NOVA

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Secrets of the Samurai Sword

PROGRAM OVERVIEW

NOVA gains access to Japanese foundries, swordsmiths, and fighting schools to reveal what makes the perfect fighting sword.

The program:

- chronicles the history of the samurai sword, which dates back to before the 10th century.
- outlines the several-stage manufacturing process of making the katana, Japan's legendary samurai sword.
- describes throughout the program what happens to the sword on an atomic level as it is fabricated.
- points out how the process begins when very pure, iron-bearing river sand is combined in a clay furnace with charcoal and heated to a near-molten state to create a pure steel known as tamahagane.
- explains what metals are and details the properties that make them useful.
- shows how small metal samples and large metal structures are tested in university labs.
- illustrates the similarities between samurai movies and their modern Western counterparts and shows how samurai films influenced the American Western.
- clarifies the difference between iron (a naturally occurring element) and steel (a manufactured alloy) and explains how steel is made and why it is so much harder than iron.
- reports that the best pieces of steel are sent on to the swordsmith, who heats, hammers, and folds the steel repeatedly in order to further combine the iron and carbon, and to draw out any remaining undissolved impurities.
- explains how the swordsmith folds and beats the steel to form a bimetallic blade with an outer high-carbon steel shell around a low-carbon steel interior.
- shows how a mixture of clay and charcoal powder is pasted over the blade's surface to further refine the sword's properties.
- follows the sword as it travels to the final polishing stage, where it is rubbed with a series of grinding and polishing stones, some no larger than a grain of rice.
- describes the life of the samurai and his code of conduct.

BEFORE WATCHING

1 Have students brainstorm a list of common uses of metal alloys (e.g., a door frame, a doorknob, or a paper clip). Write these on the board. Discuss with students what characteristics make these metal alloys well-suited for their purpose. *(The door frame is very strong, the doorknob durable, and the paper clip malleable.)* What characteristics do students think would be needed in a samurai sword?

2 Have students document the process of making a samurai sword. Organize students into four groups and assign each group one of the following topics to take notes on as they watch: iron production and forging, sword hardening and sharpening, sword polishing and detailing, and sword testing.

AFTER WATCHING

1 Have each group create and give a short presentation for the class on its topic. Lead a class discussion on the steps required to make a samurai sword. How long does it take to produce a finished samurai sword using the traditional methods outlined in the program? Which part of the process takes the longest? What characteristics of the sword set it apart from all others?

2 The samurai warrior follows a strict code of conduct and honor. Have students read "The Way of the Warrior" at www.pbs.org/nova/samurai/way.html. Samurai are considered great warriors. Why do students think they put so much importance on other traits like honor, honesty, hard work, and loyalty? What elements of the samurai code are present in students' lives or in American culture today?

CLASSROOM ACTIVITY

Activity Summary
Students explore the characteristics of metals and produce a series of posters on different alloys, outlining their properties and how they are used.

Materials for Class
- world map
- ancient time line (spanning 2500 B.C. to present day)

Materials for Each Team
- copy of "Mixed-Up Metals" student handout
- copy of the Periodic Table (with element names included)
- samples of different types of metals and alloys, including aluminum foil or lead sinkers (metals), and stainless steel, solder, or brass (alloys)
- 18-inch x 24-inch poster boards
- markers
- paper glue
- self-stick notes

Background
More than 75 percent of the elements in the Periodic Table are metals. They are characterized by a metallic shine or luster, malleability and ductility (i.e., they can be worked with or drawn into thin sheets or wires without breaking), and conductivity (they are good conductors of heat and electricity). They are usually solids at room temperature (except for mercury). All metals have relatively high densities. Two or more metals combined create a metal alloy. In an alloy, the atoms of each metal are intermixed.

While samurai swords are made of metal alloys (high- and low-carbon steels) the swords themselves are bimetallic, a condition in which the metals are bound together but not intermixed as they are in an alloy. The steel of a samurai blade is heated and repeatedly folded and beaten until the forge-welded steel forms the blade. Each layer is only a quarter of a micrometer thick. Wrapping the high-carbon steel around a low-carbon steel creates a hard, but flexible, blade.

Samurai sword blades produced a thousand years ago represent the pinnacle of swordmaking. Yet the Japanese craftsmen who made them had no instruments to precisely measure the temperature or the carbon content of steel. Instead of depending on instruments to guide them, samurai sword makers dedicated their lives to their work, relying on decades of experience to determine when each stage of the swordmaking process was complete. For instance, the heat-treating and forging temperatures were determined and set by holding the blade of the sword up to the morning sun to determine its iridescent color. The knowledge was passed down through the centuries from master to apprentice.

LEARNING OBJECTIVES

Students will be able to:

- locate metals on the Periodic Table of elements.
- identify the properties of some common metals.
- define what an alloy is.
- explain how alloys can be used to produce objects that are used in homes and in industry.

STANDARDS CONNECTION

The "Mixed-Up Metals" activity aligns with the following National Science Education Standards (books.nap.edu/html/nses).

GRADES 5–8

Physical Science
- Properties of matter

Science and Technology
- Understandings about science and technology

Video is not required for this activity.

CLASSROOM ACTIVITY (CONT.)

In this activity, students explore the nature of metals and their alloys. An alloy is a mixture of at least two metals but may also include other elements. When metals are combined with other elements, the nature of the mixture has very different properties than the individual components. For example, pure iron is too soft to use to make knives. But if carbon is added, the alloy becomes hard enough to sharpen. And if chromium is added the alloy becomes corrosion resistant. The result is stainless steel.

Procedure

1. Assemble samples of as many metals and alloys as you can prior to beginning the activity for students to examine. Construct a class table on the board with the following headers:
   - Name/Symbol
   - Color
   - Melting Point
   - Density (g/cm^3)
   - Primary Use
   - Other Properties
   - Cost per Gram
2. Organize students into teams. Provide a sample of each type of metal or alloy you have collected to each team.
3. Ask students to examine the samples and discuss what the samples have in common and how they are different. *(Many of the samples will have a similar luster and hardness. Differences include color and hardness; some metals, like lead and solder, are soft and easily deformed, while others, like the stainless steel alloys, are rigid and strong.)*
4. Have teams refer to a Periodic Table. Ask them to find their samples on the table. They will soon discover, or they may already know, that some of samples cannot be found on the Periodic Table (such as stainless steel, brass, or solder) because they are alloys (mixtures of metals, not a single element).
5. Once the section that contains metals on the Periodic Table has been identified, ask students to think of some metals that they know about and find them on the table. What do students notice about the occurrence of metals on the table? *(Students might mention that the table is mostly made up of metals, that they are mostly clustered in the middle, or that they are arranged into different groups.)*
6. Assign a metal to teams. Give them some time to find information that is missing from the class table. (See *Links and Books* on this page for resources on the Periodic Table.)
7. Have students record their results in the class table and have a discussion that examines the properties of metals including:
   - What properties are similar for all metals?
   - What properties are different for metals?
   - How many metals are used in their pure form?

LINKS AND BOOKS

Links

NOVA—Secrets of the Samurai Sword
www.pbs.org/nova/samurai
Features facts about metals, information about the samurai code, the steps to make a samurai sword, and a time line of samurai history.

Chemicool Periodic Table
www.chemicool.com
Provides an interactive Periodic Table that includes information about elements and their states, energies, characteristics, abundance, and costs.

Its Elemental: The Periodic Table of Elements
education.jlab.org/itselemental/index.html
Allows user to search facts and information about elements by atomic number, chemical name, or chemical symbol.

Periodic Table of the Elements
periodic.lanl.gov/default.htm
Gives history, sources, properties, uses, costs, and handling for each element.

Samurai History, Culture, Swords
www.jref.com/glossary/samurai.shtml
Looks at all facets of the samurai swords and culture.

WebElements Periodic Table
www.webelements.com
Includes information on elements and their properties, discovery, history, and uses.

Books

Samurai: The Weapons and Spirit of the Japanese Warrior
by Clive Sinclaire.
Guilford, Conn.: The Lyons Press, 2004.
Provides an introduction to the martial art and artistry of the samurai.

Samurai: The Story of Japan's Great Warriors
by Stephen Turnbull.
London: PRC Publishing Ltd, 2004.
Details the history, weapons, and daily life of a samurai.

CLASSROOM ACTIVITY (CONT.)

8 Once students have come to discover that most metals are not manufactured in their pure form (in fact, very few metals occur uncombined in nature) have them begin their investigation into alloys. Distribute the student handout and other materials. Assign one of the following alloys to small teams of students or let teams choose one to research:

- brass
- bronze
- cast iron
- carbon steel
- pewter
- solder
- sterling silver
- stainless steel
- wrought iron

9 Give sufficient time for students to complete their information gathering process and to produce their posters. Put a blank world map and the time line in a place where students can add information to them.

10 Have each team present its research to the class, putting a self-stick note on a world map and time line to locate where and when the earliest evidence for the alloy occurred. To conclude, have students make a class list of alloys that they come in contact with in their daily lives. (*Students will mention alloys such as brass, cast iron, wrought iron, and others.)*

11 To illustrate a real-world example of how engineers test metal alloys for toughness, show students the portion of the program (2:56) that illustrates how both small samples and large structures are tested in university labs.
www.pbs.org/nova/teachers/activities/3412_samurai.html#video
(QuickTime, RealVideo, or Windows Media plug-in required.)

12 As an extension, have students pick an alloy, and research how it is produced. Ask students to write a one-page summary that includes the percentage of metals that comprise the alloy, where the metals are found in nature, and the process needed to make the alloy.

Classroom Activity Author
Jeff Lockwood taught high school astronomy, physics, and Earth science for 28 years. He has authored numerous curriculum projects and has provided instruction on curriculum development and science teaching methods for more than a decade.

ACTIVITY ANSWER

Specific properties of metals (hardness, density, conductivity, malleability) determine how they are used and applied in household products and in industry. Gold is used for very delicate circuitry because it is so malleable and can be beaten into sheets just a few molecules thick. Sometimes cost is a major factor. Gold and silver are better conductors of electricity but are too expensive to use for ordinary wire so copper is used. Both copper and silver are too expensive to make coins from, so alloys of zinc and copper are used.

Basic facts for each alloy are provided below. Evidence for earliest use may vary as not all researchers agree about where and when each alloy was first used. Accept all reasonable answers.

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Alloy	Component Elements*	Useful Properties	Additional Facts
Brass	copper and zinc	• higher malleability than either copper or zinc • relatively low melting point • very ductile	• almost 90 percent of brass today is made from recycled brass • used to make screws and wires
Bronze	copper and tin	• much harder than pure iron • lower melting point • resistant to corrosion	• popular alloy for the production of statues and medals
Cast Iron	iron, carbon, and silicon	• low melting point • easy to cast • wears well	• many old bridges were made of cast iron • used in pipes, cookware, machine, and car parts
Carbon Steel	iron and carbon	• adding carbon makes steel many times stronger and more flexible than iron	• one of the most common building materials in the world • most widely recycled material in North America • used in cars, bridges, buildings, and appliances
Pewter	tin and copper	• very malleable • low melting point • quite soft	• oxidizes to dull-gray color over time • used to make plates, mugs, and candle sticks
Solder	tin and lead	• very low melting point	• used to connect electrical components • often mixed with flux to improve electrical connection
Sterling Silver	silver and copper	• adding copper gives increased strength while preserving ductility	• oxidizes to dull-gray color over time • used for jewelry
Stainless Steel	iron, carbon, and chromium	• does not oxidize and turn black, corrode, or rust as easily as carbon steel	• used for items such as cutlery, surgical instruments, and watchbands
Wrought Iron	iron and carbon	• very malleable • very ductile • easily welded	• purest of all iron alloys • used for fences, window coverings, and gates

* Percentages of component elements vary depending on the properties desired in the alloy. Trace elements not included.

Mixed-Up Metals

Combining two or more metals together forms an alloy. It would likely be impossible to find a single room in your house that didn't contain a metal alloy. Alloys often have different properties than either one of the elemental metals used to produce them. In this activity, you will explore the nature of different types of alloys.

Procedure

1 Your team will be assigned or will choose one of the following alloys:
- brass
- bronze
- cast iron
- carbon steel
- pewter
- solder
- sterling silver
- stainless steel
- wrought iron

2 Your report will need to address the following:
- What combination of elements make up the alloy?
- Where and when was the earliest evidence of the use of the alloy?
- What properties of the alloy make it useful in homes or in industry?
- Any other interesting facts about the alloy.

3 Produce a visual display of your research. Bring in a sample of your alloy if at all possible to show to the class during your presentation.

4 When you present your information, use self-stick notes to locate on the class world map and time line the region and time in which the first evidence of your alloy was discovered.