A Tree in 3-D and its irrational "growth cones"

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The irrational ratio of Pi, which forces the circumference of a tree to expand in growth 3.1416. times more than its diameter, is intrinsic to the reason that a tree's fiber growth is more drastic 'tangentially,' or in circumference, than 'radially;' and thus why, as we shall see, planing 'with the grain' is less predictable at radial surfaces(vertical grain) than at tangential surfaces (flat grain). The inevitably greater circumferential growth of fiber results in freer increase and movement of fibers as a tree grows. By contrast, radial growth of fibers, in thickness of growth rings, is obviously limited by the given thickness of each year's diametric expansion. In order to visualize this natural growth it is important to see a tree in 3-D, and the fact that it is made up of an exponential growth of fiber, measured as annual growth rings, but which I have called "growth cones," in their 3-D form.

A tree seedling in growth obviously begins with a pith or center, and is added to by annual growth rings, like ever-increasing cones gradually placed one over the other. Of course we know trees to be round in shape, wider at their bases and narrowing to their tops. Each consecutive growth cone consists of fiber, running more or less lengthwise, which increases simultaneously in diameter and in circumference. (For the sake of clarity, as far as a tree is concerned there are no actual "annual growth rings," but merely a continuous growth of fiber, at the living cambium layer just under the bark. The "rings" we see at a cross-cut section, or as wood grain on the surfaces of boards, are caused by seasonal variation of growth; resulting in differences of density, strength, color, etc.). Technically speaking, a tree is not a stacked layering of growth cones, as I've explained it; much less mere "annual growth rings;" but is a solid cone of fiber, constantly adding new fiber at its cambium surface, and dictated overall by the triangular (or conical, tepee-like) strength of its form. It must be this greater and freer tangential growth of fiber around the circumference that also adds to a tree's sheer strength; an entwined fibrous build-up - which then both aides and challenges us woodworkers.

Intimacy with and knowledge of medium are part of the traditional craftsman's great skill; and perhaps this is especially true of Japan (my mother's ancestral land, and my home of 23years). Uniquely, Japan has been referred to as a "fiber culture;" which, in its renowned arts, has long made use of many kinds of fiber: silk kimono, washi paper, tatami mats, bamboo, thatched roofs and earthen walls, hemp, woven fabrics, and the pervasive use of wood. In order to work fibers well, fine tools are essential; and this is heightened by the fact that much wood and materials used here were of softwood or coniferous type. Soft wood requires greater care, exacting work, and sharper blades; all of which have helped to deepen the craftsman's intimacy with medium.

While working with Japanese 'shokunin' (professional craftsmen), it was apparent that they could "read" their wood, selecting proper pieces for the given work, knowing which end of lumber was topmost in the tree, recognizing milling direction for given surfaces of wood, how to place wood within a given project, and of course knowing where to use different species of wood. In the act of "teaching" apprentices, typically the work is not explained in words but has to be deduced, watched carefully, practiced, intuited. There is a strict logic in leaving the attainment of high skill to a beginner's natural attentiveness and talent. Nonetheless, as with anyone who does a particular thing for a long time, we gradually begin to understand or read our work, grasping things previously unknown.

First we should make clear what milling or planing direction means, or cutting wood "with the grain," as it is known. Like cutting rope or shaving hair, the blade cuts cleanest when pulling, or cutting fibers in 'tension.' By contrast, cutting fibers by pushing into them, or in 'compression,' results in what is known by woodworkers as "reverse grain tear out." In the latter, fibers are broken off as much as cut, under the force of compression. Therefore, the direction or 'angle of attack' must be chosen depending on the angled layering of fibers or wood grain; as in the example of cutting rope or shaving hair. When the angle of fibers in wood is determined, planing direction can be chosen. Planing direction can also be determined by visible pore shapes, and angles of rays, as in oak. (Careful observation should bear this out).

As mentioned in the first paragraph, the difference between radial/diametric tree growth, the increase of fibers away from the pith; and circumferential growth, increase of fibers around the surface of the tree, is the ratio of Pi. This is the cause behind the difference between determining planing direction at vertical grain surfaces, and flat grain surfaces of wood. It may be easier to visualize this if we imagine a single growth cone as a sheet of paper rolled into a tube. Obviously fiber growth and movement within this form is quite limited by its thickness, or radial growth. However, fibers can increase and move more freely around the circumference, tangentially; allowing for the possibility of not only straight up and down fiber growth, but also at angles, like wavy or spiral growth. It should also be noted that the consecutive or annual growth of fiber around a tree may change in direction, so that fibers flowing one way this year, may be layered over by new fibers going another way next year. (See end of the 2nd paragraph).

Herein lies the difficulty of planing 'with the grain' at radial or vertical grain surfaces of boards. In our illustration, see not only one but several sheets of paper rolled into a tube. Again, the fiber movement is quite free tangentially - as perhaps drawn by flowing lines across the face of our tube - and this stack of cones, like a log, is then cut, of course lengthwise, but for "quarter sawn" lumber; that is, not a tangential cut parallel with the surfaces, or flat grain, of growth cones, but perpendicular to them. This cut of course reveals the long straight edges of the cut growth cones, typical of vertical grain lumber. If then we imagine the movement or angles of fibers as they are in the log or stack of paper tubes, we can see that their angles may be quite drastic or random in relation to the surface of the board. This is why milling/planing is difficult or often impossible to do in a single direction, without some reverse grain tear out.

In the case of a tangential cut or flat grain, commonly seen as concentric arches on lumber surfaces, the angle of fibers moving toward or away from this surface is limited by the thickness of each growth cone. Since the annual layers of growth cones are parallel, and a flat sawn lumber cut runs through them at a single angle, the fibers within are running at a consistent angle to the surface. Therefore flat grain is easier, not only to read, but to plane cleanly in a single direction. An analogy might be roofing layers, or imagining a stack of domes; as with a tree's growth, the early layers are lower and under, the late layers are above and over. Just as rain would run off this roof from top to bottom over the consecutive layers, the 'outside' surface of flat grain would be planed from top to bottom, or from the apex of the arches to their bases. By contrast, the opposite, 'pith side' of a flat grain board would be planed from the bottom to top, or from the bases of the arches to their apexes; like viewing roofing layers from their underside.

The difference between circumferential fiber growth and radial fiber growth in a tree also determines the reason for cupping or warping in boards; and why wood expansion and contraction due to 'relative moisture content' (RMC) is greater tangentially than radially. Of course this is generally known by woodworkers, if not equated to the quantitative growth of fiber. As we know, flat grain boards will shrink or expand more in width than in thickness; and vertical grain boards will shrink or expand more in thickness than in width. Both are following the greater quantity and freedom of circumferential fiber growth in the tree. However, obviously growth rings are often at varying angles and opposing angles within a single board -- inevitable when straight cuts run through curves or circles. The varying and opposing directions of stress, largely tangential expansion and contraction, cause lumber to warp, twist, and check -- notorious in the inevitable checking in logs or solid beams with their pith.

The indeterminate ratio of a tree's diameter to its circumference, of course, is not a problem to the tree. It just means that the same scale of measure cannot be used at d and C, and arrive at a de-finite ratio between them; nevertheless, the tree is whole unto itself, the diameter and the circumference both expanding simultaneously by an "infinite" ratio -- irrational as it may seem.

Being able to understand the inner workings of wood while making use of it, may help us to gain a greater intimacy and assurance with it; and perhaps to take advantage of these characteristics in our various uses of it, instead of being at their whim. Of course, as with most of nature's immeasurable things, each individual tree or board may have its own characteristics of density, rate of fiber growth, stress, reaction to RMC, water resistance, strength, flexibility, and etc. Woodworking is basically a constant dance between tension and compression of fibers, between pushing into, or pulling on them -- whether hewing, planing, sawing, routing, chiseling, carving, scraping, or sanding.

"A Tree in 3-D, and it's irrational growth cones" is a guideline for understanding basic form, and movements of fiber growth within; which may help us in this "constant dance." But, as the shapes of trees and their growth within are forever random and individual, as well as our tool's angle of attack, woodworking will always follow the lead of these variations. The impossibility of taking all things into consideration is wonderfully inherent in the unlimited curve of pi, and our unlimited learning curve.

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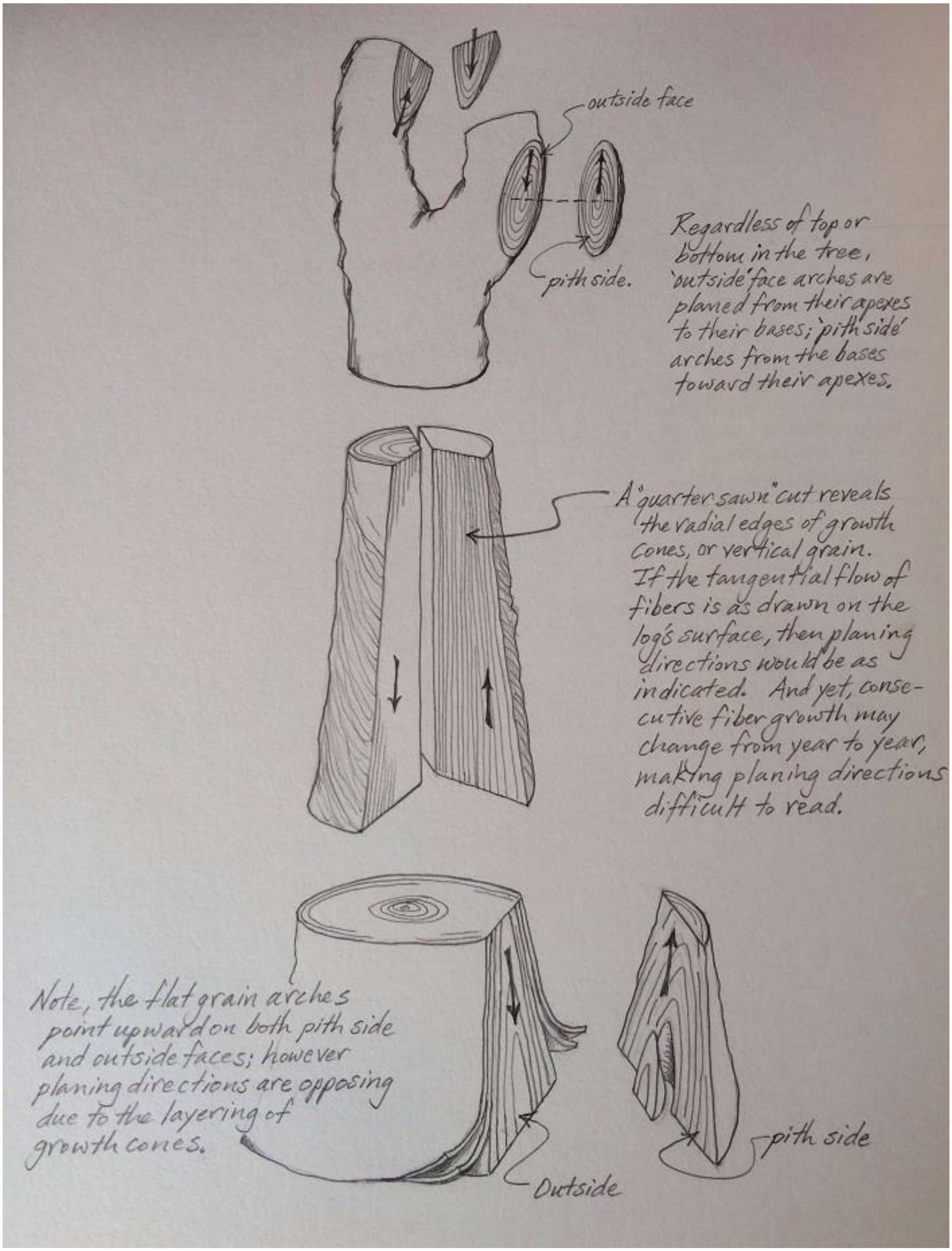
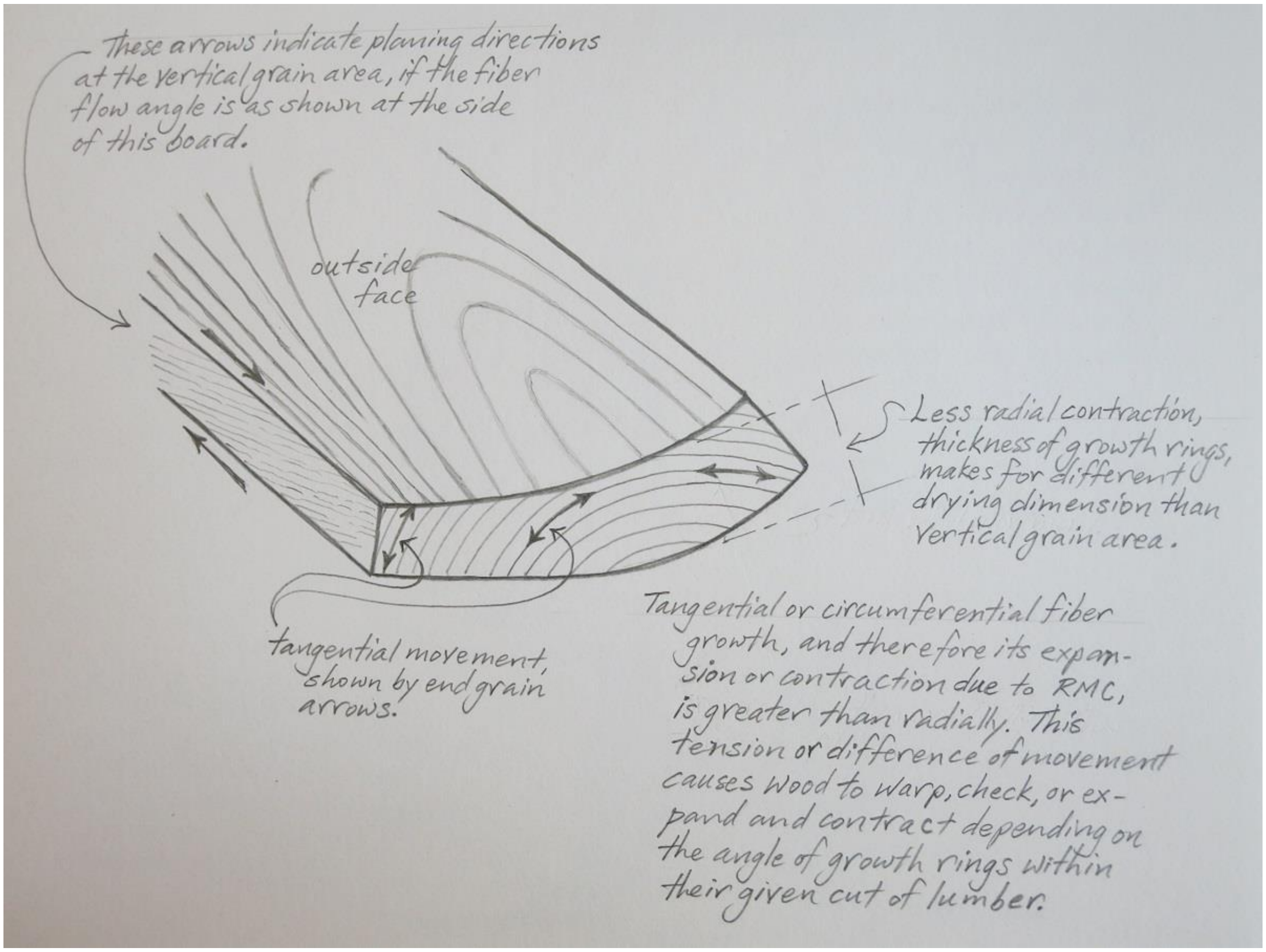
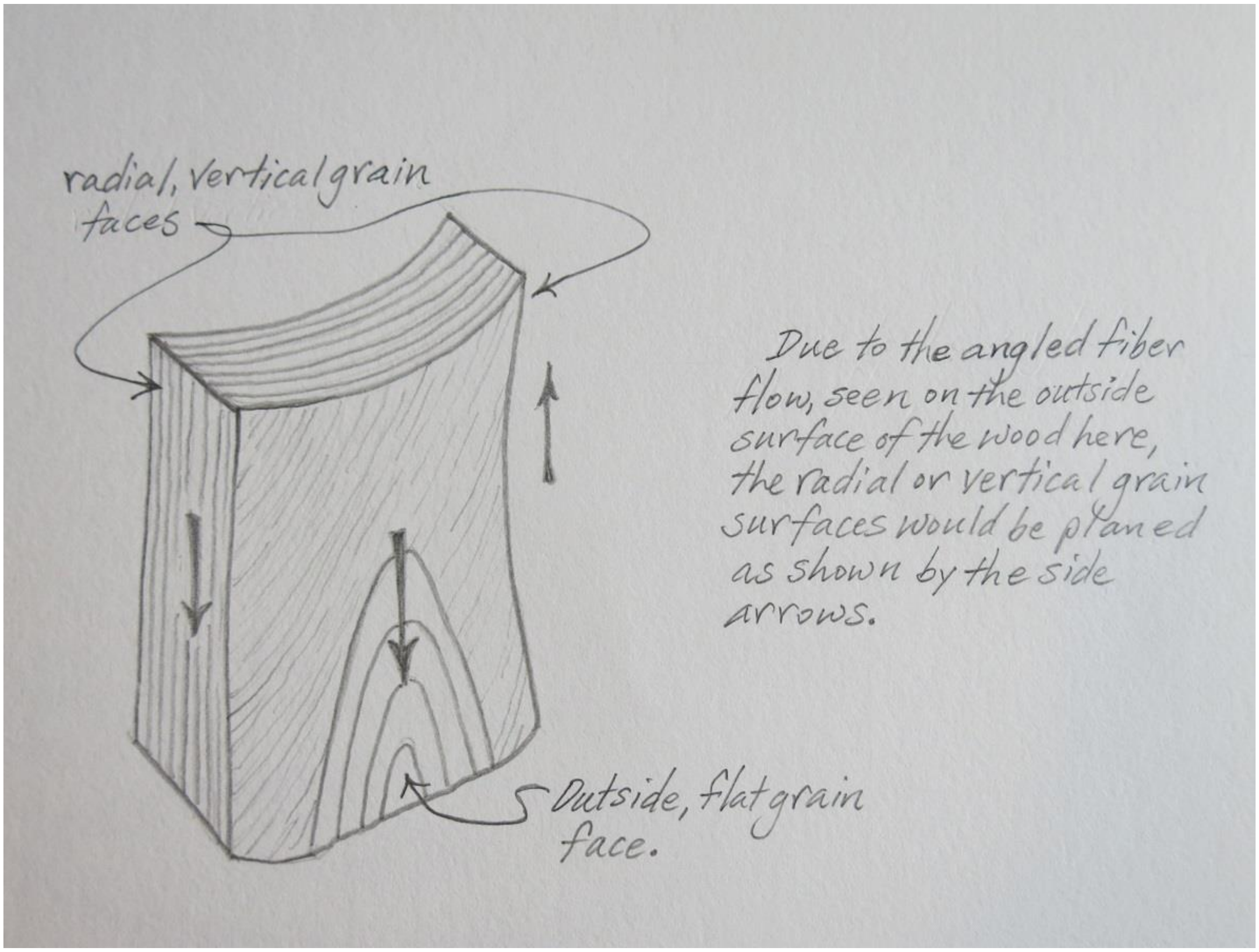

outside face
pith side.
Regardless of top or bottom in the tree, 'outside' face arches are planed from their apexes to their bases; 'pith side' arches from the bases toward their apexes.
A "quarter sawn" cut reveals the radial edges of growth cones, or vertical grain. If the tangential flow of fibers is as drawn on the log's surface, then planing directions would be as indicated. And yet, consecutive fiber growth may change from year to year, making planing directions difficult to read.
Note, the flat grain arches point upward on both pith side and outside faces; however planing directions are opposing due to the layering of growth cones.
Outside
pith side


These arrows indicate planing directions
at the vertical grain area, if the fiber
flow angle is as shown at the side
of this board.
outside
face
Less radial contraction,
thickness of growth rings,
makes for different
drying dimension than
vertical grain area.
tangential movement,
shown by end grain
arrows.
Tangential or circumferential fiber
growth, and therefore its expan-
sion or contraction due to RMC,
is greater than radially. This
tension or difference of movement
causes wood to warp, check, or ex-
pand and contract depending on
the angle of growth rings within
their given cut of lumber.


radial, vertical grain faces
Due to the angled fiber flow, seen on the outside surface of the wood here, the radial or vertical grain surfaces would be planed as shown by the side arrows.
Outside, flat grain face.