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Foreword

After long and careful study, Cynthia Eid and Betty Longhi have succeeded in assembling the first comprehensive textbook on synclastic and anticlastic forming. The clear illustrations accompanied by precise explanations provide an invaluable manual for beginning and advanced metalsmiths.

Our mutual friend, Professor Heikki Sëppa, revolutionized the field of art metals in the 1970s when he redefined the basic parameters of metal forming. For most of its history, functional forms such as teapots, bowls and other vessels were made almost exclusively using the time-honored traditions of sinking and raising. These were often embellished with repoussé, embossing and engraving, and while the results are lovely, there was little room to expand the basic form.

It was Heikki's monumental contribution of anticlastic forming (aka reverse raising) that freed metalsmiths of these traditional limitations.

Heikki introduced techniques that allow metalsmiths to bend sheet metal freely in every possible direction. As was his intention, he opened the way for craftspeople to use the medium as an art form in its own right, liberating metalsmiths from traditional constraints. In 1978 he published a landmark book called *Form Emphasis for Metalsmiths* in which he not only described his techniques, but introduced his concepts and created a nomenclature for the radically new forms he made possible. As long as we start with a mental construct of "bowl" or "vase," he reasoned, we are subconsciously limiting ourselves to preordained forms. He created a new forming vocabulary, expanding the ideas and developing new techniques, breaking them out of their historical and traditional strictures. From this origin springs the language that you will encounter in this book. You are about to enter a world of synclasting, spiculums and transitions—hang in there and the language will become natural.

Let me try to set the stage: There are four ways that a plane moves in space. First, it remains flat, extending infinitely away from its center. Second, a plane can be bent around its axis, ending in a tight fold. Third, the edges of the plane can be compressed relative to their center whereby the surface curves in the same direction at all points on the plane (synclastic movement). Fourth, the edges of a plane can be stretched relative to their center whereby the curves move in opposite directions (anticlastic movement).

Metal forming, like writing music, is a limitless creative endeavor. When I am working on a sculpture, I am struck again and again with how the forms remind me of flowers, leaves, seaweed, microphotographs of cells. I realize that I haven't created a new form as I push the metal on a stake, but instead I have unintentionally mimicked nature's basic designs. What makes the forms so attractive is their basic familiarity; though brand new, there is something in the structure that we recognize.

If there is a bias in the mission of *Creative Metal Forming* (and I think the authors are truly on a mission), it is that we are still in the early days of Heikki's revolution. Using the basic language of the medium, unfettered by historical precedents, artists in metal can continue to expand and develop the concepts presented here, adding to our understanding and to the world of art. I consider this book a milestone along an important path and I am confident that students of metalsmithing will welcome it as a guide and reference.

— Michael Good, designer & metalsmith

METALWORKING BASICS

There are a few processes that will be used on all the forming discussed in this book and it makes sense to cover them at the outset. Variations on these basics will come along in the exercises that follow.

How to Hammer

Whether you're flattening a small piece of wire or making a punch bowl, good hammering practices are universal. Hammering can be a satisfying and Zen-like experience when you are hammering comfortably and effectively. Proper alignment of the torso, arm, and hammer improve accuracy and avoid muscle strain. When hammering, keep your upper arm in a relaxed position with your elbow hanging directly down from your shoulder and your forearm perpendicular to your body. Stand straight, facing the work. Once you get yourself into this correct body posture, use your feet to move yourself so that your arm is comfortably bent to slightly greater than a right angle, with the face of the hammer resting on the metal to be formed.

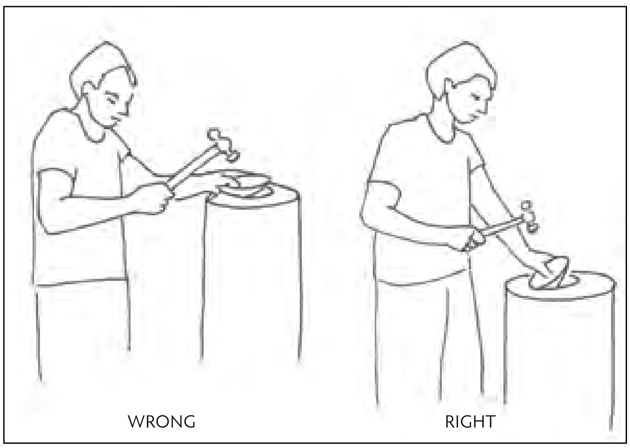
Keep Your Stance: Move Something Else

Stand so that your hammer, shoulder and elbow are lined up in front of the metal and your body is to the side of the work. This allows the hammer to come down in an arc that is perpendicular to your body.

If you need to sit instead of stand, orient yourself in the same way by moving the chair. Sitting side-saddle or twisted at the waist restricts the limbs from moving freely and can strain your muscles. Many people like to sit for fine work and stand for heavy hammering, such as forming a large vessel. One advantage of standing is that it is easier and more natural to move your body into a comfortable, non-fatiguing, non-straining posture.

Whether standing or sitting, the working height is important. Set things up so that when your arm is bent at a right angle, the hammer is slightly above the metal. If the hammering surface is too high, there is a tendency to hitch the shoulder up, raise the elbow, or stick the elbow out—all of which stress the body and reduce accuracy. A hammering surface that is too low may be hard on your back, but it tends to be better than a surface that is too high. If you find that you need to reach up to hammer, it is best to use a small platform to elevate your body. Quick and easy platforms can be

Betty Helen demonstrates the proper stance. Notice how her right shoulder, elbow, and wrist are in line with the work. The proper grip on the hammer is relaxed, with fingers and thumb comfortably encircling the handle.



Avoid working on a surface that is too high, as shown on the left. This cramps your shoulder and wrist, leading to loss of control, discomfort and possible injury.

Hammer Grips to Avoid

Do not point your finger along the handle like this— in the long term, it can lead to pain.

Do not clench the handle in a white-knuckle grip like this. Also, it is usually better to hold the handle closer to the end rather than choking up like this.

This shows an extreme version of working on a surface that is too high. Notice the extreme bend in the wrist: Ouch!

made from phone books, cement blocks, bricks or a few two-by-fours and a piece of plywood nailed together.

Wear ear protection to protect your eardrums from the hammer noise and comfortable leather gloves to dampen vibrations, prevent blisters and improve gripping power.

Shake Hands with Your Hammer

A handshake is more than just a polite greeting when it comes to hammers; it's the best way to approach them. When you pick up your hammer, reach out to it as if you were shaking somebody's hand and take hold of the handle. Use a relaxed, loose grip that will let the handle move within your hand. Grip firmly enough to guide the hammer but loosely enough that it can rebound easily.

Avoid putting your forefinger or thumb straight along the handle because this can cause tendonitis. It's generally best to hold the hammer near the end of the handle, but find the place that allows you to balance control with the force of the blow. Gripping the handle above the optimal point is known as “choking up” on a hammer. Though it's best to avoid choking up, there are a few occasions where it is acceptable, such as when you need to have control of a very heavy hammer.

Some people find it helpful to think of the hammering motion as being like the motion of throwing a ball. The whole arm works in one fluid motion. Start by appropriately orienting your body so that the upper arm is in a relaxed and stable position at your side, with a right angle at the elbow. The motion begins by lifting the hammer while holding the hand slightly upward from the wrist. As the hammer motion continues, the lower arm and hand move downward toward the point of impact so that when the hammer makes contact, the hand and wrist are in line with the arm. Avoid letting the wrist bend downward.

After impact, the wrist and the arm bounce up with the rebound of the hammer. At all times, the arm, the elbow, the wrist and the grip should be relaxed. Use your ears as well as your eyes—if you hear a single hit, then all is well; if you hear a double hit, that means your wrist or arm are tense, which is restricting the rebound of the hammer.

As you learn how to hammer comfortably and effectively, maintain this upper body position and relationship to the hammer as your work progresses. Move either the work or your feet, but not your arm/hand/hammer arrangement. Avoid hitting sideways, backwards, or any-other-ways. Hammering should maintain a natural arcing motion.

Think of being a “hammering machine.” The arm, the hammer, and the stake maintain a constant relationship. The hammer keeps going in the same comfortable position while the metal is moved over the stake. Find a rhythm. Some people are like a staccato machine gun: *ratatatatatatatat*. Some hammer in 4/4 time: *bububuBUM* or *HUPtwothreefour*. Your natural rhythm will provide a consistent surface, keeping things even, and increasing your stamina.

Annealing

The first step in forming is to ensure that the metal is annealed; i.e., in its most malleable state. This is achieved by heating metal to about two-thirds of its melting point, usually with a torch. Precious metals are sold fully annealed, while brass and copper are typically half-hard. If the metal is dead soft, hammering can begin immediately. If not, or if unsure, anneal before forming.

All of the processes described here will work-harden metal. When metal stops responding easily to hammer blows, it is time to anneal. A good rule of thumb is to anneal when the working area of the metal has been completely hammered. In this book, we refer to this as one course.

Annealing refers to a controlled heating process that allows the metal to recrystallize and create new vacancies. Here's the science: the crystals of annealed metal are unevenly spaced with aberrations called vacancies and dislocations. When metal is hammered, the grains (crystal groups) are broken into smaller units and pushed closer together as they fill in the vacancies. This stiffening process is called work-hardening. Continued working will stress the metal until it cracks or splits. To avoid this, it is standard practice to anneal at regular intervals during forming.

A common problem when annealing is getting the metal too hot or holding it at annealing temperature too long. When the metal is overheated, the crystal grain structure grows larger, a condition that makes the metal brittle and less malleable. If this occurs, planish the metal to break up the large crystals.

When annealing with a torch, use a tip that is large enough to heat the metal within a minute or two. This quick heating reduces the time required and the amount of gas used. The larger the piece of metal, the more heat it will take, and the larger the preferred torch tip. Generally, a soft flame is used for annealing.

To Quench or Not to Quench?

That is a question that metalsmiths seem to argue over endlessly. Our opinion is that it is better to wait to quench until the the red glow is gone. This avoids shocking the metal by quenching too quickly, risking stress cracks and stress to soldered seams. Furthermore, there are times when it is preferable to let the metal air cool completely, such as when you want to avoid warping a flat surface. Formed metal (i.e., metal that is no longer a flat sheet) is more forgiving of quenching, but it is always safer to allow metal to cool than to quench it. It is better practice to quench in water and than in pickle. Quenching in pickle can spray fumes and acid onto your skin, clothes and workspace. Also, quenching hot metal in pickle draws acid into the structure of the metal where it can cause brittleness.

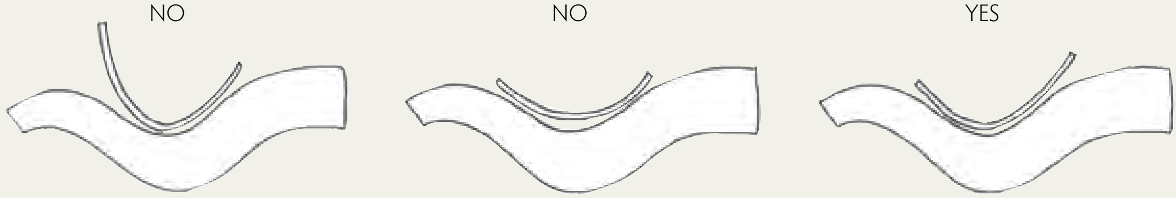
BOUGING

Bouging (pronouced "BOO-zjing"), refers to a process that smooths the bumps that are created in most forming processes. The word comes from the French verb bouger and for some reason it has carried over into use in English. Bouging refines a form and smooths the surface. In contrast to forming, there should be a close fit between the stake and the form; i.e., there should not be an air pocket between the metal and the stake. Bouging is usually done between each course of forming, or whenever the form seems to be getting out of shape. It precedes planishing. The process can also be continued, using precise, even blows, to create a finished surface and form.

Think of bouging as similar to smoothing a blanket over a bed by pushing the wrinkles from the center to the edges. Think of the mallet as your hand, and the stake as the bed. You would not pat the blanket all over to smooth it. In the same way, it is important to use overlapping blows to simulate the smoothing motion. Hammer in the same spot on the stake, sliding the metal beneath the blows so it is smoothed from the center toward the edges.

Before beginning to bouge, check the face of the mallet and refinish it if it is rough. Choose a stake that fits the form and clamp it in a vise or stake holder. Usually it is best to begin bouging at the middle of the form and then work your way out to the edges. Mark the center of the form and draw a hammer pattern with a permanent marker. The lines of this hammering pattern are dictated by the shape and form of the piece. A circular bowl, for instance, will generally be marked with concentric circles and an oval form will be marked with concentric ovals. An elongated form might use lines that follow the long axis of the piece. Guidelines help keep the form consistent and are especially important when working on symmetrical pieces.

Position the stake so that the area that matches the curves of the work is at the top, allowing you to hammer comfortably. It may be necessary to tilt the stake in the vise. To determine how the metal should sit on the stake, let go of the metal with your holding hand, and instead use the face of the mallet to hold the metal onto the stake. This indicates the balance point.



Bouging is the process of striking a curved metal form with a mallet to smooth out bumps and irregularities. It is important that the curve of the stake match the curve of the metal as closely as possible. In the first drawing, the curve of the stake is too large. In the center drawing the curve of the stake is too narrow. The third drawing shows the required fit. This explains why sinusoidal stakes have bays of various sizes and why it is helpful to have several stakes.

It is normal in the early stages of forming for the metal to become bumpy and uneven. The purpose of bouging is to correct this and at the same time to return the form to symmetry, if that is the goal.

Now that you know the correct orientation, hold the metal in position and start to bouge. Always try to hit the metal over that same "sweet spot." Following the pattern that you have drawn, move the metal across the sweet spot as the mallet continues to rhythmically strike the metal. It is important to hold the form firmly against the stake so the metal stays in contact with it.

Bouging on a sinusoidal stake…

… and the horn of an anvil.

Your ears can tell you whether the stake, metal and mallet are all working together. If you hear hollow thuds, the metal is not touching the stake. Stop and reassess the situation. If you hear nice solid rings, keep malleting.

A good test of whether the form is smooth and true is to put your thumb on the inside of the form with a finger on the other side of the metal so that they would touch if the metal were not there and pull them across the surface. If the metal form is too large to be able to do this, run your hand lightly over the form to seek out irregularities.

It is easiest to see inconsistencies in the form and surface if the metal has a uniform color. Pickle and brassbrush the form to reveal irregularities more clearly. Bouging is complete when the form and surface are smooth. Depending on your objectives, you may decide to leave the surface as is or polish or patina the metal. If you want a hammered finish, this is the time to planish.

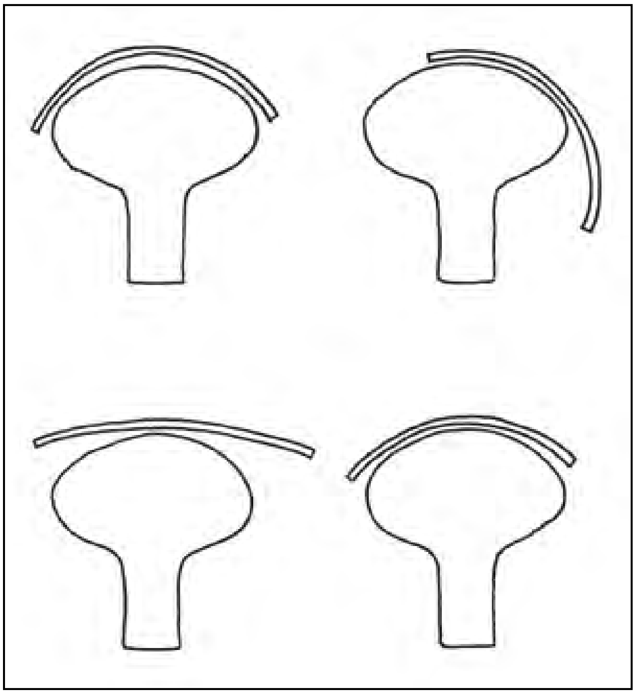
PLANISHING

Planishing uses a polished metal hammer and stake to smooth, finish, and true a form. Planishing refines the surface and the form after bouging, and the hammer marks can be very lovely. A planishing hammer has one flat face for hammering on convex forms and one slightly domed face that is meant for hammering on flat surfaces. Most planishing hammerheads are round, but there are times when a square or rectangular face is needed to follow a form or get into a corner. Planishing hammers are available in several weights; we most often use a six-ounce hammer.

Use a stake that closely matches the curve of the form. If you are choosing between two stakes, use the biggest stake that will fit inside the form—this will give the smoothest surface. In many cases, especially for complex forms, several stakes may be needed to finish the piece. To test whether a stake is appropriate for a given form, put the metal piece on the stake and gently tap. If it is a good fit, there may be a slightly hollow sound at first, but very quickly the sound will become a solid ring. Visually, the surface should smooth out without dramatically changing the form.

When choosing a stake, look at the silhouette rather than its overall form. The stake that turns out to be the best fit can be surprising sometimes. Synclastic forms are typically planished on mushroom stakes or the synclastic hammers that created them. Anticlasts are usually planished on a sinusoidal stake, a pipe or the horn of an anvil.

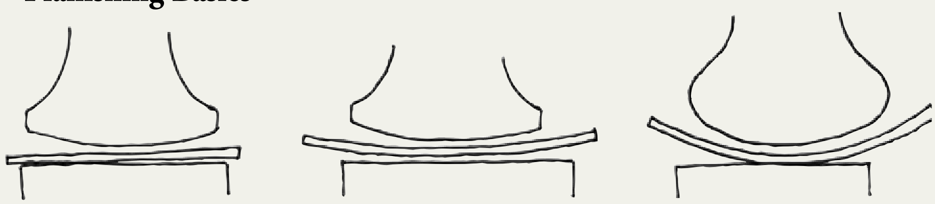
If the stake is the right size and shape, the inside surface of the metal form will be smooth. If the stake is too small, there will be little curved indentations on the inside surface of the metal. If the stake is much too small, it can be very difficult to even out the waves and irregularities. Planishing on a stake that is too broad will stretch the curve and expand the form.



In many cases a single stake can provide a range of curves. In these situations it is important not only to match the stake to the work in progress, but to pay attention so you continue to work on the appropriate section of the stake.

As with bouging, we recommend drawing a hammering pattern onto the metal with a permanent marker to ensure placement and symmetry when planishing. Hammer from the center to the edges. Sometimes, especially if the metal is very soft (copper, for instance), the metal will seem to bulge ahead of the planishing. To avoid these problems, use a larger stake and strike with a lighter touch (or use a lighter hammer).

Planishing Basics



Planish a flat surface with a slightly domed hammer.

Planish a shallow curve with a slightly domed hammer.

Planish a larger dome with a hammer face that has a matching curve.

Checkerboard Technique

Another approach to planishing is to create an open pattern in the first course, using half or a third as many blows as usual. Visualize a checkerboard in which you only hammer on the red squares. This hardens the metal in these areas and stabilizes the form. It is then possible to complete the planishing by filling in the blank spaces. Some people like to work a section with an open pattern then fill in the unplanished areas. With this method, as you work on the piece, always try to have at least an inch of checkerboard area ahead of the area that is being filled in.

If this is going to be the final finish, keep both hammer and stake polished and clean. Remove dust, grit and hair, all of which might otherwise be hammered into the surface. If you want to maintain the hammered finish, take care not to scratch it when annealing or pickling. To avoid accidental marks, wear rubber gloves or use a net bag (sold for laundering delicate clothing) to put the piece in and out of the pickle.

After planishing the entire form, check the surface. If another course of planishing is needed, anneal the metal and begin planishing again. After the final course of planishing, do not anneal the metal—leaving it work-hardened increases durability.

The checkerboard technique refers to a pattern of blows separated by unstruck areas. This strengthens and stabilizes the form.

The process of planishing, and the rules for the process, are similar to those for bouging:

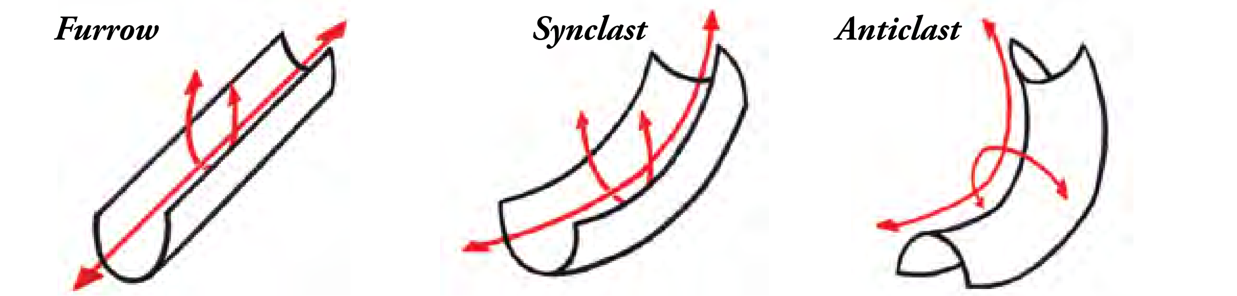
- Keep the metal in contact with the stake at the point where you are hammering.
- Because planishing blows are lighter than forming or bouging blows, use an even looser, more relaxed grip so the hammer is free to bounce and rebound. A hammer that is held with a relaxed grip finds the best orientation against the metal—one in which the face of the hammer is parallel to the metal surface. With this relaxed tapping stroke there is also less chance of nicking the metal with the edge of the hammer.
- If you hear the hammer make a double tap, you are gripping the hammer too tightly and preventing it from rebounding. A beautifully planished finish comes from hammering rhythmically and methodically with consistent overlapping blows. Each person needs to find his or her own rhythm. The important thing is to be comfortable and consistent.
- Move the metal under the hammer, always striking the same spot on the stake.
- A polished stake planishes the interior surface simultaneously with the exterior.

CONCEPTS

The Three Basic Types of Forms

Although grounded in traditional silversmithing, we make an effort to reach beyond traditional assumptions about forms. One way to facilitate this is to alter the language we use. In our system, adapted from Heikki Seppä's nomenclature, we identify three basic categories of forms: Furrows, Synclasts and Anticlasts. By using these ways of thinking about form, metalsmiths are able to build upon the fundamentals of traditional techniques and move in new directions.

Furrows	Examples include channels, cones and tubes.
Synclasts	Examples are bowls, domes and beads. Synclasts can hold water.
Anticlasts	Examples are spouts, handles and saddles. No matter how an anticlast is turned, it can't hold water.



The axial line of a furrow is straight while the radial line is curved.

The two axes of a synclast curve in similar directions (synonymously).

The two axes of an anticlast curve in opposite directions, "anti" each other.

Each form has two axes, shown here in red. The longest axis is called the Axial Line or Axial Curve. We call the shorter axis the Radial Line or Radial Curve. Using these names makes it easier to discuss forms and the techniques for making them.

For example, making a furrow comes from tube-making techniques but results in a very different object when applied to an asymmetric or tapered metal pattern. Synclastic forming is derived from the traditional process of sinking, but the methods covered here explore its possibilities more fully. The same can be said of anticlastic forming. While the techniques are adapted from those used to make a spout, the flared edge of a bowl, or the lip of a pitcher, new tools such as sinusoidal stakes (and the adaptability of these tools), allow us to explore the anticlastic process in ways that were not possible in the past. Even more exciting are the ways anticlastic and synclastic forms can be used together by creating transitions from one to the other to develop more complex forms.

Heikki Seppä
Ziphoidal Helicoid
Sterling silver
12" wide
Photo by the artist

Britt Anderson, *Alexandra cuff*
18k gold, 2⅝" by 2⅛" by 1⅜"
Photo by Robert Diamante

Sue Amendolara, *Flower of Life*
Brass, sterling, 18k gold, baby hair, imitation coral
7½" by 2½" by 2"
Photo by Robert Thomas Mullen

Timothy Grannis, *Windbell*
Brass, 7" by 5" by 6"
Photo by John Goodman

Margot di Cono, *Bracelet (untitled)*
22k / sterling bi-metal, 24k & 22k gold
Photo by the artist

Curtis H. Arima
Bladed Ball and Socket
Copper, sterling, acrylic paint
13" by 7" by 4"
Photo by the artist

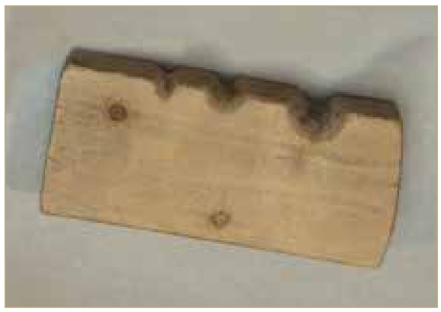
SPICULUM: Exercise #1
Straight Spiculum

Hammers

The radius of the face of the cross peen hammer needs to be proportionate to the width of the spiculum blank being formed, and to the curvature needed. That is, the smaller the pattern width, the thinner the cross peen should be. It is best to have the width of the cross peen less than half the width of the metal blank. It usually takes two or three hammers to match the range of diameters in one spiculum.

Spiculum Stake

A spiculum stake can be made from wood or plastic. Soft pine is easy to work and we feel that metal worked on pine stays smoother and shows fewer hammer marks. Maple makes a more durable block but it is harder to make. We use an 8" length of two-by-four. Saw or rasp a gentle arc across the end grain of the block, then cut two or three grooves.



To accommodate a flared end on the spiculum, wider anticlastic grooves can be cut along the side of the block using a coarse round file or rasp. This style of block is most effective for making spiculums up to 12” long and ¾” in diameter. This block can also be used for small-scale jewelry work such as small anticlasts, ruffles and forming details, so it is a good addition to a tool collection. There is space on the block for carving additional grooves and anticlastic bays as they are needed.

Decide on the pattern and trace it onto the metal. If you want to bend the spiculum after forming, the length of the pattern should to be at least nine times the width. If you want the spiculum to be curved at the ends, add extra length for leverage. This extra metal can be cut off after bending. The sample shown is made of 22 gauge NuGold that was grade-rolled and trimmed to 5″ long, ¾″ at the wide end, by ¼″ at the narrow end. After beveling the edges, anneal the strip.

Grade Thinning for Straight Spiculums

Whether we think of tiny tubes or large plumbing pipes, the thickness of the material is almost always constant. This makes sense because the diameter is also constant. Spiculums are tapering tubes, which is to say that the diameter changes as we move down the tube. If we use a strip of metal with a uniform thickness, the curve that is easy to make at the wide end will be almost impossible to form at the narrow end. The solution is to start with a strip of metal that is thinner as it becomes narrower. The process of creating this transition is called *grade thinning* or *grade rolling.*

To selectively thin a sheet by forging, strike it with a planishing hammer using many small overlapping blows. Increase the force of the blows as you move along the strip, making one end thinner than the other. We usually start hammering at the narrow end and work toward the wide end. After checking the thickness with a gauge, continue to hammer and recheck the thicknesses until the metal is graded appropriately.

To create the desired thinning with a rolling mill, open the gap between rollers and slide the wide end of the strip between them. Tighten until the rollers hold the metal without compressing it, and then back the metal out. This called a *dead pass.* Make note of the position of the dial on top of the mill.

Remove the metal, close the gap slightly, roll the strip up to the point where the thinning needs to begin, then back it out. Tighten the rollers again and repeat the process, this time going not quite as far along the strip. In most cases, a half-inch spacing works well. Repeat the sequence of tightening and rolling in and out in increments, until the thickness and width of the pattern are in proportion to each other. As the metal gets thinner, tighten the mill in smaller and smaller increments and measure after each step.

Remove the ridges that indicate each new pass by planishing lightly. The goal is to create a smooth transition of thickness along the length of the strip. Resist the temptation to anneal at this point—it will be easier to saw and file while the metal is stiff. If necessary, redraw the desired pattern on the metal and cut it out. If a narrow point on the spiculum is desired, this is the time to trim the narrow end. File the blank to even and smooth the edges.

Center: the initial blank. The strip on the left was rolled and planished. The strip on the right was thinned by planishing alone.

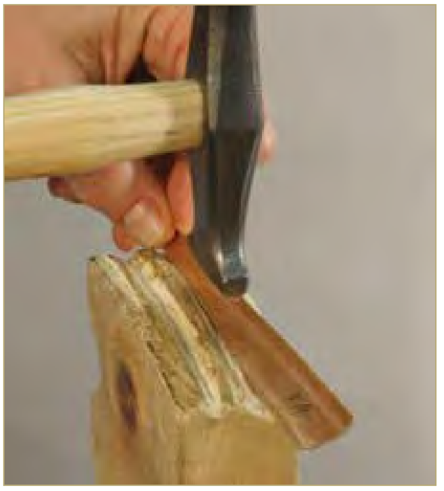
Use a scriber to mark the side of the blank that will be the inside of the spiculum. To allow the edges to meet flush when the spiculum is closed, file a slight bevel (no more than 30°) toward the inside of the blank. This beveling is more important in small diameter pieces than in pieces with larger diameters.

After preparing the blank by grade thinning, trimming and beveling, it is time to anneal.

If the metal needs to be grade thinned, do it before proceeding with the pattern. Grade rolling is only necessary for straight spiculums or if the metal being used is quite thick. Suggested relationships:

20 gauge metal for patterns from 2" to 1" wide
22 gauge metal for patterns from 1" to ½" wide
24 gauge metal for patterns from ½" to ¼" wide
26 gauge metal for patterns from ¼" or less

After grade rolling , trim to the correct pattern, file, and if necessary, bevel the edges and then anneal.



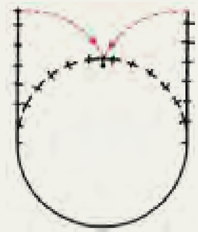
Secure the spiculum stake in a vise with the grooves facing up. Stand so that the grooves are parallel to your body. Use a cross peen hammer that is about 1/3 of the width of the spiculum. A slight curve to the long axis of the face helps avoid marks from the corners of the hammer face even better than well-rounded corners with a straight axis. Using an arced hammer face on the arced end of a spiculum block helps to keep the long axis stay straight while furrowing the spiculum. The first step is to bend up the edges of the spiculum blank. Lay the large end of the annealed and thinned strip along the largest groove and strike with a cross peen hammer just inside the edge. After moving down the entire length, reverse the strip and repeat the process just inside the other edge. Use a narrower hammer and a narrower groove as the blank becomes narrower.

After the first two rows of hammering, the strip should look like this. Note that the curves are smooth, consistent, and at the very edges of the taper.

Repeat the process at least two more times, striking just inside the previous line of hammer blows. As before, shift to narrower hammers and grooves as the form tapers. Continue this process until you reach the center; on small spiculums, the third row is usually at the centerline.

Avoid annealing because the metal should be in a work-hardened condition for the next step. Continue this process until it is difficult to get into the furrow. Because this is the last chance to work from the inside, take a moment to confirm that the surface is smooth, the deepest part of the "U" is in the center of the blank, and the form is symmetrical. Correct as needed.

The Magic U

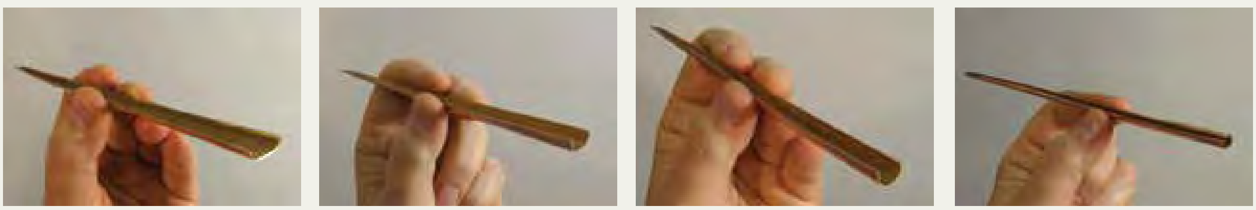


When making a spiculum, the first process is to furrow, synclast, or anticlast the metal until the width of the U-shaped cross section is about ¾ of the height. At this point the spiculum can begin to be closed by hammering the upper half of the "U" into a circle. Nancy Linkin dubbed this cross section "The Magic U."

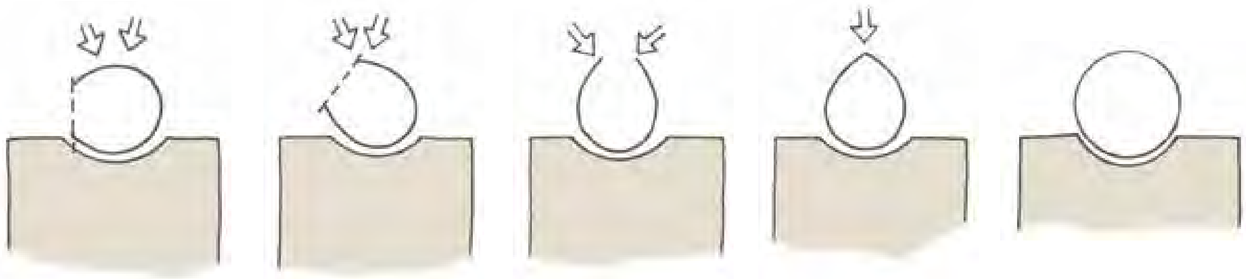
When the spiculum has been furrowed as deeply as possible from the inside, it is time to start working from the outside. Using a planishing hammer, tap gently on the sides of the spiculum, remembering to move from one groove to another as the size of the spiculum changes. Continue until the proportions of the "Magic U" have been reached. Then continue the closing process as shown on the next page.

When furrowing, the goal is that the seam should be straight and symmetrically aligned with the taper. If the form twists, this is an indication that your blows are not hitting parallel to the long axis of the spiculum. If the form is narrow, this can be corrected using pliers. For larger spiculums, hammer along the furrow parallel or slightly in the opposite direction of the twist.

The Progression of Forming a Spiculum



Closing a Spiculum



Support the spiculum in a wooden groove and tap along the sides to form a gentle oval.

Tilt the spiculum and tap closer to the edges to begin the intended teardrop shape.

Tap lightly very close to the edges to ease them closer.

When the cross section is teardrop like this, tap with a small planishing hammer along the seam.

The spiculum will close like a zipper, resulting in a round cross section.

When you can no longer reach inside the spiculum with a hammer, tap gently, following the angles shown above.

Starting at the narrow end, use a planishing hammer to slowly and evenly bring the edges together.

Proceed up the length with gently overlapping blows.

As the gap between the edges narrows, the spiculum will be turned almost entirely right side up.

Rotate the spiculum as the gentle tapping continues, but avoid striking directly on the seam. At this point it is easier to work with the spiculum pointed toward yourself.

This is the teardrop-shaped cross section we want. From here we can close the seam with blows of a planishing hammer that will simultaneously make the spiculum round.

It sometimes happens that the closing process is uneven and it becomes necessary to open the spiculum to correct the irregularity. We use a flat bladed steel tool, called a wedge tool, for this. Make your own by forging a steel rod or grind and polish a screwdriver. The blade should have softly rounded edges and a smooth polish so it will ease into the seam and spread it open.

Anneal the spiculum before using the wedge to minimize the chance of the wedge slipping. Slide the tool away from your hands. Keep the edges straight by rocking the tool vertically rather than side to side.

Set the spiculum in a nearly vertical position so gravity can help the solder flow. If possible, start soldering at the widest part of the spiculum, and finish at the narrowest. Use wire solder or long thin strips of sheet solder held in locking tweezers rather than little snippets of solder. Feed the solder into the seam as needed, pulling it along the seam with the heat and, if necessary, spreading with a solder pick.

Caution! Do not quench the hot spiculum! It can act like a gun, and shoot hot pickle or water at you! Let the spiculum air cool until you can pick it up in bare hands to put it into the pickle. If any area of the spiculum is filled with solder, it will not drain completely. In this case, put the spiculum in a solution of baking soda and water to neutralize the trapped pickle. Then rinse it well. It is usually a good idea to gently warm the spiculum to evaporate the water before further work.

Do not be concerned if everything does not solder on the first try. It is normal to need two or more soldering sessions to complete the seam. Do not add excess solder to points that will not flow—thick solder spots will create stiff areas that will not bend smoothly. It is better to stop, pickle, and resolder to get a smooth seam.

It is best to clean up and refine the surfaces of the spiculum while it is still straight, because it is easiest to reach all of the surfaces at this stage.

As a general rule of thumb, use the biggest and broadest tool that will do the job. The purpose of filing is to remove the high areas to create a uniform surface.

Keep the spiculum supported so that the effort goes into the work—do not “air file.” Remember that the forward stroke of the file is the cutting stroke. Note the groove in the bench pin seen here. This secures the spiculum while sanding. Finish with sandpaper as desired.

Bending a Spiculum

Anyone who has tried to bend a plastic drinking straw knows that it will kink and fold. (That's why somebody invented the pleated bendy straws). Technically phrased, the material needs to stretch on the outside of a bend and compress on the inside of a bend, and achieving this requires a bit of finesse.

Imagine the cross section of a tube and picture the bending process in slow motion. What starts as a circle will compress into an oval that will become thinner and thinner until it folds. To avoid that, we reshape a spiculum into an oval with its longer axis perpendicular to the bend. When we start to bend the spiculum, the cross section collapses as before, but this time the collapse takes the spiculum back to round.

In practice, anneal the spiculum and support it on a spiculum stake. Tap lightly along the length to change the cross section to a smooth oval. Anneal again and bend (preferably in bare hands rather than with tools) until the cross section is round. This can be repeated several times.

The ratio of length to diameter determines how easy or difficult it will be to bend a particular form. A long skinny spiculum is easier to bend than a short fat one.

Depending on how it was soldered, the seam may either be the strongest or the weakest area of the spiculum. A thick seam with a lot of solder tends to resist bending. A seam that did not meet well or that has been overly filed may crumple. For these reasons, position the seam in a neutral area of the bend; this will usually be the side.

Procedure for Bending a Spiculum

The best tools for bending are hands and fingers because mechanical devices tend to dent the surface. Support the spiculum between fingers and thumbs, pressing with the thumbs and pulling with the fingers. Bend until the form begins to flatten beneath your thumbs; an indication that it is beginning to go oval and is in danger of collapsing. At this point, stop and reestablish the oval cross section perpendicular to the axis of the bend. We usually do this by gently planishing, with the spiculum supported on a smooth soft pine surface. A planishing hammer works better for this process than a mallet because the planishing hammer can place the blows more accurately. Rotate the spiculum and move it along the spiculum stake to keep the surface rounded. Anneal, then continue bending.

Leverage is important in making a smooth curve. Another way to say this is that bending in the center of a spiculum is a lot easier than bending the ends where there is less to hold on to. A solution is to insert a tool that will increase leverage. Make the end of the tool rounded to minimize damage to the wall of the spiculum.

Some bumps are inevitable; planish these out with the spiculum supported in a wooden groove.

Start bending in the areas with the largest diameter because they are the most difficult to persuade. Continue toward thinner areas. Because the ends are difficult to bend by hand, it might be necessary to use pliers. Use half-round forming pliers and, rather than gripping the spiculum, hold the jaws slightly apart and use them as a bending jig.

Beyond the Exercise

This exercise has been an introduction to the possibilities of spiculums. After gaining an understanding of how to make a tapered tubular form from a flat piece of metal, this knowledge can be transferred to more intriguing and complex patterns. When you know how to create and bend spiculums, you will be able to create light and strong structures that can be wearable art jewelry, functional hollowware, or lyrical sculptures.