## Influence of Lytic Polysaccharide Monooxygenase Active Site Segments on Activity and Affinity

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Supplementary Material

A         P	V         I         P         G         I         V         I         M         D         G         I         I         G         I         G         I         G         I         I         G         I         G         I         I         G         I         G         I         I         G         I	V         V		0         1
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43430.1 Phanerochaete chrysosporium 485Q LPMO9D C1 81966.1 Neurospora crassa NCU01867 LPMO9J C1 CBM	Image: New Year of the second seco		I    I      I    I	D         C           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I	1     1     1       1     1     1	I         IN         I           I         I         I	.    .      1    .         1      1       1  <	I    I      I    I		
67190.1 Triangularia anserina S mat+ 8375.1 Triangularia anserina S mat+ LPMO9B C1C1/C4 CBM			1     1       1 <td>U         U           I         I</td> <td></td> <td></td> <td>.    .    .      .    .</td> <td>I         I           I         I</td> <td>I         I           I         I  </td> <td></td>	U         U           I         I			.    .    .      .    .	I         I           I         I	I         I           I         I	
th2p4 001333 76800.1 Thermothelomyces thermophilus LPMO9B C1 CBM	T T C C C C C C C C C C C C C C C C C C	$ \begin{array}{c} V \\ P \\ G \\ P \\ G \\ P \\ \end{array} \begin{array}{c} A \\ A \\ \end{array} \begin{array}{c} V \\ - \\ Y \\ \end{array} \begin{array}{c} V \\ S \\ S \\ \end{array} \begin{array}{c} G \\ S \\ S \\ S \\ \end{array} \begin{array}{c} G \\ S \\ S \\ S \\ S \\ \end{array} \begin{array}{c} G \\ S \\$	1       1         1	U         U           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	S L	I         S         L         K           I         S         L         K         L           I         I         S         L         S           I         I         S         I         I           I         S         I         I         I           I         I         S         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I           I         I         I         I         I         I           I         I         I         I         I         I           I         I         I         I         I         I           I         I         I         I         I         I           I         I	1     1       1 <td>1         1           1         1</td> <td></td> <td>2 K Y Q Q C [</td>	1         1           1         1		2 K Y Q Q C [
26873.2 Neurospora crassa NCU08760 LPMO9E C1 CBM 58309.1 Triangularia anserina S mat+	-       A       -       M       -       S       -       -       -       -       -       T       Y       V         -       D       -       F       -       G       -       -       -       -       T       Y       V	$\begin{array}{c} \mathbf{A} \ \mathbf{P} \ \mathbf{G} \ \mathbf{P} \ \mathbf{C} \ \mathbf{P} \ \mathbf{C} \ \mathbf{A} \ \mathbf{V} \ \mathbf{P} \ \mathbf{C} \ \mathbf{P} \ \mathbf{C} \end{array}$	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	I       I	I       I	A A I I I I I I I I I I I I I I I I I I	1     1       1 <td>1     1       1     1</td> <td>I           I</td> <td>A K Y Q Q C [</td>	1     1       1     1	I           I	A K Y Q Q C [
55652.1 Thermothelomyces thermophilus th2p4 003103	D         F         N         -         E         Y         V           1         0         1	S <b>Q</b> I - A <b>d</b> - <b>d</b> 5 <b>d</b> I I - A <b>d</b> - <b>d</b> 5 <b>d</b> I I - A <b>d</b> - <b>d</b> 5 <b>d</b> I	1     1       1     1	1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1	1         1           1         1	1         1           1         1	·         ·           ·         ·	1         1           1         1	1           1	I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I
72237.1 Heterobasidion parviporum LPMO9H C1 CBM 33408.1 Neurospora crassa NCU07974	I       I	I P G P - Y G T P G P - Y G T P G P - Y G F P - Y G	T S P T V A V T A W P T A A T W N T A A S S S S S S N A K A A L T T P	A N O P S T V P T A P S T V P T A 	P       A       G       S       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       A       P       P       A       P       P       A       P       P       A       P       P       A       P       P       A       P       P       A       P       P       A       P       P       A       P	0     0       0       0    <	A S S A P G S I I I I I I I I I I I I I I I I I I		N           O         O           I         O           I         M	r K Y G Q C A L A N S C
70248.1 Triangularia anserina S mat+ 55776.1 Thermothelomyces thermophilus	D     T     T       D     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T       T     T     T	V V G P I A I I F R P P G P I K V I Y F P	N       N		A D G V I P A G C I L K N A N W A A D G L V P A D C L V K N A N W	I     I     I       I     I       I <td>DYSNENENECWKASDDCWA</td> <td>0 L D W C Y T S A P P S G S R G C W W I I I I I I I Z A P P S G S R G C W W I I I I I I I I I Z A P P S G S R G C W W I I I I I I I I I I I I I I I I I I</td> <td></td> <td>X I V D S C / V S Q K C</td>	DYSNENENECWKASDDCWA	0 L D W C Y T S A P P S G S R G C W W I I I I I I I Z A P P S G S R G C W W I I I I I I I I I Z A P P S G S R G C W W I I I I I I I I I I I I I I I I I I		X I V D S C / V S Q K C
72238.1 Heterobasidion parviporum LPMO9I C4 CBM th2p4 005454	H     H       H       H <t< td=""><td></td><td>N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       I</td></t<> <td></td> <td>N     I       I<td>A4         I           SS         I           I</td><td>·         ·           I         ·</td><td>I         I           I         I</td><td></td><td>I I I I I I I I I I I I I I I I I I I I</td></td>		N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       N     I       I		N     I       I <td>A4         I           SS         I           I</td> <td>·         ·           I         ·</td> <td>I         I           I         I</td> <td></td> <td>I I I I I I I I I I I I I I I I I I I I</td>	A4         I           SS         I           I	·         ·           I         ·	I         I           I         I		I I I I I I I I I I I I I I I I I I I I
30263.1 Neurospora crassa NCU02240 5FOH LPMO9A C4 CBM	H H H H H H H H H H H H H H H H H H H		I       I       I         I       I       I		I       I	I     I       I <td>.    .    .      1    .    .   </td> <td></td> <td></td> <td></td>	.    .    .      1    .    .			
64619.1 Triangularia anserina S mat+ CBM 32140.1 Pestalotiopsis sp LPMO98 C1/C4	I     I       I <td></td> <td>H     H       H       H    <t< td=""><td>&gt;     1       &gt;     1       1</td></t<><td>I    I      I</td><td>-         -           -         -</td><td>I         I           I         I</td><td>I     I       I<td></td><td>I I I I I I I I I I I I I I I I I I I I</td></td></td>		H     H       H       H <t< td=""><td>&gt;     1       &gt;     1       1</td></t<> <td>I    I      I</td> <td>-         -           -         -</td> <td>I         I           I         I</td> <td>I     I       I<td></td><td>I I I I I I I I I I I I I I I I I I I I</td></td>	>     1       >     1       1	I    I      I	-         -           -         -	I         I           I         I	I     I       I <td></td> <td>I I I I I I I I I I I I I I I I I I I I</td>		I I I I I I I I I I I I I I I I I I I I
21296.1 Neurospora crassa NCU01050 4EIR LPMO9D C4 73072.1 Triangularia anserina S mat+LPMO9G	P       V       I       S       V       I         V       V       I       I       S       V       I         V       V       I <td></td> <td>1         1           1         1</td> <td>1         1           1         1</td> <td>1         1           1         1</td> <td>I         I           I         I</td> <td>.         .           I         .</td> <td>1         1           1         1</td> <td></td> <td>I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I</td>		1         1           1         1	1         1           1         1	1         1           1         1	I         I           I         I	.         .           I         .	1         1           1         1		I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I
th2p4 004487 76801.1 Thermothelomyces thermophilus LPMO9C C4	P       T       D       Y       D       Y       N         1       V	V P G P I S V I F T C I P G V I F T C	1         1           1         1	I         I           I         I	1         1           1         1		.         .           1         .	1         1           1         1	.         .           1         .	I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I
36362.1 Neurospora crassa NCU02916 4D7U LPMO9C C4 CBM 51476.1 Triangularia anserina LPMO9H C1/C4 CBM	N     N       N       N <t< td=""><td></td><td>1       1         1</td><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>H     I       I       I    <t< td=""><td></td><td></td><td>I       I       I         I       I       I</td><td>-         -</td><td></td></t<></td></t<>		1       1         1	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	H     I       I       I <t< td=""><td></td><td></td><td>I       I       I         I       I       I</td><td>-         -</td><td></td></t<>			I       I       I         I       I       I	-         -	
Th2p4 004260 CBM 56416.1 Thermothelomyces thermophilus CBM	4     4     F       3     3     3       4     5     3       1     1     1       1     1       1 <td></td> <td>I         I           I         I</td> <td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td> <td>I         I         I           I         I         I</td> <td></td> <td></td> <td>I     I       I     I</td> <td></td> <td></td>		I         I           I         I	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	I         I         I           I         I         I			I     I       I     I		
56016.1 Thermothelomyces thermophilus LPMO9E C4										
30131.1 Triangularia anserina 5 mat+										
969/7.1 Lentinus similis SACF AA9A C4 (4379.1 Collariella virescens SNLT C1/C4 56647 1 Thornetholomorot thornoohilue	I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I     I     I       I     I       I     I <t< td=""><td></td><td>I     I       I       I    <t< td=""><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>I         I           I         I   </td><td>.         .           .         .</td><td></td><td>I         I           I         I</td><td></td><td>1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1</td></t<></td></t<>		I     I       I       I <t< td=""><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>I         I           I         I   </td><td>.         .           .         .</td><td></td><td>I         I           I         I</td><td></td><td>1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1</td></t<>	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	I         I           I         I	.         .           .         .		I         I           I         I		1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1
th2p4 004397										
54722.1 Aspergillus nidulans CBM					T T A A A T T T A V A T S T S A T O V O P		.         .           1         .	I     I       I     I		0     1     1       1     X     0     C       1     X     0     C       1     X     1
52040.1 Aspergillus fumigatus 6H1Z 37553 1 Trichoderma reesei 2VTC GH618										
74460.1 Fusarium graminearum LPMO9A C1/C4 56744.1 Triangularia anserina S mat+ LPMO9D C1	1     1       1     1	I P G P - K M N I A G	G S S G A A P S T P A T P T G - S G F A P V A Q G S S A I V S S A - T A		S N T A A P V E S A P A E S		V E S A P A A		1     1       1     1	EA
th2p4 006403 58921.1 Thermothelomyces thermophilus	S         F	I P G P - A I - I P G I P G P - A I - I S G	- A S A V E O T T S A I T S S A - S A - A S A V Q O T T S A I T A S A - S A	<b>X</b> I - 1 G	S A T A A P P A A T T T A A	1           1	1     1       1 <td>1       1</td> <td></td> <td></td>	1       1		
29347.1 Neurospora crassa NCU05969 71999.1 Trichoderma reseii 502W LPM09A C1/C4 CBM	1     0     1     0     1     0       1     1     1     1     1     1     1       1     1     1     1     1     1     1       1     1     1     1     1     1     1       1     1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1     1       1     1     1     1 <t< td=""><td>I P G P - A L - I K G I P G P - T V - V S G</td><td> A V S V A O S H S A V T A T A - T A L P T S V A O G S S A A T A T A - S A</td><td>I         I         G         -         L         G         D         A         P           I         T         -         -         -         L         G         A         P           I         T         -         -         -         C         A         P           I         T         -         -         -         C         A         P</td><td>A A T A A P A A T T A P A A</td><td></td><td>V T T À P À A</td><td>-       -</td><td>.     .       1</td></t<> <td>1 1 1 1 1 2 1 2 1 2 1 2 1 2 1 1 1 1 1 1</td>	I P G P - A L - I K G I P G P - T V - V S G	A V S V A O S H S A V T A T A - T A L P T S V A O G S S A A T A T A - S A	I         I         G         -         L         G         D         A         P           I         T         -         -         -         L         G         A         P           I         T         -         -         -         C         A         P           I         T         -         -         -         C         A         P	A A T A A P A A T T A P A A		V T T À P À A	-       -	.     .       1	1 1 1 1 1 2 1 2 1 2 1 2 1 2 1 1 1 1 1 1
73254.1 Triangularia anserina Smat+ LPMO9A C1/C4 CBM :h2p4 004391 CBM	- A - S - P N Y P - A - D - P D Y P	V P G P - A L - I A G V P G P - S L - I A G	A V S S I P <b>O</b> S <b>K</b> S T A T <b>R</b> T A - S A A A S S I A <b>O</b> S T S A I T A T G - T A	<b>T T T T T T T T T T</b>	G A P V V T P T A G P V V T	T S S A P V V 0 P P 	T       T       V       -	T S A P A T S A P A P T G G T T T T A A P S G D	1     1     1     1     1     1     1       1     1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1     1       1     1     1     1     1     1	
56542.1 Thermothelomyces thermophilus CBM 9018.1 Neurospora crassa NCU07760 C1/C4 CBM	I       J       J         I       I       I	V P G P - A L - I A G V P G P - S L - I A G	A A S S I A O S T S V A T A T G - T A A S S S I A O S W A A A T A T A - S A	<b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b> <b>T</b>	G G G G A N P T A T T A A A F G A T G G S N S P A T S A A A A A F F F F F F F F F	T S A A P . A T S A A A T S Q V Q A P 2	X     I     I       I     I       I <td> T T S A A - O T T A P P S G D  T K A A P A T S A A - O T Y A A - P S G D</td> <td>-       -       -       -       -       -       -       -       V       0         A       T       S       A       A       G       G       A       C       V       0       A       C       1</td> <td>1 K X G O C 1 1 1 0 0 0 1 1 1 1 1</td>	T T S A A - O T T A P P S G D T K A A P A T S A A - O T Y A A - P S G D	-       -       -       -       -       -       -       -       V       0         A       T       S       A       A       G       G       A       C       V       0       A       C       1	1 K X G O C 1 1 1 0 0 0 1 1 1 1 1
68352.1 Triangularia anserina S mat+ th2p4 001362	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	V P G P - T V - A P Q V P G P - T L - A A G	- A R P V G H E O O O M M S R A - A T P V P Y A O O N - S S P - K M	<b>A D G T P</b> <b>I D G T P</b>	V V V V R S T V T Q K W T G		R       T       E       A       P       V       N       -	1     1       1     1	.         .           1         .	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I
29132.1 Neurospora crassa NCU07520 57961.1 Geotrichum candidum LPMO9B C1/C4	- A V L - S T Y V - G - I - K S Y I	T P G P - T L - A P E	- A K P V P V T E Q G L K S T I - T A G G - S P G N S A E P Q P Q H - T S	<b>X V G - - - - - - - T P</b>	V I V T R A T S T	I     I       I <td>M         P         N         G         E         T         A         I</td> <td>I       I</td> <td><b>M</b> T V T I I I I I I I I I I I I I I I I I</td> <td>2 L I N L C L D</td>	M         P         N         G         E         T         A         I	I       I	<b>M</b> T V T I I I I I I I I I I I I I I I I I	2 L I N L C L D
158049.1 Geotrichum candidum LPMO9A C1/C4 87087.1 Heterobasidion irregulare 5NNS LPMO9B C1	I       I	I P G P - E P - Y K S I P G P - A V - W Q G	I       I	I       I <t< td=""><td>A       A       T       S       A       A       E       E       P       A       A       -</td><td>I     I       I</td></t<> <td>T S A A S A A S A A S A A S A A S A A S A A S A A S A A S A A S A</td> <td>1         1           1         1</td> <td>.        </td> <td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td>	A       A       T       S       A       A       E       E       P       A       A       -	I     I       I	T S A A S A A S A A S A A S A A S A A S A A S A A S A A S A A S A	1         1           1         1	.	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1
th2p4 008530 th2p4 005329	I     S     I       S     I     I       I     I       I <td></td> <td>1         1           1         1</td> <td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td> <td>1         1           1         1</td> <td>.         .           1         .</td> <td>.         .           1         .</td> <td>I         I           I         I</td> <td>.                                      </td> <td>1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1</td>		1         1           1         1	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	1         1           1         1	.         .           1         .	.         .           1         .	I         I           I         I	.	1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1
59823.1 Thermothelomyces thermophilus 56665.1 Thermothelomyces thermophilus LPMO9D C1	N     N       N       N <t< td=""><td></td><td>1     1       1       1    <t< td=""><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>1         1           1         1</td><td></td><td>·         ·           ·         ·</td><td></td><td></td><td>I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I</td></t<></td></t<>		1     1       1       1 <t< td=""><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>1         1           1         1</td><td></td><td>·         ·           ·         ·</td><td></td><td></td><td>I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I</td></t<>	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	1         1           1         1		·         ·           ·         ·			I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I
th2p4 004508 73311.1 Triangularia anserina S mat+	I     I       I <td></td> <td>I       I</td> <td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td> <td>1         1           1         1</td> <td>.         .           1         .</td> <td>.         .           1         .</td> <td>1         1           1         1</td> <td>.         .           1         .</td> <td>I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I</td>		I       I	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	1         1           1         1	.         .           1         .	.         .           1         .	1         1           1         1	.         .           1         .	I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I
36150.2 Neurospora crassa NCU03000 61257.1 Thermothelomyces thermophilus	-     M     -     T     -     -     T     T       A     -     -     -     -     -     -     -     T       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -       A     -     -     -     -     -     -     -     -	PPGG- <b>RV</b> - <b>W</b> SG IPGP- <b>AV</b> - <b>W</b> SG	1         1           1         1	I         I           I         I	1         1           1         1	.         .           1         .	.         .           1         .	I         I           I         I	.         .           1         .	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1
-th2p4 003927 71839.1 Triangularia anserina S mat+ LPMO9F C1	-       E       -       -       -       -       -       -       Y       T         -       E       -       I       E       -       I       -       -       -       Y       T         -       E       -       I       E       T       D       M       D       I       S       I       A       Q       A       T       T	I P G P - P V - F T C I P G P - A V - F T C	1         1           1         1	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	1         1           1         1	.         .           1         .	.         .           1         .	I         I           I         I	.         .           1         .	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
33178.2 Neurospora crassa NCU07898 4EIS LPMO9M C1/C4 5168.1 Gloeophyllum trabeum LPMO9B C1/C4	-       A       -       -       -       -       -       T	I P G P - A V - F T C $I P G P - A V - W T G$	1     1       1     1	1         1           1         1	1         1           1         1	.         .           1         .	.         .           1         .	I         I           I         I	.         .           1         .	1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1
57612.1 Gloeophyllum trabeum LPMO9A h2p4 004335	H C C C C C C C C C C C C C C C C C C C	I P G P I P V I W T S R A P G G I P V I W S E	N E A F S G S S A A A A A I I I I I I I I I I I I I	V A S S T A	D     S       S     S       S     S       S     S       I     I       I <td></td> <td>N     N       N<td>1     1       1       1    <t< td=""><td>I U U U U U U U U U U U U U U U U U U U</td><td>N X N K C I</td></t<></td></td>		N     N       N <td>1     1       1       1    <t< td=""><td>I U U U U U U U U U U U U U U U U U U U</td><td>N X N K C I</td></t<></td>	1     1       1       1 <t< td=""><td>I U U U U U U U U U U U U U U U U U U U</td><td>N X N K C I</td></t<>	I U U U U U U U U U U U U U U U U U U U	N X N K C I



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CAD67740 1 Triangularia anserina S mat+ I PMO9E C1 CRM	, , ,						I									
Myrth2p4 001581	- 1 - 1 - 1	1 1	1	1	1	1	1 1 1	1	•	1	•	•	1	1	-	1
AEO54509.1 Thermothelomyces thermophilus CBM EAA34466.1 Neurospora crassa NCU00836 C1 CBM	· · · · · · · · · · · · · · · · · · ·	· ·	· · · ·	1 1 1 1	1 1 1 1 1 1	• • • •	1 1 1 1 1 1	1 1 1 1	· · · ·	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP61650.1 Triangularia anserina S mat+ Myrth2p4 003633	1 1 1 1 1 1 1 1	· ·	· · ·	· ·	· ·	• •	· · ·	1 1 1 1	· ·	· · · ·	· ·	· ·	1 1 1 1	· · ·	1 1 1 1	1 1
AEO55082.1 Thermothelomyces thermophilus CDP30928.1 Triangularia anserina S mat+	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	· · · ·	, LL.	, s , s	1 1 1 1	1 1 1 1 1 1		1 1
CAP61048.1 Triangularia anserina S mat+ CAP61395.1 Triangularia anserina S mat+ CBM	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1	· · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP59/02.1 Iriangularia anserina S mat+ CBM CAP65855.1 Triangularia anserina S mat+	· · · · · · · · · · · · · · · · · · ·	· ·	· ·	· ·	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	· ·	· ·	1 1 1 1	· ·	1 1 1 1	· ·	1 1 1 1	1 1
EAA63617.1 Aspergillus nidulans AN3046 C1 Avoca 407 theoreticlessing the Available to Avoca 40 for		· ·	· ·	· ·	· ·	, o			· ·	· ·	, , , ,	· ·	· ·	· ·	, , , ,	1 1
MV082493.1 Inermothelomyces thermophilus LFMU9A CI/C4 Myrth2p4 000358 Vn 0005575555 4 Thermothicities and the second	1 1 1 1 1 1 1 1 1 1	· ·	· ·	· ·	· ·	· ·	1 1 1 1	1 1 1 1	· ·	, , , ,	· ·	, , , ,	1 1 1 1	· ·	, , , ,	1 1
AP 00000/000.1 Infrmomielavioloes terrestris of LPMO95 CL CAD70347.1 Neurospora crassa NCU03328 4Q18 LPMO9F C1 CAD67481 1 Triangularia ansarina S mata	· · · ·	· · ·	, , , , , ,	, , , , , ,	, , , , , , , , ,	, , , , , ,	1 1 1 1 1 1 1 1 1	, , , , , ,	· · ·	, , , , , ,	, , , , , ,	, , , , , , , , ,	1 1 1 1 1 1	· · · ·	, , ,	1 1 1
Myrth2p4 005343 AEO59836.1 Thermothelomyces thermophilus	· · · · · · · · · · · · · · · · · · ·	· · ·	· ·	· · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1		1 1
CAP65866.1 Triangularia anserina S mat+ CAF05857.1 Neurospora crassa NCU02344	1 1 1 1 1 1 1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1
AEO60271.1 Thermothelomyces thermophilus C1 Myrth2p4 005750	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	· ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
ANB32141.1 Pestalotiopsis sp LPMO9A C1/C4 AEO61305.1 Thermothelomyces thermophilus	1 1 1 1 1 1	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	· ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP67493.1 Triangularia anserina S mat+ CAP70156.1 Triangularia anserina S mat+	1 1 1 1 1 1 1 1 1	1 1 1 1	· · · ·	· ·	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	· · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
BAL43430.1 Phanerochaete chrysosporium 4B5Q LPMO9D C1 CAE81966.1 Neurospora crassa NCU01867 LPMO9J C1 CBM	1 1 1 1 1 1 1 1	· ·	· · · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	· ·	1 1 1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
Myrth2p4 006795 CBM CAP67190.1 Triangularia anserina S mat+	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1
CAP68375.1 Triangularia anserina S mat+ LPMO9B C1C1/C4 CBM Myrth2p4 001333	1 1 1 1 1 1 1 1 1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1	· ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
AON76800.1 Thermothelomyces thermophilus LPMO9B C1 CBM EAA26873.2 Neurospora crassa NCU08760 LPMO9E C1 CBM	1 1 1 1 1 1 1 1 1 1	· ·	· · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	· ·	· · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP68309.1 Triangularia anserina S mat+ AEO55652.1 Thermothelomyces thermophilus	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	· · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1		1 1
Myrth2p4 003103 AFO72237.1 Heterobasidion parviporum LPMO9H C1 CBM	· · · · · · · · · · · · · · · · · · ·	· ·	· ·	1 1 1 1	· ·	• • • •	1 1 1 1 1 1	1 1	· ·	- - -	· ·	· ·	1 1 1 1	· ·	• • • •	1 1
EAA33408.1 Neurospora crassa NCU07974 CAP70248.1 Triangularia anserina S mat+	1 1 1 1 1 1 1 1	· ·	· ·	· ·	1 1 1 1	<mark>℃</mark> ,	H K H	 	· ·	 		· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
AEO55776.1 Thermothelomyces thermophilus	• • •	•	•	•	•	1	1 1	•	•	•	•	, ,	•	•	•	1
AF072238.1 Heterobasidion parviporum LPMO9I C4 CBM Myrth2p4 005454	1 1 1 1 1 1 1 1 1 1 1	· ·	· · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	· ·	· · · ·	· ·	· · · ·	1 1 1 1	· · · ·	1 1 1 1	1 1
AEO59955.1 Thermothelomyces thermophilus EAA30263.1 Neurospora crassa NCU02240 5FOH LPMO9A C4 CBM	· · · · · · · · · · · · · · · · · · ·	· ·	· · · ·	· ·	· ·	• •	· ·	1 1	· ·	· ·	· ·	· ·	1 1 1 1	· ·	1 1 1 1	1 1
CAP64619.1 Triangularia anserina S mat+ CBM ANB32140.1 Pestalotiopsis sp LPMO9B C1/C4	1 1 1 1 1 1 1 1	· ·	· ·	1 1 1 1	• •	• •	1 1 1 1	1 1	· ·		• •	· ·	1 1 1 1	• •		1 1
CAD21296.1 Neurospora crassa NCU01050 4EIR LPM09D C4				· ·			· ·	•					· ·	· ·		1 1
Myrth2p4 004487				•		•					•				•	
AUN/6801.1 Inermothelomyces thermophilus LPMO9C C4 EAA36362.1 Neurospora crassa NCU02916 4D7U LPMO9C C4 CBM		· · 2	2 0	· · C	· · · ·	· · 2	· · C	, , _	· · Z	· · ]	, , <mark>u</mark> , , _	, , , ,	, , <mark>u</mark> , , <mark>&gt;</mark>	· · -	, , 0	1 1 6
Myrth2p4 004260 CBM AFO56416 1 Thermothelomuree thermonhilus CBM										•	- · ·		• • •	- · ·	 	1 1
AEU56416.1 I nermothelomyces thermophilus LBM Myrth2p4 008028	1 1 1 1 1 1 1 1 1 1	· ·	 	1 1 1 1	· ·	• •	1 1 1 1 1 1	1 1 1 1	· ·	, , , ,	• •	· ·	1 1 1 1	· ·	• •	1 1
AEO56016.1 Thermothelomyces thermophilus LPMO9E C4 CAP72740.1 Triangularia anserina S mat+	1 1 1 1 1 1 1 1 1 1	· ·	· · · ·	· ·	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	· ·	· ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CDP30131.1 Triangularia anserina S mat+ ALN96977.1 Lentinus similis 5ACF AA9A C4	1 1 1 1 1 1 1 1	· ·	· ·	· ·	· ·	1 1 1 1	1 1 1 1 1 1	1 1	· ·	· · · ·	1 1 1 1	· · · ·	1 1 1 1	· ·	1 1 1 1	1 1
AST24379.1 Collariella virescens 5NLT C1/C4 AEO56547.1 Thermothelomyces thermophilus	· · · · · · · · · · · · · · · · · · ·	· ·	· · · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	· ·	1 1 1 1	1 1 1 1	· ·	1 1 1 1	- <mark>\</mark>	, , ¥,	1 1
Myrth2p4 004397 CAP65111.1 Triangularia anserina S mat+	· · · · · · · · · · · · · · · · · · ·	· ·	· ·	· ·	· ·	1 1 1 1	1 1 1 1	1 1	· ·	· ·	1 1 1 1	· ·	1 1 1 1	· ·	1 1 1 1	1 1
EAA64722.1 Aspergillus nidulans CBM ACS05720.1 Thermoascus aurantiacus 2YET LPMO9A C1/C4	1 1 1 1 1 1 1 1	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	1 1 1 1	 	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
XP 752040.1 Aspergillus fumigatus 6H1Z AAP57753.1 Trichoderma reesei 2VTC GH61B	1 1 1 1 1 1 1 1	· ·	· ·	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1	· ·	 		· ·	1 1 1 1	· · ·	1 1 1 1	1 1
CEF74460.1 Fusarium graminearum LPMO9A C1/C4 CAP66744 1 Triangularia anserina S mat+ LPMO9D C1		· ·	· ·	· ·	· ·	• •	· · ·	1 1 1 1	· ·	· ·	• •	· ·	1 1 1 1	· · ·	· ·	1 1
Myrth2p4 006403 AEO58921.1 Thermothelomyces thermophilus		· ·	· ·	1 1 1 1	1 1 1 1	· •	· 4	· ·	· ·	· · ·	· ·	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
EAA29347.1 Neurospora crassa NCU05969 CAA71999.1 Trichoderma reseii 502W LPM09A C1/C4 CBM	· · · · · · · · · · · · · · · · · · ·	· · ·	· ·	1 1 1 1	1 1 1 1		· · ·	1 1 1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1		1 1
CAP73254.1 Triangularia anserina Smat+ LPMO9A C1/C4 CBM Mvrth2p4 004391 CBM		· ·	· ·	· ·	· ·	• •	· · ·	1 1 1 1	· ·	· ·	· ·	· ·	1 1 1 1	· · ·	· · ·	1 1
AEO565542.1 Thermothelomyces thermophilus CBM EAA29018.1 Neurospora crassa NCU07760 C1/C4 CBM	· · · · · · · · · · · · · · · · · · ·	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	• •	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP68352.1 Triangularia anserina S mat+ Myrth2p4 001362	1 1 1 1 1 1 1 1	1 1 1 1	· · · ·	· ·	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	· ·	· ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
EAA29132.1 Neurospora crassa NCU07520 CD057961.1 Geotrichum candidum LPM09B C1/C4	· · ·	· ·	· ·	· ·	· ·	• •	1 1 1 1	1 1	· ·	· ·	· ·	· ·	1 1 1 1	· ·	1 1 1 1	1 1
CDO58049.1 Geotrichum candidum LPMO9A C1/C4 ETW87087.1 Heterobasidion irregulare 5NNS LPMO9B C1	1 1 1 1 1 1 1 1	1 1 1 1	· ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1
Myrth2p4 008530 Myrth2p4 008530				· ·	· ·	· ·	· · ·	, ,			, <mark>LL</mark>	· ·	· ·	· ·	•	1 1
AEO59823.1 Thermothelomyces thermophilus AEO5665.1 Thermothelomyces thermophilus I PMOGD C1		· · ·	· · ·	· · ·	· · ·	· · ·	· · · ·	· · ·	· · ·	· · ·	<mark>-</mark> 1 1	, , , , , , ,	· · ·	· · · ·	· · ·	1 1 1
Myrth2p4 004508	· · · · · · · · · · · · · · · · · · ·	•	•	•	•	•	•	•	•	•	•	-	1	•	-	•
CAP73311.1 Triangularia anserina S mat+ EAA36150.2 Neurospora crassa NCU03000	1 1 1 1 1 1 1 1 1 1	· ·	· ·	1 1 1 1	1 1 1 1 1 1	• •	1 1 1 1 1 1	1 1 1 1	· ·	· ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
AEO61257.1 Thermothelomyces thermophilus Myrth2p4 003927	1 1 1 1 1 1 1 1 1 1	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1 1 1	 	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	1 1 1 1	1 1
CAP71839.1 Triangularia anserina S mat+ LPMO9F C1 EAA33178.2 Neurospora crassa NCU07898 4EIS LPMO9M C1/C4	1 1 1 1 1 1 1 1	· ·	, , , , , ,	1 1 1 1	· ·	• • • •	1 1 1 1 1 1	1 1	· ·	· ·	1 1 1 1	· · · ·	1 1 1 1	1 1 1 1 1 1	· ·	1 1
AEI35168.1 Gloeophyllum trabeum LPMO9B C1/C4 BAV57612.1 Gloeophyllum trabeum LPMO9A	· · · · · · · · · · · · · · · · · · ·	· ·	· · · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1 1 1	1 1	· ·	· ·	, <mark>LL</mark> , Ø	· · · ·	1 1 1 1	1 1 1 1	1 1 1 1	1 1
Myrth2p4 004335		-	•	•	•	•	1	-	-	•	•		-	•	•	1



Figure S1. Full length multiple sequence alignment without linker region and CBM and associated phylogenetic tree of AA9 LPMOs. All available AA9 LPMO sequences of Neurospora crassa, Podospora anserina S mat+ (syn. Triangularia anserina S mat+), Thermothelomyces thermophilum (syn. Myceliophthora thermophila), Crassicarpon hotsonii (syn Myriococcum thermophilum) as well as all AA9 LPMOs listed under the headers "characterized" and "structure" in the CAZy database were aligned using the MAFFT-DASH algorithm based on the protein secondary structure. Prior to phylogenetic analysis the C-terminal linker region and the CBM1 were deleted from the alignment. Phylogeny was inferred by using the RaxML-NG algorithm applying the Wheelan & Goldman model with frequencies and gamma distribution (4). The color code of the tree corresponds to the top line of the alignment and indicates the respective segments: Seg1, red; Seg2, blue; Seg3, orange; Seg4, green; Seg5, magenta. Gray squares next to the sequence name column indicate the presence of a CBM1. The color code used to color sequence names indicates the regioselectivity of AA9 LPMOs as previously published [1]: C1, yellow; C4, blue; C1/C4, green. Amino acids considered relevant for catalysis or substrate interaction are colored in the multiple sequence alignment: His, light blue; Arg and Lys, blue; Asp and Glu, red; Asn and Gln, green; Tyr and Phe, yellow.

## full length



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	CAP67740.1 Triangularia anserina S mat+ LPMO9E C1 CBM	
	Myrth2p4 001581	
	AEO54509.1 Thermothelomyces thermophilus CBM	
	EAA34466.1 Neurospora crassa NCU00836 C1 CBM	
	CAP61650.1 Triangularia anserina S mat+	
	Myrth2p4 003633	
	AEO55082.1 Thermothelomyces thermophilus	
	CDP30928.1 Triangularia anserina S mat+	
	CAP61048.1 Triangularia anserina S mat+	
	CAP61395.1 Triangularia anserina S mat+ CBM	
	CAP59702.1 Triangularia anserina S mat+ CBM	
-	CAP65855.1 Triangularia anserina S mat+	
	CAP67466.1 Triangularia anserina S mat+	
	EAA63617.1 Aspergillus nidulans AN3046 C1	
	AKO82493.1 Thermothelomyces thermophilus LPMO9A C1/C4	
	Myrth2p4 000358	
	XP 003657366.1 Thermothielavioides terrestris 3EII LPMO9E C1	
	CAD70347.1 Neurospora crassa NCU03328 4QI8 LPMO9F C1	
	CAP67481.1 Triangularia anserina S mat+	
	Myrth2p4 005343	
	AEO59836.1 Thermothelomyces thermophilus	
	CAP65866.1 Triangularia anserina S mat+	
	CAF05857.1 Neurospora crassa NCU02344	
	AEO60271.1 Thermothelomyces thermophilus C1	
	Myrth2p4 005750	
	ANB32141.1 Pestalotiopsis sp LPMO9A C1/C4	
	AEO61305.1 Thermothelomyces thermophilus	
	CAP67493.1 Triangularia anserina S mat+	
	CAP70156.1 Triangularia anserina S mat+	
	BAL43430.1 Phanerochaete chrysosporium 485Q LPMO9D C1	
	CAE81966.1 Neurospora crassa NCU01867 LPMO9J C1 CBM	
	Myrth2p4 006795 CBM	
	CAP67190.1 Triangularia anserina S mat+	
	CAP68375.1 Triangularia anserina S mat+ LPMO9B C1C1/C4 CBM	
	Myrth2p4 001333	
	AON76800.1 Thermothelomyces thermophilus LPMO9B C1 CBM	
	EAA26873.2 Neurospora crassa NCU08760 LPMO9E C1 CBM	
	CAP68309.1 Triangularia anserina S mat+	
	AEO55652.1 Thermothelomyces thermophilus	
	Myrth2p4 003103	
	AFO72237.1 Heterobasidion parviporum LPMO9H C1 CBM	
	EAA33408.1 Neurospora crassa NCU07974	
	CAP70248.1 Triangularia anserina S mat+	
•	AEO55776.1 Thermothelomyces thermophilus	
	AFO72238.1 Heterobasidion parviporum LPMO9I C4 CBM	
	Myrth2p4 005454	
	AEO59955.1 Thermothelomyces thermophilus	
	EAA30263.1 Neurospora crassa NCU02240 5FOH LPMO9A C4 CBM	
	CAP64619.1 Triangularia anserina S mat+ CBM	
	ANB32140.1 Pestalotiopsis sp LPMO9B C1/C4	
	CAD21296.1 Neurospora crassa NCU01050 4EIR LPMO9D C4	
	CAP73072.1 Triangularia anserina S mat+LPMO9G	
	Myrth2p4 004487	
	AON76801.1 Thermothelomyces thermophilus LPMO9C C4	_
	EAA36362.1 Neurospora crassa NCU02916 4D7U LPMO9C C4 CBM	
	CAP61476.1 Triangularia anserina LPMO9H C1/C4 CBM	
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44		
-44 	CAP61650.1 Triangularia anserina S mat+	
	Myrth2p4 003633	
97 40	AEO55082.1 Thermothelomyces thermophilus	
68	CDP30928.1 Triangularia anserina S mat+	
	EAA34466.1 Neurospora crassa NCU00836 C1 CBM	
44	AEO54509.1 Thermothelomyces thermophilus CBM	
8697	Myrth2p4 001581	
•	CAP67740.1 Triangularia anserina 5 mat+ LPMO9E C1 CBM	
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	CAD70547.1 Neurospora crassa NC005528 4QI8 LPMO9F C1	
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99	AFO61305 1 Thermothelomyces thermonhilus	
	CAP67493 1 Triangularia anserina S mat+	
	Myrth2n4 005343	
	AEO59836.1 Thermothelomyces thermophilus	
91 👝	CAP59702 1 Triangularia anserina S mat+ CBM	
<b>⊢∟</b>	CAP61395.1 Triangularia anserina S mat+ CBM	
8/ 16	EAA63617.1 Aspergillus nidulans AN3046 C1	
.8	CAP61048.1 Triangularia anserina S mat+	
цг	CAP67466.1 Triangularia anserina S mat+	
45	CAP65855.1 Triangularia anserina S mat+	
	CAP70156.1 Triangularia anserina S mat+	
-	BAL43430.1 Phanerochaete chrysosporium 485Q LPMO9D C1	
•	ANB32141.1 Pestalotiopsis sp LPMO9A C1/C4	
-	AEO60271.1 Thermothelomyces thermophilus C1	
	Myrth2p4 005750	
	CAF05857.1 Neurospora crassa NCU02344	
1	CAP65866.1 Triangularia anserina S mat+	
67	AFO72237.1 Heterobasidion parviporum LPMO9H C1 CBM	
7 90	AEO55652.1 Thermothelomyces thermophilus	
	Myrth2p4 003103	
	CAP68309.1 Triangularia anserina S mat+	
47	Myrth2p4 006795 CBM	
1 57	AON76800.1 Thermothelomyces thermophilus LPMO9B C1 CBM	
96	Myrtnzp4 001333	
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co L	CARCOTED.1 Triangularia anserina 5 Math	
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97	Murth2n4 005454	
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96	AC059955.1 Inermothelomyces thermophilus	
65	ANB32140.1 Pertalotionnic on LPMO98 C1/C4	
54 -	CAD21295 1 Neurospora crassa NCU01050 4FIR LBMORD C4	
146	AON76801 1 Thermothelomyces thermophilus I PMO9C C4	
77	CAP73072 1 Triangularia anserina S mat+LPMO9G	
56	Myrth2p4 004487	
23	AFO72238.1 Heterobasidion parviporum LPMO9I C4 CBM	
61	CAP61476.1 Triangularia anserina LPMO9H C1/C4 CBM	
- <b>1</b> -	AEO56416.1 Thermothelomyces thermophilus CBM	
- <b>-</b>	Myrth2p4 004260 CBM	
-1811	CAP72740.1 Triangularia anserina S mat+	
980	AEO56016.1 Thermothelomyces thermophilus LPMO9J C4	
80	Myrth2p4 008028	
70	CDP30131.1 Triangularia anserina S mat+	_
/3	EAA36362.1 Neurospora crassa NCU02916 4D7U LPMO9C C4 CBM	
08	EAA64722.1 Aspergillus nidulans CBM	
97	AEO56547.1 Thermothelomyces thermophilus	
	Myrth2p4 004397	
60	CAP65111.1 Triangularia anserina S mat+	
98	AEO55776.1 Thermothelomyces thermophilus	
	CANDO4UB.1 Neurospora crassa NCU07974	
12	CAP70248.1 Triangularia anserina 5 mat+	
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	Murth 2nd 004335	
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	Myrth2pd 004508	
99 02	CAP73311 1 Triangularia anserina S mate	
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100	Myrth2p4 005329	
85	AEO59823.1 Thermothelomyces thermophilus	
°° 03	Myrth2p4 008530	
98	EAA33178.2 Neurospora crassa NCU07898 4EIS LPMO9M C1/C4	
	AEO61257.1 Thermothelomyces thermophilus	
	CAP71839.1 Triangularia anserina S mat+LPMO9F C1	
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71	AFIGER CO. C.	
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**Figure S2. Comparison of the phylogenetic trees inferred from full length (left) and** "**segments only**" (right) multiple sequence alignments. The three main clusters are color coded (Cluster 1, black; Cluster 2, blue; Cluster 3) and a subgroup of sequences changing from Cluster 1 to Cluster 2 when phylogenetic inference is not based on the full dataset, but the sequence information is highlighted in pale blue. Taxa color code: yellow, C1-oxidizing; blue, C4-oxidizing; green, C1/C4-oxidizing. Gray boxes besides the taxa names indicate the presence of a CBM.



Figure S3. Schematic representation of the secondary structure elements of the catalytic domains. (a) *Nc*LPMO9C, (b) *Nc*LPMO9C<sup> $\Delta$ Seg2</sup>, (c) *Nc*LPMO9F and (d) *Nc*LPMO9M.  $\alpha$ -Helices and  $\beta$ -strands are shown in blue and red, respectively. Disulfide bonds are depicted as dotted lines. Transparent regions are indicating gaps in the multiple sequence alignment and dotted regions are highlighting the Seg1–5 are defined as given in Supplmentary Table S1. the secondary structure elements were determined using the DSSP algorithm [2] as implemented in GROMOS++ [3]



**Figure S4. Front and top view of crystal structures of selected AA9 LPMOs.** The crystal structures and homology models of eight LPMOs is shown in "front view", at which the copper atom and the putative, planar-like substrate surface binding region is facing the bottom, and "top view), at which the previous visualization is rotated by

90°. Each structure represents one of eight distinct clades of the phylogenetic tree. (A) *Nc*LPMO9F (GeneBank: CAD70347.1; PDB: 4QI8), (B) *Pc*LPMO9D (GeneBank: BAL43430.1; PDB: 4B5Q), (C) *Tt*LPMO9B (GeneBank: AON76800.1; SwissModel template: 5TKF with 41.68 % sequence identity), (D) *Nc*LPMO9D (GeneBank: CAD21296.1; PDB: 4EIR), (E) *Nc*LPMO9C (GeneBank: EAA36362.1; PDB 4D7U), (F) *Cv*AA9A (GeneBank: AST24379.1; PDB: 5NLT), (G) *Hi*LPMO9B (GeneBank: ETW87087.1; PDB: 5NNS), and (H) *Tr*LPMO9A (GeneBank: CAA71999.1; PDB: 5O2W). Segments 1 to 5 are colored according to the previously introduced color code (S1: red; S2: blue; S3: orange; S4: green; S5: purple). The catalytic copper atom is shown as orange sphere.

AP61650.1 Triangularia anserina S mat+	N     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td>K N N N H N S V T F Y</td> <td>T - D - Q A V</td> <td><b>D D D D D D D D D D</b></td> <td>P     T     -       P     T     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -       P<td>N 1 1 1 1 1 1 1 1 1 1 1 1 1</td><td>W P M - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -</td><td>R S S Y H N P - G S - I</td><td> T P Q F Y Y T A N</td><td>N I Y N I - I - I - I</td><td>2 2 Y [169]</td></td>	K N N N H N S V T F Y	T - D - Q A V	<b>D D D D D D D D D D</b>	P     T     -       P     T     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -     -       P     -       P <td>N 1 1 1 1 1 1 1 1 1 1 1 1 1</td> <td>W P M - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -</td> <td>R S S Y H N P - G S - I</td> <td> T P Q F Y Y T A N</td> <td>N I Y N I - I - I - I</td> <td>2 2 Y [169]</td>	N 1 1 1 1 1 1 1 1 1 1 1 1 1	W P M - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	R S S Y H N P - G S - I	T P Q F Y Y T A N	N I Y N I - I - I - I	2 2 Y [169]
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EO54509.1 Thermothelomyces thermophilus CBM	Λ	K N T N Y N S F T F T	I I I I I I I I I I I I I I I I I I I	0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	L V L L L L L L L L L L L L L L L L L L	4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		A S D Y H N P W P A G	I P Q F Y Y T V N	N I Y N N - F -	H N Y [169]
lyrth2p4 001581 H D		KNTN YNSFTFT XXTN YNSFTFT							I P O F Y Y T V N 		
AP6//40.1 Triangularia anserina S mat+ LPMO9E C1 CBM D 0002657266 1 Thermothialswipider terrestric still DMO0E C1						1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1			N I I X X I N X X X X X X X X X X X X X		
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AP59702.1 Triangularia anserina S mat+ CBM					L L L L L L L L L L L L L L L L L L L						Y = P Y [169]
Add3617.1 Aspergillus nidulans AN3046 C1				5         5           4         4           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1							
AP61048.1 Triangularia anserina S mat+	P F - F - F - F - F - F - F - F - F - F	PVPA ETVGFK		<ul> <li>B</li> <li>A</li> <li>A</li></ul>	A T Y - P	T A E S A Y Q O	T W R L L	ADFLHLASORG	G A E F Y L V F N	N I W D F D D V Q Q - L -	M S R [169]
AP67466.1 Triangularia anserina S mat+	<b>X X X X X X X X X X</b>	R N S N S Y N I G F W	V     F     N     N     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H <td><ul> <li>D</li> <li>d&lt;</li></ul></td> <td>L L L L L L L L L L L L L L</td> <td>L C N C N C N C N C N C N C N C N C N C</td> <td>M M C S M O</td> <td>K D R L H E G H V - R - 1</td> <td> R A Q F Y I A Y N</td> <td>N K W T N - N P</td> <td>A A Y [169]</td>	<ul> <li>D</li> <li>d&lt;</li></ul>	L L L L L L L L L L L L L L	L C N C N C N C N C N C N C N C N C N C	M M C S M O	K D R L H E G H V - R - 1	R A Q F Y I A Y N	N K W T N - N P	A A Y [169]
AP65855.1 Triangularia anserina S mat+				() () () () () () () () () () () () () (							
AF/01200.1 Irrangularia anserina 5 matt AL43430.1 Phanerochaete chrysosporium 4B5Q LPMO9D C1 H G	Xi         Xi         Xi           Xi         A         A           Xi         A         A           D         D         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I           I         I         I <td></td> <td>H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H<td>5 5 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4</td><td></td><td>I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I</td><td></td><td></td><td></td><td></td><td>r</td></td>		H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H     H <td>5 5 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4</td> <td></td> <td>I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I</td> <td></td> <td></td> <td></td> <td></td> <td>r</td>	5 5 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I					r
NB32141.1 Pestalotiopsis sp LPM09A C1/C4	M 11 M 12 M 12	ETTN HYSHGVSFV	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	9 4 1 7 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1 <t< td=""><td>T T T T T T T T T T T T T T T T T T T</td><td>T F A S G L L L</td><td>L T T V H S A S S E G</td><td> G A Q F Y I L I N</td><td>N I Y Y P P N N</td><td>r 1 - 1 Y [169]</td></t<>	T T T T T T T T T T T T T T T T T T T	T F A S G L L L	L T T V H S A S S E G	G A Q F Y I L I N	N I Y Y P P N N	r 1 - 1 Y [169]
E060271.1 Thermothelomyces thermophilus C1 H G				() () () () () () () () () () () () () (		H H I I I I I I I I I I I I I					
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AP65866.1 Triangularia anserina S mat+		I T Q N H Y S N G V T F Q			I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	H F H F H F H F H F H F H F H F					
FO72237.1 Heterobasidion parviporum LPMO9H C1 CBM	N 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SPASTTT SVTVE	M - H - Q Q P G D R S - I - C A	ANE-AIGGDH-YG	I I I I I I I I I I I I I I	A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A     A	YWATEVLNDI	C G H F H V A S S V G	G A Q F Y I L I N	NIYQIIII	r 1 X [169]
EO55652.1 Thermothelomyces thermophilus	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I		M H - A O P G D R S C A		I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td></td> <td></td> <td></td> <td></td> <td></td> <td>N</td>						N
Nyrth2p4 003103 AP68309 1 Trianeularia anserina S mat+	M         M           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U           U         U	Image         Image <th< td=""><td></td><td>A N E - A I G G N H - F G A N E - A I G G N H - F G</td><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>N           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td></td><td></td><td></td><td>1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td><td>2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2</td></th<>		A N E - A I G G N H - F G A N E - A I G G N H - F G	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	N           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1				1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
Nyrth2p4 006795 CBM	I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I	L P P S N S V T I	M - H - Q Q P G D R S - I - C N	N N E - A I G G A H - W G		1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1       1     1     1	YWGTRDLNA	C G K M H T A G Q S G	G A Q F Y I L V N	N I H A A - A - I	S S Y [169]
ON76800.1 Thermothelomyces thermophilus LPMO9B C1 CBM H G	M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M     M       M       M <t< td=""><td>L P A S V S V T V E</td><td>M H - Q Q P G D R S C S</td><td>S S E - A I G G A H - Y G</td><td>P W A - K</td><td></td><td>YWGTKDLNS</td><td>C G K M H T A G S A G</td><td> G A Q F Y I L V N</td><td>N I H A F - I - I</td><td>S G Y [169]</td></t<>	L P A S V S V T V E	M H - Q Q P G D R S C S	S S E - A I G G A H - Y G	P W A - K		YWGTKDLNS	C G K M H T A G S A G	G A Q F Y I L V N	N I H A F - I - I	S G Y [169]
Nyrth2p4 001333	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I					С ( ) ) ) ) ) ) ) ) ) ) ) ) )					
AAZ00/3.2 Neurospora crassa NCU00/00 LPMO9E C1 CDM AF81966 1 Neurospora crassa NCU01867 I PMO9I C1 CBM	Math         Math           2         2           2         2           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1 </td <td></td> <td></td> <td></td> <td>I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I</td> <td></td> <td>A           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I</td> <td></td> <td></td> <td></td> <td></td>				I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I		A           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I				
AP67190.1 Triangularia anserina S mat+	4         64           4         64           4         64           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           4         60           5         60           6         7           6         7           6         7           7         7           6         7           6         7           7         7           7         7           7         7				I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I						
AP68375.1 Triangularia anserina S mat+ LPMO9B C1/C4 CBM	R         R           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	L P Q S N S V T V E	M - H - A Q N G D R S C S	S Q E - A I G G A H - H G	P M R - K - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1		FWGTKDLNA	C G K M H A A G G A G		- W - W - W - W - W - W - W - W - W - W	T N Y [169]
AP64619.1 Triangularia anserina S mat+ CBM	VSIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	TPTV	W R - H T L T S - G P	P N N - V M D A S H - K G	I I I I I I I I I I I I I I I I I I I	U 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	NWGTSWVINI	AGLHLYELSW		N I Y S M T T - S -	5 K Y [169]
Iyrth2p4 005454	V S I I I I I I I I I I I I I I I I I I	T P T Y D G V K A I	W - R - H T L D S - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1 - G - 1	P D D - V M D P S H - L G	I I I I I I I I I I I I I I			AGEHHAAGSPN	G A Q L Y I L I N	NIYSMS-P	0 1 <u>Y</u> [169]
E059955.1 Thermothelomyces thermophilus	V 00 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		M		I I I I I I I I I I I I I I I I I I I				G A O L Y L L I N		S S Y [169]
AA30263.1 Neurospora crassa NCU02240 5FOH LPMO9A C4 CBM				A D D - V M D A S H - K G						N I Y S M S P - S -	S 1 Y [169]
NB32140.1 Pestalotiopsis sp LPMO98 C1/C4 H L											
ON76801.1 Thermothelomyces thermobilus LPMO9C C4	4         64           >         >           0         0           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1				I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	b         C           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
AP73072.1 Triangularia anserina S mat+LPM09G						U         U           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
Myrth2p4 004487	N         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O	V P S Y X G V T A I	W R - Y M L S T - T G S - A P		I I I I I I I I I I I I I I	(1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1)       (1) </td <td>V M C T E K V I N O</td> <td></td> <td></td> <td></td> <td>r 1 [169]</td>	V M C T E K V I N O				r 1 [169]
FO72238.1 Heterobasidion parviporum LPMO9I C4 CBM	N		W H - H T L A G A D P S - D S	S A D - P I D P S H - K G	I I I I I I I I I I I I I I	0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SWGVDRLIAI	K G K V H G A S S Y P	G A Q F Y I K I N	N I Y Q I - I - I - L -	P 5 Y [169]
AP61476.1 Triangularia anserina LPMO9H C1/C4 CBM	1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1				I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I       I <t< td=""><td></td><td></td><td></td><td></td><td></td><td>R P Y [169]</td></t<>						R P Y [169]
EO56416.1 Thermothelomyces thermophilus CBM	4         4           4         4           5         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4           4         4	A P S S N S V G A W A D S S N S V G A W								SITYDSGRPNNGIGI	8 S Y [169]
Ayrth2p4 004260 CBM AP72740 1 Triangularia anserina S mat+	N         N           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	A F V V I I I I I V V I G A V			I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	b         cc           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
EO56016.1 Thermothelomyces thermophilus LPMO9J C4 H G	I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I         I	A P N N G N N I G A W	Y Q - H V I G G A Q F P N D F	P D N - P I A K S H - K G	1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	T W G V D N L I N I	NGWVHSAYSQG		N I Y G A T G Q P D N N - G -	D = P X [169]
Myrth2p4 008028	<ul> <li>N</li> <li>N&lt;</li></ul>	A P N N G A W	Y Q - H V I G G A Q F P G D	P D N - P I A P S H - K G		N           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I           I	VWGVDNLINI	DGWVHSAYTPGIIII	G A Q F Y I T I N	N I Y G A A G E P D N N - G -	2 P Y [169]
DP30131.1 Triangularia anserina S mat+	1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1 <t< td=""><td>A P S Q F N I G A W</td><td></td><td></td><td>I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I</td></t<> <td>U     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I<td></td><td>KGWSHSAYSNM</td><td></td><td>O I W V A S - V P D N G - R -</td><td>X P Y [169]</td></td>	A P S Q F N I G A W			I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I	U     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td></td> <td>KGWSHSAYSNM</td> <td></td> <td>O I W V A S - V P D N G - R -</td> <td>X P Y [169]</td>		KGWSHSAYSNM		O I W V A S - V P D N G - R -	X P Y [169]
AA36362.1 Neurospora crassa NCU02916 4D/U LPMO9C C4 CBM H G											
EO56547.1 Thermothelomyces thermophilus					I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	B         B           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
Nrth2p4 004397 H G	D G L N K Y I R	S P A T N D L T F L		P G D Y V L D P S H - K G	1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1	D         D           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1	K W A T I R M I D	IGGKVHQADFACNDPA	A H P N R G A E S Y L Y F N	N I Y I G D	
AP65111.1 Triangularia anserina S mat+	D G R - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	SPKT NDLSFR	W - F - H F R P E - I - I - I - I	PTD-ILDPSH-KG			EWATIKMIAI	KGRAHMADINFKV-	- DNTRGPESYLF	N I Y V F - F - F	0 K Y [169]
EO55776.1 Thermothelomyces thermophilus	H     I       H     I       H     I       H     I       H     I       H     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td>MAKKG - NVATHLTLE</td> <td>F - R - M W A D A S Q - 1 - 1</td> <td></td> <td>V Y D - L A - A</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>S T Y [169]</td>	MAKKG - NVATHLTLE	F - R - M W A D A S Q - 1 - 1		V Y D - L A - A						S T Y [169]
Addated Size Neurospora Crassa NcUU/9/4	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I			5     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	5         8           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
ST70240.1 Hanguaria anserina 3 mat ST704379 1 Collarialla virescens SNLT C1 /C4	4         6           4         6           5         7           7         7           7         7           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1				I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td>4         24           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1</td> <td></td> <td></td> <td></td> <td></td> <td></td>	4         24           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
LN96977.1 Lentinus similis 5ACF AA9A C4	M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M         M					M         M           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I					
1 T H L	A W Q V G Q D D Y V N - P P V R Y A R	K L A D N G V T L N		0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	I I I I I I I I I I I I I I I I I I I		PWASDLER	GAKWHVAGTVM	G A Q F Y I L V E	ELWRVNQG-G-Q-	V N Y [169]
AA36150.2 Neurospora crassa NCU03000 H	G Y E G F S P A S S P K T I Q F	Q W P N Y D V T A V	1 1 1 1 1 1 1 1 1 1 1 1 1 1	0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	L M M M A		. N W G T A - L I V	NHQWHQAN	I P O F Y V I I	DIXSIC	r 1 1
EO56665.1 Thermothelomyces thermophilus LPMO9D C1 H P											
AP73311.1 Triangularia anserina S mat+			I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
TW87087.1 Heterobasidion irregulare SNNS LPM09B C1 H	G F V P Y N T P T G Q S T I Q R	E W D T Y N V T A Y		Image: state	P L V - S		TWGMGQLVAI				T N Y [169]
1 R H R	G Y D P D L P P E V O L N Q T W M I Q R	QWATINDITAV	I I I I I I I I I I I I I I I I I I I	W L - H A I G	I I I I I I I I I I I I I I I I I I I	- P N - L A - L	LWYQKDFQRWDG	PSLWHVAL	K P Q F Y I F I D	DVYSEENAN-R-	r 1 <u>v</u> [169]
EO59823.1 Thermothelomyces thermophilus	G Y D P N L P P E T C L N Q T W M I Q R	QWATIDITAV	I I I I I I I I I I I I I I I I I I I	N I - N I - I H A I G	L C C C C C C C C C C C C C C C C C C C	1 F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M - F M	L W Y Q K D F Q R W D G	P S L W H V A L	K P Q F Y I F I D	D V Y S E E N A N N - R -	r 1 7 [169]
Nyrth2p4-008530 H P AA33178-2 Neurosonas srassa NCLI07808-4615 I DMOOM C1 /C4 H O	G F F F X Y F A I I I I I I E G Q V V I V I I I I F G Q V V I V I V I I I I I I I I E G Q V V V I V I V V V V V V V V V V V V V					5         2           4         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1					
F061257 1 Thermothelomycres thermophilus					I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	Image: square         Image: s					
AP71839.1 Triangularia anserina S mat+ LPMO9F C1 H 0	FY Q PY M D PY M G N N K P Q R V S R	S I P G N G V I L H	I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I           I         I	M P D S H - M G	1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1           1	H       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1 <t< td=""><td>N L S K G P S G I I S</td><td>S S K V H A A W A Y P</td><td></td><td>D A Y K E - I E</td><td>TDMDLSIAOAY [169]</td></t<>	N L S K G P S G I I S	S S K V H A A W A Y P		D A Y K E - I E	TDMDLSIAOAY [169]
lyrth2p4 003927 H 0	FYQPYQDPYMGDNKPDRVSR	S I P G N G V T L Y	I I I I I I I I I I I I I I I I I I I		L L L L L L L L L L L L L L	M 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	V W A D T P L M T I	PSAYHAMEYP	G A Q F Y I T Y D	D A Y K	0 P Y [169]
EI35168.1 Gloeophyllum trabeum LPMO9B C1/C4	G Y L P Y N D P Y T T - P A P O R I E R			N P S H - V G	I		KWAATDVLSA	NSTWHOADTYP		N V Y T <u>F</u> -	I S Y [169]
AV57612.1 Gloeophyllum trabeum LPM09A			I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>N V Y S G I I I I I I I I I I I I I I I I I I</td> <td>r 5 r [169]</td>							N V Y S G I I I I I I I I I I I I I I I I I I	r 5 r [169]
AP68352.1 Triangularia anserina S mat+		S S S N A D D G V H I O						NNSWHFAKNKGIIII MNSWOSSIIII			
AA29132.1 Neurospora crassa NCU07520 H R			I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I	5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I	()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()         ()					
AA29347.1 Neurospora crassa NCU05969 H R	GFD-SSLNYMANPPAVGW	KANNQNGISIQ	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	L L K C K L K C	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1	K W G S D Q L I A I	INNSWHSAGOPN	G A Q N Y I S V N	N I Y Q S - L -	S S Y [169]
AP66744.1 Triangularia anserina S mat+ LPMO9D C1 H	G Y D I N S F P Y T V P P K V A A W	TASNTDNGVFVQ	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	H C H C H C H C H C H C H C H C H C H C	F V I N I O		R W A S D V L I D 1	INNSWHSGDINI	G A Q N Y I R F N	N I Y R I I I I I I I I I I I I I I I I I	0 S Y [169]
EO58921.1 Thermothelomyces thermophilus	N F D P F T H P Y M Q - N P P T V V G W		I 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	<ul> <li>日</li> <li>日<td>I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I       I    <t< td=""><td></td><td></td><td></td><td> G A O N Y I L A N</td><td></td><td>V 1 Y [169]</td></t<></td></li></ul>	I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I     I       I       I <t< td=""><td></td><td></td><td></td><td> G A O N Y I L A N</td><td></td><td>V 1 Y [169]</td></t<>				G A O N Y I L A N		V 1 Y [169]
Ayrth2p4 006403											V T Y [169]
EF/4460.1 Fusarium graminearum LPIMO9A C1/C4 0471999 1 Trichoderma reseii 507W IPMO9A C1/C4 CBM	6 L N F 6 A A A F E I I I I N I F K E L A A A A V D D T T F D V F I I I I N I V D D T V V G W	T b b b 1 b N G 1 1 <mark>F O</mark>							I I I I I I I I I I I I I I I I I I I	1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1     1       1 <td></td>	
AP57753.1 Trichoderma reesei 2VTC GH61B	G F I L - D Y Y Q K Q N T G - H F P N V A G W		1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1    <	5     5       4     5       4     5       4     4       4     4       4     4       4     4       4     4       4     4       1     4       1     1       1     1       1     1       1     1       1     1	I I I I I I I I I I I I I I	0         0           4         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1           1         1				I I I I I I I I I I I I I I	
EO56542.1 Thermothelomyces thermophilus CBM	N Y D P T T D W Y Q P - N P P T V I G W	T A A D O D N G I N I V		N P E S H - I G	P Y D - K A		R W A A D A L R A I	GNSWHGAQSPN	G A Q A Y I L F N	N P Y V S - S -	P D Y [169]
4yrth2p4 004391 CBM	N Y D P T T D S Y Q D N P P T V I G W	A A D Q Q D N G I N I V		I   I   M   P   E   S   H   I   G     I   I   I   I   I   I   I	Mathematical Structure       Mathematical Structure         Mathematical Structu	<ul> <li>B</li> <li>I</li> <li>I&lt;</li></ul>	к w а а D а ц к А 1	G N S W H G A S S P N	G A Q A Y I L F N	N P Y V D - D	P D Y [169]
AP73254.1 Triangularia anserina Smat+ LPM09A C1/C4 CBM	NYDPTTHFYQ===P=NPPTVIGW wypptsepvw										
P 752040.1 Aspergillus fumigatus 6H12	G Y L V N O Y P Y M S - N P P D T I A W					(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)				1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1 <t< td=""><td></td></t<>	
CS05720.1 Thermoascus aurantiacus 2YET LPMO9A C1/C4	GYIVNOYPANS-NPPEVIA	STTATDLGVELO		H - H C H - H C - H - H C - H - H C - H - H	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	5 4 1 1 4 4 1 1 4 1 1 1 1 1 1 1 1 1 1 1	IWASDNLIA	N N S W H S A Q N Q D	G A Q N Y I L I N	N I Y Q K - L - N	S S Y [169]
DO57961.1 Geotrichum candidum LPMO9B C1/C4	L S N P F R D P Y M N - P V P D R V G W	SFFGHHAGUCLTFY		н н н н н н н н н н			VWVSDKIIAI	INNSWHSAGODL	G A Q F Y I L V N	N I Y N U I N	X S Y [169]
D058049.1 Geotrichum candidum LPM09A C1/C4	S S L V Y Q D P Y A N - P V P E R I T W	SFEGHESGNGATFY	W T - V	I I R G	L	9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	EWISDKIIA	INNSYHSAYDEL	G A Q F Y I L V N	N I Y N G - L -	r S Y [169]



Figure S5. "Segments-only" multiple sequence alignment. All available AA9 LPMO sequences of Neurospora crassa, Podospora anserina S mat+ (syn. Triangularia anserina S mat+), Thermothelomyces thermophilum (syn. Myceliophthora thermophila), Crassicarpon hotsonii (syn Myriococcum thermophilum) as well as all AA9 LPMOs listed under the headers "characterized" and "structure" in the CAZy database were aligned using the MAFFT-DASH algorithm based on the protein secondary structure. The multiple sequence alignment was then assembled in a way that left only the indicated segments (Seg1-5) in the alignment. The phylogeny was inferred by the RaxML-NG algorithm applying the Wheelan & Goldman model with frequencies and gamma distribution (4). The color code of the tree corresponds to the top line of the alignment and indicates the position/possession of the respective segments: Seg1, red; Seg2, blue; Seg3, orange; Seg4, green; Seg5, magenta. Gray squares next to the sequence name column indicate the presence of a CBM1. The color code used to color sequence names indicates the regioselectivity of AA9 LPMOs as previously published [1]: C1, yellow; C4, blue; C1/C4, green. Amino acids considered relevant for catalysis or substrate interaction are colored in the multiple sequence alignment: His, light blue; Arg and Lys, blue; Asp and Glu, red; Asn and Gln, green; Tyr and Phe, yellow.



**Figure S6. Cartoon representation of the homology model of AON76800.1** *Thermothelomyces thermophilus* LPMO9B. The segments are colored red (Seg1), blue (Seg2), orange (Seg3), green (Seg4) and magenta (Seg5). The disulfide bonds are highlighted by stick representation. The numbers 1–3 indicate the disulfide bonds between the residues 18–49, 38–173 and 70–133, respectively. The second disulfide bond is binding and shortening Seg2 and thereby mimicking a short Seg2. The Homology model was generated using SWISS-MODEL [4–8] (template: PDB entry 5TKF, sequence identity: 41.86%, QMEAN: -2.03).



**Figure S7. SDS-PAGE of purified LPMOs and LPMO variants.** *Nc*LPMO9C (Lane 1), *Nc*LPMO9C<sup>ΔCBM</sup> (Lane 2), *Nc*LPMO9C<sup>ΔSeg2</sup> (Lane 3), *Nc*LPMO9C<sup>ΔSeg2, ΔCBM</sup> (Lane 4), *Nc*LPMO9F (Lane 5) and *Nc*LPMO9M (Lane 6). Lanes and molecular weights of the marker proteins (Precision Plus Protein Unstained Standards, Bio-Rad) are indicated. The precast gel (4–20% Mini-PROTEAN® TGX Stain-Free<sup>TM</sup> Precast Gel, BioRad) was stained with colloidal Coomassie blue (Bio-Safe<sup>TM</sup> Coomassie G250 Stain, BioRad) for 1 h and destained overnight.



**Figure S8. Determination of kinetic constants of** *Nc***LPMO9M**, *Nc***LPMO9C and** *Nc***LPMO9C variants for**  $H_2O_2$ . As substrate 2 mM 2,6-DMP in 100 mM sodium acetate buffer, pH 6.0 was used. The LPMO acitivity assay was performed as previously published [9].The calculated *K*<sub>M</sub> and *k*<sub>cat</sub> values are given in **Table 1**. Error bars show the standard deviation of three replicates.

(a)	1	HTIFQKVSVNGADQGQLKGIRAPANNNPVTDVMSSDIICNAVTMKDSNVLTVPAGAKVGH	60
	61	FWGHEIGGAAGPNDADNPIAASHKGPINVYLAKVDNAATTGTSGLKWFKVAEAGLSNGKW	120
	121	AVDDLIANNGWSYFDMPTCIAPGQVLMRAELIALHNAGSQAGAQFYIGCAQINVTGGGSA	180
	181	SPSNTVSFPGAYSASDPGILINIYGGSGKTDNGGKPYQIPCPALFTCPAGGSGGSSPAPA	240
	241	TTASTPKPTSASAPKPVSTTASTPKPTNGSGSGTGAAHSTKCGGSKPAATTKASNPQPTN	300
	301	GGNSAVRAAALYGQCGGKGWTGPTSCASGTCKFSNDWYSQCLP	343
(b)	1	HTIFQKVSVNGADQGQLKGIRAPANNNPVTDVMSSDIICNAVTMKDSNVLTVPAGAKVGH	60
	61	FWGHEIGGAAGPNDADNPIAASHKGPIMVYLAKVDNAATTGTSGLKWFKVAEAGLSNGKW	120
	121	AVDDLIANNGWSYFDMFTCIAPGQYLMRAELIALHNAGSQAGAQFYIGCAQINVTGGGSA	180
	181	SPSNTVSFPGAYSASDPGILINIYGGSGKTDNGGKPYQIPGPALFTC	227
(c)	1	HTIFQKVSVNGADQGQLKGIRAPANNNPVTDVMSSDIICNAVTMKDSNVLTVPAGAKVGH	60
	61	FWAPSVYHKGPIMVYLAKVDNAATTGTSGLKWFKVAEAGLSNGKWAVDDLIANNGKSYFD	120
	121	MPTCIAPGQYLMRAELIALHNAGSQAGAQFYIGCAQINVTGGGSASPSNTVSFPGAYSAS	180
	181	DFGILINIYGGSGKTDMGGKPYQIPCPALFTCPAGGSGGSSPAPATTASTPKPTSASAPK	240
	241	PVSTTASTPKPTNGSGSGTGAAHSTKCGGSKPAATTKASNPQPTNGGNSAVRAAALYGQC	300
	301	GGKGWTGPTSCASGTCKFSNDWYSQCLP	328
(d)	1	HTIFQKVSVNGADQGQLKGIRAPANNNPVTDVMSSDIICNAVTMKDSNVLTVPAGAKVGH	60
	61	FWAPSVYHKGPIMVYLAKVDNAATTGTSGLKWFKVAEAGLSNGKWAVDDLIANNGWSYFD	120
	121	MPTCIAPGQYLMRAELIALHNAGSQAGAQFYIGCAQINVTGGGSASPSNTVSFPGAYSAS	180
	181	DPGILINIYGGSGKTDNGGKPYQIPGPALFTC	212
(e)	1	HYTFPKVWANSGTTADWQYVRRADNWQNNGFVDNVNSQQIRCFQSTHSPAQSTLSVAAGT	60
	61	TITYGAAPSVYHPGPMQFYLARVPDGQDINSWTGEGAVWFKIYHEQPTFGSQLTWSSNGK	120
	121	SSFPVKIPSCIKSGSYLLRAEHIGLHVAQSSGAAQFYISCAQLSITGGGSTEPGANYKVS	180
	181	FPGAYKASDPGILININYPVPTSYKNPGPSVFTC	214
(f)	1	HGFVDNATIGGQFYQFYQPYQDPYMGSPPDRISRKIPGNGPVEDVTSLAIQCNADSAPAK	60
	61	LHASAAAGSTVTLRWTIWPDSHVGPVITYMARCPDTGCQDWTPSASDKVWFKIKEGGREG	120
	121	TSNVWAATPLMTAPANYEYAIPSCLKPGYYLVRHEIIALHSAYSYPGAQFYPGCHQLQVT	180
	181	GSGTKTPSSGLVSFPGAYKSTDPGVTYDAYQAATYTIPGPAVFTC	225

**Figure S9. Analysis of** *NcLPMO* **variants by liquid chromatography-electrospray ionization mass spectrometry (LC-ESI-MS) confirmed their mutations.** Section a, *NcLPMO9C*; Section b, *NcLPMO9C*<sup>ΔCBM</sup>; Section c, *NcLPMO9C*<sup>ΔSeg2</sup>; Section d, *NcLPMO9C*<sup>ΔSeg2, ΔCBM</sup>, Section e *NcLPMO9F* and Section f, *NcLPMO9M*. Sequence sections colored in red were identified by the software Global Proteome Machine (GPM) by performing MS/MS ion searches against a homemade database containing the host cell proteome and all target sequences. Amino acids marked in green are marked as "unlikely to find" due to too short or too long peptides (or glycosylation).



Figure S10. Differential scanning calorimetry (DSC) thermograms of the scan and rescan of *Nc*LPMO9C. Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted curves are shown as a purple line and the transition midpoint temperature (Tm) is indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15  $\mu$ M *Nc*LPMO9C concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



Figure S11. DSC thermograms of the scan and rescan of *Nc*LPMO9M. Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted  $T_m$  curves are shown as a purple line and the transition midpoint temperatures are indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15  $\mu$ M *Nc*LPMO9C concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



Figure S12. DSC thermograms of the scan and rescan of *Nc*LPMO9F. Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted  $T_m$  curves are shown as a purple line and the transition midpoint temperatures are indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15  $\mu$ M *Nc*LPMO9C concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



Figure S13. DSC thermograms of the scan and rescan of *Nc*LPMO9<sup> $\Delta$ Seg2</sup>. Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted *T*<sub>m</sub> curves are shown as a purple line and the transition midpoint temperatures are indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15 µM *Nc*LPMO9C concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



Figure S14. DSC thermograms of the scan and rescan of  $NcLPMO9C^{\Delta CBM}$ . Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted  $T_m$  curves are shown as a purple line and the transition midpoint temperatures are indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15  $\mu$ M *NcLPMO9C* concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



Figure S15. DSC thermograms of the scan and rescan of  $NcLPMO9C^{\Delta Seg2, \ \Delta CBM}$ . Baseline subtracted raw data are shown as a grey scatter plot and the fitted curve is shown in black. The fitted  $T_m$  curves are shown as a purple line and the transition midpoint temperatures are indicated by a vertical dotted line. Starting the scan at 20 °C, a temperature ramp of 1 K min<sup>-1</sup> was applied until reaching 90 °C. For the rescan, the sample was cooled down with a temperature ramp of 1 K min<sup>-1</sup> immediately after reaching 90°C and when reaching 20°C the rescan was started without delay. A 15  $\mu$ M NcLPMO9C concentration in 50 mM potassium phosphate buffer, pH 6.0 was applied to the instruments measurement cell.



**Figure S16. Monitoring of thermal denaturation by circular dichroism (CD).** ECD spectra of 3 mg mL<sup>-1</sup> *Nc*LPMO9C (left panels) and *Nc*LPMO9C<sup>ΔCBM</sup> (right panels) at different temperatures (top panels) for a wavelength range between 200–250 nm. Using the BestSel web server (http://bestsel.elte.hu) the secondary structure was predicted for all different temperatures (lower panels) [11].



Figure S17. Bar plot showing the ratio of  $\Delta H_{cal}$  of the DSC rescan and  $\Delta H_{cal}$  of the first scan. This ratio is used to asses possible refolding of the protein [10]. The horizontal line indicates the threshold for reversible unfolding. Data were calculated from the thermograms shown in Supplementary Figures S10-S15.



Figure S18. HPAEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> RAC with 1.25  $\mu$ M of the indicated LPMOs in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S19. HPAEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> RAC with 1.25  $\mu$ M of the indicated LPMOs in the absence of ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S20. HPAEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> CMC with 1.25  $\mu$ M of the indicated LPMOs in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S21. HPAEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> CMC with 1.25  $\mu$ M of the indicated LPMOs in the absence of ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S22. Quantification of cellodextrins in the supernatant released in a batch conversion by 1.25  $\mu$ M of LPMO and LPMO variants after a 24 h incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5 on 2 g L<sup>-1</sup> RAC or CMC in the absence of ascorbic acid. The integration windows for product quantitation were defined as described in Supplementary **Table S3**.



**Figure S23. HPAEC chromatogram of Xylogluco-oligomer products released from the reaction** of 2 g L<sup>-1</sup> XG with 1.25 µM of the indicated LPMOs in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S24. HPAEC chromatogram of Xylogluco-oligomer products released from the reaction of 2 g L<sup>-1</sup> XG with 1.25  $\mu$ M of the indicated LPMOs in the absence of ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 3<sup>rd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



**Figure S25. HPSEC chromatogram of products released from the reaction** of 2 g L<sup>-1</sup> XG without LPMO in the absence ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12]

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**Figure S26. HPSEC chromatogram of products released from the reaction** of 2 g L<sup>-1</sup> XG without LPMO in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S27. HPSEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> XG with 1.25  $\mu$ M *Nc*LPMO9C in the absence ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S28. HPSEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> XG with 1.25  $\mu$ M *Nc*LPMO9C in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S29. HPSEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> XG with 1.25  $\mu$ M *Nc*LPMO9C<sup>ΔCBM</sup> in the absence ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



Figure S30. HPSEC chromatogram of products released from the reaction of 2 g L<sup>-1</sup> XG with 1.25  $\mu$ M *Nc*LPMO9C<sup>ΔCBM</sup> in the presence of 1 mM ascorbic acid after 24 h of incubation at 30 °C in 50 mM ammonium acetate buffer, pH 5.5. The data are baseline corrected using a baseline detection algorithm with a polynomial of the 2<sup>nd</sup> degree and a tolerance of 10<sup>-14</sup> [12].



**Figure S31. Normalized integrated intensity of negative controls without ascorbic acid.** The area under the curves from **Figures S27-29** were integrated. The integrated peaks within the elution windows as described in Supplementary **Table S4** are showing no hydrolytic background of the LPMO preparations.



Figure S32. Normalized, integrated Elution window 3 over the conversion time. Curves are normalised to the maximum of the *Nc*LPMO9C curve. The curves are fitted to the data points using the following function:  $y = ae^{-bx} + c$ .



**Figure S33. Sensograms of LPMO binding to cellulose surface in its oxidized and reduced state.** The binding behavior of *Nc*LPMO9C (a) and *Nc*LPMO9C<sup>ΔCBM</sup> (b) injected in two different concentrations (400 nM and 1600 nM) to the cellulosic substrate was recorded in the presence of oxygen (black line) and in the absence of oxygen supplemented with 10 mM gallic acid as reductant (dotted line). Sensograms were adjusted to the same response at the begin of the first injection.



Figure S34. Representation of the mobility of the amino acid segment around the catalytic sites. Crystal structures of (a) TtLPMO9E (GeneBank: LPMO CP\_003657366.1; PDB: 3EII), (b) NcLPMO9F (Genebank: CAD70347.1; PDB: 4QI8), (c)PcLPMO9D (Genebank: BAL43430.1; PDB: 4B5Q), (d) NcLPMO9A (GeneBank: EAA30263.1; PDB: 5FOH), (e) NcLPMO9D (GeneBank: CAD21296.1; PDB: 4EIR), (f) NcLPMO9C (GeneBank: EAA36362.1; PDB: 4D7U), (g) CvAA9A (GeneBank: AST24379.1; PDB: 5NLT), (h) LsAA9A (GeneBank: ALN96977.1; PDB: 5ACF), (i) HiLPMO9B (GeneBank: ETW87087.1; PDB: 5NNS), (j) NcLPMO9M (GeneBank: EAA33178.2: PDB: 4EIS), (k) TrLPMO9A (GeneBank: CAA71999.1; PDB: 5O2W), (l) TaLPMO9A (GeneBank: ACS05720.1; PDB: 2YET). Top row: ribbon in gray and segments 1-5 in red, blue, orange, green, and magenta, respectively. Bottom row: flexibility indicated via "b-factor putty", that is, from blue via green to red and from narrow to wide tubes corresponds to low to high flexibility of the respective regions.

Table S1. Definitions of segments around the catalytic site of *NcLPMOs*. The segment definitions for *NcLPMO9C*<sup> $\Delta CBM$ </sup> and *NcLPMO9C*<sup> $\Delta Seg2$ </sup>,  $\Delta CBM$  are identical to *NcLPMO9C* and *NcLPMO9*<sup> $\Delta Seg2$ </sup>, respectively.

			Segments		
Enzymes –	Seg1	Seg2	Seg3	Seg4	Seg5
NcLPMO9F	A15-G30	I62-P75	P107-F123	H146-Y157	I192-Y204
NcLPMO9C	G15-N27	V58-P86	L115-S132	H155-Y166	I199-Y217
NcLPMO9M	Q12-G40	V71-P85	R118-N136	S161-Y171	V205-Y215
NcLPMO9 <sup>4Seg2</sup>	G15-N27	V58-P71	L100-S117	H140-Y151	I184-Y202

**Table S2. Purification scheme of recombinantly produced LPMOs.** Culture supernatants of *P. pastoris* fermentations have been purified by hydrophobic interaction chromatography (HIC), anion exchange chromatography (AIEX), and size exclusion chromatography (SEC). The total protein concentration was determined with the Bradford method except for the pools indicated with an "\*", which were measured with the bicinchoninic acid (BCA) assay. To the previously published purification protocol of *Nc*LPMO9C [13] a SEC step was added. *Nc*LPMO9F was produced by Kittl *et al*.

Purification step	Total protein [g]	Yield [%]
NcLPMO9 <sup>∆Seg2</sup>		
Culture supernatant	6.02	100
HIC	0.84	14
AIEX	0.80	13
NcLPMO9M		
Culture supernatant	4.48	100
HIC	0.49	11
AIEX	0.32	7
NcLPMO9С <sup>ΔСВМ</sup>		
Culture supernatant	6.72	100
HIC	3.70	55
AIEX	1.04	15
SEC*	0.28	4
$NcLPMO9C^{\Delta Seg2, \ \Delta CBM}$		
Culture supernatant	3.84	100
HIC	0.11	2.9
AIEX	0.10	2.5
NcLPMO9C		
Stock*	0.13	100
SEC*	0.01	8
NcLPMO9F		
Stock*	0.005	

**Table S3. Elution windows defined to integrate detected products in HPAEC chromatograms used for RAC and CMC conversion experiments.** Values are in minutes. DP = Degree of polymerization (e.g., cellobiose id DP2)

DP2	DP3	DP4	DP5	DP6	Total
[10.40, 11.00]	[13.60, 14.25]	[16.00, 17.00]	[18.50, 19.40]	[20.50, 21.36]	[4.90, 45.00]

r.	Released Cellodextrins [µM]					
Enzyme	DP2	DP3	DP4	DP5	DP6	Total
RAC + ascorbic acid						
Control	6.6	0.0	0.0	0.0	0.0	6.6
NcLPMO9F	26.2	10.7	10.3	17.2	12.8	77.2
NcLPMO9C	88.2	77.9	26.4	4.2	5.2	201.9
$NcLPMO9C^{\Delta CBM}$	20.4	8.6	9.0	5.1	3.6	46.7
$NcLPMO9^{\Delta Seg2}$	12.8	0.0	0.0	1.5	0.0	14.4
$NcLPMO9C^{\Delta Seg2, \Delta CBM}$	15.8	0.0	0.0	1.0	0.0	16.8
NcLPMO9M	40.3	50.9	34.8	25.4	19.4	170.8
CMC + ascorbic acid						
Control	14.8	0.0	0.0	1.0	0.0	15.8
NcLPMO9F	13.0	2.8	2.3	2.7	5.6	26.5
NcLPMO9C	61.9	25.2	0.0	0.0	0.0	87.1
$NcLPMO9C^{\Delta CBM}$	24.8	12.0	7.4	5.2	3.5	52.8
$NcLPMO9^{\Delta Seg2}$	16.0	0.0	0.0	2.1	0.0	18.1
NcLPMO9C <sup>(ASeg2, ACBM)</sup>	15.7	0.0	0.0	2.1	0.0	17.8
NcLPMO9M	17.8	2.1	3.2	3.2	2.0	28.4

Table S4. Quantification of cellodextrins in the supernatant released by 1.25  $\mu$ M enzymes after a 24 h incubation on 2 mg/mL RAC or CMC in the presence of 1 mM ascorbic acid. The integration times of product elution windows are defined as described in Supplementary Table S3.

Table S5. Quantification of cellodextrins in the supernatant released by 1.25  $\mu$ M enzymes after a 24 h incubation on 2 mg/mL RAC or CMC in the absence of ascorbic acid. The integration of product elution windows are defined as described in Supplementary Table S3.

Engrado	Released Cellodextrins [µM]						
Enzyme	DP2	DP3	DP4	DP5	DP6	Total	
RAC, no ascorbic acid							
Control	0.0	0.0	0.0	0.0	0.0	0.0	
NcLPMO9F	1.5	0.7	0.9	0.4	0.1	3.6	
NcLPMO9C	6.7	5.2	6.3	1.7	0.2	20.1	
$NcLPMO9C^{\Delta CBM}$	0.0	0.0	0.0	0.0	0.0	0.0	
NcLPMO9 <sup>∆Seg2</sup>	0.0	0.0	0.0	0.0	0.0	0.0	
$NcLPMO9C^{\Delta Seg2, \Delta CBM}$	0.0	0.0	0.0	0.0	0.0	0.0	
NcLPMO9M	0.0	0.0	0.0	0.0	0.0	0.0	
CMC, no ascorbic							
acid							
Control	0.0	0.0	0.0	0.0	0.0	0.0	
NcLPMO9F	11.6	4.1	7.5	3.6	1.5	28.3	
NcLPMO9C	22.9	10.9	14.8	5.0	0.7	54.3	
$NcLPMO9C^{\Delta CBM}$	0.0	0.0	0.0	0.0	0.0	0.0	
$NcLPMO9^{\Delta Seg2}$	0.0	0.0	0.0	0.0	0.0	0.0	
$NcLPMO9C^{\Delta Seg2, \Delta CBM}$	0.0	0.0	0.0	0.0	0.0	0.0	
NcLPMO9M	0.0	0.0	0.0	0.0	0.0	0.0	

**Table S6. Elution windows used to integrate XG conversion products in HPSEC chromatograms.** Values shown are in min. The upper boundaries were excluded from the integrations as indicated by the open bracket "[".

Elution window 1	Elution window 2	Elution window 3
[7.40, 11.00[	[11.00, 12.00[	[12.00, 14.75[

Table S7. Nucleotide sequences of primer pair used to generate *Nc*LPMO9C<sup>∆CBM</sup> and *Nc*LPMO9C<sup>∆Ceg2, ∆CBM</sup>.

Primer name	Sequence (5'→3')
P213X_F	GTCCAGCTTTGTTCACTTGT <u>TAA</u> GCTGGTGGTTC
P213X_R	CAAAGCTGGACCTGGAATTTGGTATGGCTTAC

**Table S8. Statistics of the peptide mapping with liquid chromatographyelectrospray ionization mass spectrometry (LC-ESI-MS).** Results with 1 unique peptide have been removed from the table. Two human proteins have been removed. Rows that were showing the used protease were also deleted from the table. The likelihood that a peptide is a random match is indicated the log(e) score. E.g., the log(e) of the first row corresponds a 1 in 10419.3 chance that this result is a false positive. The coverage indicates sequence coverage.

	Coverage	log(e)	Unique	Lta:Duct ID
	[%]	Score	Peptides	UniProt ID
NcLPMO9C	53	-419.3	34	NcLPMO9C
NcLPMO9C <sup>∆CBM</sup>	88	-622.4	50	<i>NcLPMO9C</i> <sup>∆CBM</sup>
	72	-668.6	53	<i>Nc</i> LPMO9C <sup>∆Seg2</sup>
NCLPW09C <sup>Locg2</sup>	45	-63.6	6	C4R8X7 (P. pastoris)
	62	-570.3	47	$NcLPMO9C^{\Delta Seg2, \Delta CBM}$
	60	-149.4	13	C4R8X7 (P. pastoris)
	48	-72.4	7	C4R300 (P. pastoris)
	36	-72.3	8	A0A1B2JFA7 (P. pastoris)
NLat DMOOCASeg2. ACBM	33	-214.1	19	C4R9F6 (P.pastoris)
	25	-93.5	10	C4QW09 (P. pastoris)
	23	-68.6	8	C4R862 (P. pastoris)
	22	-70.9	7	A0A1B2J744 (P. pastoris)
	21	-65.4	7	C4QY07 (P. pastoris)
	21	-63.3	7	C4R7U0 (P. pastoris)
	71	-244.7	27	NcLPMO9F
	71	-62	7	A0A1B2J759 (P. pastoris)
	68	-359.3	33	A0A1B2JHZ1 (P. pastoris)
	39	-163.5	18	A0A1B2JGG7 (P. pastoris)
	39	-41.4	6	A0A1B2JCS3 (P. pastoris)
NcLPMO9F	38	-67.5	11	A0A1B2JEK0 (P. pastoris)
	28	-44.2	6	A0A1B2JGF8 (P. pastoris)
	17	-40.2	6	A0A1B2JIZ2 (P. pastoris)
	17	-38.8	6	A0A1B2J5L5 (P. pastoris)
	10	-54.8	6	A0A1B2J5W9 (P. pastoris)
	8.8	-35.8	5	A0A1B2J841 (P. pastoris)
NcLPMO9M	84	-369	32	NcLPMO9M

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