**Summary of integrative structure determination of A representative atomistic model of the Populus Secondary Cell Wall (PDB ID: 9A3U | pdb_00009a3u, PDB-Dev ID: PDBDEV_00000215 )**

| *1. Model Composition* | |
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| *1.1. Entry composition* | - Lignin: chain(s) A [L10], B [L21], C [L32], D [L43], E [L54], F [L65], G [L76], H [L87], I [L98], J [L109], K [L11a], L [L12b], M [L13c], N [L14d], O [L15e], P [L16f], Q [L17g], R [L18h], S [L19i], T [L20j], U [L21k], V [L22l], W [L23m], X [L24n], Y [L25o], Z [L26p], AA [L27q], AB [L53Q], AC [L79k], AD [L105K], BA [L28r], BB [L54R], BC [L80l], BD [L106L], CA [L29s], CB [L55S], CC [L81m], CD [L107M], DA [L30t], DB [L56T], DC [L82n], DD [L108N], EA [L31u], EB [L57U], EC [L83o], ED [L109O], FA [L32v], FB [L58V], FC [L84p], FD [L110P], GA [L33w], GB [L590], GC [L85q], GD [L111Q], HA [L34x], HB [L601], HC [L86r], HD [L112R], IA [L35y], IB [L612], IC [L87s], ID [L113S], JA [L36z], JB [L623], JC [L88t], JD [L114T], KA [L37A], KB [L634], KC [L89u], KD [L115U], LA [L38B], LB [L645], LC [L90v], MA [L39C], MB [L656], MC [L91w], NA [L40D], NB [L667], NC [L92x], OA [L41E], OB [L678], OC [L93y], PA [L42F], PB [L689], PC [L94z], QA [L43G], QB [L69a], QC [L95A], RA [L44H], RB [L70b], RC [L96B], SA [L45I], SB [L71c], SC [L97C], TA [L46J], TB [L72d], TC [L98D], UA [L47K], UB [L73e], UC [L99E], VA [L48L], VB [L74f], VC [L100F], WA [L49M], WB [L75g], WC [L101G], XA [L50N], XB [L76h], XC [L102H], YA [L51O], YB [L77i], YC [L103I], ZA [L52P], ZB [L78j], ZC [L104J] (20 residues)<br>- Xylan-m8: chain(s) AE [X37f], AF [X21F], BE [X38g], CE [X39h], DE [X40i], EE [X41j], FE [X42k], QF [X58V], RF [X59W], SF [X60X], VE [X16A], WE [X17B], XE [X18C], YE [X19D], ZE [X20E]<br>- Cellulose: chain(s) AG [CEL17], AH [CEL2x], AI [CEL4n], AJ [CEL5d], AK [CEL73], AL [CEL8t], BG [CEL18], BH [CEL2y], BI [CEL4o], BJ [CEL5e], BK [CEL74], BL [CEL8u], CG [CEL19], CH [CEL2z], CI [CEL4p], CJ [CEL5f], CK [CEL75], CL [CEL8v], DG [CEL1a], DH [CEL30], DI [CEL4q], DJ [CEL5g], DK [CEL76], DL [CEL8w], EG [CEL1b], EH [CEL31], EI [CEL4r], EJ [CEL5h], EK [CEL77], EL [CEL8x], FG [CEL1c], FH [CEL32], FI [CEL4s], FJ [CEL6i], FK [CEL78], FL [CEL8y], GG [CEL1d], GH [CEL33], GI [CEL4t], GJ [CEL6j], GK [CEL79], GL [CEL8z], HG [CEL1e], HH [CEL34], HI [CEL4u], HJ [CEL6k], HK [CEL7a], IG [CEL1f], IH [CEL35], II [CEL4v], IJ [CEL6l], IK [CEL7b], JG [CEL1g], JH [CEL36], JI [CEL4w], JJ [CEL6m], JK [CEL7c], KG [CEL1h], KH [CEL37], KI [CEL4x], KJ [CEL6n], KK [CEL7d], LG [CEL2i], LH [CEL38], LI [CEL4y], LJ [CEL6o], LK [CEL7e], MG [CEL2j], MH [CEL39], MI [CEL4z], MJ [CEL6p], MK [CEL7f], NG [CEL2k], NH [CEL3a], NI [CEL50], NJ [CEL6q], NK [CEL7g], OG [CEL2l], OH [CEL3b], OI [CEL51], OJ [CEL6r], OK [CEL7h], PG [CEL2m], PH [CEL3c], PI [CEL52], PJ [CEL6s], PK [CEL8i], QG [CEL2n], QH [CEL3d], QI [CEL53], QJ [CEL6t], QK [CEL8j], RG [CEL2o], RH [CEL3e], RI |

[CEL54], RJ [CEL6u], RK [CEL8k], SG [CEL2p], SH [CEL3f], SI [CEL55], SJ [CEL6v], SK [CEL8l], TF [CEL10], TG [CEL2q], TH [CEL3g], TI [CEL56], TJ [CEL6w], TK [CEL8m], UF [CEL11], UG [CEL2r], UH [CEL3h], UI [CEL57], UJ [CEL6x], UK [CEL8n], VF [CEL12], VG [CEL2s], VH [CEL4i], VI [CEL58], VJ [CEL6y], VK [CEL8o], WF [CEL13], WG [CEL2t], WH [CEL4j], WI [CEL59], WJ [CEL6z], WK [CEL8p], XF [CEL14], XG [CEL2u], XH [CEL4k], XI [CEL5a], XJ [CEL70], XK [CEL8q], YF [CEL15], YG [CEL2v], YH [CEL4l], YI [CEL5b], YJ [CEL71], YK [CEL8r], ZF [CEL16], ZG [CEL2w], ZH [CEL4m], ZI [CEL5c], ZJ [CEL72], ZK [CEL8s]
- SODIUM ION: chain(s) AM [L13c], AN [L24n], AO [L30t], AP [L40D], AQ [L47K], AR [L57U], AS [L73e], AT [L77i], AU [L84p], AV [L93y], AW [L111Q], BM [L13c], BN [L25o], BO [L31u], BP [L40D], BQ [L47K], BR [L57U], BS [L73e], BT [L77i], BU [L84p], BV [L95A], BW [L111Q], CM [L14d], CN [L25o], CO [L33w], CP [L40D], CQ [L47K], CR [L57U], CS [L73e], CT [L77i], CU [L84p], CV [L95A], CW [L111Q], DM [L14d], DN [L25o], DO [L33w], DP [L40D], DQ [L48L], DR [L57U], DS [L73e], DT [L77i], DU [L84p], DV [L95A], DW [L111Q], EM [L14d], EN [L25o], EO [L33w], EP [L40D], EQ [L49M], ER [L57U], ES [L73e], ET [L77i], EU [L84p], EV [L95A], EW [L111Q], FM [L14d], FN [L25o], FO [L35y], FP [L40D], FQ [L49M], FR [L57U], FS [L73e], FT [L77i], FU [L84p], FV [L96B], FW [L111Q], GM [L14d], GN [L25o], GO [L35y], GP [L40D], GQ [L49M], GR [L590], GS [L73e], GT [L77i], GU [L84p], GV [L96B], GW [L111Q], HL [L54], HM [L15e], HN [L25o], HO [L35y], HP [L40D], HQ [L50N], HR [L601], HS [L73e], HT [L77i], HU [L84p], HV [L96B], HW [L111Q], IL [L76], IM [L16f], IN [L25o], IO [L35y], IP [L40D], IQ [L50N], IR [L601], IS [L73e], IT [L77i], IU [L84p], IV [L96B], IW [L111Q], JL [L76], JM [L16f], JN [L25o], JO [L36z], JP [L40D], JQ [L50N], JR [L601], JS [L73e], JT [L77i], JU [L84p], JV [L96B], JW [L111Q], KL [L76], KM [L16f], KN [L25o], KO [L36z], KP [L40D], KQ [L50N], KR [L601], KS [L73e], KT [L77i], KU [L84p], KV [L98D], KW [L111Q], LL [L76], LM [L16f], LN [L25o], LO [L36z], LP [L40D], LQ [L52P], LR [L601], LS [L73e], LT [L77i], LU [L85q], LV [L99E], LW [L111Q], ML [L76], MM [L16f], MN [L27q], MO [L37A], MP [L41E], MQ [L55S], MR [L612], MS [L73e], MT [L77i], MU [L85q], MV [L99E], MW [L111Q], NL [L76], NM [L16f], NN [L27q], NO [L37A], NP [L41E], NQ [L55S], NR [L634], NS [L73e], NT [L78j], NU [L86r], NV [L100F], NW [L111Q], OL [L76], OM [L18h], ON [L27q], OO [L37A], OP [L42F], OQ [L55S], OR [L645], OS [L73e], OT [L79k], OU [L91w], OV [L100F], OW [L111Q], PL [L76], PM [L18h], PN [L27q], PO [L37A], PP [L43G], PQ [L55S], PR [L645], PS [L73e], PT [L80l], PU [L91w], PV [L100F], PW [L111Q], QL [L87], QM [L18h], QN [L27q], QO [L37A], QP [L45I], QQ [L55S], QR [L645], QS [L73e], QT [L80l], QU [L91w], QV [L100F], QW [L111Q], RL [L87], RM [L18h], RN [L27q], RO [L37A], RP [L46J], RQ [L55S], RR [L645], RS [L73e], RT [L81m], RU [L91w], RV [L100F], RW [L111Q], SL [L87], SM [L19i], SN [L27q], SO [L38B], SP [L46J], SQ [L55S], SR [L645], SS [L73e], ST [L82n], SU [L91w], SV [L100F], SW [L111Q], TL [L87], TM [L21k], TN [L27q], TO [L38B], TP [L47K], TQ [L55S],

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| | TR [L645], TS [L73e], TT [L83o], TU [L92x], TV [L102H], TW [L114T], UL [L87], UM [L22l], UN [L28r], UO [L38B], UP [L47K], UQ [L55S], UR [L645], US [L74f], UT [L84p], UU [L92x], UV [L104J], UW [L114T], VL [L98], VM [L23m], VN [L29s], VO [L38B], VP [L47K], VQ [L56T], VR [L667], VS [L76h], VT [L84p], VU [L92x], VV [L105K], WL [L98], WM [L24n], WN [L29s], WO [L38B], WP [L47K], WQ [L56T], WR [L69a], WS [L76h], WT [L84p], WU [L92x], WV [L105K], XL [L98], XM [L24n], XN [L29s], XO [L38B], XP [L47K], XQ [L56T], XR [L69a], XS [L76h], XT [L84p], XU [L92x], XV [L106L], YL [L12b], YM [L24n], YN [L29s], YO [L38B], YP [L47K], YQ [L57U], YR [L69a], YS [L77i], YT [L84p], YU [L92x], YV [L107M], ZL [L12b], ZM [L24n], ZN [L30t], ZO [L38B], ZP [L47K], ZQ [L57U], ZR [L70b], ZS [L77i], ZT [L84p], ZU [L92x], ZV [L111Q]<br>- water: chain(s) AX [L87], AY [L37A], AZ [L645], BX [L98], BY [L38B], BZ [L656], CX [L11a], CY [L39C], CZ [L667], DX [L12b], DY [L40D], DZ [L69a], EX [L13c], EY [L41E], EZ [L70b], FX [L14d], FY [L42F], FZ [L71c], GX [L15e], GY [L43G], GZ [L73e], HX [L16f], HY [L44H], HZ [L74f], IX [L17g], IY [L45I], IZ [L75g], JX [L18h], JY [L46J], JZ [L76h], KX [L19i], KY [L47K], KZ [L77i], LX [L21k], LY [L48L], LZ [L78j], MX [L22l], MY [L49M], MZ [L79k], NX [L23m], NY [L50N], NZ [L80l], OX [L24n], OY [L51O], OZ [L81m], PX [L25o], PY [L52P], PZ [L82n], QX [L26p], QY [L54R], QZ [L83o], RX [L27q], RY [L55S], RZ [L84p], SX [L28r], SY [L56T], SZ [L85q], TX [L29s], TY [L57U], TZ [L86r], UX [L30t], UY [L58V], UZ [L87s], VW [L10], VX [L31u], VY [L590], VZ [L88t], WW [L21], WX [L33w], WY [L601], WZ [L89u], XW [L43], XX [L34x], XY [L612], XZ [L91w], YW [L54], YX [L35y], YY [L623], YZ [L92x], ZW [L76], ZX [L36z], ZY [L634], ZZ [L93y], AAA [L94z], BAA [L95A], CAA [L96B], DAA [L97C], EAA [L98D], FAA [L99E], GAA [L100F], HAA [L101G], IAA [L102H], JAA [L103I], KAA [L104J], LAA [L105K], MAA [L106L], NAA [L107M], OAA [L108N], PAA [L109O], QAA [L110P], RAA [L111Q], SAA [L112R], TAA [L113S], UAA [L114T]<br>- Xylan-m2: chain(s) BF [X43G], CF [X44H], DF [X45I], EF [X46J], FF [X47K], GE [X1l], HE [X2m], IE [X3n], JE [X4o], KE [X5p], LD [X220], MD [X231], ND [X242], OD [X253], PD [X264]<br>- Xylan-m4: chain(s) GF [X48L], HF [X49M], IF [X50N], JF [X51O], KF [X52P], LE [X6q], ME [X7r], NE [X8s], OE [X9t], PE [X10u], QD [X275], RD [X286], SD [X297], TD [X308], UD [X319]<br>- Xylan-m6: chain(s) LF [X53Q], MF [X54R], NF [X55S], OF [X56T], PF [X57U], QE [X11v], RE [X12w], SE [X13x], TE [X14y], UE [X15z], VD [X32a], WD [X33b], XD [X34c], YD [X35d], ZD [X36e] |
| *1.2. Datasets used for modeling* | - De Novo model, Zenodo: 10.5281/zenodo.10179190<br>- NMR data, Zenodo: 10.5281/zenodo.8377844 |
| ***2. Representation*** | |
| *2.1. Number of representations* | 1 |

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| 2.2. Scale | Atomic |
| 2.3. Number of rigid and flexible segments | 0, 115 |
| ***3. Restraints*** | |
| 3.1. Physical principles | Information about physical principles was not provided |
| 3.2. Experimental data | |
| ***4. Validation*** | |
| 4.2. Number of ensembles | 0 |
| 4.3. Number of models in ensembles | Not applicable |
| 4.4. Number of deposited models | 1 |
| 4.5. Model precision | Not available |
| 4.6. Data quality | Data quality has not been assessed |
| 4.7. Model quality: assessment of excluded volume | Satisfaction: 100.00% |
| 4.8. Fit to data used for modeling | Fit of model to information used to compute it has not been determined |
| 4.9. Fit to data used for validation | Fit of model to information not used to compute it has not been determined |
| ***5. Methodology and Software*** | |
| *1.* 5.1. Method name | Initial Polymer Placement |
| 5.2. Method type | Molecular Placement of Cellulose, Xylan and Lignin |
| *2.* 5.1. Method name | Equilibration with Molecular Dynamics |
| 5.2. Method type | A series of compression simulations to assemble the matrix polymers (xylan and lignin) onto the xylan coated cellulose microfibril. This is followed by the placement of water molecules and ions for charge neutrality. Experimentally observed density values are used as a validation metric at this stage. For further details see cited manuscript DOI:10.1126/sciadv.adi7965 |
| *3.* 5.1. Method name | Production Simulations in the NVT ensemble |
| 5.2. Method type | This step involves running molecular dynamics for 100ns (50,000,000 steps with a 2fs timestep) to explore the dynamics of biopolymeric components. Periodic boundary conditions are considered for the simulations. For further details see cited manuscript DOI:10.1126/sciadv.adi7965 . CHARMM compatible files for this system are available for download, visualization and analsis at https://doi.org/10.5281/zenodo.10179190 |

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| 4. 5.1. Method name | Proximity Calculations for Reproduction of ssNMR Observables |
| 5.2. Method type | This step involves calculating the fraction of 'sink' atom type within 1nm of a 'source' atom type. The source and sink atoms are chosen based on ssNMR experiments. There are two types of sources Xylan-sourced (methyl carbon on the acetate group attached to xylose) or Lignin-Sourced (Ring atoms C3 and C5 on the Syringyl residues and atoms C4 and C3 on the Guaicol residues of lignin). The sink atoms for Xylan-sources include Cellulose atoms (C4 atom on Glucose) and Lignin atoms (Ring atoms C3 and C5 on the Syringyl residues and atoms C4 and C3 on the Guaicol residues). The sink atoms for Lignin-sources include Cellulose atoms (C4 atom on Glucose) and Xylan atoms (methyl carbon (CA2) on the acetate group attached to xylose). For a chosen source atom in the system, a count of sink atoms within 1nm of that source atom is calculated. This is repeated for each and every source atom and the total count is used to calculate the fraction of sink atoms within 1nm of the source atom. This metric also measured by ssNMR, is used to validate the spatial arrangement of polymers in the atomistic model. For further details see cited manuscript DOI:10.1126/sciadv.adi7965 |
| 5.5. Software | CHARMM (version C44a) |