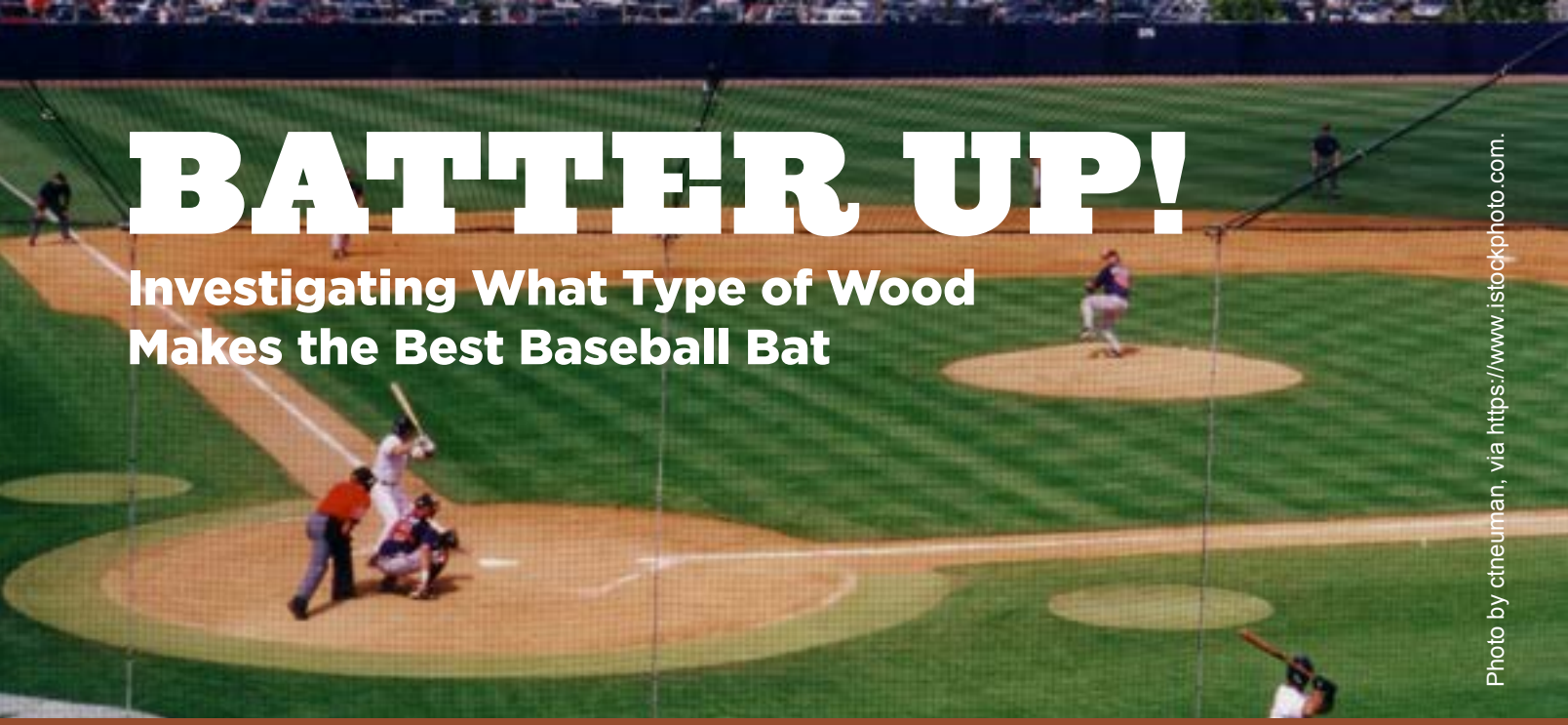


BATTER UP!

Investigating What Type of Wood Makes the Best Baseball Bat

Photo by ctneuman, via https://www.istockphoto.com.

Meet the Scientists!

Photo courtesy of Patrick Drane, University of Massachusetts-Lowell, used with permission.

◀ DR. PATRICK DRANE,
Mechanical Engineer

I have always found math and science very interesting. I have enjoyed being able to use those concepts and tools in engineering to investigate mechanical systems, design tools, and solve problems. I would never have predicted, as a youth, that I would be working with baseball bats and other sporting equipment. It is great to be able to solve problems with products that are widely used.

Photo courtesy of David Kretschmann, USDA Forest Service.

◀ DR. DAVID KRETSCHMANN,
Retired Wood Research Engineer

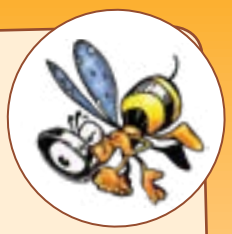
Growing up, my parents owned an auto body repair business. Being around auto repair sparked my curiosity of how things worked and held together when subjected to extreme conditions. I also learned the skills of problem-solving when putting things back together. I am fortunate that now I get paid to problem-solve and break things for a living!

What Kind of Scientists Did This Research?

- **mechanical engineer:** This type of engineer deals with tools, machinery, and the application of **mechanics** in industry.
- **wood research engineer:** This type of engineer studies the engineering properties of wood to ensure that wood harvested in the United States is utilized to its fullest potential.

Glossary words are in **bold** and are defined on page 29.

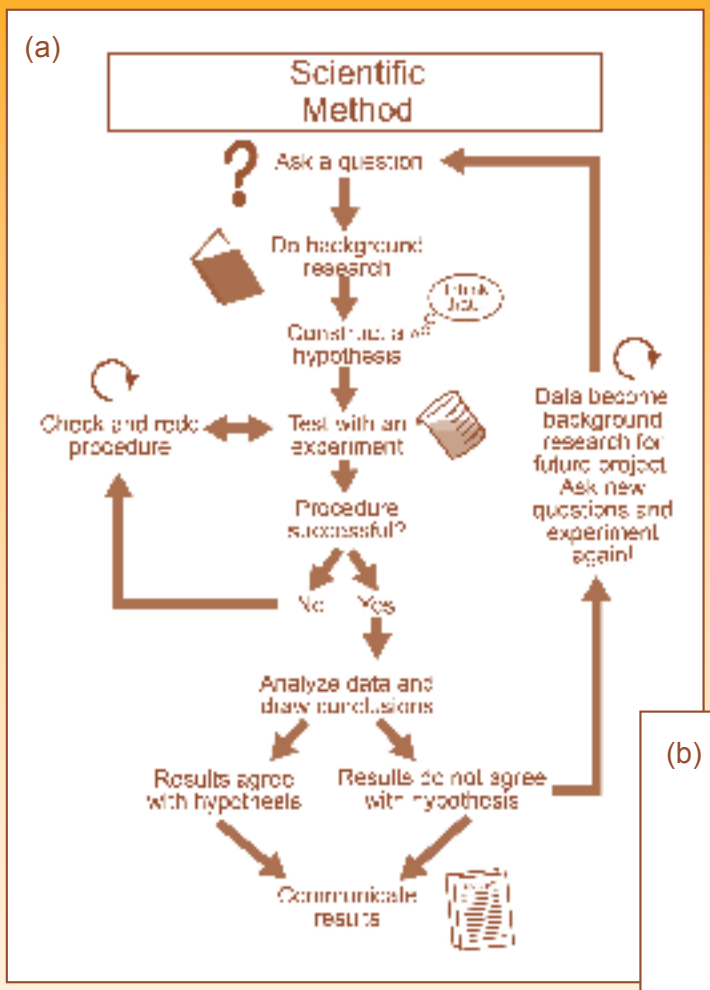
Thinking About Science and Engineering

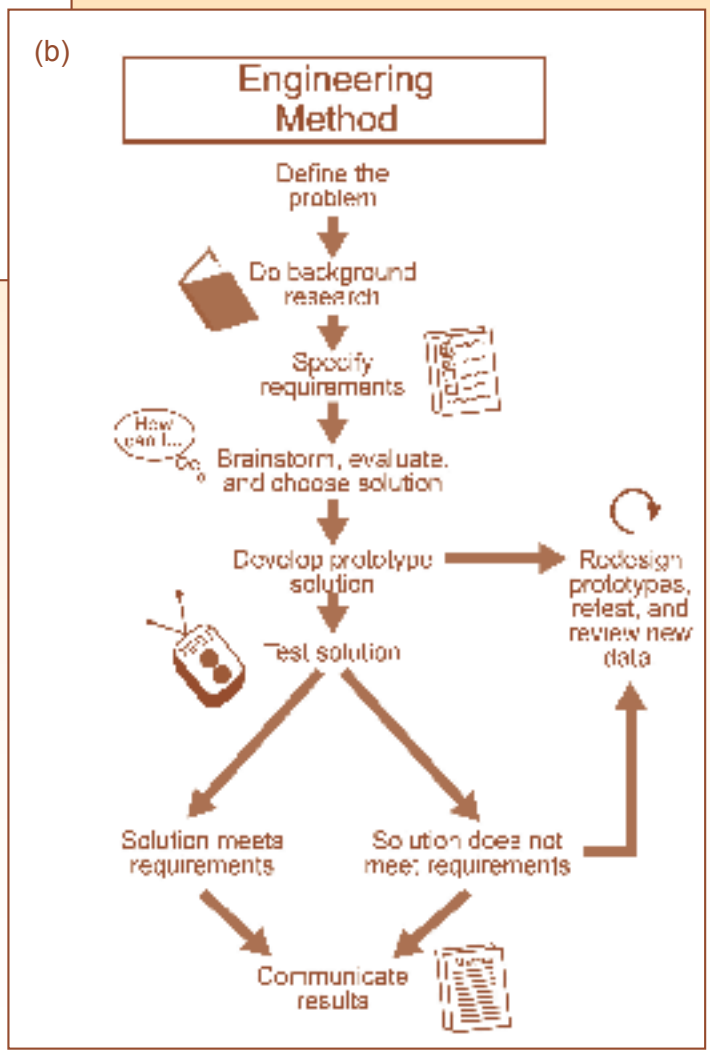


In most *Natural Inquirer* articles, this section is called "Thinking About Science." However, engineers did the research in this article. Science and engineering are closely related. Science and engineering have some interesting similarities and differences. Sometimes scientists conduct research to solve a problem, and sometimes they conduct research to provide new information about a topic. Scientists study how nature works and generally conduct experiments using the scientific method. Engineers apply scientific and mathematical knowledge to help solve a problem. Engineers and scientists also create things to help them answer questions and solve problems. Engineers have a method they use to help them solve problems. It is called the engineering design process (figures 1a and 1b).

In recent times, different types of wood have been used to create baseball bats. One of the reasons different wood is used is because baseball players want to try different types of wood bats. They are interested to see if the design and type of wood will affect how far the ball is hit. However, some types of wood break easier than others resulting in an increase in bat breakage rates.

In this research, the engineers wanted to understand more about wood used to make baseball bats. Baseball bats can and do break. To help prevent baseball bats breaking, the engineers wanted to figure out a way to test wood for baseball bat manufacturing. This wood testing process could be used now and into the future to determine the suitability of different wood for baseball bat manufacturing.





Figures 1a and 1b. Examine the scientific method and engineering design process illustrations. What similarities and differences do you see?

Illustrations by Stephanie Pfeiffer.

Will the Emerald Ash Borer and Climate Change Affect White Ash Baseball Bats?

Much of the white ash wood used to manufacture baseball bats comes from trees in Northern Pennsylvania and New York (figure 2). The white ash trees in these areas are experiencing problems. One problem is the emerald ash borer (figure 3). The emerald ash borer is a beetle that is **native** to Asia. The beetle was first found in Detroit, Michigan, in 2002. Since that time, the beetle's range has spread. The range of emerald ash borer now includes Pennsylvania and New York, where much of the white ash for bats is harvested. The **larval** stage of the beetle feeds on the inner bark of white ash trees. Feeding by the beetles causes trees to have problems with transporting water and nutrients, which weakens the tree. Over time, the trees can become so weak that they die.

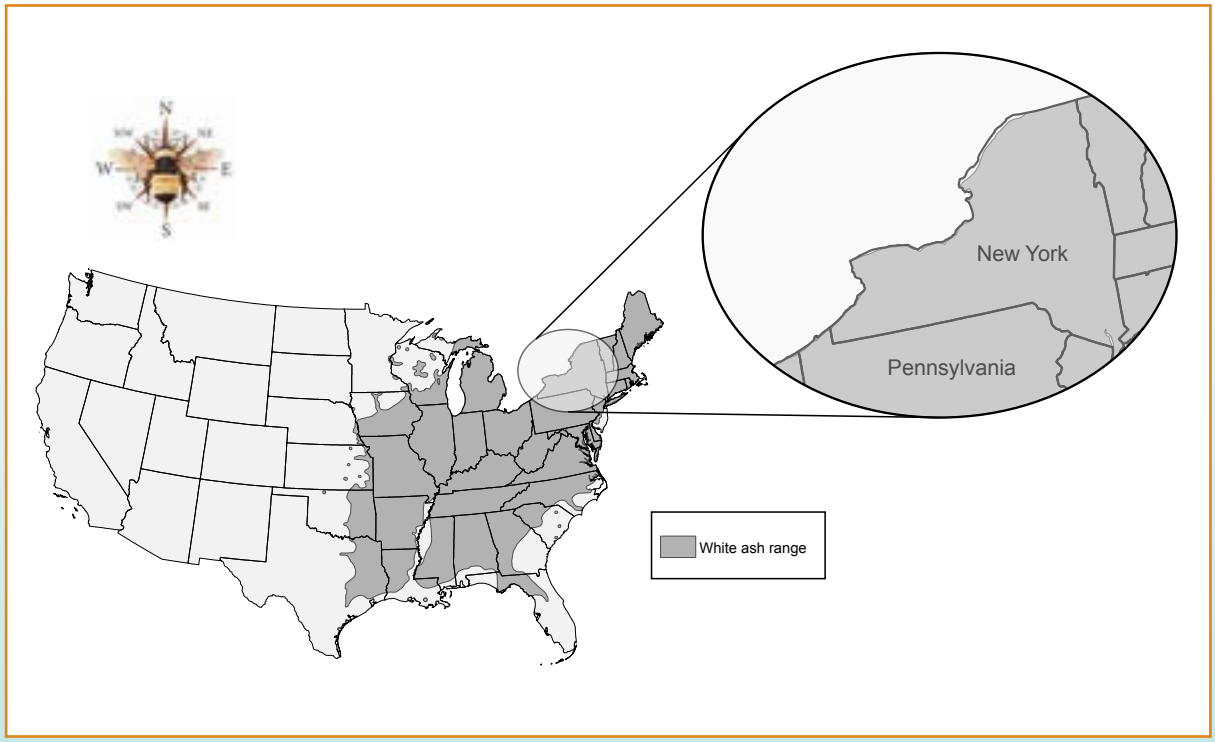


Figure 2. Have you seen white ash trees near where you live?
Map by Carey Burda.

Figure 3. Emerald ash borer is a beetle native to Asia. Since its arrival in the United States, the beetle has caused problems for white ash trees.

Photo by Debbie Miller, USDA Forest Service, via https://www.bugwood.org.

Another problem white ash trees are facing is climate change. Climate change refers to how Earth's climate may be changing over time. In the past few years, most scientists have agreed that measured and recorded changes in Earth's climate over the past 100 or more years point to a warming of Earth's surface. Extreme cold temperatures in Northern Pennsylvania and New York help to kill the emerald ash borer and provide relief to the white ash tree. However, if the climate warms in this area, the emerald ash borer may be able to live through the winter. If more emerald ash borers survive the winter, the trees will be under greater threat and may not be able to survive.

Due to the challenges facing white ash trees, baseball bat manufacturing companies have tried new types of wood to make baseball bats. For more information, visit https://www.scientificamerican.com/article/baseball-bats-made-from-ash-may-fall-victim-of-climate-change/.

Thinking About the Environment

Over time, as baseball players have wanted to try different types of bats, various types of wood have been used to make the bats. Over 750 different types of trees are found in North America. Although most of these trees would not be suitable for making bats, the number of choices is large enough to need a consistent selection process.

Typically, northern white ash has been used in baseball bats (figure 4). White ash is native to North America and is known as a strong, light wood. The characteristic of the wood being strong but light makes it perfect for baseball bats. In the 1990s, baseball bat manufacturers started using sugar maple (figure 5). Some players thought that using bats made from sugar maple trees might increase the distance a batted ball would fly. Sugar maple is a very **dense** wood, but it tends to break easier than white ash. Other types of wood, such as bamboo, birch, and hickory, have also been used to make bats (figure 6).

Figure 4. Northern white ash has strong, light wood. It is found throughout North America.

Photo by jdwfoto, via https://www.istockphoto.com.

Figure 5. Sugar maple is a dense wood that has been used in the manufacturing of baseball bats.

Photo by Chris Aquino, U.S. Fish and Wildlife Service.

Figure 6. Hickory was used for bat manufacturing in the 1950s. Read about the use of hickory wood bats in "Time Warp" on page 35 of this journal.

Photo by DNY59, via https://www.istockphoto.com.

Baseball for All!

A Player's Reflection From the First All Girls' Baseball Tournament

Written by Kayla Tanner

My trip to Florida will be one I'll never forget! We did everything from baseball to visiting Universal Studios to hanging out at the pool at the hotel. I met some amazing girls who can really play some baseball. My team, the Carolina Terminators, was one of 12 teams from around the country who went to Orlando for the first ever All Girls' Baseball Tournament (figure 7). We didn't get to practice together as a whole team because two of our teammates were from outside of North and South Carolina. We went to our first games looking like a real team that had played together forever.

Figure 7. The Carolina Terminators baseball team at the first all girls' baseball tournament.

Photo by Beth Tanner, used with permission.

I don't think anyone expected us to take first place, but when we got that final out, we felt like we were a part of history! And we were! We all signed a jersey, and we think it will be displayed in the women's exhibit in the Baseball Hall of Fame (figure 8)! We are just girls who love to play baseball, and now we have found other girls with that same love for baseball!

Figure 8. A commemorative jersey signed by the winning Carolina Terminators team.

Photo by Beth Tanner, used with permission.

Introduction

Two different kinds of breaks are found in a baseball bat. These breaks are called either a single-piece failure (SPF) or a multi-piece failure (MPF). An SPF is when a bat breaks but stays in one piece. An MPF is when a bat breaks into two or more pieces (figures 9a-d).

In recent years, the number of baseball bat breakages has increased. Following this increase, people began to look at how wood was chosen for baseball bat manufacturing. A Wooden Baseball Bat **Specifications** list existed. The list, however, had not been reviewed and updated in a long time.

In 2008, the Baseball Office of the Commissioner and the Major League Baseball (MLB) Players Association

Figures 9a-d. Look at the four photos.

Are these SPF or MPF breaks?

How do you know?

Photos by Steve Schmieding, USDA Forest Service.

appointed a team of wood and bat experts led by Forest Service Engineer David Kretschmann. The research team was asked to address the concern that more bats had been breaking in recent decades. Changes were implemented from the recommendations of these experts, and bat breakage rates declined by 67 percent.

The Wooden Baseball Bat Specifications list was updated to include the new recommendations and a list of recommended wood **species**. However, the updated list of recommended wood species was based on how a wood species had performed in the past. This list of wood specifications for existing wood species would not help identify whether a new wood species would be acceptable for bat manufacturing. Experts had not identified **criteria** for wood species to be considered acceptable for MLB bats. Therefore, the research team determined that a test for the suitability of wood species in bat manufacturing was needed.

Number Crunch

If the breakage rate is 100 percent, what would a 30-percent decline in bat breakage rate mean in number form?

Reflection Section

In your own words, what problem were the engineers trying to solve?

Two types of breaks in baseball bats are: an SPF or an MPF. Which break do you think is more serious? Why do you think this?

Methods

The engineers looked at three main tests: a **durability** test, a clear **dowel** test, and a batted-ball performance test. The engineers did their testing in the University of Massachusetts-Lowell Baseball Research Center (figure 10). The engineers first tested white ash because white ash has been the preferred wood to use for baseball bats for many years. The engineers used white ash as the benchmark. A benchmark is something with which to compare other things. In this case, a white ash baseball bat was the benchmark to which other woods were compared during the testing process.

To develop a testing process, the engineers tested yellow birch and compared it with white ash (figure 11). The first test examined durability. Durability for wood baseball bats is a product of several things: wood **density**, wood species, wood slope of grain (SOG), impact location, and impact **velocity**.

The wood SOG refers to the straightness of the wood grain along the length of the bat (figure 12a). Straighter grain along the length of the bat means the bat is less likely to break (figure 12b). Impact location refers to where the baseball hits the bat. Impact velocity refers to the speed in which the bat is hit by the baseball. To test durability, the engineers used an air cannon. The air cannon can be used to shoot baseballs at velocities of up to 200 miles per hour (mph).

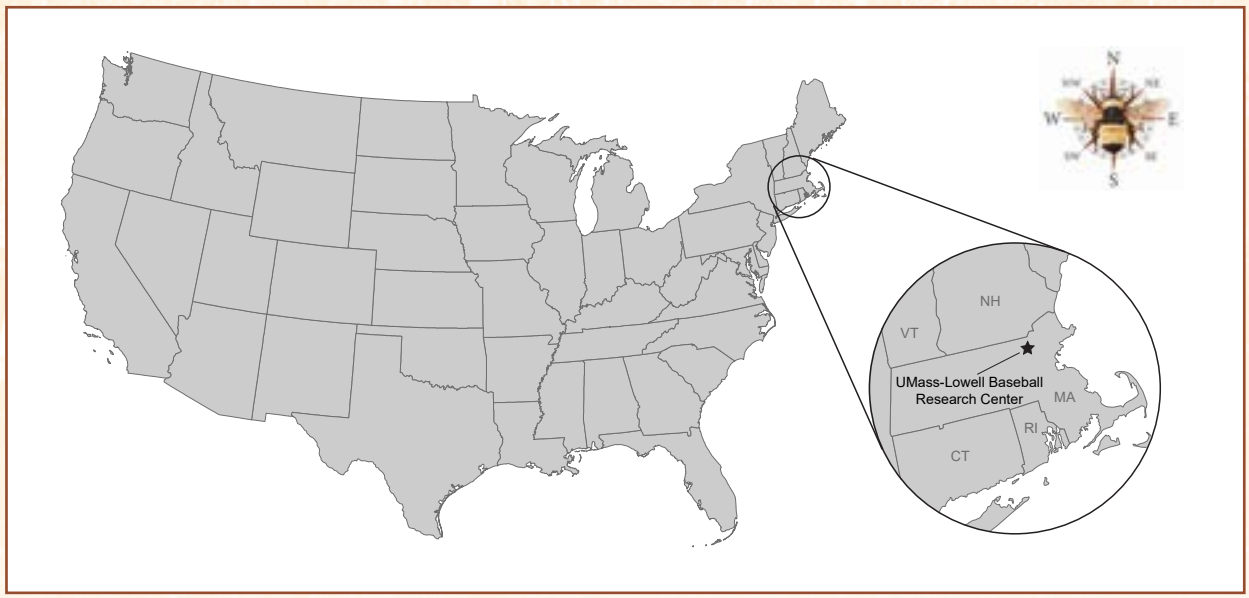


Figure 10. The University of Massachusetts-Lowell Baseball Research Center is located in the Northeastern United States. Map by Carey Burda.

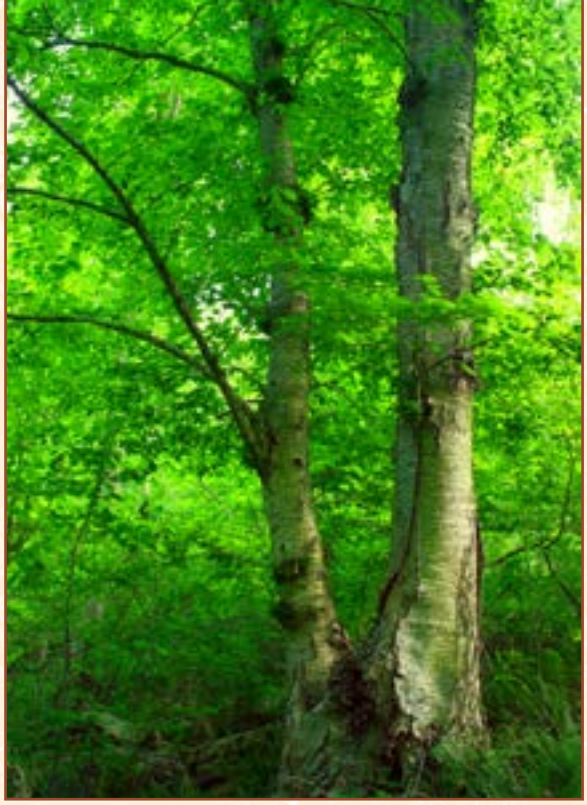


Figure 11.
Yellow birch is used for lumber and many wood products.

Photo by Nicholas A. Tonelli via Wikimedia Commons. https://creativecommons.org/licenses/by/2.0/legalcode.

Figure 12a. Wood slope of grain is important because a straighter grain along the length of the bat means that the bat may be less likely to break. Illustration by Stephanie Pfeiffer.

Figure 12b. In this photo, David Kretschmann is examining a game-used broken bat and determining the slope of grain in the handle. The clear plastic object on the handle is a slope-of-grain gauge.

Photo by Steve Schmieding, USDA Forest Service.

The engineers measured the density of each wood species tested (table 1). Density is the relationship between the mass (weight) of a substance and how much space it takes up. If two items take up the same amount of space, the heavier item is denser. Two bats made from the same wood species may have slightly different densities, because the density of wood from the same species can be different.

Table 1. Average density of three wood species.

Wood species	Average density (pounds per cubic foot)
White ash	39.83
Yellow birch	41.70
Sugar maple	42.20

Data from California State University Dominguez Hills.

How Fast Can Major League Pitchers Throw a Baseball?

The average Major League Baseball pitch velocity is between 90 mph and 92 mph. A few pitchers have pitched balls at velocities of 100-102 mph. However, these high-velocity pitches are rare, due mostly to the limits of the human body.

Number Crunches

How many kilometers per hour is equivalent to 200 miles per hour?

How do these velocities compare to the velocity of cars driven on a highway?

Low-, medium-, and high-density versions of each bat were tested. Each bat was tested at four impact locations. An impact location is a place on the bat that comes in contact with the ball as it is hit. The impact locations were 2, 10, 14, and 16 inches from the tip of the barrel (figure 13).

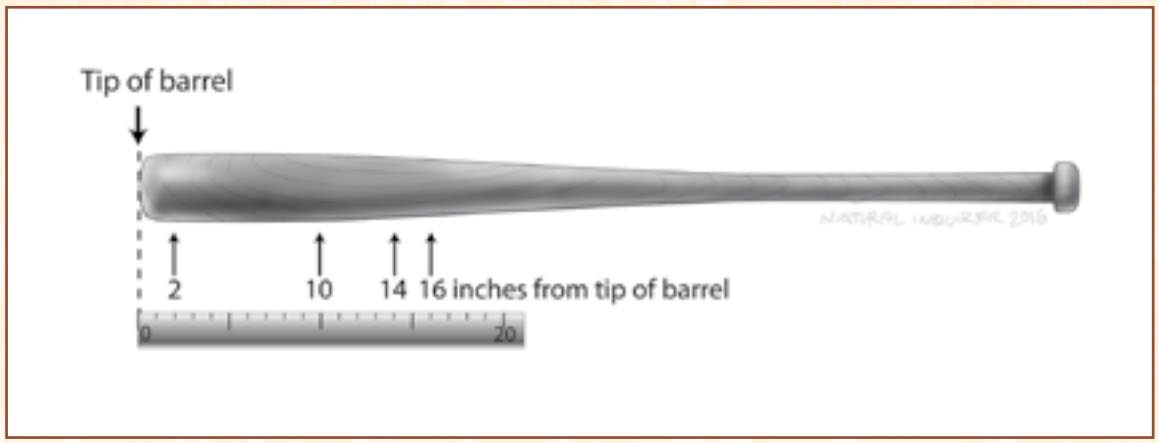


Figure 13. The impact locations are marked along the barrel of the bat. Illustration by Stephanie Pfeiffer.

The bats were tested at 5-mph increments up to the peak testing speed. A total of five impacts were made at peak testing speed if the bat had not broken during the process. The testing ended when the bat initially cracked or the testing sequence was completed.

SPF (single-piece failure)-**threshold** and MPF (multiple-piece failure)-threshold velocities were established for each of the impact locations (table 2). Recall that SPF is when a bat breaks but stays in one piece. MPF is when a bat breaks into two or more pieces.

Table 2. What do you notice about the velocity thresholds as they get farther away from the tip of the barrel?

Location from tip of barrel (inches)	SPF threshold (miles per hour)	MPF threshold (miles per hour)
2	125	170
10	135	160
14	110	130
16	105	135

Number Crunch

In table 2, notice that the data are given in inches and miles per hour.

Generally in science and engineering, the metric system is the way scientists and engineers communicate information.

As a number crunch challenge, re-create table 2 so that it uses the metric system for the data.

The engineers also tested the clear dowel and batted-ball performance for each type of bat (figures 14a and 14b). The clear dowel testing examined the wood before it was carved into a baseball bat. This test examined the strength and stiffness of the wood. The batted-ball performance test was used to determine if a particular wood species performed differently than the bat carved from white ash.

Figure 14a. David Kretschmann is placing one of the test dowels into the test frame for bending tests. The clear box is used to control the environmental conditions, such as temperature, under which the test is being conducted.

Photo by Steve Schmieding, USDA Forest Service.

Figure 14b. David Kretschmann and Timothy Nelson are examining a single-piece failure (SPF) of one of the dowels with a straight slope of grain.

Photo by Steve Schmieding, USDA Forest Service.

Reflection Section

The engineers tested several different impact locations on the barrel of the bat. Why do you think they tested several different locations rather than just choosing one location?

The engineers also tested different bat densities. Why do you think testing a high-, medium-, and low-density version of each bat would be important?

Findings

Based on their testing, the engineers created a process to evaluate different wood species for use in baseball bat manufacturing. For each wood species, the proposed testing process is as follows:

Background information is provided about the proposed wood species. The background information includes what type of tree the wood comes from and basic information about the tree.

A preliminary durability test is performed on 12 low-density bats. All bats are impacted at the 14-inch location.

If the proposed wood species passes this test, then a dowel sample test is performed. As part of this test, 180 dowels undergo the test.

Next, a complete dynamic bat test is performed. A complete dynamic bat test includes durability testing of 15 low-, 15 medium-, and 15 high-density bats. Half of the bats are impacted at multiple locations. The engineers proposed that if more than 2 of the 15 bats tested experience SPF or MPF below the thresholds in table 1, then that bat density would not be suitable for baseball bat manufacturing.

Finally, a test is conducted to compare whether the proposed wood species performs differently than the white ash species, which is used as a benchmark.

If all of these tests and comparisons are passed, then the proposed wood species is accepted as a suitable wood to use for baseball bat manufacturing.

Reflection Section

Creating a protocol to test something can be difficult but rewarding work.

Do you think the engineers who created this protocol would find their work rewarding?

Why or why not?

Think of a time when you created something.

For example, it could be building a play fort with pillows and blankets, making a tree fort, or creating a town from building blocks or Legos®.

Did you have to try different designs and then find the best one for your creation?

Name two ways in which what you did was like being an engineer.

Discussion

The proposed testing process involves five main steps to determine whether a wood species is suitable for making baseball bats. The engineers used white ash as the benchmark species to compare other wood species because of white ash's proven durability over time. When the engineers tested yellow birch using the proposed test protocol, they concluded that the durability, performance, and material properties were all similar to white ash. Therefore, yellow birch would be suitable for use in MLB bats. Engineers hope to see a reduction in the number of SPFs and MPFs now that this testing protocol is in place for determining whether a particular wood is acceptable for use in baseball bat manufacturing.

Reflection Section

Engineers often use math and science to solve a problem.

After reading this article, name some of the science and math topics that the engineers used to help them design a protocol for testing wood for baseball bat manufacturing.

Engineers need to be good problem solvers and critical thinkers.

What other characteristics do you think would be helpful if you were an engineer?

(Hint: After you brainstorm, take a look at our scientist & engineer cards to see a list of characteristics that scientists and engineers find helpful. You can find the cards at http://www.naturalinquirer.org/scientists-v-92.html)

Adapted from Ruggiero, Eric; Sherwood, James; Drane, Patrick; Kretschmann, David. 2012. An investigation of bat durability by wood species. Procedia Engineering 34 (2012): 421-432.

Glossary

accumulate (ə **kyü** m(y)ə **lāt**): The act of collecting or gathering.

analyze (**a** nə līz): To study or examine carefully.

criteria (krī **tir** ē ə): Standards on which a judgment or decision may be based.

dense (**den(t)s**): When the molecules of a substance are close together.

density (**den(t)** sə tē): The condition of a substance having its parts close together.

dowel (**daů(ə)l**): A round rod or stick used especially for cutting up into dowels.

durability (důr ə **bi** li tē): Capability of something to last over a long length of time.

hypothetical (hī pə **the** ti kəl): Imagined as an example for further thought.

larval (**lär** vəl): Relating to the wormlike feeding form that hatches from the eggs of many insects or animals that changes form when it becomes an adult.

longitudinal (län jə **tüd** nəl): Involving the repeated observation over time with respect to one or more study variables.

manufacturing (**man** yə **fak** chər): The making of goods or articles.

mechanics (mi **kan** iks): The details of the way something works or is done.

metric system (me trik **si** stəm): A system of weights and measures based on the meter and on the kilogram.

native (**nā** tiv): Living or growing naturally in a particular region.

prescribed fire (pri **skrīb(d) fīr**): The controlled application of fire to wildland fuels under certain weather conditions as a forest management tool.

specifications (**spe** sə fə **kā** shəns): A description of work to be done or materials to be used—usually used in plural.

species (**spē** shēz): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

threshold (**thresh** hōld): The place or point of beginning.

velocity (və **lä** sə tē): The rate of change of position along a straight line with respect to time.

Marks and definitions are from https://www.merriam-webster.com. Accented syllables are in **bold**. Definitions are limited to the definition used in the article.

FACTivity

Time Needed

Two class periods

Materials (for each student or group of students)*

- Paper (a variety of weights and types of paper)
- Plastic straws
- Wooden Popsicle® sticks
- Toothpicks
- Natural items (sticks, leaves, etc.)
- Glue
- Tape
- Paper clips
- Ruler/measuring tape
- Any other items that you think students may want to build with

In the research presented in this article, the engineers developed a protocol for determining whether different types of wood are useful for making baseball bats. In order to create this protocol, the engineers had to test different types of wood. Similar to the engineers, you will explore different materials to see what type of material and combination of material makes the best tower.

The question you will answer in this FACTivity is:
What material or combination of materials creates a stronger tower?

*Educators - this FACTivity is intentionally open-ended so that students can use their creativity to build and modify the towers. Please feel free to use different materials or present the student with different challenge activities as appropriate.

Photo by UroshPetrovic, via https://www.istockphoto.com.

Methods

You (or your team) will be provided with a variety of materials. Your challenge is to create the strongest tower with the materials you have. Your tower needs to be 12 inches in height. The way you will test the strength is that each group will use the same textbook to place on top of the tower to see if it holds it.

As you create different towers, keep a detailed list of materials used and a sketch of your design on the graphic organizer provided. After you test your tower for strength using the textbook, make notes about what happened and what you think may improve your design. Create at least three different designs.

Once everyone has had a chance to create at least three tower designs, each student or team can present their best design to the rest of the class. Below are some questions to talk about when you present your design.

What materials did you use?

Why do you think those materials did the best job of creating a strong tower?

What do you think could improve your tower design?

Batter Up! FACTivity Graphic Organizer

	Materials used	Sketch of design for tower	What happened when the textbook was placed on top of the tower?	What is a way to improve the design?
Tower 1				
Tower 2				

	Materials used	Sketch of design for tower	What happened when the textbook was placed on top of the tower?	What is a way to improve the design?
Tower 3				
Optional: Tower 4				

Natural Inquirer Connections

You may want to reference this *Natural Inquirer* article for additional information and FACTivities:

- For more information on comparing different types of materials, read "Which Do You A-Door?" in the *Natural Inquirer* Bioenergy edition.

This article, along with others, can be found at: http://www.naturalinquirer.org/all-issues.html.

If you are a trained Project Learning Tree educator, you may use "Tree Treasures," "We All Need Trees," "A Few of My Favorite Things," "Resource-Go-Round," and "Paper Civilizations" as additional resources.

Web Resources

Forest Products Laboratory: Broken bat incidents down by half in Major League Baseball thanks to research at USDA Forest Products Laboratory
https://www.fpl.fs.fed.us/news/newsreleases/releases/20110607.shtml

White Ash tree guide: Arbor Day Foundation
https://www.arborday.org/trees/treeguide/TreeDetail.cfm?ItemID=1082

Scientific American: Baseball Bats Made from Ash May Fall Victim of Climate Change
https://www.scientificamerican.com/article/baseball-bats-made-from-ash-may-fall-victim-of-climate-change/

Exploratorium: Tools of the Trade [Baseball bats]
https://www.exploratorium.edu/baseball/features/tools-of-the-trade.html