CHAPTER TWO

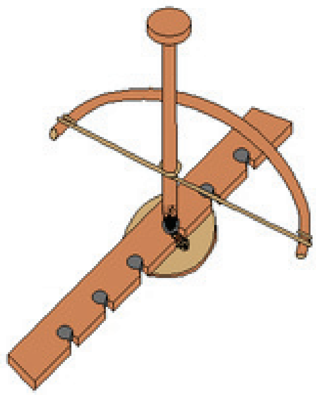
PYROTECHNOLOGY

STUDENTS LEARN THE PROPERTIES OF FIRE AS THEY STUDY HOW THE TIMUCUA USED FIRE TO SOLVE THE PROBLEMS OF DAILY LIFE.

WHAT IS PYROTECHNOLOGY?

Pyrotechnology is the use of fire to enhance your everyday life. Today, most people in the western world don't depend directly on fire. Some might have a wood fireplace that warms their homes in the winter. Others might roast hotdogs and s'mores over campfires on vacation. And a few people (like mechanics and chefs) use flaming blow torches as tools. For the rest of us, fire's only useful to light up nice-smelling candles, right? Well…unless there's a power outage. In extreme cases, when all the flashlights are out of batteries, modern Floridians do still depend on fire.

How did the Timucua start fires? They used a tool called a bow drill. This is an advanced version of rubbing two sticks together to create friction. A fire bow is only about two feet long. How does it work? The spindle (a short section of wood) is twisted into the string of the fire bow. When the bow is moved back and forth, it turns the spindle, twisting it in one of the little depressions in the fireboard below. The disc on top allows the user to apply a slight downward pressure on the spindle. This pressure keeps the spindle from jerking out of the tiny depression while it spins. Plenty of friction is created as the spinning action rubs the spindle against the fireboard. When done properly, this friction produces a tiny pile of black ash and a spark. At this point, the fire-maker sets down the bow and lifts the spark onto a nest of tinder. (Tinder is a material that catches fire easily, like cattail fluff.) Next, he or she blows lightly on the tiny glowing ember, giving it oxygen so it will lick into flame. It takes a tremendous amount of practice to master this skill.



Fire Drill, photo by Wikipedia

When the moving bow rubs against the fireboard to create friction, MECHANICAL ENERGY is converted into HEAT ENERGY. When the friction generates a spark, HEAT ENERGY is converted into LIGHT ENERGY and HEAT ENERGY. Combustion occurs when this spark begins to burn the tinder material. At this point, the tinder's CHEMICAL ENERGY is converted to HEAT ENERGY and LIGHT ENERGY.

PYROTECHNOLOGY

ACTIVITY – WHAT FIRE PRODUCTS DID THE TIMUCUA USE?:

BACKGROUND: The Timucua used four products of fire to improve their daily lives: light, heat, smoke, and ashes. The table below lists each of these fire products along with various Timucua needs satisfied by fire. As you read the following paragraphs, fill in the table to reflect which fire product the Timucua used to satisfy each need.

Timucua Need or Task	Light	Heat	Smoke	Ashes
Seeing at Night				
Staying Warm				
Cooking				
Repelling Insect Pests				
Making Clothing				
Antiseptic and Healing				
Shaping Wooden Tools				
Firing Pottery				
Making Stone Tools				
Building Houses				
Making Canoes				
Managing Forests				
Warfare				

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LIGHT AT NIGHT

Back in the 1500s, fire wasn't an obsolete technology. Sure, the Timucua's ancestors had been using pyrotechnology for thousands of years. But it hadn't gone out of style. In fact, fire influenced every aspect of Timucua life. It was as common as flipping a light switch. If the Timucua wanted to light their homes at night, fire was their only resource. Today, we light our homes using electricity. In most power plants, electricity is created by generators. These generators are powered by turbines. The turbines are turned by steam. The steam is made by boiling water. The water is boiled by burning fossil fuels. Hmm. That's fire isn't it? Perhaps we use more pyrotechnology today than we realize.
Fire Resource Used: LIGHT

STAYING WARM

Florida is a warm state, but temperatures do drop below freezing in winter. The Timucua lived in palm huts that had an open smoke hole in the roof and a low open doorway. During cold snaps, the temperature inside could really drop. Leather clothing and fur blankets help to warm the people, but not the house. If the Timucua didn't want the water in their water bags to freeze overnight, they needed to heat the air inside their huts too. Fire was the logical solution. The Timucua burned tree branches as fuel. Those trees spent their lives soaking up the sun's energy and storing it in their leaves, roots, and branches. When their wood was burned, that stored solar energy was released as light and heat.

The trees used photosynthesis to turn LIGHT ENERGY (sunlight) into CHEMICAL ENERGY (wood). The Timucua used fire to turn CHEMICAL ENERGY into HEAT ENERGY and LIGHT ENERGY.
Fire Resource Used: HEAT

THIS DIAGRAM DESCRIBES WHAT HAPPENS WHEN WOOD BURNS IN A FIRE:

Wood +	*FIRE*	Light +
A Little Heat +	⟶	LOTS of Heat +
Oxygen	*BURNS*	Carbon Dioxide +
		Water Vapor Gas

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PYROTECHNOLOGY

ACTIVITY - BALANCING CHEMICAL EQUATIONS:

BACKGROUND: Wood is made mostly of cellulose, a carbohydrate. If complete combustion occurs, the only end products are carbon dioxide ($C0_2$) and water vapor (H_20). Most fires have incomplete combustion. Why? Because the mix of oxygen, heat, and fuel aren't quite right. Incomplete combustion makes ash and smoke along with $C0_2$ and H_20.

When balancing a chemical equation, be sure that the same number of carbons, hydrogens, and oxygens are found on each side. Look at this equation for complete combustion. How many water vapor molecules (H_20) are needed to balance this equation?
Hint: 60_2 is 12 oxygens. 6 x 2 =12. The formula for cellulose (wood) is $C_6H_{12}0_6$.

$$C_6\,H_{12}\,0_6 \;+\; 6\;0_2 \longrightarrow 6\;C0_2 \;+\; \underline{\qquad}\;H_20$$

6 Carbons	=	6 Carbon
12 Hydrogens	=	12 Hydrogens
18 Oxygens (6+12)	=	18 Oxygens

CREATIVE COOKING

Fire provided the Timucua with more than just light. It also provided energy for cooking food. Why cook? Cooking helps to preserve food. Hard-boiled eggs last a lot longer than raw eggs. Cooking can also remove toxins or bacteria. No reason to get food poisoning if you don't have to. Cooking improves taste. Many wild vegetables are so bitter that no one would want to eat them raw. The cooking process leaches out the bitterness. And most importantly, cooking reduces the amount of energy you use in the process of eating. Wild apes spend almost half of their time eating because it takes that long to find and chew the raw foods. Think about it. Both meats and vegetables become more tender during the cooking process. Consider the difference in chewing required when eating a raw carrot versus a cooked carrot.

How did the Timucua do their cooking? They could cook meat on a spit over an open fire, boil soups and vegetables in a pot of water over a fire, or roast meat in an underground pit oven using hot coals. Most modern Floridians use stoves, microwaves, and ovens. We hardly ever use fire for cooking anymore. Oh, except for grilling. And gas stoves. And for making those yummy flaming desserts.
Fire Resource Used: HEAT

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The Timucua didn't have refrigerators or freezers to preserve food. To prevent spoiling, they dried foods instead. Fruits, like grapes and plums, can be dried in bright sunlight. But meat will spoil long before it can sun-dry. (Flies lay eggs in the meat too. *Ugh.*) The Timucua solved this problem by cutting venison (deer meat) into thin strips, then hanging these strips above a smoky fire. The heat of the fire dried the venison. Without moisture, bacteria can't grow. Instant preservation! And since bugs don't like smoke, the egg-laying flies stayed away too.
Fire Resources Used: HEAT and SMOKE

Corn was also preserved by drying. Its dried kernels were hard to grind up – and impossible to chew. So the Timucua softened them by soaking them in lye. What is lye? It is potassium hydroxide (KOH), a compound found in wood ash. If you pour water into a bowl of wood ashes, it creates a yellowish liquid called lye - a very caustic material. When dried corn is soaked in lye, its cell walls begin to dissolve. This allows the kernels to absorb moisture, soften, and swell. The swollen corn is called hominy, and it's much easier to grind up than before. Lye also increases corn's nutritional value. It denatures (breaks down) corn proteins. This frees up the vitamin niacin so that humans can digest it.
Safety Note: Lye is extraordinarily corrosive and will burn through several layers of skin.
Fire Resource Used: ASHES

When the Timucua baked cornbread or cattail bread, they did not have yeast or baking soda to help it rise. As a result, their breads were fairly dense and flat. They did have access to one leavening agent: fire ashes. One of the many compounds found in wood ash is called "potash" or potassium carbonate ($KHC0_3$). This didn't make bread rise nearly as high as modern baking soda (sodium bicarbonate, $NaHCO_3$), but it did help a bit. How? Both compounds release carbon dioxide gas during the cooking process. These gas bubbles make the bread lighter and fluffier.
Fire Resources Used: ASHES

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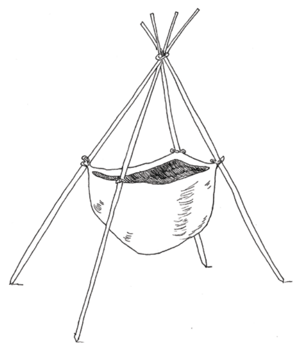
EXPERIMENT- COOKING BEFORE POTTERY:

BACKGROUND: In North America, pottery was invented on the Florida-Georgia coast about 4,000 years ago. Long before that, native peoples were cooking soups using pots made from deer hide. First, they suspend the pot over the fire pit. Next, they filled the pot with water and let the water soak into the hide a bit. Then they built up the fire. As long as the level of the water in the pot was higher than the level of the flames, the pot did not burn. It worked because water is an excellent conductor. The water drew heat away from the hide pot and into the water, meat, and vegetables. If the water boiled too low, the fire would touch a dry spot on the hide. *Uh-oh*. Holey pot. Leaking soup. Bad day.



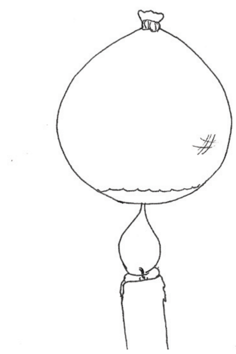
Animal hide suspended from poles for cooking.

EXPERIMENT: Instead of hide pots and campfires, we'll experiment with balloons and candles. First, put on your safety goggles and blow up a balloon. Once your balloon is tied, move your second balloon and cup of water to the side.

Light your candle. Hold the air-filled balloon high above the candle flame. The first balloon represents a hide pot with no water inside. Slowly lower your balloon. How close do you think you can get to the flame before it pops? And it WILL pop. With no water inside, there's nothing to carry the flame's heat away from the rubber surface of the balloon.

Now pick up balloon number two. Pour ¼ cup of water into the balloon. Blow it up to the same size as your first one. Lower the balloon towards the flame. The water-filled section of balloon should be closest to the flame. Does it pop? The water inside the balloon is conducting heat away from the balloon surface.

Next, hold the balloon beside the candle and move it towards the flame. The water is still at the bottom, not at the side where the flame will touch. Do you think it will pop?



Cooking before pottery experiment, balloon #2.

The balloons in this experiment serve as models for the Timucua hide pot. How are the balloons different from actual hide pots? How could these differences affect our experiment?

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PYROTECHNOLOGY

THE PREHISTORIC WAR ON BUGS

Smoke served as an important insect repellent in Timucua homes. At night, when the Timucua slept, mosquitoes and gnats could fly right into the palm huts and nibble on the people. To prevent this, the Timucua lit tiny smudge fires under their sleeping benches. These small fires used dried corn cobs as fuel. Smudge fires surrounded the sleeping person with a bit of smoke and kept the biting bugs away.

Other Florida bugs (including carpenter bees, carpenter ants, and termites) eat wood or tunnel through it. Timucua huts would have made a tasty treat. To keep these pests in check, the Timucua probably left a fire burning in their huts all day and night. The smoke discouraged wood-damaging insects from moving in.
Fire Resource Used: SMOKE

Interesting Fact: Modern bee keepers use smoke to cover up their bees' pheromones. What are pheromones? They're the warning smells that bees make when their hive is in danger. With these pheromones masked, bees can't instant message each other to ATTACK. The bee keeper is able to open the hive and remove some honey without being mobbed by angry bees. Did the Timucua use smoke to harvest honey? The best answer is "maybe." The European Honey Bee was introduced to North America by the Spanish in the 1600s. The Timucua living after this time might have used smoke to harvest honey. But before the Spanish came, there were no honey bees (and no honey) in Florida.

FASHION IN THE FIFTEEN-SIXTIES

De Bry engraving of Timucua fashion

Timucua people didn't wear a lot in the way of clothing. They did use loin cloths year round. (A loin cloth is like a bikini bathing suit.) And they wore long, flowing matchcoats to keep them warm in the cold weather. They needed blankets for wrapping babies, and leather for making packs and bowstrings.

Changing a fresh animal pelt into a baby blanket required a bit of skill and - of course - fire. First you needed to scrape away the fat, hair, and blood vessels. To ease this process, hides may have been soaked in a lye solution (made from ashes and water). This caustic liquid loosened the hair follicles so they were easier to scrape away.

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Next, the Timucua spent hours stretching and twisting the hide near a smoky fire. The fire's heat helped to dry the hide, preventing the growth of bacteria. The constant stretching broke apart the hide's collagen fibers (connective tissues). This made the hide soft and flexible – temporarily. Without wood smoke, the hide would harden as it dried, just like a rawhide dog bone. So what did the smoke do? Wood smoke contains formaldehyde, and this gas bonded to the fibers so they could never link back together. This made the hide permanently soft and flexible. That's a quality you want in your loin cloth.

Fire Resources Used: ASHES, HEAT, and SMOKE

De Bry engraving of Chief Saturiwa preparing his men for battle. Remember, this is NOT considered an accurate depiction of their tattoos.

The Timucua are known for their use of tattoos. Rene de Laudonnière, a French explorer, wrote that "Most of them ornament their bodies, arms, and thighs with handsome designs. The ornamentation is in permanent color because it is pricked into the skin." The higher-ranked members of the village had more tattoos than anyone else, an easy-to-recognize sign of status. These permanent dotted designs were probably tattooed into their skin using bone needles. Wood ashes rubbed into the holes served as a blue dye. The ashes also helped to reduce the risk of infection, an important consideration in a time before antibiotics. When the ashes were rubbed into the holes, they formed a physical barrier (like a Band-Aid), which crusted over and protected the injured tissue. The presence of ashes also sped up the body's production of fibroblasts. What are fibroblasts? They are tiny fibers that help to bind wounded skin together, allowing it to heal. One study reports that wounds treated with ashes healed three days sooner than those treated with a modern antibiotic ointment. Who knew?

Fire Resource Used: ASHES

The Timucua also used fire to create medicines. For example, they boiled cherry bark to create a medicinal tea that eased coughing. They boiled other medicinal herbs in water to create steam that was inhaled.

Fire Resource Used: HEAT

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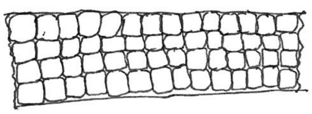
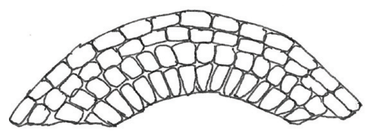
WOODEN TOOLS

The Timucua needed wood to make hunting tools: straight pieces for spears and arrows, curved pieces for bows. Since tree limbs bend as they grow, perfectly straight branches are pretty rare. The Timucua combined the technologies of fire and steam to straighten and curve branches into any shape they needed.

How do heat and steam bend wood? The combination of heat and moisture weakens the cell walls inside the wood. This makes the wood more flexible, so it can be compressed a lot (squeezed smaller) or stretched just a little. If the wood is held in the new shape until it dries, its new shape becomes permanent.



In the straight wood to the left, the tree's cells are roughly the same size and shape. Look at the bent wood to the right. Heat and steam have weakened the cell walls, allowing the cells to change shape. The cells on the inside of the curve are compressed together, while the ones on the outside of the curve are stretched.



Steam-bending wood may seem like an obsolete art. After all, it's easier to just buy a modern bow and arrow, right? But if you want to play acoustic guitar, be glad the technology is still around. That's how artisans make the curved sides of fine guitars and violins even today.

Fire Resource Used: HEAT

FIRING POTTERY

To make pottery, the Timucua mixed water and clay to create a soft, pliable material that is slicker than Play-Doh. They coiled the wet clay into the shape of a container, and as the clay pot dried, it hardened. This was only a physical change. It was not permanent. If the dried pot got wet, it became squishy again.

Replica of Florida native pottery

Florida's early people learned that heating the dried clay in a 760°C (1400°F) fire made it permanently hard. How does this process work? Clay is a mixture of alumina, silica, and water molecules that are chemically bonded together. Once the fire is hot enough, the clay's water is released, allowing the silica and alumina to bond tightly to each other. Now the clay has been changed to a ceramic. It can't absorb water anymore. That's a good cooking pot.

Fire Resource Used: HEAT

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ACTIVITY – CONVERTING TEMPERATURES:

BACKGROUND: Scientists worldwide use the metric system, but modern Floridians are more familiar with standard units. The Timucua had no standardized measuring system for temperature, but they had a clear understanding of the temperatures that affected health, foods, and tools. How clear is your understanding of metric units for temperature? Use the formulas below to complete the table, converting between standard and metric units.

FAHRENHEIT TO CELSIUS:

$$C = (F - 32) \times \frac{5}{9}$$

CELSIUS TO FAHRENHEIT:

$$F = C \times \frac{9}{5} + 32$$

Important Timucua Temperatures	Degrees Fahrenheit	Degrees Celsius
Water Freezes	32° F	
Healthy Body Temperature	98° F	
Water Boils		100° C
Heat-treating Chert		350° C
Firing Pottery	1400° F	

Interesting Fact: Both the Fahrenheit and Celsius scales were invented by European scientists in the 1700s while the Timucua were still living in Florida!

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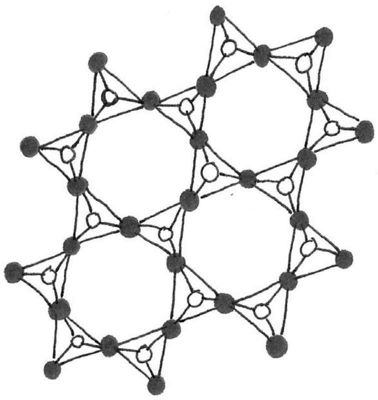
STONE TOOLS

Chert is the only tool-making stone found in Florida. It is usable in its raw state, but the Timucua improved its quality using fire. First, they chipped out the basic shapes of the tools they wanted to make. Then they buried the half-made tools in a bed of sand beneath a fire. When chert is heated to about 350°C, it becomes more glass-like. This allowed flint-knappers to create finer sharp-edged tools, like knives and projectile points. Fire-treating also makes chert about 50% easier to crack, so it became much easier for the flint-knapper to shape. Unfortunately, these heat-treated tools were too fragile to be used for rough work like chopping or pounding. Heavy-duty tools, like axes and hammers, were made from whelk shells instead.

Raw Chert

How does a fire make chert more glass-like? Well, scientists aren't exactly sure. They do know that chert is actually a type of quartz. Like quartz, chert is made up of molecules in a crystalline framework.



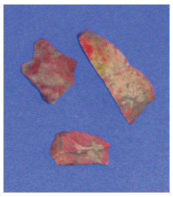
Above:
This is a diagram of the solid crystal structure of quartz. The black dots are oxygen atoms. The white dots are silicon atoms. Each oxygen atom is bonded to SIX other atoms. These bonds give the stone its strength and make flints and cherts useful tool-making materials.

Heat seems to remove water molecules trapped in this framework, so the molecules of crystal can pack more tightly together.

Heat also affects the bits of iron impurities stuck in the framework. Heat turns iron into hematite (red iron oxide). This gives fire-treated chert a reddish color.

When this red hematite melts, it helps to glue the crystal structure even more firmly together. How does all of this help make sharper-edged tools?

When a flint-knapper works with raw chert, any crack he makes is a bit ragged. It zig-zags around the crystals.



Fire-treated Chert Chips (Debitage)

In fire-treated chert, the bonds between crystals don't break. Instead, the stone cracks cleanly through the middle of the crystals, creating a smooth, sharp edge.

Fire Resource Used: HEAT

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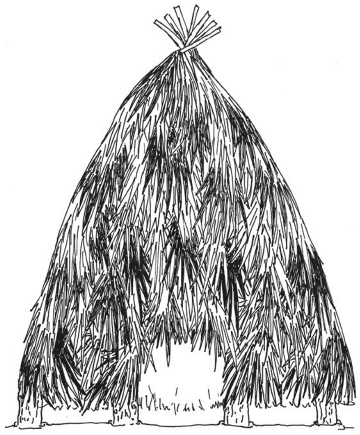
HOME SWEET HOME

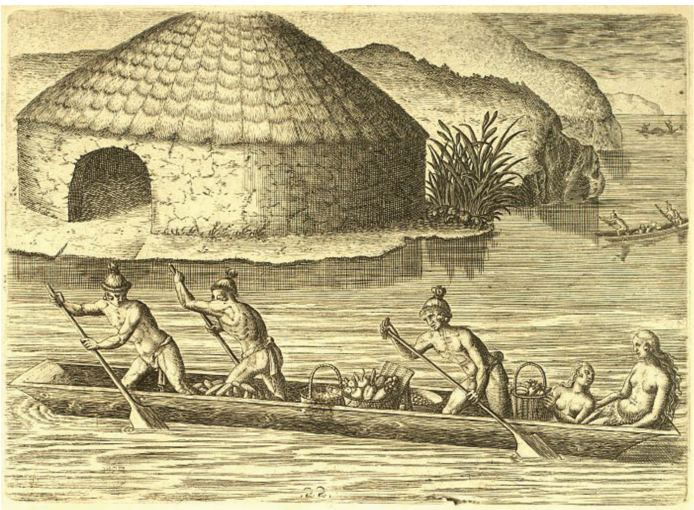
A Timucua hut required about eight tree trunks, each roughly 8-10 inches in diameter. Steel axes did not exist in Timucua times, and it would take a LONG time to chop all of those trees using a shell axe. Instead, the Timucua carefully set a fire at the base of the tree, so the flames would char and soften the wood. After they extinguished the fire, they used shell axes and chisels to chip away the blackened wood. Then they set another fire. After it burned for a while, they extinguished it and chipped away the char again. This saved time and effort.



Palm-thatched Hut, courtesy of the University Press of Florida

When building a council house, they needed much larger trees, some weighing over 1,000 pounds. Chopping even one tree like that with native tools would take days. It's possible that they girdled the trees well ahead of time (cutting away the bark all the way around the trunk) to weaken them. By combining fire and shell tool technologies with this technique, native Floridians were able to harvest these massive trees.

CANOE BUILDING



De Bry engraving of Timucua men canoeing to storehouse

When the Timucua made a dugout canoe, it was a major undertaking – even after they'd cut down the three-foot wide tree. It would take weeks to chip out a canoe shape using only shell tools. The Timucua shortened this time to only a few days with the use of fire. Hot coals were placed along the length of the log. After the coals burned down into the wood, the coals were removed, and the Timucua chipped away the charred material below. Then they added coals again: burn, chip, burn, chip, burn chip. They slathered wet clay across the parts of the log that should not be burned, then continued chipping and burning. When the interior of the canoe was smooth and uniformly deep, the canoe was complete. Florida archaeologists discovered one dugout with a hole burned right through the side. *Oops.*

Fire Resource Used: HEAT

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LAND MANAGEMENT AND HUNTING

The Timucua intentionally used fire to manage their lands. Their goals were to prevent wildfire, enhance agriculture, and improve hunting. Community fire drives were staged towards the end of winter, just before spring planting. The fire was carefully planned so that it would burn across the agricultural fields. The stems from last year's crop, along with any weed growth, burned away and were returned to the soil as ashy nutrients.

The fire was allowed to burn through some forestland too. Its flames and smoke flushed animals towards hunters waiting with bows and arrows. As the fire burned through the woods, it thinned out the forests' thick tangle of saw palmetto, greenbriar vines, and leaf litter. Left alone, these materials could have fueled an uncontrollable lightning fire. But the Timucua's carefully planned burn transformed them into nutrients for the forest soil. As a bonus, birds like quail love the open spaces created by burns. Quail populations increased, and so did quail hunting for the Timucua. These planned burns were designed to end when winds blew the flames toward a river or marsh where the water extinguished them.

Today, state and US forestry services use prescribed fire to manage public forests. This improves the habitat and prevents dangerous wildfires. We've learned a thing or two from the Timucua.
Fire Resource Used: HEAT and SMOKE

WARFARE

The Timucua understood fire's destructive power. When one chief declared war on another, he ordered that flaming arrows be shot into the roofs of the enemy's huts. The huts were made of dry palm fronds, grape vines, and tree trunks. They were highly flammable. They were also fairly small, only 25 feet wide. The people inside could escape easily, so no one was killed. But the enemy was now faced with plenty of rebuilding work, and not much time to wage war in return. Like all Timucua uses of fire, this was an effective strategy.
Fire Resource Used: HEAT

De Bry engraving of Timucua warfare

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ACTIVITY – GETTING TO KNOW FIRE:

BACKGROUND: The Timucua used fire in every aspect of their daily lives. They knew how fire responded to wind and breath, how its heat affected clay and chert, and how its smoke impacted bugs. They understood which parts of a fire were hottest and knew how to use fire as a tool without hurting themselves or their environment.

This intimate understanding of fire developed through simple, everyday observation. Because the Timucua had neither clocks nor thermometers, they had to estimate the times and temperatures for cooking, firing pottery, and heat-treating chert. The more experience they had, the better their time estimations.

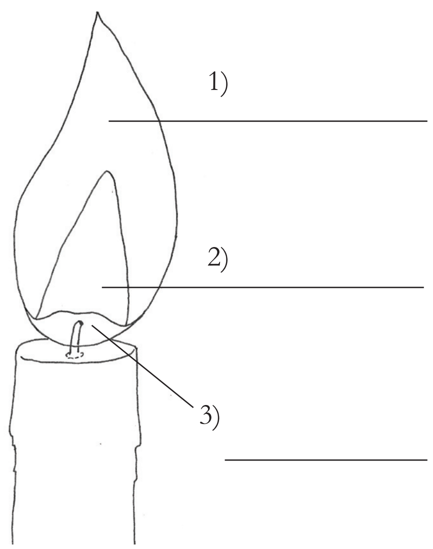
A campfire reaches temperatures between 900°C and 1100°C. Candle wax burns up to 1400°C, significantly hotter than the fires the Timucua had.

TEMPERATURE AND COLOR OF CANDLE FLAMES

Color	Color Name	Temperature in Celsius	Temperature in Fahrenheit
	Red	700-900°	1300-1700°
	Shadowy Orange	1100°	2000°
	Yellow	1200°	2200°
	Faint White	1300°	2400°
	Blue	1400°	2600°

ACTIVITY – GETTING TO KNOW FIRE continued:

INSTRUCTIONS, PART I: Wear your safety glasses throughout this experiment. Do not touch the flame. Observe your candle flame. On the flame diagram, use colored pencils to fill in the colors you observe in your candle flame. Write the name of each color on the line provided. Use the table titled "Temperature and Color of Candle Flames" to complete statements a) - c).



a) The HOTTEST part of the flame is located:

____

b) The COOLEST part of the flame is located:

____

c) The SMOKE (if any) is located:

____

INSTRUCTIONS, PART II: Blow gently on the flame for at least five seconds without blowing it out. Observe any changes that occur in the shape of the flame, the color of the flame, and the color, amount, and location of smoke. Record your observations on the lines below.

Flame Shape: ______________________________

Flame Color: ______________________________

Smoke: ______________________________

PART III: Blow the candle flame out. Observe any changes in the smoke (color, amount, location, odor) as well as the appearance of the wick. Record your observations on the lines below.

Smoke: ______________________________

Wick: ______________________________