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The ULTIMATE COMPILATION of REFERENCES for:

FORGING

AN ILLUSTRATED GUIDE TO

FORGING

BY

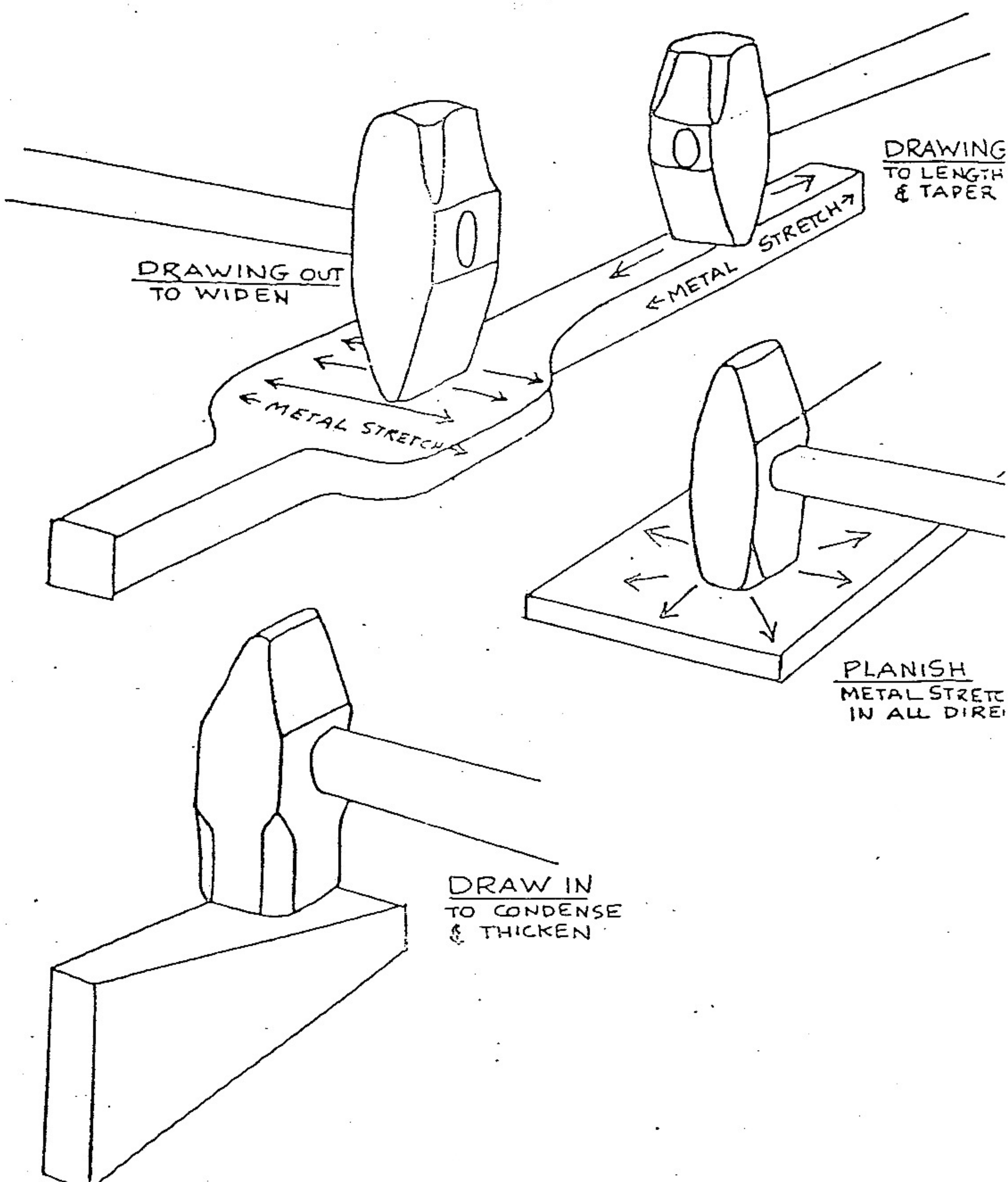
JOHN T. FIX

FLATTENING, DRAWING, AND UPSETTING
THE THREE BASIC FORGING PROCESSES

GENERAL CONSIDERATIONS

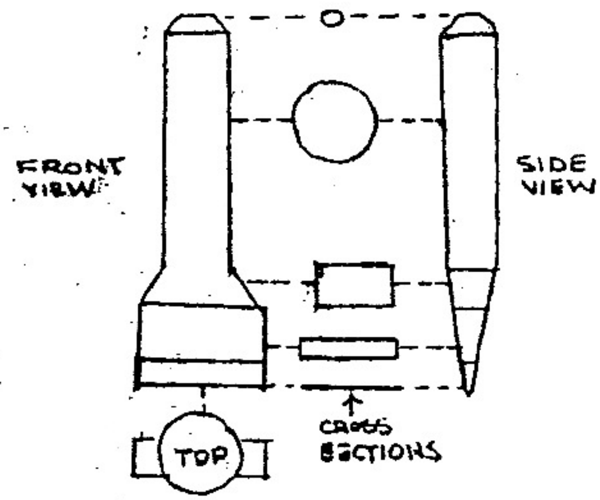
1. WORK THE WHOLE LENGTH OF STOCK TO KEEP PROPORTIONS UNIFORM.
2. IF MAKING MULTIPLES, DEVELOP PIECES STEP-BY-STEP SIMULTANEOUSLY.
3. KEEP STOCK SQUARE AND WORK ALL EDGES UNIFORMILY.
4. CORRECT MISTAKES AS SOON AS THEY APPEAR.

FORGING HAMMER POSITIONS FOR STRETCHING METAL IN DESIRED DIR

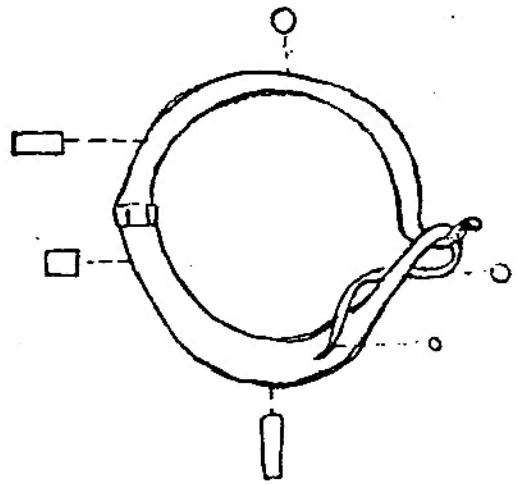


FORGING

is a process which changes the cross section of a metal bar, rod, or wire with pressure applied by a hammer, as seen in the orthographic projections of a chisel and necklace as shown below.



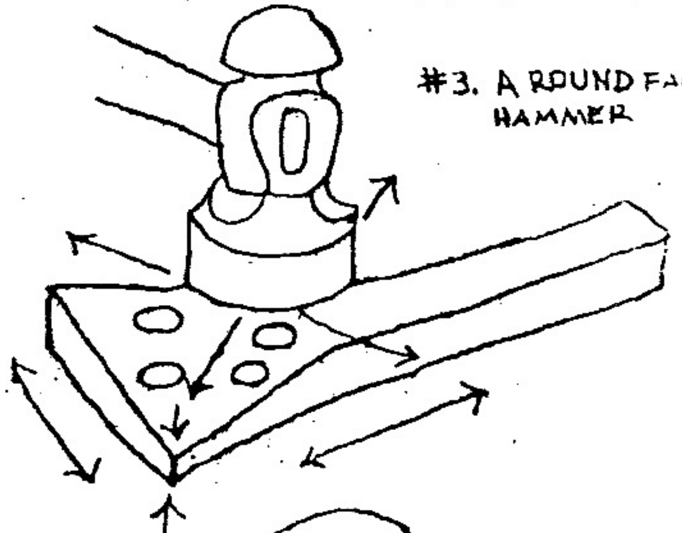
#1. CROSS SECTIONS OF A CHISEL



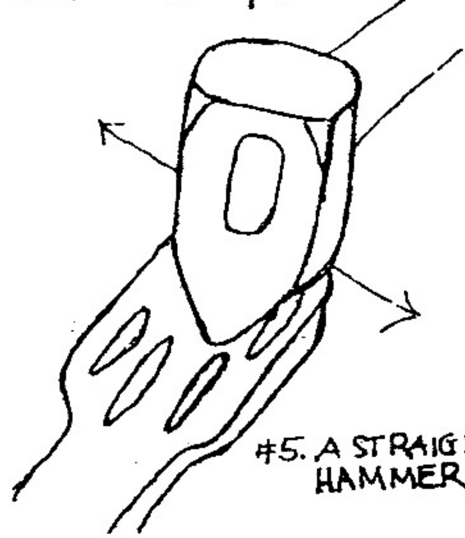
#2. CROSS SECTIONS OF A NECKLACE

HAMMERS

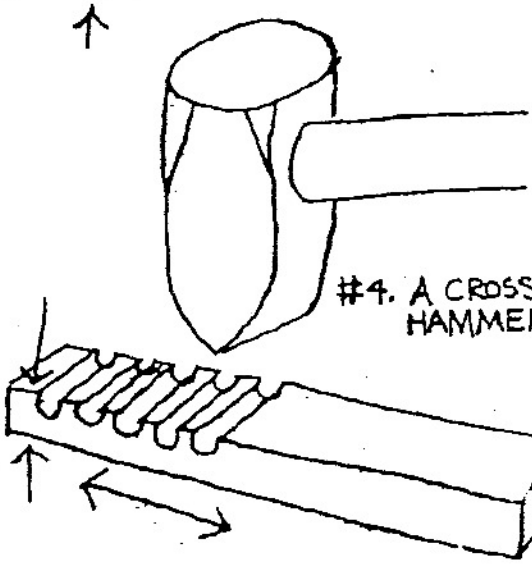
There are two basic hammers: those with round faces and those with oval or cross peen faces.



#3. A ROUND FACE HAMMER



#5. A STRAIGHT PEEN HAMMER



#4. A CROSS PEEN HAMMER

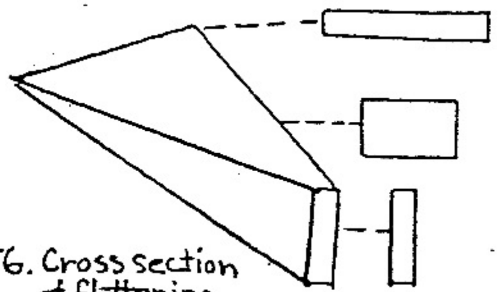
#3. A round face hammer delivers force equally in all directions and is used for flattening.

#4. A cross peen hammer delivers force at right angles for drawing.

#5. A straight peen hammer delivers force parallel to the handle and is used for spreading.

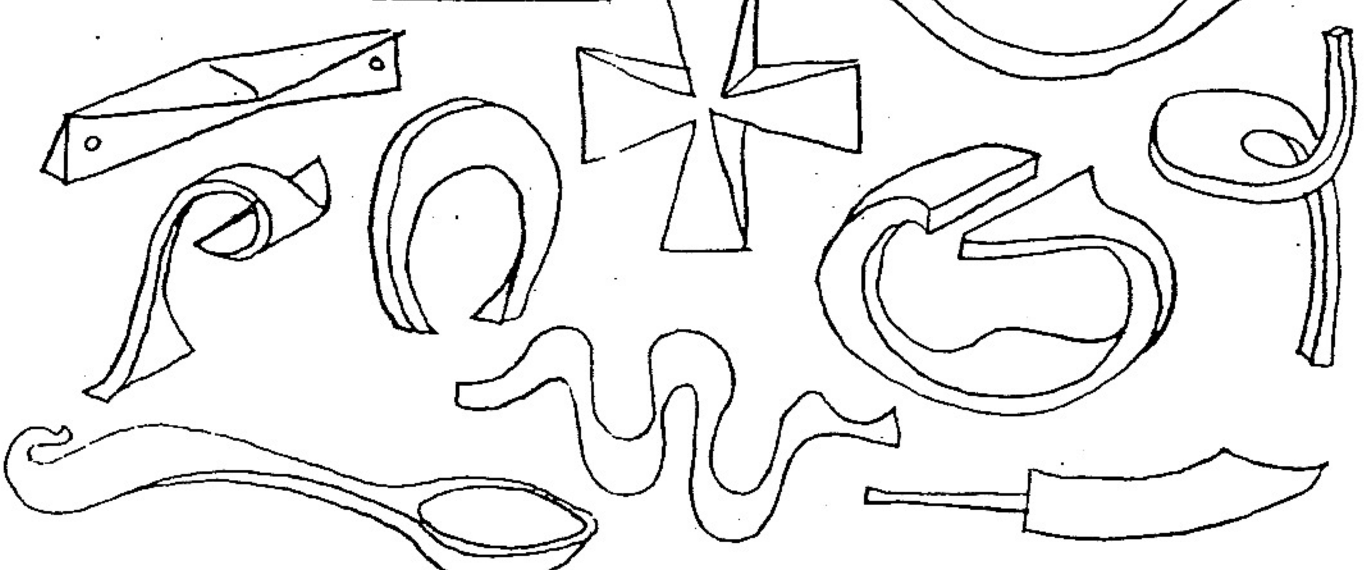
FLATTENING

is a process WHICH flattens or spreads the cross section of a bar or rod. See illustration #6.



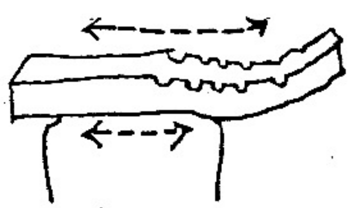
#6. Cross section of flattening

#7. EXAMPLES OF VARIOUS FORMS CREATED BY FLATTENING.



CORRECT WORKING METHOD:

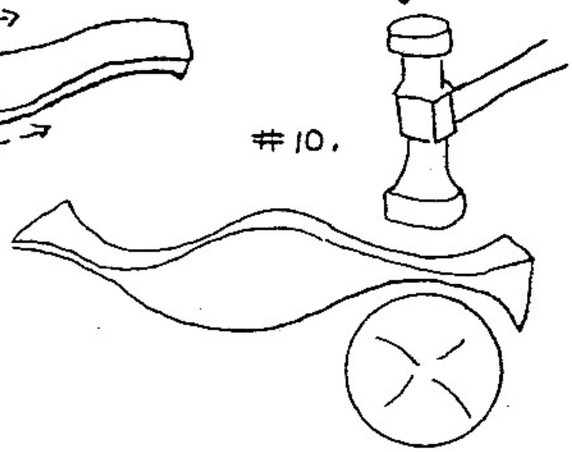
Work from center toward edges using stakes to refine forms as in fig. 8, 9, and 10.



#8.

#9.

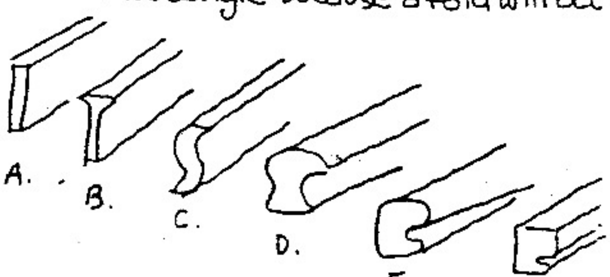
#10.



INCORRECT WORKING METHODS:

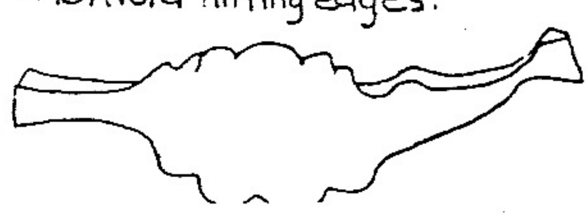
See FIGS. 11 and 12

#11. Avoid hammering the thin edge of a rectangle because a fold will occur.



A. B. C. D. E. F.

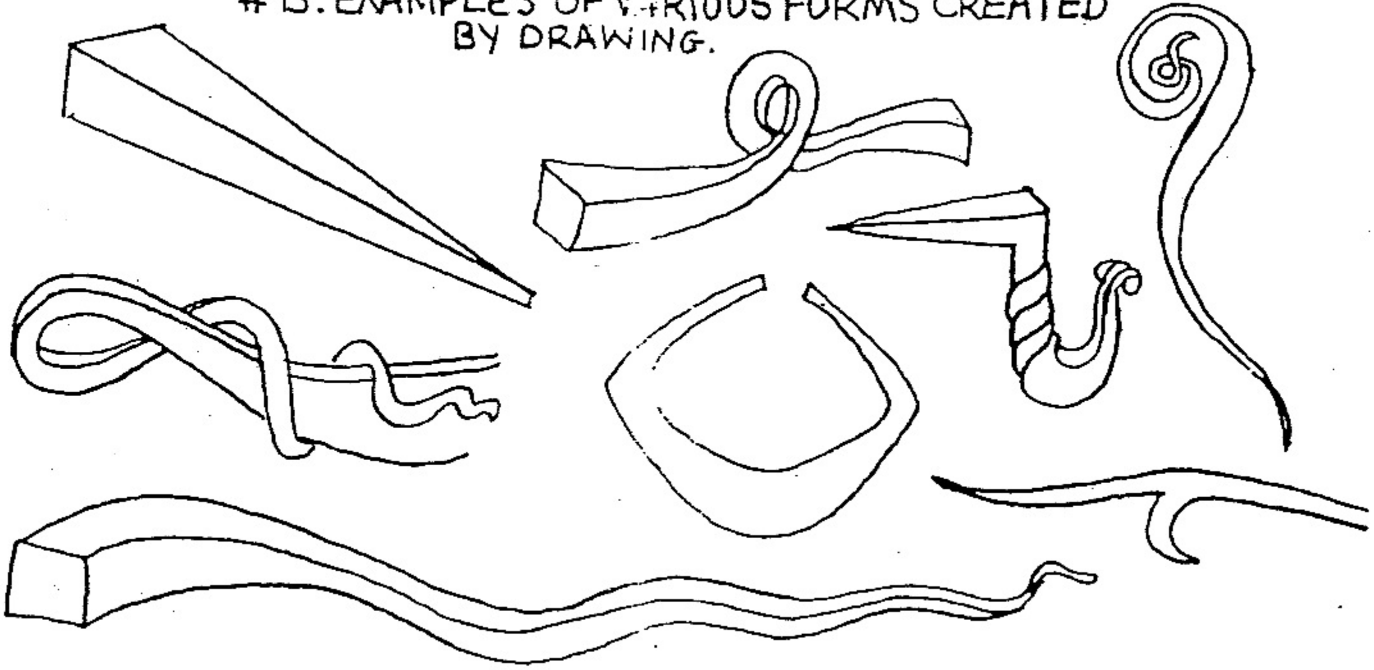
#12 Avoid hitting edges.



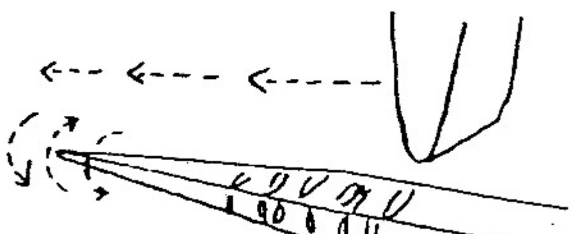
DRAWING

is a process which reduces the diameter and lengthens a bar or rod. It is done with a cross peen hammer.

#13. EXAMPLES OF VARIOUS FORMS CREATED BY DRAWING.

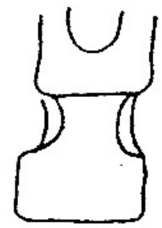


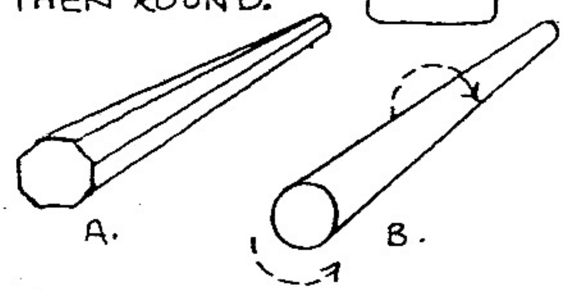
#14. USE CROSS PEEN HAMMER WORKING TOWARD ENDS.



#14.

#15. PLANISH TO OCTAGONAL SECTION AND THEN ROUND.



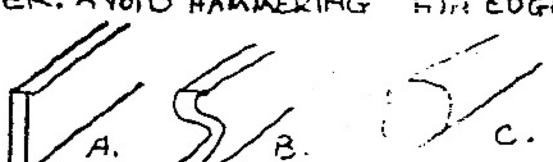


A. B.

#16. IF STOCK GETS OFF SQUARE CORRECT IT IMMEDIATELY BY FILING OR HAMMERING ROUND, THEN CONTINUE DRAWING.

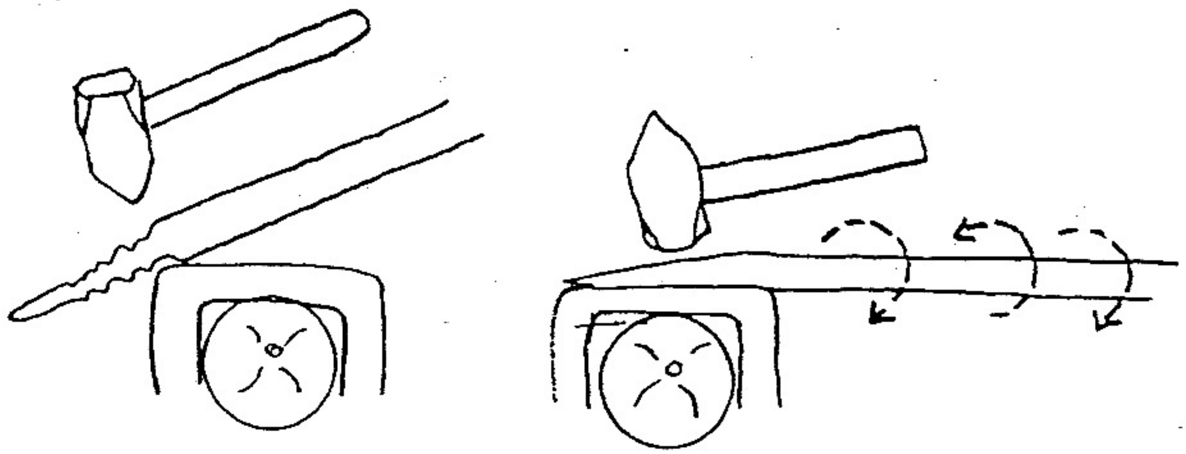
A. B. C. D. E. F.

#17. REMEMBER! AVOID HAMMERING ON EDGES OF A RECTANGLE!

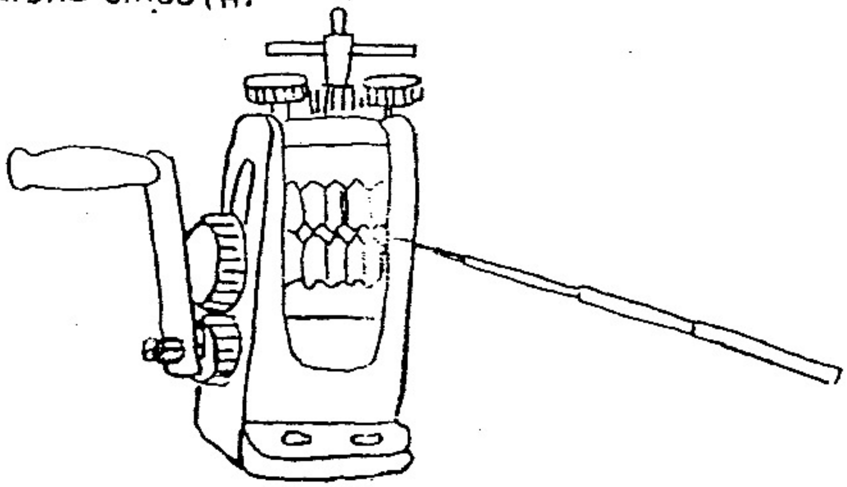


A. B. C.

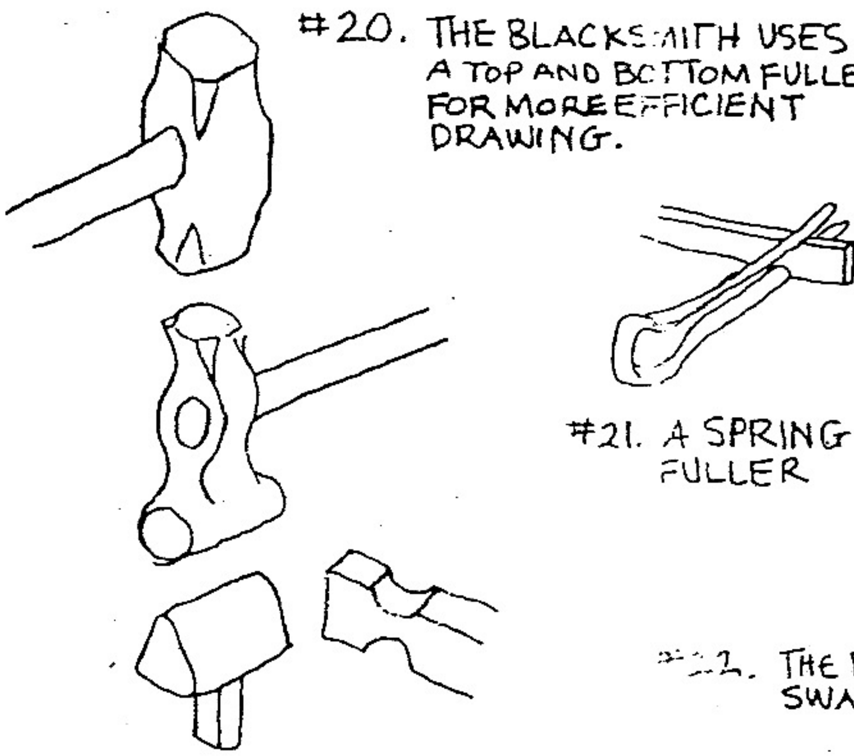
#18. FOR MORE EFFECIENT DRAWING, (A) USE THE ROUNDED EDGE OF AN ANVIL, THEN (B) SMOOTH ON FLAT SURFACE.



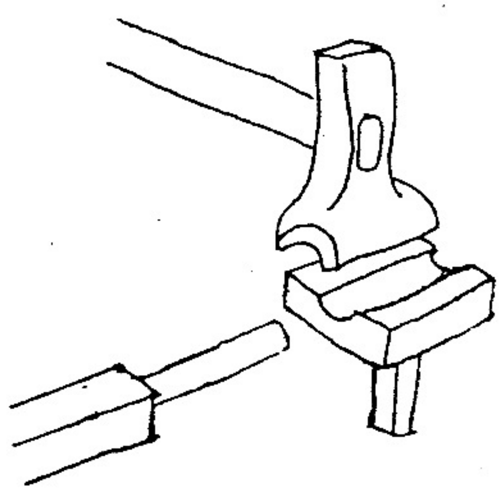
#19. THE JEWELER USES A WIRE ROLLING MILL FOR GRADE DRAWING, THEN PLANISHS SMOOTH.



#20. THE BLACKSMITH USES A TOP AND BOTTOM FULLER FOR MORE EFFICIENT DRAWING.

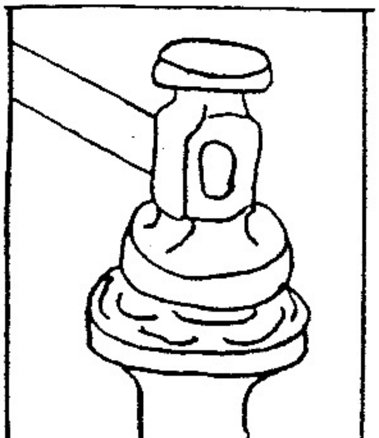


#21. A SPRING FULLER



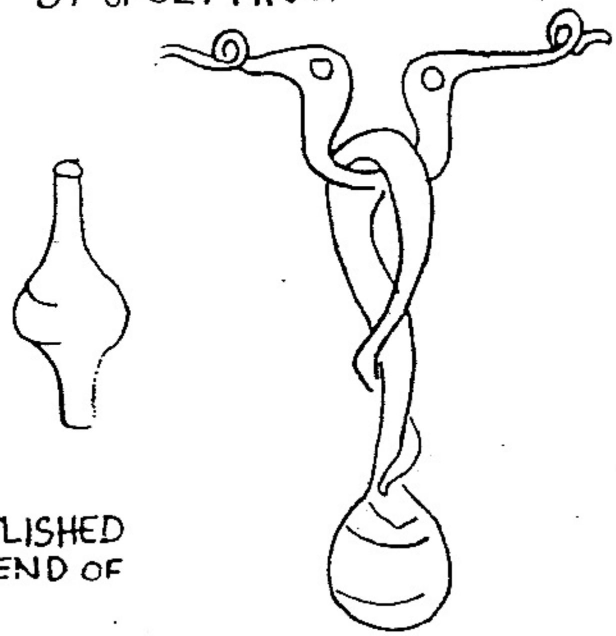
#22. THE BLACKSMITH ALSO USES THE SWAGE FOR SMOOTHING THE WORK.

UPSETTING is a process which increases the diameter or thickness of a bar or rod.

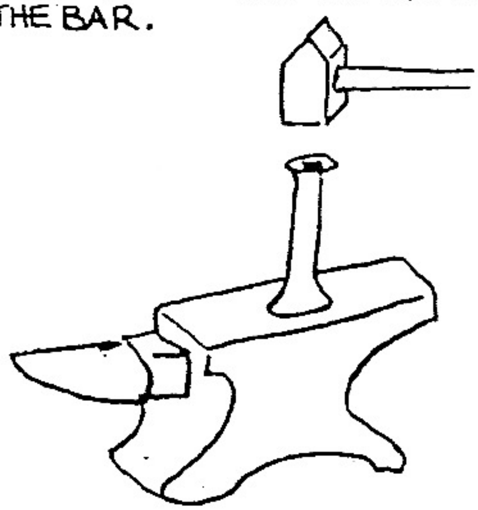


#23. AN EXAMPLE OF UPSETTING

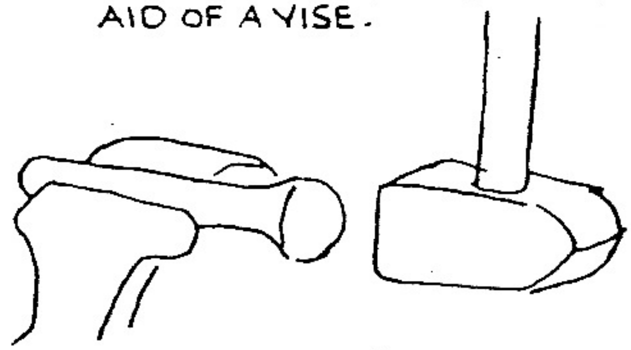
#24. EXAMPLES OF TWO FORMS CREATED BY UPSETTING.



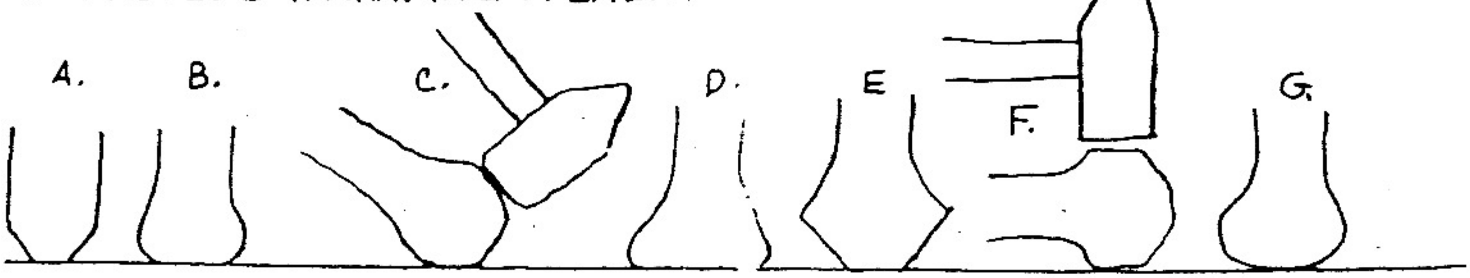
#25. A. UPSETTING IS ACCOMPLISHED BY HAMMERING ON THE END OF THE BAR.



#25.B. MORE EFFICIENT UPSETTING IS ACCOMPLISHED WITH THE AID OF A VISE.

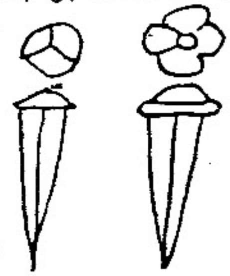


#26. STEPS IN MAKING A BALL

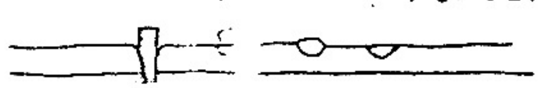


#27. IF FOLDS OCCUR CORRECT BY HAMMERING OR FILING.

#28. NAILS ARE MADE BY UPSETTING WITH A HEADER.

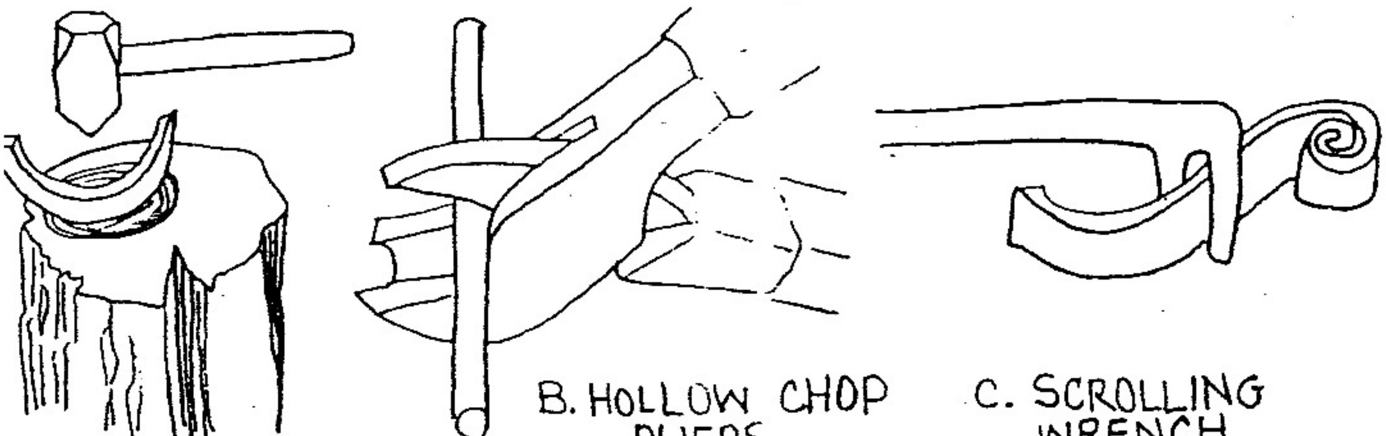


#29. THE HEADS OF RIVETS ARE MADE BY UPSETTING



IORE COMPLEX AND INTERESTING F RMS CAN BE CREATED BY BENDING, TWISTING, JOIN NG, & SPLITTING

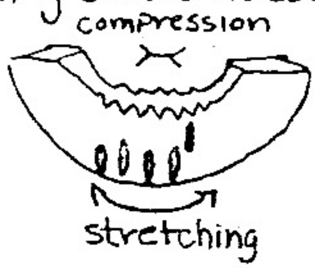
ENDING is done in the hollo a stump or with hollow chop pliers or a scrolli ng wrench.



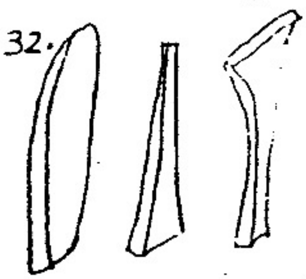
30. A. HOLLOW STUMP B. HOLLOW CHOP PLIERS C. SCROLLING WRENCH

ending occurs naturally when one edge is stretched longer than another.

31.

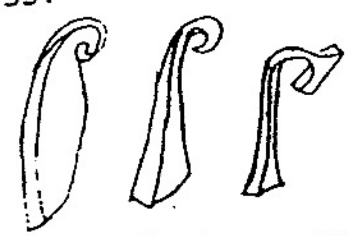


#32.



FLATTENED FORMS

#33.

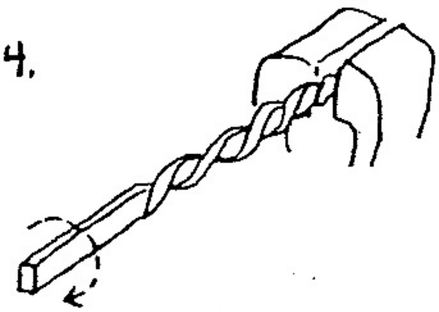


FLATTENED FORMS BENT INTO SCROLLS

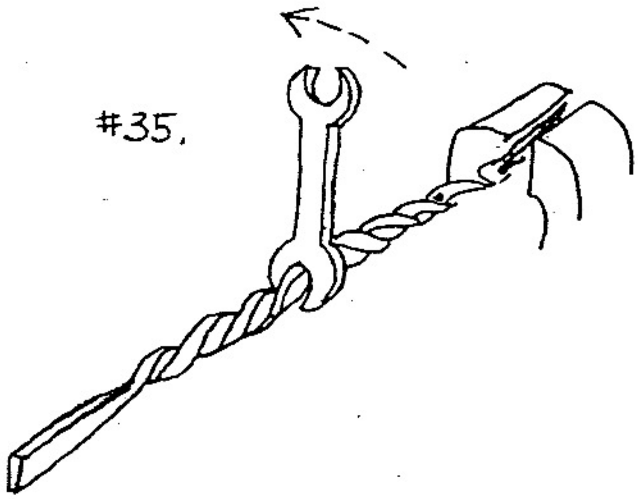
ending must be done before flattening because a rectangular section ill not bend on its long edge.

TWISTING can be done with a pliers, wrench, or drill.

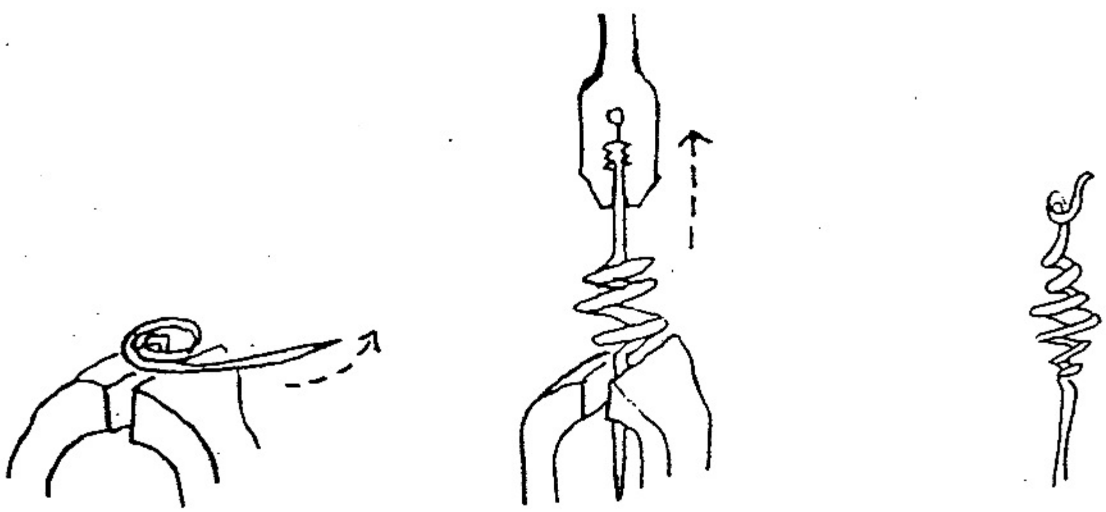
#34.



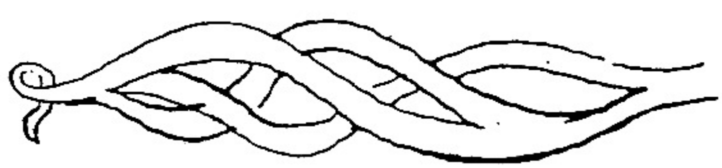
#35.



36. A FORM MADE BY TWISTING AND STRETCHING.



37. SEVERAL ELEMENTS MAY BE JOINED TOGETHER AND THEN TWISTED.

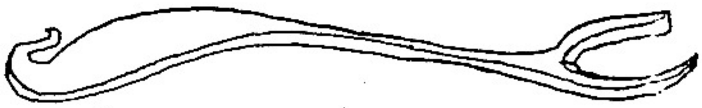


SPLITTING

can be done with a saw or chisel; then additional forging may be done.

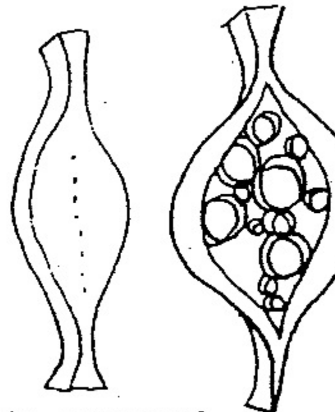
#38.

A BLANK BEFORE SPLITTING.



A FORK WHICH WAS SPLIT FROM A BLANK AND THEN FORGED.

#39.



BEFORE SPLITTING.

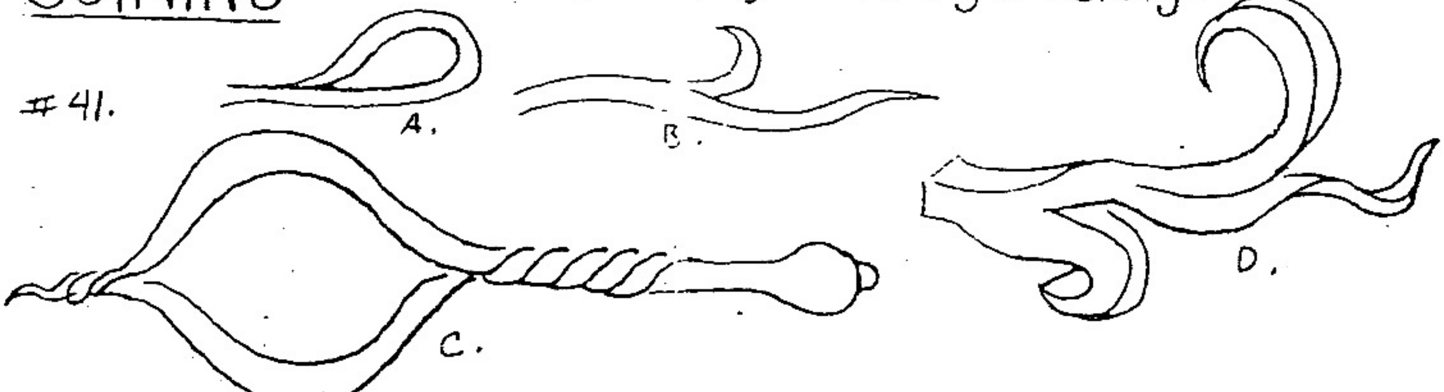
A PENDANT DEVELOPED FROM A SPLIT FORM.

#40. HINGES MADE BY SPLITTING.

JOINING

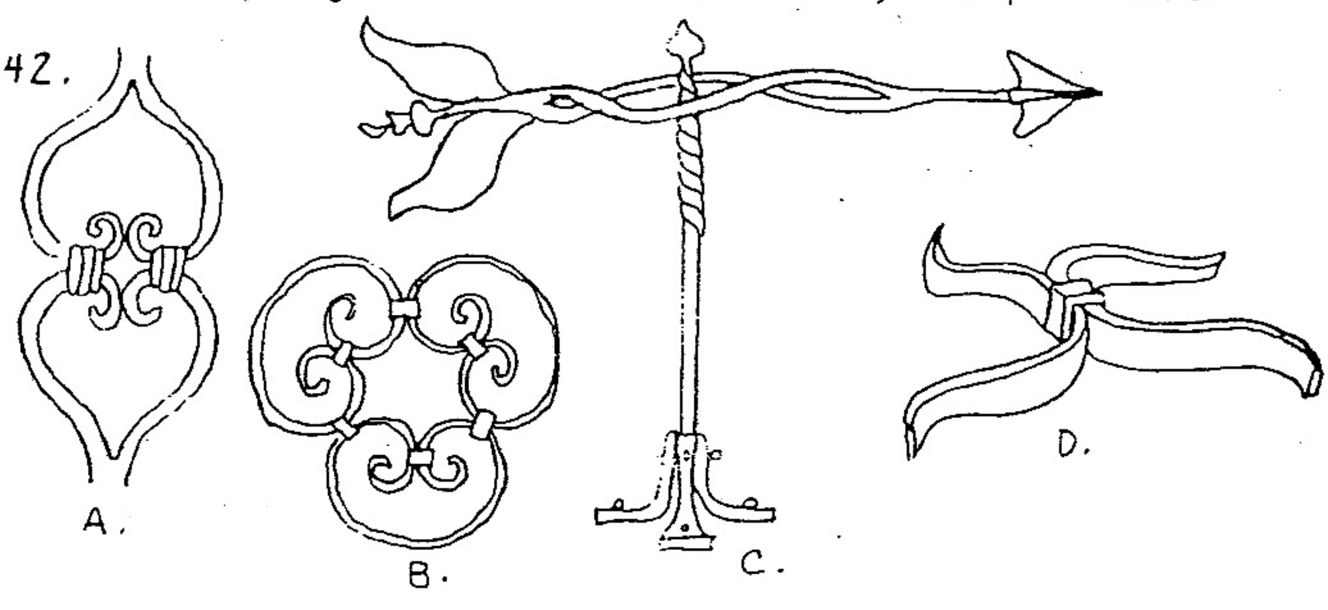
can be accomplished by soldering or welding.

#41.



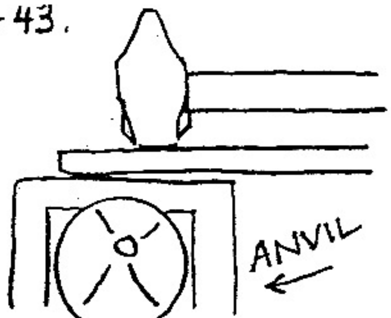
Objects may be joined with collars, screws, bolts, or rivets.

#42.

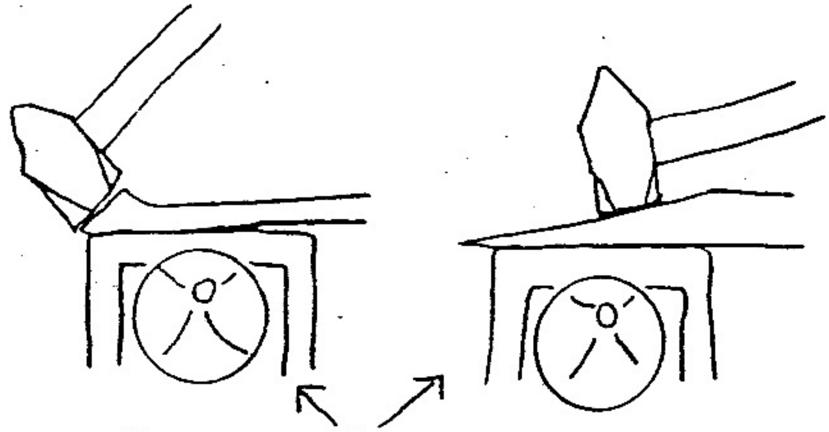


TYPES OF HAMMER BLOWS

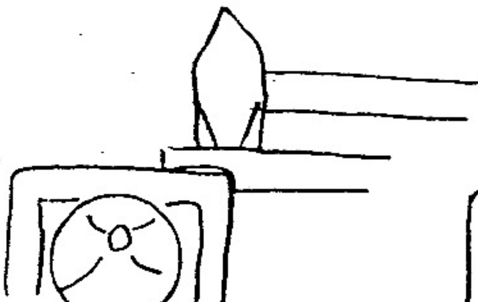
#43.



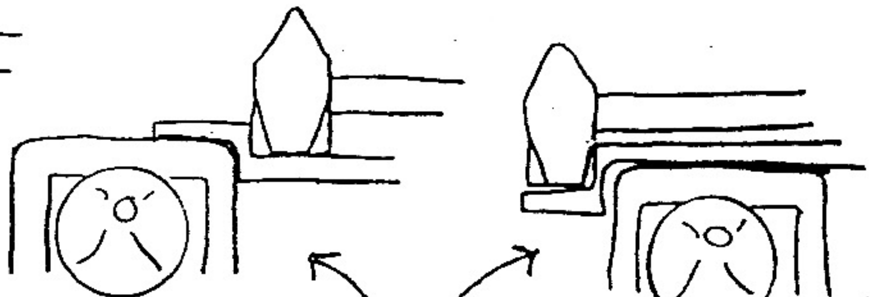
A. FULL FACE



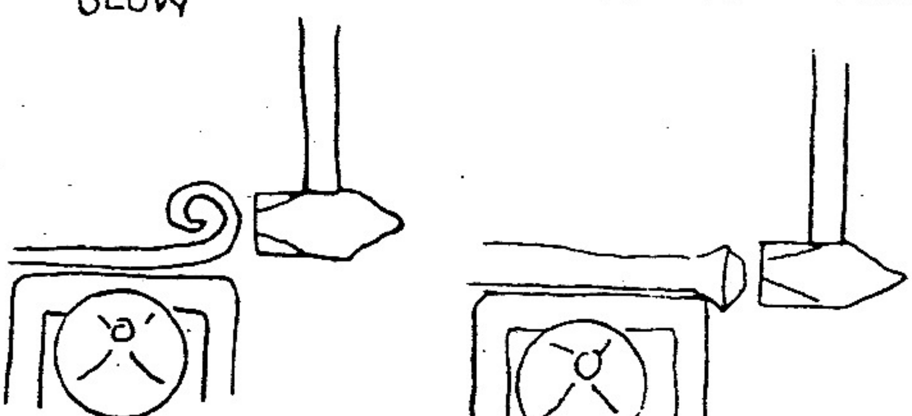
B. ANGLE BLOWS



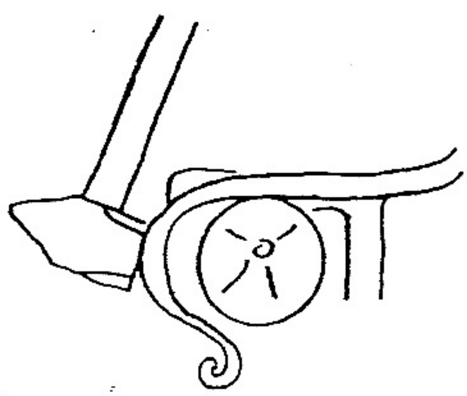
C. HALF-FACE BLOW



D. EDGE TO EDGE BLOW



E. BACK BLOWS



F. BENDING BLOW

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3. Coyne, John. The Penland School of Crafts Book of Jewelry Making. Indianapolis; N.Y.: Bobbs-Merrill, 1975.

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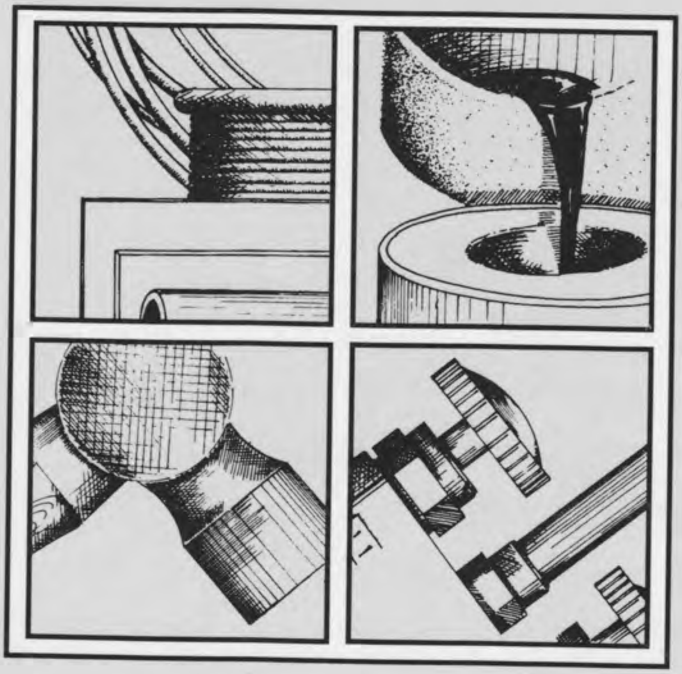
5. Meilach, Dona. Decorative & Sculptural Ironwork. N.Y.: Crown Publishers, 1976.

6. von Neumann, Robert. The Design and Creation of Jewelry. PA.: Chilton Book Co., 1972.

7. Weygers, Alexander. The Modern Blacksmith: The Making of Tools. N.Y.: Van Nostrand Reinhold.

Revised Edition

THE COMPLETE METALSMITH

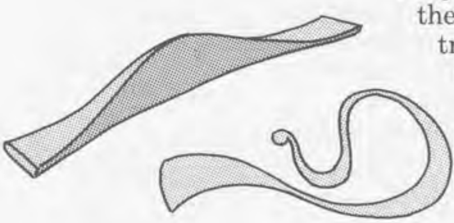


Tim McCreight

An Illustrated Handbook

Forging

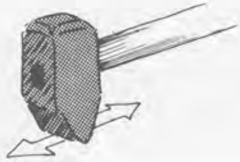
The shaping of a rod through the controlled use of a hammer is an ancient and basic technique of metalsmithing. Beginners are often surprised to discover how plastic metal can be.

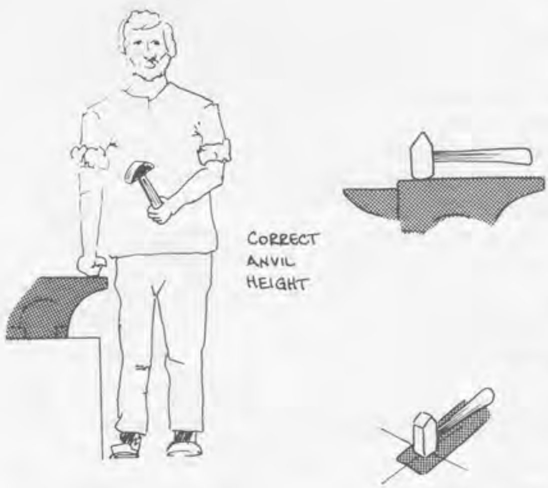


Forging may be defined as the controlled shaping of metal by the force of a hammer. This technique lends itself to graceful transitions from plane to plane and appealing contrasts of thick and thin sections. It is equally appropriate for large and small work. Gold, sterling and copper forge very well. Low-zinc brasses can also be forged but will require frequent annealing. It is a sign of good forging to require very little filing. Force and control must work together.

Directional Control

Control in forging comes from the cross peen of the hammer. Its wedge shape can push the metal in only two directions. This "push" can be directed along the axis to increase length or outward from the axis to increase breadth.





Tips

- Sit or stand close to the work in a posture you can comfortably maintain.
- Work on a smooth, hard, stable surface.
- Keep fingers and thumb wrapped around the hammer handle, not pointing along it.
- Anneal as needed; don't press your luck.
- Keep the hammer face polished.
- Don't hold the work piece where you intend to hit it.
- The hammer must make solid contact with anvil.

Certain tools of the manual crafts scarcely changed in form for ten or more centuries, because they were perfectly suited to the requirements of these crafts.

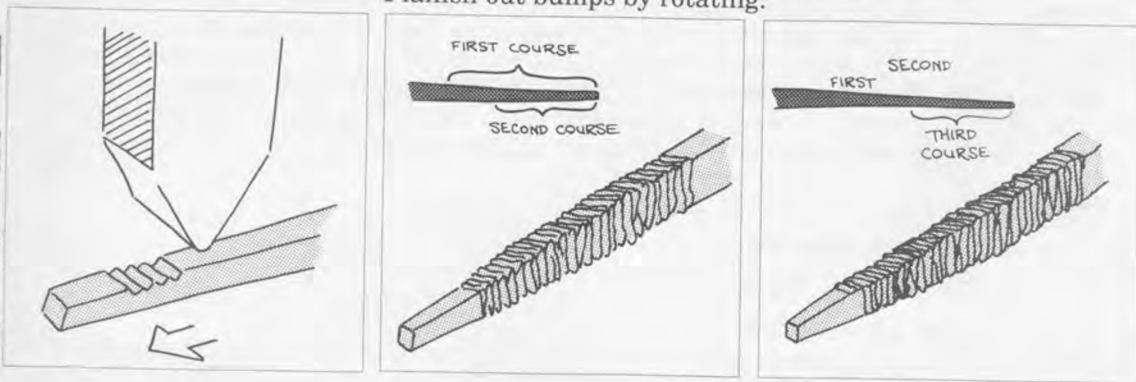
Maurice Daumas,
A History of Technology & Invention

Forging

Control and force must play equal roles in proper forging. Careful attention to the height of the anvil and the shape of the hammer face will help in both areas.

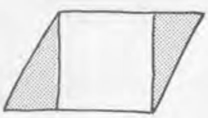
Forging A Taper

Work on square stock striking all sides equally. Planish out bumps by rotating.

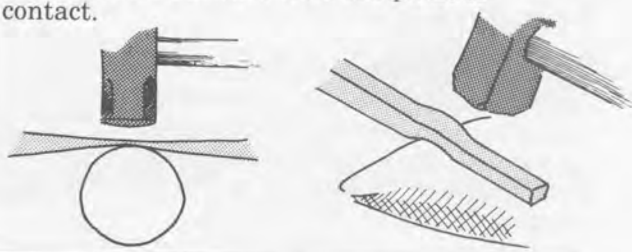


The Rhombus

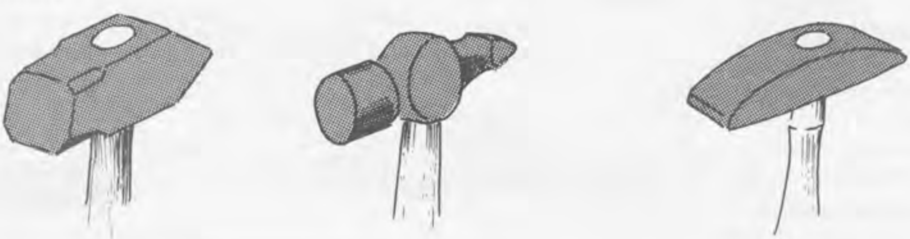
This refers to a cross section shape that is easy to make but hard to correct. Either file off the shaded areas or forge into round rod and from there return to square section.



An alternate forging method uses the curve of an anvil horn or a stake to force the metal to flow outward from the point of contact.



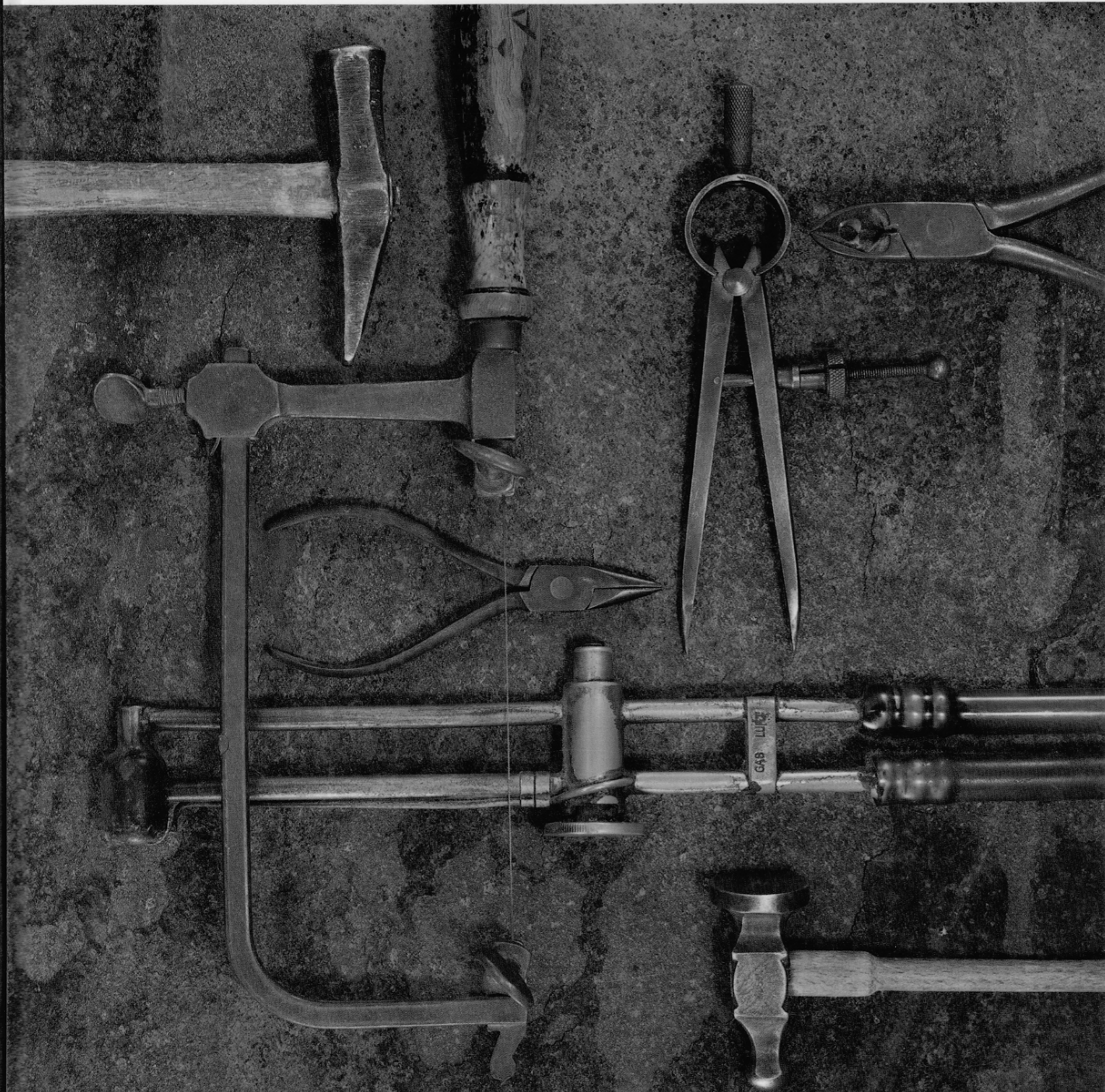
Hammers



Haste in every business brings failures. Herodotus, 450 B.C.

Practical jewelry making

Loosli / Merz / Schaffner



UBOS / SCRIPTAR

Procedure

Forging consists in deforming material by means of a hammer. It enables one to widen, lengthen and upset bars, rods and plates so as to bring them to the desired dimensions and shapes.
Forging also includes the compression of material in the case of cast ingots and blanks.
Unlike iron, most precious metals and non-ferrous heavy metals are cold-forged. According to the title of the alloy and the stresses it is to undergo, heating up to 700° C is permissible.
When forging causes hardening of the material through compression, annealing is necessary for restoring the metal's crystalline structure. The process must be repeated whenever the same degree of hardness is reached anew.

Tools

Forging hammer
For ordinary forging operations, a heavier version of the jeweler's peen hammer (planishing hammer) is used. For more special work, one needs several hammers of widely different sizes and shapes. The size and weight of the hammer must be proportionate to the dimensions and weight of the workpiece. Hammers which are too light do not have a deep kneading effect: they cause no more than superficial upsetting.

Forge tongs
For gripping the workpiece.

Square flat block
For forging operations needing a flat support.

Beak iron
For forging operations needing an angular, cylindrical or perhaps tapered support.

Stake
For forging operations needing a concave or convex support. Stakes of this kind are clamped in the vice.

Ring gauge
This is used for forging rings from blanks and also for enlarging them and correcting their shape.

Forging hammers, anvils and ring gauges are made of tool steel with hardened working faces.

I Forging hammer
1 face
2 peen
3 angle
4 handle hole
5 handle

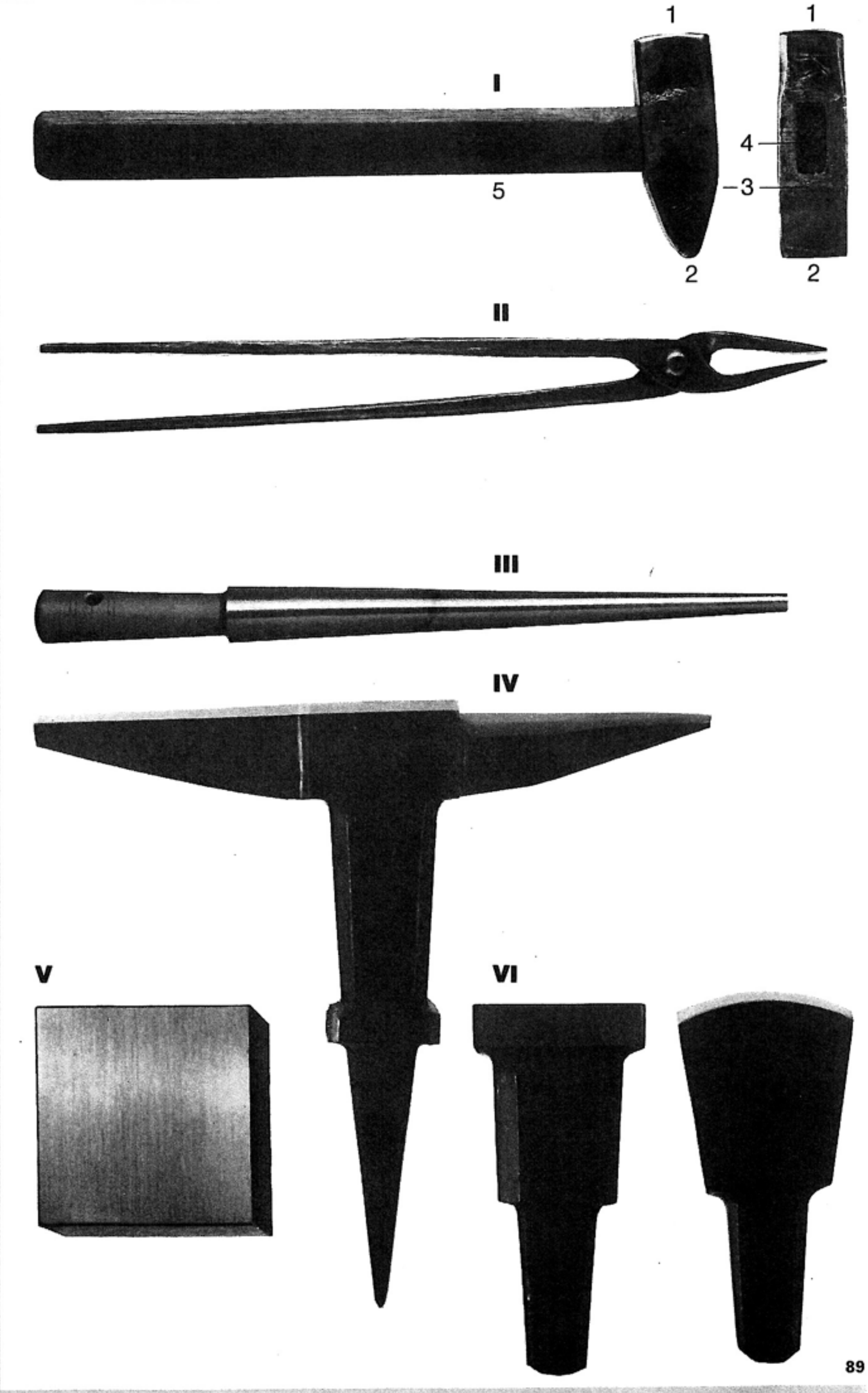
II Forge tongs

III Ring gauge

IV Beak iron

V Flat square block

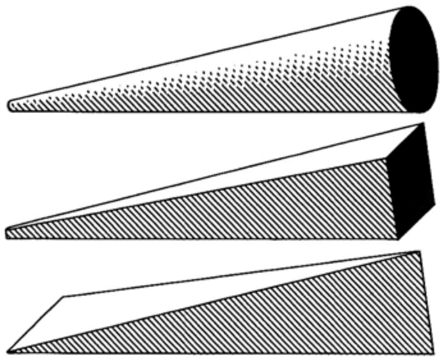
VI Stakes

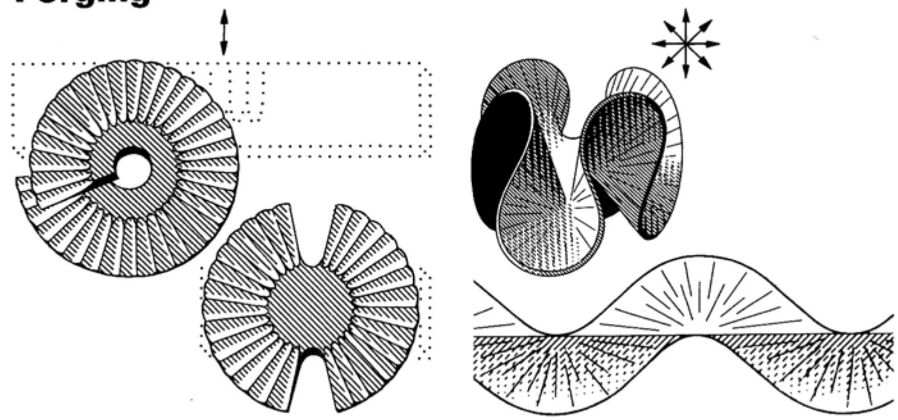


Forming techniques

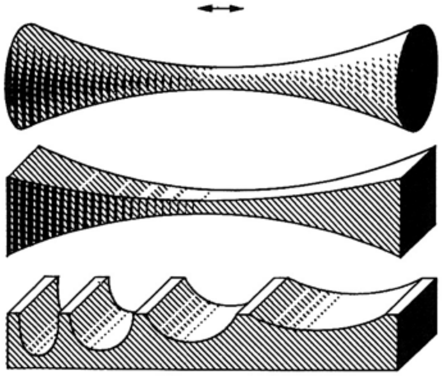
24 Forging

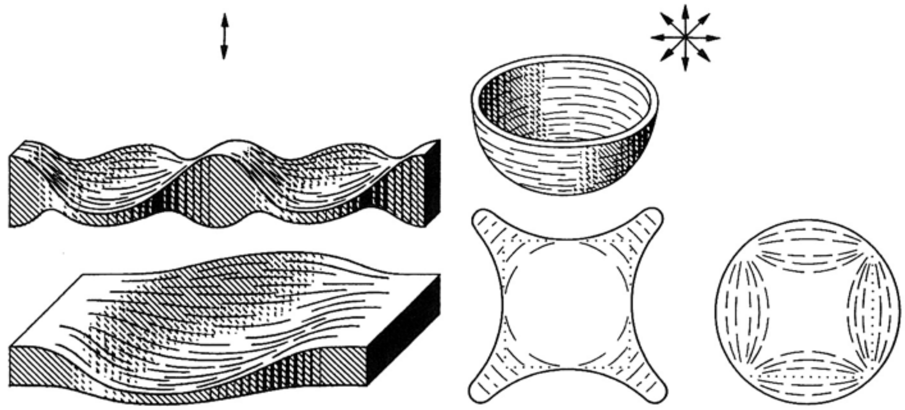
From the outside inwards





From the inside outwards



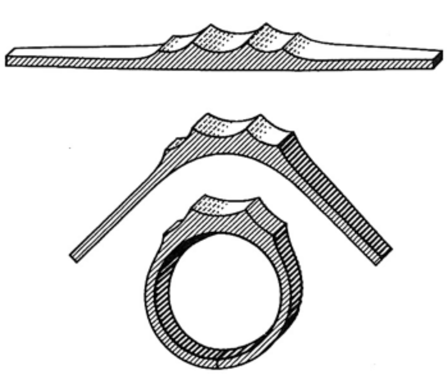


Observe:

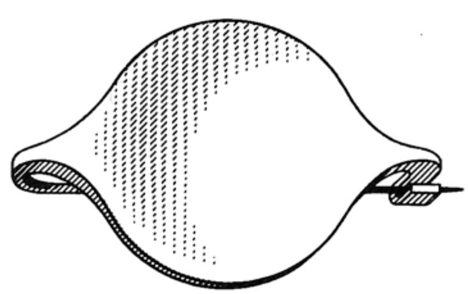
- the different effects obtained by forging with the face or the peen of the hammer
- how are the edges formed?
- how often is annealing necessary?
- the ductility of the material and the possibilities of upsetting it (note measurements)

Forming techniques

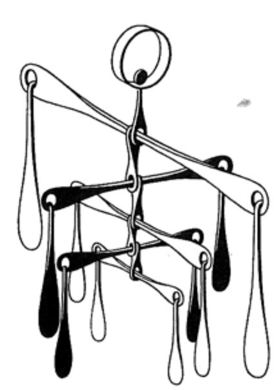
Possibilities of creation



Ring



Brooch



Pendant

The Theory and Practice of
Goldsmithing

Prof. Dr. Erhard Brepohl

TRANSLATED BY Charles Lewton-Brain

EDITED BY Tim McCreight

Brynmorgen Press

5.8.2 THE DEFORMATION PROCESS DURING FORGING

Ball peen and forging hammers are designed to achieve radical displacement of material. Both intrude deeply into the metal and displace material adjacent to the impact. They seriously alter the shape of the block.

The blow from a ball peen hammer displaces the structure all around the point of impact, whereas the metal beneath a forging hammer stretches only in one axis, namely at right angles to the peen. The block is lengthened in this direction. This important distinction accounts for the ability of the forging hammer to control the direction of flow during forging. In the case of both these hammers, the surface is dramatically altered and needs to be beaten smooth periodically as work progresses.

Where only minor changes in form are needed, the ball peen and cross peen hammers are replaced by planishing hammers. Crowned (lightly domed) faces are used on flat surfaces and absolutely flat faces are used on curved surfaces like bracelets.

5.8.3 HAMMER SHAPES

Perhaps the most basic hammer shape, and another icon of the metalworker's art, is a simple *forging hammer*, also called a *mechanics hammer*, shown in figure 5.41a. Variations on this, called a *goldsmiths hammer*, *tinsmiths hammer*, and *cross peen hammer* can be found in almost every trade that works metal. In every case, the distinguishing feature is a blunt wedge-shaped peen at a right angle to the handle on one end, and a flat or slightly crowned face on the other.

In all the hammers described, a wooden handle is stuck through the eye of the hammer and wedged tightly. The handle should be made of ash or a similar hardwood with elongated grain so it will be strong and still somewhat elastic. The body of the hammer should stay soft, but it is helpful if the striking surface is hardened. A steel with a carbon content between 0.38% and.05% is used. The faces of a metalsmith's hammer must be free of all scratches and pits. If a mark is accidentally made in a hammer, a good smith will immediately stop work to polish it out, knowing that using a scarred tool is a waste of time.

Of course every workshop has occasion to drive nails, pound a chisel or in other ways use hammers in a way guaranteed to mar their surface. For this reason, be certain to equip your shop with a traditional carpenter's hammer for these occasions.

Most hammers have two faces, the exception being small specialty hammers made to reach into tight places. In some cases the two faces of a hammer are in the same family, such as planishing faces. At other times a single hammer will combine faces from two different families, as for instance in a forging hammer, which combines a cross peen with a planishing face. Here are some popular hammers.

Goldsmith's or *Bench hammer.* This top quality hammer is used for small scale forging and shaping. The face is round and slightly crowned. The opposite end is a cross peen.

Raising hammers. Both striking surfaces are cross peens with different curvatures. The corners are slightly rounded to prevent marring the metal.

Forging hammer. This hammer has a sharper peen than the raising hammer and typically has a squarer body. The other end is a flat face, usually round or octagonal, slightly crowned and polished smooth.

Ball Peen hammer (sometimes called a *machinists* or *embossing hammer*). The striking surface forms a hemisphere and the opposite end a smooth, round face. These are available in a range of sizes.

Planishing hammer. The two faces of this hammer are circular and well polished. One face should be flat for working on curved surfaces and the other slightly crowned, for striking flat surfaces.

Finishing hammer. Hammers in this large and diverse family have polished faces and can be square, round or rectangular, either flat or convex.

Chasing hammer. (figure 5.42) This familiar icon of goldsmithing is used to strike small tools.

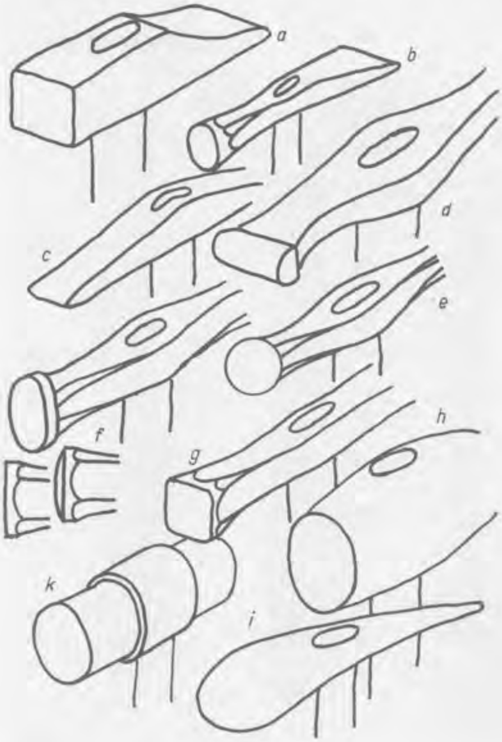


Figure 5.41
Goldsmithing and silversmithing hammers.
a) machinists hammer, b) bench hammer, c) forging hammer, d) raising hammer, e) ball hammer, f) planishing and smoothing hammer, g) tray or plate hammer, h) wooden mallet), i) horn mallet, k) plastic mallet.

Accordingly, its flat face is unusually large for its light weight, the better to "find" the tool. The handle is best made of a close-grained wood and sanded so thin it is springy. The back peen of the hammer is a small sphere that is useful for texturing or making rivets. The handle is shaped to an oval that makes a comfortable grip.

MALLETS

By definition, a mallet leaves no hammer marks on the surface of a workpiece. These were traditionally made of wood, but are now available in several kinds of plastic, including nylon, Delrin and other plastics. These are typically cylindrical, the striking surface is flat or slightly convex with rounded edges. While more expensive than wood, these mallets have the

Figure 5.42
Special hammers. Chasing hammer, "Nyloflex" plastic hammer with changeable hammer faces, bounceless plastic hammer.
(Firma J. Schmalz, Pforzheim)

advantages of being somewhat heavier and lasting longer than their wooden forebears.

Horn mallets. This is a traditional mallet made out of the solid end of a cow's horn. The natural conical shape is retained, creating a flat face on one end and a blunted point on the other. These have been eclipsed by the less exotic but more practical plastic mallets, and are difficult to obtain nowadays.

5.8.4 ANVIL AND STAKE SHAPES

Figure 5.43 illustrates some of the scores of anvils and stakes used by metalsmiths. The best stakes are made of top quality tool steel, well shaped, polished to a mirror finish, and hardened on the surface to minimize marring. Though the proper material is steel, these tools are traditionally called *irons.*

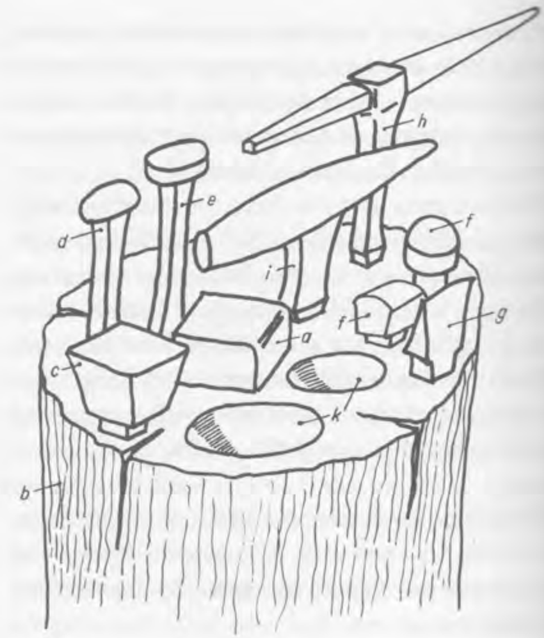


Figure 5.43
Anvils and other stakes.
a) bench block, b) wooden stump, c) flat anvil, d) "fist" stake, e) bottoming stake, f) small horned stake, g) splitting chisel stake, h) blowhorn stake, i) T-stake, k) depressions in the wooden stump for sinking and forming.

As with hammers, anvils and stakes should be kept in a state of high polish. In proper use the hammer never strikes the anvil or stake directly, which would make a mark. If such a blemish occurs, the stake should be sanded and polished to return it to its original state. Some studios cover their stakes and anvils with a cloth containing a little oil to inhibit rust.

Bench anvil. This is a small steel block used at the bench for delicate hammering operations such as riveting or light forging, (figure 5.46). The block should have at least one polished surface and one crisp edge. It is useful to have one edge rounded. Sizes vary, but usually fall between 50-100 mm (2"– 5").

Wooden stump. Though some stakes are made to fit in a vise, far more common is a tapered square peg made to secure each stake into a wooden stump. Because the wood provides a mass that will absorb the blow, the force does not bounce back. In addition, wooden stumps are inexpensive and weighty enough to stay in position. It is typical to also carve some shallow depressions in the wood for sinking, thereby enlarging the usefulness of the tool. Stumps have been a part of metalsmithing studios for centuries, and nothing has come along to improve on them.

Flat vertical stake. This simple but useful stake is not unlike the bench anvil, consisting of a rectangle of steel, in this case attached to a tapered foot for securing into a stump.

Dome stake. This is a sturdy stake, usually about 20 cm high (6") that can be mounted in a wooden stump. The striking surface is usually hemispherical and is always polished. It is used for forging, raising and planishing, and is made in several different sizes. Especially in the larger versions, this is also called a *mushroom stake* because of its shape.

Bottom stake. This tool is used to form and planish the bottom of a vase or bowl, and may be round, oval or square, always with a polished flat top. It is advantageous to have a bottom stake with both sharp and rounded edges.

Figure 5.44
Small stake heads of different sizes with an extension arm and stake holder (Firma J. Schmalz, Pforzheim)

Flanging stake. This stake looks like a large stone mason's chisel and has a sharp-edged striking surface with one flat side and the other side at an angle.

Small stakes. This family of stakes includes a range of shapes used to make spoons, lips, spouts and ornaments. Most are only about 12 cm high (8") and come in many different cross sections, with both rounded and sharp edges. It is particularly useful if a whole set is available. By also having an extension holder and extension arm, these small stakes can be used in a wide range of applications, including the often problematic walls of hollow containers.

Horn stakes; Also called *T-Stakes* (figure 5.43). Horn stakes are available in several styles. One type consists of two conical horns of different sizes. Another, similar tool, has two tapered "horns" one of which is flat on its top surface. In both of these cases the top surface of the stake runs parallel to the floor. In a third type, the conical horns slope downward, usually terminating in a bluntly rounded tip. These versatile stakes can be used for bending bracelets, raising, forging and planishing.

Further stake shapes. Along with the standard shapes described above, a silversmith might sometimes need special stakes which he makes for himself. These can sometimes be modified from stakes on hand, but sometimes they must by cast for the job. The inventory of such "irons" in different shapes and sizes is the pride of the silversmith and is the basis of his work.

Mandrels (figure 5.45). These are a sort of stake with specialized uses that give each tool its name. Bracelet mandrels are generally round or oval, and ring mandrels are always round, sometimes with a milled channel to accommodate a stone culet. Bezel mandrels are available in round, oval, square and rectangular versions, though the round is undoubtedly the most useful. The photos in figures 5.48 & 5.49 illustrate some of the uses of a ring mandrel.

Figure 5.45
Various mandrels. Ring mandrel, angular mandrel, bracelet mandrel. (Firma J. Schmalz, Pforzheim)

Figure 5.46
Hammering a workpiece with the peen of a hammer on the bench block.

Figure 5.47
Forging a rod on the bench block.

5.8.5 THE CARE OF TOOLS

It is important to understand that every mark on a hammer face or anvil will be stamped into the workpiece with every blow. It is therefore essential to maintain these tools in pristine shape, taking care with their use and storage. Tools that are used infrequently should be protected against rust with a thin coating of oil.

5.8.6 THE EFFECT OF DIFFERENT HAMMER SHAPES ON THE MATERIAL

Flat striking face

Figure 5.50 illustrates the effect of different hammer shapes as they impact on metal. As seen in the first drawing, the effect of a flat hammer face is a vertical force distributed over a relatively large area. This means the force per unit area is relatively small. As explained earlier, the friction between the hammer face and the metal further limits the ability of the metal to move sideward, with the effect that a flat-faced hammer is not especially effective as a tool for moving material.

The structure of the metal under a blow is condensed. First the grains directly under the strike surface are deformed and press outward against their neighboring grains outside the pressure field. Because the force of the blow is distributed so broadly, the effect of this is usually small, limiting the use of the flat faced hammer to finishing, where this effect can be very helpful. The edges of the striking face should be slightly rounded so they don't leave dents. The hammer with a flat striking face is well suited as a finishing and planishing hammer.

Figure 5.48
Forging a ring on a round ring mandrel.

Figure 5.49
Forging a ring on a parallel ring mandrel.

Crowned striking surface
In this situation, (not illustrated), the primary force is again vertical, but this time with some of the impact pressing outward. This fact, combined with the reduced friction of the face against the metal, results in a blow that achieves greater deformation than the flat faced hammer with the same amount of force. If the striking surface is equally rounded on all sides, the effect will also be equal on all sides. The relationship between the vertical and the sideways forces can be modified by the degree of curvature; the more strongly rounded the hammer shape, the deeper the hammer will intrude into the material under it. That is to say, a highly crowned hammer will move more metal faster and leave more dramatic marks.

Spherical striking surface
The logical extension of a crowned face is a ball peen, as seen in figure 5.50b. Here the force is concentrated into a small area of surface contact, with the result that a high pressure is developed. The force of the blow is strongly vertical, but includes strong forces pushing outward. Naturally with ball peen hammers the deformation forces are always uniformly concentric just as with the slightly crowned hammer.

Wedge shaped rounded striking face
The force delivered by a cross peen hammer is vertical and outward, but unlike the ball peen, this outward force moves in only two directions, perpendicularly forward and back from the wedge-shaped face. Because of its limited surface contact, the hammer

bites deeply into the metal, and delivers its force effectively. Because this hammer allows for maximum control over the direction of deformation, it is preferred for rapid forging.

5.8.7 PRELIMINARY FORGING

Preliminary forging has more to do with the internal structure of the material than with its eventual shape. All cast ingots should be forged for the following reasons:

- Through powerful forging, dendritic crystal growth and large grains are broken and recrystalized by subsequent annealing to create an evenly distributed fine grained structure.
- Rolling and drawing apply force primarily to the surface of a block, leaving the core section barely affected. Vertical hammer blows, by contrast, affect the metal throughout, and lead to a more homogenous structure.
- Hand forging is often the most efficient way to bring the ingot to a size and shape ready to be rolled or drawn.

For preliminary forging to achieve these desired results, the material must be strongly deformed. Proper forging, therefore, requires a heavy hammer and a stable smithing surface. When forging a square or rectangular rod, the cross peen is used to deliver close, evenly spaced blows at a right angle to the axis of the bar. This is done on a flat anvil, first on one side, then on its opposite side, and then on the remaining two sides. After hammering all four sides, the surfaces are made smooth throughout with a slightly crowned hammer, starting first on the corners, which might otherwise crack. The rod is then annealed and the process repeated until the ingot approaches the desired shape.

The ingot used to make wire is often a round rod, which should be reduced to a square cross section for rolling through the mill. This is done with a crowned hammer, taking care to keep each side perpendicular to its adjacent sides.

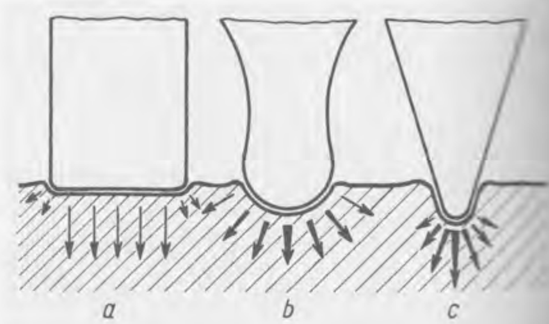


Figure 5.50
The effect of various hammers upon the structure of the material: a) flat, b) spherical surface, c) wedge-shaped striking peen.

5.8.8 PRECISION FORGING

Though the term *smith* derives from *smite* or "strike with a tool," over the years the trade has evolved to the point where the term goldworker is probably more accurate than goldsmith. This neglect of basic hammering skills is unfortunate, because forging offers interesting shapes and a unique design process. In addition, forging offers a unique opportunity to synthesize process and form. Whenever possible, I encourage smiths to leave the hammer marks on the piece, in this way demonstrating the truth to materials so essential to this process.

The following basic exercises are a useful way to approach forging, but bear in mind that these samples are intended only to present the basic vocabulary of the process of forging. A talented goldsmith will combine these and invent new forms to create innovative jewelry. These exercises can be worked in copper or brass, which is recommended for training exercises.

Forging exercises

A faultless material of the highest possible ductility is the prerequisite for successfully carrying out forging operations. Sterling silver (Ag 925) responds very well to hammering, as does a gold alloy of Au 750 or higher. Both these metals have a ductility of over [illegible]. Forging is possible, though, with all silver alloys and any gold over Au 500, which is to say, 12K or higher. In order to leave the object at its highest possible

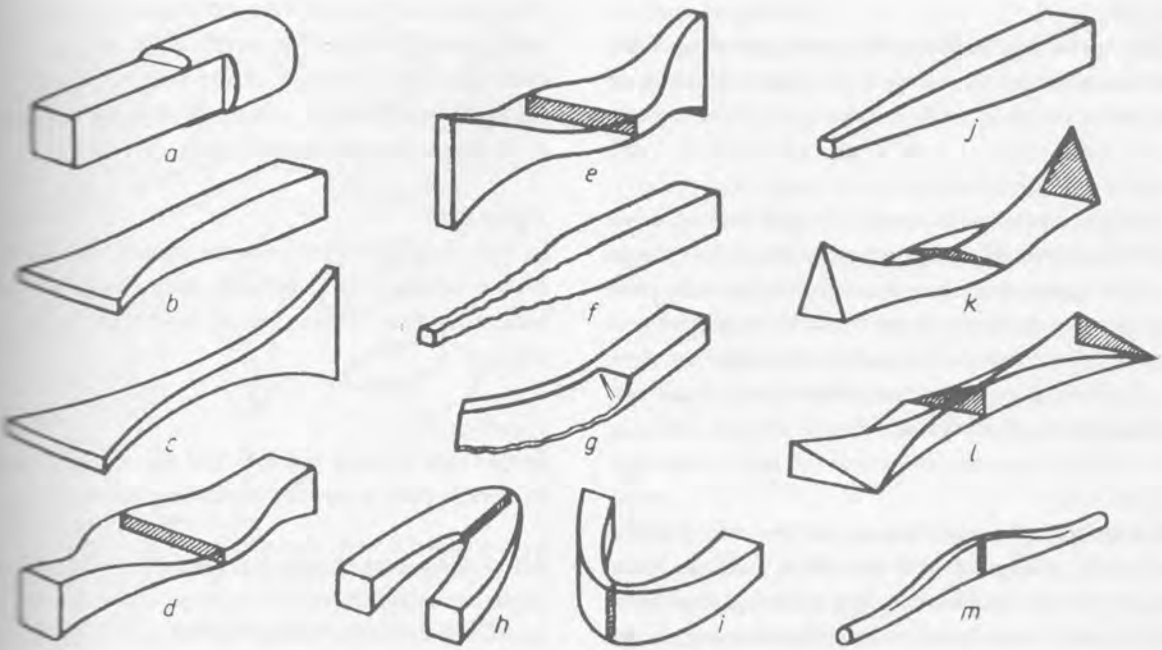


Figure 5.51
Elementary forms of cross section change when forging.

toughness, it is preferred, where possible, to end with a hammering rather than an annealing operation. Of course it is also possible to heat harden some alloys.

Figure 5.51a
In this exercise a round rod is forged with a slightly crowned planishing hammer against an anvil. After striking one surface with overlapping, evenly-spaced blows, rotate the rod 180° and repeat the pattern of blows on the reverse side. Rotate the bar 90°, watching carefully to see that the side just formed is perpendicular to the anvil, and holding the rod tightly so it doesn't turn in the hand. Strike a series of blows as before, always being careful that each adjacent side is at a right angle. If the form distorts and forms a rhomboid cross section, the rod must be hammered into a six-sided rod, then rounded and finally squared off again.

Figure 5.51b
By forging one end of a square rod of two opposite sides, you will create the first fundamental forged form – a wedge-like widening of the end of the rod.

Figure 5.51c
If opposite ends of a rod are forged at right angles to each other, the result creates another basic forged shape in which a surface transmutes into an edge and vice-versa. To increase the widening force of the hammer, use the cross peen of the hammer along the axis of the rod. The rod can be widened significantly by striking a fan-like pattern of hammer blows.

Figure 5.51d
If the same blows are directed at the center rather than the ends of a square rod, the resulting form will take the shape shown in this example.

Figure 5.51e
This exercise combines the two preceding ones, widening the center section and the two ends on opposite axes.

Figure 5.51f
To create a taper, a rod must be forged thoroughly on all sides, preferably with a cross peen hammer placed at right angles to the axis of the rod. In the early passes, hammering begins at the top of the taper and progresses all the way to the end. As the taper emerges, hammering is confined to the lower part of the rod, always working on all sides in opposition.

Figure 5.51g
If a square rod is struck more on one side than the other, a rectangular cross section is formed. If the blows are delivered to the edge of the bar, and limited to one side only, the rod will curl away from the force of the blow, and the section will become triangular.

Figure 5.51h
Here a square rod has been bent into a graceful curve, then forged at the height of the arc, widening the metal here and accentuating the curve.

Figure 5.51i
In this case the rod was bent then forged out flat at the bend using a horn stake.

Figure 5.51j
To refine a taper, start as described above in figure f, then move to lighter blows to smooth out the surface. To convert the taper to a round form, strike the corners to create an octagonal cross section, then strike the taper while rotating it.

Figure 5.51k
In this exercise, the square rod is forged out like a roof by striking with a slightly crowned hammer on opposite edges of the top surface of the bar. As shown in figure g, striking one side only will cause the rod to curve. Proceed by working alternately on the near and far edges of the bar, creating a triangular cross section with a straight axis. The pitch of the angle will be determined by the angle of the hammer blow. The midsection is altered by additional striking, making it shallower and wider than the ends.

Figure 5.51l
In this variation of the previous sample, the sloping surface alternates to one side, then the other, and back to the first, creating a wavy rhythm of planes and edges.

Figure 5.51m
In this case a round rod is forged flat on one side in its middle with a crowned planishing hammer.

All of these basic forms can be used as design elements, translated directly into pieces of jewelry. These samples only begin to hint at the rich variety and beauty of forged shapes, which become especially active when repeated on a larger form. These exercises use a short straight bit of rod, but it is also possible to start by forming a rod or bar into a ring that can be soldered then forged on a mandrel or stake.

Of course many ideas first come to life on a drawing board, but forging is a particularly fine example of the way designs can come spontaneously from working directly with metal.

Making a solid band ring
The ring illustrated here, (figure 5.52), is most often made today through lost wax casting, but for generations it was made by forging. The techniques are still viable, and this ring is a valuable exercise in perfecting hammering skills. In addition, there are slight differences between a cast and worked form that are made clear by making this ring. The instructions that follow describe the process as starting with a rod, but it is also possible to cast a "blank" that supersedes the first couple steps.

- Start with a square rod as thick as the thickest part of the ring. Step roll the rod in the wire mill on both ends to make the shank.

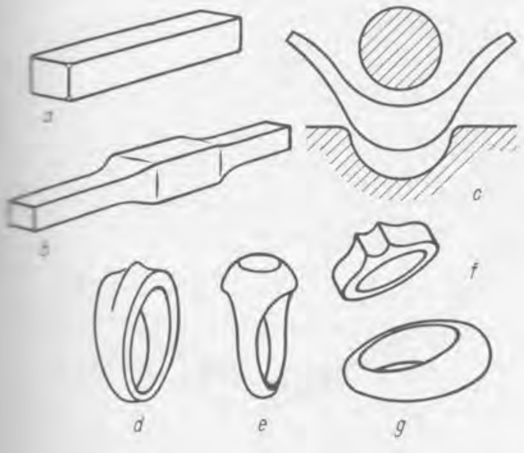


Figure 5.52
The making of a forged band ring.
a) rough bar, b) basic form with step-rolled shank, c) bending it around on wood or plastic, d) to g) various shapes of the band ring.

- If the shank is to be flat, these sections can be further reduced in the flat rolling mill.
- Even out the tapers just created by striking with a slightly crowned hammer on a curved stake or the horn of an anvil.
- Carve a half round groove in plastic or endgrain wood roughly to the outer dimension of the proposed ring. As shown in 5.52c, set the annealed ring blank into position with a steel rod or ring mandrel on top. Strike the mandrel with a large mallet, forcing the ring to curve around the rod. The thickest section of the form must be curved first; the thinner areas of the shank will follow easily, being malleted in any convenient way until the ends are brought together.
- Both ends of the shank are fitted together and joined with hard solder, after which the shank can be made truly round. The ring size should be a little smaller than needed to allow for hammering and filing as the ring is brought to its final shape.
- Figures 5.52d through 5.52g illustrate variations that can be worked on the basic ring form. In each case, use a hammer first to rough out the form, then follow with files, burs, and sandpaper.

Making ring shanks

Where the preceding description applied to large rings made entirely through forging, here we turn the process to the creation of smaller shanks that can be fitted with settings for stones or other ornaments. There are two general ways to proceed.

In the first, follow the instructions above, forging a square rod so its thickest section is in the middle and it tapers evenly toward each end. This is pounded into a wide groove as before to bend it around, and the ends are soldered together to form a ring. From here the shank can be trued on a mandrel and filed to a graceful shape. The only disadvantage with this approach is that the shank has a seam in the thinnest place.

The other way to proceed starts with a similar square rod, but in this case it is thinned in the middle section, as shown in 5.53a. This can be done by hammering over a curved stake (like the horn of an anvil) or by repeated back and forth rolling in a flat rolling mill. To get started, the rollers must be opened wide enough to allow the entrance of the bar, which is set into the mill with an equal length projecting on each side. Tighten the rollers as much as possible and roll a little in each direction, re-tighten, and so on, until the desired thickness is reached.

Once the shank form has been achieved, the process continues in more or less the same way, bending the shank, soldering it closed, and truing it up through use of a mallet, followed by filing.

Figures 5.53c, d and e illustrate a few of the many shapes that can be made this way.

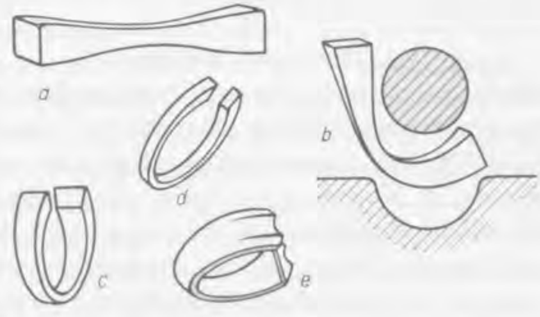


Figure 5.53
The making of a forged ring shank.
a) step-rolled basic shape, b) bending the form on wood, c) to e) various shapes of ring shank.

JEWELRY
CONCEPTS AND TECHNOLOGY

OPPI UNTRACHT

AUTHOR OF "METAL TECHNIQUES FOR CRAFTSMEN"

Tempering Temperatures: Judgment by Heat-Produced Colors on Polished Steel

Color	Temperature °F	°C	Temper	Tools, etc.
Light straw	400	204.4	Very high	Engraving tools, files
Straw yellow	428	220	High	Finishing tools, lathe tools, scrapers, twist drills, razors
Golden yellow	469	242.7		Cold chisels, hammer faces
Dark brown-bronze	500	260	Medium	Drills
Purple or peacock blue	531	277.2		Chasing punches, dies, other punches, gouges, shear blades, springs
Full dark blue	550	287.7	Low	Hot chisels, knives
Pale blue	610	321.1		Hacksaws, other saw blades, needles, screwdrivers
Gray-black	630	332.2	Soft to dead soft	Too soft for steel tools

TOOLS USED IN THE FORGING PROCESS

THE ANVIL: The impact-receiving surface

The *anvil* is the iron block on whose working surface hot or cold metals are formed by forging with hammers. Originally it was a flat, leveled stone. Small bronze anvils were developed in the Bronze Age for use in making the smaller, finer metal objects made then. These often had an attached lower spike or *tang* that could be driven into the ground or into a groove in a wood support to secure them to position.

Today's anvil is made of a forged or cast iron core to which steel parts are welded. The main parts are the following: the flat, rectangular top or *face* which is cantilevered over the base, made of ½–1½ in thick steel welded to the body and drawn to a hard temper. When struck, a good anvil will emit a ringing note (for which reason it is called a "ringing anvil"). The *beak* or *horn* is the horizontal, flat or conical projection from the face, and is used for shaping curved forms. Opposite the horn is the *heel* or *squared tail* which is punched with a ½–1 in square *hardie hole* to receive the shank of a chisel when cutting through metal, and into which most forging tools and some smaller anvil tangs will fit, and a round, ½ in diameter *pritchell hole* into which round stock is placed for bending. Between the face and the horn is a drop and a smaller rectangular extension called the *table*. The rest of the body narrows to a *waist*, then into a spreading base and *feet*. In manufacture the working surfaces are welded to the core, then hammer shaped. The whole is heated to cherry redness then plunged into cold water to harden the working surfaces which are grindstone leveled and smoothed and polished with emery and crocus.

The craftsperson finds an anvil weighing about 25 lb sufficient for his or her needs, but for heavier work as in silversmithing and blacksmithing, anvils weighing up to 300 lb are made. To mount such a heavy tool so that it does not move when struck, traditionally it is placed on a section of a hardwood tree trunk whose height places the anvil face level with the knuckles of the worker when his arms hang loosely at his sides. Well below eye level, this height allows the full hammer weight to strike the work without strain or excessive bending, and takes advantage of the added force of gravity. The anvil base is held to the tree trunk support by large nails. Special heavy steel stands are also used for anvil mounts.

6–225 GOULIMENE, SOUTHERN MOROCCO. Jeweler forge hammering a small silver ingot on an anvil anchored in the earthen floor in preparation for use in forming a forged wire ornament. *Photo: Oppi*

OTHER WORK SURFACES FOR FORGING

Miniature horn anvils with round and flat horns and a hole for shaping rivets are used by the jeweler for small forging. Typical working surfaces are 3⅞ in × 2⅝ in (9.84 cm × 6.67 cm); or 5¾ in × 2¼ in (7.30 cm × 5.72 cm).

Train rail sections about 12 in (30.5 cm) can be used as an anvil. One end can be ground to a beak shape, and the whole working surface should be polished.

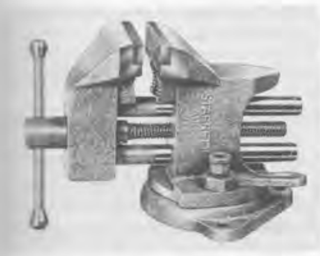
Surface blocks or *bench blocks* are cast iron or steel plates whose five upper or all six surfaces are true,

6–226 *ROUND BENCH BLOCK* Made of alloy steel, hardened and ground top and bottom. Weighs 5 lb, has a working surface of approx. 4⅞ in Ø; 1½ in high; has nine holes varying from ⅛–37/64 in Ø; and two V-grooves at right angles. Base is hexagonal to allow it to be held rigid horizontally in vise jaws. *Photo: Courtesy L. S. Starrett Co.*

smoothly ground, case hardened, and polished to a mirror finish. They are therefore accurate for use in bending right angles, for flattening work, and shaping small forms. Their sizes and thickness vary.

Swage or *design blocks* are steel blocks 4–18 in (10–46 cm) square, and between 2½–3 in (6.4–7.6 cm) in thickness. In a typical model, two of the sides are serrated with half-cylinder grooves whose widths vary from ⅛–2 in (0.32–5.1 cm). The other two sides may have V-shaped grooves in a range of sizes, or other shapes. The block is used placed on an anvil or held in a bench vise. Rod and wire are placed in one of its grooves and hammered to change their sectional shape, or to reduce their size. The flat sides may contain depressions of various shapes, or holes that pass completely through the block. Into these, metal pieces or lengths can be placed and shaped or bent by hammering.

Bench vises are made with an *anvil* surface on the immobilized part attached to the workbench. These can be used for occasional anvil work. A *leg vise* is a heavy vise that has a leg or extension between it and the floor. The leg supports the vise when it is used to hold a heavy anvil that must take heavy blows.



6–227 *BENCH VISE WITH ANVIL* Has full 360° swivel base whose position is controlled by a swivel wrench lock. Jaw width is 3 in, max. jaw opening 3 in, and has pipe-sized jaws to allow it to hold round tools such as mandrels. Weight 19 lb. *Photo: Courtesy L. S. Starrett Co.*

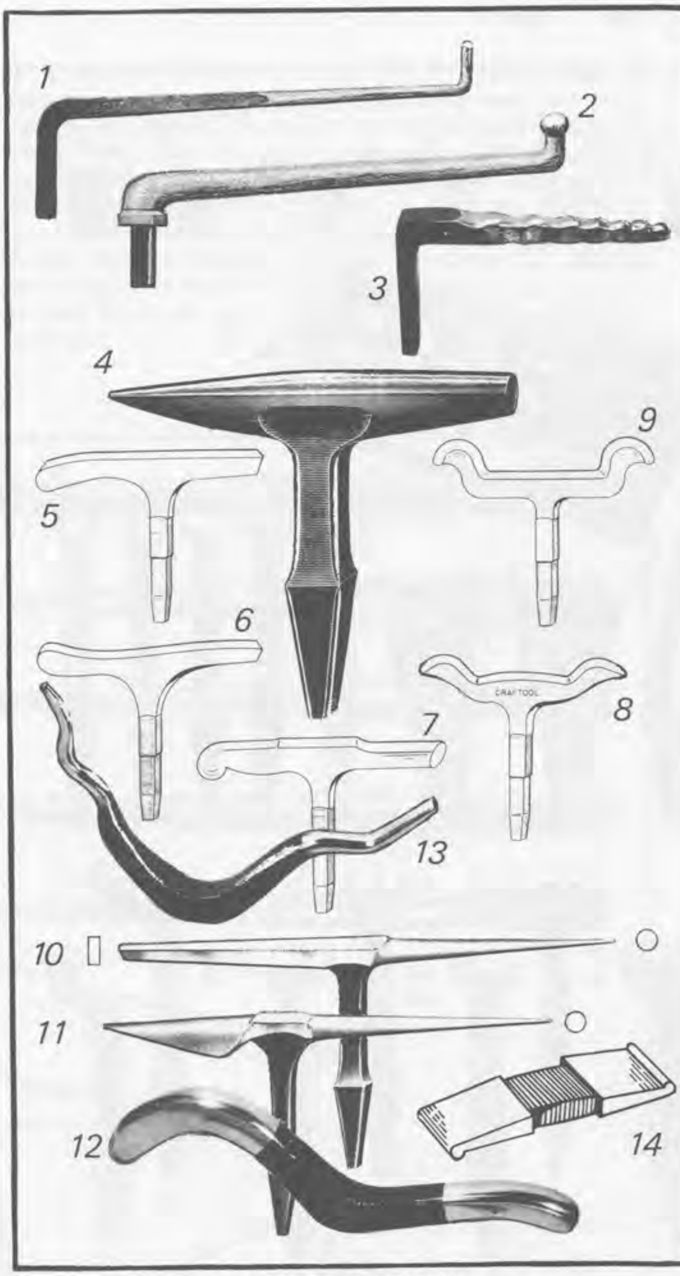
Combination bench pin and anvil units that clamp onto a worktable are available and provide a small hammering surface.

Hardwood tree stumps called *steadies,* cut perpendicularly to the floor with a height of from 30–40 in (76–102 cm), and of diameter of approximately 18 in (46 cm), have hollows of different diameters and depths used for shaping scooped out of their upper surfaces, and a hole to hold an anvil tang. They are old, traditional, and very useful forming surfaces or places to hold an anvil.

STAKES

Stakes are large and small anvils used mainly by silversmiths to make holloware or flatware, but also by any jeweler when the occasion arises to shape and form metals. They are made in a great variety of shapes designed for general or specific functions. Almost all have a single tang which projects below the working surface and enters a hole in the workbench containing a *metal bench tool socket* to hold the anvil firmly in place. Tangs can also be placed into a hole in an *extension arm,* also called a *horse extension,* clamped in a bench vise, placed in the hardie hole of a large anvil, or in a hole in a tree stump. The few anvils without tangs must be clamped in a vise's jaws to hold them. Because of the variety of forms, only an arbitrary division can be made among them based on their number of working part projections (not including the tang).

TWO-PROJECTION STAKES These are generally called *T-stakes* or *tee-stakes* because of their general conformation



6–228 *SILVERSMITH'S ONE-PROJECTION STAKES*

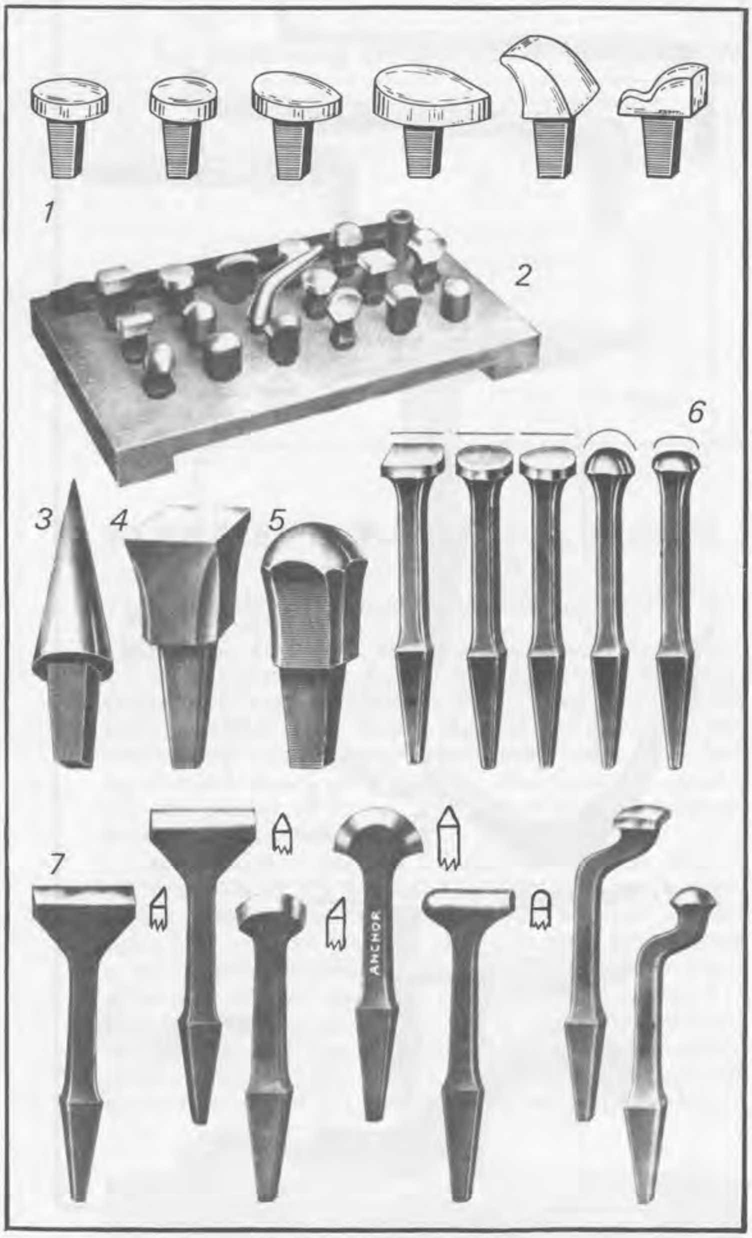
1. *Snarling iron,* end Ø ¼ in, length 16½ in, weight 2 lb.
2. *Snarling iron,* end Ø ¾ in, length 16½ in, weight 2 lb.
3. *Spout and handle iron,* 6½ in long.

SILVERSMITH'S TWO-PROJECTION STAKES: T-STAKES

4. *Standard bick iron* (also called bickern, beakiron, beakhorn) T-stake with one tapered horn-shaped arm, and one cone-shaped arm, length 11 in, width 1½ in, height 7½ in.
5. *Common T-stake* with downward bending arm and square arm, length 11 in, width 1½ in, height 7½ in.
6. *Common T-stake with* round-ended upward-bending arm, and sloping square arm, length 12 in, width 1½ in, height 7½ in.
7. *Raising T-stake* with ball end, central anvil surface, and elliptical end with 70° undercut, length 12 in, height 7½ in.
8. *Spout T-stake,* length 10¼ in, width 1½ in, height 7½ in.
9. *Cow's tongue T-stake,* length 10½ in, width 1½ in, height 7½ in.
10. *Blowhorn T-stake* with tapered mandrel and square-tapered arm, total length approx. 20 in.
11. *Beakhorn T-stake* with tapered mandrel, and tapered elliptical horn arm, total length approx. 18 in.

SILVERSMITH'S TWO-PROJECTION STAKES WITHOUT TANG: CRANK STAKES

12. *Crank stake* (crank means bent or crooked) held in a vise, length 15 in, width 1⅜ in, weight 6 lb.
13. *Handle and spout crank stake,* held in a vise, each arm 9 in long, weight 3½ lb.
14. *Anvil bar,* held in a vise for straight edge work, width 3 in, thickness ⅞ in, length 10 in.



6–229 *SILVERSMITH'S NONPROJECTION UPRIGHT STAKES*
1. *Anvil heads,* left to right: flat head or bottom stakes, Ø 1¾ in; dome head, slightly rounded, Ø 1⅝ in, height 1⅝ in; teaspoon head, length 2 in, width 1¼ in; tablespoon head, length 3 in, width 1¾ in; slope head, length 1¾ in, width 1¼ in; valley head, length 1¾ in, width 1⅛ in.
2. Assortment of *anvil heads* in a *rack.*
3. Cone *anvil stake* (taper iron), cone length 5 in, largest Ø 1⅞ in, height 7 in, weight 2¼ lb.
4. *Flat, square anvil stake,* top 4 in square, height 10 in, weight 17½ lb.
5. *Mushroom stake,* Ø 3½ in, height 9¼ in.
6. *Mushroom stakes,* height 10½ in, *left to right:* flat, three square, one round edge, 2½ in square; flat, round, Ø 2 in; egg-shaped, domed, 2 in wide, 2½ in long; high dome, round, Ø 2 in; shallow dome, round, Ø 2 in.
7. *Hatchet-* and *fist-type forming and planishing stakes,* all 1¾ lb, except as noted. *Left to right:* straight, single-bevel face, width 2⅜ in, height 9½ in; straight, double-bevel face, width 2⅜ in, height 9½ in; rounded, half-moon, single-bevel face, width 2⅜ in, height 9½ in; rounded, half-moon, double-bevel face, width ¼ × ¾ in, height 1¼ in; rounded face, width 2⅜ in, height 9½ in; bent, square, shallow dome, Ø 1⅝ in, height 11¼ in, weight 3½ lb; bent, round, full dome, Ø 1¾ in, height 11¼ in, weight 3½ lb.

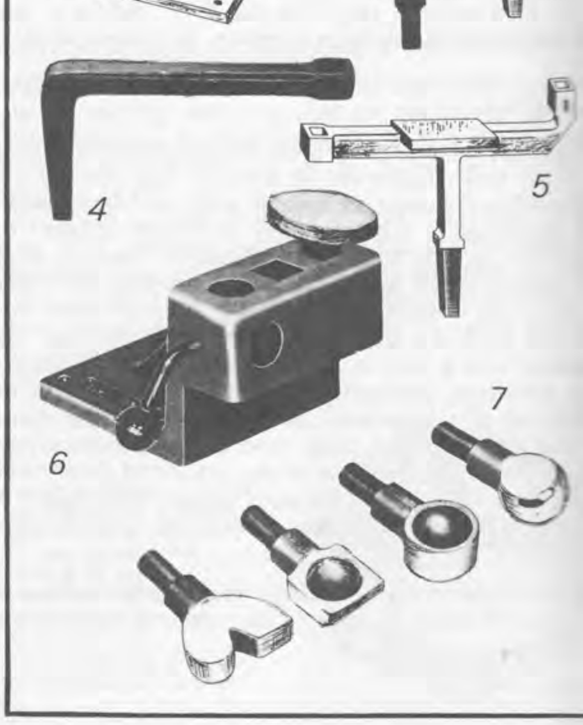
to the shape of the letter T. They have two ends that ject horizontally or obliquely beyond the tang. These according to their functions. Not all of them have spe names, but some are named after their function and o after their resemblance to some other form. Among are raising stakes, crimping or valley stakes, cow's tong blowhorns, and common T-stakes.

ONE-PROJECTION STAKES These have only one obliqu horizontal projection from the tang. Among these spout stakes, flaring stakes, and snarling irons.

NONPROJECTION UPRIGHT STAKES These have forms are centered directly above the tang. Among these round head, mushroom, ball, dome, half-dome, bottom planishing, oval, spoon, dish, pan, corner, concave, ho cone, straight, taper, horn, creasing, fluting, square (*teest* is a general name for a small anvil), half-m hatchet, and others.

All working surfaces must be kept highly polished greased when not in use for protection against rust.

6–230 *STAKE AND ANVIL HOLDING DEVICES*
1. *Standard stake and anvil holder* that accommodates most T-st screwed to the bench, height 4 in, width 5 in.
2. *Offset extension arm,* vise held, used for stakes and anvil heads
3. *Vertical extension arm,* height 7 in, width 1¼ in.
4. *Right-angle extension arm,* held in vise or stake holder.
5. *Double extension arm* for stakes, anvil heads, and anvils, with tral flat anvil, length 16½ in, width 1¾ in, height 9 in.
6. *Multi-stake holder,* holds all standard stakes and anvils verti and also has a horizontal 1 in diameter hole with clamp permitting the use of the special horizontal anvils *below.* (Craft
7. *Horizontal* anvils used with the multi-stake holder *above,* *right to lower left:* ball with flat side; concave bowl with flat reverse surface; concave bowl within a square, with square reverse surface; heart anvil with variously shaped work surfaces.

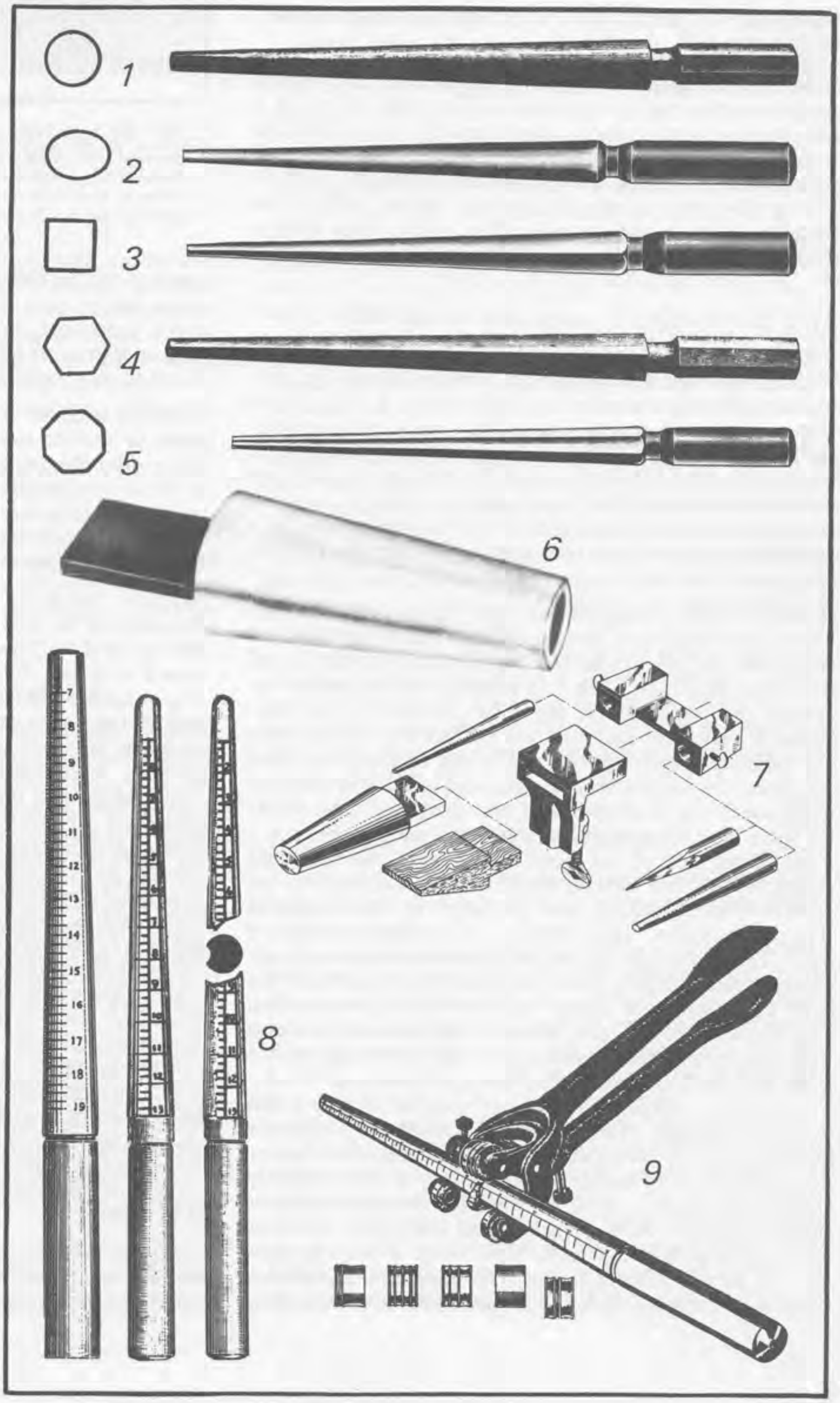


working surface becomes nicked, this defect will be imparted to any metal placed over that position and struck with a hammer. The work surface in this case must be refinished by grinding, if necessary, and repolished.

Metalsmiths now carve stakes from *devcon* or *nylon blocks* which are both hard and resilient.

MANDRELS

In metal forming techniques, a *mandrel* is a straight or tapered metal bar of circular, oval, or other section used as a core around which metal may be forged, bent, or shaped. On occasion, wood mandrels are used, but metal ones allow greater accuracy. A *straight mandrel* of solid metal rod is used as a core when wrapping wire around it to form links. Long, *tapered steel mandrels* called *triblets* are circular, oval, oblong, square, or octagonal in section, and are used for shaping and enlarging rings and conical forms. Special tapered mandrels are made for shaping conical bezels. Hollow mandrels of large tapering circular or oval forms are used to shape rigid bracelets and large cylinders.



6–231 *BEZEL, RING, AND BRACELET MANDRELS* (triblets)

1. *Round steel bezel mandrel,* small Ø 10 mm, large Ø 22 mm, 7½ in long.
2. *Oval steel bezel mandrel,* small Ø 5 × 6 mm, large Ø 16 × 18 mm, 7½ in long.
3. *Square steel bezel mandrel,* small Ø 4 mm, large Ø 20 mm, 6 in long.
4. *Hexagonal steel bezel mandrel,* small Ø 3 mm, large Ø 14 mm, 11¾ in long.
5. *Octagonal steel bezel mandrel,* small Ø 2.5 mm, large Ø 10 mm, 8 in long.
6. *Oval bracelet mandrel,* small end 1⅜ × 1⅞ in, large end 3 × 3½ in, 6 in long plus 3 in tang. These gray iron-hardened, cast, polished mandrels are used for forming bracelets and oval forms. Similar mandrels are available with round section.
7. *Bezel and ring mandrel vise (upper right)* with small and large openings to hold small- and large-diameter mandrels. It is kept in place by the bench pin vise (*below it*) which overlaps and clamps it down. The mandrels are tightened in position with thumbscrews. The oval bracelet mandrel (*far left*) has a rectangular tang of the same dimension as the wooden bench pin (*below it*) that fits into the slot of the bench vise.
8. *Ring mandrels* of hardened tool steel, with engraved, marked graduations. *Left to right:* size range 7–19; size range 1–13; size range 1–13, with longitudinal groove for holding a ring set with a stone. Used for shaping, straightening, sizing or gauging, and enlarging rings, and when setting stones in rings.
9. *Ring stretcher* that will enlarge a ring shank in platinum, yellow gold, and silver up to three sizes, white gold to one size. The ring is placed in size position on a mandrel, one with a groove used if stones are present. The plain back of the shank is rolled with any of the five rollers set in the holder whose shapes will accommodate a variety of ring shank sections. Any standard steel mandrel is grasped in the roller holder, and the upper handle is raised and lowered which makes the roller pass over the shank and stretch it.

SHAPING SHEET METAL WITH A MANDREL

Sheet metal and strip as for a ring shaft can be curved or shaped into a completely cylindrical form by placing the sheet over the depression in a design block or a groove in a wood block, putting a straight mandrel on top of it, and hammering the mandrel down with a wood mallet until it forces the metal to the bottom of the depression. If a cylinder is wanted, the edges of the sheet can be hammered down on the mandrel until they meet and form a seam, thus completing the cylinder. Lubricate the mandrel to facilitate its removal after the form is finished.

FORGING A CIRCLE OR CYLINDRICAL FORM ON A MANDREL

A ring or cylinder *without seams* can be mandrel forged, starting with a metal disc. First drill or punch a hole in the center of the disc large enough for the mandrel to pass through. Using flat-faced hammers, forge the metal by upsetting its edges, turning the disc gradually, and exposing all edges equally to hammer blows. Anneal the metal at intervals, and work it until a circle of the desired thickness or width forms around the mandrel.

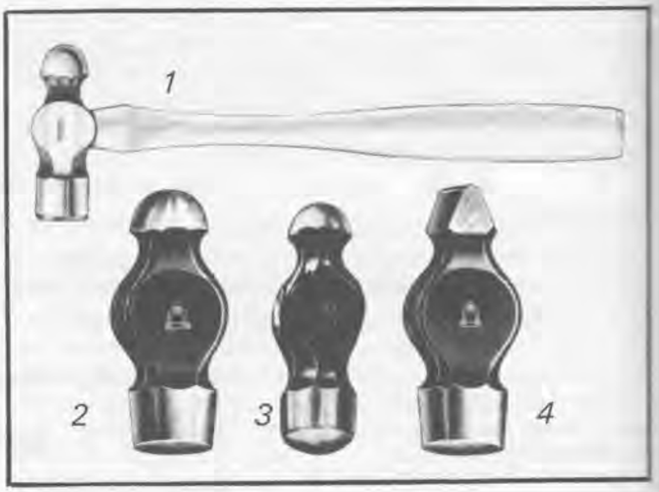
THE HAMMER: A percussion impact tool

Hammers are the main tools of the group used for *striking,* the basic act employed in shaping metals by forging. A hammer consists of two basic parts: a *lever* which is the *handle, shaft,* or *haft,* usually made of a springy hardwood such as ash or hickory (or today also from fiberglass), upon which in crosswise position is fixed the *metal hammer head.* The head contains a *hole* or *eye* into which the shaft is forced and is held on the handle by a malleable iron wedge driven into a split in the handle's end.

HAMMER HEADS Hammers are our oldest tools, the first extension of the hand. Prehistoric hammers were made of stone and had no handle but acquired one at the end of the Paleolithic Age. This tool-holding device greatly increased the leverage that could be imparted to the tool. Today a variety of hammers are designed to execute special functions in metalwork, their form derived from that function. The various *shapes, sizes,* and *weights* of hammer heads are made of drop-forged tool steel, and their working faces have been hardened, tempered, and polished.

On either side of the head's shaft hole are flat areas called *cheeks.* The *working ends* can bear two similar, but differently sized *striking faces* that may vary in degree and type of curvature (flat, convex or crowned, dome, or ball). The *face edges* can range from square to completely rounded and merging with the head. The length of the *head extension* from center hole to face can vary from very short to long to give it reach. The hammer can also have one regular face opposed by a different shape at the other end, or both ends can have irregular shapes.

A common, *all-purpose hammer* used in forging is the *ball peen hammer,* often called a *machinist's* or *engineer's* hammer, and we take this as a basic example for further description. At one end it has a face that is flat or slightly convex that can be used for striking and planishing or smoothing metal. At the opposite end is the *peen* (*pein* or *pane*) which is round or ball shaped, thus giving the hammer its name. Other hammers can have a *straight peen* running in the same direction as the shaft, or a *cross peen*



6–232 THE BALL PEEN HAMMER
1. Hammer with hickory hardwood handle.
2. Hammer head with one flat and one ball peen face.
3. Hammer head with one convex and one ball peen face.
4. Hammer head with one flat and one cross peen face.

running in the direction perpendicular to the shaft. The peen end is used for many functions such as drawing down, stretching, or bending, by striking the metal. Indentations or grooves are formed by the impact that causes the metal to move plastically by deformation without rupture.

HAMMER WEIGHT Hammers of a single form are often made in various *weights* or *sizes.* The heavier the weight, the greater the impact of each blow. The hammer weight is chosen according to the work to be done. In jewelry work, the hammers used may range in weight from a few ounces to five pounds (a heavier hammer cannot be comfortably lifted with one hand).

HAMMER SHAPING AND MAINTENANCE It is sometimes necessary after purchase or accidental damage to a hammer to modify, "dress," reshape, or polish the face, or to round its edges. Reshaping can be done by forging, but this is hard work, and grinding can substitute for it, but should not be drastic. Cool the grinding wheel and the hammer by allowing cold water to drop on both while grinding so that the friction of grinding will not create heat high enough for the hammer to lose its temper. If the grinder is not near water, it should be piped to it by a rubber or plastic hose, or use a pail with a small hole at the bottom into which a length of tubing is forced to serve as a spout that drips water on the work. Drip rate can be controlled by a clamp-type clothespin.

Follow shape grinding or surface grinding with polishing the surface or face with fine-grit paper abrasives, then with tripoli on a polishing wheel, and rouge on a buffing wheel to achieve a mirror finish. Hammer faces should always be kept highly polished and free of scratches and dents which otherwise will be imparted to the metal with each blow.

If a hammer becomes softened by overheating, it must be retempered. After all shaping and surfacing, remove the handle, heat it to cherry redness, and quench it in brine. Polish a portion of the face to be able to see the change of color; temper it to a golden yellow, then quench it in water.

HAMMER STORAGE AND SURFACE PROTECTION When not in use, hammers should be placed in a dry location in racks or stands that hold each one separately to keep their

6–233 *PORTABLE HAMMER AND ANVIL RACK*
The lower shelf has a wooden grill into which the anvil tongs fit. Designed by BERTIL GARDBERG, Finland, for use in his workshop. Photo: Oppi

faces from hitting each other. If the tool will not be used for a long time, cover the metal with a thin coat of petroleum jelly or oil it lightly to prevent rusting and preserve its high polish. Wipe off the protecting lubricant before use. Should rust appear on a hammer (or other tool), soak the metal for 24 hours in a half-and-half solution of kerosene and gasoline in a covered container, then wire brush and repolish the surface.

HAMMER CATEGORIES

Categorizing hammers is difficult because many hammers are used for *more than one purpose,* or a hammer may have *two working faces* designed for completely different functions. Certain basic divisions can, however, be made.

HAMMERS USED FOR INDIRECT STRIKING

In one group are hammers that are always or occasionally used to strike an *intermediary tool* that contacts the metal, such as *punches* of any kind, *stamps, dies,* and *puncturing tools.* A hammer always used for striking is the broad, flat face of the chasing hammer used to strike chasing and repoussé punches. The flat face of an *all-purpose* hammer such as that of a ball peen hammer, can be used to strike cold chisels, center punches, design and hallmark stamps, one-part circle-cutting dies used to make a blank, or a sharp-pointed tool to penetrate sheet metal. Flat-faced planishing hammers whose flawless, polished faces must be preserved, should *not* be used for any of these purposes as their faces may become marked.

HAMMERS USED FOR DIRECT STRIKING

The category of hammers used to work metal directly is much larger and includes all those used for shaping, raising, and finishing forms. Though intended mainly for creating holloware, these hammers also are used in jewelry making.

Forging hammers used for forging thick metal forms weigh considerably more than those used for light forging. A sledgehammer used by one person may weigh up to 6 lb. To make it easier to lift repeatedly, it is made with a shorter thicker handle than others. Their faces may be rounded or cross peen, used respectively to spread or to thin and taper metal.

Silversmithing hammers are used in the starting stages of raising, and for forging, have well-rounded or oval faces in a variety of contours, and range in weight from 3 oz to 2¾ lb. Heavier hammers are used in initial forming stages, and lighter ones at later form refining stages.

Embossing hammers, sometimes called *doming hammers,* are silversmithing hammers that have smaller, rounded faces. They are used to emboss or raise forms on sheet metal, and for sinking forms, usually from the inside while the work rests on a resilient surface. They weigh between 6 oz and 2 lb.

Raising hammers have rectangular, blunt or wedge-shaped cross peen faces of different widths and degrees of edge sharpness. Edges are usually rounded to minimize cutting the metal. They are used to strike the outside of forms to raise them by stages from flat sheet to dimensional forms. In some, the face is set at a slight angle, pointing inward to the handle, to help drive the metal to the anvil or stake and simultaneously compress it. They weigh from 11 oz to 3½ lb. *Collet hammers* are related in shape to raising hammers but are generally lighter in weight. They are used to shape concave forms and for edge thickening.

Planishing hammers, including *bottoming hammers,* have round or square faces available in large to small diameters. The face may be flat, or slightly convex (called *crowned* or *full*). They are used to smooth, level, or planish metal surfaces, usually after they have been worked by other hammers such as peen hammers that have made dents and ridges in the work. Because planishing hammers are flat or only slightly convex they must be struck true center to avoid marking the metal with the face edges. *Spotting hammers* are a form of planishing hammer and have a slightly convex face that leaves a spot on the metal upon impact, hence the name. Planishing hammers weigh 4–12 oz.

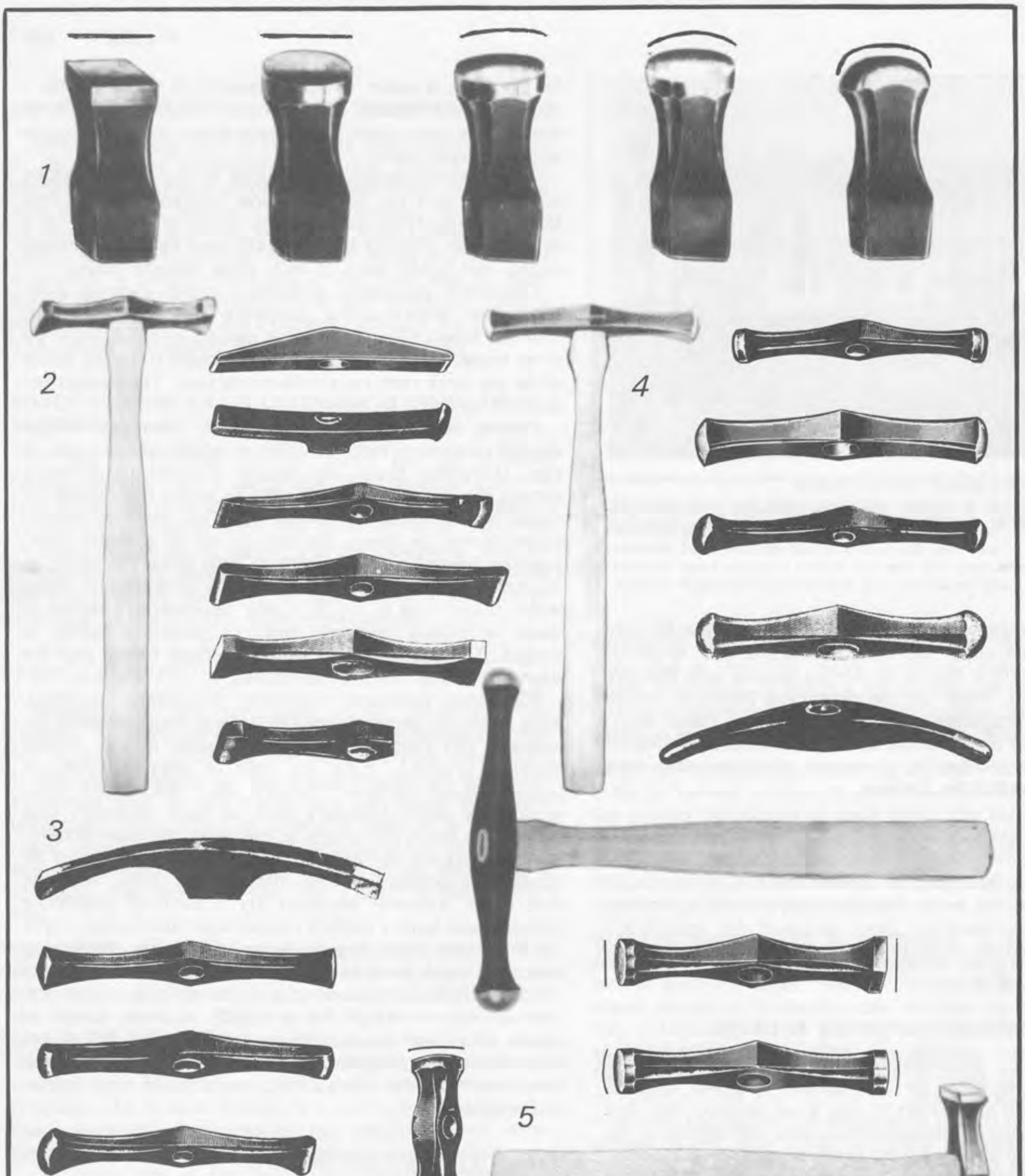
Special function hammers for direct striking include the *riveting hammer* which has a slightly concave, round or square face, and is available in weights from 2½–9 oz; and a *blocking hammer* which has a large hook shape head extension that allows it to reach inside deep forms, and weighs 8 oz.

THE USE OF THE HAMMER

Some general comments can be made about practices related to the use of hammers in forging and other hammering operations.

The *stance* of the worker in relation to the work and the distance from it are important for efficiency and comfort. First establish the *striking level* in relation to whether you work in a standing or sitting position. The anvil face in either case should be even with the forearm when in the horizontal position at the completion of a stroke. Adjust the striking level of the anvil accordingly.

When executing a hammer stroke, keep the upper arm against the side. Hold the hammer handle with a firm grip toward the end (*not* near the head, as this imbalanced position limits efficient hammering), the index finger extended for control alongside the handle. In *light hammering,* the striking movement is made mainly with the wrist, which moves the hammer in short arcs while the rest of the arm moves minimally. In *heavy hammering,* greater



6–234 *SILVERSMITHING HAMMERS*

1. *Basic hammer face shapes:* square, flat; round, flat; round, slightly convex; round, convex; oval, ball.
2. *Raising hammer shapes:* both ends cross peen, straight; one end cross peen, other end rounded cross peen; both ends wedge shaped, one straight, the other curved; collet type, both cross peens straight and rounded, different sizes; both cross peens square, different sizes; one-faced hammer, rounded cross peen.
3. A selection of other *raising hammers* with various face shapes.
4. *Embossing, doming, or forming hammer shapes:* round, convex; square, convex; domed; large ball; small ball.
5. *Planishing hammer shapes:* long head, one face round, the other square, both flat; both ends oval, one slightly convex or crowned, the other more convex; short head, both faces round, one flat face, the other slightly convex for spotting.

impact must be brought to bear on the work. The whole forearm may move as much as a radial arc of up to 90°, and the hammer head which extends beyond the hand moves in an even greater arc. By a law of physics, *mass multiplied by acceleration equals force,* therefore, the hammer weight and the speed of fall determine the impact force. By choosing a hammer of a proper weight and controlling the rate of the blows and their arc distance, the force of impact can be controlled. These decisions are based upon experience.

Normally in jewelry making the blows struck are relatively light. The degree of impact force needed is regulated by the weight of the metal being worked, and the particular metal, which can be yielding and soft or tough and rigid. For example, in repoussé work where relatively thin-gauge metal is shaped, the blows are short-arced, rapid, and light on the punch; while in forging thick metal, the blows are less frequent, fall in greater arcs, and are considerably heavier in impact. *Scale of work* also determines the size and weight of hammer and degree of impact. In work that requires a prolonged series of blows, as when raising, planishing, or texturing metal, a hammering rhythm is established that helps to coordinate the movement of the arm and the tool.

THE EFFECTS OF HAMMER IMPACT ON METAL

Springback is the ability all metals have to be subjected to deformation *up to a certain limit,* and then return to their original size and shape. If the force of compression exerted upon the metal exceeds its elastic or springback limit, it becomes changed in shape and size. This is what happens when metal is forged by hammer blows in bending, shrinking, stretching and elongating techniques that give it a new and permanent form.

In *direct metal hammering,* the aim is to make the hammer work on the metal through a percussive impact applied to a specific place. Generally the face falls squarely on the metal, and oblique strokes are avoided as they can irregularly scar the metal rather than move it. In *indirect metal hammering,* as when striking a tool with a hammer, the aim is to transfer the impact from the struck tool to the point where the tool contacts the metal. In both cases, the force of the blow makes the metal move in some way by *displacement* or *deformation.*

MULTIDIRECTIONAL MOVEMENT: Flat impact spread forging

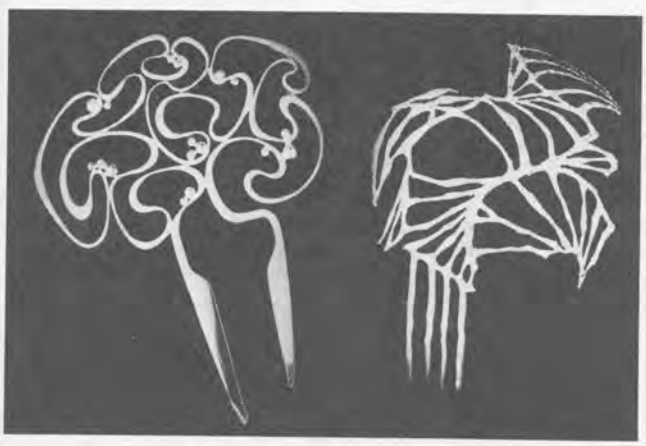
The basic concepts of forging relate to the *shape of the hammer face* and the *angle of its impact* on the metal. By the proper choice of hammer shape and by control of the striking angle, the metal can be deformed in any desired direction. When striking metal squarely with a flat- or convex-faced hammer, and the metal is supported, it spreads *in all directions* from the point of impact and in the direction of least resistance. The flatter the face, the broader the extent of the area struck; the more convex it is, as in a dome or ball face, the smaller the area struck. These actions occur in spotting, smoothing, planishing, and bottoming.

SELECTED DIRECTIONAL MOVEMENT: Angular impact reduction or stretch forging

A rectangular, regularly curved face, as the cross peen of a raising hammer, when struck squarely on the metal forces it to move at a *right angle* to the point of impact. This occurs in the act of forming longitudinal grooves, as when crimping or fluting, or when rounding. If the same hammer strikes at an *acute angle* to the metal, or if a hammer is used that has a face whose curve angles slightly downward in the direction of the handle (as in the case of some raising hammers), the metal moves *in the direction of the angle* or obliquely. This occurs in raising and forging when stretching, shrinking, and tapering the metal. When these acts are performed toward or at the *edge* of the metal, the result is thinning.

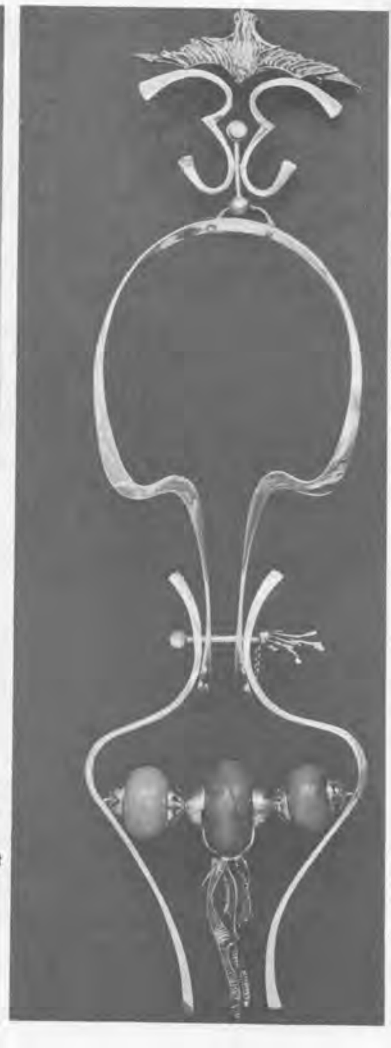
PERPENDICULAR DIRECTIONAL MOVEMENT: Upset forging

By striking a flat-faced hammer at a *right angle* to the *end* of a bar or wire, as when making a rivet head, or striking a cross peen hammer at a *right angle* to the *edge* of sheet metal, called respectively upsetting and edge thickening, the metal spreads in a direction *perpendicular to the axis* of the form.



6–235 PÅL VIGELAND, Norway. Forged hair ornaments, the left made of a single forged wire, calligraphically thick and thin due to forging. The right is pierced work, with forged surface texture. *Photo: Pål Vigeland*

6–236 CLAËS E. GIERTTA, Sweden. Forged silver ring with hammered surface texture. *Photo: Sven Petersen*



6–237 NILDA C. F. GETTY, U.S.A. "Tribal Flight." Sterling silver forged neck/body ornament, with African amber and moonstones. It unscrews at the point where the lower unit is attached to place it on the neck. *Photo: Les F. Brown*

MALLETS AND RESILIENT HAMMERS

Mallets and hammers made of various materials that are softer than metal are used in forging and otherwise to bend, flatten, and shape metal without marking its surface. *Wood-headed mallets* use hardwood such as boxwood or other close-grained wood and are formed with their end grain perpendicular to the face for added strength. They are available in flat, domed, or cross peen faces, in various sizes. *Rawhide mallets* are made of spirally wrapped, tough, rawhide (untanned) leather in different head diameters and lengths. The protective coating of shellac painted on the face of a new rawhide mallet must be sandpapered off before it is first used. *Leather-faced wooden mallets* exist. *Horn mallets* are available in conical shapes that are the natural horn form. *Rubber mallets* have the disadvantage of rebounding after they strike the metal. Less liable to rebound are mallets made with *detachable, threaded-on brass or nylon faces,* the latter available in eight degrees of hardness, from super soft to extra hard. Their advantage is they can be replaced when worn.

COLD PUNCHES AND COLD CHISELS

These chisels are so called because they are used on cold work. They are smaller in size than hot work chisels and punches, but like them are also used in forging to cut metal and make grooves and holes. (See Repoussage and Chasing, Chapter 5 and Metal Inlay, Chapter 8.)

BASIC FORGING OPERATIONS

USING HAMMER AND ANVIL

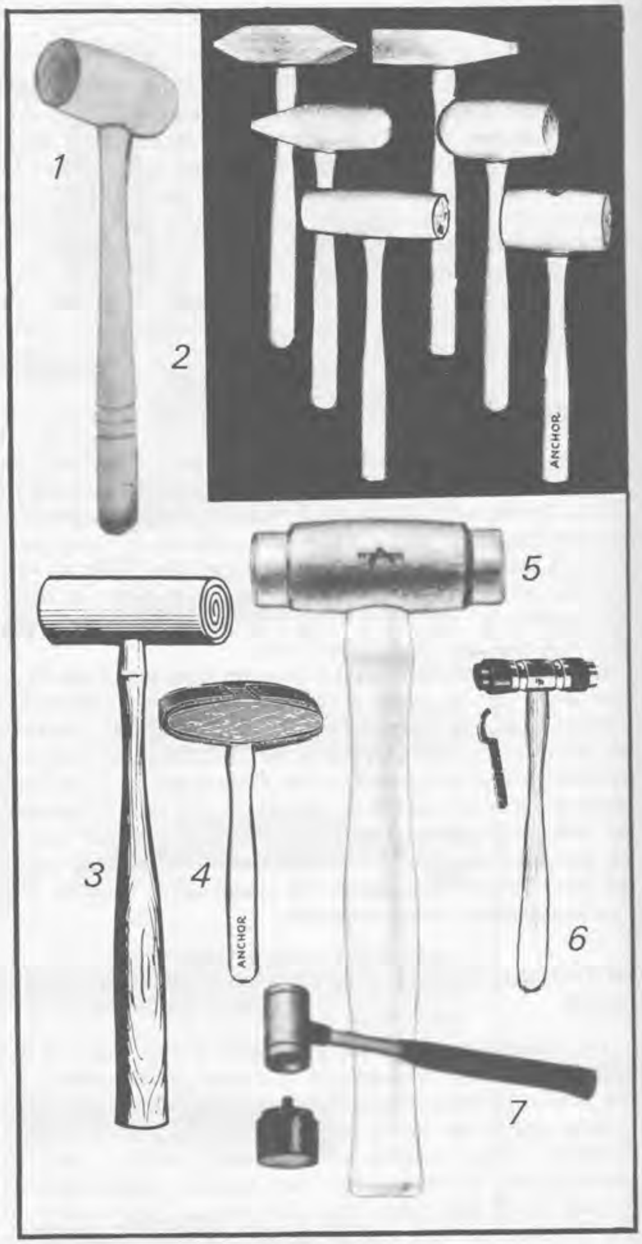
Whether the metal is worked hot or cold, the forging techniques which comprise most of the basic ways (apart from casting) of shaping metal are the same. Forging can be done on solid bar, wire, sheet, or cast metal.

ROUNDING UP

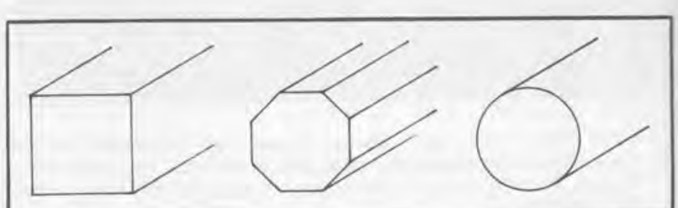
In rounding up, sometimes called *roughing,* a flat-faced hammer is used on square bar or wire stock to take it through stages in which its corners are hammered. When done methodically, as when shaping a square bar into a round one, the square's edges are hammered, while the bar rests flat on the anvil, to form a hexagonal shape in section. The edges of this shape are then smoothed with the hammer to make a totally round form. Rounding up also works to rearrange the crystal structure of the metal, consolidating and therefore strengthening it internally.

SWAGING

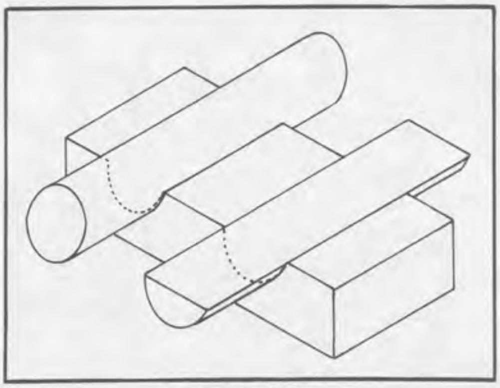
Swaging can be a form of rounding up, but is also used to otherwise change the cross section of a bar by hammer blows. This can be done while holding the metal on a flat anvil surface, but is more frequently accomplished by placing it in the groove of a *swage block* whose shape and size is selected according to need, and like a die, controls the form that results. Depending on circumstances, the metal is either turned constantly as it is hammered and shaped, or kept stationary as for instance when a half-round or triangular form is swaged. Swaging is also a



6–238 *MALLETS AND RESILIENT HAMMERS*
1. *Boxwood-headed mallet* with wooden handle, head $2\frac{3}{8}$ in long, face Ø $1\frac{3}{8}$ in, length with handle $10\frac{1}{2}$ in.
2. *Wood-headed forming mallets:* wedge shape, wedge and dome, narrow flat face, wedge and oblong face, flat and dome face, broad flat face, heads 3–$5\frac{1}{2}$ in long. (*Anchor*)
3. *Rawhide mallet* with wooden handle, head lengths available from $2\frac{1}{8}$–$3\frac{1}{4}$ in, Ø 1–2 in in one-eighth-inch progressions.
4. *Wood wedge-shaped mallet* with strip leather face.
5. *Cast iron base hammer* with rawhide faces, wooden handle.
6. *Metal hammer* with detachable, threaded-in faces available in fiber, nylon, or brass; with wrench to remove and tighten faces. (*Abbey*)
7. *Nupla hammer holder* available in various weights from 6 oz to 3 lb, with removable plastic faces graded and color coded in eight degrees from extra hard to soft; separate tip with attached thread, available Ø 2, $1\frac{1}{2}$, and 1 in. (*Abbey*)



6–239 ROUNDING UP



6–240 SWAGING

means of reducing the section of a tube by repeated, opposing blows to gradually make a decrease in diameter, or when tapering a tube end to a smaller opening.

DRAWING DOWN OR FORGING DOWN

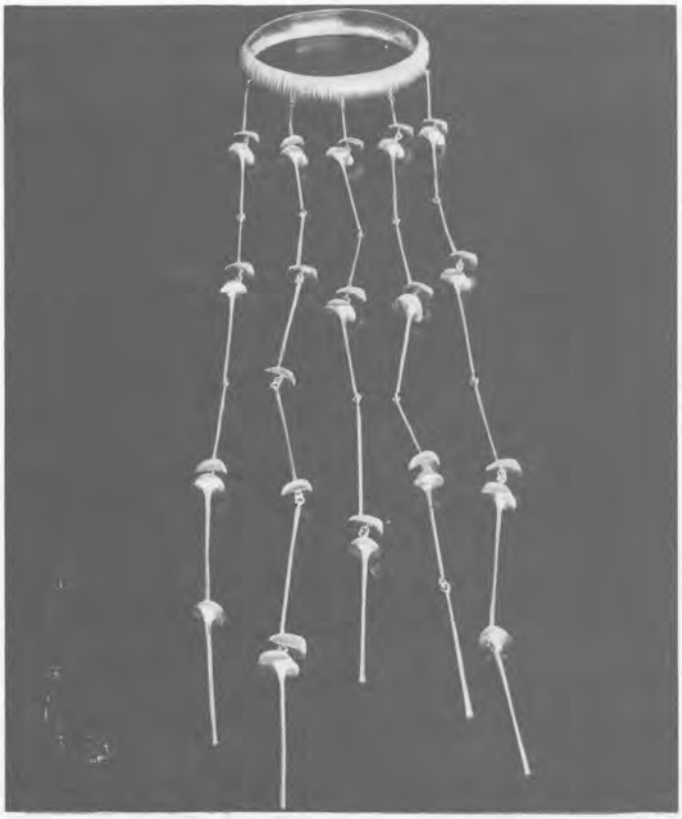
Drawing down is the act of reducing the cross section of a metal bar to increase its length without much increase, if any, in its width. This is accomplished by hammering it with a cross peen hammer to a taper. There are three basic tapers. A *round taper* is one in which the bar is drawn down equally on all sides so that it eventually forms a conical point if the process is continued. A *flat taper* is one in which a square or rectangular bar is drawn down on two opposite sides, first with a cross peen hammer on one or both opposing sides, then with a planishing hammer on the other two surfaces or edges, to contain and continue the line of the taper. If the taper is allowed to spread or expand toward the thin end, it is called a *fishtail taper,* a type used when forming the cutting ends of some chisels. *Piping* is a form of taper that consists of forming a hollow in a bar that tapers in its longitudinal direction. Piping can also occur unintentionally when the top and bottom surfaces of a bar stretch while the metal between those surfaces does not, thus forming side grooves or *pipes*. Where these are undesirable, they are eliminated by hammering the sides on which they appear at an early stage. Drawing down is usually followed by planishing.

COUNTERDIRECTIONAL DRAWING DOWN

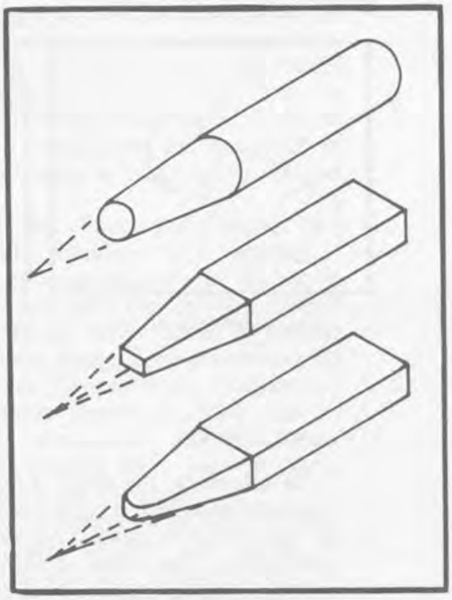
Counterdirectional drawing down is an application of plain drawing down and not actually a separate process, but as it is used so much in forming forged jewelry, it is mentioned here. In counterdirectional drawing down, two opposing tapering planes are formed on the same bar so that their opposition resembles a *tetragonal sphenoid* or wedge-shaped form whose wedges taper to a point in opposite directions when the piece is short. When these opposing planes are formed on a long bar or wire, and that bar is curved instead of straight, the opposing planes merge gradually into each other to present the sculptural appearance, due to subtle changes in planes, evident in most forged jewelry.

SETTING DOWN

Setting down is a means of reducing the cross section of a part of a forging. Only that area is worked while the rest remains as is.

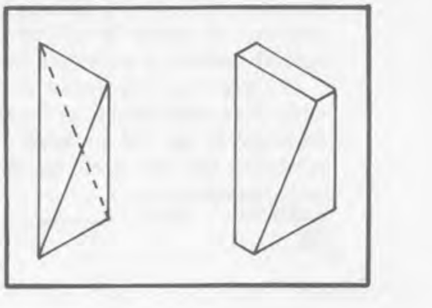


6–241 DIETER MÜLLER-STACH, U.S.A. "Body Chimes." Silver neckpiece, 800/1,000. The 34 hanging units were made by lost wax casting, their stems forged after casting. Length 28.5 in. *Photo: Dieter Müller-Stach*



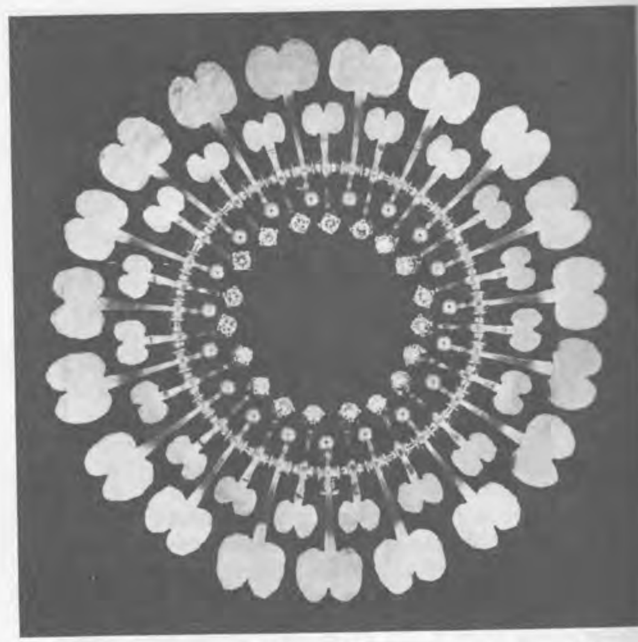
6–242 *DRAWING OR FORGING DOWN*

6–243 TORUN BÜLOW-HÜBE, Denmark, designer; manufacturer Georg Jensen Sølvsmedie A/S, Copenhagen. Forged sterling silver wristwatch armband with smoky quartz watch glass. *Photo: Courtesy Georg Jensen Sølvsmedie A/S*

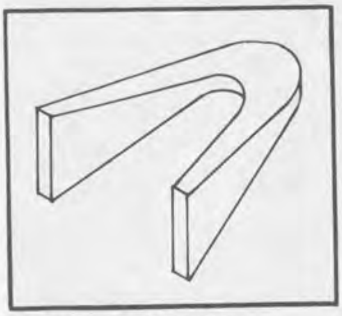


6–244 *THE TETRAGONAL SPHENOID* (wedge)

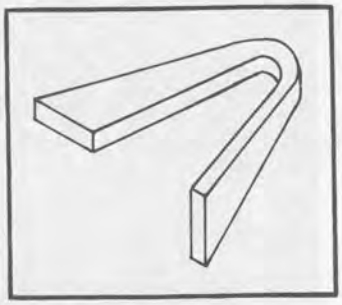
6–245 CLAUDE MOMIRON, France. Forged gold ring with malachite, with smoothly modulated transitions from thick to thin on different planes. *Photo: Claude Momiron*



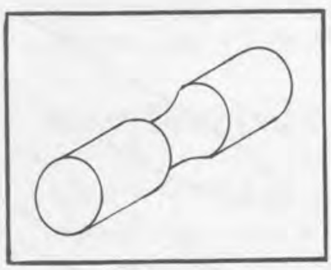
6–250 TAPIO WIRKKALA, Finland, designer; manufacturer Kultakeskus Oy, Hämeenlinna. Forged 14K gold brooch with diamonds, showing the typical surface texture of forged hammer marks, left intact, on the two sets of 19 repeated units strung on a chain. *Photo: Courtesy Suomen Taideteollisuusyhdistys, Helsinki*



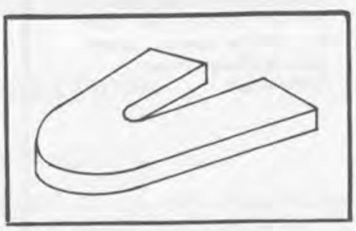
6–246 *ONE-DIRECTIONAL DRAWING DOWN ON A CURVE*



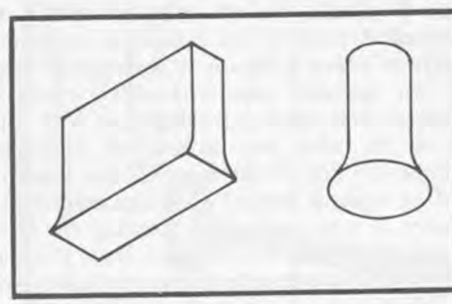
6–247 *OPPOSITE, TWO-DIRECTIONAL DRAWING DOWN*



6–248 *SETTING DOWN*



6–249 *SPREADING*



6–251 *UPSETTING A BAR OR A SHEET EDGE*

SPREADING

In spreading, the metal is thinned or widened or both by hammering it with a *cross peen hammer* with blows angled to the direction toward which the desired spread should take place. The metal is then flattened and smoothed to remove hammer marks by a *planishing hammer* while the work rests upon and is supported by an anvil or stake of appropriate form.

UPSETTING

Upsetting is the reverse of drawing down. Its purpose is to *thicken* the metal by hammering it in the direction contrary to its longitudinal axis, as at the *end of a bar,* causing it to bulge out; or in its developmental direction, as at the *edge of a sheet,* causing it to become edge thickened. Corners of sharp bends of bars and wire are upset to spread them and make the bend rigid.

In upsetting, the metal is held upright or horizontally with the hands, tongs, or in a vise while it is worked by a hammer at its end or edge. Thick bars can be upset by pounding the bar itself on the face of an anvil, a process called *jumping up.*

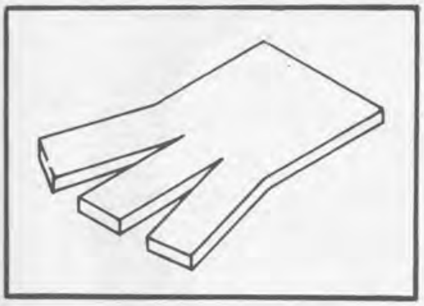
FORGING BY HAMMER, ANVIL, AND OTHER TOOLS

CUTTING

Cutting metal can be done while the metal is hot or cold. A relatively thick bar such as an ingot can be cut by hammering a *cold chisel* at the severance point first on one side, then on the other. The metal can then be easily broken off at the point of the groove by striking it off with a hammer. If there is any danger of dulling the chisel or scarring an anvil face, place the ingot on a piece of soft brass before cutting. Thick sheet metal can be cut by placing it vertically in a *bench vise,* then hammering the projection with a sharp cold chisel to sever it. This method can be used as a means of reducing or trimming thick stock.

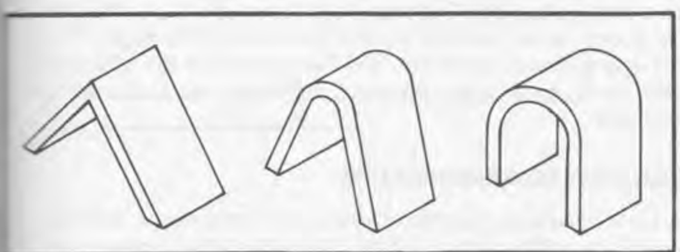
SLITTING OR SLICING

In slitting, *sharp chisels* are driven through sheet metal or bars to make a cut in order to divide the metal into parts that can then be spread apart at the cut line. A broad shape can be slit into several smaller ones that can then be shaped by forging or other means into subsidiary forms that remain a continuous part of the larger mass.



6–252 *SLITTING*

6–253 SIGURD PERSSON, Sweden. Forged silver bracelet whose hollow terminal forms are inspired by seed shapes. *Photo: Sune Sundahl*



6–254 *BENDING*

6–255 TORIL BJORG, Norway, designer; manufacturer David Andersen, Oslo. Each repeat unit of this forged sterling silver bracelet is made with one wire, forged and bent to link with the previous one. *Photo: Teigens Fotoatelier, courtesy David Andersen*

BENDING

Bending in forging is an important process, and is discussed in Chapter 4. To those remarks we add here only what specifically relates to bending metal in forging.

Forge bending in most cases consists of hammering bar, rod, or wire with *forging hammers* while holding the work on an *anvil* or *stake*. Both nondeforming and deforming angular and curved bends are used in forging. Most characteristic of forging, however, are bends that warp the metal out of its normal, flat plane by torsion. In this case, the metal is twisted by the exertion of a lateral force from hammer blows that causes it to gradually turn about its longitudinal axis at the place worked while the rest remains the same as before, or is then hammered to twist it in an opposite direction. Torsion is a way of creating a smooth flow of one surface plane into another that so often indicates that a piece of jewelry has been made by the forging process.

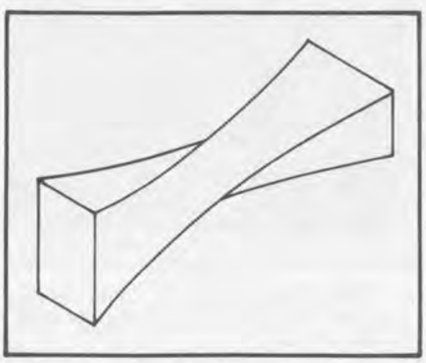
In torsional bending or planar deformation, the initial bending of the rod or wire can be done with *pliers* if the metal is small in scale; when heavier it is hammered into the depression of a *swage block, metal mold,* the hollow in a *tree stump,* or over a *mandrel.* The work is then transferred to and held against a metal-resisting surface such as an *anvil, stake* of suitable shape, or a *surface block,* and forcefully hammered with *forging hammers* along the plane of torsion. Greater force is needed to permanently stretch and shrink a plane than is needed for simple bending. The plane warp can be left as it is after hammering, or it can be filed smooth.

TWISTING

Twisting is a method commonly used in forging to create a form or to decorate it. It too depends on the force of torsion. It is most commonly done on solid wire or bar stock that has lengthwise edges so that the pattern of the twist can be seen. Twisting can be done while the metal is hot or cold. If a continuous twist is the aim, the entire piece of metal must be annealed. If the metal is to be twisted in one place or in a relatively small area, it can be annealed *locally* with a torch flame, while the rest is left in a harder state. The softened area is more easily twisted and the rest remains intact.

A single, right-angle twist can change the plane of rectangular stock to the opposite direction by a rotation of 90°, and the form can then be forge shaped and developed further as described above. A square bar or other ridged shapes can be self-twisted in as many turns as desired along its entire length. Thinner gauge square wire can be twisted with a hand drill. (See Twisted Wire, Chapter 6.) Depending on thickness, short lengths of wire can be twisted by placing one end horizontally in a stationary *vise,* while the other end is grasped by a pair of *pliers, hand clamp, spanner wrench,* or *tap wrench.*

Wires and bars formed of a composite of several units having different cross-sectional shapes, or made of different metals can be twisted together. These can first be joined in their length by soldering, or only at their ends to facilitate their being twisted; the twist itself then serves to hold the units together. Lengths of twisted wire can be shaped further by bending, forging, or rolling.



6–256 *TWISTING*

6–258 L. BRENT KINGTON, U.S.A. Oxidized sterling silver forged bracelet, with gold domes at the ends. The cross-sectional shape and pattern of reverse twists was inspired by the Vendel torque. Instead of welding the flanges together, the stock was extruded by an open roll pass through the rolling mill wire rolls, in the manner shown in the diagram. The ridged end areas contrast with the convolutions of the central area. *Photo: Myers Walker*

6–257 DENMARK, Late Bronze Age, Period VI, approximately 6th century B.C. Bronze forged Vendel torque found at Rigerup, Holbak County. Such torques are believed to have been imported to Denmark from North and East Germany. Four flanges were welded to a bar in a cross-form section, narrowing toward the ends which terminate in a hook-clasp. The entire length, first straight, was twisted while hot, at intervals, in opposite directions. Seventeen have been found in Denmark, frequently in pairs, indicating, as contemporary bronze statuettes show, that they were so worn. *Photo: Danish National Museum, Copenhagen*

6–259 L. BRENT KINGTON, U.S.A. Forged sterling silver bracelet with gold wire and shot end ornaments. The form is typical of twisted wire stock forged work. Ø 3 in. *Photo: Myers Walker*

6–260 L. BRENT KINGTON, U.S.A. Oxidized sterling silver forged bracelet with end balls in gold. The twist pattern results from twisting square stock. Ø 3 in. *Photo: Myers Walker*

FULLERING TO PARALLEL DRAW DOWN

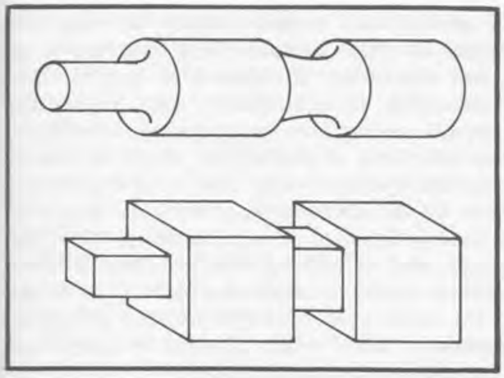
Fullering is making grooves or hollows in forged metal with a *cross peen hammer,* or making necks and shoulders in a bar by the use of grooves in a *swage block.* A rod can be drawn down parallel by placing it over the edge of a flat-edged *stake* or a *fuller,* and hammered on the opposite side by a *cross peen hammer,* followed by a *flat-faced hammer.*

ROUTING TO REMOVE MASS

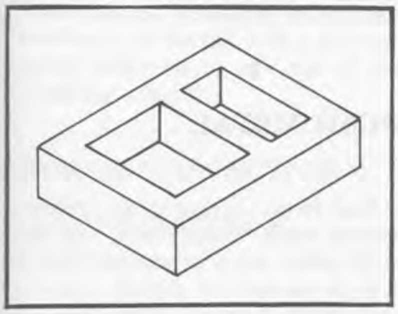
Cold chisels can be used to rout out depressions in thick metal, to scoop out a furrow, to completely remove an area, or to make a depression. (See Metal Inlay, Chisels in General, Chapter 8.)

PUNCHING TO PIERCE METAL

In punching, a cold, sharp-pointed, hand-held *punch,* a *chisel,* or a *tapered drift* (a tool similar to a punch, used to enlarge a pre-existing hole) is forced through the metal to create a hole or opening, or to enlarge one, while the metal rests on an anvil or other surface. The punching tool should emerge through the metal into the hardie hole or pritchell hole in the anvil face, or into a softer metal or wood surface on which the metal has been placed. When punching this stock, the punch is brought almost through, the piece is turned over, and the action is repeated from the opposite side. The difference between punching and drilling a hole is that in punching, no metal is removed, while in drilling, chips of the metal are continuously removed until a hole is formed. A punched hole has its special appearance because the metal volume is the same as at the start, only spread and bulged at either side of the opening. A mandrel can then be inserted into the hole, and the part worked by forging to spread the metal around the mandrel in a direction opposite to the rest.

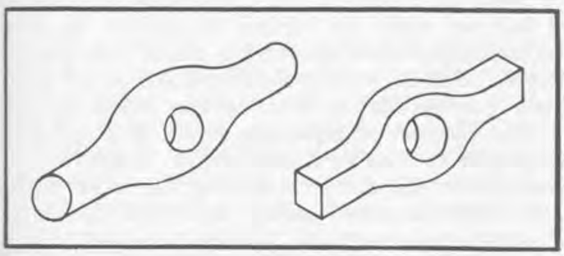


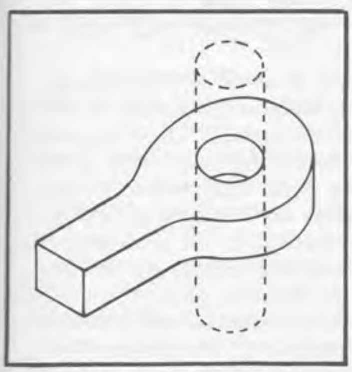
6–261 *FULLERING*



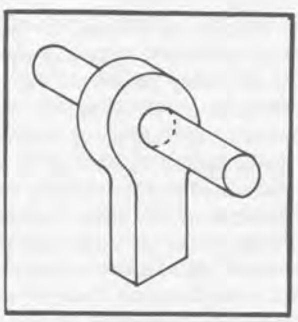
6–262 *ROUTING*

6–263 *CORING*





6–264 *PUNCHING*



6–265 *HOLLOW FORGING ON A MANDREL*

CORING

In coring, a sharp, *hollow punch* is used to cut a circular piece out of the metal.

HOLLOW FORGING MANDRELS

A mandrel can be inserted into a hole formed in the metal, and the part worked by forging to spread the metal around the mandrel in a direction opposite to the rest to form a ring or cylinder. Transitions from round to square can be made this way.

METHODS OF JOINING FORGED PARTS

COLD, RIGID JOINS

RIVETING Riveting is used for joining work-hardened forged parts that must remain in that condition, and therefore cannot withstand any hot joining processes. A hole is pierced through the parts and a rivet is passed through it, then hammered down to form a head at either end. The join can be rigid or movable. (See Rivets and Riveting, Chapter 10.)

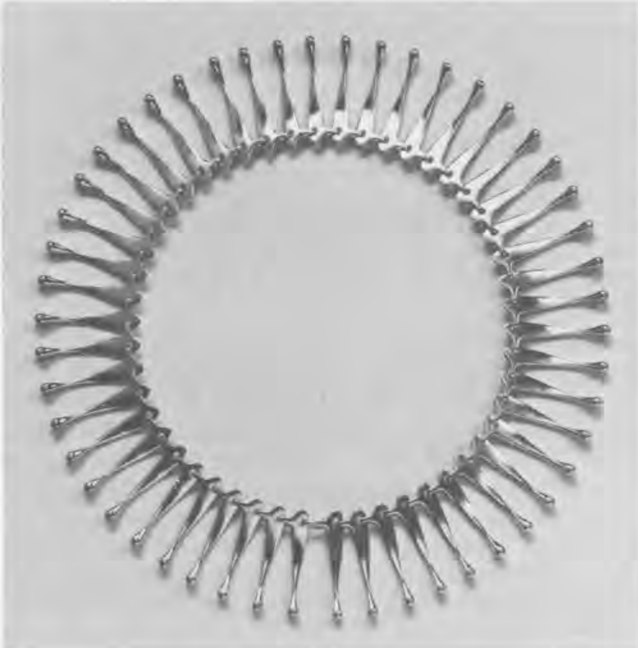
SCREWING In joining parts with screws, a hole is drilled and tapped through the parts and the screw threaded in it. The screw can then be made permanent by forming a second head at the end opposite the head, as with a rivet. (See Screws, Chapter 10.)

BOLT AND NUT A bolt is a threaded pin or rod that has a head (of any shape) at one end and a screw thread on the straight, nontapering shaft. The shaft is passed through a hole in the coupled parts and is secured by threading the shank with a matching threaded nut. (See Bolts and Nuts, Chapter 10.)

COLLARING A collar is a band or encircling ring hammered to surround two (or more) parts being held together to restrain their motion partially or completely. The collar is open where its ends meet. It is sometimes used to cover an opening or an end to prevent endwise motion. In cross section it can be flat, round, or half-round, or combinations of these.

WRAPPING Wire or strip metal can be wrapped several times around parts to be held together. The methods of doing this are greatly varied. (See Wrapping and Coiling

6–266 *Left:* MICHAEL JOHN JERRY, U.S.A. Forged wire and fabricated sterling silver neckpiece with agate slab, moonstone, and pearls. Size 11 × 6 in. *Photo: Michael John Jerry*
6–267 *Right:* Detail of the forged neckpiece showing the agate slab placement. To put on the neckpiece, the two small spirals are pinched together and pulled down and back, releasing the collar. A white gold hinge behind the agate frame swings the stone out of the way to allow the collar to come down and unhook. *Photo: Michael John Jerry*



6–268 BENT GABRIELSEN P., Denmark, designer; manufacturer Georg Jensen Sølvsmedie A/S, Copenhagen. Forged silver necklace using 50 repeats of the same unit, each hooking into the next by a forge-spread and bent end. *Photo: Erik Junior, courtesy Georg Jensen Sølvsmedie A/S*

Wire and Strip, p. 206.) If the wire is stiff, its ends will stay in place; if not, certain techniques must be employed to prevent the wrapping from raveling.

COLD, MOVABLE JOINS

COLD PUNCHING HOLES A hole can be punched through with a *cold punch* and other parts, links, bolts, and hinge pins can then be passed through this hole to make a movable connection.

LINKS AND HOOKS Separate links of wire can be used to hold parts that have holes in them for this purpose. Hooks that are an integral part or extension of the main body can pass through a hole or loop in an adjoining body.

BALL AND SOCKET A ball and socket joint is a *universal joint* or coupling that permits swiveling and turning at any angle (free movement of the parts joined). Essentially it consists of a rod extending from one part passed through a hole or fitting into a cup of another part. To keep it in place, the rod end is forged or upset to make it larger than the diameter of the opening. Depending on the design of the parts, such a joint can swivel completely or stay in a chosen position. In any case, the members are freely movable.

HINGING If a hinge is forge formed as an integral part of two adjacent members, the parts can be held together and operate as a hinge by inserting a hinge pin. (See Glossary: Jewelry Findings.)

HOT JOINING METHODS

Methods of hot joining forged parts can be used, but normally this softens the forged parts as the heat anneals them. Parts *can* be planished after heat joining to work harden them, depending on the design situation.

Welding is a method used to join not only ferrous, but nonferrous metals as well. Ferrous metal welding is a large subject, and the reader is referred to special texts dealing with this area of metalwork. For nonferrous welding, see subjects dealing with metal fusion techniques.

Spot welding, is a form of welding in which two parts are welded at isolated points rather than in a continuous seam by the use of an *electrical spot welding machine*. This is largely used in the field of commercial jewelry, for making eyeglasses, and in making repairs where a more widely diffused heat would endanger the piece. It is rather surprising that the small, hand-held spot welding apparatus available has not been more widely adopted by individual craftspersons for use in fabricating jewelry.

Soldering forged parts is also possible. (See Soldering, Chapter 10.)

FINISHING A FORGED METAL SURFACE

Planishing metal after final forge shaping is the smoothing of the surface to remove minor irregularities and any undesirable visible signs of other work processes. This is done by the use of an 8–13 oz flat- or slightly convex-faced, highly polished *planishing hammer* when the surface to be planished is convex, and a somewhat more convex-faced hammer when the surface is concave. In this traditional finishing method, the work is placed over a supporting, highly polished, smooth-surfaced stake whose contour closely corresponds to that of the object to be planished. The purpose of planishing is *not* to *shape* the metal, but to give the *surface a final texture*. Therefore, to prevent work distortion due to stretching, the work must *make contact* with the stake's surface which will then support it against the hammer blows, and its shape will be retained. The supporting surface area must be larger than that of the contact area of the hammer face when it strikes the work.

Planishing is done by placing a series of relatively rapidly delivered, light but equally weighted, regularly spaced, overlapping blows on the object's surface. Their sequence depends on the shape of the object, and may follow a concentric, spiraling, or radiating path. Each blow overlaps the last, and the object is always kept in contact with the stake surface by shifting it according to the area worked. Because of the local compression that occurs on the work at the point of each percussive hammer blow, the visible surface develops a series of bright, facetlike marks at those hammer contact points as planishing progresses. When properly supported, the undersurface of the work becomes smooth and bright. To best be able to see the progress and development of the facet marks while planishing is in progress, first pickle the work to a matte, dead white. Each blow of the hammer will then appear as a shining spot. Edges may become misshapen during planishing, but they can be filed smooth once planishing is completed.

Filing a surface after forging is another finishing technique. Whether to leave a surface with its obviously hand-forged hammer marks, or to reduce the form to its basic shape by removing all evidence of the forging process and refine the work surface to a specular, mirrorlike, reflecting smoothness, is a matter of personal choice. Both hammered and smoothed surfaces are legitimate, and combinations of the two can coexist in a single work. *Files* of all cuts and cross sections may be used to level risings, to smooth and refine surface contours, to eliminate work marks, and to give a surface uniform flow. Coarse files are used first to take the surface down to the deepest groove level, followed by finer files to eliminate the coarse file marks.

Texturing, in which surface character is created by the use of tools such as *engraving liners*, or *rotary milling burs* such that light is reflected in various ways, is another finishing technique.

Stamping the surface partially or totally with *small-patterned stamps* can be done to give a surface textural richness and a special character.

Hand polishing the surface after forging gives it a soft, semibright finish. This can be done with *steel wool*, leaving the surface with a matte, parallel-scratched appearance.

Mechanical polishing can create an effect ranging from semimatte, achieved with a *scratch brush*, to a high mirror finish, achieved by the use of abrasives and buffing and polishing wheels.

FORGING IN ACTION

DEMONSTRATION 6

ALBERT PALEY makes a forged brooch

Photos: David Darby

The process of making a piece of jewelry by the technique of forging imposes the same structural problems, considerations, and skills as are involved when making a large construction in forged wrought iron, though differences in metal and scale impose differences in design. In making jewelry by forging, the metal is generally worked by *cold forging*, shaped primarily by hammer blows aided at times by the use of other tools. An exception occurs when using platinum, palladium, and their alloys which are often hot forged at temperatures ranging from 1472–2372° F (800–1300° C).

In the development of the form of a piece of jewelry such as this forged brooch, Paley does not begin by making a fully developed drawing of the design concept. Instead, based on his knowledge of the possibilities of tools, materials, and techniques, he relies on an intuitive approach to the design. A design idea is often triggered by an aspect of the forging process itself, and modified by a structural or mechanical necessity. The form develops during the work, taking on changes of shape and plane suggested by the special technology unique to the forging process. Every forming process—be it forging, casting, or fabricating—contains its own esthetic concepts, unique to that particular process, which the craftsperson must investigate and exploit to create a design having integrity.

Additional practical considerations enter into design development. Size, weight, stability, and the mechanical means of placing the piece on the body or attaching it to clothing are factors that each exert their influence.

In creating this brooch, Paley wished to make the design a statement in metal alone, using the forging technique as the means of determining the form, therefore no stones or other materials were used.

ANNEALING

1 Unless the metal is already in an annealed condition, ready to be forged when purchased, anneal it so that it has an optimal hot or cold working character. The ¼ in (6.35 mm) square sterling silver bar used to create the main form is placed in an *annealing pan* containing *pea pumice* and is heated uniformly with a soft, reducing flame that is kept moving at an even rate over its entire surface. When annealing, it is important to bring the metal to the proper annealing temperature for that particular metal. Overheating should be avoided as it causes the metal to form unnecessarily large crystals that result in its structural weakness, and under work, may cause it to crack. To assure the accuracy of the desired annealing temperature, which in the case of silver is particularly critical, apply a *flux* that matures at a known temperature to the entire surface by brushing, dipping, or spraying. Because flux matures to a glassy state at about 1000° F (590° C), this indicates the desired annealing temperature is near. Sterling silver is annealed at 1200° F (648° C). By another method of judging annealing temperature, small, round, pill-like *Thermo Pensils* are placed next to the metal. This proprietory product is made of a material that matures at a specific temperature, and the pill is watched so that when this occurs, the flame is removed.

After every anneal, pickle the metal to remove the flux and any surface oxides. Scratch brush the surface to relieve it of any adhering oxide particles which otherwise would be forged into it and become the cause of undesirable surface irregularities.

FORGING

2 The most effective initial forging tool is a narrow-faced, rounded, *cross peen hammer*. Forging hammers are made in several weights and one is chosen according to the need. Each hammer blow on the bar makes a ridged dent in the metal which causes displacement, increases temperature, and spreads the metal widthwise, especially at the edges. Edge spread called *shouldering* is sometimes undesirable and must be watched, because it may lead to

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cracking; if necessary eliminate it by forging the edge in the opposite direction.

At the start, a basic, transitional forged form—a tapered wedge shape is *drawn down* from the square silver bar by hammering it with a 2 lb *cross peen hammer* in blows that fall perpendicular to the work while it is held on the flat, polished face of an *anvil*. Other basic sectional forms can also be made from a bar as seen in this chapter. One with exciting possibilities, often seen in forged jewelry, and used here, is the *tetragonal sphenoid*. This is formed by working the wedge shape from opposite sides, increasing the taper and spread in a direction away from its origin. Two opposing planes then develop at right angles to each other. If the form is straight, these planes remain intact and are clearly seen. In the case of this piece, the form will be extended to a long, curved, ellipsoidal shape, so that the warp of its planes ultimately brings the same planes together where the form closes.

To achieve a maximal directional change and visible separation of the planes, only one pair of sides is worked at a time, and the metal is annealed before changing the direction of the work. By limiting the direction of the hammer blows this way, internal stress occurring in the metal because of compression forces is reduced, which eliminates the chance of edge cracking.

After initial drawing down with the cross peen hammer, the surface is worked with a slightly convex-faced *planishing hammer* to level the hammer-raised ridges; if not, the highest ones might become folded over and would ultimately develop into surface cracks. The round planishing hammer also acts to distribute the metal in all directions while it levels.

3 By working and thinning the metal through blows of the cross peen hammer in the side *opposite* to a desired direction of bend, a slight curve, bend, or warp of plane is achieved. Through repeated blows, the direction of shaping and widening the metal is controlled. If, however, the curve is sharp, the stock must be initially bent by hand, by a tool such as pliers, or by hammering it to the desired shape *before* forging starts.

PLANISHING

4 Planishing or smoothing a surface to a plane is accomplished by hammering the metal with a smooth-faced, slightly convex *planishing hammer* while the work is placed on a resisting or supporting surface such as an *anvil*. The anvil face must be absolutely clean, smooth, and dent-free or the metal will pick up these irregularities. Planishing is used as a means of achieving a refinement of transitional warp-curved planes and forms.

5 The surface on which planishing is done may be the curved beak of a forging anvil or an *anvil stake* chosen for its appropriate size and shape, whose extension is placed in the anvil's hardie hole, or the work may be placed directly on the flat face of the anvil. When metal is planished or otherwise cold worked, it is condensed and toughened because of changes in the grain shape of its crystal structure due to compression, a condition called *work hardening*. As a result, each forged element of the several of which this brooch is made is placed in a state of rigidity, a condition Paley uses to advantage. As his jewels are generally large, their total weight becomes a major consideration. In order to preserve the work-hardened strength of the forged parts, they are intentionally assembled by *cold working* processes such as riveting, swaging, and wrapping. Where

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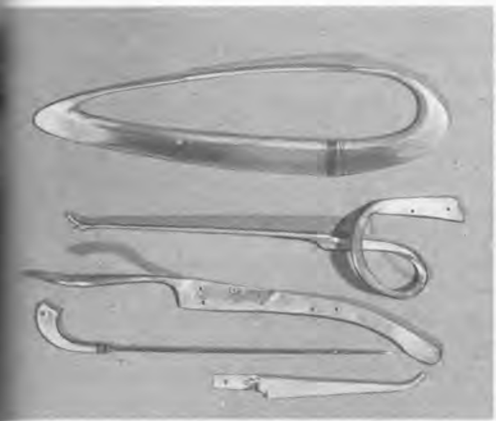

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soldering is the method of joining, the parts being joined automatically become annealed during soldering and thereby softened. Jewels that are made with extensive soldering generally depend for their strength on mass or the mutual support of structural parts of the piece. By employing cold worked assembly methods, the work-hardened strength of large, relatively thin, light parts is preserved and can be utilized for structural rigidity.

REFINING FORM AND FINISHING

6 Forged surfaces can be left showing the subtle texture of hammer blows, or they can be leveled, smoothed, and refined by filing and finishing. Here the shape of the forged form is refined initially by a *coarse-cut file,* followed by *fine-cut files.* The file shape chosen for use depends on the contour of the plane being filed. (See Files and Filing, Chapter 4.)

7 Even after filing, a form can be subtly altered, or work hardened if necessary, by using a planishing hammer. Any marks that result can again be removed by files.

8 Edges are refined by the use of a fine-cut file. *Beveling* or file faceting the edges at an angle to the main planes draws attention to the *mass* more effectively than does a flat surface with straight edges, and it also emphasizes the line movements that develop when edges curve. Further finishing consists of using *emery paper* in successively finer grits, starting with 350, proceeding to 450, and ending with 600 grit. The surface is next rubbed with *fine pumice,* and then scratch brushed.

9 Here we see that the ellipsoidal form made from the silver bar was soldered at the union where, because it seemed "natural and logical," a section of a copper, silver, and gold laminate was placed to serve as a visual focal point on the frontal plane of that form. After soldering, the form was again hardened by working it with a *mallet.*

Most of the surfaces on Paley's jewelry are scratch brushed to a satin finish and not highly polished, because he feels that the linear character of forged forms is confused and interrupted by multiple, bright reflections. In this case, however, to achieve highlights on the beveled edge only of the ellipsoidal form, it is polished with a *felt lap* which, because of its hardness, preserves the edge and the relative flatness of the plane. Small recessed areas inaccessible to buffs and laps can be reached with a *hand burnisher.*

10 The major elements of the piece are seen here before assembly. Each piece has been drilled at positions appropriate to receive the joining rivets. In the development of the design, it was initially decided that the vertical back plane of the ellipsoidal shape (seen here in a thin, upended position at the top) was the logical place for the placement of the pin-holding device, and was also a suitable surface where other parts could be riveted. The joining system of *overlapping riveted plates* as a means of creating multiple, flowing forms, developed from this practical, structural necessity. These three elements (plus the pinstem), their placement, and interrelationship established the *basic* structure of the brooch. A fourth element was needed and was made to project the ellipsoidal form to a position perpendicular to the body and to support it in that position.

11 In placing the pinstem so as not to interfere with a major element, a secondary element was introduced to hold it and its hinging device. A pin guard or closing device was forged out of heavy sheet and placed at the back of the ellipsoidal shape at the end opposite the pinstem hinge. The end of the pinstem is threaded and held by screwing it into an internal thread made with a *bottoming tap and die.* Here the hinged section is fitted and joined, to be held in place by a rivet.

12 The work-hardened elements are here being joined together by the use of rivets made of sections of silver wire. A riveting hammer is used to form the rivet heads and then hammer them flush with the surface plane of the part on which they appear. After filing, emerying, and scratch brushing, the rivet head becomes invisible and does not interrupt the visual flow of the planes.

13 It was decided to utilize the space created by the forward projection of the ellipsoidal shape by incorporating elements that hang from its forward part as well as from another part of the brooch structure. These would be

mobile as they hang in air away from the body. Because they are mounted loosely in drilled holes, they are set in motion by movement of the wearer.

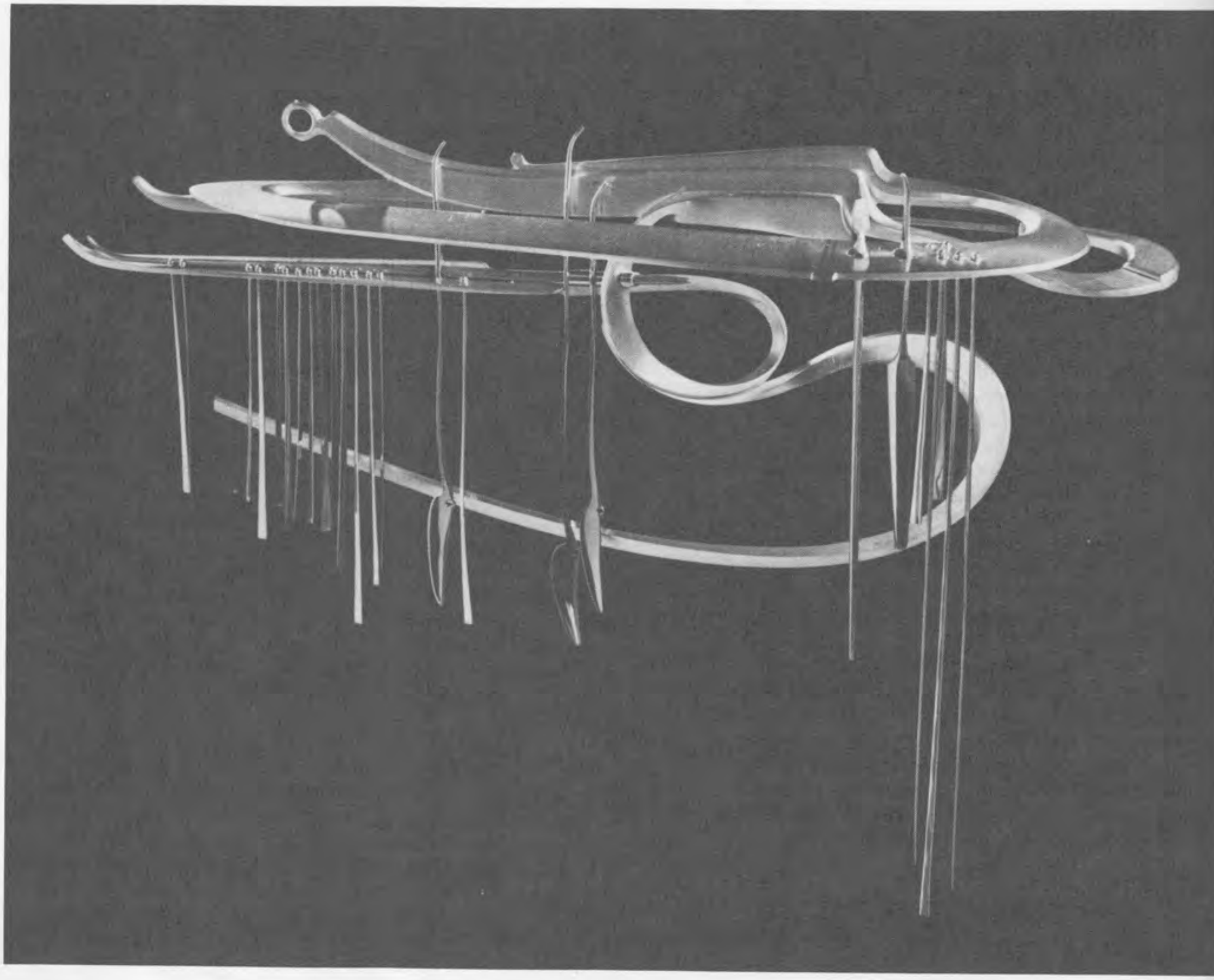
Shown here is the development of some of these small, gold, hanging elements, starting with rough forging, through intermediate stages, to a refined, polished form. The use of a high polish of these parts was a deliberate choice as a means of catching and reflecting light and to establish a reference to body movement, thereby accenting such movement. The contrast these bright parts make with the satin finish of the rest creates visual variety.

The addition of these vertical parts meant added weight, thereby creating a need for the fourth supporting element mentioned above. This element thus serves a dual function —that of holding the ellipsoidal shape in its forward projecting position, and of providing an area from which the free-hanging elements can be suspended.

14 The finished piece, Brooch No. 75-1, is 9 in wide and 6 in high (22.9 cm × 15.2 cm); weight 5½ oz t.

Photo: Bruce Miller

The hanging elements in 14K yellow gold employ internal hinging in the outer ring, and an axial form in the lower left. The smaller gold elements use a ball and socket joint that allows radial movement, and because they are loose and move, these elements contrast with the structural rigidity of the forged forms. Another contrast occurs between their verticality and thinness, and the horizontality of the heavier forged forms.



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Forging

Forging alters the thickness and shape of metal through the force of a hammer. By applying this force from different directions, the metal can be stretched or condensed. It is necessary to have a sturdy metal support surface underneath the metal being forged, such as a stake or an anvil, and the proper hammer for specific forging processes.

The most basic forging techniques are tapering the length of a square or round wire and widening a piece of stock metal. Both ways of moving metal are performed in a calculated and controlled manner.

MATERIALS

Copper, silver, or gold bar stock, square or round, size dependent on project*

TOOLS & SUPPLIES

Chair with adjustable height
Anvil
Tree stump or other anvil support
Hearing protection
Forging hammer
Soldering kit, page 27
Planishing hammer
File (optional)
220- and 400-grit sandpaper (optional)

**I recommend practicing forging on a piece of copper bar stock that is 5 or 10 mm thick.*

STEP BY STEP

1 Adjust your chair to the proper height in relation to the height of the anvil on the tree stump. Your forearm, wrist, and hammer should all be in alignment, with room left for making hammer blows (see photo). If this position does not feel relaxed and you begin to ache after hammering, readjust the chair.

2 Put on the hearing protection. Hold the forging hammer so it will move loosely within your grip and your hand will feel relatively stress-free. If you are using unnecessary force, your wrist and arm will begin to ache, so ease up and make yourself relax.

C

3 Begin making hammer blows at the place where you want the metal to stretch, letting the weight of the hammer do all the work (photo C). Make your hammer blows count. The metal will move with each blow, so precision is desirable. To taper the metal, position the face of the hammer

FAR LEFT: **Rob Jackson**
Radcliffe Nail Ring, 2004. 2.2 x 2.2 x 1 cm. Iron, 18-karat gold, ruby; forged, hand fabricated, tube set. Photo © artist. Courtesy of Penland Gallery, Penland School of Crafts, Penland, North Carolina

LEFT: **Britt Anderson**
Ring, 1998. 18-karat yellow gold, black pearl, diamond, 18-karat white gold; anticlastic raising, fabricated, soldered, depletion gilded, sandblasted. Photo © Ralph Gabriner

RIGHT: **Marguerite Chiang Manteau**
Fruit & Seed Bracelet & Bead, 2003. 17.8 x 6.4 x 5.8 cm. Sterling silver, 18-karat gold, 14-karat gold; hand fabricated, hinged. Photo © Hap Sakwa

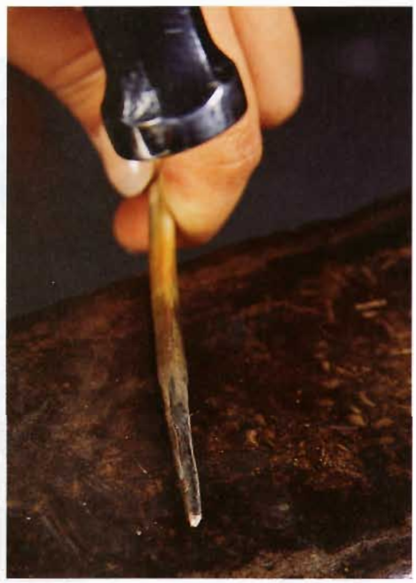
FAR RIGHT: **So Young Park**
Nativity Series Brooches, 2004. Each, 5 x 5 x 1 cm. 18-karat gold, sterling silver; dapped, soldered. Photo © Jae Man Jo

B

C

perpendicular to the length of the bar (photo B). To widen the metal, the face of the hammer should be parallel to the length of the bar (photo C).

4 As soon as the hammer blows make a pinging sound instead of a dull thud, anneal the metal (see page 48). Thoroughly dry the metal after annealing to prevent the anvil and hammer from rusting.



5 Once the metal is close to being sufficiently tapered or widened, planish the metal. (Planishing means removing any forging marks with the slightly curved side of the planishing hammer until the metal surface is as smooth as it can be.) Planishing does stretch the metal a bit, so take this into account when determining when to stop forging.

6 If you wish to clean the forged stock completely, file off any facets (bumps made from the planishing hammer), and then sand the piece with 220- and 400-grit sandpaper.

Bench Tips

When tapering a round bar, it is helpful first to stretch the metal and form it into a square (see photo). Then, go back and hammer the square corners until the edges are curved and the bar returns to its round shape.

If a square bar becomes rectangular while being tapered and you want it to remain square, turn the bar 90 degrees and continue hammering to re-square the metal.

If you have widened the metal in a curved fashion, you may need to clean up the curve with a file. Experiment to see what results you achieve when you hammer directly on the thin edge of the curve. You can thicken the edge of a forged piece by lightly hammering directly onto the edge at a 90-degree angle.

A Lark Jewelry Book

THE ART & CRAFT OF MAKING JEWELRY




Joanna Gollberg

A COMPLETE GUIDE TO ESSENTIAL TECHNIQUES

Hands On

Successful forging is a total integration of the body and mind of the artist with his or her tools and technique. John explains how the careful selection of hammers, anvils, and work surfaces, coupled with proper posture, grip, and blow, effect the outcome of a piece. Through tapering, cross sectioning, curving, and planishing a silver rod, John demonstrates how metal moves. Through stamping and polishing, he brings a forged piece to its completion.

1 The ideal forging hammer weighs 2 to 2¼ pounds (0.9 to 1 kg) with a handle length of approximately 10 inches (25.4 cm). Lighter hammers are limited in the scope of work they can perform and will only accommodate thin wire. Heavier hammers are unwieldy, require substantial physical exertion, and are best suited to breaking down thick ingots. A forging hammer should have a ball-peen face on one end of the head and a straight, narrow, cross-peen face on the other end.

2 The forging hammer's ball-peen face is circular and slightly domed in profile. Any sharp edges and facets are removed, and the face is highly polished. This face is used for planishing (smoothing and refining) and for imparting the final, characteristic faceted surface. Quality forging hammers can be purchased "fully dressed," which is preferable, or "off the rack." This latter hammer type can be hand-dressed with a belt sander and a polishing arbor, but this is a time-consuming and messy process.

3 The cross-peen face of the forging hammer is oriented sideways, perpendicular to the axis of the handle. All sharp edges and corners are sanded smooth and rounded, and the surface is highly polished. This is the hammer's "workhorse" face, used for all of the major preliminary forming and shaping of forged pieces.

4 Anvils come in many shapes and sizes. Miniature bench-top anvils are too small and light for forging. They are hard to secure in place and tend to "dance" around the bench-top. If they fall off, they pose the threat of personal injury. Conversely, massive blacksmithing anvils are too heavy and have coarse, unfinished surfaces that are unsuited to fine work. A good forging anvil for jewelers and precious metalsmiths usually weighs between 45 and 75 pounds (20.4 and 34 kg), has a brightly polished, hardened, and flat working surface, and a polished horn. (The horn is a cone-shaped projection at one or both ends of the anvil.) A section of railroad track, made of high-grade steel, is a cheaper alternative to a commercial anvil, but it resonates like cathedral bells when struck with a hammer. This noise can be greatly diminished by clamping a piece of wooden 2 x 4 on each side of the narrow section of the railroad track beneath the work surface. However, ear protection remains an absolute necessity! Regardless of style or type, it is important to mount the anvil atop a tree stump or sturdy stand of appropriate height. When mounted, the anvil's flat surface should be approximately 26 to 30 inches (66 to 76.2 cm) from the floor, depending on seat height.

5 Both square and round wire or rod stock are suitable for forging. However, because of the extra metal in the four corners, square stock has greater mass than round stock of the same gauge. This greater mass affords the potential for greater surface dimension. Cast ingots can also be forged and are a good way to recycle clean scrap metal. These ingots can either be cast in square or rectangular cross-section, and are limited in length only by the dimensions of the ingot mold used. Preformed ingots, such as those used for forged flatware serving pieces (bottom, right), can be cast by clamping simple, handmade frames of the desired shape (made from mild steel bar stock) between the halves of the steel mold.

6 When working at the anvil, it is extremely important to sit at a proper height to avoid injury to arm and wrist. It is generally easier to adjust the height of the seat than to raise or lower the anvil. Select a chair or stool that allows the alignment of hammer, wrist, and forearm to be as straight and relaxed as possible. If the seating is too high or too low, the wrist must be contorted into an over-flexed position that can quickly cause pain or discomfort, fatigue, and possible long-term physical damage. I use an adjustable-height, rolling office chair in my studio.

7 Equally important as seat height is the manner in which the forming hammer is gripped and swung during the forging sequence. I grip the hammer firmly enough with my thumb and forefinger to ensure that it won't fly out of my hand (photo A), and simply rest my other three fingers comfortably on the handle (photo B). This allows the hammer to pivot freely in my grip while maintaining control.

It is neither necessary nor advisable to try to swing the hammer with great force or to lift it between successive blows. The weight of the hammer's head does all of the work. Both the anvil's surface and the hammer's face are hardened. This creates *recoil* (that is, the hammer bounces back up) when the hammer strikes the metal on the anvil. This recoil eliminates the need to lift the hammer between blows. Rather, it is only necessary to aim successive blows as the hammer drops. All swinging of the hammer is done from the relaxed wrist, not the elbow. The forearm should remain basically motionless, with the elbow comfortably anchored.

Two additional, important considerations when hammering: The hand and fingers holding the metal stock should be kept off the anvil to avoid smashed fingers, and suitable hearing protection should always be worn.

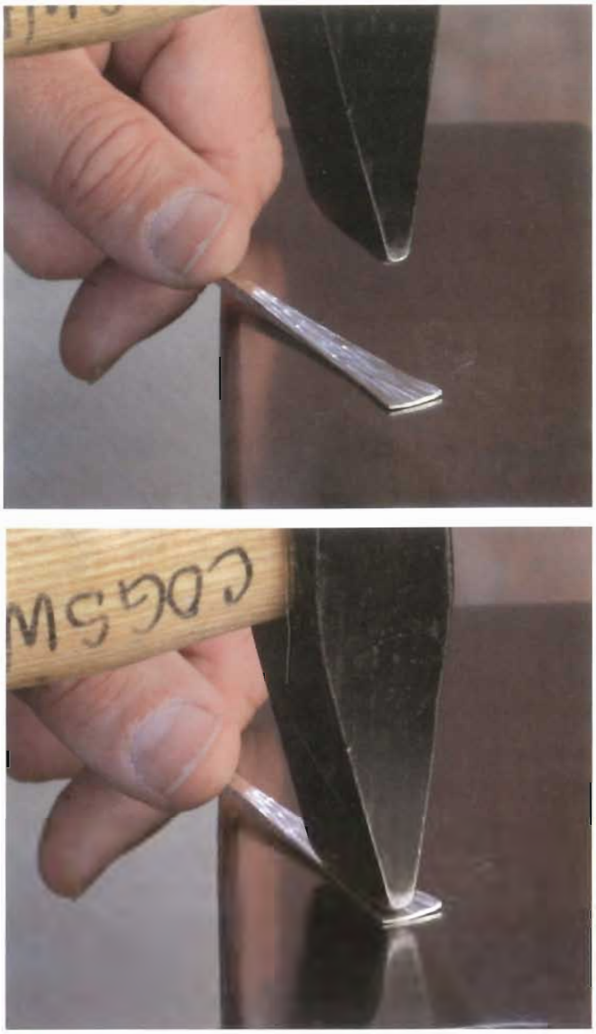
8 It is important to understand the manner in which the blow from the hammer's cross-peen face moves metal. Metal always spreads out from the point of impact at a right angle (perpendicular) to the cross-peen's lengthwise axis. The angle of presentation of the hammer face to anvil produces varying results. As shown in photo C, if the hammerhead strikes vertically (a "neutral" blow), the metal moves out evenly in opposite directions. If the handle is lowered as shown in photo D, the hammer's face strikes the metal at an inclined angle that "pushes" the metal away from the point of impact in one direction. Lifting the handle (photo E) "pulls" the metal, again in a single direction. Carefully adjusting the angle of each blow allows the metal to be selectively spread and shaped in a controllable fashion.

Conversely, the ball-peen face is always presented to the anvil with a neutral blow (straight up and down). Since metal moves out radially in all directions from the point of impact, there is no directional control, and the blow only thins and stretches. The ball-peen face is never used for shaping, but rather to remove the hammer marks left by the cross-peen and to produce the final planished surface.

9 To lengthen or "draw out" a piece of metal stock, the cross-peen face of the hammer is struck perpendicular to the lengthwise axis of the metal. As the metal stretches out from the point of impact at right angles to the cross-peen face, the stock is reduced in thickness along a single axis with little or no increase in width. If the hammer blows are confined to only one single surface or plane, the metal will develop a gradual wedge-like taper with little change in width. This controlled elongation along a single axis is called directional stretching. Generally, I recommend slightly lifting the end of the hammer's handle when tapering to draw, or pull, the metal toward you. This keeps the hand and hammer out of the line of vision, making it easier to see the area being worked.

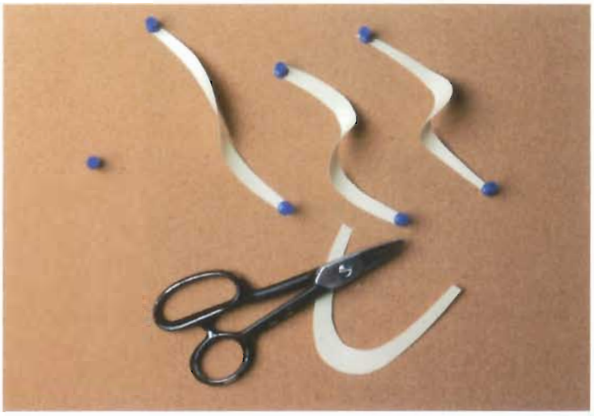
10 When metal is hammered equally on two adjacent planes, a gradual reduction in both width and height occurs, yielding a uniform taper. The stock lengthens as its cross-sectional dimension is reduced. If a pronounced taper is desired, this hammering sequence is repeated several times, with the starting location moved closer to the end of the stock each time. If the metal becomes too work-hardened, it may be necessary to anneal the taper periodically. Because the springiness and strength from work hardening are usually desirable in the finished forging, any annealing should be done as early in the process as possible.

11 When forging tapers, there is a natural tendency for a diamond-shaped cross-section to develop (above, left). This tendency is understandable, since our arms are situated at the sides of our bodies, not in the center of our torsos. The result of this offset orientation is a slight inclination, or tilting to one side, of the hammer blow. If allowed to go too far, this diamond-shaped cross-section can be irreparable, causing wasted time and material. The solution is to anneal the errant taper, then to rest it on edge, widest axis held vertically, while hammering the opposite edge. Once the taper begins to "re-square," slowly rotate the taper while hammering any angular edges until the taper is rounded out and circular in cross-section. Re-anneal the metal and resume the tapering process.

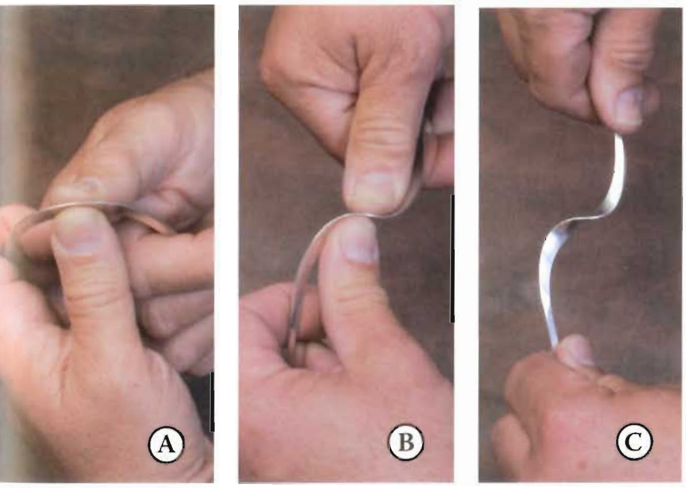


12 When cross-stretching (widening) metal, the blows of the cross-peen face are placed parallel to the lengthwise axis of the metal. The directional stretching that occurs makes the metal stock wider, with little or no growth in length. When forging a flare, I work from the center of the stock out toward the edges and avoid striking the edges as much as possible. Leaving the edges thicker imparts structure and strength. Care and accuracy should be exercised when hammering. Well-considered and well-placed hammer blows at this stage translate into reduced planishing and corrective filing later. I forge cross-sections to approximately 90 percent of the desired dimension. Planishing brings the piece to its final dimension as it removes the cross-peen marks.

13 When cross-stretching curves, I always leave the inner (concave) edge of the curve thicker than the outer edge for strength and stability. The combination of the wedge-shaped cross-section and the work-hardening from hammering gives the object strength with flexibility. To this end, any annealing should be done as early in the forging process as possible.



14 Sample patterns made from stout paper (old manila file folders are my favorite) are helpful when figuring out possibilities for new projects and variations. The "speed" of the initial forged curve (its degree of curvature) determines how pronounced the "sine wave" curve will be after shaping. Quickly scissor-cut dimensional maquettes provide both an accurate forecast of how the final metal recurve will look and a pattern to follow when forging. These paper samples also help reduce wasted time and metal. I find it useful to tack these models onto a corkboard mounted on the wall near my forging area.



15 The initial forged curve made in step 13 can be opened into a reverse curve. I firmly grip each end while supporting the curved section with opposed thumbs at the point of the bend (see photo A). As shown in photos B and C, I twist the legs in opposite directions to create the recurve. Note: To facilitate final finishing, the original curve should be fully planished and its edges filed while it is still flat.

16 The ball-peen face of the hammer is used to smooth and refine the metal and to produce the characteristic highly reflective, faceted surface.

17 After planishing was complete, I used a flat hand file to refine straight and convex-curved edges. A crossing file is used on concave, inner edges. Broad, major surfaces should not require filing if they have been properly planished.

18 I polished all edges first, using a hard felt wheel charged with bobbing compound or tripoli (see photo). The wheel's firm surface acts like a lap, producing flat, crisp planes. To prevent rounding of the edge, the direction of the wheel's rotational spin should always be in line with the axis of the edge, never perpendicular to it. I then used a wool buff (also called a rag buff) charged with one of the same compounds to polish all broad surfaces. I started polishing parallel to the outer edges, and then I polished multi-directionally, with overlapping passes, in the center. It is important to firmly hold the work to prevent it from being grabbed by the buff and pulled from your hands. Also, eye protection must always be worn and ample exhaust ventilation must be provided for respiratory protection. I usually wear leather-palmed gloves to help keep my hands clean and to protect against frictional heat build-up.

19 After preliminary polishing was complete, the item was thoroughly washed to remove any polishing compound. Stamps were placed on the reverse side, in a location where they wouldn't weaken or distort the item (see photo). After stamping, any blemishes (called "echoes") created on the front side were removed by locally repolishing with bobbing compound or tripoli.

20 For the forged item's final buffing, I used red or blue rouge on a 54-ply, unstitched, fine muslin, lead-centered buff that was 6 inches (15.2 cm) in diameter. I wore inexpensive brown cotton gloves for this operation to prevent fingerprints on the finished surfaces.

About the Artist

A studio goldsmith, silversmith, and educator, John Cogswell received his BFA and MFA from the State University of New York, New Paltz, and is currently on its faculty. He previously taught at Parsons School of Design, New York, New York; Pratt Institute, New York, New York; and Hofstra University, Hempstead, New York. He was the director of the jewelry and metalsmithing department at the 92nd Street YMHA/YWHA in New York, New York from 1985–96, and has maintained his own metal studio since 1979.

John conducts frequent workshops for nationally recognized crafts schools, art centers, and metal guilds and societies. He has frequently served as a juror, contributing author, and technical consultant for contemporary jewelry texts, magazines, and catalogs. His work has appeared in numerous exhibitions and is part of many public and private collections, including The Jewish Museum, New York, New York; The Ackland Art Museum, Chapel Hill, North Carolina; and John Michael Kohler Arts Center, Sheboygan, Wisconsin.

John Cogswell *Neckpiece*, 2000
16 x 20 cm. Sterling silver; forged. PHOTO BY ARTIST

Gallery

Many years ago, while still a novice, I attended a workshop taught by Barry Merritt in Rochester, New York. Barry invited me to visit the studio where he worked. It was the studio of Ronald Hayes Pearson, master metalsmith and unquestionably the finest forger of his time. I had become somewhat familiar with his work from countless hours spent lying in bed at night, staring at photographs of his forged pieces in the few books I could find, trying to figure out how he did what he did. By day, I'd sit in my studio, banging away on my railroad track anvil, trying to emulate what I'd seen. I quickly learned that the work in those pictures, deceptively straightforward and visually simple in appearance, was not nearly so simple or straightforward at all. Now, I had the opportunity to actually visit him in person. I was thrilled beyond words.

When introduced to Ronald Hayes Pearson, intoxicated by a mixture of youthful awe, excitement, and nervousness, I blithered on about my admiration for his work and how much I wanted to be able to forge like him. Ronald listened to me patiently, puffing on his pipe, and then said, "I can show you how to forge, but you will still have to learn. And when you have learned, don't try to forge *my* way. Forge *your* way." I have never forgotten that tutorial nor the wisdom of that simple statement.

As a metalsmith, I have always been amazed and gratified by the vastly dissimilar bodies of work that are produced by individuals who employ the same techniques, the same tools, and the same materials, yet somehow manage to come up with radically different solutions. The work that appears in this gallery is a perfect illustration of how inspiration, individuality, and talent, combined with competent technique, can produce unique, diverse results. As you look at these images, bear this thought in mind: These pieces are temporal by-products of an ongoing creative process, a documentation of each artist's continuing creative exploration and development. The best is yet to come.

Fred Fenster *Choker*, 1998
20 cm in diameter. Sterling silver; forged. PHOTO BY ARTIST

Fred Fenster *Choker*, 1998
18.8 cm in diameter. Sterling silver; constructed, forged. PHOTO BY ARTIST

Adrian Luxmoore *Neckpiece*, 2000
1.2 x 11.5 x 10.8 cm. 18-karat gold; forged, constructed.
PHOTO BY TAYLOR DABNEY

Adrian Luxmoore *Rising from the Cross*, 1999
22 x 10 x 10 cm. Sterling silver; raised, forged, constructed. PHOTO BY ARTIST. PRIVATE COLLECTION

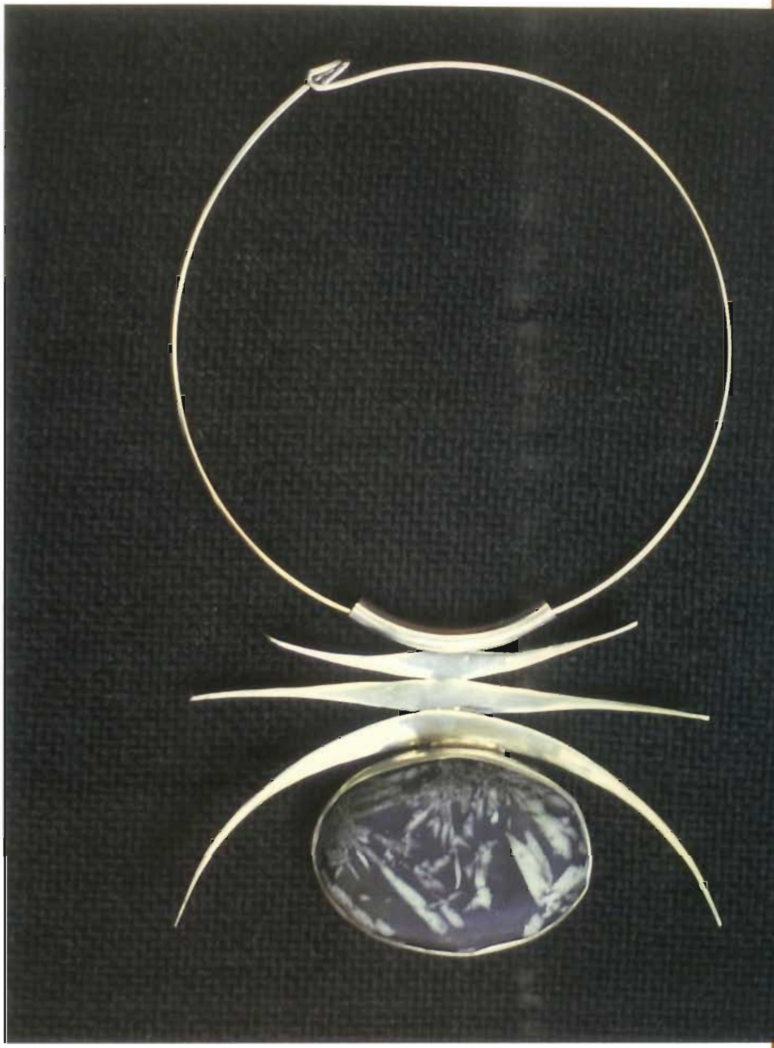
Mary Schimpff Webb Untitled, 1998
10 x 2 cm. Blue pearl, sterling silver, gold; forged, hand fabricated, soldered. PHOTO BY ARTIST

Mary Schimpff Webb Untitled, 1998
1.8 x 13 x 13 cm. Sterling silver, quartz; forged, hammered. PHOTO BY ARTIST. COURTESY OF HARRIETTE HILL

Yvonne Arritt *Collar with Pendant*, 1988
21 x 14 x 1.5 cm. Sterling silver, stalactite; forged, constructed.
PHOTO BY HOLLY LEE

Yvonne Arritt *Seaweed Earrings*, 1988
Each, 6 x 2 x 2 cm. 18-karat gold/sterling silver bimetal; fold forged.
PHOTO BY HOLLY LEE

Yvonne Arritt *Nautilus Pin*, 1988
4.5 x 5.5 x 1 cm. Sterling silver; forged.



Ed Brickman *Neckpiece with Stone*, 2002
7.2 x 11.8 x 1.4 cm. Sterling silver, stone, fine silver bezel; hand fabricated, hammered, soldered. PHOTO BY ARTIST

Ed Brickman *Neckpiece*, 2002
14 x 6.3 x 0.2 cm. Sterling silver, glass bead; bent, forged. PHOTO BY ARTIST

Ed Brickman *Guitar*, 2004
10.8 x 3.3 x 0.9 cm. Sterling silver; forged, soldered, polished.
PHOTO BY ARTIST

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