# Euclid's Door

## Building the Tools of 'By Hand & Eye'

*By George R. Walker & Jim Tolpin*

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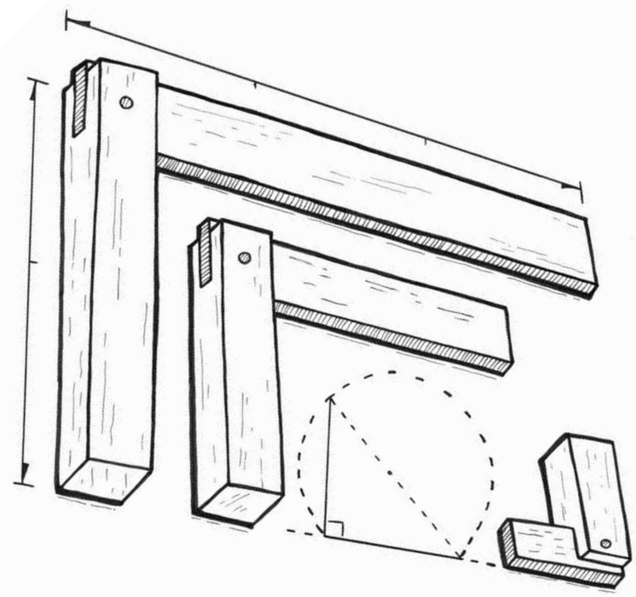

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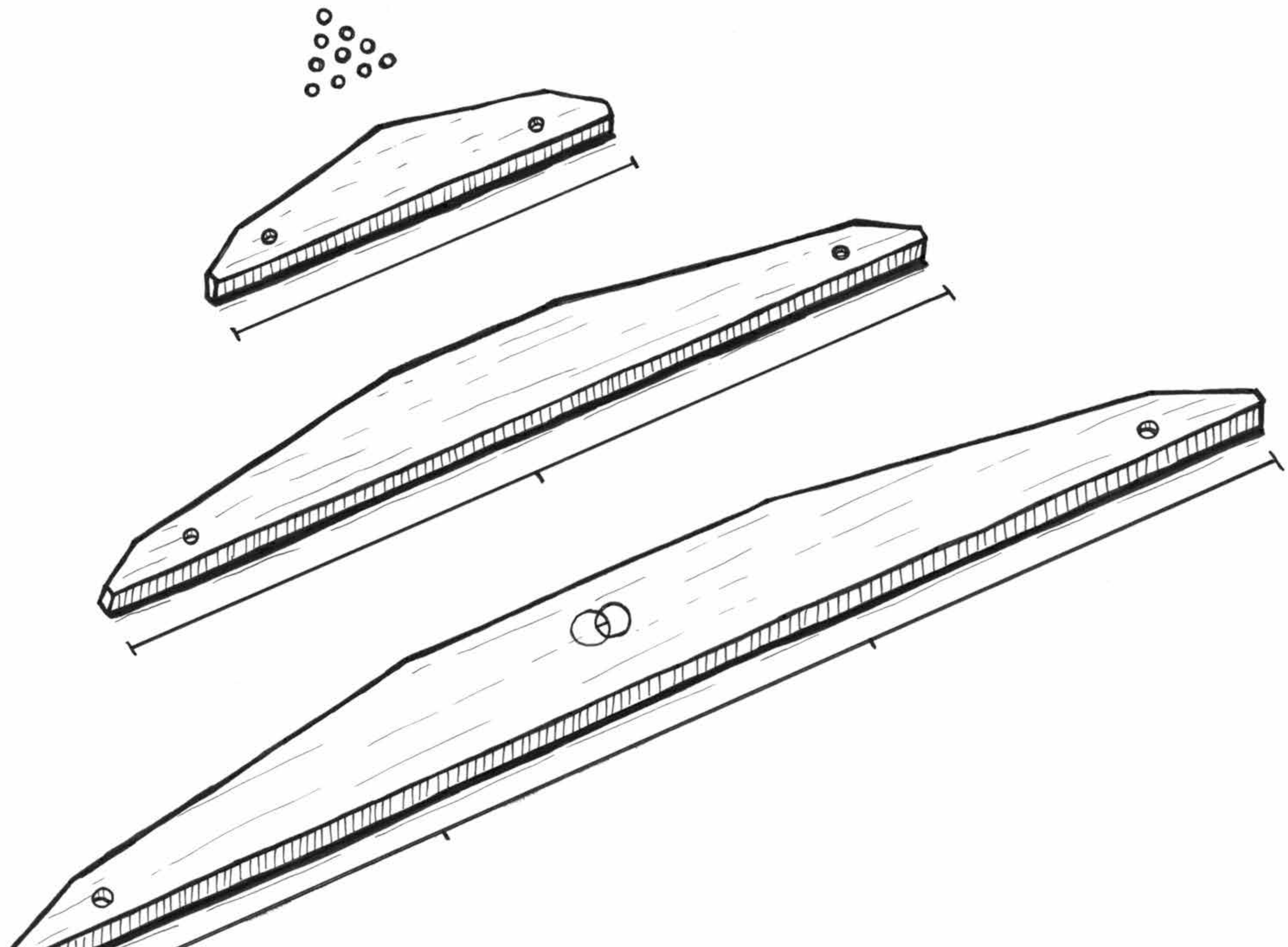

## *Chapter 2*

# The Builder's Bootstrap

Our first build is a set of straightedges. We use them to harness the power of lines. "Line" is one of those words that tells us where we are: "She stepped over the line" or "he got out of line." It can be a challenge or a warning: "Don't go past the line." It can mark the difference between joy or disappointment: "The ball shot over first base and landed outside the line." It tells us when we are ready to begin: "I've got everything lined up." A work of art can be described as something with good lines, or sharp lines or even lost lines. A brilliant sentence is described as a great line. Obviously, we use lines to help us navigate our world. The Russian writer Aleksandr Solzhenitsyn proclaimed, "The line separating good and evil passes not through states, nor between classes, nor between political parties either – but right through every human heart." We use this word so often and so descriptively because it's something we can imagine clearly. It's more of a picture than a word. For good or ill, our lives are guided by, restricted by and inspired by lines.

This is the first of three important builds that make up a trio of tools we refer to as tools for testing. Straightedges, winding sticks and try squares are foundational tools that we use to create and prove lines, planes and solids. There's a great mystery about this trio of tools that's often taken for granted. They are a bridge to bootstrap an idea into something real that we can touch, to go from empty space to the world of solid objects. This first build is the only tool that does not have a geometric construction behind it. Reason being, the straightedge embodies a simple straight line. Straight lines fall into the small group of things such as points at the very foundation of geometry itself. They are self-evident truths that we use to build everything else. A bit of mystery that can even twist our brains in knots trying to describe. Euclid defined a point as "a location without magnitude." Other writers defined a point as a location without parts, without height, depth or length. So… a point is nothing? But… it's the beginning of everything?

It helps to think of geometry as a story that uses points and lines instead of words, Fig. 2.1. The ancients used a device called a tetractys, a magic pyramid of points that revealed the progression from nothing to everything in the built world in just four steps.

The top of the pyramid is a single point. It occupies no space, but it does signify a beginning and is the source of all that follows. The second level has two points and brings with it the potential to connect them with something new: a line. Lines don't have thickness or width, but they do have length, meaning we broke out of nothing – i.e. the dimensionless and into the world of one dimension. Lines can be segments contained between points or they

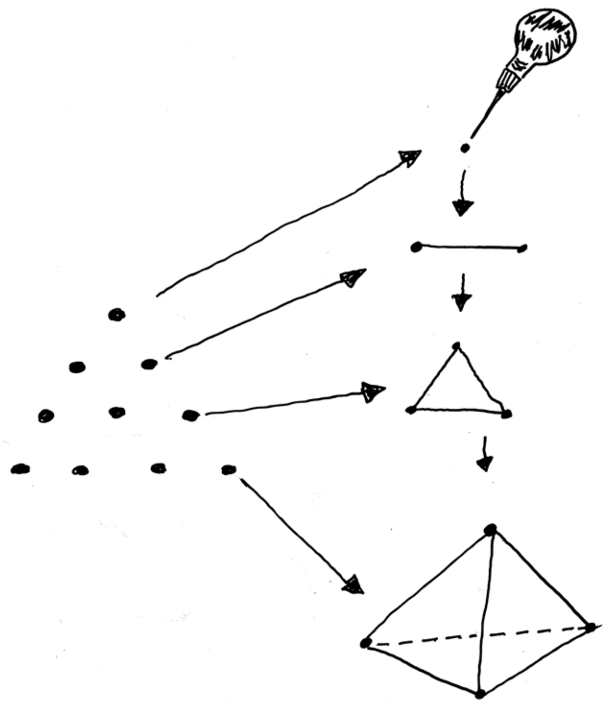

*Fig. 2.1 This iconic pyramid symbolizing the power of geometry shows up in historic paintings as well as medieval heraldry. To those who know its meaning, it signals a great mystery.*

can extend to infinity. Our straightedge is a template we can use to draw straight lines or to extend them. It gives us the power to generate and explore this world of one dimension.

The third level down contains three points. If we add a third point somewhere outside our line and connect all three, we create a triangle. More than that, we've given birth to a plane. A two-dimensional flat surface that has both length and height. Just as a line can be straight, a plane is flat. This is a powerful property we exploit when stacking stones to make a wall or joining boards together. A straightedge is also a tool to test flatness. The final level with four points explodes the possibilities. Add a fourth point outside our triangle and connect all with lines to create a solid. A solid is something that exists in three dimensions – height, width and depth – and represents everything in the built world. A solid takes up space bounded by lines and planes. Much of the time when dealing with solids we are working with rectilinear forms. Enter the try square: a template used to test two planes that meet at a right angle. So let's start up magic mountain and see what we can create out of thin air.

In this chapter we build a set of straightedges, a set of straight sticks that would hardly get a glance from a non-woodworker. To those of us who build things, this is "the tool" that captures the perfection of a straight line and gives us the power to harness it and exploit it. When I say perfection I mean that in a very specific sense. The word "perfect" gets tossed about so much that its meaning gets lost: the perfect sunset, the perfect omelet, the perfect color. These are all subjective things, but when we talk about perfection with a straightedge it's a different animal. The simplest definition of "perfect" is flawless. We are trying to create a tool with one long edge perfectly straight and flat: flawless. Now "flawless" in the world of wood, an organic material, is different from "flawless" in steel or granite, which both have crystalline structures. That's why billiard tables have slate tops. That said, we are going to build a set of wooden straightedges that will allow us to check for straight lines and flatness at a very high level and are ideal for building furniture. I've used many straightedges over the years. When I was a machinist, we sometimes worked with cast iron straightedges so heavy we hoisted them with cranes and it took two workers to slide them across a work surface. When I took up woodworking, I used a precision steel straightedge for a few years. That all changed when Jim and I started exploring artisan geometry and made some of these traditional layout tools from wood. We both quickly realized that our wooden versions exceeded their modern metal cousins. Aside from the fact that they are less likely to accidentally dent or mar the work, they have a feel to them that's key to accurately and efficiently prepping boards. In fact, it's the property of flex in a wooden straightedge that makes it a superior tool. It helps us to feel rather than just see when a board is true. More

# *Euclid's Notes*

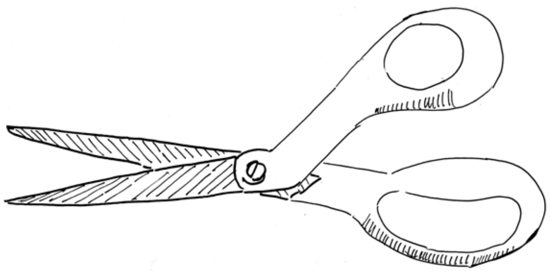

***Fig. 2.2*** *Even a lowly pair of scissors has a mountain of background instructions behind it.*

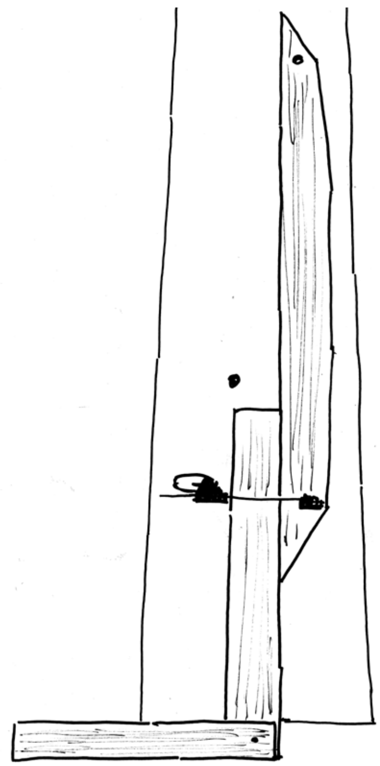

***Fig. 2.3*** *Almost every build we are going to execute uses extended lines to dial in perfection. We extend the lines from our square with a straightedge. That's why the straightedge is the first and most important tool.*

## The Power of a Self-proving Line

Pick up any object in your house made in a factory. It could be something as simple as a pair of scissors.

Obviously, you are looking at some metal blades and possibly plastic grips. If sharp and working properly, the scissors makes clean effortless cuts. But underneath the shiny metal and clean cuts is a long list of engineering specs and tolerances used to transform some molten steel into the working tool in your hand. Tolerances spell out the important parts to make it function. For example the thickness of the blades may be 1/8" plus or minus .002". This plus or minus business can vary a great amount depending on whether it's a tiny shaft driving the shutter on an expensive camera or the diameter of wooden power poles used to string utility lines. One might be plus or minus in millionths of an inch, and the other might be simply plus or minus an inch. What they have in common is that they both have an ideal size but it's possible to be minus or plus and still be OK.

In geometry, there are a couple of unique situations that fly in the face of this. Since the first human drew a straight line or used a string to scribe a circle, we've been chasing perfect flatness (or straightness) and a perfect circle. What's unique about this is there is no such thing as a flat surface plus or minus and no such thing as a circle plus or minus. They are both standards of perfection you can only approach from one side. In other words, you can create a very flat surface, something on the plus side of a tolerance, but there is no minus side. You can't make something more flat than dead flat. In fact, this search to achieve the perfect circle and the perfect flatness is something industry spends billions on trying to achieve. It means engines that are more powerful and fuel-efficient, and telescopes that can see farther into space.

But back to our straightedges and layout tools, most of which rely on flat surfaces and straight lines. The beauty of this perfect thing we are chasing is that the thing itself can help us sneak up on perfection. Take a straight stick and trace a line from its edge. Flip the stick and trace a second line close to the first. Those two mirror-image lines point out how far the stick is from perfection. The same goes for when we are dialing in a square. We extend the square blade with straight lines out into space with a long straightedge then flip the square and draw a mirror image set of lines, Fig. 2.3.

Those extended straight lines show us how far we are from true. This self-proving property is why our ancestors were able to reach astounding levels of perfection in architecture and shipbuilding with nothing more than a few strings and simple tools.

about that at the end of this chapter.

We are going to build three straightedges with different lengths: short, medium and long. Lengths are arbitrary but it's handy to have one that's as long as your arm, another as long as your forearm, and a shorty as long as your foot. Moving forward, the long straightedge will play a key role in testing and proving all our other tools. In addition, we use these tools to verify that the soles of our planes are flat. A good straightedge stands at the base of everything we do at the workbench.

### Burn the Heretic

There's another practical reason why a straightedge is important, but first, a confession. My workbench top is not flat. Before you report me to the workbench police, consider this: How many antique workbenches have you seen in the wild that have dead-flat tops? At best they might have a dished-out spot where much of the work took place; at worst they look like badly weathered driftwood washed up on the shore. Nothing like we've come to expect today to create good work, yet they taunt us in all their glorious dumpiness. In a perfect world we'd all prefer a worksurface as flat as a granite block. In my case, my workbench started out flat when I built it 20 years ago. That original pristine worksurface has settled and moved and gotten used and abused over two decades of work. Now it looks more like something that survived a battle, with scars from saw blades, knives and drill bits. It has a working area that's "flattish" if you take your glasses off and don't look too closely. I can hear you saying "why don't you take a day and flatten it?" I admit, it's been on my to-do list for the last 10 years. It doesn't rise to the top of my list because the flatness and accuracy of my work is a function of my bench planes and my straightedges. A good straightedge can make up for some of the shortcomings in a workbench just like a truly sharp iron can make up for flaws in a handplane. (Oops, did I just utter another blasphemy?) I've built cabinets with piston-fit drawers on this less-than-flat workbench. I can even prep boards on a picnic table in the backyard and get good results with the aid of straightedge. A good straightedge is small and portable, and allows you to transport your skill and its "truth" anywhere you go. It gave artisans in the past the freedom to pack their kit of tools into a basket and hoist it over their shoulder on a stick. Finally, a straightedge is much easier to test and true up than to flatten and true a benchtop the size of a small aircraft carrier. I hereby give you absolution for the sin of owning a workbench with a less-than-perfect top. Just so long as you build a set of straightedges and learn how to use them.

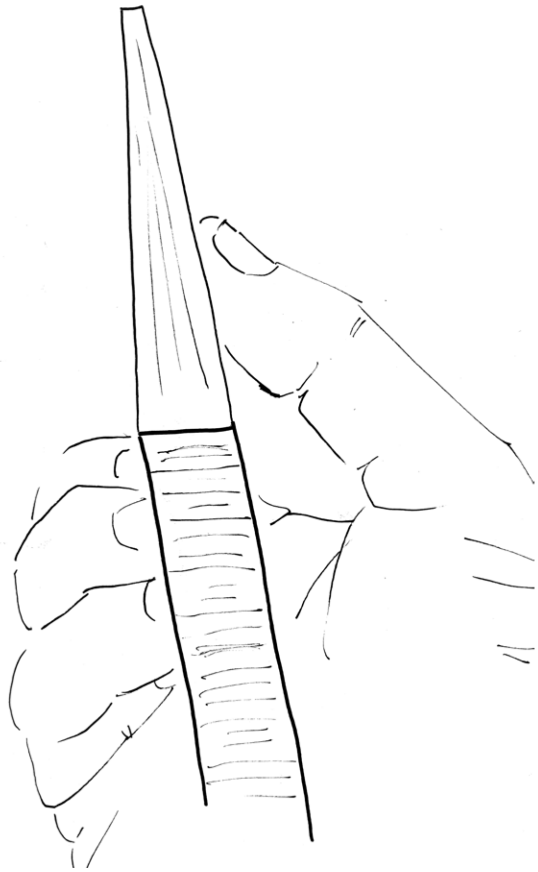

***Fig. 2.4*** *Your eye has an innate ability to detect a straight line by sight alone. Good enough to sort sheep from goats.*

### Getting Started

We start this build with two identical hardwood blanks that are approximately 3' long x 3" high x 3/8" thick. Refer to Chapter 1 for details about

# Euclid's Notes

## How Good is Good Enough?

The idea of wooden layout tools in a modern setting may seem out of place, especially when antique examples of wooden tools are often a shadow of their former selves – old folding boxwood rulers with hinges holding on by a thread or wooden handplanes with broken totes and a mouth wide open. They don't inspire confidence, so it begs the question: Can user-made wooden tools meet the demands of a modern woodshop?

Today we put numbers on everything. Yet, these layout tools are from a time when "good enough" was simply called "true." In furniture making, true means a door closes smoothly or a drawer glides freely. It means joinery fits together tightly without having to resort to clamps to pull them closed. Yet, if we put a number on the "truth" of these tools, are they good enough?

Turns out the methods to fine-tune these tools relies on ideas that are used today in cutting-edge technology. Think about a dial indicator, for example, Fig. 2.5. It's a device that uses a series of gears to exaggerate a tiny amount of movement into a reading we can see on the dial (or digital readout).

This mechanical exaggeration lets us measure beyond what the naked eye can see.

In our tool builds we'll use a long straightedge in much the same way to exaggerate by extending lines out into space. The farther out we go the easier it is to detect errors. Sort of like shooting a rocket to the moon. A small error can cause a huge miss if extended over long distances. Using this long straightedge method and fine pencil lines, it's possible to tune these tools to an amazing high level. How high? It's possible to get winding sticks parallel, end to end, within one thousandth of an inch. Pretty good with just a handplane and simple geometry.

What about the squareness of a hand-made wooden try square? After final tuning, we measured the error on our extended square lines out in space and used trigonometry to put a number on it. We fell within 30 seconds of a true right angle (angles are divided up into degrees, minutes and seconds). To put that into perspective, consider a corner for a building, let's say a new workshop that's 18' long. If our angle is 30 seconds off, our building would be out of square by 1/32". Good enough? Translated into furniture building, it means a large case piece like a chest of drawers with a right-angle corner off by 30 seconds would be off by the thickness of a human hair at the opposite corner. Good enough?

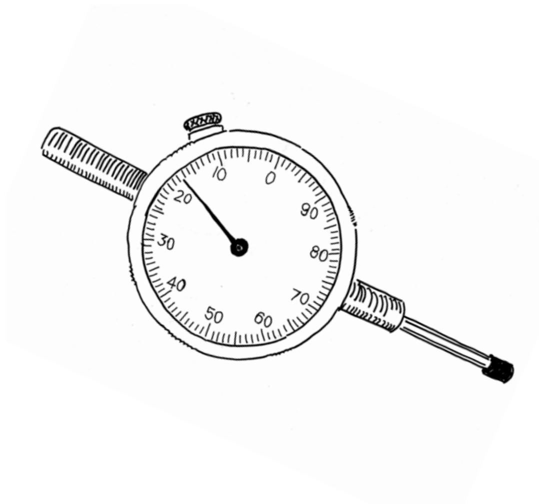


***Fig. 2.5*** *Many of our leaps in technology have been made possible by the ability to measure things with greater precision, whether it be time, distance or weight.*

We also examined traditional methods for truing flat surfaces. Two simple techniques that we take for granted are rocking parts back and forth (teeter tottering) against each other, and holding parts together and using light to check for straightness. We begin by using the teeter totter method to locate high spots. It's a rough measurement and points to the obvious flaws. Just how large of a high spot can you feel just through your fingertips? We experimented with precision steel feeler stock, and it turns out you can detect a high spot that's just .002" (two thousandths of an inch). Now that might not sound like much; it's about half the thickness of a human hair. But it's actually a large amount even in the world of woodworking. If you execute a joint and it has a .002" gap it would show to your eye as a visible gap. So to take it to a higher level, hold the parts up to the light to detect high or low spots. With a little patience and a sharp handplane you can tweak a pair of straightedge blanks so that the slightest twinkling of light passes between them. That slight twinkle is a gap that's as small as .0005" (one half of one thousandths of an inch). We can reach high levels of true that can meet and exceed "good enough" in the world of woodworking. Don't kid yourself and think our ancestors didn't have the ability to achieve this with their tools. They might not have put a number on it, but they had the geometry to get there.

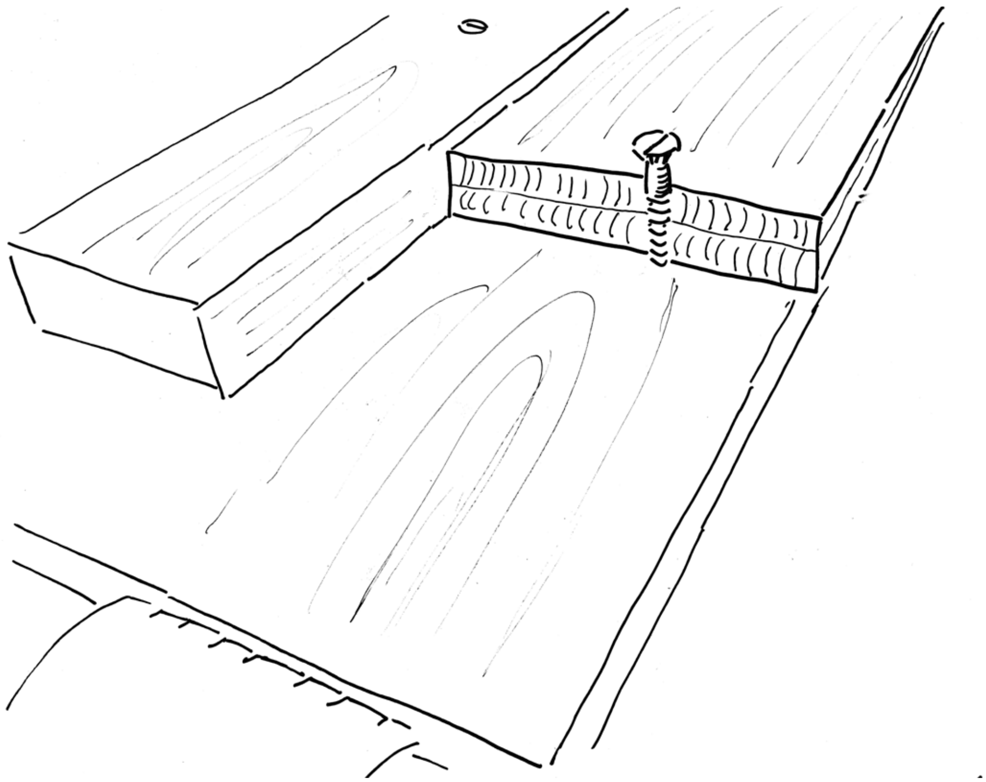

***Fig. 2.6*** *Shoot blanks in pairs and make sure you orient them the same way each time you place them back in the shooting board setup.*

stock selection and rough prep. Both these blanks will be processed together until we've successfully dialed in that flawless edge we are after. In fact, we need them identical because one is going to prove the other. Once we confirm that they are flawless, we'll crosscut the second blank into our short and medium straightedges.

Once the blanks acclimate to your shop, there is a bit more prep to do before we work on those edges. There is an important truth to keep in mind right away. Just like building a cabinet or a table, some parts are critical and require our focus while other surfaces don't require the same level of precision. On each of these tool builds there are critical surfaces that must be spot on. We devote our skill and effort to making those as perfect as we can. Secondary surfaces don't require the same level of attention so we may get by with just eyeballing it. One example of a secondary property on our straightedges is the straightness side to side as we look down its length. We want it to be straight but it's good enough if we can eyeball down its length and it looks arrow straight, Fig. 2.4.

No need to do back flips. If one or both of your blanks has a slight curve or bump down its length, touch up those high spots with a handplane until it looks good to your eye. Once you have them both flat to your eye go ahead and plane them to their final thickness of 5/16". From this point pair the blanks together for shooting the long edges. You can secure your sacrificial board to the benchtop and drive a screw in one end as a stop to hold the blanks for shooting, Fig. 2.6.

Pairing these blanks together means you are shooting an edge that's 5/8" thick. That's about the thickest edge you can successfully shoot on a long-grain shooting board. We also want them thin enough that they have a little flex side to side while in use. We'll discuss that in more detail at the end of the chapter.

## Setup for Long-grain Shooting

Most of these tool builds require shooting with a handplane. You'll want to use the longest handplane available. For metal planes, this would be a No. 8 or a No. 7 (using Stanley's numbering system); in a pinch you can get by with a No. 6. In wooden bench planes it would be a jointer 24" to 30" long. At its simplest, a handplane is nothing more than a block of metal or wood that gives us precise control over the cutting action of the blade. The iron in a handplane is nothing more than a wide chisel. A shooting board is a fixture that takes out some of the variables in handplaning. It eliminates the side-to-side tilt of the plane when working thin edges. Because we are trying to create a flawless surface on the narrow long edge of our blanks, we need all the help we can get. In this case we will use our sacrificial board as a long-grain shooting board. Grab a batten out of your scrap box that's a bit longer than your blanks. Secure it to the sacrificial board with a few screws so that the blanks overhang the long edge of the board by 1/4" or so. Secure the sacrificial board to the bench by snugging it tight against a planing stop on one end and with a holdfast on the other. Leave enough space on the benchtop so that you can lay your handplane on its side and push it down the entire length of the blanks, Fig. 2.7.

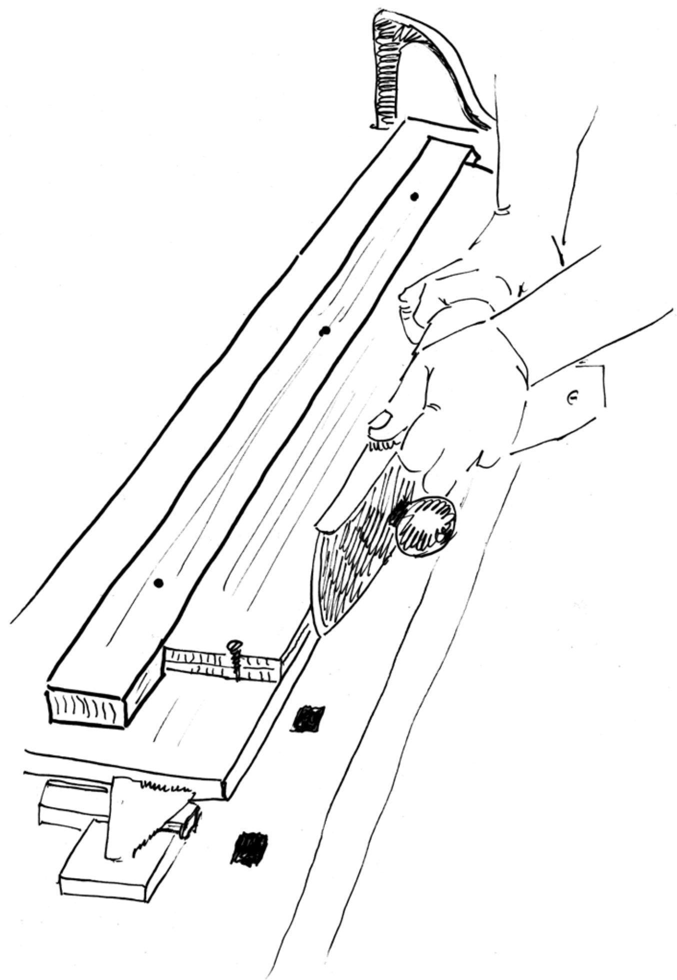

***Fig. 2.7*** *This long-grain shooting technique uses the geometry built into the handplane to sneak up on the perfect straight edge.*

This method of long-grain shooting differs from cross-grain shooting. When working cross grain, the shooting board itself acts as a fence to control the action of the plane. In long-grain shooting the handplane actually floats along the edge of the workpiece. The sole of the handplane creates a mirror image of itself on the edge of the work. I made that sound too easy. In reality, it takes a bit of fussing and proving to get to our destination, but we will achieve that mirror image of a truly flat straight edge.

Before we begin shooting, mark a reference face and edge on each blank with a pencil, and also mark which blank sits on top. It doesn't matter how you decide to pair them up for shooting, but once you begin the process, you need to place them back in the shooting board in the same orientation every time. The final prep step in our shooting board is to verify we are shooting an edge that's at a right angle to our face. This is another case of a secondary and not-so-critical property. It's OK to eyeball it. Just shoot one long edge on one blank and stand it up on edge on your workbench. Get your eye down even with the workbench top and judge whether the blank looks like it's standing vertically. It's sort of the same way you judge whether a picture frame on a wall is level. If it looks like it's standing straight at attention, it's good enough, Fig. 2.8.

If it's off, you can either place a paper shim under the blanks on the shooting board or slightly tilt the blade on the handplane. Later, when we build our try squares, the edges become critical and we'll dial in the edges of those blanks to a high

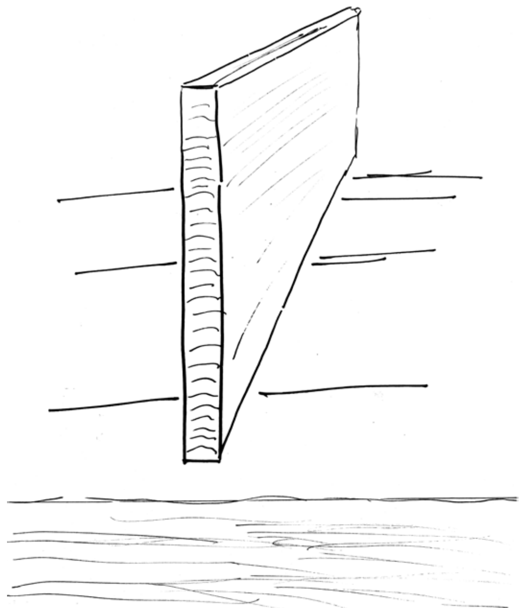

***Fig. 2.8*** *Is it plumb? This is another example of a secondary property we can eyeball for now. Future builds, such as the try squares, will be less forgiving.*

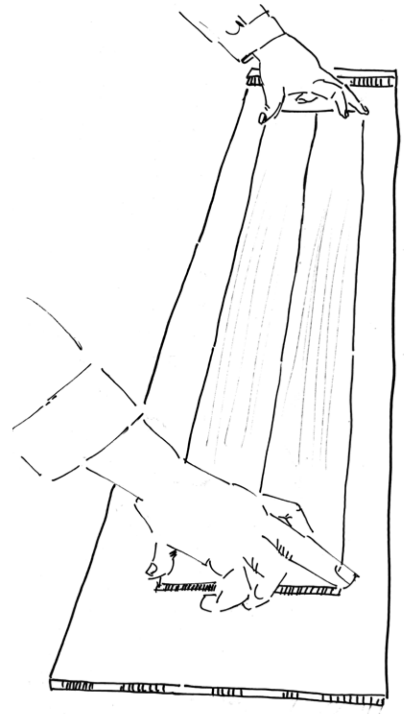

***Fig. 2.9*** *Testing for high spots by feel helps to get in the ballpark. As you creep up on a true edge, it also gives you a sense of how your correction passes with the plane are progressing.*

level of squareness. But for our straightedges, if the blanks stand up at attention on the workbench, we're good to go.

## Dial in our Straightedges

Now pair the blanks together on your shooting board and take a series of light passes until both edges are cleaned up along their entire length. You want to see two full-width continuous shavings. The two edges should feel like one surface when you pass your finger over them. Pull them out and see where we are and how straight they are. Bookmatch the two reference edges and lay them flat on your bench or proving board. After this first cleanup, the edges are usually convex along their length. You probably will be able to teeter totter them by lightly pressing them together at each end, Fig. 2.9.

The two inner edges may look surprisingly convex, but you have to remember that by shooting them together and bookmatching the pair, you are seeing them as a mirror image of each other and doubling any error. Rock the blanks back and forth and note where the high spot is centered.

## Stop Cuts

Place the blanks back in the shooting board in the same orientation you started with. Now we'll do a series of stop cuts to shave off the convex hump, Fig. 2.10.

Place the plane an inch or so on one side of the high spot and make a pass, pulling the plane away on the far side of the high spot. Then take a second pass, this time starting the plane an inch or two back and lifting it away an inch or two farther along on the far end. If the high spot is in the center you can make a series of these stop cuts until

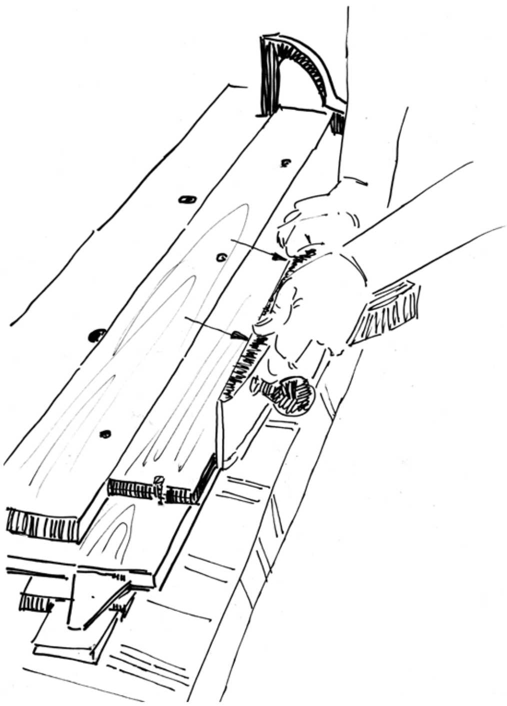

*Fig. 2.10 A stop cut is a localized correction that begins and ends on either side of a high spot.*

the start and stop is just short of the far ends of the blanks. Once you've completed these stop cuts, take one or two long plane passes along the entire length until once again you get that continuous shaving from both blanks. You may have successfully eliminated the high spot or, more likely, you've shaved a good amount from it. Remove the blanks and bookmatch them to test if they still rock back and forth. Worst case, the convex condition is better but still needs to be corrected. If it persists, note the location of the high spot again and execute another series of stop cuts. It may take several attempts, but eventually the high spots are removed enough that the two blanks will not rock against each other.

## Sneaking up on Perfect

Now we take them to another level of flatness. With the blanks still bookmatched, hold them up to a light to see if you can see daylight. It's likely the edges will now be slightly concave, touching at the ends but showing a narrow beam of light down the middle. If that's the case, place them back in the shooting board and make one light stop cut on one end only, followed by a full-length pass. You are getting close to perfection so your corrections must be slight. It's easy to overdo it and push the pieces back to a convex condition. You might want to back off the depth of cut on your plane to a finer shaving. Go back and forth making correcting cuts, always checking to see if the blanks teeter totter and checking with a bright light. One sign that you are getting close to a true edge: The light dimly showing between the blanks might begin to jump to multiple spots from one correction to the next. This means that instead of correcting one large high spot or hollow you are correcting multiple tiny almost microscopic high spots or hollows. You will also note that when you first held it up to the light, you could see a fairly intense beam of light making its way to your eye. As the blanks creep up on perfection, the light may still show through in a spot or two but it's just a twinkling of light scattered along the length. When you reach that state, your blanks are true.

## Finishing Touches

The finesse part is done; now to the fun part. Take your second blank and divide its length into three equal parts. Crosscut at the one-third mark to produce your medium and short straightedges, Fig. 2.11. Traditionally, these tools were given some sort of profile on the top (non-working) edge. Artisans did this for two reasons. First, to identify it as a tool so no one would mistake it for a random chunk of wood. Second, it's thought that increasing the amount of exposed end grain helps the tool remain stable. You can accomplish this by either tapering the tool toward the ends or adding some sort of curve, Fig. 2.12.

Finally mark and drill a 5/8"-diameter hole approximately 4" from one end on the long straightedge. This hole has a dual purpose. Use the hole to hang the tool from a peg, and more importantly as a way to secure the straightedge to other

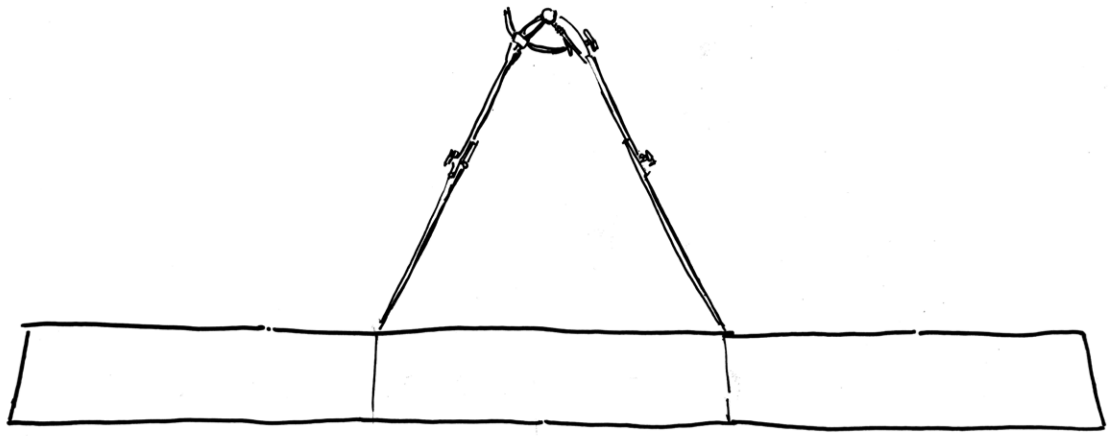

***Fig. 2.11*** *Step it off into three parts and use one third for the small straightedge and the remaining two thirds for the medium tool.*

objects with a clamp. This long straightedge will become your primary tool for dialing in the tools that follow. On the two shorter straightedges you can drill a smaller hole that's just used for hanging on a peg. Finally, give the tools a couple of coats of your favorite finish. I like to use an oil-varnish mix or just good old shellac.

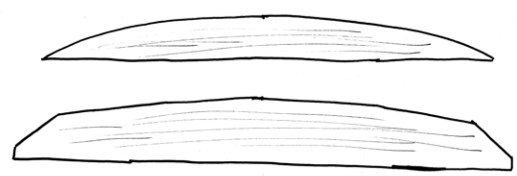

***Fig. 2.12*** *Profiles on the top let you know instantly which is the working edge.*

## Using Your Straightedges

We used light to prove that critical edge when building our tools, but in practice at the workbench, this tool is used more by feel than anything else. This was no doubt a distinct advantage in pre-industrial workshops with poor lighting conditions. When joining the long edges of boards for glue-ups we want those edges straight and true. This is where our wooden straightedge shines. As we check our boards with the straightedge it can give us three different kinds of feedback: teeter totter, bow flex or squeegee.

First, check for high spots feeling if the straightedge teeter totters over a hump. Even with your eyes closed you can rock the tool and feel the severity and the location of any high spot. You can address those defects with stop cuts using the same methods we used to true our straightedge. You also may detect a concave surface. If the surface is dished or concave, then the ends of the straight-

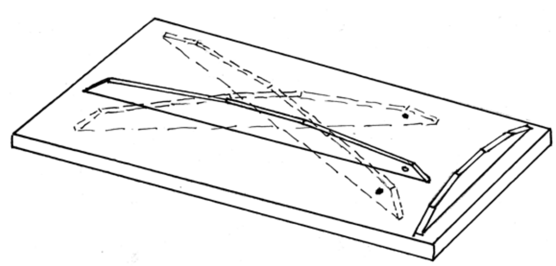

***Fig. 2.13*** *A good straightedge takes the guesswork out of flattening lumber. The power of a straight line in a wooden tool helps us to true the surface.*

edge will touch but the middle of the tool will float above the surface. You can verify that it's dished by flexing the straightedge back and forth laterally. If the board is dished out, you can feel the straightedge float over the area where it's not contacting the board; you'll feel it touching on the ends but not in the middle. This ability to flex side to side slightly to feel the edge is one of the advantages a wooden straightedge has over a stiff metal version. You can remove this hollow by making a stop cut that runs off just one end of the board, followed by a full-length pass. When your edge reaches flatness, you can feel the straightedge touch along its entire length like a squeegee. Finally, if the edge is true, the tool will make a solid click when you set the straightedge down on the board and there will be noticeably more friction when you slide it along the edge. Once you've jointed a few boards and used a straightedge to prove your work, you'll become familiar with this solid-sounding click when the tool engages a true edge.

These same methods apply to flattening the faces of boards. The only difference is that a wide face of a board requires that we check for true in a diagonal pattern, Fig. 2.13. If you look closely at this checking of diagonals, you see the pattern is actually a triangle. Geometry teaches us that if each side of the triangle is true, then we have defined a plane.

When flattening rough lumber, make a quick check on the length and width, and across diagonals. I always attack first whichever area seems to be the most out of flat. Once the worst spots are tamed, it makes truing a board much simpler. Often it's just a matter of cleaning up the remaining saw marks. You can true a board dead flat using only a handplane and a straightedge. However, a common fault we see in prepping stock is boards with twist or wind along their length. A straightedge will detect twist, but winding sticks are quick to help us see because they "magnify" the width of the boards they are placed on. Used in tandem with a straightedge they help us produce dead flat surfaces. So now let's build a set of winding sticks.