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ABSTRACTS OF PAPERS PRESENTED BY IAWS FELLOWS

ALONI R.[1], LANGHANS M.[2], ALONI E.[1], SCHWALM K.[2], ULLRICHC I.[2]: [1]Department of Plant Sciences, Tel Aviv University, Tel Aviv 69978, Israel; [2]Institute of Botany, Darmstadt University of Technology, Schnittspahnstr. 3, 64287 Darmstadt, Germany - **Auxin production, its transport pathways and their role in wood formation** (Paper)

Auxin is the primary hormonal signal which controls cambium activity, wood formation, patterns of vessels, their diameter and density. Localization of the bioactive auxin, namely, free IAA, was visualized by auxin-response element-*GUS* expression in the DR5 *Arabidopsis* transformant; while total auxin distribution, the sum of cytoplasmic free and conjugated IAA, by immunolocalization with specific monoclonal antibodies. Analysis of the youngest shoot region revealed a succession of auxin production events during leaf-primordium development, starting with *de novo* build-up of a massive bound-IAA pool in the youngest primordia before vascularization, and from this bound-IAA reservoir the free IAA is later released by hydrolysis. From the sites of free-IAA production in shoot organs, the auxin moves along the plant through three main transport pathways: (1) vascular tissues (preferentially via the cambium), (2) protective tissues (mainly through the phellogen), and (3) sieve tubes. The continuous polar auxin flow from leaves to roots through the cambium controls xylem and phloem formation, while the movement via the protective tissues induces phellogen activity and controls cork development. Free IAA (detected by *DR5:GUS* expression) moves via the vascular cambium in well developed *Arabidopsis* plants, preferentially between their differentiating vessels and sieve tubes, thus explaining the formation of radial patterns of secondary vessels and sieve tubes. The auxin acts as a morphogenetic signal, forming polar concentration gradients along plants from the free-IAA producing leaves to the root tips and inducing polar patterns of increasing vessel diameter and decreasing vessel density form leaves to roots. The importance of these findings for understanding vascular element patterns in the wood of forest trees will be discussed.

BRÄNDSTRÖM J.[1], RUEL K.[1], COCHAUX A.[2], J-P. JOSELEAU[1]: [1]CERMAV-CNRS, B.P. 53, 38 041 Grenoble cedex 9, France; [2]CTP, B.P. 251, 38 044 Grenoble cedex 9, France - **Cell wall ultrastructure of recycled pulp fibres** (Poster)

Recycled fibres are important as a raw material for the forest industry and their use is an essential part of a sustainable society. To develop the utilization of recovered Paper and to enhance products derived from recycled pulp, detailed knowledge on the micro- and ultrastructure of recycled pulp fibres is needed. We have used transmission electron microscopy (TEM) to study the chemical and morphological ultrastructure of fibres from reference pulps (well defined recycled soft- and hardwood chemical and mechanical pulps) as well as pulps produced from sorted urban waste Paper. The results have shown large differences in fibre ultrastructure, e.g. external and internal fibrillation, depending on pulp studied and treatment applied. Fibres originating from mechanical pulp are characterized by rather compact cell walls but these fibres often seem to improve their inter-fibre bonding abilities during recycling because of lignin hydration. Chemical pulp fibres, which tend to be well fibrillated as undried virgin pulps, often seem to become less flexible during recycling, due to cellulose microfibril coalescence, i.e. hornification. However, the phenomenon of microfibril coalescence is far from being homogenous, probably as an effect of uneven hemicellulose and lignin removal during pulping. The micro- and ultrastructure of recycled pulp fibres produced from sorted urban waste Paper is characterized by a large heterogeneity. Nevertheless, by combining ultrastructural observations with assessment of global fibre, pulp and Paper properties it is possible to evaluate recovered Paper grades and recycling procedures despite the large heterogeneity.

BRÄNDSTRÖM, J., FERNANDO D., HAFRÉN J., DANIEL G.: Wood Ultrastructure Research Centre, Dept. of Wood Science, Swedish University of Agricultural Sciences, Box 7008, SE 750 07 Uppsala, Sweden - **Tracheid ultrastructure of Norway spruce (*Picea abies* L. Karst.) wood and its influence on mechanical pulp and final Paper products** (Paper)

The manner of how wood fibres are treated during mechanical pulping and the properties of the final Paper products are dependent on the cell wall micro- and ultrastructure. Our studies have been focused on how tracheid ultrastructure affects properties such as fibrillation, light scattering, Paper smoothness and inter-fibre bonding. During refining, two major types of fibrillation have been found to occur. In both cases, fibrillation results from the initial cracking of the secondary cell wall along sites of weakness present in the cell wall and subsequent splitting along the orientation of cellulose microfibrils. Depending on crack initiation and propagation, the tracheids will have areas of the middle lamella, primary- and secondary cell wall exposed on the surface. Previously it has been shown that extractives, lignin, cellulose and hemicellulose are the major components determining fibre surface topochemistry, but we have also localised negatively charged pectic acids in compound middle lamellae areas on the pulp fibre surface, where it forms patches of presumably high negative charge. As fibre surfaces are important for fibre-fibre bonding in Paper, also minor changes in its chemical composition will affect final pulp and Paper properties. Detailed studies of compression wood tracheids have shown that these tracheids may collapse less readily than normal wood tracheids and thus contribute to the surface roughness of Paper based on mechanical pulp. In this respect, we have focused on the importance of the microfibril angle of the outer layer of the secondary cell wall (i.e. S1) since this layer is much thicker in compression wood tracheids than in tracheids of normal wood. The results have shown that the microfibril angle is higher and less variable in compression wood tracheids and this supports the hypothesis that compression wood tracheids have an adverse effect on the surface roughness of Paper products produced from mechanical pulps.

CHANG HUI-TING, CHANG SHANG-TZEN, SU YU-CHANG: School of Forestry and Resource Conservation, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan - **Influence of butyrylation on photostability of milled wood lignin** (Poster)

Photostabilization of butyrylated MWL was investigated. Chemical changes of MWL were confirmed by NMR and FTIR spectra after butyrylation. Improvements in photostability of MWL by butyrylation were evaluated by spectral analyses including ESR, FTIR and UV-VIS spectra. According to the data obtained from ESR analyses, butyrylation reduced the amount of phenoxyl free radicals of MWL after irradiation, and then inhibited the photooxidation of lignin followed by a significant decrease in the formation of coloured chromophores. The carbonyl, carboxyl and quinoid structures were less detected in the butyrylated MWL after irradiation than that of untreated MWL. The content of degradable water-soluble materials from the photodegradation of MWL was also reduced by the butyrylation.

CHANG SHANG-TZEN, CHENG SEN-SUNG, LIU JU-YUN, TSAI KUN-HSIEN, CHEN WEI-JUNE: School of Forestry and Resource Conservation, National Taiwan University, #1, Section 4, Roosevelt Rd., Taipei 106, Taiwan - **Chemical composition and mosquito larvicidal activity of essential oils from leaves of different *Cinnamomum osmophleum* provenances** (Poster)

Chemical compositions of leaf essential oils from eight provenances of indigenous cinnamon (*Cinnamomum osmophloeum* Kaneh.) were compared. According to GC-MS and cluster analyses these essential oils and their relative contents were classified into five chemotypes - cinnamaldehyde type, linalool type, camphor type, cinnamaldehyde/cinnamyl acetate type, and mixed type. In the larvicidal activities of leaf essential oils and their constituents from five chemotypes of indigenous cinnamon trees were evaluated by mosquito larvicidal assay. Results of larvicidal tests demonstrated that the leaf essential oils of cinnamaldehyde type and cinnamaldehyde/cinnamyl acetate type had an excellent inhibitory effect against the fourth instar larvae of *Aedes aegypti*. The LC_{50} values for cinnamaldehyde type and cinnamaldehyde/cinnamyl acetate type against *A. aegypti* larvae in 24 h were 36 ppm (LC_{90} = 79 ppm) and 44 ppm (LC_{90} = 85 ppm), respectively. Results of the 24-h mosquito larvicidal assays also showed that the effective constituents in leaf essential oils were cinnamaldehyde, eugenol, anethole and cinnamyl acetate and that the LC_{50} values of these constituents against *A. aegypti* larvae were below 50 ppm. Cinnamaldehyde had the best mosquito larvicidal activity with an LC_{50} of 29 ppm (LC_{90} = 48 ppm) against *A. aegypti*. Comparisons of mosquito larvicidal activity of cinnamaldehyde congeners revealed that cinnamaldehyde exhibited the strongest mosquito larvicidal activity.

CHU FANG-HUA[1], CHEN YU-RONG[1], LEE YI-RU[2], WANG SHENG-YANG[3], CHANG SHANG-TZEN[1], SHAW JEI-FU[2] : [1] School of Forestry and Resource Conservation, National Taiwan University, Taipei, Taiwan; [2] Institute of Botany, Academia Sinica, Nankang, Taipei, Taiwan; [3] Institute of BioAgricultural Sciences, Academia Sinica, Nankang, Taipei, Taiwan - **Establishment of expressed sequence tags from Taiwania (*Taiwania cryptomerioides* Hayata) seedling cDNA** (Poster)

Taiwania (*Taiwania cryptomerioides* Hayata), native to Taiwan, is one of the “living fossils” from the Tertiary period. To isolate genes involved in wood formation and biochemical synthesis from this tree, 436 randomly selected clones from a cDNA library derived from seedlings were sequenced and analyzed. Contig analysis of these expressed sequence tags (ESTs) identified a total of 246 unigene sets. Based on the results obtained by BLASTX analysis, 10.1% of these ESTs were involved in protein synthesis and processing, including highly expressed small heat shock proteins (smHSPs); 3.9% were related to the cell rescue and defense, including highly expressed cysteine proteinase inhibitors; 0.7% were involved in secondary metabolism. However, 39.0% of ESTs showed no significant similarity to any other protein sequences in public databases. These sequences indicate the uniqueness of Taiwania, and its remarkable value as a living fossil.

CLAIR BRUNO[1, 2], GRIL JOSEPH[2], BABA KEI'ICHI[1], THIBAUT BERNARD[2], SUGIYAMA JUNJI[1]: [1]Laboratory of Biomass Morphogenesis and Information, Research Institute for Sustainable Humanosphere, Kyoto University, Uji-Kyoto 611-0011, Japan; [2]Équipe Mécanique de l'Arbre et du Bois, Laboratoire de Mécanique et Génie Civil (LMGC), UMR 5508 CNRS - Université Montpellier 2, Place E. Bataillon, CC 048, 34095 Montpellier CDX 5, France - **Growth stresses at the cell wall level in poplar tension wood and its consequences on anatomical observations** (Paper)

Angiosperms generate high tensile stress in the upper side of the trunk or branches in order to keep the trunk upright or to maintain branches at a predetermined angle. This is called reaction wood and is characterised in some species by the presence of a peculiar gelatinous layer (G layer) in wood fibres. The G layer is dominated by cellulose microfibrils that are orientated along the fibre axis. Based on macroscopic investigations, the G layer has been suspected to be responsible for the high tensile stress of tension wood as well as high growth stresses in a living tree. In this study, the mechanical behaviour of the G-layer has been investigated at the cell wall level. Observations of strains after releasing the stress by sectioning have been precisely monitored. Surface strains were observed with atomic force microscopy (AFM) and strains along the fibre were observed by optical microscopy on serial sections made after embedding of samples. Both techniques clearly showed the high deformation of G layer compared to the adjacent layer, which suggests that *in situ* the G-layers were in a higher tensile state than the other cell wall layers. During sectioning, the release of stress affects the shape and the thickness of the G layer from the section surface to around 30 µm and can sometimes cause its detachment from other layers up to 100 µm. Then in classical microtomy (sections 10 - 20 µm thick), the G layer is always observed in a swelled condition and can appear detached. If it can be considered as an artefact for anatomical observation, the specific study of these deformations should provide some interesting information about the mechanical state of the layers and the structure of the G layer.

COCHARD HERVÉ[1], MAYR STEFAN[2], COUTAND CATHERINE[1], JERONIMIDIS GEORGE[3]: [1]UMR PIAF, INRA/UBP, Site de Crouelle, 63039 Clermont-Ferrand, France; [2]Institut f. Botanik, Universität Innsbruck, Sternwartestr. 15, A-6020, Innsbruck, Austria; [3]Composite Materials Engineering, Reading University, Whiteknights, Reading RG6 2AY, U.K. - **Xylem wall collapse and cavitation in *Pinus* spp.** (Paper)

Wall reinforcement in xylem conduits is thought to prevent wall implosion by negative pressures but direct observations of xylem geometry during water stress are still largely lacking. In this study we have analyzed the changes in xylem geometry during water stress in needles of four pine species (*Pinus* spp.). Dehydrated needles were frozen with liquid nitrogen and xylem cross sections observed, still frozen, with a cryo-SEM and an epifluorescent microscope. Decrease in xylem pressure during drought provoked a progressive collapse of tracheids below a specific threshold pressure (Pcollapse) that correlates with the onset of cavitation in the stems. Pcollapse was more negative for species with smaller tracheid diameter and thicker walls suggesting a tradeoff between xylem efficiency, xylem vulnerability to collapse and the cost of wall stiffening. Upon severe dehydration, tracheid walls were completely collapsed but lumina still appeared filled with sap. When dehydration proceeded further tracheids embolised and walls relaxed. Wall collapse in dehydrated needles was rapidly reversed upon rehydration. A modeling approach was developed to predict wall deformation upon exposure to negative xylem pressure. The model is based on an explicit anatomical description of pine needle vascular bundles. We discuss the implications of this novel hydraulic trait on the xylem function and on the understanding of pine water relations.

DOMEC JEAN-CHRISTOPHE, PRUYN M.L., GARTNER B.L.: Department of Wood Science and Engineering, Oregon State University, Corvallis, OR 97331 USA - **Axial and radial profiles in xylem conductivity, water storage and native embolism in young and old-growth ponderosa pine trees** (Paper)

Our first objective was to quantify effects of tree age and stem position on axial and radial specific conductivity (ks) native trunk embolism, in trunks of young and old-growth ponderosa pine (*Pinus ponderosa* Dougl. ex Laws). Our second objective was to determine the compartmentalization of sapwood water storage in old-growth trees. By felling or climbing mature trees, we obtained detailed radial and vertical profiles describing variation in ks, native embolism and RWC (relative water content), and we estimated trunk water potential (Y). Young trees had a lower ks and a lower rate of native embolism (corresponding to 5 PLC, % loss of conductivity) than anywhere in the trunk of the old-growth trees. Within sapwood at all heights in the old-growth trees, outer sapwood had 25-50% higher native ks than inner sapwood, but there was no significant difference in native embolism between the outer, middle and inner sapwood. These results suggested that refilling of embolisms was completed despite the 140-years difference in wood age among these radial positions. Native embolism in old-growth trees was lower at the base of the trees (about 14 PLC) but was higher in the crown wood, with embolism increasing from 17 PLC in the outer to 25 PLC in the inner sapwood. Within the old-growth trees, the base had a 5% higher daily change in RWC and had 5-10 % less native embolism than the top. Although during the dry season the inner sapwood tended to be even more saturated than the outer sapwood, the outer part of the sapwood (that represented 40% of the sapwood volume) contributed to more than 55% of the overall stored water.

DOMEC J-C, MEINZER F.C, GARTNER B.L., WOODRUFF D.: Department of Wood Science and Engineering, Oregon State University, Corvallis, OR 97331 USA - **Transpiration-induced axial and radial tension gradients within the trunk of Douglas-fir trees** (Poster)

The aim of this study was to estimate in situ axial and radial tension gradients in trunks of Douglas-fir trees based on radial profiles of sap flux density (Js) and xylem specific hydraulic conductivity (ks). Heat balance probes were used to determine daily time courses of Js at four radial depths in the trunks of 24-yr-old trees, which were subsequently felled to obtain samples of sapwood for determination of axial ks at the same locations where Js was measured. Radial ks was determined on wood cores extracted near the locations where Js and axial ks were measured. Tension gradients were estimated from the ratios of Js to ks. Relationships between Js and ks were non-linear, resulting in non-uniform axial and radial tension gradients from outer to inner sapwood. Axial tension gradients ranged from 0.007 to 0.01 MPa m-1 and were 50% higher in the outer sapwood than in the inner sapwood. Radial tension gradients ranged from 0.15 to 0.23 MPa m-1 and were lower in the middle sapwood than in the inner or outer sapwood. The calculated radial Js based on radial tension gradients and measured radial ks was about 100 times smaller than the axial Js.

EL BALKALI IDRISS, GEORGE BEATRICE, MERLIN ANDRÉ, DEGLISE XAVIER: LERMAB (Joint research unit on wood material) UMR INRA 1093, Université Henri Poincaré, Nancy 1, B.P. 239 54506 Vandoeuvre les Nancy cedex, France - **Durability of natural colour of different wood species under solar type exposure** (Paper)

For joinery applications, the use of wood covered by a clear finish depends strongly on the quality and durability of its surface. During weathering in outdoor conditions and mainly because of the action of the sun, wood colour is modified with varying rates according to the wood species of concern. The natural colour of a large range of wood species from various origins was measured, using the CIEL*a*b* system. European woods are lighter in colour than African species. Those from Asia or America are intermediate. Clear woods have the strongest colour variation: decreasing of lightness and increasing of yellowing. The variety of coloured aspects of woods which are to be linked to the specific extractives they contained is discussed by considering their origin. The exposure of wood samples to sunlight in an accelerated weather-o-meter allows us to characterise the durability of their natural colour. The relationship between colour stability and extractive content as measured from the extraction yield according to the ASE process is then discussed. In order to stabilise colour of wood samples of poor durability, we impregnated them with substances extracted from woods which are characterised by higher colour stability. We have then studied their behaviour during weathering when they are subjected to an exposure to sunlight.

FRANKENSTEIN C.[1], SCHMITT U.[2]: [1]University of Hamburg; [2]Federal Research Centre for Forestry and Forest Products, Leuschnerstr. 91, 21031 Hamburg, Germany - **Wound callus formation in poplar (*Populus tremula* L. x *Populus tremuloides* Michx.) a microscopic study** (Paper)

Callus formation after mechanical wounding of poplar trees was examined by light and transmission electron microscopy. Wounds of 5 x 10 cm² were set at the end of May with weekly or fortnightly sampling at the lateral wound edges. The maximum response period was ten weeks. The experiments were carried out in 2002 with four trees, each of them with eight wounds. Microscopy revealed two strategies until a typical lateral wound callus subdivided into xylem, cambium and phloem has developed. The first strategy is characterized by the following four steps: (1) formation of a uniform parenchymatous tissue at the wound edge by division of cambium as well as undifferentiated xylem and phloem cells; (2) formation of a wound cambium within this parenchymatous zone as a tangential continuation of the undisturbed cambium further away from the wound; (3) deposition of strictly radially orientated xylem and phloem cells by the new wound cambium; (4) formation of additional cambial cells along the lateral side of the wound, which then forms tissue continuously covering the wound. The second strategy can be subdivided into three developmental steps: (1) formation of parenchymatous cells at the wound edge; (2) formation of a wound cambium within the differentiated phloem tissue, semicircular in outline and including parts of differentiated phloem; (3) formation of xylem and phloem cells by the wound cambium with preferred deposition of cells towards the wound surface. Both strategies may occur simultaneously in the same tree or even in different segments of one wound.

GARTNER BARBARA L.[1], DOMEC JEAN-CHRISTOPHE[1], MEINZER FREDERICK C.[2], WOODRUFF DAVID[3]: [1]Department of Wood Science and Engineering, Oregon State University, Corvallis, OR 97331, USA; [2]USDA Forest Service, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331 USA; [3]Department of Forest Science, Oregon State University, Corvallis, OR 97331, USA - **Gradients of xylem water tension across Douglas-fir trunks: deducing patterns and causes** (Paper)

It is often assumed that the tension gradient in the stem xylem is the same at all radial depths. In this research we used patterns of sap flux during transpiration (J_s) and specific conductivity of excised wood segments (k_s) to show that xylem tension gradients must differ substantially across the radius. The J_s at any point is a function of both k_s (the water flux that occurs per tension gradient) and the driving force (the tension gradient). Therefore, the axial xylem tension gradient is J_s / k_s. Radial tension gradients can be calculated from adjacent axial tension gradients. Axial k_s and J_s, and radial k_s were measured at consecutive depths at the same heights within the sapwood of four individuals of 24-year-old Douglas-fir trees. A) The mean values of J_s declined about linearly from the outer to the inner sapwood. In contrast, axial k_s was relatively flat across the outer sapwood, and then fell rapidly in the middle and inner sapwood. The value J_s / k_s showed that axial xylem tension gradients were about 0.01 MPa m^{-1} in the outer sapwood, and declined to half that value in inner sapwood. Therefore, there is a substantial difference in xylem tension across the radius during transpiration. B) Axial k_s appeared to be controlled largely by resistance caused by pits rather than by frictional loss to the cell wall itself, as seen by the stronger correlation of axial k_s with tracheid length than with tracheid diameter (r^2 = 0.76 vs. 0.49). The interpretation is that longer tracheids have higher k_s because water has to flow through pits less frequently per axial distance traveled. C) Tension gradients were 25 times higher in the radial than axial direction, but because the radial k_s was only 1/2500 times the axial k_s, the calculated radial J_s is only about 0.01 times the measured axial J_s. It is still unknown by what pathways the water flows in the radial direction. Cells are 100 times longer than wide, which explains very little of the 2500-fold difference in axial and radial k_s.

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The aim of this study was to obtain information about the relationships between wood and fibre properties and growth rate controlled by thinning. The study is related to larger research consortium (Optimization of the quantity and quality of wood raw material in forest management and industrial processes, PURO). The results of this study will be used to model relationships of stem and wood properties and their distribution along the stem. To investigate the effects of different thinning intensities on tree growth and wood properties in Norway spruce (*Picea abies* (L.) Karst.), 24 sample trees were harvested in thinning experiments in southeastern Finland in Heinola (61°10'N, 26°01'E) and Punkaharju (61°49'N, 29°19'E). Thinning intensities were low, normal and high (i.e. stand basal area after the thinning was 40, 30 and 20$m^{-2}ha^{-1}$, respectively). The experiments have already been studied for 30 years and they approach maturity. This gives us an opportunity to investigate total volume production and thinning removal, as well as wood properties, during the whole stand rotation. The sample discs were taken at breast height (1.3 m) and at 12 m on the stem for the X-ray densitometry analysis to measure basal area increment, earlywood-latewood ratio and wood density. Fibre length, cell wall thickness, lumen diameter, and cross-sectional cell shape were also studied at breast height with image analysis on thin sections. In Heinola, normal and high thinning intensities increased the growth rate and decreased fibre length compared to low thinning intensity. The effect of thinning on earlywood-latewood ratio and mean wood density were low. In Punkaharju, the normal and high thinning intensity slightly increased growth rate, but more clearly increased earlywood-latewood ratio, whereas the effect on mean density and fibre length were small.

KIM SOO YOON[1], LEE HO KWANG[1], SINGH ADYA[2], BEETS PETER[2]: [1]Dept. of Forest Products & Technology, Chonnam National University, Gwangju, Korea; [2]New Zealand Forest Research Ltd., Rotorua, New Zealand - **Ultrastructural characteristics of *Pinus radiata* affected by frost** (Paper)

Frost rings are known to develop in response to an abrupt drop in temperature to below zero during the growing season due to factors such as early or late frost or volcanic eruptions. Frost-rings have been studied mainly from dendrochronological aspects to obtain the information on climatic conditions of the past. Not much is known about the features of cells that comprise frost-rings beyond the knowledge that cells are abnormal in their form, tend to collapse and stray from the normal course of linear files characteristic of normal wood. This investigation was undertaken to understand the structural abnormalities in wood cells which developed in tissues within the frost-ring of *Pinus radiata* at Whakarewa forests in Rotorua, New Zealand from normal wood by light microscopy (LM) and transmission electron microscopy (TEM). LM showed that the cells in the frost ring were thin, displaying varying degrees of collapse. TEM micrographs show that cell walls in the frost-ring did not have compact textures and stained uniformly with potassium permanganate. The walls affected had irregular contours and were highly porous in some cells. Middle lamella in the frost-ring areas was poorly developed. TEM observation suggested strongly that freezing temperature brings about pronounced modifications in cell wall content and composition. The effect of freezing temperature stress on physical and mechanical properties of cell wall will be discussed.

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According to the definition in the IAWA list of microscopic features for hardwood identification, disjunctive parenchyma cells are axial or radial parenchyma cells partially disjoined but with contacts maintained through tubular or complex wall processes. Disjunctive wood parenchyma cells can apparently be seen in some species of the *Sophora* group (Fabaceae), and appear to occur in many tropical hardwoods. However, there are no detailed studies on the morphology of disjunctive parenchyma cells and on the ontogeny of xylem with such cells. It is not easy to detect disjunctive cell walls by conventional light microscopy in histological sections and their occurrence might be overlooked. By contrast, disjunctive cells can be clearly visualized by scanning electron microscopy (SEM) and by laser scanning confocal microscopy (CLSM). In this work, we investigated the three-dimensional (3-D) structure of xylem in several tropical hardwoods with disjunctive parenchyma cells by conventional light microscopy, CLSM, and SEM. We hoped that a detailed anatomical analysis would reveal the structure of disjunctive cells and give us clues to understand the pattern of development of the tubular cell extensions and the factors that trigger their formation. The disjunctive parenchyma cells had various arrangements in the xylem of different species and they could occur in the ray parenchyma, or among the apotracheal parenchyma within libriform fibres, and also among the paratracheal parenchyma around vessels. Such arrangements suggest that the walls of adjacent parenchyma cells become disjunctive and form tubular processes during the growth of fibres and vessels. The tubules had lignified multilayered secondary walls, and simple pits at the points where one cell contacts a tubule of another cell. The axial and ray parenchyma with disjunctive cell walls formed a common parenchyma network via protoplasmic connections through the tubular processes.

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The water pathways in wood, such as vessel networks and individual vessel elements, intervessel and intertracheid connections via bordered pits, and intercellular spaces, were investigated in *Machilus thunbergii, Populus alba, Fraxinus lanuginosa, Quercus mongolica, Kalopanax pictus,* and *Cryptomeria japonica*. Resin-casting with the application of polystyrene or low density polyethylene, and SEM were used to visualize the three-dimensional structure (3-D) and arrangements of vessels, vessel element morphology, 3-D structure of pits, and intercellular spaces. Arrangements of vessels and tracheids and occurrence of intervessel or intertracheid pits were also visualized by laser scanning confocal microscopy (CLSM). The structure and arrangements of water conducting cells and passages were specific for each species but it could be generalized that frequent intervessel pit connections, or tangential pitting of tracheids, at the growth ring boundaries provide the main pathway for transfer of water from latewood of one growth ring to earlywood of the next growth ring.

KOSTIAINEN KATRI[1], KAAKINEN SEIJA[1], EK FREDRIK[2], VAPAAVUORI ELINA[1], SIGURDSSON BJARNI D.[4], LINDER SUNE[3], KUBISKE MARK E.[5], SOBER JAAK[6], KARNOSKY DAVID F.[6], SARANPÄÄ PEKKA[2]: [1]Finnish Forest Research Institute (METLA), Suonenjoki Research Station, FIN-77600, Suonenjoki, Finland; [2]Finnish Forest Research Institute (METLA), Vantaa Research Centre, PO Box 18, FIN-01301 Vantaa, Finland; [3]Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences, P.O. Box 49, SE-230 53 Alnarp, Sweden; [4]Icelandic Forest Research, Mogilsa, IS-116, Reykjavik, Iceland; [5]USDA Forest Service, North Central Research Station, Forestry Sciences Laboratory, 5985 Highway K, Rhinelander, WI 54501 USA; [6]School of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI 49931, USA - **Does climate change affect the wood structure and chemistry of Norway spruce (*Picea abies* (L). Karst.) and trembling aspen (*Populus tremuloides* Michx.)?** (Paper)

The effects of fertilisation and elevated CO_2 on growth rate and wood structure (fibre dimensions) and wood chemistry of Norway spruce were studied from a long-term nutrient-optimisation experiment in Flakaliden, northern Sweden (64°07' N, 19°27' E, alt. 310 m). The experiment was established in 1987 in a 28-year-old stand. The amount and composition of the nutrient addition was determined each year on the basis of nutrient analysis of foliage, the monitoring of nutrients in the soil water and predicted growth response. Altogether 12 trees from irrigated-fertilised plots and 12 control trees from untreated plots were selected for analysis of wood properties, after 12 years treatment. In addition, in summer 1996, 12 whole-tree chambers were installed at Flakaliden. The main aim of the chambers was to study the effects of elevated CO_2. In a second study, the effects of elevated [CO_2] and [O_3] and their interaction on wood chemistry and anatomy of five clones of 3-year-old trembling aspen (*Populus tremuloides* Michx.) were studied from the Aspen Free-Air CO_2 Enrichment (FACE) experiment in Rhinelander, Wisconsin, USA, where the saplings had been exposed to four treatments: control (C; ambient CO_2, ambient O_3), elevated carbon dioxide (CO_2; 560 ppm during daylight hours), elevated ozone (O_3; 1.5x ambient during daylight hours) and their combination ($CO_2 + O_3$) for three growing seasons (1998-2000). The fertilised Norway spruce trees had shorter and thinner-walled fibres than the control trees. The concentration of lignin was 7% higher in fertilised trees compared to control trees. Elevated CO_2 had only minor effects on mature wood properties of spruce while nutrient optimisation had more marked effects and thus may affect ecosystem processes and suitability of wood for different end-use purposes. In juvenile wood of aspen, elevated O_3 induced statistically significant reductions in diameter growth and vessel lumen diameter, as well as increased cell wall thickness and wall percentage, and in one clone, a decreased fibre lumen diameter. The lignin concentration increased under elevated O_3 in four clones of aspen. However, elevated CO_2 ameliorated the effect.

LIU SHENGQUAN[1], GRIL JOSEPH[2], THIBAUT BERNARD[2]: [1]Lab. of Wood Science & Technology, Forest Utilization College of Anhui Agricultural University, CHINA; [2]Laboratoire de Mécanique et Génie Civil (UMR CNRS 5508) of Montpellier University 2, FRANCE - **Studies on wood density variations of plantation poplar 69 (*Populus deltoides CV. I-69/55*) in China** (Paper)

In the study, 6 trees of plantation poplar 69 (*Populus deltoides CV. I-69/55*), growing in the forest centre in the suburb of Tianchang city, Anhui Province of China were selected as material. The radial and axial variation of wood density, earlywood density (DEW), latewood density (DLW) and relative wood density (Dmax-Dmin and DLW-DEW) within a tree and among the trees was studied using microdensitomitry methods. We found that the tree effect on wood density is very significant, but earlywood density and latewood density. For 6 poplar trees, the height effects on wood density are different. The height effect on wood density is significant in tree 1, tree 2 and tree 6, but other trees. A similar difference occurred in earlywood density and latewood density. Also, there are large differences for radial variation patterns of wood density in 6 trees. In general, it has two kinds of patterns like increasing from pith to bark and decreasing outward at different heights. This radial variation pattern similarly occurs in the relative wood density (Dmax-Dmin and DLW-DEW). Moreover, the axial variation of wood density in 6 poplar trees has the same variation patterns. It indicates that the wood density of poplar in the bottom (below 2m) is lower than that in the top (4m to 6m). This axial variation patterns similarly occurs in earlywood density and latewood density. It shows that the latewood density increases form the bottom to the top eventually; Relative density Dmax-Dmin increases roughly with the height of the tree between the 8th and 13th year. Between first and 8th year, we can see that relative density fluctuates a lot in this area. But for the difference between Latewood density and Earlywood density, height seems not to affect DLW-DEW except for heights of 0.3m and 6m, from the 5th to the 13th year. Finally, the inter-ring variation of wood density in different ages has the general variation pattern. It increases from earlywood to latewood eventually. It also clearly shows that there are large fluctuations for wood density in young ages like from 1th to 5th year in 6 poplar trees.

MATON CLARISSE[1, 2], **GARTNER BARBARA L.**[2]: [1]Institut National Agronomique Paris-Grignon, 16 rue Claude Bernard, 75 231 Paris Cedex 05, France; [2]Department of Wood Science and Engineering, Oregon State University, Corvallis, OR 97331, USA - **Longevity of the needle-to-stem xylem connections in conifers: patterns and potential causes** (Paper)

The scanty literature suggests that needle traces of evergreen conifers typically make connections annually with the newly made stem xylem, and then break the connections with the previous year's annual ring. The goal of this research was to census numerous species to learn how universal this ‘typical’ pattern is, and to explore possible causes of the observed pattern in one species. The study's context was to better understand the spatial use of sapwood for water transport. First we applied a vacuum to the distal end of the needle's cut surface, placing the stem base into a vat of aqueous stain. We then recorded through which annual ring(s) the stain flowed in the stem. The vacuum was applied to either 1- or 2-year old foliage taken from 4-6-year-old saplings of 16 species from a tree nursery. Species varied greatly in their patterns. For example, when the vacuum was applied through 2-year-old needles, stain moved most frequently through the 2-year-old ring for four species, through the 1-year-old ring for four species, through the current year's ring for three species, and with too much variability for classification for three species. Secondly because we assume that needles fall off a stem after their water source has been disconnected, we studied whether needle fall was more closely related to the age of the stem or to the stem's diameter to infer controls over needle trace connection. There appeared to be a threshold stem diameter at which needles were shed, and needle fall was more related to diameter than age in 5-year-old *Pseudotsuga menziesii* saplings. This suggests that the needle trace longevity is limited by the rate at which it can increase in length, but more research is needed to learn the universality of this result. The overall study shows that there are numerous and species-specific patterns of how long leaves are able to pull water through different rings. These patterns may affect both the physiology of different needle cohorts and the radial pattern of water flux in sapwood. More work is needed on the phloem connections to learn whether the phloem or the xylem connections drive the observed patterns.

MILLER REGIS B., **WIEMANN MICHAEL**: USDA Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726-2398, USA - **Separating the species of rosewood (*Dalbergia*): Is it possible?** (Paper)

Species of genuine rosewood belong to the pantropical genus *Dalbergia* (Leguminosae-Papilionoideae). According to ILDIS, there are 130 species of trees, shrubs and lianas. Several tree species are commercially important for musical instruments and fine furniture including African blackwood (*D. melanoxylon*), Indian rosewood (*D. latifolia*) Honduras rosewood (*D. stevensonii*), cocobolo (*D. retusa*), Brazilian rosewood (*D. nigra*) and several others. The heartwood of *Dalbergia* typically is hard, heavy, dark coloured and highly variegated. It generally has storied homocellular rays that are one to three cells wide and relatively short, large vestured pits, nonseptate fibres, and an abundance of axial parenchyma in various combinations of banded, diffuse-in-aggregate, aliform and confluent. For the most part the genus can be separated from its close relatives like *Pterocarpus* and *Machaerium*, but the individual species within the genus cannot be identified, even grouping species is not practical. However, if we limit the species to only commercially important species and we know the country of origin, it is possible to identify some of the commercial species. Since CITES added Brazilian rosewood (*D. nigra*) to Appendix I, it has become even more important to find methods to separate the commercial species of rosewood especially those from Brazil. Although there are 13 tree species of *Dalbergia* in Brazil, there are only five commercial species: kingwood (*D. cearensis*), tulipwood (*D. decipularis & D. frutescens*), Amazon rosewood (*D. spruceana*), and Brazilian rosewood (*D. nigra*). Kingwood and tulipwood can be separated using several characters, but *D. spruceana* and *D. nigra* are difficult to separate. To separate these two species we measured the density (6% MC) and fluorescence of 13 specimens. The mean density of *D. spruceana* is 1016 kg/m^3 and of *D. nigra* it is 855 kg/m^3. The surface fluorescence is negative for all, but the water extract fluorescence is negative for *D. nigra* and blue for *D. spruceana*. In addition the ethanol fluorescence is green-blue for *D. nigra* and blue for *D. spruceana*. These three characters used in combination accurately separate these two species of rosewood.

NILSSON THOMAS, BJÖRDAL CHARLOTTE: Department of Wood Science, Swedish University of Agricultural Sciences, Uppsala, Sweden - **Using wood-degrading bacteria as tools in studies on wood fibre structures** (Paper)

In an on-going European project, BACPOLES, we have produced several enrichment cultures of wood-degrading bacteria from samples of archaeological wood and pilings of wooden foundations. The bacteria have not yet been identified. The morphology of the bacteria and the variation in mode of cellulose attack suggest that several species of bacteria have been cultured. Each enrichment culture, however, seems to contain just one species of active bacteria. The bacteria attach to the cellulose microfibrils and degrade the wood fibres by forming grooves in the fibre surface. The patterns created by the grooves reflect the orientation of the cellulose microfibrils in the layer attacked. Thus, visual information on cellulose microfibril orientation can be gained by exposing various fibres to the bacteria. The fibres may be in the form of solid wood, but if information of the outermost fibre layers is required, delignified or pulped fibres should be used. There is no need for a delignification process, since the bacteria are capable of degrading lignified fibres. Results for a number of fibres will be reported.

PERRÉ PATRICK, RÉMOND ROMAIN, PASSARD JOËLLE: LERMAB (Joint research unit on wood material) UMR INRA 1093, ENGREF (School of Forestry), 14, rue Girardet, 54 042 Nancy cedex, France - **Heat and mass transfer and creep mechanisms in wood as an engineering material: a comprehensive computational model able to link theory and practice** (Paper)

Understanding the mechanical behaviour of wood is essential to analyse industrial operations or in-use behaviour of wooden products. Because mechanical behaviour strongly depends on temperature and moisture content levels, the intricate coupling between heat and mass transfer and mechanical aspects has to be considered to achieve this goal. The drying operation is complex, and the most sophisticated models are therefore found in this domain. Nowadays, a comprehensive approach is usual (species characterisation, physical formulation, mathematical modelling, computational simulation and model validation), and the computational model is a tool that is now used not only to improve existing procedures but also to imagine and tune innovative processes. This Paper proposes a comprehensive formulation regarding the physical and mechanical aspects, which has been simplified concerning the geometrical aspects. Actually, a clever 1-D formulation has been derived, which allows symmetrical or non-symmetrical configurations to be computed. The resulting computational time is surprisingly low (around one second per simulation). Two examples of applications are given, demonstrating the potential of this tool: (1) Formation of wood: a piece of wood is heated keeping a high level of moisture content, bent and subsequently dried. The effect of temperature level on stresses and recovery part is analysed and (2) Dimensional changes of an in-use wooden piece due to climatic changes. The deformation level is depicted as a function of the piece thickness.

PERRÉ PATRICK: LERMAB (Joint research unit on wood material) UMR INRA 1093, ENGREF (School of Forestry), 14, rue Girardet, 54 042 Nancy cedex, France - **Homogenisation as a new approach to explain the anisotropy of wood shrinkage in the transverse plane: the cumulative effect of the ultrastructure and the cell morphology** (Paper)

Several explanations are available in the literature to explain why wood shrinkage is anisotropic in the transverse plane: effect of ray cells, difference between radial and tangential cell walls, alternation of earlywood and latewood. However, none of these explanations are in agreement with all the experimental observations. A new approach is proposed in this Paper. The shrinkage coefficient is a prediction from the microstructure of wood using homogenisation techniques. This approach requires three main stages: (1) characterisation: the local shrinkage, at the cell wall level, is determined by careful experiments using an environmental scanning electron microscope (ESEM), (2) representation: the morphology of the cellular structure of wood is defined thanks to a Finite Element mesh directly built from digital images of the real structure of the wood. The software *MeshPore*, developed by the author, is used for this purpose, and (3) homogenisation: from the two previous pieces of information, the so-called macroscopic shrinkage values are computed using a computational code named *MorphoPore*, developed by the author. Two examples are depicted in this Paper, earlywood and latewood of Spruce (*Picea abies*). The predicted shrinkage anisotropy is in agreement with the experimental data. Thanks to the deterministic approach, we can state that the local anisotropy behaviour of the cell wall properties together with the cell arrangement resulting from the cambial activity are responsible for the macroscopic behaviour of the tissue.

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Oulu, Measurement and Sensor Laboratory, Teknologiapuisto 127, FIN-87400 Kajaani, Finland - **The effect of site and fertilisation on tracheid dimensions of Norway spruce** (Poster)

Cell size and wall thickness directly influence the physical properties of wood. The general pattern of variations in fibre dimensions of conifers is well known. Differences in cell dimensions reflect the changes occurring in the cambium during maturation, but can also be affected by silvicultural treatments, like fertilisation. In this study the purpose is to find out whether fertilisation increases growth rate and leads to smaller, thin-walled fibres. The effect of fertilisation on the anatomical properties of Finnish Norway spruce (*Picea abies* (L.) Karsten) will be studied at two experimental sites, Heinola, in southern Finland, and Kemijärvi, in northern Finland. The average annual temperature sums for Heinola and Kemijärvi are 1250 and 700 degreedays, respectively. In both experiments, fertilisation has been conducted at five year intervals since 1961. In 2002 five randomly selected trees from fertilised and control blocks at both sites were selected and felled. Sample disks were taken at breast height. Transverse sections (thickness 16 µm) were cut with a cryomicrotome and stained with safranin. The fibre dimensions will be measured from the pith to the cambium at five year intervals from the growth rings. The diameter and cell wall thickness of the fibres will be measured with a novel laser-aided technique. A round Ne-He laser-light spot will be projected through the transverse wood section. A CCD-Camera will be used to record the transmitted diffraction pattern, from which the average cell wall thickness and diameter of the tracheids will be determined. The purpose is to measure changes in tracheid dimensions within the growth rings by moving the sample in the beam. The aim of the study is to develop and apply a new, less laborious method to measure the dimensions of tracheids.

ROSNER SABINE[1], WIMMER RUPERT[2]: [1]Institute of Botany, Department of Integrative Biology, University of Natural Resources and Applied Life Sciences, Vienna, Gregor Mendel-Strasse 33, 1180 Vienna, Austria; [2]Institute of Wood Science and Technology, Department of Material Sciences and Process Engineering, University of Natural Resources and Applied Life Sciences, Vienna, Peter Jordan Str. 82, 1180 Vienna, Austria - **Wood growth and quality traits influencing hydraulic and mechanical properties of young Norway spruce clones** (Poster)

Stem segments of Norway spruce (*Picea abies* L. Karst.) clones (field age 4-5) were tested for their behaviour under mechanical stress, for their specific hydraulic conductivity (k_s) and vulnerability to drought stress. Vulnerability to drought was measured as the pressure treatment necessary to result in 50 % loss of conductivity (PLC50) and as the percent loss of conductivity at 4 MPa pressure application (PLC_{4MPa}). Growth traits investigated were total dry biomass, tree height and stem diameter; quality traits were grain angle, basic density, percent of compression wood of the transverse cut face, ring width, percent of late wood, lumen diameter and wall thickness of early wood cells, and fibre length. The clones showed significant differences in their hydraulic efficiency, vulnerability to drought, and in their mechanical properties, such as the bending strength and stiffness (MOE_b) and the axial compression strength and stiffness (MOE_a). High flow rate at full saturation and low vulnerability to drought were not conflicting processes with some clones, indicated by the rather weak positive correlation between PLC_{4MPa} and k_s ($R^2 = 0.15$). Hydraulic and mechanical behaviour were found to be determined by wood growth and quality traits different from each other. Variation in k_s could be explained to 98% by a regression model based on ring width and grain angle, other important determining traits (or vice-versa) were total dry biomass, tree height, lumen diameter, fibre length and late wood percentage. Traits found to influence vulnerability to drought (PLC_{4MPa}) negatively were high biomass production and big stem diameters ($R^2 < 0.4$). More than 80% of MOE_a variation could be expressed by variation of basic density solely.

RUELLE JULIEN[1], BEAUCHENE JACQUES[2], THIBAUT ANNE[2], THIBAUT BERNARD[3]: [1]CIRAD/Université Antilles Guyane, Cayenne, France; [2]CIRAD, Kourou, France; [3]CNRS, Cayenne, France - **Some features of tension wood anatomy compared with normal wood for six tropical species** (Paper)

In order to investigate different features of tension wood, six species from Guyanese tropical forest were investigated in the genera *Laetia, Eperua, Carapa, Simarouba, Ocotea and Miconia.* Young mature trees exhibiting a characteristic schedule of verticality restoration were selected for each species. In situ growth stresses at the stem periphery were measured at eight circumferential positions, to assess the effective mechanical reaction by the existence of a peak of very high tensile stresses in a sector whose amplitude was generally around 90° and qualified as tension wood. The zones where growth stresses were in the more frequent range where considered as normal wood. Wood specimens were cut in the vicinity of the growth stress measurements in order to measure some mechanical and physical properties and to look at anatomical differences between tension and normal wood. As suspected, tensile growth stress was very much higher in tension wood zone, because longitudinal modulus of elasticity was slightly higher. Longitudinal shrinkage was also much higher in tension wood than in normal or opposite wood, thus this was a complementary parameter to verify that the wooden specimen was really in the tension wood sector. Specimens from two zones of tension wood and normal wood (4 in total per tree) were selected as representative of each type of wood. Vessel frequency was lower in tension wood compared to normal wood, as found between tension wood and opposite wood in other studies. The very high differences in longitudinal growth stress and shrinkage should come from differences in fibres between the two types. Surprisingly, in one species no clear difference can be observed between tension and normal wood fibres. Two species have classical tension wood with G layer fibres. One has a very peculiar multilayered pattern for the secondary wall and the two other have only small differences in fibre geometry and apparent chemical composition. Estimation of mean microfibril angle show differences between the two types of wood. More investigation should be done at the nanoscale level in order to explain the very specific longitudinal behaviour of tension wood, using fibre wall mechanical models.

SCHIMLECK L.R.[1], JONES P.D.[1], DANIELS R.F.[1], PETER G.F.[2], EVANS R.[3], CLARK A.[4], STÜRZENBECHER R.[5], MORA C.[6]: [1]Warnell School of Forest Resources, University of Georgia, Athens GA, 30605, U.S.A.; [2]School of Forest Resources and Conservation, University of Florida, Gainesville, FL, 32611, U.S.A.; [3]CSIRO Forestry and Forest Products, Private Bag 10, Clayton South MDC, Victoria, 3169, Australia; [4]USDA Forest Service, Southern Research Station, Athens, GA 30602, U.S.A.; [5]University of Applied Sciences for Forest Products Technology and Management, Markt 136, A-5431 Kuchl, Austria; [6]Department of Forestry, North Carolina State University, Raleigh, NC, 27695, U.S.A. - **Nondestructive estimation of wood properties of *Pinus taeda* radial wood strips by near infrared spectroscopy** (Paper)

Recently, at the University of Georgia, several experiments have been conducted to investigate the ability of near infrared (NIR) spectroscopy to rapidly estimate the wood properties of *Pinus taeda* L. (loblolly pine). Research has focussed on developing wood property calibrations using large sample sets of diverse origin; developing wood property calibrations using NIR spectra collected from green wood; comparing wood property calibrations developed using NIR spectra collected from the radial-longitudinal and transverse surfaces of matching radial wooden strips; and developing wood property calibrations using NIR spectra having decreased spectral resolution. This Paper will briefly describe the findings of each experiment.

SINGH ADYA[1], DAWSON BERNARD[1], SCHMITT UWE[2], KIM YOON SOO[3]: [1]New Zealand Forest Research Institute Limited, Rotorua, New Zealand; [2]Bundesforschungsanstalt für Forst-und Holzwirtschaft (BFH), Hamburg, Germany; [3]Department of Forest Products and Technology, Chonnam National University, Gwangju, Republic of Korea **- The role of confocoal microscopy in understanding wood-coating interaction** (Paper)

The use of confocal laser scanning microscopy (CLSM) was evaluated as a novel tool in understanding wood-coating interaction using clear coatings and radiata pine (*Pinus radiata*) as the substrate. In the first set of experiments, polyurethane-based clear varnish was applied to kiln-dried sapwood radiata panels. Using combined CLSM and light microscopy (LM) this wood-polymer composite system was examined in order to understand the wood-coating interface, and the coating penetration into the underlying wood tissues. In the second set of experiments, designed to enhance coating penetration into radiata wood through ponding, the effect of ponding on coating penetration was studied using a resin primer. The depth of coating penetration was examined by LM and scanning electron microscopy (SEM). Bacterial colonisation of wood cells and pit membranes was examined by CLSM and SEM and bacterial colonisation and degradation of pit membranes was studied by transmission electron microscopy (TEM). In the first set, sliding-microtome cut sections of the wood-polymer composite were first examined by LM after staining sequentially with toluidine blue and Sudan IV to enhance the contrast of wood cell walls and the coating respectively. The same sections were then examined by CLSM in order to make a direct comparison of the two microscopy techniques used for their value in examining the wood-coating interface. Confocal fluorescence images were acquired using an argon/krypton laser with excitation wavelengths of 488, 568 and 647 nm and a16x multi-immersion lens. The images were collected at 600 and 665 nm. In the second set, CLSM was mainly used to examine bacteria in the ponded wood. The visualisation of bacteria was enhanced by treating wood sections with nitrobenzoxadiazole glycerophosphoethanolamine (NDB-PE) prior to examination with the CLSM as above. Standard protocols were employed for the other microscopy techniques used. In the first set, confocal fluorescence enabled us to understand the intricate physical interaction between the coating and the wood surface not achievable by LM. It was possible to clearly resolve penetration of the coating material into fine cracks and delaminations in the cell walls in the surface layer of wood, which apparently formed during planing and/or sanding of the wood. The coating appeared crimson and wood cell walls purple, but these were sharply contrasted making it possible for the coating to be clearly differentiated from wood cell walls. The ability of CLSM to bring the coating and the wood into the same focus by building a composite of a series of optical sections was also a crucial factor in achieving the definition required to examine the very intricate penetration pathways of the coating. In the second set, the use of fluorescent dye NBD-PE afforded visualisation of bacteria in wood with remarkable clarity because of its specific binding to lipid components of cell membranes, which imparted strong fluorescence to bacteria. As wood cell walls do not contain lipids, they exhibited only a weak fluorescence. Bacteria were most abundant in ray parenchyma cells, which contained large aggregates of bacteria appearing as fluorescent masses. Bacteria occurred singly or in small groups in tracheids, and were most abundant on pit membranes. Preferential colonisation of pit membranes by bacteria present in tracheids was also observed by TEM, which provided evidence of pit membrane degradation. Collectively, these observations help explain why in radiata pine the coating penetrated deeper in the ponded wood as compared to the wood that had not been ponded. Thus, CLSM has the potential to extend our knowledge of wood-coating interaction, particularly when used in combination with other microscopy techniques, and we encourage the use of this instrument in future studies of wood-coating polymer composites.

THIBAUT BERNARD[1], RUELLE JULIEN[2], CLAIR BRUNO[3]: [1]CNRS, Cayenne, France; [2] CIRAD/Université Antilles Guyane, Cayenne, France; [3]CNRS/Université Montpellier 2, Montpellier, France - **Reaction wood: anatomy versus mechanical approach** (Paper)

Scientists, both in anatomy and mechanics, have described very different situations on upper and lower parts of inclined stems or branches. Anatomists were the first to describe what they call reaction wood, i.e. compression wood on lower parts of gymnosperm and tension wood on upper parts of angiosperm stems. The terms tension or compression were chosen by analogy with an inclined cantilever beam. Later on, mechanical analysis showed that this analogy was not valid for a growing stem. But it was experimentally put into evidence that, during its differentiation, tension wood generated very high tensile stress while compression wood generated high compressive stress at stem periphery, in the longitudinal direction (compared to high tensile stress in normal wood for angiosperms and gymnosperms). This difference in growth stress value on the two sides of the stem is used to restore verticality or prevent branch “weeping”. Experimental work combining mechanical and anatomical approaches was performed on gymnosperms and angiosperms (with G layer fibres in tension wood) in a very active process of verticality restoration after a strong perturbation. Longitudinal growth stresses were measured at different angular locations around the stem while anatomical observations were made on the wood at the vicinity of these measurements. There was a perfect correlation between mechanical reaction (specific growth stress value) and reaction wood occurrence. Moreover, there are some cases when strongly inclined big trees do not present any reaction at all (mechanical and anatomical) and cases when perfectly straight trees show a typical sector of reaction wood with associated specific reaction growth stresses. We suggest a general mechanical definition of reaction wood, in order to investigate tension wood of many species where no anatomical features of typical tension wood were found (probably more than half of tropical species).

THULASIDAS P.K., BHAT K.M.: Division of Forest Utilisation, Kerala Forest Research Institute, Peechi - 680 653, Kerala, India - **Heartwood percentage, colour, extractive content, and basic density of home garden teak (*Tectona grandis* L. f.) from wet and dry localities of Kerala, India** (Poster)

This study assessed the quality of teak wood produced from homesteads and farmlands at a harvestable age of around 30-35 years. The general notion is that teak grown in home gardens is of inferior quality with more sapwood, paler wood and lower durability and fetches a lower price in the timber market compared to that grown in forest plantations. To study this, five dominant teak trees (35-years) were felled from a typical home garden forestry in a wet locality having rainfall around 3500 mm and from a dry site (<2300 mm rainfall). The result was compared with the same aged forest plantation teak (rainfall >3000 mm) from Nilambur, Kerala famous for Malabar teak world-wide. A 5-cm cross-sectional disk was removed from each tree at breast height (BH) level for various physical property studies. The heartwood proportion of stem volume (under bark) was 71, 64 and 73%, respectively from wet and dry sites, and forest plantation. Even though stem diameter of the trees differs significantly ($P<0.05$) at BH level (39.6, 21 and 31 cm, respectively) between the three localities, the heartwood percentage did not show any significant variation ($P>0.05$). The colour of heartwood from wet site, as determined by the *CIE L*a*b** system, differs significantly ($P<0.05$) from dry site and plantation with more yellowness of its chromaticness index b* (i.e. less saturation of colour). This paler colour was attributed to lower extractive content (12%) of heartwood as against 16 and 13%, respectively in dry and plantation sites when analysed through ethanol–benzene solubility as per ASTM standard (1981). No significant difference was observed between wet, dry and plantation teak with regard to wood basic density values (600, 645 and 597 kg/m^3, respectively) ($P>0.05$). Basic density values for teak are similar to those reported elsewhere. The above results indicate that wet site areas can produce harvestable timber of larger diameter logs having heartwood of the same proportion as that of dry and plantation, though the wood is paler with lower extractive content than dry and plantation sites. However, no definite relationship could be established with regard to wood density. Paler colour of heartwood and poor log form due to lack of silvicultural practices by the small timber holders might be a price limiting factor of teak wood from homesteads in the timber market.

UGOLEV B.N., SANAEV V.G.: Boris N. Ugolev, Moscow State Forest University 141005, Mytischi-5, Moscow Region, Russia - **Wood science development and university education in Russia** (Paper)

The integration of wood science and education began at the beginning of the last century. In this Paper the main stages in Wood Science development in Russia are outlined. In 1968 a council was set up to coordinate Wood Science activity. Since 1990 it has been functioning at Moscow State Forest University under the auspices of the IAWS. Today the interstate Regional Coordinating Council of Wood Science (RCCWS) unites scientists from 10 countries. RCCWS is a scientific, informational and educational policy making body. It holds annual sessions and seminars in various Russian cities and organized international symposia on "Wood Structure, Properties and Quality" (in 1990, 1996, 2000, 2004). The report contains the review of the Papers presented at the fourth symposium in St. Petersburg; these Papers reflect the breadth of studies by Russian scientists and their foreign colleagues. Wood Science must take the key position in the system of Wood Technology education. Now in Russia we have a general course in "Wood Science and Forest commodities" and advanced courses in "Wood Physics", "Wood chemistry", and "Mechanics of Wood and Wood composites". University textbooks on Wood Science by S.I. Vanin (1934, 1940, 1949), L.M. Perelygin (1949, 1957, 1969), B.N. Ugolev (1975, 1986, 2001) contain a body of canonical knowledge, as well as the results of their investigations. Multiprofile Forest University promotes an interdisciplinary approach to wood science development. The place and "credit" to Wood Science depend on the various specialities of different educational programmes. Wood Science education in Russia is part of a many staged forest education system, providing a general approach in a period of social transformation. It is especially important in the frame of Bologna educational process.

WANG SHENG-YANG[1], WU CHI-LIN[2], CHU FANG-HUA[2], CHIEN SHIH-CHANG[3], KUO YUEH-HSIUNG[4], SHYUR LIE-FEN[3] & CHANG SHANG-TZEN[2] : [1]Department of Forestry, National Chung-Hsing University, 401 Taiwan; [2]School of Forestry and Resource Conservation, National Taiwan University, Taipei, 106 Taiwan. [3]Institute of BioAgricultural Sciences, Academia Sinica, Taipei, 115 Taiwan; [4]Department of Chemistry, National Taiwan University, Taipei, 106 Taiwan - **Chemical composition and antifungal activity of essential oil from *Chamaecyparis formosensis* wood** (Poster)

The chemical composition of the essential oil from *Chamaecyparis formosensis* wood was examined. GC-MS data and retention indices coupled with some reference samples were used to identify 34 constituents of the wood volatile oil from *C. formosensis*. α-Eudesmol (18.06%), β-guaiene (8.0%), (-)-β-cadinene (7.89%), 2-(4α,8-dimethyl-1,2,3,4,4α,5,6,7-octahydro- naphthalen-2-yl)-prop-2-en-1-ol (7.03%), α-muurolol (6.49%), 1,5-dimethyl-3-hydroxy-8-(1-methylene-2-hydroxyethyl-1)-bicyclo[4.4.0]dec-5-ene (5.52%), σ-selinene (4.78%), santolina triene (4.60%), eremophilene (4.32%), humulene (4.11%), myrtenol (4.11%), and τ-cadinene (3.25%) were found to be the main constituents in the essential oil of *C. formosensis* wood. In addition, two typical wood decay fungal, *Laetiporus sulphureus* and *Trametes versicolor*, were selected to test the antifungal activity of essential oil. A strong antifungal activity was exhibited by wood essential oil against *T. versicolor* and *L. sulphureus*. Complete growth inhibition of *L. sulphureus* and *T. versicolor* at concentrations as low as 50 and 100 µg/mL, respectively, was observed. Moreover, 7 characteristic volatile compounds, including epi-cubenol, chamaecynone, myrtenol, *cis*-myrtanol, 12-hydroxyisointermedenol, 4α-hydroxy-4β-methyldihydrocostol, were isolated and purified from ethyl acetate frction of wood extractives. Chamaecynone possessed the strongest antifungal activity within these isolated compounds. The antifungal indexes of chamaecynone were 88.2 and 67.3 for *L. sulphureus* and *T. versicolor* at the dosage of 50 µg/mL. This is the first report to demonstrate that the wood essential oil of *C. formosensis* possesses strong antifungal activity.

WHEELER E.A.[1], SIMPSON T.D.[2], RODGERS S.L.[2], GASSON P.E.[3], BROWN K.R.[2], BARTLETT J.A.[4], BAAS P.[5]: [1]Wood & Paper Science, Box 8005, N.C. State University; [2]D.H. Hill Library, Box 7111, N.C. State University; [3]Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3DS, U.K.; [4]Marine, Earth, and Atmospheric Science, Box 8208, N.C. State University; [5]NHN, Universiteit Leiden Branch, P.O. Box 9514, 2300 RA Leiden, The Netherlands - **InsideWood. A new internet-accessible wood anatomy database** (Poster)

InsideWood is a new, extensive, Internet-accessible wood anatomy reference, research, and teaching tool. This collaborative effort integrates information from wood anatomy databases for modern and fossil woods compiled at North Carolina State University and the wood uses database of the Royal Botanic Gardens, Kew, U.K., with guidance from N.C. State's D.H. Hill Library. Modern woods are described using the IAWA List of Features Suitable for Hardwood Identification, and the fossil woods by a subset of these features. As of May 2004 there were over 5800 records for modern woods and over 1200 records for fossil woods. The primary objective of the InsideWood web site is to provide an interface to search the database by IAWA feature number, keyword, or to browse by family or genus. Another objective of the site is to serve as a repository for photomicrographs of wood structure, particularly previously unpublished images. A virtual reference collection of microscope slides now includes 6,200 digital images from the wood collections of the National Herbarium of The Netherlands, some 2000 scans of existing 35 mm photographs (including donated images of Lauraceae from H.G. Richter,

Sapindaceae from R. Klaassen, Cornaceae from Shuichi Noshiro), and 500 original digital photographs. The fossil wood database will be searchable on-line by 2005. Metadata for the image collections, which are related to species descriptions, include photographer and institutional affiliation, wood collection number, and technical information on the image. The robust relational data structure allows easy access and expansion, and agrees with current protocols for digital libraries and information science. The InsideWood web site will have value in 1) helping with wood identification, 2) providing data that can be incorporated into phylogenetic studies, and 3) serving as a resource for any course that teaches about the internal structure of woody plants.

WHEELER, E.A.[1], WIEMANN M.C[2]: [1]Department of Wood and Paper Science, N.C. State University, Raleigh, NC 27605; [2]USDA Forest Products Laboratory, Madison, WI 53705 - **Woods of the Miocene Bakate Formation, Fejej Plain, Ethiopia** (Paper)

Twelve wood types have been recognized in a collection of permineralized woods from Locality FJ-18 of the Bakate Formation in the Fejej Plain of southern Ethiopia. These woods were collected by J.A. Fleagle, SUNY, Stonybrook, and are from individual stumps. Selected characteristics of these woods were earlier used to infer a MAT of 26^o C, an estimate within 1^o C of the present MAT. More recently, the affinities of the woods were investigated. Families that are identified with certainty include the Combretaceae, Sapotaceae, and Leguminosae. This wood assemblage differs from other known Neogene wood assemblages of Ethiopia. All the woods are characterized by thick-walled fibres and basic specific gravity estimates range from 0.63 to 0.82, suggesting a dry deciduous forest. One wood is ring porous, a characteristic only seen in deciduous trees. The high proportion of woods with narrow vessels and high vessel densities also is consistent with a relatively dry environment.

WIEMANN MICHAEL C., MILLER REGIS B., GREEN DAVID W.: USDA Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726-2398, USA - **Specific gravity as a predictor of mechanical properties** (Paper)

The mean and variation of specific gravity among species is different for gymnosperms, temperate angiosperms and tropical angiosperms. For these three broad groupings, mean specific gravity and variability (range and standard deviation) is lowest in gymnosperms and highest in tropical angiosperms. Specific gravity is a good predictor of mechanical properties, but most predictive models are based on gymnosperms and temperate angiosperms. With more tropical species entering the structural timber market, specific gravity as a proxy for measured mechanical properties has assumed greater importance, but the predictive models may not be appropriate. We compare models of specific gravity as a predictor of stiffness, breaking strength, compressive strength, shear and hardness for gymnosperms, temperate angiosperms, and tropical angiosperms in both the green and air-dry condition. In general, the exponential increase in mechanical properties with specific gravity is smallest among gymnosperms and largest among tropical angiosperms.

ZHANG S.Y.[1, 2], LI SHI JUN[1, 2], REIDL BERNARD[1, 2]: [1]Forintek Canada Corp.; [2]Université Laval, Quebec, Canada - **Impact of wood and fibre characteristics on the mechanical properties and dimensional stability of black spruce medium density fibreboard panels** (Paper)

Medium density fibreboard (MDF) panels from different raw fibre materials of black spruce (*Picea mariana* (Mill.) BSP.) were manufactured under the same conditions to quantify the effects of rotation age and log position (or wood and fibre characteristics) on the mechanical properties and dimensional stability of the MDF panels. To investigate the effects of different rotation ages, raw fibre materials from three age zones (classes) were collected from each sample tree: 1) 20-year-old (1st-20th rings) which contain 100% juvenile wood; 2) 21-40-year-old (21st to 40th rings); and 3) 41-80-year-old. In addition, samples from the butt, middle and top logs were collected from the same tree to quantify the log position effects. Selected wood physical and chemical properties of each sample were determined to investigate their effect on the mechanical properties and dimensional stability of the MDF panels. Both analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were performed to examine differences among different samples. The results show that modulus of rupture (MOR), internal bonding (IB), and water absorption of MDF panels made from 20-year-old fibre material zone are significantly superior to those of panels from the 20-40-year-old and 40-80-year-old fibre materials; the linear expansion (LE) from the 20 year-old fibre material is significantly higher than from the two other zones. However, panels made from the 20-40-year-old and 40-80-year-old fibre materials have no significant differences in MOR, IB, water absorption, and LE. Panel modulus of elasticity (MOE) and thickness swell (TS) are dependent on the panel density due to interactions among the three age classes. This study suggests that a shorter rotation age or a higher percentage of juvenile wood in black spruce trees will lead to better-quality MDF panels. MOE and IB of MDF panels from the top log and middle log are significantly superior to those from the butt log; however, there is no significant difference in MOE and IB between the top log and middle log panels. Water absorption of the top log and middle log panels is significantly lower than that of the butt log panel, and the difference in water absorption between the top log and middle log panels is not significant. The top log panels have the smallest TS which is significantly different from that of the middle log and butt log panels, whereas the butt log panels have the highest TS. Difference in LE is not significant among the 3 log positions. Therefore, it appears feasible to sort black spruce logs for optimal end uses.