The process of drying in wood is directly related to the following:

- Cellular structure of the wood
- Energy available to break bonds between water and wood and to evaporate water
  - o Heat energy – Temperature of air in a kiln, excitation of molecules from an electromagnetic source (microwave, Infrared, etc.)
- Mass transfer potential – a way to move the water away from the wood surface
  - o diffusion along a concentration gradient, from a source of high humidity to a sink of low humidity
  - o bulk movement through moving air (e.g. air flow in a dry kiln)

Cellular Structure

Softwoods have one major longitudinal cell type, the tracheid, which provides both the mechanical support and the water conduction functions in the tree. Hardwoods have tracheid and fiber cells for support and vessel cells for conduction. Softwood tracheids are about 4 times longer and 10 times narrower than hardwood vessels. Softwood tracheids are closed at each end and the radial face of each cell is perforated with many tiny openings called pits whereas hardwood vessel cells are open at the ends and are free of pits on the transverse walls.

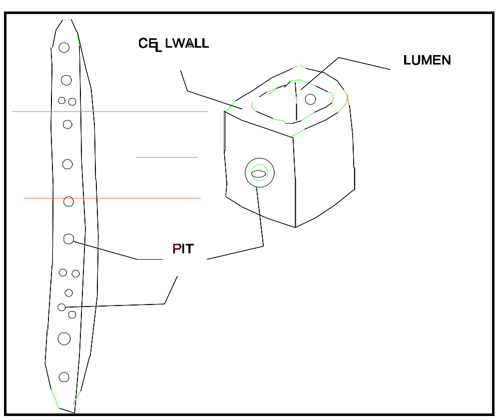

Figure 1. Sketch of a typical softwood tracheid.

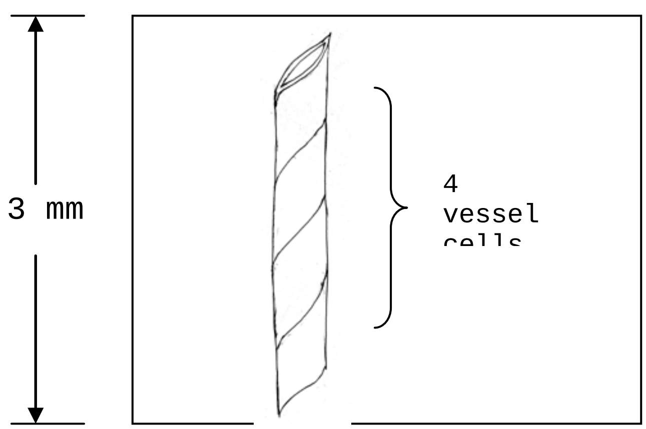

Figure 6.Vessel cells Connected longitudinally via perforation plates.

WATER IN WOOD

Water is an essential ingredient to life and as such is found throughout all living cells. In the tree, water is transported through the lumens of water transport cells and it also saturates the cell walls giving rise to two classifications of water in wood.

Free water - Liquid water found in cell lumens and other void spaces in wood.

Bound water - Water molecules that penetrate the cell walls and chemically bound to cellulose molecules. It is the removal of bound water that causes shrinking of wood.

In softwoods nearly all of the water is found as free water in the lumen or bound water within the cell wall of tracheid cells. In hardwoods, water is found in the cell walls of all the cell types but most of it is contained as free water within the lumens of the large vessel cells.

The major portion of water transport in a living tree occurs in the outer **sapwood**, in the tracheids of softwoods and the vessels of hardwoods. The sapwood in conifers normally has a very high moisture content.

In the **heartwood** zone of the tree, the cells are dead and no longer involved in water transport. The heartwood normally has a lower moisture content than sapwood in confers, however the moisture content of heartwood and sapwood are often very similar in hardwoods.

HOW WATER MOVES THROUGH WOOD

The movement of fluids through wood is a complex phenomenon involving diffusion and pressure driven flow. Gases and vapors can move through the cell walls as well as the void spaces of the wood by the diffusion of molecules along a concentration gradient. The uptake of water into wood is called sorption and the loss of water from wood is referred to as desorption or drying. Drying of wood with an MC greater than FSP involves both free water and bound water.

Bound water movement through wood is an example of diffusion where the water molecules move from wetter wood to drier wood. The molecules jump from cellulose molecule to cellulose molecule within the cell walls and between adjacent cell walls.

Free water movement in wood occurs because liquids can move through an intricate pathway of interconnected capillaries of lumens and pits in response to a pressure gradient or surface tension forces. In softwoods, since the tracheids are closed at the ends, all flow between adjacent tracheids must go through the pits between the cell walls in a transverse direction. In hardwoods the vessels are basically open at the ends and water flows freely between these ends (very little flow occurs through pits in hardwoods).

An approximate condition in wood when the cell walls are saturated with bound water but the cell lumens do not contain any free water is called the **fiber saturation point (FSP)**. Changes in the amount of bound water in wood (below the FSP) affect the physical and mechanical properties of wood.

Moisture from the air (water vapor) penetrates dry wood (below FSP) by diffusion, as bound water. When dry wood is exposed to a humid environment the wood will only take up moisture as bound water and the moisture content will not exceed the FSP, unless moisture condenses onto the surface of the wood. The condensation of water onto a wood surface exposes the wood surface to free water. When liquid water is in direct contact with wood it is taken up into wood as free water by the processes of absorption and capillary action. If the temperature and humidity conditions that wood is exposed to are kept constant, then the wood will eventually reach a moisture content in equilibrium with its environment. This condition is referred to as the **equilibrium moisture content (EMC).**

In the absence of any direct contact with liquid water, wood will reach an EMC for constant temperature and relative humidity and this EMC varies very little between species. Table X shows the EMC for wood over the range of common temperature and relative humidity conditions.

Table X. Equilibrium moisture content of wood at various temperature and relative humidity combinations.

Temp-erature (F)	**Relative Humidity (%)**									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
70	2.5	4.5	6.1	7.7	9.3	11.0	13.5	16.4	20.6	~25
80	2.4	4.5	6.0	7.6	9.1	10.6	12.5	15.7	20.0	~25
90	2.4	4.5	5.8	7.3	8.9	10.6	12.5	15.5	19.5	~25
100	2.4	4.0	5.7	7.1	8.6	10.2	12.4	15.0	19.4	~25
110	2.3	4.0	5.4	6.8	8.4	9.9	12.0	14.8	19.0	~25
120	2.3	4.0	5.3	6.6	8.2	9.7	11.8	14.1	18.8	~25
130	2.0	3.7	5.1	6.4	7.8	9.4	11.5	13.8	18.7	~25
140	<2.0	3.6	4.8	6.0	7.5	9.0	10.9	13.4	17.5	~25
150	<2.0	3.2	4.5	5.7	7.2	8.6	10.3	13.0	16.6	~25
160	<2.0	3.1	4.3	5.4	6.8	8.2	9.8	12.4	16.2	~25
170	<2.0	<3.0	3.9	5.2	6.5	7.8	9.6	11.8	15.8	~25
180	<2.0	<3.0	3.8	4.8	6.0	7.4	9.0	11.4	15.5	~25
190	<2.0	<3.0	3.6	4.6	5.7	7.0	8.8	10.9	14.2	~25
200	<2.0	<3.0	3.3	4.4	5.4	6.6	8.4	10.8	14.0	~25
210	<2.0	<3.0	3.3	4.1	5.1	6.3	8.0	10.4	13.8	~25