2.3 THE SCIENCE OF BOW DRILL FIRE MAKING: BIOLOGY

2.3.1 TEACHING TIPS

Suggested Approach

In Biology, fire making is used to pique students' interest and lead them to study various biological concepts. The lab is designed for one lab period (about 45 minutes). As written, this is ideally done with the teacher leading the students through the "Procedure" section while demonstrating the technique. Actually demonstrating the technique can take as little as 5-10 minutes. The Introduction and Procedure can be completed in about 15 minutes. This leaves 15-20 minutes for a wrap-up discussion and the "Analysis and Conclusions".

If time is available, the teacher can provide the students with an opportunity to try the technique themselves. This can be done in several ways with different levels of structure built into the activity. In one case, the students are divided into lab groups with each group receiving its own bow drill set. Each student in the group is given an opportunity to try the bow drill individually while the other group members offer suggestions to maintain proper form. While this approach has the students emulate the technique demonstrated by the teacher, a less structured alternative is often used. Instead of one student operating the bow drill with the others watching and supporting, the students are told that as many members of the group as possible (or the entire group) are to be directly involved. This creates an open-ended problem, as they have been shown no technique for performing this task as a group. Students tend to come up with very creative solutions but the possibility of frustration is greater since they have less guidance. Both approaches require multiple bow drill sets. If the teacher has only one bow drill set, student volunteers can be allowed to try the technique in front of the class, individually or as a group.

If time allows, another possible introduction, provided in Section 7.1.1, involves having students imagine being lost in the woods and needing to stay overnight. They then brainstorm what their biggest threats to survival are. Through discussion and questioning, the teacher leads students to an understanding of the "Law of Threes" (Section 7.1.1). This provides a "public service" to students by sharing critical information that can help them survive should they get lost in the future.

Before beginning, you also need to decide whether you and your students will use a "beginner's bow drill" or a fully functioning bow drill set in an attempt to produce an ember. Options for acquiring the apparatus suited to your purpose are discussed in Section 3.1. It's important to set the students' expectations realistically. If you do the basic demonstration, tell them there are a few more steps to actually produce an ember, but you will be showing most of the process. If you wish to attempt to produce an ember, plan more time than if you were just demonstrating technique.

Safety Suggestions

-Schools may not want smoke generated in a classroom, even in a small amount.

The technique can be demonstrated with virtually no smoke to illustrate the science concepts involved, but obviously no ember would be produced. An outdoor location is ideal. Also, some students may be sensitive to smoke, or have asthma or allergies. Appropriate precautions must be taken.

-If you desire to show students the entire process and blow an ember into a flame, be sure to have a fume hood, sink or similar fireproof site immediately available and at no risk to students. Again, an outdoor location is ideal.

- Whenever working with sticks, be sure that you and your students have sufficient space to avoid injuring one another.

- While the bowstring is wrapped around the spindle, it is under considerable tension. During this time, the spindle can fly off the bowstring if not sufficiently restrained. This most commonly happens 1) while attempting to wind the bowstring around the spindle and 2) while spinning the spindle with the bow. Use appropriate caution. As with any activity where objects may fly through the air, safety glasses are indicated when students are operating the apparatus or near someone else who is operating the apparatus.

- Even if there is no smoke, the surfaces of the spindle and fireboard that are in contact get hot. Warn students not to touch them.

Extensions

The materials section of the lab introduces the components of the bow drill apparatus and provides an opportunity to discuss various types of woods and their properties. This can be extended to a study of the habitats of various trees. For example, in what habitat would one expect to find the wood used in this lab? Question 6 under “For Further Investigation” lists suggestions for information that can be gathered from field guides. A field trip to identify and gather material would provide an excellent opportunity to compare the field guide information to the living tree.

If time permits, the “Analysis and Conclusions” portion of the lab may compare results from different species of wood or from "green" wood versus "seasoned" wood. Questions and discussions concerning human technology and interaction with the environment can be developed here.

Question 13 under “Analysis and Conclusion” introduces the discussion of the energy relationship between photosynthesis and combustion. This discussion can be extended in many ways. For example, mechanical energy is obviously converted to heat energy during the bow stroke. Students may require help to understand that chemical energy stored in their bodies is converted to mechanical energy to move the bow (glucose - ADP-ATP interaction).

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THE SCIENCE OF BOW DRILL FIRE MAKING: BIOLOGY (TEACHERS' EDITION)

The suggestions offered to the teacher in this Teachers' Edition are written in the font currently being used, Comic Sans MS, and are not present in the student edition. The portions of the labs (both student and teacher editions) providing information to the student are in *Arial Italics font*. **Where the student is to compete a task or answer a question,** Arial regular font **is used.**

INTRODUCTION

Fire is one of nature's most powerful tools for both altering and maintaining ecosystems. Some plant species, such as pitch pine, require fire to reproduce. Fire opens their cones and allows their seeds to fall to the soil and grow.

Fire is also a vital tool for humans. Fire allows humans to live in cold climates, cook food, purify water, make tools and offers protection. Today we don't often see fire directly at work in our everyday life. Usually we see only its effects - hot water, heated buildings, manufactured products, etc. If we desire fire, it is easy to strike a match or a lighter and instantly have it. But how did people make fire before matches and lighters? How is fire made using only "natural" resources? This lab will provide some answers to these questions by investigating fire by friction using the bow drill.

OBJECTIVE

To understand the science behind making fire by friction.

PROCEDURE

As with most skills, the knowledge required for success with the bow drill can be divided into three types: materials, methods and theory. We'll start with materials.

Materials: *The parts required for a bow drill are listed below. Figures 1-4 illustrate some of the components.*

Use the information in the next section and any information from your instructor to write a brief description of the following components of a bow drill fire making apparatus.

A. bow

Relatively rigid, approximately arm length with good curvature. Allows you to

rotate the spindle much more rapidly than can be done with the hands alone. You can have the students compare spinning the spindle with their hands versus with the bow, or you can demonstrate for them.

B. spindle

A little less than thumb thickness and length from end of thumb to outstretched pinky finger. Spins rapidly in the fireboard. Friction between the spindle and fireboard generates the heat and dust required to produce an ember.

C. fireboard

A little less than thumb thickness, length of your forearm, width of arm or hand. Creates heat and "dust" by friction with the spindle. This hot dust is compacted and further heated in the notch of the fireboard to form an ignited ember.

D. handhold

Sized to fit comfortably in your hand. Holds the spindle straight in place. Allows you to control the normal force applied to the spindle/fireboard interface.

E. lubricant

Any material that reduces friction between surfaces. I usually wait till later in the lab to give the following details, and I have them figure it out using a series of questions. We do not want lubrication at the fireboard/spindle interface because the friction produces the heat and dust necessary for the ember. But friction at the handhold is a waste of energy (effort) and should be minimized through the use of a lubricant. Water and water-based products are not effective lubricants. Soap works well as do conifer needles. Skin oil, easily obtained from the side of the nose or scalp, also works.

F. tinder bundle

Tinder is any very dry, fine, easily combustible material. For practice, jute twine (from garden or hardware shops) works great. Unravel the twine (or whatever you're using) and make a baseball-softball size mass. You want a lot of material but also adequate air circulation. This is a bit of an art. Birch bark does not catch fire until there is an open flame, but it can be useful in extremely thin pieces mixed throughout to help when the ember ignites. Cattail down does not ignite easily, but some people use it as an "ember extender" - that is, although it does not ignite, it smolders and produces heat and hot mass that effectively

increases the size of the ember and the chance of ignition.

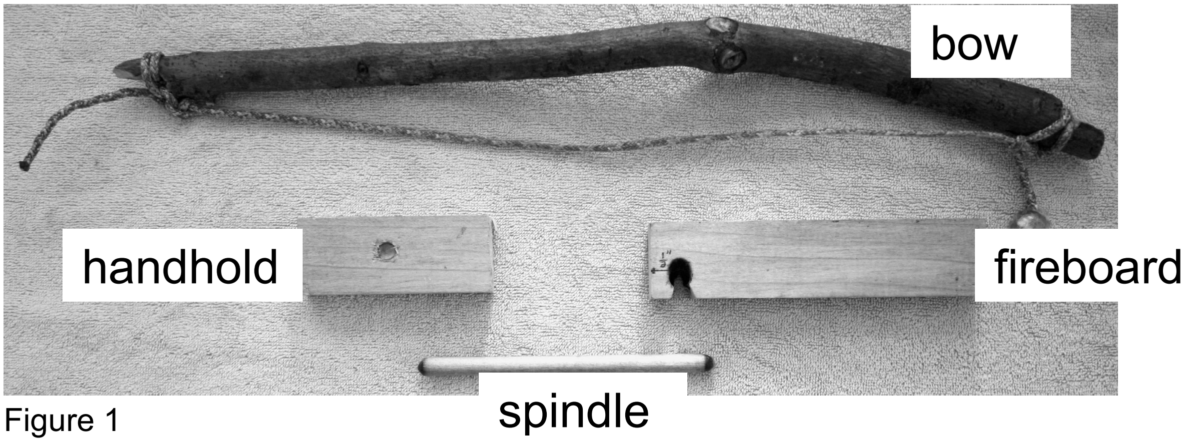

Figure 1

Technique: *The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 2-4 during the following description).*

The bowstring is wrapped around the cylindrical spindle. (Figure 2)

Figure 2

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 3)

Figure 3

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 4)

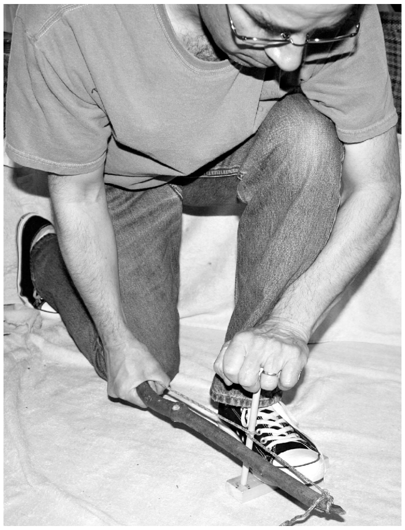

Figure 4

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.

The proper technique will be demonstrated for you now.

Make observations using sight, sound and smell. List them below.

Depending on your age group and focus, you may want to review the five senses here. This is also an opportunity to distinguish between observation and inference.

There are many visual observations - the person's body position and motion, the position and motion of the bow drill etc. Many sounds are also audible. Soon after, someone usually detects a burning smell - often before smoke is actually seen. One reason I like to use cedar is that the aroma is pleasant to most people.

ANALYSIS AND CONCLUSION

Answer the following questions on a separate piece of paper.

1. Was a fire created? If not, explain your result.

Answers vary with results

2. What is an ember and how is it formed?

An ember is a smoldering mass of wood particles. They were worn from the spindle and handhold and heated by friction while being compacted in the notch.

3. At what part(s) of the bow stroke does the spindle stop moving (it's velocity becomes zero)?

Beginning and end

4. Acceleration is change in velocity. If the velocity is not changing, what is the acceleration?

Zero

5. What physical force generates the heat energy that creates the ember?

Friction

6. Why is a lubricant used between the spindle and the handhold?

The purpose of the handhold is to apply pressure to the spindle and keep it properly aligned. Friction at the spindle-handhold interface does nothing to help create the ember. Instead this friction slows the spindle and wastes the energy of the operator.

7. Pine trees (and some other conifers) contain a natural resin that can act as a lubricant. Why would this make pine a poor choice for the spindle and fireboard of a bow drill?

At the spindle-fireboard interface friction is necessary to produce the material and heat that will create the ember. Using a wood that contains a lubricant will make it more difficult to generate the necessary friction.

8. Oak and maple are 2 of the hardest woods in the northeast. Do you think these would be a good material for a spindle and fireboard? Explain your answer.

Very hard wood is also a poor choice for bow drill material. The wood needs to be soft enough to wear away with moderate force. If the wood is too hard it

will be difficult or impossible to produce enough "dust" to create an ember (or the texture of the dust will not be right)

9. Describe a difference between coniferous and deciduous trees? Give three examples of each.

The most common answer will probably be that conifers keep their needles all year and deciduous trees lose their leaves in the fall. This is mostly true although there are coniferous species like tamarack that shed their needles in fall. Other common answers are that conifer leaves are usually needle or scale shaped and they produce seeds in cones. Specific examples will vary with location but in upstate New York conifers include Eastern White Pine, Balsam Fir, Red Pine, Pitch Pine and Eastern Hemlock. Common deciduous species include White Oak, Sugar Maple, Quaking Aspen, American Beech and Paper Birch

10. How is fire similar to respiration that occurs in living things? How are they different?

Both consume a hydrocarbon fuel using oxygen. Both convert chemical energy to some other form. Fire releases energy quickly and at a much higher temperature than a living organism could tolerate. Respiration releases energy more gradually. Energy released through respiration is used for a wider variety of purposes than burning.

11. It is said that the burning ember produced by a bow drill is really the liberation of the solar energy that has been stored in the wood. Explain how this is true. (Hint: Think about photosynthesis.)

Through the process of photosynthesis, plants store the light energy of the sun in the chemical bonds of glucose and other compounds. The energy emitted from the burning ember as heat and light results from breaking those chemical bonds, and rearranging the component atoms into lower energy molecules (like carbon dioxide and water). The difference in energy between the starting material (wood) and the combustion products (carbon dioxide and water) is released as heat and light, making this an exothermic reaction.

FOR FURTHER INVESTIGATION

1. What is the purpose of the notch in the fireboard?

2. What other ways have been used by people to make fire by friction?

3. What other techniques besides fire by friction did people use to make fire?

4. Why do you think different cultures used different techniques? Support your answer with at least one example.

5. Instead of making fire, some people harvested fire and stored it. How was this done?

6. Is fire making a uniquely human activity in the animal world? Support your opinion.

7. From what species of tree does your wood come? (Ask your instructor if you don't know.) Using a physical or electronic field guide, gather the following information about this tree:

   a. Scientific name (genus and species)
   b. Family
   c. Common name of one other tree in this family
   d. Height
   e. Width
   f. Describe the bark
   g. Describe the cones or seeds
   h. Type of land where it grows (habitat)
   i. Geographic area where it grows (range)
   j. Name one animal that uses the tree
   k. Name 2 things people use the tree for
   l. Describe symbiotic relationships the tree has with other plant species
   m. Describe common uses for this tree by people.
   n. Name at least one insect pest for this tree and describe the damage done.
   o. Name at least one insect that benefits the tree and describe the benefit to the tree.
   p. Sketch the tree in its preferred environment

8. What is an indicator species? Is the tree used in this lab an indicator species for its preferred habitat? If not, name at least one plant species that is an indicator species in that habitat. Name the book or website used to find this information.

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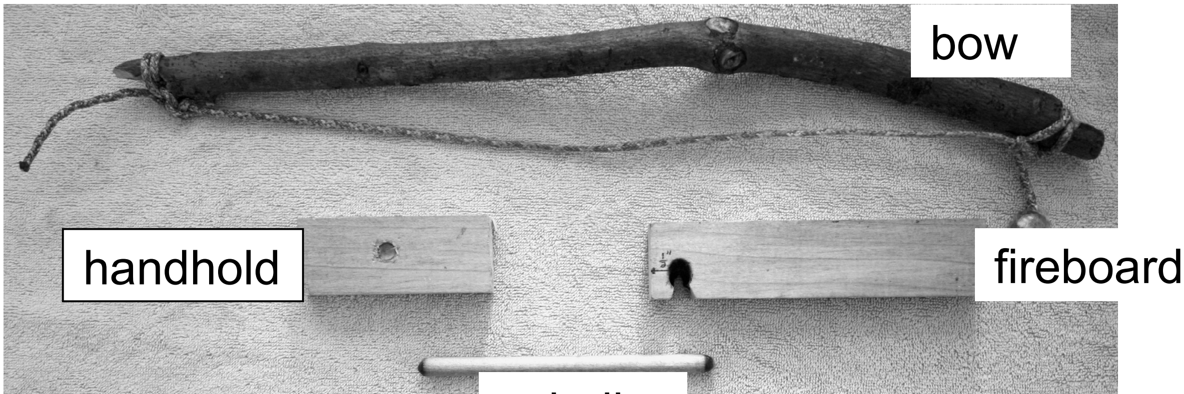
B. spindle

C. fireboard

D. handhold

E. lubricant

F. tinder bundle



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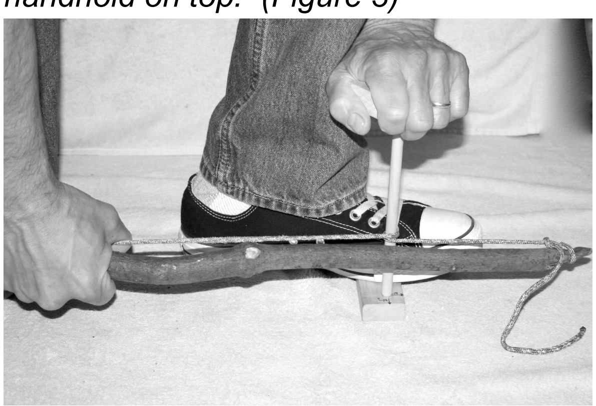

Figure 3

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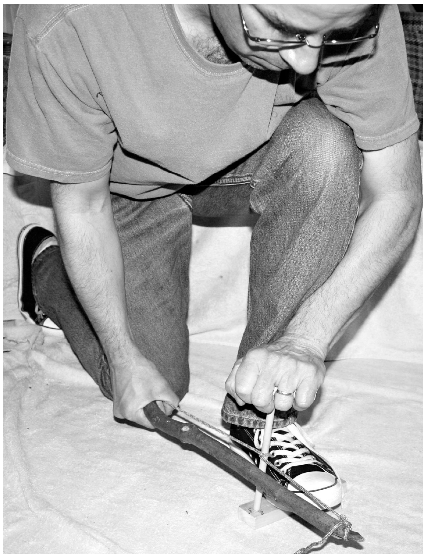

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FOR FURTHER INVESTIGATION

1. What is the purpose of the notch in the fireboard?
2. What other ways have been used by people to make fire by friction?
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4. Why do you think different cultures used different techniques? Support your answer with at least one example.
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3 The Bow Drill

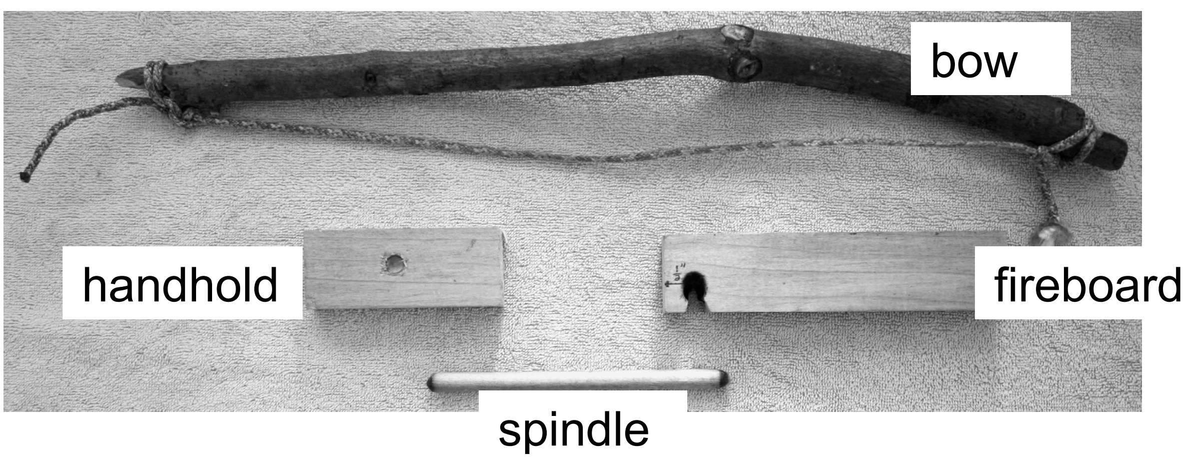
3.1 ACQUIRING A BOW DRILL SET

The quickest and cheapest way to begin your “quest for fire” is to make a “beginner’s bow drill” as described in detail in Section 3.1.1 below. This bow drill set is the easiest to build and learn with. One disadvantage is that while easy to use, creating an ember is difficult with these sets.

Section 3.1.2 outlines how to make a standard, fully functional bow drill set from natural materials. While requiring more effort and tools to build than the beginner’s set, the standard bow drill set can reliably produce an ember. In addition, one develops a connection to the tree and habitat from which the wood was harvested.

Lastly, Section 3.1.3 lists sources for purchasing pre-made bow drill sets. Other ideas for obtaining bow drill sets are included.

Regardless of which of these methods you choose, a working knowledge of the bow drill components is required. A brief description follows. Note that more information about bow drill components is included in the teacher edition of the labs.



Bow: Relatively rigid with a little flexibility, approximately arm length with a good curvature and some sort of notching or branching at the ends to tie the bowstring.

Cord: Required for the bowstring. If it is too thin or too thick, the cord may be difficult to work with.

Spindle: A little less than thumb thickness and length from end of thumb to the outstretched pinky finger.

Fireboard: A little less than thumb thickness, length of your forearm, and width of your arm or hand

Handhold: Sized to fit comfortably in your hand.

Lubricant: Any material that reduces friction between surfaces. Water and water-based products are not effective lubricants. Soap works well as do conifer needles. Skin oil, which is easily obtained from the side of the nose or scalp, also works.

Tinder bundle: (Only needed if you intend to start a fire.) Tinder is any very dry, fine, easily combustible material. For practice, jute twine (from garden or hardware shops) works well.

3.1.1 Making a Beginner Bow Drill Set

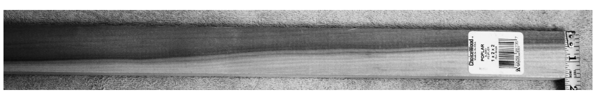
Below is a shopping list for your local hardware store. You may have some items around the house. Avoid oak, maple or other hardwoods. Stores like Home Depot and Lowes have poplar and pine available and inexpensive.

Materials Checklist:

_____ Wood dowel (for spindle) 3/8 inch (in) diameter. Usually sold in 48 in lengths.

Later you will cut (or break) this into 6 in lengths. Cost ~ $1 for poplar

_____ Wood board (for fireboard) 1 in thick by 2 in wide, usually sold in 24 in length or longer.



The shorter lengths are usually straighter and easier to handle. Avoid pieces with many knots or cracks. A few are ok but you need areas clear of knots or cracks to mate with the spindle. $1.90 for 24 in, $3.20 for 48 in. The advantage to the 24 in is that, though cumbersome, it is can be used without cutting.

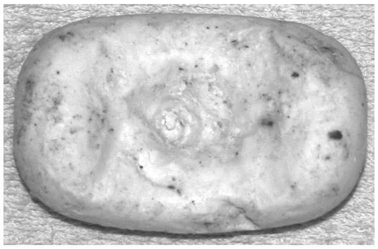
_____ Wood board (for handhold) You can cut a 4 in length of the 24 in fireboard (above) to make a 2 in x 4 in handhold (1 in thickness). You can also use any scrap of wood that fits pretty comfortably in your hand. Usually people like something thicker than 1 in, but that's personal preference. Hardwoods work well here because they will not wear away as quickly. Some people carve a soft stone like soapstone because is virtually never wears and reduces friction to as close to zero as possible. However, it requires a greater initial investment in time and tools.

_____ Cord (for bowstring) "Paracord" or "550 cord" or "parachute cord" are common terms for a 1/8 in diameter nylon cord that is widely available.

Since you only need about 4 feet to start, there is probably something around the house or classroom that you can use. The cord can be a little thicker or thinner or made from different material (ex. cotton). The cost for "paracord" or the equivalent is $5 - $10 for 50 feet.

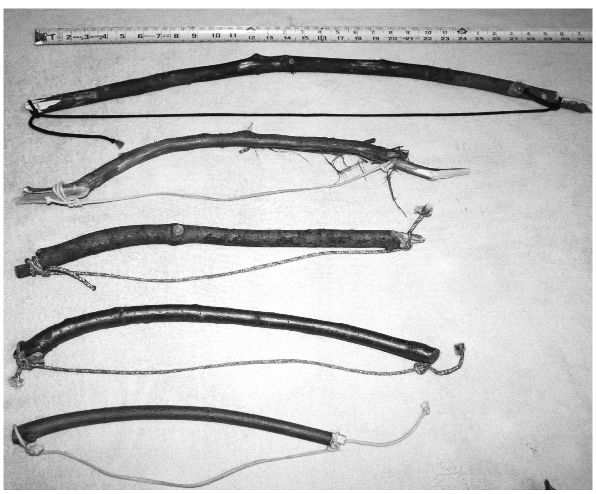
_____ Tinder: Tinder is any very dry, fine, easily combustible material.
For practice, jute twine (from garden or hardware shops) works well. Unravel the twine (or whatever you're using) and make a baseball size mass. You want a lot of material but also adequate air circulation. This is a bit of an art. Birch bark does not catch fire until there is an open flame, but it can be useful in extremely thin pieces mixed throughout to help when the ember ignites. Cattail down does not burn well, but some people use it as an "ember extender" - that is, although it does not ignite, it smolders and produces heat and hot mass that effectively increases the size of the ember and the chance of ignition.

_____ Lubricant: Use a bar of inexpensive bar soap, like Ivory.



Avoid strongly perfumed soap because the handhold will heat up some and the smell will become more pronounced and usually unpleasant. Pine, cedar or hemlock needles also work.

_____ Bow: I've never used anything from a hardware store to make a bow, though I've heard of people using long, thin slabs of wood that bend when a string is attached. I've procured my bows from fallen branches or trees that need pruning. You're looking for a branch with significant curvature and about the length from your elbow to fingertips, though usable bows can be longer or shorter. The advantages of different length bows are discussed in the teachers' version of the physical science lab.



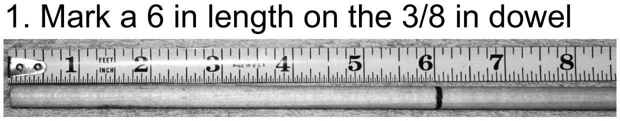
Usually, the bow is relatively thin (thumb thickness) but most importantly it cannot be too flexible or brittle. A strong rigid bow works fine. I learned on this type of bow. Bows with some flexibility are a little better as they can help keep the string in tension, even if the string stretches or knots loosen.

<u>Assembling:</u>

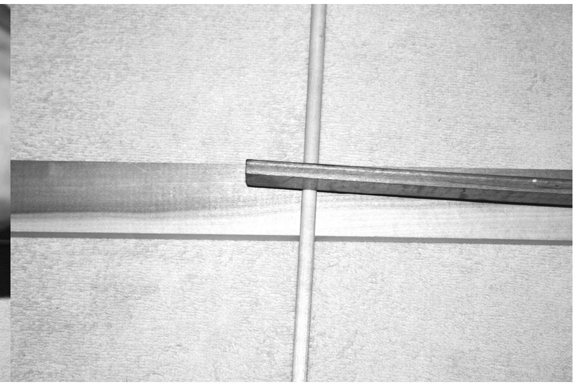
Once you've gathered the above materials, it's time to begin to assemble your new bow drill set.

<u>Spindle</u>

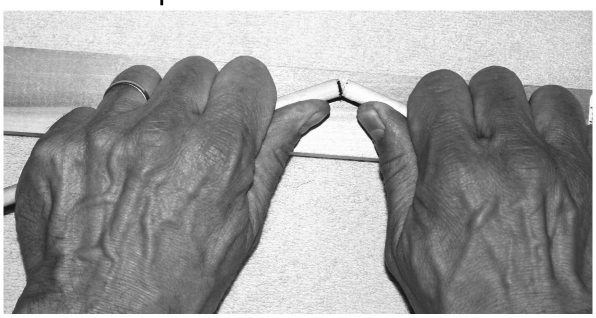
1. Mark a 6 in length on the 3/8 in dowel



2. Score the dowel on the 6” in mark with a flathead screwdriver or similar tool (even the edge of most rulers will work).

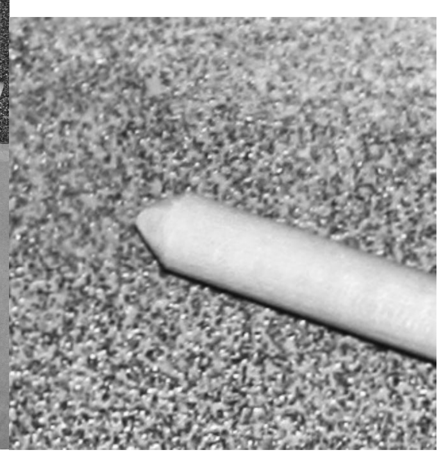
Grasp the dowel on each side of the score mark and break it. As no sharp tools are used, this technique can be used in class.



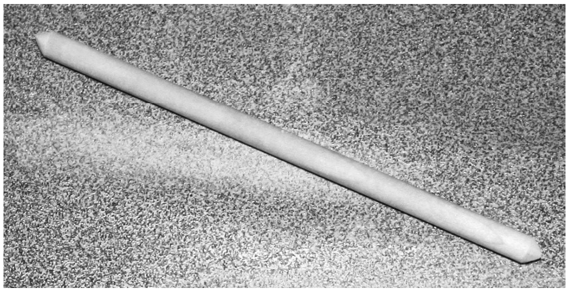
OR

Cut the dowel with a saw or knife.
Either way, you now have a 6 in spindle.

3. Rub one end of the spindle on a piece of medium to coarse sandpaper to produce an end with a dull point.



Avoid a sharp point for safety reasons. Rotate the spindle while rubbing to get the end as symmetrical as possible. Repeat the procedure on the other side.



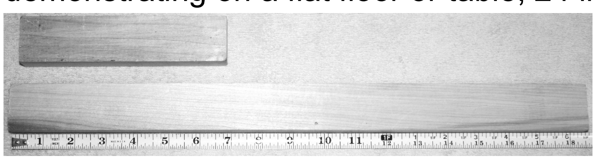
OR

Use a knife to create the dull points on the ends.

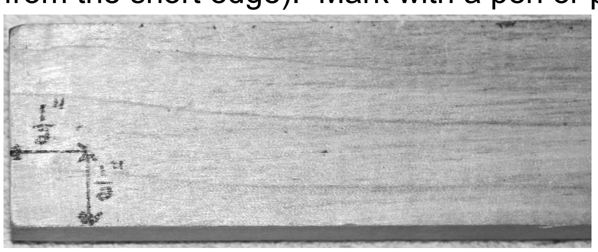
Your spindle is now done.

<u>Fireboard</u>

1. If your board is longer than 24 in, cut it to about 8-12 in.   If you purchased the 24 in board, you can use it “as is”. Longer fireboards are cumbersome, but if you’re demonstrating on a flat floor or table, 24 in should be ok.

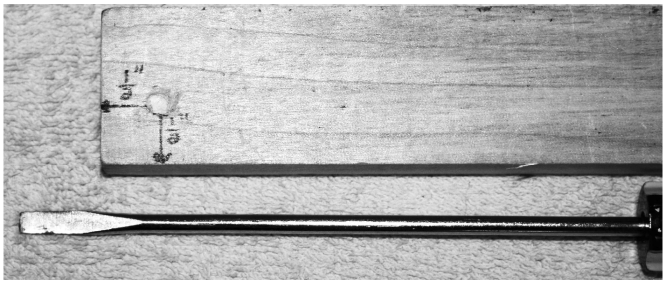


2. Measure about ½ in from the long side of the fireboard (also be sure to be at least ½ in from the short edge). Mark with a pen or pencil.



3. Use a flathead screwdriver to start a hole at the mark you made. Push down on the screwdriver and twist back and forth to create a hole in the fireboard.

4. You are creating a depression in the fireboard so the spindle will “seat” and not slide off the fireboard, when spun with the bow.



5. Once the depression looks deep enough to keep the spindle in place, you’re done. Keep in mind that if this depression is too shallow, getting the bow drill started will be difficult.

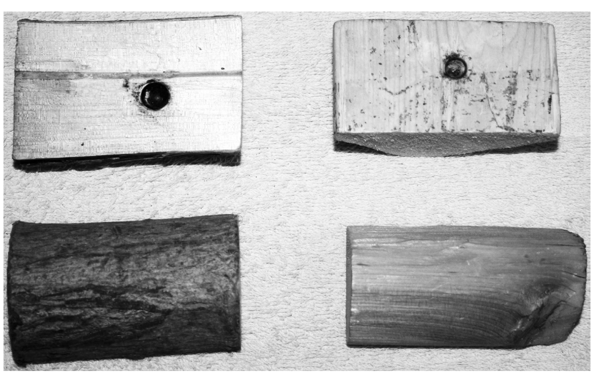
OR

Make the depression with a knife or other sharp tool.

NOTE: This is all you need for a beginner’s fireboard. To create an ember, a notch needs to be cut as described in Section 3.2, Technique.

Handhold

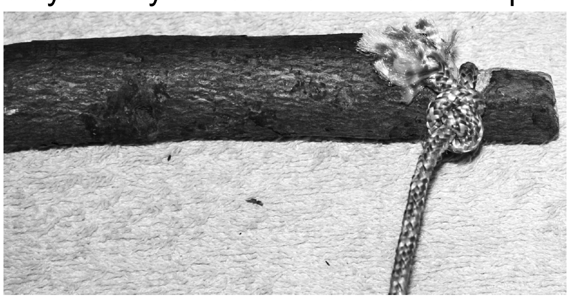
Once you’ve found a piece of wood (or other material) suitable for a handhold as described in the beginning of this chapter, carve a depression in the middle of it in the same way you did with the fireboard. Make the depression in the handhold a little deeper than the fireboard. You want to avoid the spindle “popping out” of the handhold.



Bow

1. Examine each end of the branch you chose to use as your bow. You are looking for places to easily tie the bowstring, like knots or other irregularities. Try tying one end of your bowstring and pull hard. If it holds, you have a good attachment site. If there is no good natural attachment site, you’ll need to use a knife or saw to cut a notch.

2. Once you have a suitable attachment site at each end, tie your bowstring to one end (Don't cut your cord yet). This should be a secure knot. All that matters is that the string stays firmly attached and doesn't slip or loosen.



3. Next, cut your cord so there is about 10" beyond the far end of the bow.

4. Tie the bowstring to the other end of the bow. This knot also should not slip, but make it as uncomplicated as possible. You will need to readjust the tension of the bow often so the easier the knot is to undo, the better. The bowstring usually should have a little slack in it. This will depend on the diameter of the spindle and the flexibility of the bow. Soon you will wrap the bowstring around the spindle and this will increase tension. Also, if you have a very rigid bow, the bowstring needs to be a little looser or you won't be able to get the spindle on. If your bow has some flexibility, the bowstring doesn't need to be as loose because the bow will bend and provide "slack" to wrap around the spindle.

3.1.2 Making a Standard Bow Drill

Because there are several fine references that describe in detail how to make a bow drill from natural materials, the procedure is only briefly described below. My primary reference in book form is “Tom Brown’s Field Guide to Wilderness Survival” (see Reference Chapter for full citation). The websites http://www.wildwoodsurvival.com/survival/fire/bowdrill/index.html and http://www.natureskills.com/survival/creating-a-bow-drill/ are among several that provide detailed information, pictures and video.

Wood Selection

Choose wood from a medium hardness tree that is dry but not rotting. People tend to have success with trees like cedar, aspen, willow, poplar and cottonwood. Avoid very hard woods like oak and hickory and soft, resinous woods like some pine, fir and spruce. To test the wood, push your thumbnail into it. Your nail should make a clear mark in the wood. If the wood crushes or crumbles, it is too soft. It your nail barely makes a mark, it is too hard. It is best to collect the wood from dead branches of trees that are well off the ground and away from water sources.

Spindle

The spindle should be a straight cylinder, 6 – 8 inches (in) long and about ¾ in diameter. Look for a straight round branch with as few knots as possible. After selecting, carve the surface as smooth and round as possible. The spindle should roll easily on a flat surface. A larger or smaller spindle can still produce an ember, but bent or non-circular ones usually don’t. Experiment with different sizes as different people prefer different dimensions.

If a round branch is not available, one can use a large knife or hatchet to split larger pieces of wood until close to the required size. The problem with this method is that an irregular, angular cross section is obtained and much more carving is required to produce a symmetrical, round spindle.

Fireboard

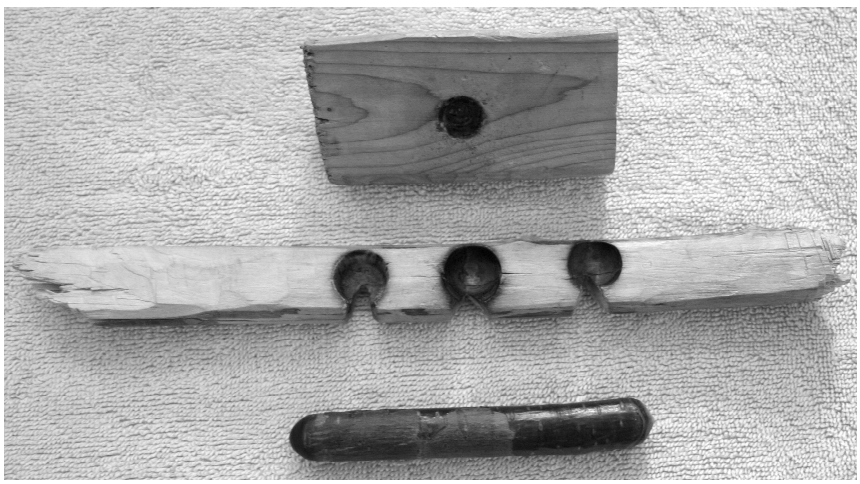
The fireboard should be ½ - 1 in thick, 8 – 12 in long, at least 2 in wide and made from the same wood as the spindle. If it’s not possible to make it out of the same wood, then use a wood of similar hardness. When the fireboard and spindle are of significantly different hardness, the harder one tends to wear the softer one quickly without producing an ember. Ideally, one branch can provide both the fireboard and spindle. The thicker part of the branch near the tree provides the fireboard, while the spindle is made from the smaller diameter section of the branch farther from the tree trunk. To make the fireboard, harvest the branch and cut it to length. Imagine your branch having 4 sides at right angles. Using a knife or abrading surface, create 2 parallel, flat surfaces. One of these surfaces (bottom) needs to be flat to rest on the ground without rocking back and forth. The parallel surface (top) needs to be flat to easily mate with the spindle.

As with the spindle, the fireboard can be made by splitting a large section of tree branch or trunk to the required size using a knife or hatchet. A knife or abrading tool is used to produce the required flat, parallel surfaces.

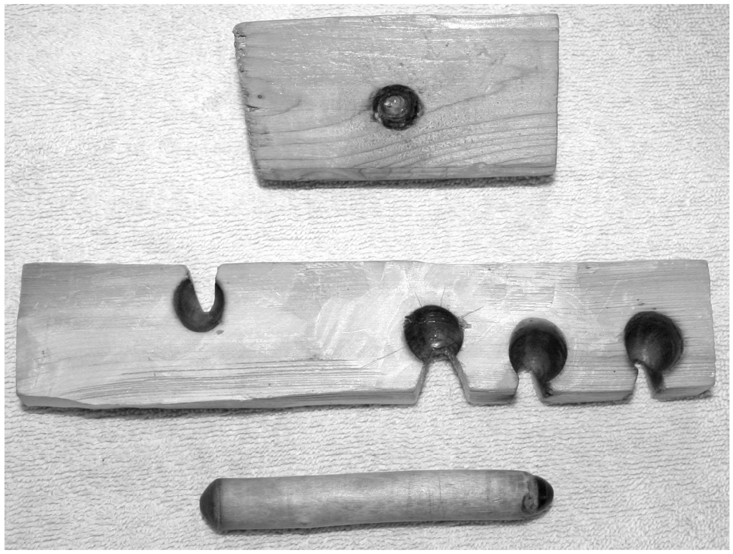
Handhold

The handhold is the same as described is Section 3.1.1. It should fit comfortably in your hand, have a relatively deep depression to hold the spindle and be as hard or harder than the spindle. While the handhold can be made out of the same wood as the other components, stone, bone or harder woods can also be used.

Photographs of 2 very productive bow drill sets are below.



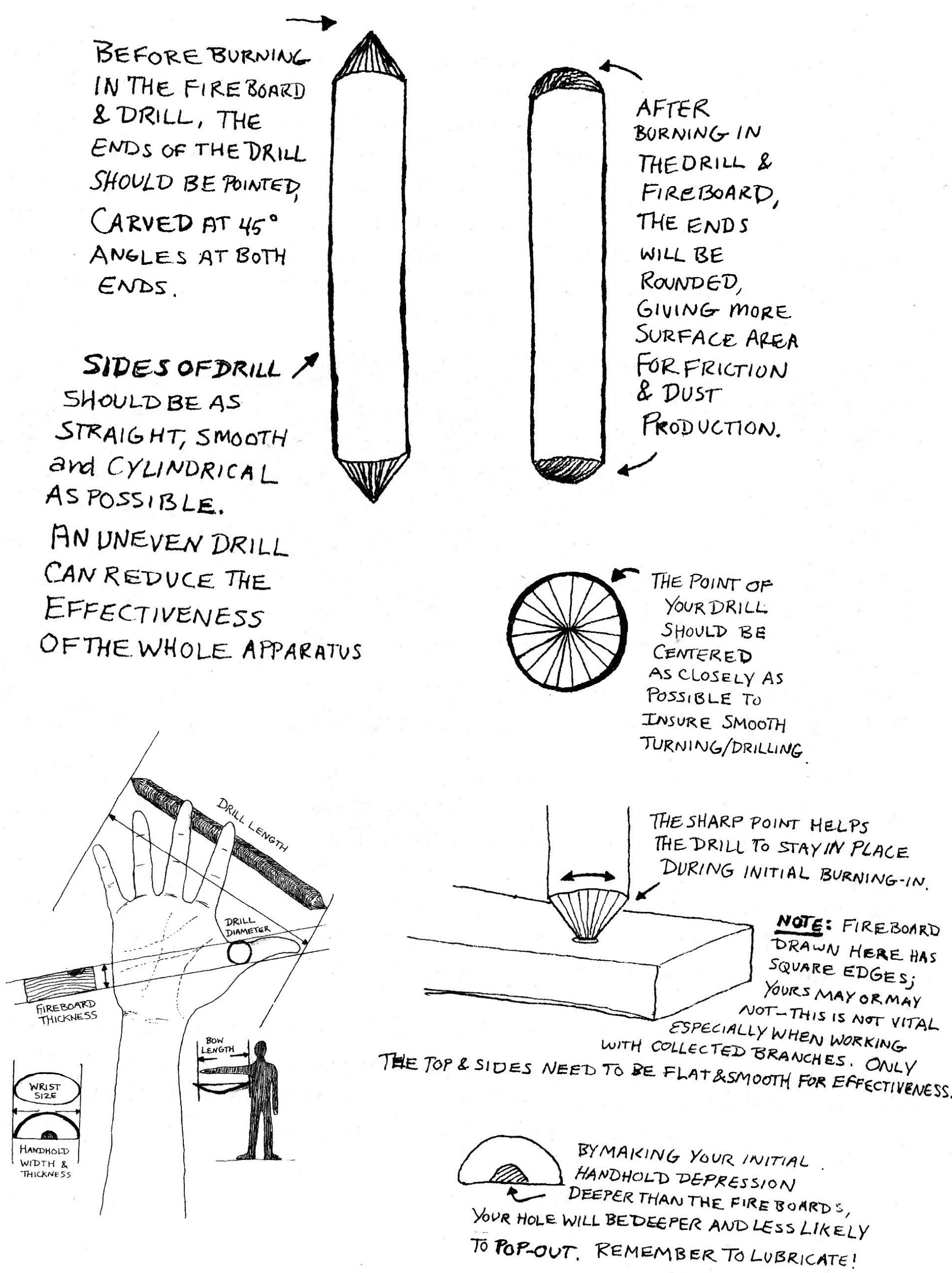
The fireboard and spindle in the above photograph were both carved from a branch harvested from a wild cherry tree. Several fires were started with this set. The fireboard shows a little of the curvature and change in width typical when made from a branch.

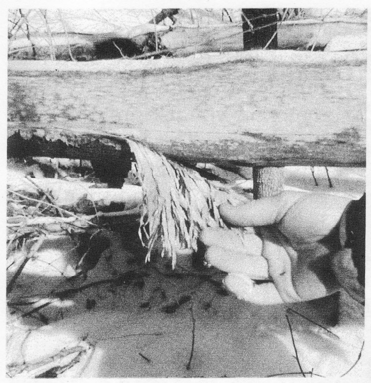


The fireboard and spindle in the photograph above were made from an 8 in diameter cedar trunk. The section of trunk was first rough split with an axe, then more carefully spilt and carved with a sturdy knife. The fireboard has the typical angular appearance produced by this method.

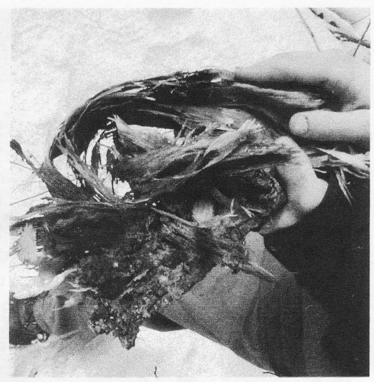
The diagram and photographs on the next 2 pages are courtesy of Ricardo Sierra and Hawk Circle Programs, a wilderness skills education program in Cherry Valley, New York. See References for full citation. The diagrams provide a concise summary of bow drill information.

BOW DRILL DETAILS





1) Stripping the loose inner bark from the ash tree.



2) A handful of inner bark strips.

3) Fibers after being buffed and rubbed together to create finer more flammable fibers for a tinder bundle.

4) Blowing a bow drill coal into a flame with the tinder from the inner bark of the ash tree.