# On Making Chairs Comfortable <br> How to fit the seat to the sitter 

by Alan Marks

Many contemporary chair designers seem more interested in innovation than in good seating. The imagination must be indulged, but should the end product please the eye at the expense of the body? Dr. Janet Travell, who was once therapist to President Kennedy (it was she who prescribed the rocking chair as back therapy) points out, "You wouldn't dream of buying shoes that don't fit you. But have you ever stopped to consider whether the chairs you sit in are right for you? One can go into most homes and not find a single chair that's properly designed to support the framework of the human body."

The industrial designer, in his eagerness to take advantage of new production techniques and materials, may mistakenly assume that human flesh and bones will conform to the same configurations as plastic and steel. Discomfort, however, is not always a deficiency. Thonet's most successful bentwood chair, employed by generations of avaricious Parisian cafe owners, is sufficiently uncomfortable that customers rarely dally after eating. But getting people back on their feet in a hurry is not what this article is about.

Ideally, a chair used by only one person ought to be custom-fitted, like a tailored suit or custom shoes, especially if the owner will be spending a lot of time in it. The fit of an office chair, for instance, can make the difference between productive workdays, and uneasy ones. Bad chairs create back problems. As there are few mass-produced chairs designed for very tall or very short people, and since even the most "average" person is still an individual, I custom-fit the chairs I design. I interview the client at home and take measurements from chairs he or she considers acceptable, of ten taking a width measure from one chair and a height from another and so on. I work in centimeters because they scale up easily (FWW \#31, p. 56); the inch sizes given here are approximate.

The Humanscale seating guide, along with a number of other ergonometric guides worked out by Henry Dreyfuss Associates (MIT Press, 28 Carleton St., Cambridge, Mass. $02142,1974, \$ 37.50$ ) provides a wealth of information for the designer. In it are worked out the critical angles and measurements for the entire range of chair types for men or women of average, large or small build. For each possible combination, a rotating dial gives optimum seat height, depth and angle, backrest height and angle, and armrest height. If you build custom-fitted chairs, this guide is a real time-saver, although individuals in each of the five given categories will still vary.

The seat-Begin designing your comfortable chair by considering the seat's height, width, depth, shape and the material to pad it. If this is a one-off chair to be used by more than one person, it is safer to use the measurements suitable for the average person. If you, like me, mistrust statistics, turn to the nearest suitable human reference-yourself, for example.

I am about average height, and the distance from the floor to the underside of my bent leg is about $50 \mathrm{~cm}(193 / 4 \mathrm{in}$.). For the average person, then, the front edge of the seat has to be lower than this to avoid pressure on the sensitive arteries that feed the lower leg. If you are designing the average dining chair, choose a front edge height of $45 \mathrm{~cm}(173 / 4 \mathrm{in}$.).

Seat depth, the distance from the front edge to the back, is critical. If too deep, the sitter will be forced to slouch or else will suffer the discomfort of pressure on the back of the leg, which cuts off blood circulation and cramps tendons. If the depth is too shallow, discomfort may result from the decreased area over which body weight is distributed.

Most commercial sof as have a seat depth of between 53 cm and 56 cm (21 in. to 22 in .). According to Humanscale, however, depths greater than 43 cm ( 17 in .) will be uncomfortable for most small women and for at least half of all men. These people have to forgo back support, either sitting ramrod-like toward the front edge or sliding their pelvises forward and slouching. The sofa is therefore an in-between piece of furniture-not really comfortable for sitting nor well suited for lying down. The similarity between the words "couch" and "slouch" seems more than coincidence. For the average person, the distance between the rear of the bent lower leg and the plane of the lower back is $44 \mathrm{~cm}(171 / 4 \mathrm{in}$.). I generally subtract 2 cm to $4 \mathrm{~cm}(3 / 4 \mathrm{in}$. to $11 / 2 \mathrm{in}$.), for a seat depth that allows freedom of movement.

The seat of a dining chair should be wider at the front than at the rear, so the sitter's legs can spread. Good widths are 46 cm ( 18 in .) at the front and $36 \mathrm{~cm}\left(14 \frac{1}{4} \mathrm{in}\right.$.) at the rear.

A flat, hard seat is rarely comfortable for long sits. A contoured wooden seat, even if it faithfully reproduces the imprint of all the bones, muscles and curves of a resting derriere, is not comfortable either; the smallest shift in position causes misalignment. A seat must provide support over as wide an area as possible. A deep bucket seat such as found in sports cars does this well. It does not, however, permit the change in back position needed to relieve muscle strain. The most comfortable contour is the ever-changing one made by the sitter adjusting position on a cushioned surface. Only the most general sort of contour for the cushion underlayment is needed-at most a $20-\mathrm{mm}(3 / 4-\mathrm{in}$.) depression for the buttocks. A ridge in the middle of a seat is a real pain.

To counteract "foam pinch," caused by too much soft polyurethane (the deeper the sitter sinks, the more pressure is exerted on the sides of the thighs and buttocks), try laminating different densities of foam together. The portions of the chair bearing the most weight should have the highest density foam. The parts of the body most sensitive to pressure, such as the back of the knees and the bony portions of the upper back, should rest on softer material. I prefer to keep dining and office chairs as firm as possible, with perhaps an inch of high-density foam over a contoured plywood base. Most plas-

tic foams can be readily cut with a bandsaw, and can be laminated using contact cement either brushed or sprayed on.

You might want to try a relatively new type of foam patented and manufactured by Kees-Goebel, 4954 Provident Dr., Cincinnati, Ohio 45246. Called Temper Foam, it is both viscous and elastic, almost like a marshmallow. Body heat softens it so that it conforms to the sitter's shape, distributing body weight evenly over the entire contact area. After use, it slowly regains its original shape.

At the bottom of the pelvic girdle two knobs of bone jut out. You can feel the pressure these two knobs exert if you sit on your hands. They're about 13 cm ( 5 in .) apart and 13 cm ( 5 in .) from the plane of the back. If these bones bottom out in sitting, most of the body weight is supported by two tiny areas barely 6 mm ( $1 / 4 \mathrm{in}$.) square each. This hurts. A twolayered cushion - high density foam on the bottom, medium density on top-is one way to deal with this problem. A nother way is to add webbing at critical points covered by a single layer of foam. With a circle cutter set to a $12-\mathrm{cm}$ ( $43 / 4$-in.) diameter cut two holes in the flat plywood seat, centered 13 cm ( 5 in .) from the rear edge and $6.5 \mathrm{~cm}\left(2 \frac{1}{2} \mathrm{in}\right.$.) on either side of the centerline. Round the edges with a rounding-over bit to prevent chafing of the webbing, which should be tacked in Xs over the holes. Using this technique, as little as $1 / 2$ in. of the proper foam padding makes the seat quite comfortable.

Nylon-reinforced rubber webbing, such as available from Constantine, 2050 Eastchester Rd., Bronx, N.Y. 10461, has replaced the traditional jute variety. Besides being strong and durable, it is elastic. I have used it in both sofa and easy-chair construction. You can tack it to wooden seats, or use special metal clips that fit into routed grooves, making installation quick and eventual replacement easy.
A cheap alternative to rubber webbing, which apparently possesses all its strength and springiness, consists of longitudinal latex cords wrapped and tied with synthetic threads and covered with a thin bonding layer of latex. Because this web-
bing comes in several strengths, various grades can be combined to achieve the chair support needed for maximum comfort. In attaching it, the material is stretched to twice its original length, so the frame must be sturdy enough to withstand this constant tension. It can be obtained from Sanglatex USA, Inc., PO Box 269, 921 Baker Road, High Point, N.C. 27261, and from Mateba Webbing, 715 Pine St., Dunville, Ontario N1A 2M4.

The back-Again, to design a comfortable chairback, we must consider some basic human anatomy. The spinal column consists of 24 vertebrae that form a reverse curve. The lower five, the lumbar vertebrae, comprise the concave curve of the small of the back. They attach to the sacrum, the broad triangular bony structure of the pelvis. The twelve segments above the lumbar are the thoracic or dorsal vertebrae, forming the convex dorsal curve. Above them come the seven cervical vertebrae of the neck, a concern in specialized seating. In addition to the curve along the length of the spine, there is the curve across the width of the back made by the rib cage, shoulders and waist. Any comfortable chair must consider this curve too.

The spine has two functions that concern us here. It supports the body and it enables the body to twist and bend. Because the weight it carries continually shifts during normal motion, it must flex in all directions. This flex is permitted by tough yet elastic ligaments which fasten the vertebrae to one another. The entire spine is balanced and held in position by pairs of muscles in the back, abdomen and hips. If a muscle contracts to a new position, its complementary muscle must relax enough to allow it to do so. To hold the body in any one position against the force of gravity, both muscles tense. Thus even when the body seems at rest, muscles can become fatigued if body weight is not supported by the chairback.
The two sources of back discomfort are stretched ligaments and fatigued muscles. The ligaments that can cause the most pain when stretched are the two that run front and back the

entire length of the spine: the anterior and posterior longitudinal ligaments. Too much curve at the small of the back, too small an angle where the back meets the seat, or sitting upright in too low a chair can deform the spinal curve, stretching the anterior ligament. Too little support will allow the spine to bow, stretching the posterior ligament. A comfortable chairback must be designed to keep these two ligaments free of tension.
The other cause of discomfort, muscle fatigue, can be alleviated in one of two ways. You can try to relieve weight from the lumbar region by increasing the angle between the chairback and the seat, and providing a suitably cupped cavity for supporting the upper body. The farther a chairback reclines, the less weight the muscles have to balance and the more important the cushioning of this cavity becomes. The second way to deal with fatigue is to allow for movement rather than locking the muscles into a single, tiring position. Back muscles should constantly change their state of tension, as in walking. The most comfortable stool I ever designed was one whose legs and seat flexed to permit twisting and swaying. Avoid deep lateral curves in straight, upright chairbacks; they cause fatigue by inhibiting sideways body movement.

I use four reference points to plot the basic comfortable curve for the back of an easy chair: the juncture between the seat and the chairback (point $a$ in figure 2), the reversal point between the lumbar curve and the dorsal curve ( $b$ ), the reversal point of the dorsal curve (c), and the end of the dorsal curve (d). Draw a straight line between points $b$ and $c$, and a concave curve from points $c$ to $d$. The convex curve drawn from points $a$ to $b$ not only provides lumbar support, it creates a slight pocket for the buttocks to expand into. A comfortable chair does not crowd the sitter here. If the chair seat is padded, measurements must be taken with the padding compressed, as it will be in use. This is the effective seat level.
Little weight rests on the chairback except in the most laidback chairs. Cushioning for the lower back should be generally firm; for the upper back, soft. The lateral curve can be achieved with curved back rungs or shaped upholstery.

The armrests-We have all sat in chairs with armrests so high that shoulder muscles are tensed. Armrests that are too low feel awkward, encouraging the sitter to slouch. Ideally, armrests should take half the weight of the arms, while the remaining half is taken by the shoulders. The average adult re-
quires an armrest $22 \mathrm{~cm}(83 / 4 \mathrm{in}$.) above effective seat height. The distance between arms should be at least 49 cm ( $191 / 4 \mathrm{in}$.). Large people will need more width.

The seat/back angle-To understand the variations possible for the angle between seat and back, consider the metamorphosis of an imaginary chair through the range of chair types, from dining chairs through executive and easy chairs, ending with the lounge chair (figure 3). The basic comfortcurve built into the back remains constant throughout, though neck and head support must be progressively added as the sitter's weight shifts back. The three factors that do change are the angle between the comfort-curved back and the seat, the angle between the seat and the floor, and the height of the seat from the floor.

In the dining chair, the seat is parallel to the floor and the back is vertical (a). If you now, in imagination, hinge the back where it attaches to the seat and slowly tilt it (b), you reach a point at which the sitter begins to slide forward-about $102^{\circ}$. To prevent this, the entire chair must tilt as a unit (c), while maintaining a seat/back angle of $95^{\circ}$ or less, which is a good, standard angle. This, however, raises the front edge and creates uncomfortable pressure at the back of the knee. To relieve this pressure, we lower the chair toward the floor (executive chair). Continuing to tilt and lower the chair reclines the body enough for the seat/back angle to be increased again (d), since a forward slide has been forestalled (easy chair). Any further recline is now accomplished by increasing the pitch of the back (e). Metamorphosis complete, we end up with a lounge chair.

Pat measurements such as from Humanscale can lead to a good chair, but there's more to it. I remember a fellow student asking Carl Malmsten how he knew that a chair he'd drawn would be right. Malmsten looked askance at the youth and retorted that he had been designing chairs for fifty years, that was how he knew. Designing a comfortable chairback has much to do with experience and a lot to do with instinct. Given comfort as a criterion, there still remain endless possibilities for expressing individuality and originality. A designer should welcome at least some limitations. They are rather like the weights a diver uses to explore the ocean floor.

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[^0]:    Alan Marks wrote on how to develop ideas for chair design into working drawings in FWW \#31, Nov. '81.

