermeable membranes; only allowing smaller carry-on bags and sending back the larger ones!" These are valuable analogies that demonstrate student understanding and could be used in assessments. At the general biology level, an understanding of body systems and organ functions is foundational for more advanced life science studies.

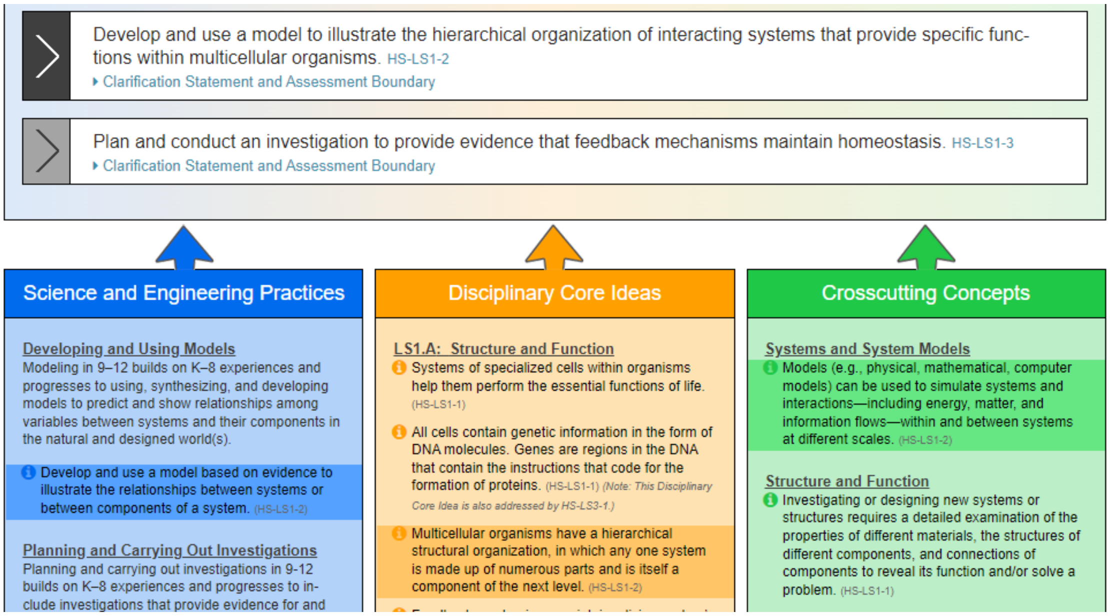
Differentiation: The instructor should make post-it notes available to students as further ideas, wonderings, or questions are likely to surface in this activity. Students should be working in small teams with onsite investigations and/or sharing their take-aways with video simulations in a remote setting. Many teachers utilize rotating roles of leadership, gathering supplies, note-taking, etc. with student lab teams to support student opportunities with experiences. The smaller teams also provide a richer class experience as different teams often raise a larger variety of ideas or inquiries. Their ideas surface as they improve their initial models and share them in a gallery walk.

Lesson Progression: Small teams of students dig deeper into how kidneys help to maintain life with simulation apps and dialysis tubing investigations. Students use the experiences to add more detail or revise their small group models of how kidneys work in the body. Students might also further research the structure of kidneys, but our focus on organs and loss (beginning with kidneys) encourages the following:

- Specialized cells or tissues assist organisms with essential functions that maintain life; getting rid of waste and retaining essential components.
- Kidneys are just one part of the urinary system, and work with other components at various levels to maintain life.
- Multiple systems interact with feedback mechanisms to maintain a living system, for example kidneys filtering blood (circulatory system) and eliminating wastes through the urinary system.

The Performance Expectation states:

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [HS-LS1-2]



The small groups of students are asked to refine their models with these experiences. To promote additional systems, the facilitator might ask the groups to consider the role of kidneys in living systems and what other organs or systems contribute to the maintenance of the human body.

Students display their refined small group models in a Scientist Circle for other groups to review, question, and possibly use post-it's to add questions or wondering to the DQB. This second viewing provides an opportunity for students to see model components and descriptions that other groups used to communicate their understanding. The communication of scientific ideas and understanding can take many forms and students learn about effective communication strategies and how other groups may have incorporated other ideas, systems, or interactions with their models. You can expect some students will have drawings as models, while others use arrows and words to describe how the model functions.

From this, the teacher or a student could lead the building of a class consensus model. If this is the first-time students are modeling and working on a class consensus model, the teacher plays an important role in asking for the evidence that supports each part or interaction added to the consensus model. The facilitator is also responsible for guiding a productive discussion that exemplifies respect for others' ideas and rationale. It is the evidence presented that determines whether the “part or idea” should be part of the class model. Students may disagree with one another, and arguments should be based on evidence. This is where the establishment of discussion norms that command respect, equity, and use of evidence are practiced. Discussions can be messy as students work out disagreements and will require time. However, the debates in the Scientist Circle mimics the peer review process of science and demonstrates how credible theories or solutions to problems are developed and critiqued. These are valuable, interpersonal skills that will assist students in any career pathway they choose.

Assessment: Why is a urine sample an important part of an annual physical?

This might be done as a homework assignment or an exit card to assess individual student understanding of analyzing a waste product to assess health. Teachers might ask students to explicitly to include their understanding of kidneys’ function and importance in maintaining life. Students could also use a model to communicate their understanding.

Supporting Resources:

NIH National Institute of Diabetes and Digestive and Kidney Diseases

100 YEARS Cleveland Clinic

MAYO CLINIC

LS1: From Molecules to Organisms: Structures and Processes			
LS1.A: Structure and Function			
Primary School (K-2)	**Elementary School (3-5)**	**Middle School (6-8)**	**High School (9-12)**
All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow.	Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.	All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.	Systems of specialized cells within organisms help them perform the essential functions of life. All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Lesson 3 – Are transplants the best solution?
45 Minutes or Homework Activity

This Lesson: The student question for this activity can be adapted to be in better alignment with your students' questions on the DQB. The lesson encourages a focus on the issues surrounding organ transplants. There are numerous videos, websites, and articles; we have shared just a few. Students may also contribute personal experiences with a family member or friend. Student choice is a powerful motivator, therefore, providing the student question, asking students to weigh in, and encouraging students to gather evidence to support their response makes a homework assignment more meaningful!

Materials:

- Initial Video: Meet Blake**: https://serpmedia.org/scigen/l6.6a.html**
- Web access for videos and/or printed articles, such as:
  - Waitlists & Transplants
    - https://www.kidney.org/atoz/content/transplant-waitlist
    - https://www.kidney.org/atoz/content/Antibodies-and-Transplantation

- Concerns with rejection
    - Immunosuppressants
      - https://www.kidney.org/atoz/content/immuno
      - https://transplantliving.org/after-the-transplant/preventing-rejection/side-effects/
      - Abstract: Effect of immunosuppressive agents on long-term survival of renal transplant recipients: focus on the cardiovascular risk.
        Boots JM1, Christiaans MH, van Hooff JP. (2004)

      - https://kidshealth.org/en/teens/kidney-transplant.html
      - https://www.urmc.rochester.edu/MediaLibraries/URMCMedia/life-sciences-learning-center/documents/TEACHERRejection7-23-09.pdf

- Students could interview a family member or friend who is struggling with the loss of an organ.

Science Background: Multiple organs can be considered here to promote student thinking about other organs and systems necessary for maintaining life. The "Meet Blake" video above is about a heart transplant.

Vocabulary: Homeostasis, Antibodies, Antigen, Immunosuppressants, chronic vs acute rejection.

What Students Figure Out? Students figure out that gaining access to a replacement organ is difficult. They also learn that transplanted organs require continued monitoring and a variety of other concerns to avoid rejection. Difficulty in procuring organs (waitlists), organ viability, and immunity suppression, make recipients subject to many other conditions. We may call them side effects, but they can carry major impacts and ongoing issues!

Differentiation: Multimedia approaches assist students with reading difficulties and subtitles can assist English Language Learners. Too much, can be too much! So we recommend either a jigsaw approach for students to decipher content together, or asking students to weigh in publicly and then support their view with evidence they gather.

Lesson Progression: The “Meet Blake” video provides another look at a successful transplant, yet it is only a partial story. The student question asks, “Is a transplant better than dialysis?” Students are asked to weigh in publicly whether they think transplants are better than a mechanical device that performs the organ’s functions. Students must then research and use evidence to support their view. Students can work in teams during a class or individually as a homework assignment. They can use the suggested resources and research additional or more current articles.

This could also be set up like a jigsaw! To set up a jigsaw activity, decide which of the articles or videos might work best for your students. There are updated articles almost every day, consider doing your own quick search or building a search for relevant and credible articles into a student assignment. Inviting your students as partners in learning offers practice with research skills and empowers them (be prepared to help them narrow their discoveries). Divide up the class into 4-6 small teams of students, so that each team will dig into one website, article, or video and make note of the 3-5 most important learnings from that resource. That team should be given time to discuss what they think everyone else should know about that resource. Students then split back up to their original small groups to discuss the important issues found within each resource.

Students can present their arguments in teams or as a whole-class discussion. This provides opportunities to question sources and reinforce norms for productive discussions. Students will learn that many organs have similar rejection or viability concerns and that some are more critical than others. As students share their findings and evidence to support their views, consider using this Final Rule Criteria chart as a wrap-up activity. The students’ brief explanations will help you to design follow-up activities as they may have additional questions or misunderstandings. The criteria not selected, will also raise concerns about what is fair and equitable in our society. *The Final Rule Criteria* applies to all transplanted organs which might help students understand the complexity of using existing organs for transplant in the final challenge.

This activity will likely answer some of their original questions on the driving question board about transplanting organs. Add the learning information to a row on the Summary Chart to build their understanding of organ loss and potential solutions. This activity also sets students up for additional organ inquiries in the culminating argument challenge.

Supporting Resources: See the example Summary Board.

Summary Board

What did we do?	What did we observe?	What did we figure out?	What additional questions do we have?
Watched videos about girls with kidney disease	Dialysis has to be done consistently and transplanted organs need to be matched closely for them to work successfully.	There are two kidneys in humans, but you only need one working kidney to survive. Dialysis or a transplant can help you to live. Dialysis takes a lot of time.	Are females most likely to get kidney disease? How long does a transplanted kidney last? How much does a transplant cost?
Developed a Model of how kidneys function in the human body	All models showed the kidney contributing to urine and eliminating waste from the body.	Kidneys are part of the urinary system in humans	How does it get the waste from the whole body? How does a kidney know what is waste and what should be left in the body?
Dialysis tubing experiment, and interactive Osmosis Simulation. We adjusted our models to include a semi-permeable membrane and the interaction of circulatory and urinary systems.	The dialysis tubing has really small holes in it and only allows small substances to pass through while retaining larger particles.	The kidneys can filter blood to get cellular wastes and pass that waste into the urine. The kidneys interact with both the urinary and circulatory systems in the body. They regulate waste and clean the blood for humans to survive.	Why can’t the kidney be fixed? Do cells also have semipermeable membranes so they can stay together but get the garbage out?

Lesson 4

Why can't we just make our own new organs?

2 - 45 minute sessions

This Lesson: Personalized medicine is growing by leaps and bounds. Almost daily one hears about cancer treatments that are designed specifically to reduce a specific tumor in one person. The ability of researchers to understand the characteristics of a condition and then use that understanding to design treatments has grown significantly. Many believe we are in "The Biology Century" where incredible solutions to long-experienced illnesses and diseases will take place!

The middle-level BioFab storyline breaks ground on regenerative medicine with the Axolotl Salamander's ability to grow new limbs, or a tail. That unit discusses the various types of cells that must be organized into tissues and bone, etc. for limb regeneration. This follows with the cutting-edge work of advancing cellular therapies with replacement organs for humans. Although we have not yet achieved the growth of personalized organs, the research is advancing daily.

In this lesson we offer example resources and web-based activities that assist in student understanding and how scientists work in research and development. The teacher can choose sample resources in response to the Driving Questions students have posted and direct student teams into discovering the various types of cells present in different organs. This may be part of the curriculum already if students are diving deeper into stem cell pluripotency. Better yet, let students do the searching for credible resources! When they find resources they are excited about, it motivates additional questions, and they want to learn more. "It's easy to steer a moving ship" so let their excitement help you to dig deeper into concepts.

Materials: Video and web-based articles surrounding this topic. Again, the currency of the resources selected will depend on the class, time and teacher guidance. We offer a few articles and videos that assist and show how cutting-edge scientists work in research and development.

From our teacher reviews: *"To consider the concept of decellularization and recellularization it's important for students to understand that an organ is made up of multiple tissues and the cells that make up those tissues are different from the cells in another tissue. Pulling all the cells apart and then having them coalesce back together so that they organized into tissues which then organize in a way to make the final organ work is a very high level but important process."*

This concept is addressed in a broader way through the Middle School BioFab Lesson on regenerating limbs, where students consider all of the different materials needed. However, if students have not considered the different types of cells that make up organs, the concept of STEM cells and their potential to differentiate into different cell lines (pluripotency), this is another place where a partial model of STEM cell differentiation would be helpful. Consider these resources to enhance student understanding and encourage your students to frame more questions!

How cells become specialized! (video intro)

HHMI BioInteractive Lesson: Tissue Regeneration in Animals NGSS (2013) HS-LS1.A, HS-LS1.B This short lesson in regeneration can be used as a remote activity or homework prior to engaging students in the potential for organ regeneration in humans.

National Geographic documentary: How to Make a Heart Beat. Intro: 3:28 mins.
Full Episode 11: National Geographic explores the latest science that may be on the verge of producing a limitless supply of replacement body parts.

Pig Kidneys Transplanted to Human in Milestone Experiment: Experts predict that such nonhuman-to-human "xenotransplants" may become a viable option within the next decade

[In the lab with scientist Doris Taylor, Ph.D., and “ghost hearts”] In this article, the regenerative medicine and cell therapy pioneer shares her latest breakthroughs and the future of mending hearts at the Texas Heart Institute.

[Can we grow a personalized human heart?]

Can we grow a personalized human heart?

Dr. Doris Taylor, who directed regenerative medicine research at Texas Heart Institute in Houston until 2020, shows off groundbreaking technology in which she took a ghost-like shell of a pig's heart, and infused it with beating human stem cells. Her talk took place on stage at the 2022 Life Itself conference, a health and wellness event presented in partnership with CNN. Source: CNN

There are also multiple video resources in the BioFab-NGSS Scientist Profiles that speak to aligned industries and the scientists’ journeys into those career paths.

- BioFab/NGSS Scientist Profile - Communication
- BioFab/NGSS Scientist Profile - Asking Questions and Defining Problems
- BioFab/NGSS Scientist Profile - Constructing Explanations & Designing Solutions
- BioFab\NGSS Scientist Profile - Arguing From Evidence
- BioFab/NGSS Scientist Profile - Using Mathematics & Computational Thinking

Our teacher review groups commented that:

“These high-quality videos provide students with an introduction to the culture and practice of science.”

> “The students can see themselves in the career pathways these diverse scientists share. I am so happy to see women in powerful roles and that they have taken very different academic experiences to get there!”
>
> “The Science and Engineering Practices have not been thoroughly implemented in our school. It’s through these video examples that we see how modeling, data analysis, and communication skills are so important to the futures of our students.”

Science Background: Additional organs and systems contributing to maintaining homeostasis can and should be considered here. This promotes student thinking about the interactions of human body systems that work together in maintaining life. There are a couple of major discoveries that focus on the decellularization and recellularization of organs. Several years ago, a calf heart was decellularized and recellularized with human cells. That heart was “jump-started” and continued to beat in the laboratory for more than 60 days! A heart this size would be capable of supporting a child. Recently, a pig’s kidneys were decellularized and recellularized with human cells, and implanted in a person who was clinically dead, but still on life support with the family’s permission (Thompson, 2022). Those kidneys continued to function as though they were the patient’s kidneys. These developments move us closer to the replacement of organs in repairing human systems.

Vocabulary: Homeostasis, decellurization/recellularization, Ghost organs, STEM cells, pluripotency, BioPrinting

What Students Figure Out? Students discover the variety of cell types present in vital organs like the kidneys, heart, lungs, etc. and learn about the advances modern science is making in regenerating cells. This activity acquaints students with cutting-edge advancements in a variety of human system areas and sets the stage for considering questions about organ availability, why we aren’t yet capable of producing organs, is organ regeneration an ethical consideration, how important are the various organs, and where is the science today? Students begin to figure out that these are complex problems that require complex thinking. Learning about the various organ research areas also sets up the class for research into other organs beyond kidneys with the final problem-solving challenge.

Differentiation: Multimedia approaches assist students with reading difficulties and those with subtitles assist English Language Learners. The small and large group discussions also help ELL students to learn and practice using a new language. Productive Talk Moves assist all students in civil discourse, respecting others’ ideas, and provides multiple opportunities for students to clarify their understanding and improve communication skills. All students learn by talking!

Lesson Progression: There are several ways this lesson can be used in developing students' understanding of advances in regenerative medicine and the methods scientists use in problem-solving. The leading student question is focused on a connection to our middle-level unit phenomenon, where the Axolotl salamander can regrow its limbs and tail. If students have not experienced this before, then the HHMI BioInteractive Lesson on Tissue Regeneration in Animals (50 minutes) will assist their curiosity. This could be given as a homework assignment or an in-class activity. If possible, begin with questions from the Driving Question Board to set the stage for student ownership of this activity. Students might have posted questions such as:

- Can humans recover from kidney disease? The teacher might add, “Are other animals capable of repairing themselves? This might raise students’ interests as some might have seen a pet salamander regrow a limb or tail.
- Students might share that their grandfather had his heart fixed, why can’t we just fix the kidneys we have? Again, the teacher might say, “I wonder which human organs are fixable, or is it a matter of the extent of the damage to the organ?”
- Another might have posted that they heard of STEM cells that can be turned into any kind of tissue, so can they be used to fix kidneys? A teacher prompt wondering about what students know about STEM cells, and how they know it might assist a follow-up lesson.

This is likely to generate even more interest among students in the capacity of humans to regenerate their tissues and organs. Use that interest to encourage students to share their ideas, further wonderings, and questions in their small groups. Students could continue to add additional questions to the DQB, which assists teachers in connecting students’ interests with learning goals.

Again, student choice empowers students in a classroom. At this point, team interests with different organs might be emerging, and that might direct resources to particular groups. The additional articles and short videos can be used in an open exploration to help students answer some of their own questions. The Pig Kidney Transplant and Ghost Hearts articles have more difficult reading levels, yet they carry a human story that students relate to, even if “they don’t get” the more technical ideas presented. The *How to make a Heart Beat* introductory video and the Scientist profile videos are all between 3 and 8 minutes; which allows the small groups of students to choose 3-4 of them within a class period. The facilitator of learning might ask each small team to choose one of the articles and 2 of the videos. This will likely provide the entire class with a few interesting perspectives about organ loss and how the emerging industry is tackling some of the challenges facing human diseases. Asking students to decipher 3-5 important points they discover in each article or video, puts them in charge of making judgments and decisions. Again, use their questions as much as possible to direct their attention to issues of homeostasis, how researchers work at solving these problems, how data can be powerful, and any ethical concerns along the way.

Through a whole class discussion, have each of the small groups share the types of cells needed for organs. Working again towards consensus, “Can we figure out what are some of the major challenges facing organ regeneration or manufacturing? How are scientists working to achieve and meet these challenges?”

Directing students to reflect on how scientists work, can validate the continued work they will do using the Science and Engineering Practices (SEPs). Taking this one step further, you might ask if these skills are also used in other careers? Please see the skills chart we created by using responses from NH business and industry surveys and recommendation from leading business magazines and employment apps. We saw how the skills employers are seeking align well with the NGSS SEPs. We have used this to help others see the importance of the “practices” for any career field.

Add the students’ discoveries to the Summary Chart and be sure to use them to answer some of the original questions from the DQB. As possible have students take their question from the DQB and place it on the Summary Chart. The collective figuring out of student questions drives partnerships in learning between student teams and the teacher. This empowers students and helps them to develop their own problem-solving skills, which should be practiced throughout the academic year.

Lesson 5 - If we had $100 million dollars, which area of regenerative medicine should we invest in, and why?

2-3 Class Periods of 50 minutes

This Lesson: This final challenge reflects back to the original phenomenon of kidney loss, the things we figured out through the various activities about organ's functions in support of life and options to survive when they fail (as recorded on the Summary Chart), and now expand our thinking to consider how to best invest in research, is similar to an engineering problem. It involves a systematic investigation of the problem, analysis of the variables that should be considered, and using that analysis to drive the best design for a solution. It is a hypothetical problem, but one where student groups can choose to investigate different organs or areas of regenerative research. In building their arguments for where the research dollars are best spent, students should be considering the current science breakthroughs, humanity needs, the ethics of who benefits, and how to best present their argument to potential investors.

Materials: Web access, data analysis software (Excel), and presentation software and/or physical poster materials. Mostly web-based resources such as recipient needs and availability of organs for transplants. Realtime organ donor websites assist with a more personal concern and engagement of students.

Science Background: Multiple organs can be considered here and can promote student thinking about the various human systems that support life. Students might research the need and availability of organs, such as kidney, liver, heart, lungs, pancreas, eyes, brain/nerves, and intestines. Students should work in their small groups with ideally an area that the team chooses. Teacher facilitators should push for evidence-based arguments and encourage students to use quantitative data within their argument. There is current data about human needs, availability of organs, probability of successful transplants, resiliency of transplants, and medicals costs readily available. They might also focus on the indicators of successful regenerated organs in various trials which can assist teachers with cutting-edge research, long after our project.

The ethics pieces can be hard to consider, but if a diseased organ tends to occur more frequently in certain genders, age groups, or ethnic populations, who gets to decide on the area of most importance, is an ethical decision. As students present their arguments, facilitators should consider the use of "scientific sentence stems" that students can use to voice their ideas, questions, and rebuttals. For example, "I don't understand the evidence you have for ___________, could you please explain it further?" Or, "I disagree with your data, as I found ________________." these types of stems help students to communicate their thinking without personal attacks. Also recall the activity where students tried to determine the characteristics used to decide organ recipients in Lesson 3. Read more about the use of these stems here!

Vocabulary: This will vary but be considerate of the intended big ideas considered by the content standards. Student presentations may involve repeating terms that deserve consideration by the entire class.

What Students Figure Out? Students figure out that opinions can be easy to state, but supporting a good argument is hard, and that getting funding to solve human disease is important and harder. They will utilize their science and engineering skills in the process and learn purposely about the various organs and systems that work together to maintain life. They may find it difficult to decide which argument is the best. Understanding the evidence is just one part, communicating that evidence to others is also a significant challenge.

Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-LS1-3)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)

Students quickly learn about the complexity of the problems, the human impacts, population needs, ethical concerns for who might get the organs, etc. Along the way, they are collaborating with peers on their research and considering how to communicate outcomes to different audiences.

This challenge project is engaging for students and aligns well with ELA persuasive writing:

CCSS.ELA-LITERACY.W.9-10.1

Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

*Also, as many sophomores are also getting their license to drive, they might consider why they might or might not become an organ donor. This could be used as an exit card or reflective exercise with high school students.

Engaging in Argument from Evidence

Argumentation is the process by which explanations and solutions are reached.

High School (9-12)

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
- Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

The Engaging in Argument Practice is needed in almost any career or profession. Be it presenting a business plan for a bank loan, or negotiating a raise with your boss, strong argument provides students with agency! It will take practice and multiple experiences to do this well. Here is where students need to do the heavy lifting in building a response, but teachers will need to coach them with good questions and perhaps examples. We do know from experience, that as students present their arguments, everyone is learning. They can practice healthy skepticism and how to best challenge other's work without personally attacking their classmates. Getting to that point is the teacher challenge!

- Have you established class norms for discussion?
- Have students had the opportunity to practice engaging with their peers when they disagree?
- Do they understand how "I respectfully disagree with __________ because ________________________!" is useful from both sides of the argument?
- Do they know how to find credible sources and validate them?

*Be sure to ask your media center facilitator or English teachers for advice on students' abilities for research and debate structures.

Differentiation: As students work collaboratively to build their arguments for funding, they are researching about the organ or regenerative process they chose. They are discussing the validity and importance of their findings. They may decide to use software to assist mathematical comparisons and charts or to build them manually. At each turn, the social interactions and decision-making present a variety of inputs to help students understand their work. These approaches assist students with a variety of learning needs. The facilitator's role is to ensure the interactions are productive. This can require a step back for the teams to consider: who is doing the most talking, who is doing the research, and who might need more of an invitation to participate. These self-awareness pauses are healthy for any group dynamic, including teachers with students. *Recall that the one doing the most talking, is likely learning the most too!*

Lesson Progression: This challenge is a project-based learning activity. The challenge involves choice, reflection on previous activities and what was figured out, and group decisions about leadership and roles for each group member. The experience and autonomy of your students matters a lot in terms of the scaffolding you might need to include. As mentioned in previous lessons, the recording of what was figured out in the Summary Chart, can go a long way to assist student thinking and productivity. The Summary Chart should be prominently displayed for all groups to have as a visual aid. You might want to establish a process model or flowchart that the teams construct together, beginning with asking questions and unpacking the problem. Then moving to investigative work (research) and analyzing data and outcomes. They will need to consider their audience and how to best communicate their argument for the $100 million prize of funding!

Student teams embark on their work and the teacher facilitates productive work and discussion by interacting with each small group. The teacher might also connect with the school's media specialist to assist students with online search tools and finding valid and reliable resources. As a facilitator try to avoid answering questions but instead think out loud about your own wonderings as guidance. If possible, invite an industry-related scientist, engineer, or parent to listen in on the presentations. When students realize there's an expert in the audience, they often choose to make their work even better.

Have students research the need and availability of a variety of organs, such as kidney, liver, heart, lungs, pancreas, eyes, and intestines. Students can work in teams with an assigned organ or one that is chosen randomly. Facilitators should push for quantitative data in their arguments. Current data is available for variables such as human needs, availability of organs, probability of successful transplants, resiliency of transplants in transit, needs for anti-rejection drug therapies, costs, etc. They might also focus on recent successes with transplants.

With poster presentations or through a debate, students should have the opportunity to present their arguments with their peers. Students will learn from each other about different organs as components of systems, current work in regenerative science and engineering, and a variety of ways students can present their work. A final assessment might ask students individually to choose the most successful argument for the $100 million in research funding and why it was successful. Peer critique as in scientific peer reviews are learning experiences for all involved.

Supporting Resources:

Kidney:

Waitlists & Transplants

https://www.kidney.org/atoz/content/transplant-waitlist

https://www.kidney.org/atoz/content/Antibodies-and-Transplantation

Concerns with anti-rejection drugs.

https://www.kidney.org/atoz/content/immuno

https://transplantliving.org/after-the-transplant/preventing-rejection/side-effects/

How We Are Growing Organs In The Lab? | Dr. Jim Wells | TEDxCincinnati

Similar resources exist for other organs or system components.

Conclusion: Regenerative medicine and bioengineering are rapidly evolving. The lessons above encourage students to consider the cutting-edge discoveries being made and how they might someday transform the treatment of disease and degeneration. This project-based unit serves to differentiate learning opportunities for students, and as an amplifier to encourage student learning beyond the kidney. Bringing in cutting-edge science provides opportunities to ask questions they have and encourages the definition of real problems in need of solutions. At the high school level, this encourages students to research, evaluate available information, and consider how their own personal lives may or may not be affected by these new technologies.

Teachers may use all or just parts of this high school unit. They may encourage teams to explore organ structures and the variety of cells present…muscle, scaffolding materials, blood vessels, etc. Blending inquiry with student research will also encourage currency in the resources used. This area is impacted daily with developments made by scientists and engineers, which may inspire students' career trajectories as all disciplines are needed to advance research and development of organ therapies.

"*This activity gives the students the opportunity to investigate a regenerative process of their own and to develop an argument to fund its development. It's relatively open-ended and allows the students choice*." ~Chris Harper