Joining Legs to Aprons

The size and location of mortise-and-tenon joints affect their strength

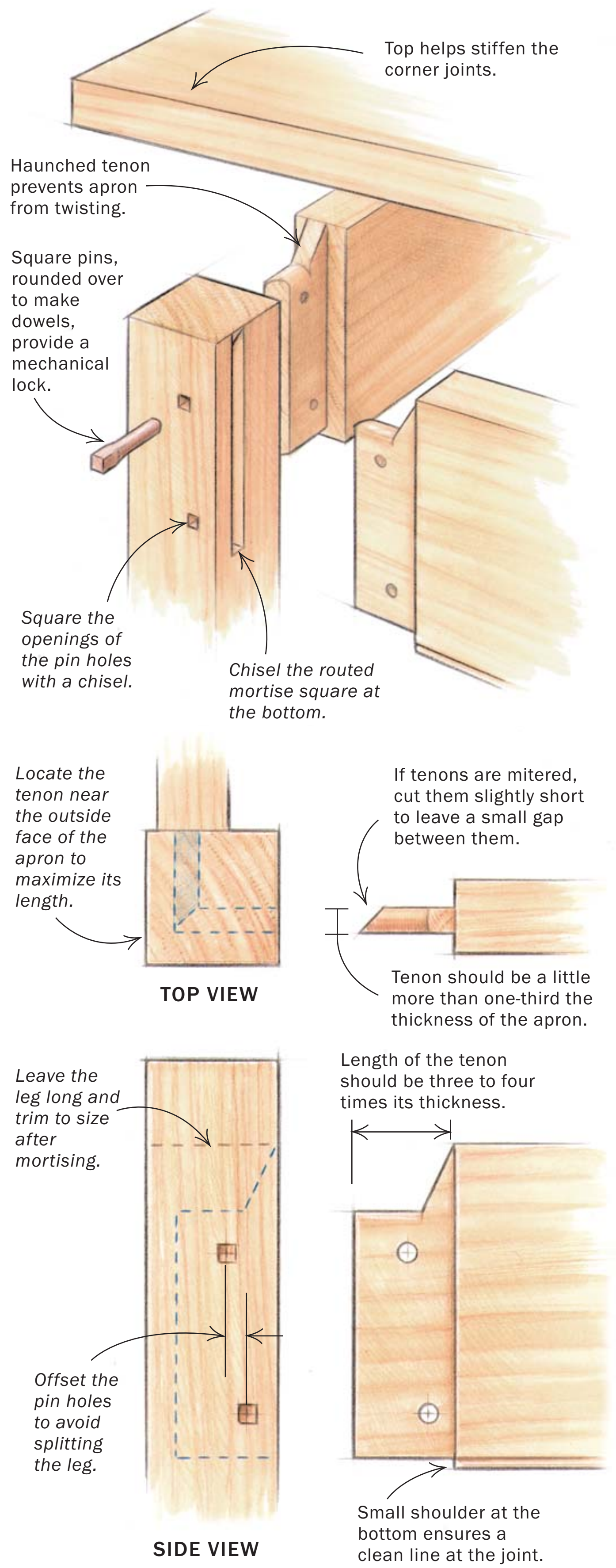
BY GARRETT HACK

The life of a table is often not easy. Legs get kicked; the table gets pushed and pulled across uneven floors, leaned against and sometimes even sat upon. To make matters worse, the very nature of wood adds to the stress. As the tabletop shrinks and swells with seasonal changes, the movement works against the integrity of the table's structure. Where is all this stress felt? It's the leg-to-apron joint that holds a table together and gives it rigidity. When that joint fails, the table falls apart.

Leg-to-apron joints must withstand three different kinds of stress. One is shear—a vertical load directly above a joint, such as when someone sits on the corner of a table. Leaning heavily on the top of a table midpoint above the apron causes the joints to undergo a bending stress trying to lever them apart. Shoving the table sideways or bumping against a leg gives the joints a mixture of twisting forces. Also, as a tabletop that is

Photo, this page: Michael Pekovich

A STURDY LEG-TO-APRON JOINT



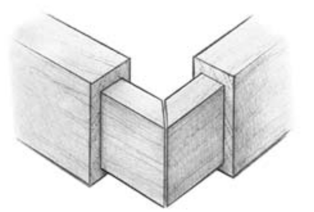
fastened too tightly to the apron expands or shrinks, it can try to twist the joints. The best defense against these stresses is a well-designed, tight-fitting mortise-and-tenon joint that locks apron to leg. The mortise and tenon is not only a good joint for tables, but the same principles also apply to designing joints for cabinet doors and chairs.

Size the tenon

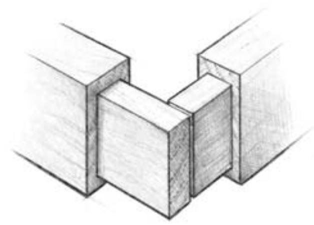
When deciding on the sizes of joinery components, the key is to attain a workable balance. Too large a mortise, and you risk weakening the leg; too skimpy a tenon, and you lose glue and mechanical strength. The ideal joint would have a large tenon with lots of glue surface, it would be the full height of the apron to best resist twisting, and the mortise would be cut from the center of the width of the leg for maximum strength. But it's not just the sizes of the mortise and tenon that you have to balance: The shoulders on both sides of the tenon must be substantial enough to do their work. They butt against the leg and resist bending and twisting forces trying to lever apart the joint. A good rule of thumb is to size the tenon thickness a little more than one-third the thickness of the apron.

While the one-third rule is a good general guide to follow, sometimes it's better to make exceptions. If I'm building a table out of butternut or a similar softwood, with aprons only ¾ in. thick, I make the tenons at least 5/16 in., maybe even ⅜ in. thick. Any smaller and a sharp bump to the leg might snap the tenon right off. Because you rarely see the thickness of an apron, one good design strategy is to make it thicker—⅞ in. or 1 in. will provide larger, stronger shoulders.

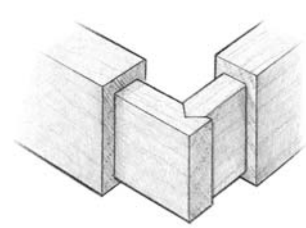
WHERE TENONS MEET



Miter them, but skip the glue on the very ends. Hack does not bother to glue the end grain of the miters, reasoning that the bond is unreliable.



Butt them together if you have tenons of unequal width.



Bird's-mouth joints often are found in Asian furniture. This design offers additional strength because the tenons interlock.

Maximize tenon length— Two other aspects of the tenon affect the joint strength. One is the amount of long-grain glue surface on the cheeks of the tenon; the other is the length of the tenon, which is affected by where the mortise is cut on the leg. Naturally, a longer tenon has more glue surface and provides more mechanical strength to the joint. As a general rule, the longer the tenon, the better, assuming the leg can accommodate it. A tenon length that's three to four times its thickness is quite adequate. When laying out the size and placement of tenons, a full-scale, top-view drawing will help you understand the orientation and relationship of all of the parts.

One engineering principle states that the stress on any part is

Drawings: Bob La Pointe

BEGIN BY ROUTING THE MORTISE

Routers are quick and accurate. *Although his mortises often require additional handwork, Hack cuts most of them with a machine he made from scrap parts. It has a router mounted horizontally to a sliding table that can be adjusted in three dimensions.*

least along the centerline or neutral axis. A centered mortise or tenon is stronger because it has all of that wood on both sides bolstering it. For this reason, I prefer to have a shoulder on both sides of a tenon (rather than one side only) to better resist bending stresses from either direction. Even a small shoulder will cover any bruised edges on the mortise that result from cutting the joint.

A centered mortise might be ideal, but the farther to the outside of the leg you position a mortise, the longer the respective tenon will be. Too far out and the cheek of the mortise is more vulnerable to splitting under stress. Deciding on the exact placement is a judgment call that varies with each project. I have butted tenons together inside the leg, but doing so makes one tenon shorter than the other. Butting tenons together works when joining aprons of unequal width, where the wider tenon can be the shorter one because it has extra glue surface. I've also cut half of each tenon long and the other half short and locked one tenon into another with a bird's-mouth cut as Chinese furniture makers sometimes do. But I

Cut the bottom square. *Use chisels to clean out the bottom corners of each mortise as an index to seat the tenons later on.*

Scribe lines for the haunch. *A marking gauge extends the lines of the existing mortise that indicate where to cut the angled haunch.*

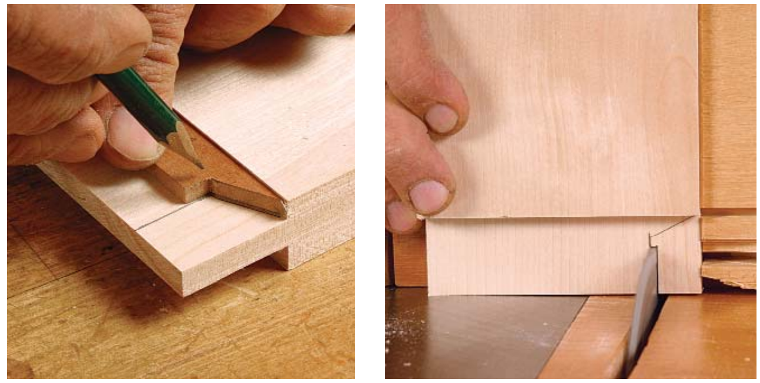
Chisel the haunch by hand. *There is no other practical way to cut the slope for this shape. Hack leaves the table legs long to keep them from splitting along the top edge while he chisels the haunch.*

Check the results using a small shopmade template. *The template makes it easy to check your progress as you cut the angled mortise.*

Photos, except where noted: William Duckworth

Tenons on the tablesaw. *With the workpiece firmly clamped against this tenoning jig, the tablesaw can cut tenons cleanly and accurately.*

FIT THE TENON TO THE MORTISE



Trim tenons to size and shape. *A matching template made to the negative shape of the one used to check mortises shows where to cut the angled haunch on the tenons. The first cut is made with a stop block on the miter gauge.*

prefer to miter the tenons within the joint without actually joining them. This is easy to do, and it can add 15% to 20% more glue surface and length to the tenons. If I must incorporate drawers into an apron, the size of the rail usually calls for a completely different tenon design (see the story on the facing page).

Shorten the tenon height with a haunch

A tenon the full height of the apron affords lots of glue surface and strength against bending and twisting forces. But there's a trade-off: A full-height mortise weakens the leg, especially if there are two mortises at the corner of the leg. With the top of the mortise open, any serious stress on the apron can more easily split the top of the leg. So the strength of such a joint relies almost entirely on the glue bond because the mechanical strength is compromised.

A simple solution, and one I prefer, is to shorten the tenon considerably for the top ¾ in. to 1 in. or so and cut an angled haunch. With this design detail, what little glue surface you lose is balanced against having a much stronger mortise.

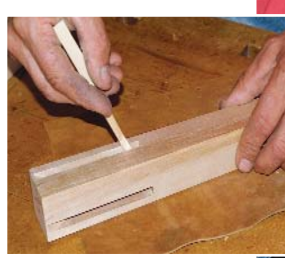
I cut the haunch on the tenon by hand with a dovetail saw and then clean it up with a chisel. For speed and accuracy, I lay a wooden template on the tenon to mark out the haunch and use another one made as the mirror image of that pattern to size the mortise at the haunch end. To cut the mortise for the haunch, I first mark out the sides aligned with the mortise with a mortise gauge, chop the waste, and refine it using the template and a chisel. Because I cut many of my mortises with a router bit, I keep the top of the mortise below the haunch round for a small measure of added strength. Also, a small ⅛-in. shoulder at the bottom of the apron tenon will hide any small inaccuracies in cutting the mortise, and it allows for vertical alignment when the table is assembled.

Adjust the fit and use glue sparingly

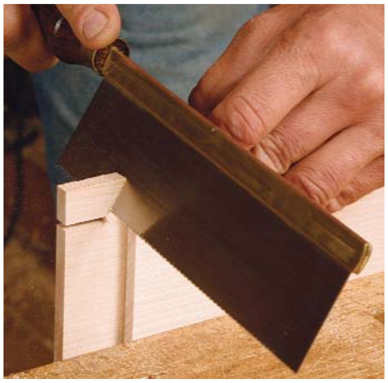
The best design and the strongest glue won't overcome a joint with carelessly fit shoulders or a sloppy fit between tenon and mortise. Even when I cut these joints with accurate machine setups, I still often find it necessary to improve the fit with a few passes of a shoulder plane or a chisel. I want the shoulders to fit tightly over their entire surface and the tenon to slide into place with a minimum of force for a good glue bond.

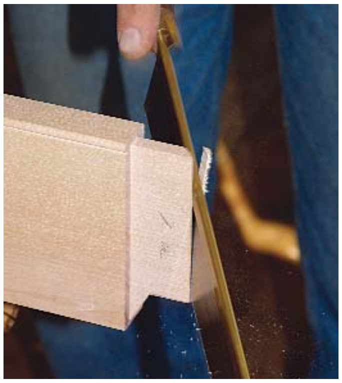
Part of the long-term strength of the joint is the snugness of the fit, or what I call its mechanical strength. Glue adds strength, but how long does a glue bond last? By its very nature a mortise-and-

GLUE AND PIN THE JOINT



You don't need a lot of glue. *With snugly fitting mortise-and-tenon joints, a thin layer of yellow glue spread evenly is all you need for a good bond.*





This handwork is fast and accurate enough. *A dovetail saw makes quick work of trimming the angled haunch and mitering the ends of the tenons.*

tenon joint has wood fibers running cross-grain to one another, which weakens the bond. Flexible modern glues can accommodate some of this movement.

Before gluing, I always dry-fit and clamp the parts together to discover any problems that may arise while there's still time to solve them. To ease assembly, I chamfer the ends of each tenon. Glue-ups can be stressful, but it is worth taking care to place the glue so as to avoid drips and oozing joints that would be a headache to clean up later. With a thin stick about half the width of an ice-cream stick, I apply a light amount of glue into the mortise and on both tenon cheeks. The flat edge of the stick is perfect to squeeze out the glue in a thin, even layer. Another trick that works well is to cut a light chamfer around the mortise to contain any squeeze-out. Ideally, the joint should slip together under light clamping pressure.

For large tables and for peace of mind, I often pin the leg-to-apron joints. I use a hard, straight-grained wood such as rosewood, ebony or maple for the pins. A contrasting wood can add a pleasing visual detail, and two small pins are stronger than one large one. Most often, I drill holes for the pins after gluing and drive them in either from the outside or inside of the leg, depending on whether or not I want them to show. □

Garrett Hack is a contributing editor.

Pins are an insurance policy. *Small hardwood pins will hold the joint tightly, even if the glue fails. Hack leaves the outside end of the pin square and holds it with a wrench as he hammers it home.*

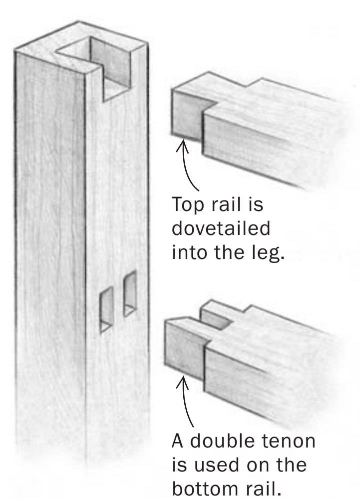
Unique solutions for different design problems

Not all aprons call for a single haunched tenon mortised into the leg. The problems presented by some leg-to-apron joints require uncommon solutions. One example is an apron that incorporates drawers into the design, such as those you'd find on a desk or some kitchen tables.

Aprons with drawers often have a narrow rail under the drawers that joins into the leg, and such rails have tenons that can't be any higher than the height of the rail, nor probably any longer than the other tenons joining into the leg. Still, these tenons are doing quite a bit of structural work. The solution is to make double tenons parallel to one another, which doubles the glue surface and provides good resistance to twisting and bending forces (see the drawing above).

TWO TENONS ARE BETTER THAN ONE

Narrow rails under drawers need beefier tenons. Doubling them up maximizes the strength you can get from such a small piece of wood.



Extrawide aprons offer another example of design problems that require different solutions (see the drawing below). Wood movement over such a wide apron is, of course, a consideration. But more than that, another real concern is that a long mortise can weaken the leg. The long sides of the mortise can flex easily, and the apron-to-leg joint loses vital mechanical strength. The solution is simply two mortises with a groove for a stub tenon between them and an angled haunch at the top. The two mortises still have plenty of glue surface and lock the apron along its full height. If wood movement is a concern, glue only the top part of the tenon, then pin the lower part with elongated holes, as you would on a breadboard end, so that the apron can move slightly. Also, cut the bottom mortise a little long to accommodate the anticipated movement.

WIDE APRONS NEED A BREAK

A mortise longer than 4 in. or so can threaten the structural integrity of a leg. A break in the middle for a haunched tenon alleviates that problem but still keeps the apron from twisting.