Stronger, Better, Faster, Smarter
Exploring the Muscular-Skeletal System through the Lens of Biotechnology
Terri Eros

Introduction

I work in a middle school which serves approximately 850 students from 2 distinct backgrounds. Roughly 65% of the students come from middle to upper middle class, largely 2 parent families with at least one parent being college educated. The other 35% come from a lower socio economic background, often single parent, often with limited education. Two additional challenges are that a subset of these students have limited English proficiency and we also do inclusion for a group of students who have severe physical, intellectual and/or behavior impairments.
For this curriculum unit, I will focus on my 6th grade Science classes. It will be incorporated in the present SEPUP (The Science Education for Public Understanding Program) unit Studying People Scientifically/Bodyworks.

Rationale

In studying human body systems, students look at the structures and functions of the respiratory system, digestive system, and cardiovascular system. Special attention is given to the liver, the lungs and the heart. Overall it is a unit that students enjoy doing. There are a number of hands on activities starting with making life size drawings of internal organs and using clay to make a 3D model in a plastic form. As written, there is a student investigation where they use chemical indicators to determine that exhaled breath has a greater concentration of carbon dioxide than room air. There is also a lab where students investigate the role of mechanical digestion and surface area. Having said that, why do I think that it needs to be supplemented? The answer is that it doesn't meet the Next Generation Science Standards. A quick glance at the question bank shows that too much of the focus is on memorizing content and that content doesn't even match the disciplinary core ideas for middle school. By shifting the focus to biotechnology, my plan is to use more of the engineering aspect of science.

This summer, while attending a different seminar at the Yale National Institute, I had the opportunity to hear Dr. W. Mark Saltzman talk a little about global health issues. As part of that, he described some of the advances in medicine and how they affected both the quality and longevity of different populations. His talk inspired me to not only change the lens through which I teach the human body but to do it in such a way that it might challenge my students to someday be part of the problem solvers.

Objectives

My goal is to have students both explore existing solutions as they apply to fixing muscular skeletal issues and engineer their own. One of the NGSS middle school standards focuses on the role of the brain and nervous system as it relates to controlling immediate behavior and/or memories. In the current unit, students are supposed to investigate touch sensitivity as an example of human variability. It is an activity that many middle school teachers, including myself, skip as it involves students poking each other with little connection made to the nervous system. By incorporating biotechnology, I want students to see how complex the interactions are between senses and responses. We usually take the interaction of nerves, muscles and bones for granted, giving no thought to movement until something goes wrong. Rather than have students focus on labelling the bones of the skeleton, our emphasis will be on the different types of joints. Students will incorporate several of the common core language arts standards as they read about prosthetics through history ending with a debate of form compared to function. The design of a running prosthetic foot looks nothing like a real foot but it meets the physical requirements of flexibility, stability and weight bearing needed to complete the action. As a culminating stem activity, students will create their own "hand". If it can be arranged, I would also like to bring in one or two guest speakers. Right now, I'm thinking about someone from the Nemours Children's Hospital as it is the right age group and also someone from the prosthetics group in Newark. The latter offers a unique perspective as the founder got into the field having needed his own prosthetic as a young man. Depending on resources, I would like to look at the role that 3D printing can play. In 2015, a nine year old boy in Claymont, using library resources, printed himself a new prosthetic hand. For my honors' section, I would like students to do an independent research project on an existing adaptive technology or medical intervention. As an enrichment, I could encourage my students to investigate the other biotech solutions for problems in other systems such as the heart lung machines or drug delivery systems using my own research sites as a starting point.

Research

Like Mark Miodownik, the author of Stuff Matters, I too grew up watching The Six Million Dollar Man, a show built around the premise that not only could medicine save a life but it could make a man "Better, Stronger, Faster". Through a secret government project, Steve Austin, was given a bionic right arm, two bionic legs and a bionic eye which enabled him to see further, run faster, and lift heavier objects. With his newly acquired abilities, he became a champion of justice. The show was so successful that it spawned "The Bionic Woman". Like her male counterpart, and former boyfriend Steve Austin, Jamie Summers also received bionic legs, a bionic arm, but to add variety, a bionic ear after a near fatal accident. At the time, that level of prosthetics was as much science fiction as the tricorders on Star Trek, but where do we stand today, almost 40 years later?

The year 2016 saw a breakthrough when a paralyzed man, Nathan Copeland, demonstrated that he had touch sensation in his brain from a robotic hand.[1] Although there have been several other instances of one way communication from the brain to the limb, this was the most successful attempt in the other direction. It is the latest of engineering feats to replace body parts lost to injury, disease, and in some cases, missing from birth. The use of prosthetics dates back thousands of years. In Egypt, the nearly 3,000 year old mummified remains of a noblewoman revealed that she had an artificial toe made of wood and leather. [2] Not only did the prosthetic big toe allow her to have a more normal gait, since 40% of the weight of walking is on that area, but it allowed her to continue wearing the type of sandal associated with her station in life. In short, her replacement part was both functional and aesthetically pleasing.

Throughout history, military injuries have produced the greatest need for prosthetics. An early recorded case is the Roman General Marcus Sergius. In the second Punic war, he lost his right hand. Not to be deterred, he had a prosthetic made of iron, fashioned so that it could hold his shield and trained himself to use his left hand for his knife. He went on to have a long military career, including being captured by and escaping from Hannibal twice. [3]

The Dark Ages 476-1000 saw little progress in the field of artificial body parts other than the hand hook and the peg leg. Prosthetics, like a knight's false leg, were there more for appearance than function.

Through most of the middle ages, prosthetics did not improve dramatically though there were a few innovators. Ambroise Pare, a French barber surgeon, reintroduced the idea of using ligature, rather than cauterization, to stop bleeding in patients being amputated. Another practice he adopted from the Romans was to treat the wounds with a mixture of egg yolk, oil of roses and turpentine rather than the boiling oil cauterization. [4] Pare also created several working prosthetics. His developed a mechanical hand capable of flexing and grasping which was operated by catches and springs. He also set the standard for an above the knee prosthetic that consisted of a kneeling peg and a prosthetic foot. It used a suspension harness, had a locking knee and, a fixed equines position for the foot (i.e., limited ability to move toward the ankle). [5]
However, it was a colleague of his, Lorrain, a French locksmith, to suggest a change in materials. Previously, iron, steel, copper and wood had been the usual substances. Lorrain instead used leather, paper and glue for the construction as opposed to iron, thus making

the new appendage both lighter and more easily styled to resemble its biological counterpart.

The end of the 17th century saw Pieter Verduyn invent the first non-locking below the knee prosthesis in 1696. In 1800, James Potts, an Englishman, improved the design by adding an articulated foot that was controlled by tendons that ran from the knee to the ankle. He used a wide variety of materials including a wooden shank and socket, steel knee joint and catgut for the tendons. Potts' invention was extremely popular. Originally known as the "Anglesey Leg" after the same named Marquess who lost his original leg in the Battle of Waterloo, it was brought to the United States in 1839 by William Selpho, who sold it under his own name. The Selpho leg was further improved in 1846, by Benjamin Palmer, whose main focus was on improving the aesthetics. He added an anterior spring which helped better simulate natural movement, concealed the tendons, and added an exterior layer that hid the gaps between the components and the working mechanism. In 1863, Dubois Parmlee was given credit for his use of a suction socket, polycentric knee and multi-articulated foot. Sometimes ideas came faster than the technology to make them happen. In 1868, Gustav Hermann had an idea to replace the steel components with aluminum to make limbs lighter and more usable but it wasn't until 1912 that one would be constructed by Charles Desoutter, an engineer, for his brother Marcel, who lost his leg in an airplane accident. [6]

The First World War created the need for medical solutions at an unprecedented rate. The field of plastic surgery grew as soldiers sought treatments for disfigurements so severe as to make them social outcasts. Even greater was the need for replacement body parts. Before "The Great War", severely injured soldiers often died as a result of gangrene and infection. Advances in surgery and antiseptics saved lives but resulted in a staggering percentages of amputees. On the German side, over 67,000 amputees were reported. According to the U.S. Department of Veterans Affairs, the United States numbers were significantly smaller, as they reported slightly more than 4,000 amputations performed on U.S. service personnel. The two countries would handle their amputees in two different ways. In the US, the Artificial Limb laboratory was established at Walter Reed Hospital in 1917. Its mission was to give every amputee a "modern limb" enabling them to pass as an able bodied citizen in the workplace. Form was more important than function with the emphasis on "looking" normal. Painted copper plate took the place of missing eye sockets and maxillary bone, complemented by glass eyes helped maintain facial symmetry. The "Carnes" arm was not efficient for mechanical work but it filled in for the missing appendage and was both low cost and easily mass produced.

Germany took a completely different approach. Already suffering economically as a result of the war, Germany needed to find a solution to these “war cripples” that would be beneficial to both the individual and society as a whole. The country needed a way to keep them off the welfare rolls and help the men still see value in their ability to contribute. Their answer was to design for function rather than appearance with the goal of returning amputees to the workforce. In Berlin, the Test Center for Replacement Limbs was headed up by Georg Schlesinger. An engineer by training, Schlesinger was a great believer in the work of Frederick Taylor’s “scientific management” which applied scientific analysis to better maximize productivity. Setting aside any need to replicate natural biology in either structure or appearance, his idea was that a proper prosthesis should be mass producible and adaptable enough to be used in different lines of work. The result was the Siemens-Schuckert-Works Universal Arm, invented in 1916, which was basically a socket for interchangeable parts. For pop culture fans, imagine a real life Inspector Gadget. The “hands” ran the gamut from hammers, to cutlery, to clamps whose ends could be attached to machines. Although a part of me cringes at the thought of a man becoming part of a machine, I can’t discount the self-esteem that comes from being useful. “Sunday” arms, made either for show or with elaborate mechanical devices to mimic natural movements, were fine for the well off, but too expensive and fragile for the average amputee. Although definitely not life like, the universal arm was much more useful for those that worked with their hands.

Fast forward a hundred years and the debate between form and function has resurfaced but it looks like this time, function will win. Advances in both biomechanical engineering and materials science are creating prosthesis that in some cases surpass natural design. In 2008, Oscar Pistorius, a double leg amputee, petitioned to compete in the Olympic Games in Beijing. He had a history of successes at the Para-Olympics and wanted to compete against his non-disabled peers. Initially, he was turned down as some saw his running blades, made of carbon fiber, and modeled after a cheetah’s leg as giving him an unfair advantage. The debate is not limited to Olympic athletes or even pro sports. There have been several lawsuits around the country regarding suburban swim leagues and the use of prosthetic “flippers” in place of missing arms and or legs in competition. It is a topic I intend for my students to research and then debate. [7]

The replacement of body parts is certainly not limited to those lost to injury from some catastrophic event nor are the majority even visible to the naked eye. I'm referring to, of course, the thousands of joint replacements that happen annually that improve our quality of life and help us remain active long past the years of our ancestors.

Joint research

Before students can understand joint replacement, they need to understand how the musculoskeletal system works. Most think that bones are solid, providing a framework for the rest of the body structures and see the skeletal system in isolation. The reality is markedly different. The musculoskeletal system is made up of bones, cartilage, bursae, joints, tendons, ligaments and muscles. Movement happens when the nervous system sends messages through the receptor arc to the muscles. The muscles are attached to the bones with tendons and ligaments. Ligaments and cartilage also attach bones to bones. Bursae are small fluid filled sacs located at points of friction between a bone and the surrounding soft tissue, such as skin, muscles, ligaments and tendons that protect them from rubbing against the bare bones.

Bones are amazing things. Inside the larger bones are cell producing factories found in the bone marrow. The marrow produces all of the different cells that make up the blood, such as red blood cells, white blood cells (of many different types), and platelets and does so at a rate of millions of different cells every hour. All of these cells develop from a type of precursor cell found in the bone marrow, called a stem cell. Most of the hematopoietic stem cells stay in the marrow until they are transformed into the various blood components, which are then released to the blood stream.

The skeletal system can be viewed as two parts: the axial skeleton and the appendicular skeleton. The axial skeleton consists of the 80 bones in our upper body including those that make up our skull, hyoid (small bone at our throat), our vertebrae (back bones), ribs and sternum. Although our arms and shoulders hang from the axial skeleton, they are considered part of the appendicular skeleton. Joining them to make up the 126 bones of the appendicular skeleton are our two legs and our pelvis from which they hang. Bone surgery has been around for a very long time with the focus mainly being on repairing breaks. As I read Mark Miodownik's account of being disappointed that his own fractured leg would require nothing more than immobilization through casting, I reflected on my middle child's experiences.

It was a few weeks before she was to begin kindergarten, we had a great day planned. She decorated her bedroom with her hand and feet prints. I held her upside down and aloft so that she could make her marks high on the walls. It would be 6 more weeks before I could do that again. That afternoon saw her taking her first and last ice skating lesson. After a particular nasty fall, she complained of having trouble standing. The instructors reassured me it was only a sprain and she would be fine in the morning. It wasn't, she wasn't. It was two non-displaced fractures of her lower leg and a toe to mid-thigh cast for six weeks. Except for my guilt over not taking her immediately to the hospital, her recovery was uneventful and she became quite good at doing tricks with her pint size walker. Fast forward 16 years, same daughter, different leg and much more serious complications. This time it was a car accident. Her foot had somehow gotten caught under the pedal putting so much torque on her tibia that it broke completely through with one end piercing the skin. She did further damage as she crawled away from the burning car. Waiting for the ambulance, I said all the things moms' are supposed to say to keep their children calm. We were fortunate to have an excellent orthopedist waiting at the hospital. In order to repair the leg, he put in a steel rod and attached the bone sections to it with titanium screws. Although new bone would eventually fill in around the break, the metal rod will forever be part of her leg. He said the surgery went well but also warned us of the possible things that could go wrong. Because of the nature of the surgery there was the possibility of infection. Rejection of the metal, though unlikely, could also cause a problem. Fortunately a slight limp and a few scars on her leg are her only mementos, that and setting off metal detectors. I think there is a tendency to take some things, like orthopedic surgery, for granted because it seems so commonplace. One thing that has come out of my research is a new appreciation for the pioneers in the field. One that has particularly impressed me is Sir John Charnley and his work on hip replacements.

The human body has over 400 joints, also known as articulations, where bones connect. It is these articulations that allow movement. They are classified by either their structure (what they are made of) or their function (the amount and type of movement they allow.) There are three types of functional joints: immovable (synarthrosis) joints as in the skull where the bones are held together by fibrous tissue; slightly movable (amphiarthrosis) where cartilage holds the bones together as in the joints of the spine and lastly freely movable (diarthrosis) joints, also known as synovial joints, like at the hip and knee, where there is the most movement. [8]

Since the NGSS views structure and function as cross cutting concepts, it is worthwhile to look at the joints in the human body through both lenses here as well.
In addition to being classified by their functions, joints can also be described by their structures. The first type is fibrous. In this case the articular surfaces (where the two bones meet) are held together by fibrous connective tissue, allowing very little movement. A second type is cartilaginous. As the name implies, cartilage is what holds these bones together, allowing slight movement. In some cases, these are temporary joints where the cartilage will change to bone with adulthood. The growth plates of long bones are examples of this type of joint. Lastly, there are synovial joints and are the type we are most concerned with in joint replacements.

In synovial joints, the ends of the bones are covered by cartilage and a lubricating fluid called synovia which is produced by the synovial membrane which line the connecting ligaments. These can be further described based on the type of movement it allows. Gliding (plane) joints have flat or slightly curved articular surfaces and can be found in the intertarsal and intercarpal joints of the hands and feet. Hinge joints present a convex (curved outward) part of the bone meeting a concave (curved inward) part of another bone. It is called a hinge joint because it acts like a door hinge, only allowing bending and straightening motions as in our elbows and knees.
A third type is a pivot or swivel joint. In a pivot joint, the rounded end of one bone fits into the groove in another bone, allowing it to pivot against the other bone allowing a greater range of motion. Where the radius meets the ulna is an example of a pivot joint. In the hands, we find two additional style of synovial joints. The overall flexibility of our wrists we owe to condylar (ellipsoidal) joints. Here an oval shaped bone end fits into the concave surface of another bone. A related type and only found in the thumbs is a saddle joint. Similar to condylar joints, saddle joints allow even more movement. Opposable thumbs are one of the reasons we can use tools so efficiently. The last type is the ball and socket joint. The round end of one bone fits into the concave socket of the other bone which gives us a wide range of motion. Only the shoulders and hips are this type of joint.

Range of motion describes how far and in what direction a joint can move and is measured in angles using a goniometer. Several things can affect range of motion including negative things such as injury, disease, or a mechanical problem. Positive factors include many forms of exercise, especially those disciplines that encourage the controlled stretching of the ligaments. When there is a significant loss of mobility or when people experience high levels of pain due to the loss of the synovial cushioning, then surgical options may be needed.

Total hip arthroplasty (THA) is considered to be one of the most successful orthopedic procedures happening in the world today. Its roots however go back to the nineteenth century. In 1891, Dr. Theodorus Gluck, in Germany, sought to use ivory to replace femoral heads of patients who hip joints had been destroyed by tuberculosis. Another popular treatment method that soon followed was to try to minimize the friction of the bones by inserting different types of tissues, including those from pigs, between the articular faces. An American surgeon, Marius Smith-Pederson gets credit for creating the first mold arthroplasty out of glass. The inertness of the material meant that there wasn't any rejection by the body but its fragility meant that it shattered when exposed to the normal hip joint forces. Marius would later work with a colleague Philip Wiles to create one of stainless steel and attached to the bone with bolts and screws. Metal on metal became the standard under Dr. George McCay, an English surgeon, with some modifications. He combined a cemented hemiarthroplasty stem with a one piece cobalt chrome socket. Although his survival rates were significantly better than previous trials, this method fell out of favor in the mid 1970's due to the presence of metal particles found in cases where revision surgery was needed.

Yet it is Sir John Charnley, another English orthopedist, who is considered the father of THA. In the early 1960's, he designed the model for his low friction arthroplasty. To minimize wear, he created a smaller femoral head which still allows full range of motion. His design consisted of three parts: a metal femoral stem, a polyethylene component and acrylic bone cement. Fifty years later, it is still the basis of most hip replacements today. What I like most about Charnley's story however is not the outcome but that it illustrates his journey to success. One of the major differences between elementary and middle school science is the introduction of uncertainty. Students do not want to be wrong and yet in the real world to achieve innovation, there will be a large number of failures along the way. Students need to develop the mindset that failures are learning opportunities. When things don't happen as desired or expected, the situations need to be analyzed for flaws or misunderstandings and new solutions or procedures put in place.

Building on the work of others, Charnley's first design comprised of two Teflon cups, his idea being that the use of plastics could avoid the metal pieces that plagued McCay's work but it didn't work. His next step was to keep the stainless steel femoral head but use a Teflon cup. It was better but still produced too much wear. Keeping his materials the same, he altered the head of the femur to create a smaller "ball" with the idea that less surface area, less friction wear and tear. For his adhesive, instead of using McCay's metal screws and bolts, he used acrylic dental cement. Although not considered good protocol today, Charnley often tested possible materials for rejection by placing small amounts of them under his own skin. In lab simulations, the modifications seemed to work. Teflon seemed ideal as it was inert, durable, and produced little friction. However, when used in actual replacements, it failed in large numbers and sent Charnley back to again considering the all metal approach. Today, all prosthetic equipment is etched with a serial number which allows the medical profession to better tract what happens after a patient leaves the hospital. Charnley was ahead of his time in having his patients sign contracts giving him access to their remains on their passing. In this way, he could collect data on how his hip replacements fared in the real world.

One of the reasons that it is so important that scientists be good record keepers and good communicators is that it allows others to bring their thinking to the problem. Whereas Charnley had given up on plastics, his technician, Harry Craven, had not. Charnley’s mind was closed but his assistant’s was open to the possibilities of High Density Polyethylene (HDPE) pitched to him by a plastics salesman. Using his own initiative, Craven tested the new material and was able to convince Charnley of its merits when he showed that it produced wear of only 1/2000 of an inch after two continuous days of friction testing, which was far less than with Teflon. [9]

Fast forward to 2017 and a total hip arthroscopy could be metal to metal, metal to ceramic, ceramic to ceramic, or metal to plastic depending on patient characteristics and medical availability.

Another area of joint replacement focuses on knees. The biggest reason for needing knee surgery, as in hip surgery, is due to deterioration from osteoporosis. A secondary cause, besides age, is overuse which is seen most in professional athletes or people who engage in activities that put a lot of stress on their knees. The knee is a hinge joint where the femur (thighbone) abuts the tibia (lower leg). In a total knee replacement, the head of the femur is removed and replaced with a metal shell. The corresponding end of the tibia is also removed and replaced with a channeled plastic piece with a metal stem. If the kneecap is also in poor shape, it can be reinforced with a plastic “button”. In addition to replacing the areas where the bones have worn down, it is also important to deal with the connective tissue; in this case the posterior cruciate ligament, which stabilizes each side of the knee joint. In some cases, a new ligament is grafted in place after being harvested from a different section of the body if the original cannot be repaired. In some cases, it is even replaced by a polyethylene post.

Teaching Strategies

Instruction will incorporate the following eight Science and Engineering Practices. Students will obtain, evaluate, and communicate information as they use multimedia to build background knowledge on the musculoskeletal system. They will use mathematics and computational thinking as they test their working prosthetics. They will develop and use models to show the different types of joint movement. Defining problems and designing solutions will be used as students strive to create prosthetics that can grasp and/or pick up objects. Specific strategies chosen to best meet the needs of this age group and diverse population include flexible grouping depending on the nature of the activity, rotating roles and responsibilities, encouraging participation and building vocabulary and content knowledge through think, talk, write, pair, share, modify writing. Instead of a traditional KWL, students will do a see, think, wonder which gives them something concrete to consider starting with an image of various prosthetics. The emphasis will be on formative assessment using focus questions and providing multiple pathways to demonstrate knowledge for summative assessments. The three strands of the Next Generation Science Standards (NGSS) will be the basis of creating assessments that incorporate the cross cutting concepts and science and engineering practices along with the disciplinary core ideas on matter and its interactions.

NGSS Standards:
MS-LS1A All living things are made up of cells. In organisms, cells work together to form tissues and organs that are specialized for particular body functions.
MS-LS1D Each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain; The signals are then processed in the brain, resulting in immediate behavior or memories.

Essential Questions:
How do structures work together to fulfill the function(s) of a system?
How does a structure's form and composition determine its function?
condylar

Lesson Plans for DTI unit
Objectives:
Students will create a picture book/google slide presentation that they can share with another class/school about the human skeleton with the focus on the joints appropriate for a third grade classroom.
Students will create a 2d and 3d model of a synovial joint using classroom/household materials.

Students will develop knowledge of the history of prosthetics through focused research using teacher previewed websites.
Students will investigate the properties of different materials.
Students will debate the “fairness” of using prosthetics in athletic competitions.
Students will work with the Meadowood staff and the art teacher to create an assistive device that will allow the students with limited mobility/control of their hands to draw/paint.
Students could research using 3d printing to make a prosthetic using sites from a teacher prepared resource list with comprehension questions RACER format.
Have students assemble prosthetic using 3d printed pieces.
As part of being career and college ready, students will interview a professional in the field of prosthetics. They will prepare for the interview by doing background research.
Overview-This part of the unit will focus on using the 5E strategy-Excite, Explore, Explain, Evaluate, Extend with the Excite portion being linked to using phenomena
Day 1 -2 Building Background Knowledge of the Skeletal System
Excite
Show video of gazelle legs
Explore
Challenge students to tie their shoes with their eyes closed. Then ask them to do it wearing gloves, then ask them to do it wearing mittens, then ask them to do it wearing mittens with their hand in a sock and the rubber band holding the thumb against the fingers. With each limitation, discuss how the restriction affected their success.
Explain
My students are fortunate to have one to one devices so they can access information directly through the internet. Another option would be for the teacher to prepare the readings ahead of time. Have students build some background knowledge on the skeletal system by using the Nemours Kids Health Website. It offers students the option of reading/listening in either English or Spanish. In addition, it allows some differentiation in level of content by choosing either the kids or teen information. There is also a parent level that is useful for both educators and parents. The focus should be on connecting movement to the interaction of nerves, tendons, muscles, and bones rather than naming the bones. If there are students who have a different primary language besides English or Spanish, arrange for a translation of the relevant factual material either through a school translator or through google docs. After reviewing copyright and fair use laws, I have taught my students how to cut and paste into google docs information from sites that they can then translate. The chrome environment also provides the read/write extension that will read passages to students.
Evaluate
At the end of the lesson, students should be able to identify that there are three types of functional joints and provide an example of each.
Extend
Students will create 2 or 3d models of joints and explain orally or through another medium, how each works to help the body move.

Days 5-8

Students will develop their knowledge of prosthetics, looking at both the historical development, and the current state. Articles will be chosen to match students' Lexile levels if possible. If not, other reading strategies such as focused partner read/summarize; pair/share and jig sawing will be used. It is impossible to discuss the improvements in prosthetics without also considering the advances in material science. Based on their understanding of the muscular-skeletal system, students will take a critical look at the properties of different materials from the stand point of serving as replacements. They will do simple hands on observations of strength, flexibility, ease of changing shape, and reaction to stress and friction. Materials to be investigated include different types of plastic, wood, different types of metal, ceramics, and glass. Based on their increased background knowledge, each student will prepare three questions before having a guest speaker connected with prosthetics. Depending on schedules, the interview may even be conducted through a videoconference. After reading several articles on the advantages of "prosthetic flippers", they will debate whether function specific prosthetics should be allowed in athletic competitions.

Days 9-12

Students will create an assistive technology device to help students with limited mobility or other impairments "paint". To reconnect the role of the brain and nervous system, the focus will be on how the student "controls" or "interacts" with the device.

Students will share their designs, give and receive constructive feedback from their peers, and reflect in writing on any changes.

Extension

When I initially started this unit, my thought was to include looking at the role biotechnology plays in the different systems we currently study including the cardiovascular. I quickly realized that while I found it fascinating, it was too high of a level for most of my students. I'm including that annotated material as a resource to be used through either a gifted program or in a higher grade level.

Endnotes

[1] Devlin, Hannah. "Mind-controlled Robot Arm Gives Back Sense of Touch to Paralysed Man." The Guardian. October 13, 2016. <https://www.theguardian.com/science/2016/oct/13/mind-controlled-robot-arm-gives-back-sense-of-touch-to-paralysed-man>.
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Biography Engineering Prosthetics
Bibliography

Classroom-Ready STEM Lessons: Adaptive Technologies. Accessed July 30, 2017. http://archive.constantcontact.com/fs155/1102261797598/archive/1115428969467.html.

Detailed lesson plan that tries to get students to understand different medical conditions through the use of scratched glasses, wheelchairs, crutches, and taped thumbs. While I admire the thought, I question whether middle schoolers won't focus on the competition part rather than adaptive technology. That said I would use the taped thumb concept as part of having students discover all that is involved in shoe tying.

"An Assistive Artistic Device - Activity." Www.teachengineering.org. Accessed July 30, 2017. https://www.teachengineering.org/activities/view/wpi_assistive_device_activity1.

Can be used as an extension or a modification. Students design and construct an appliance that attaches to a disabled student's hand that can hold an art implement (brush, crayon, marker, etc.) that allows them to draw even though they don't have the fine motor abilities to grasp. Can be created using a 3d printer but can also be constructed of other simple materials.

"Engineering Bones - Lesson." Www.teachengineering.org. Accessed July 30, 2017. https://www.teachengineering.org/lessons/view/cub_biomed_lesson01.

Very complete set of lesson plans that explore biomedical engineering. The first focuses on bones. It includes a pre and post assessment, written background information for the teacher and separated vocabulary lists. It offers extensions to both upper and lower grade levels. In addition to the skeleton, it also looks at other parts of the body-eyes, ears, circulatory, and even digestive.

"Lending a Hand: Teaching Forces through Assistive Device Design - Activity." Www.teachengineering.org. Accessed July 30, 2017. https://www.teachengineering.org/activities/view/wpi_lending_hand_activity1.

Lesson incorporates concepts of force and motion as students work to construct a "hand" that is capable of grasping a cup.

Tierney, Jacob. "Prosthetics Project Gives Southmoreland Middle School Students Hands-on Lesson." TribLIVE.com. December 28, 2016. Accessed July 30, 2017. http://triblive.com/local/westmoreland/11634369-74/sikorski-stem-students.

Article for students to read about another group of middle schoolers who created hands using a three d printer

"EGFI – For Teachers » 1, 2, Robot Hands Please Tie My Shoe." Overview. Accessed July 30, 2017. http://teachers.egfi-k12.org/robot-hands/?utm_source=Teachers+Newsletter+October+2013&utm_campaign=egfi+teachers+sept.+2013&utm_medium=archive.

Lesson plan that helps students discover how complex a simple task like tying a show can be as it has them do it blindfolded (emphasizing touch), then with heavy gloves on, then with splinted fingers (loss of joint mobility), then lastly with pliers (loss of touch sensation). It would be good to add taking away opposable thumb by putting into glove and then taping.

"EGFI – For Teachers » Lesson: Build a Prosthetic Device." Overview. Accessed July 30, 2017. http://teachers.egfi-k12.org/lesson-build-a-prosthetic-device/.

This site provides a lesson plan for students to create their own artificial leg. Along with form and function, it adds the idea of natural appearance. This would be a good point for a class debate as the merits of appearance are weighed against form and function-think about an artificial real looking foot compared to the more usable scoop prosthetic.

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Appendix

Extension

When I initially started this unit, my thought was to include looking at the role biotechnology plays in the different systems we currently study including the cardiovascular. I quickly realized that while I found it fascinating, it was too high of a level for most of my students. I'm including that annotated material as a resource to be used through either a gifted program or in a higher grade level.

Additional annotated resources for pursuing extension research on heart/lung systems

Cardiovascular System

Even after learning about the basic structures of the heart, students don't really understand how it is a combination of electrical and muscular motions.

http://www.heart.org/HEARTORG/Conditions/Arrhythmia/PreventionTreatmentofArrhythmia/Living-With-Your-Pacemaker_UCM_305290_Article.jsp#.WeZhVxgrLrc Good link that demonstrates how a pacemaker functions and clearly makes the connection between the frequency of electrical impulses and the rhythm of the heart.

https://watchlearnlive.heart.org/CVML_Player.php?moduleSelect=chlcad shows the formation of plaque from cholesterol and then the resulting blood clot and heart damage

https://watchlearnlive.heart.org/CVML_Player.php?moduleSelect=cstent link from the American Heart Association that shows angioplasty being performed and a stent being left in place to keep blocked artery open

https://www.healthline.com/health/heart-bypass-surgery#preparation7 discusses coronary bypass surgery in detail including the use of a heart lung bypass machine and cooling down the body

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5358116/ very scholarly article that goes into the history of the development of an artificial heart. On the whole too technical but two things of note are Charles Lindbergh's involvement and the cost. Of historical note is the experimenting on dogs and success measured in hours. Also talks briefly about heart lung machines.

http://www.madehow.com/Volume-6/Artificial-Heart.html article that talks about the materials that make up an artificial heart but is more than 17 years out of date as this point

http://ethw.org/Artificial_Heart short succinct article that focuses on Barney Clark and Jarvik-7

http://collections.si.edu/search/results.htm?q=set_name%3A%22Artificial+Hearts%22&start=0 collection of objects from the Smithsonian institutes collection. There are pictures, dimensions, and a brief history of the design and its use. Of special note is the Sewell Howell pump that is made using an erector set.