CHAPTER 10 SPIRALS. SPIRALS, SPIRALS: ORIGIN AND TYPE

In the plant cell wall, the cellulose molecule is made up of strands of cellulose called microfibrils, macromolecules, and fibrils. These are oriented, directionally, differently in the cell wall in the different layers (see Fig. 9.4). In the secondary (S) layers they are in helical spirals of different angles to give the cell wall strength. Cellulose spirals in cell walls observed under the microscope of branch and heartwood are of different origins. The presence of spirals observed in heartwood, axial tracheid cells is used for identification of the wood species but there are many other types of spirals that can be mistaken for these spirals. There are 6 types of spirals in coniferous wood, branches, and roots. Only one type assists in species identification. Thus the following illustrates are presented to clarify who's who.

10.1 Soft rot fungal activity in 2nd axial tracheids

Fungal soft rot is found on surfaces of wood that has been undisturbed in a wet fresh water (not marine) environment for a long period of time. They are common in wet archaeological wood. The result is disorganized, pulpy, soft, surface tissue. The fungi penetrate the S2 layer of the cell wall of axial tracheids, move lengthwise hydrolysing (digesting) the helical coil of microcellulose fibrils, and leave behind a hollow cylindrical canal (Fig.10.1a) void of cellulose. These spiral voids assist in identifying the presence of soft rot fungi. In cross section (Fig.10.1b) they appear as pits. There are many species of soft rot fungi. They are ascomycete fungi and many have been shown to hydrolyse not only cellulose, but as well, hemicellulose, pectin and starch in the cell. Lignin is rarely hydrolysed but some species may alter it.

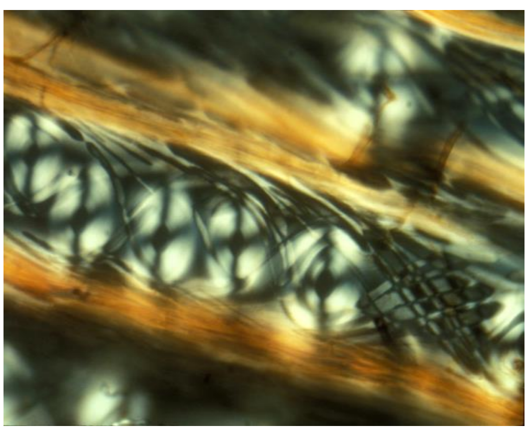

Fig.10.1a

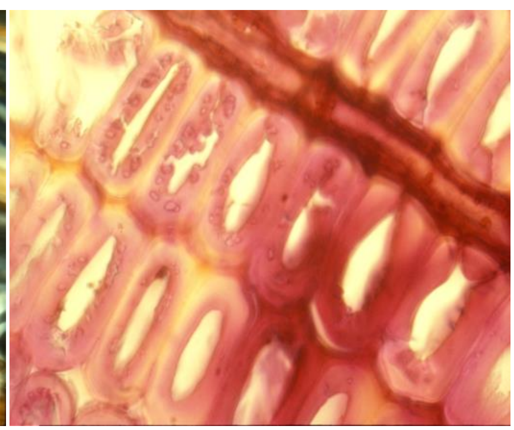

Fig. 10.1b

Fig. 10.1a polarized light photo of the tangential surface of 2nd axial tracheids infested by soft rot fungi. The fungi hydrolyse the cellulose and leave empty, spiral, circular canals along the helical spiral of microcellular molecules. The crosier cross is a polarizing light phenomenon of bordered pits in the axial tracheid. **Photo MLFlorian**

Fig. 10.1b- cross section of heartwood 2nd xylem axial tracheids showing voids in the S2 layer of the cell wall caused by soft wood fungi. **Photo MLFlorian**

10.2 Inherent tertiary spirals on the inner surface of axial tracheids of yew-*Taxus brevifolia*-yew, and Doug fir-*Pseudotsuga menziesii.* Figs.10.2 a-f

Anatomic inherent structural spirals are present in both *Pseudotsuga menziesii* -Doug fir and *Taxus brevifolia* -yew species in 2nd xylem tracheids of wood and branch and roots and are an aid for species identification. Doug fir, has structural spiral thickenings (Figs. 10.2a -d), on the S3 inner layer of the axial 2nd xylem tracheid in heartwood, branch and root. The main difference between these spirals, and others, is that they are formed by raised spiral thickenings in a helical along the S3 innermost layer of axial tracheids. The angles or the pitch of these spirals change with the tracheid length and in the tangential view they appear steeper than in radial view. Thus the pitch of the spiral thickenings cannot be used to separate species.

Taxus spirals (Figs.10.2e-f) are formed the same way as in Doug Fir .It is reported that in *Taxus* they are present in late and early wood in the same amounts but in Dough fir they are more common in early wood, but from observation this varies widely.

In compression wood the spirals that are observed are the result of separation of cracks or cavities between microcellulsose molecules in S2 layer as a result of external pressure on the tissue. It is under discussion as to whether the spiral thickenings and the cavities can occur in the same tracheids. But it is suggested that in compression wood of Doug fir only cavities occur and in Yew both may occur.

The photos (Figs.10.2c and d,) showing the spiral thickenings in the branch and root of Doug fir are very difficult to see. This may be caused because they are not completely developed and appear very delicate or in the preparation of the sections, for the microscope slides, were cut too thin to show the complete thickness of the spirals.

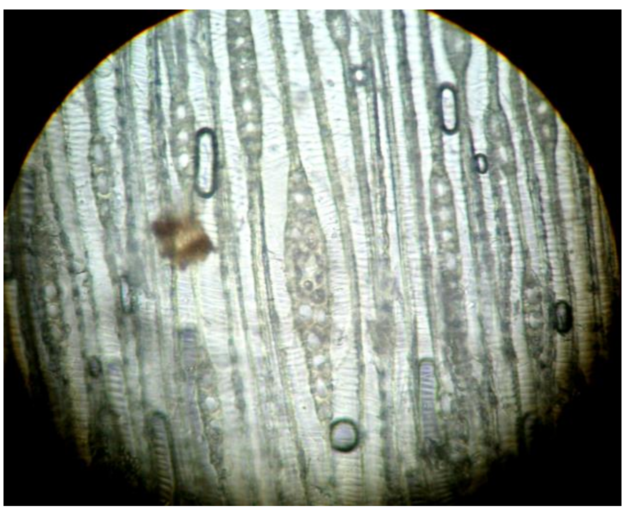

Fig.10.2a

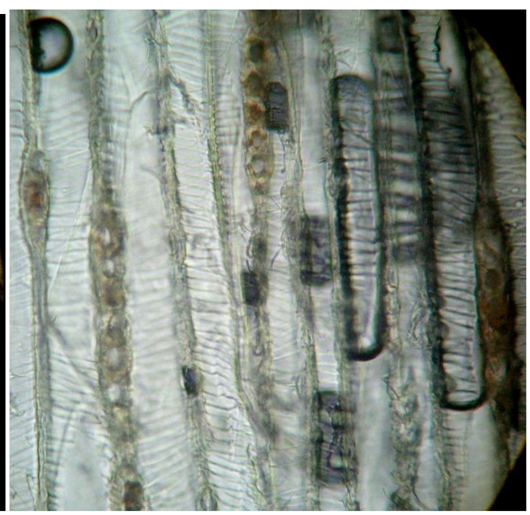

Fig.10.2b

Fig.10.2a, tangential surface showing anatomical spirals of Doug fir (*Pseudotsuga menziesii*) that are thickenings on the S3 inner surface of the cell wall of 2nd xylem axial tracheid. **PhotoMLFlorian**
Fig.10.2b, a higher magnification of Doug fir (*Pseudotsuga menziesii)* showing anatomical spiral thickenings in early wood axial tracheids. When air is trapped in the tracheid the spirals are more visible. **PhotoMLFlorian**

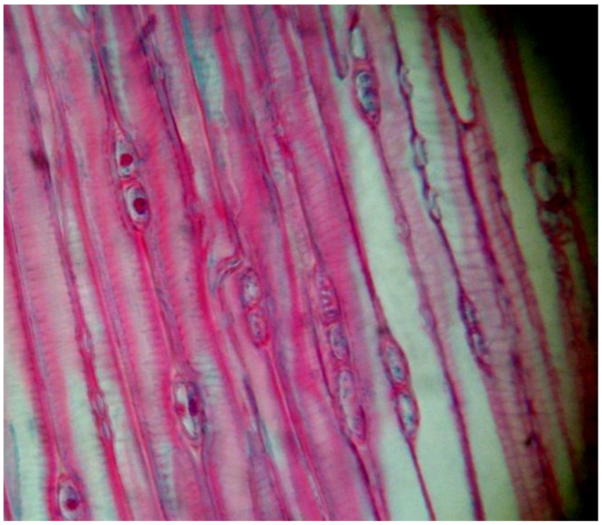

Fig.10.2c

Fig.10.2d

Fig.10.2c-, branch of Doug fir (*Pseudotsuga menziesii)* shows narrow anatomical spiral thickenings in 2nd xylem axial tracheid. The voids in tracheids are due to sectioning at a slight angle and show the lumen of the cell. **Photo MLFlorian**
Fig.10.2d-, shows root of Doug fir(*Pseudotsuga menziesii)* shows narrow spiral thickenings in 2nd xylem axial tracheid. The voids in tracheids are due to sectioning at a slight angle and show the lumen of the cell. **Photo MLFlorian**

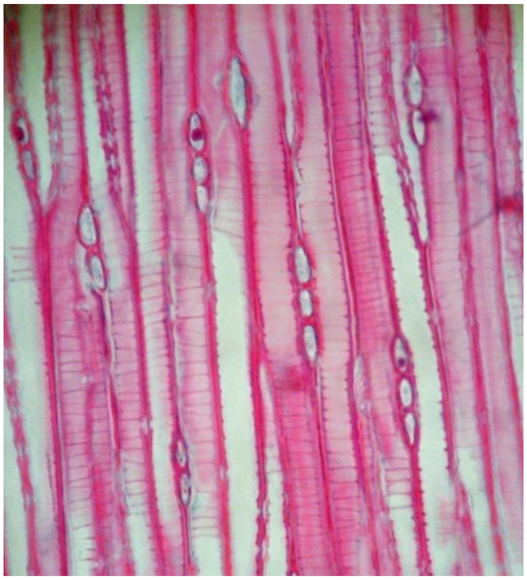

Fig.10.2e

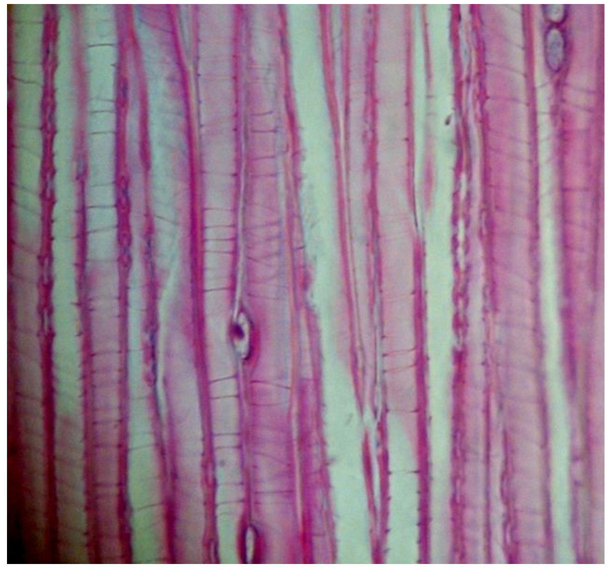

Fig.10.2f

Fig.10.2e tangential view of *Taxus brevifolia (*yew) branch spirals seen at right angles to the 2nd xylem axial tracheid walls. There are a great many and close together The voids are due to sectioning at a slight angle and are the lumen of the cell. **Photo MLFlorian**

Fig.10.2f – Tangential view of *Taxus brevifolia (*yew) root spirals seen at right angles to the 2nd xylem axial tracheid walls. There is a great many and close together. **Photo MLFlorian**

10.3 Cracks- crevices- striations- checking in compression wood. Fig.10.3

Cracks- crevices- striations- checking- all names are used (Fig.10.3), they follow the direction of the helical spiral in the S2 layer of the cell wall in compression wood of 2^{nd} xylem axial tracheids. They are cracks between the cellulose fibrils. In compression wood they are cause by mechanical pressure resulting in cellulose fibril separation caused by bending of the tissue. This is common in branches or tree trunks that are physically stressed by wind or weight of snow, etc. In these cases the compression wood tracheid walls are very brittle and may crack along the line of the helical cellulose fibril. Thus they are caused by separation of cellulose microfibrils due to environmental pressure on the compression wood. They are in patches not in the full length of the tracheid.

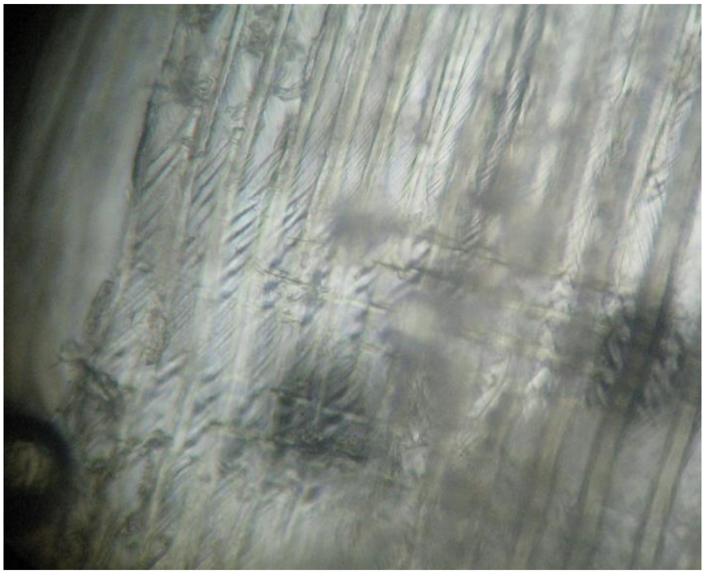

Fig.10.3

Fig.10.3 cracks on the radial surface of the cell wall of axial tracheids in compression wood of 2^{nd} xylem axial tracheids in Western red cedar (*Thuja plicata*). Photo MLFlorian

10.4. Defibration (cell separation) and loss of soluble hemicellulose, pectin, and cellulose. Fig. 10.4

Fig.10.4

Fig.10.4 shows tissue fragmentation- defibrillation- due to loss of hemicellulose and pectin. Because the cellulose microfibril spirals are voids, cellulose has also been removed. The lignin that has remained is supporting the cell skeleton. The sample is a 10,000 year old archaeological branch artifact (1225 T 21 B3:2). PhotosMLF

Fig.10.4 shows the breakdown of the wood tissue releasing single cells. This process is called defibration. The surface of wood has a fuzzy appearance. The chemicals in the cell wall vary in their solubility and vulnerability due to biodeterioration and environmental impact. Pectin and hemicellulose are the most soluble, next to cellulose and then the extremely insoluble lignin. If pectin and hemicellulose are water leached from the wood tissue the cells are freed from each other. On close examination it is apparent that the spirals are voids and thus the lignin may be all that is holding the cellulose skeleton together. If this is a compression wood in a branch it would have a high percent approx 40%, lignin in construction of the cell wall supporting this theory. This deterioration could have been cause by advanced stage of soft rot, extreme environment or concentrated chemicals. Chemicals such as high concentration of salts and acids can also cause defibration.

10.5 Primary protoxylem spiral thickenings in the stem pith region and in leaf or branch traces. Figs.10.5 a-b

Primary protoxylem is the first formed xylem in the initial growth of a stem or tree bud. As the stem grows the protoxylem is always present in a stem at the margin of its pith. It is together with other tissues such as a cambium and phloem in a bundle- the vascular bundle. The protoxylem cells in first years growth of a plant is required to transport water and nutrients to all parts of the plant. To maintain a flow all protoxylem has spiral which efficiently moves the water. After a year, new growth rings occur and produce 2nd xylem in branch sapwood and it takes over the job because the protoxylem remains its small original size. But it is always present and the vascular bundle always has the cambium for some future growth. The cambium when activated produces traces for leaves and branches. These traces contain primary protoxylem with their spirals. Thus spirals are present close to the pith (Fig.10.5a) and in branch and leaf traces as shown in Fig.10.5b.

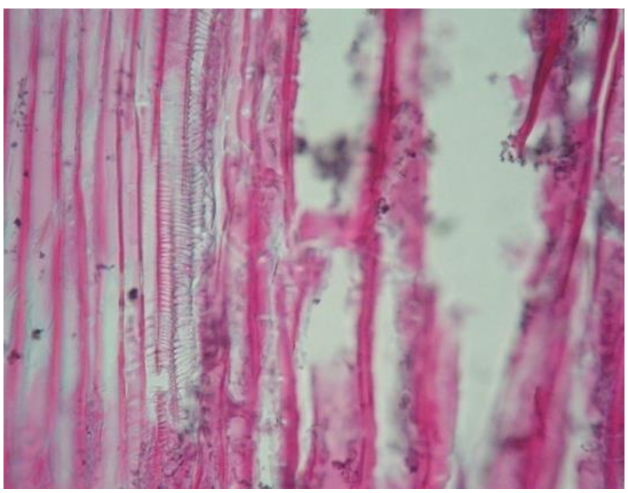

Fig.10.5a

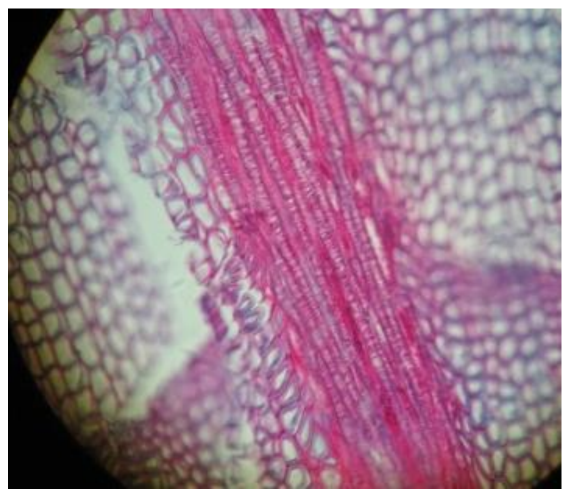

Fig.10.5b

Fig.10.5a tangential surface of hemlock (*Tsuga heterophylla*) branch in the central pith region. The large cells to the right are pith cells. To its left is a small group of narrow cells with spirals. These are primary protoxylem cells close to the pit region. **Photo MLFlorian**

Fig.10.5b, cross section of *Abies* (fir) branch. The central swath of deeply stained cells is primary protoxylem cells of either a branch or needle trace. It shows spiral thickenings in the narrow protoxylem cells. **Photo MLFlorian**

10.6 Spirals in 2nd xylem cells caused by high temperature. Fig.10.6

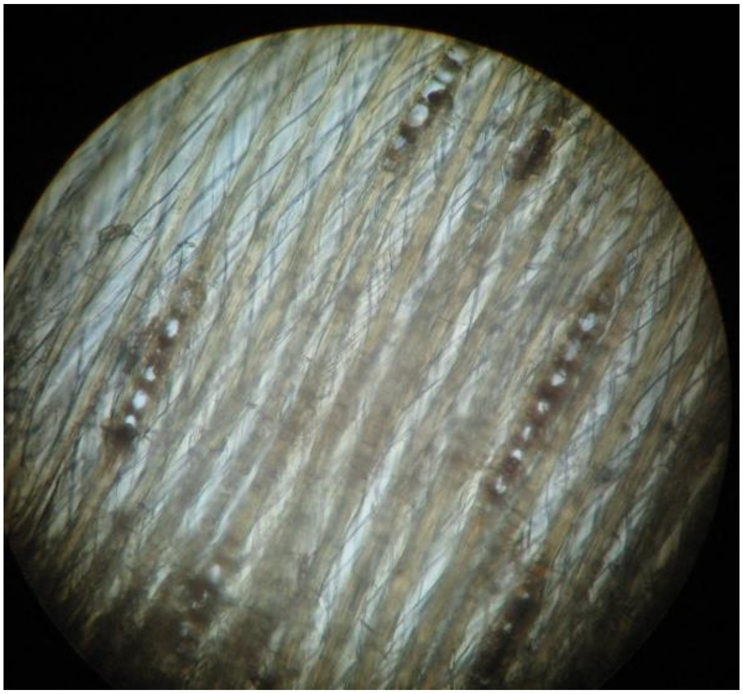

Fig.10.6

Fig. 10.6 Tangential surface of spruce wood that was damaged by the extreme high temperature, pyrolysis of the hot gas ,from Mt. St. Helen's pyroclastic flow. MLF Photo.

Fig.10.6 shows spirals that are voids from the loss of cellulose that was volatized by the extreme heat.