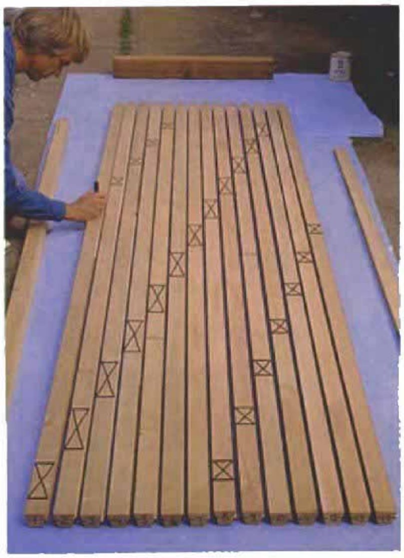
Cantilevered treads. **The author's spiral staircase rises on treads mounted atop ribs that extend through a hollow column. The treads wind their way from an enlarged first tread to a second-level landing that is borne primarily by ledgers affixed to the wall.**

A Freestanding Spiral Stair

Using stock lumber and common shop tools to build an elegant circular staircase

by Steven M. White



Coopered column. **The author marks the entry and exit mortises on the collated staves prior to precutting the mortises.**

Just a pinch. **To keep the staves intact during glue-up, White does not cut the mortises all the way through.**

Column glue-up. **Subassemblies of glued-up staves are clamped together so that their bottoms are in alignment.**

As a woodworker, I have always liked curved staircases because they combine function with graceful, sculptural beauty. A spiral stair built around a central column is the simplest version of a curved staircase, but it's still a challenge to build. In this article I'll talk about a spiral stair that I've built for several clients and the straightforward techniques I've developed for fabricating its parts with common shop tools. For the twists involved in laying out a spiral stair, see the sidebar on p. 90.

Lightening the visual load–To my eye, most pole-supported spiral stairs are aesthetically flawed because they lack a graceful balustrade. Their handrails and balusters are often used as part of the structural support of the stair, and as a result they can look pretty clunky. To avoid this problem, my stair transfers the loads from the treads by way of cantilevered ribs that pass through a hollow column. This allows me to border the stair with a delicate row of balusters supporting a sinewy handrail (photo facing page).

Each tread/rib assembly resists three forces: the downward load of a person; twisting due to offset loading on the tread (the fact that a person would step near the front of a tread rather than directly over the rib); and horizontal, or back-and-forth, wiggle.

To resist the downward load, I use a strong, cantilevered rib that passes completely through the column and out the opposite side. Such a design transfers the load from the tread to purely vertical reactions on the column. It also allows the ribs to be revealed as tenons on the side opposite the treads. I put ½-in. chamfers on these tenons, emphasizing their sculptural qualities as they spiral from floor to floor.

For a 36-in. radius stair, I've found that a 2-in. by 6½-in. rib is adequately strong. Because the stresses on a cantilevered beam decrease with distance from the point of cantilever, I taper the ribs for the sake of appearance (top drawing, p. 89).

I also know that a 2-in. by 6½-in. rib will sufficiently resist twisting at its outer end, and that treads made from solid 2x lumber will be strong enough to withstand the offset load. To minimize horizontal wiggle, I rely primarily on the tread itself being drawn tightly against the column with lag screws. In addition, I run the front baluster of each tread through the tread and into the tread below. This interlocks all the treads and further reduces any wiggle.

For the stair featured in this article, I used vertical-grain Douglas fir throughout, which is a strong, attractive and economical wood. Incidentally, I bought unsurfaced stock for the ribs because it's a full 2 in. thick. Then I dressed it myself, netting ribs 1$\frac{13}{16}$ in. thick.

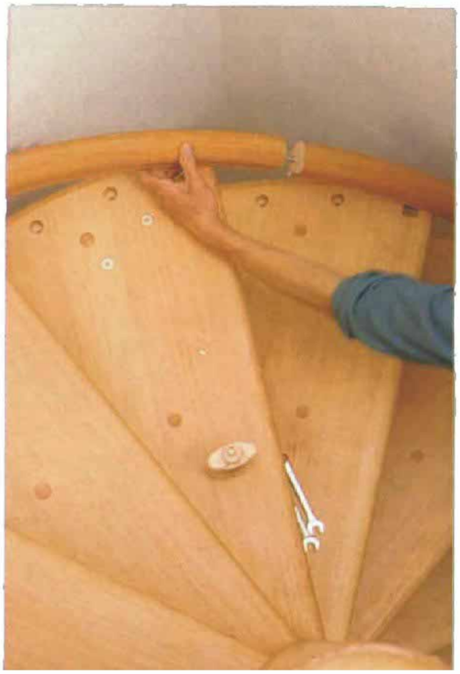
Cylindrical column–The center column is round, with 24 mortises (two for each rib) in a precise spiral. To effect this, I built a 14-sided coopered cylinder in which the width of each stave is the same width as a rib.

First I ripped 9-ft. lengths of 2x6s into 1$\frac{13}{16}$-in. wide staves, beveled inward at 12.86° on both edges. I got that number by dividing 14 into 360° and then dividing the result by 2, I fine-tuned the bevel by first running some scrap lumber and cross-cutting it into 14 sections to see how they fit together. To ensure correct alignment of all the staves during assembly, I cut a ¼-in. wide groove down the center of each beveled edge for plywood splines.

The next step was laying out and cutting the rib mortises. I placed all the staves side by side on a large, flat surface and numbered

Doing the twist. **Stretched across a bending form made of 2x4s on plywood bulkheads that duplicate the radius of the stire, thin laminations of Douglas fir are clamped and glued into a handrail blank.**

Shaping the handrail. **White makes several passes with a custom ogee bit to shape the handrail. The groove in the underside of the rail was cut with a 1-in. straight bit.**



Handrail joint. **Handrail sections are joined with a rail bolt. A hole in the underside of the upper rail allows access to tighten a nut onto the bolt's machine-threaded end.**

Rail return. **At the landing, the handrail engages the wall by way of a curved section cut from a solid piece of stock. Its bolt hole is plugged with a dowel.**

them to avoid any confusion later. On each stave I marked a 6½-in. high mortise for the front side of one rib and a 3-in. high mortise for the protruding tenon of another rib. These mortise locations were laid out sequentially, at 8.156-in. intervals, corresponding to the rise of the stair (top photo, p. 87). I then crosscut each mortise with a power miter saw, being sure to leave a little wood uncut on the backside to keep the stave in one piece (middle photo, p. 87).

Now I was ready to assemble the column. I began by gluing up trios of staves, using pipe clamps to hold them together. I left the alignment splines and glue out of the mortise regions to ease the cleanout still to come. Then I glued up the four sub-assemblies using twisted ropes as clamps (bottom photo, p. 87). Fourteen staves at 1$\frac{13}{16}$-in. width yielded a column diameter of about 8 in.

Once the glue had dried, it was a simple matter to split out the mortise waste with a chisel. The resulting holes, however, were narrower on the inside than on the outside because of the stave being beveled, so I pared out the sides of the mortises with a chisel. I used a test rib to check for a snug, smooth fit through each mortise.

To round the column, I planed down the 14 corners by hand to create a 28-sided cylinder. Then I used my plane and sandpaper to work the assembly into a smooth cylinder.

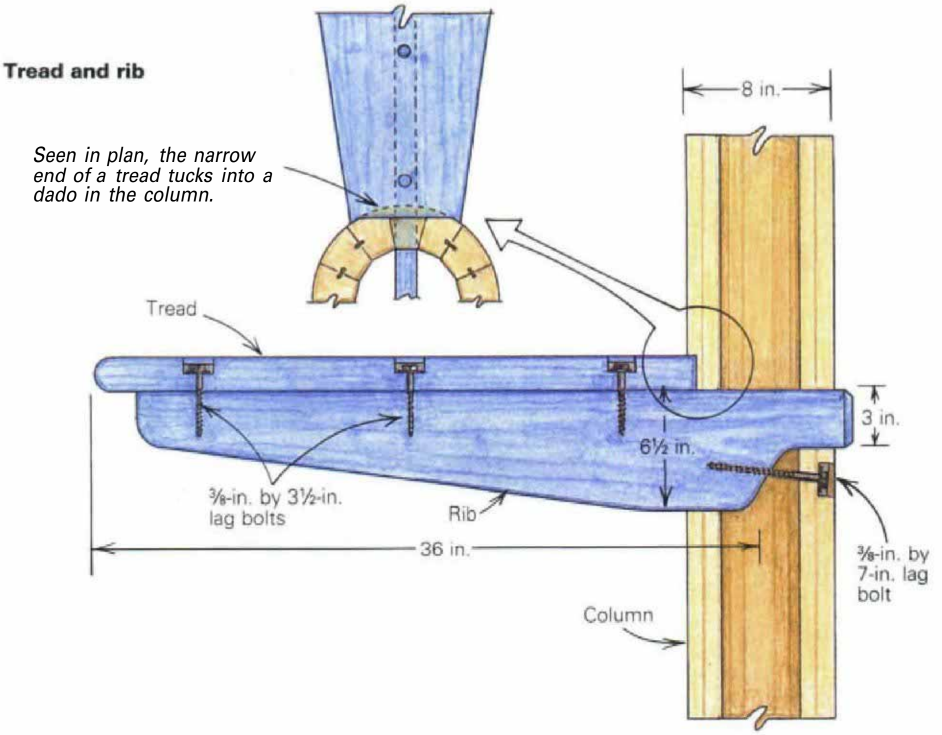
Treads and ribs—I began the tread part of the project with a cardboard template. Each tread is 1/14 of a circle, or 25.71° of arc, and my template started as a simple pie slice at this angle with a 36-in. radius. To this I added 1¾ in. of width to both the front and back edges, to give a generous nosing and to widen the narrow end of the tread. The narrow end of each tread is curved to match the column's face. The curved corners flare into a straight cut that allows the tread to be let into dados cut into the column (large photo, p. 91).

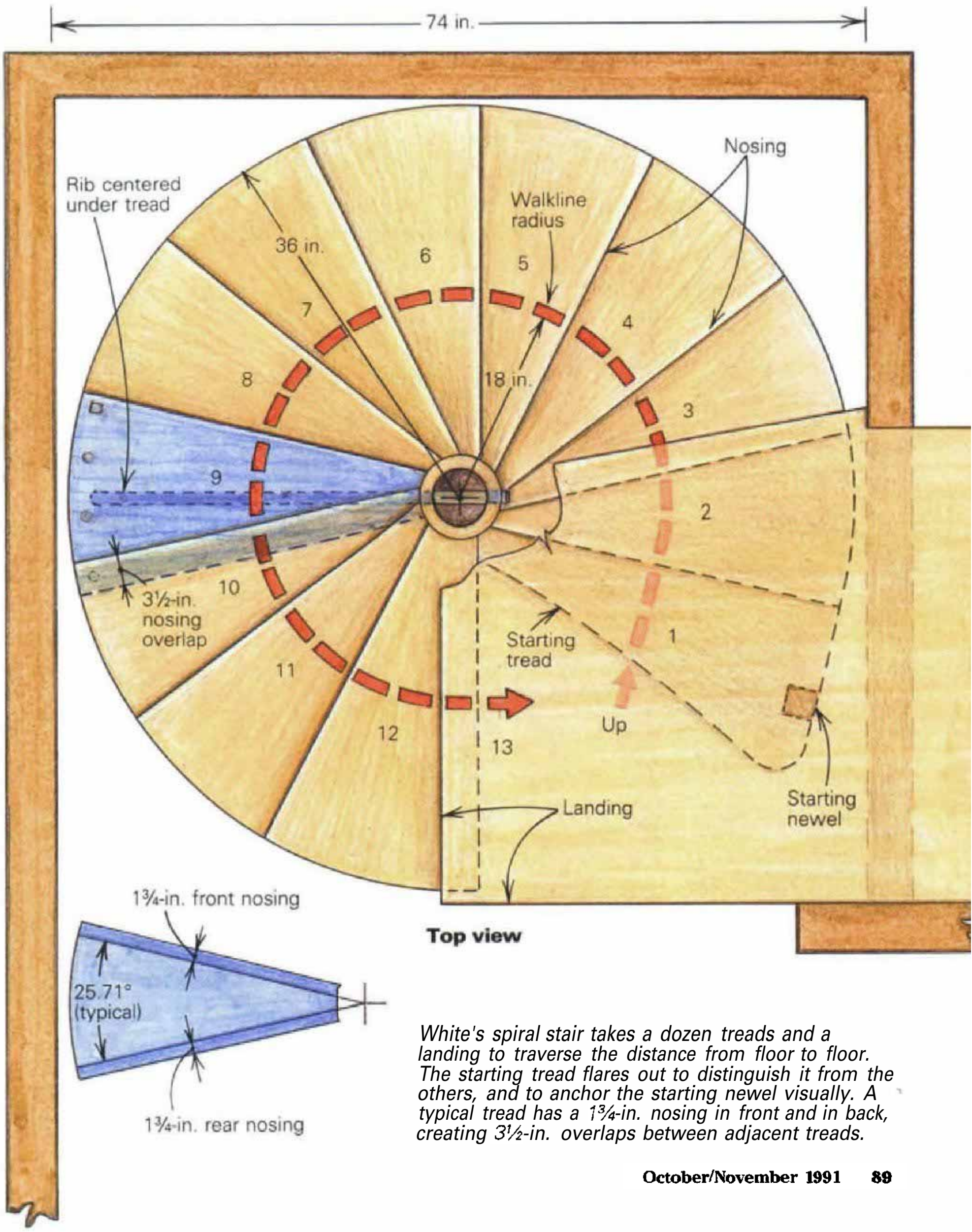
I glued up pairs of 2x12s to get the wide stock required for wedge-shaped treads. Then I sawed out the treads on the diagonal, making sure that the front edge of each tread was parallel to the grain. A trammel-point jig on my bandsaw helped me to cut smooth outside arcs on the treads.

All the treads are identical except for the starting tread and the landing tread (drawing right). Traditional staircases usually feature a prominent starting step, so I widened the first tread toward the newel post. I also widened the top landing to meet the door opening. The landing is flush with the second-story subfloor so that it can be carpeted to match the upstairs-hall floor.

I used a ¾-in. roundover bit to soften the edges of the ribs and treads. After a good sanding, I glued and screwed each tread to its rib. Each rib is under the centerline of its tread.

The balustrade—I make spiral handrails by gluing up thin laminations over a bending form (top photo, facing page). This is a full-





White's spiral stair takes a dozen treads and a landing to traverse the distance from floor to floor. The starting tread flares out to distinguish it from the others, and to anchor the starting newel visually. A typical tread has a 1¾-in. nosing in front and in back, creating 3½-in. overlaps between adjacent treads.

Drawings: Bob Goodfellow

size cylinder representing the diameter and height of the staircase, and is made of spaced 2x4s screwed to plywood bulkheads laid on sawhorses. Because I was building an outer handrail, I built the cylinder to the exact radius of the inside of the handrailing, in this case 33⅛ in. I built the rail in two halves, so the form needed to be just half a cylinder, and only half the stair height—about 5 ft.

Calculating the angle at which the rail spirals up the cylinder is a straightforward rise/run calculation. In this case the unit rise was 8.156 in. and the unit run was 1/14th the circumference of a 33⅛-in. radius circle, or 1/14 (2pi x r), which equals 14.87 in. Knowing the rise and run, the angle of ascent is $\tan^{-1}$ (rise/run) = 28.75°. With this information I plotted reference points on the 2x4s to guide the placement of the handrail laminations.

Starting with 10-ft. long Douglas fir stock 2⅜ in. thick, I ripped nine laminations, each ¼ in. thick, for a 2¼-in. wide rail. Keeping the laminations in order makes for less-visible glue lines later. I use a ripping blade on my table saw and glue the sawn laminations unplaned.

I have always managed to glue up all the plies of a spiral rail at once, but I have to work fast. I lay out all my pipe clamps and C-clamps near the cylinder, set all the laminations side by side in the right order on a fiat surface with the center marked on each piece, and check that I have plenty of glue.

One time, incredibly, I ran out of glue partway into the spreading. Luckily, a friend was helping, and he spread what glue we had while I raced to the nearest hardware store, where I stood in line, twitching with adrenalin flashes as I pondered the uses of a partially laminated handrail. But I only lost about five minutes, and the glue-up was saved.

For handrail laminations, I use a toothbrush to apply aliphatic resin glue. I then stack the laminations in order and carry them to the cylinder. I first clamp the center, then work outwards, clamping the rail to the 2x4s and aligning their edges with the reference points. Bending 2¼-inches worth of laminations can take a lot of force, and pipe clamps are handy for the initial bending. Then I check for gaps between plies and clamp wherever I find one—any unglued gaps can later split the whole rail open. The 40-or-so clamps I have are barely enough for a 10-ft. bend. Once the rail is aligned and clamped to my satisfaction, I let it cure for 24 hours. With this staircase, I repeated the operation for the other length of rail.

I clamp the cured handrail in my bench vise and square up the rail cross section with rasps, planes and scrapers. This operation is easy enough, but the next operation—shaping the rail—is not. Although I have a custom-made ogee router bit (made by Oakland Carbide, 1232 51st Ave., Oakland, Calif. 94601; 415-532-7669) to shape the rail with a minimum of passes, the rail has no flat surface to guide the router. I compensate for this by warping the plastic router base with shims to conform to the twist of the rail (bottom left photo, p. 88). But the operation requires a steady hand. After routing, I use sandpaper and plenty of elbow grease to finish the handrail sections. Last, the upper length of handrail needed a wall-return piece at the landing (bottom right photo, p. 88), which I attached with a standard rail bolt.

The balusters on this stair are 1-in. square spindles. On any stair or landing, I try to keep the space between balusters to no more than 4½ in. both for the safety of any children using the stair and for looks. In this case I used three balusters per tread. I machined round tenons at the base of each baluster to fit into holes drilled into the treads, but left the tops long to be cut on site.

This stair has three newel posts: a starting newel and two landing newels. I made them from 4x4s, bandsawing a four-sided taper in the mid-section (photo, p. 86). A commercially made ball top caps each newel. One of the landing newels sits atop the center column and has a tenon at its base to fit into the column.

Pulling it all together—I began the installation with the second-floor landing. Ledgers screwed to adjacent walls provided support for three of its four comers. The fourth comer bore on a dado in the stair column. This intersection was further strengthened with a lag bolt.

Once I had the landing in place, I temporarily installed the column. Making sure that the column was plumb, I traced around it at the floor. Then I removed the column and screwed a wooden disc the diameter of the inside of the column to the floor. I slipped the column over over this disc and tethered the top of the column to the landing with a rope. This allowed me to rotate the column as I inserted the treads. A rotating column isn't necessary if there is good access to all sides of the stair.

Installing the treads is the fun part of the job (large photo, facing page). I start at the bottom, pushing each one home and then drawing it tight to the column with a ⅜-in. by 7-in. lag bolt. Once all the treads are in place, I permanently lag-bolt the column to the landing and plug the recessed bolt holes with dowels.

Balustrade assembly began with the newel posts. Once they were in place, I was ready to join the two lengths of spiral handrail. To determine their finished length, I laid them in position atop the treads and marked them where they overlapped. Then I square-cut the two abutting ends and joined the pieces with glue and a rail bolt (bottom middle photo, p. 88). Next, I bevel-cut the tops of several balusters to 32 in. These balusters were inserted through the front hole of several treads and temporarily braced plumb. This would establish the top of the handrail at 34 in. above the nosings of the treads. Setting the spiral rail on top of the balusters, I screwed the downstairs end of the handrail to the starting newel. This intersection is further strengthened with a ½-in. dowel. Upstairs, the handrail engages the wall with a return that is Molly-bolted to the wall. Toenailing the balusters into the rail fixed it in position, and I could then fill in the rest of the balusters. I measured and cut each one individually to ensure a tight, plumb fit.

Spiral-stair layout

For a spiral stair of any given diameter and floor-to-floor rise, there is an optimum unit rise and number of treads per revolution. You find these two numbers by applying the standard rise-to-run formula to the stair at its walkline.

The rise-to-run formula is: two times the rise plus the run should total 24 in. to 25 in. Also, the maximum comfortable incline for a spiral stair is considered to be 43°, at which point the rise equals the run. In our formula, a 45° stairway would result if the rise and run were both 8 in. to 8⅓ in.

The walkline is the line followed by a person using the stair, and for treads less than 36 in. wide this is generally taken as the centerline of the stair. The length of the walkline provides the basic measure from which the length of run is calculated. This stair has an outside diameter of 72 in., or a radius of 36 in. Its walkline radius is therefore 18 in., and the walkline length in one full revolution is the circumference of a circle with an 18-in. radius. The circumference of a circle is found with the formula 2pi x radius. For this stair, the walkline circumference is therefore 113 in. The minimum desirable run of a tread is about 8 in., so I divided 113 in. by 8 in. to get the number of treads needed per revolution for the stair. The answer is 14.1, which I rounded to 14 treads per revolution.

This staircase has a total rise of 106 in. The fact that the run was about 8 in. dictated a rise of about 8 in. Because 106 ÷ 8 = 13.25 rises, I rounded down to 13 rises, resulting in a unit rise of 8.156 in. There were to be 13 rises, so the stair would spiral less than one revolution. It would have 12 treads, with the 13th step being the landing.

One final layout concern should not be overlooked. I have seen designers specify a 12-tread-per-revolution stair with a 90° arc (quarter-circle) landing at the top. This is generally not desirable because of headroom considerations. Imagine descending such a stair. As you reach the front edge of the ninth tread down, you are faced with the back edge of the landing above you. As you step off the ninth tread, will your head clear the landing? It will—but only if you're short. The accepted figure for headroom on a stair is 80 in. In order for nine steps to drop you 80 in., the unit rise would have to be about 9 in., assuming the landing had very little thickness to further encroach on headroom. Most codes allow a 9-in. rise for a spiral stair, but as I explained above, such a stair would be very steep. The best solution to this problem is to cut back the landing to a 60° arc.

An excellent book on spiral-stair layout is *Designing Staircases,* by Willibald Marines, (Van Nostrand Reinhold, out of print). In it, Mannes presents diagrams summarizing the optimum layout for stairs of varying diameters and heights. —*S. W.*

The fan part. **Once the column has been slipped over its base and tethered to the landing, White can insert the numbered treads into their mortises, and the stair quickly takes shape. Note the dados above the mortises at the top of the column. The dados accept the ends of the treads, making a clean joint and reducing wiggle.**

Rail-to-newel. **At the starting newel, the handrail is affixed with a ½-in. dowel and a 2-in. galvanized drywall screw.**

Pass-through balusters. **The leading baluster on each tread passes through a mortise to engage the tread below it. White used a 1-in, chisel to square the mortises.**

The balusters that extend through the front of each tread and into the tread below were fixed in place by dowels driven horizontally into each tread. They help link the entire assembly into a single unit, reducing the tendency of individual treads to wiggle as they are stepped on. Although it looks like it would be impossible to install these balusters with the handrail in place, there was no problem. They are flexible enough to bend out of the plane of the handrail as they are driven home with a hammer and a wooden block (photo above).

To stiffen the balustrade at the bottom of the stair, I drove a ⅜-in. steel pin through the rail and into a stud in the wall. Fortuitously, a stud was located adjacent to the rail's closest proximity to the wall.

I finished up by fairing the joint between the handrail sections to make a smooth transition. Then I applied three coats of Daly's Floor-Fin (a urethane and tung-oil finish) to the entire stair (Daly's Inc., 3525 Stone Way N., Seattle, Wash. 98103; 800-521-0714). I like the way this finish looks, and it's easy to apply—it's a brush-on and wipe-off finish. It's also formulated to hold up to the rigors of foot traffic. ☐

Steven M. White is a designer, carpenter and woodworker specializing in staircases. He lives in Berkeley, Calif. Photos by Charles Miller.