CLAIMS

We claim:

1. An engineered phosphopentomutase comprising a polypeptide sequence having at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: ~~4, 12, 16, 90, 198,~~ 352, 412 and/or 418, or a functional fragment thereof, wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set and wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: ~~4, 12, 16, 90, 198,~~ 352, 412 and/or 418.

~~2. The engineered phosphopentomutase of Claim 1, wherein said polypeptide sequence has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO:4, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions in said polypeptide sequence selected from 22/68/180/188/257/266, 22/68/257/266, 22/137/257/266, 22/180/188/257/334, 22/188/257/266/341, 22/257/266, 22/257/355, 82/92/192/308, 82/308, 151/225/251/256/257/287/355/357/391, 188/257/266/334, 188/257/266/334/355, 257/341, 257/355, and 308, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 4.~~

~~3. The engineered phosphopentomutase of Claim 1, wherein said polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 12, and wherein said polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions selected from 22, 118, 150, 155, 191, 235, 238, 239, 244, 256, 263, 265, 266, 267, 284, and 355, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 12.~~

~~4. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 16, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions selected from 22/82, 22/82/238, 22/118/256, 22/191/238/256, 22/238, 82/118/191, 82/118/238, 82/238, 82/238/256, 118/191, 118/238, 150, 150/155/180/239, 150/155/188/235/334, 150/155/235/239/334, 150/180/188, 150/188/235/239/334, 150/235/239, 150/235/239/334, 155/188/235/239, 155/235, 155/235/239, 155/235/239/244, 180/188/239/334, 180/334,~~

~~188/235/308, 188/239/265/308, 188/239/266, 188/239/308, 188/308, 188/308/334, 235, 235/239, 235/239/244, 238, 238/256, 238/316, 239, 239/308, 265, 308, 308/334, and 334, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 16.~~

~~5. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 90, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions selected from 16, 21, 22, 52, 53, 65, 77, 82, 114, 118, 120, 133, 135, 155, 156, 172, 188, 189, 191, 220, 221, 222, 225, 236, 244, 251, 257, 261, 267, 284, 287, 334, 357, 369, 391, 394, and 397, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 90.~~

~~6. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 90, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions selected from 21/79/308, 21/276/301, 77, 117, 147, 150, 156, 179, 220, 221, 222, 239, 261, 266/276/287/308, 266/308, 272, 284, 301, 308, 355, and 391, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 90.~~

~~7. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 198, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions selected from 21, 26, 94, 111, 114, 205, 228, 265, 266, 276, 287, 293, 301, 308, 374, and 401, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 198.~~

~~8~~2. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 352, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions in said polypeptide sequence selected from 147/156/222/261/284, 147/156/222/261/284/391, 147/156/222/261/391, 147/156/261, 147/156/261/284, 147/156/261/308/334/355/357, 147/156/261/391, 147/156/391, 147/179/261/391,

147/222/284/391, 147/222/391, 147/261, 147/261/391, 147/284/391, 147/391, 156/179/261/284/391, 156/222/261,

156/222/391, 156/239/261/391, 156/239/391, 156/261, 156/261/284, 156/261/284/391, 156/284, 156/391, 222/239/261/391, 222/261, 222/261/284, 222/261/284/293, 222/261/391, 222/391, 239/261/284/391, 261, 261/391, 284/391, and 391, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 352.

~~9~~3. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 412, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions in said polypeptide sequence selected from 77/112/121/255, 100, 100/112/155, 112/120/121, 112/120/121/241/255/300, 112/121, 112/121/255/287, 121/255, and 255, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 412.

~~10~~4. The engineered phosphopentomutase of Claim 1, wherein the polypeptide sequence of said engineered phosphopentomutase has at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NO: 418, and wherein the polypeptide sequence of said engineered phosphopentomutase comprises at least one substitution or substitution set at one or more positions in said polypeptide sequence selected from 53, 77, 100, 112, 120, 121, 147/156, 155, 156, 160, 241, 255, 267, 285, 287, and 300, wherein the amino acid positions of said polypeptide sequence are numbered with reference to SEQ ID NO: 418.

~~11~~5. The engineered phosphopentomutase of Claim 1, wherein said engineered phosphopentomutase comprises a polypeptide sequence that is at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more identical to the sequence of at least one engineered phosphopentomutase variant set forth in Table ~~4.1, 5.1, 6.1, 7.1,~~ 8.1, 9.1, 10.1, 11.1, and/or 12.1.

~~12~~6. The engineered phosphopentomutase of Claim 1, wherein said engineered phosphopentomutase comprises a polypeptide sequence that is at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more identical to SEQ ID NO: ~~4, 12, 16, 90, 198,~~ 352, 412, and/or 418.

~~13~~7. The engineered phosphopentomutase of Claim 1, wherein said engineered phosphopentomutase comprises a variant engineered phosphopentomutase set forth in SEQ ID NO: ~~12, 16, 90, 198,~~ 352, 412, and/or 418.

~~14~~8. The engineered phosphopentomutase of Claim 1, wherein said engineered phosphopentomutase comprises a polypeptide sequence that is at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more identical to the sequence of at least one engineered phosphopentomutase variant set forth in the even numbered sequences of SEQ ID NOS: 352 ~~6~~ 546.

~~15~~9. The engineered phosphopentomutase of Claim 1, wherein said engineered phosphopentomutase comprises a polypeptide sequence forth in at least one of the even numbered sequences of SEQ ID NOS: ~~6~~352-546.

~~16~~10. The engineered phosphopentomutase of any one of Claims 1-~~15~~9, wherein said engineered phosphopentomutase comprises at least one improved property compared to wild-type *E. coli* phosphopentomutase.

~~17~~11. The engineered phosphopentomutase of Claim ~~16~~10, wherein said improved property comprises improved activity on a substrate.

~~18~~12. The engineered phosphopentomutase of Claim ~~15~~11, wherein said substrate comprises compound **(4)**.

~~19~~13. The engineered phosphopentomutase of any one of Claims ~~1~~10-~~18~~12, wherein said improved property comprises improved production of compound **(1)** and/or compound **(3)**.

~~20~~14. The engineered phosphopentomutase of any one of Claims 1-~~19~~13, wherein said engineered phosphopentomutase is purified.

~~21~~15. A composition comprising at least one engineered phosphopentomutase of any one of Claims 1-~~20~~14.

~~22~~16. A polynucleotide sequence encoding at least one engineered phosphopentomutase of any one of Claims 1-~~20~~14.

~~23~~17. A polynucleotide sequence encoding at least one engineered phosphopentomutase, said polynucleotide sequence comprises at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NOS: ~~3, 11, 15, 89, 197,~~ 351, 411, and/or 417, wherein the polynucleotide sequence of said engineered phosphopentomutase comprises at least one substitution at one or more positions.

~~24~~18. A polynucleotide sequence encoding at least one engineered phosphopentomutase comprising at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more sequence identity to SEQ ID NOS: ~~3, 11, 15, 89, 197,~~ 351, 411, and/or 417, or a functional fragment thereof.

~~25~~19. The polynucleotide sequence of any one of Claims ~~22~~16-~~24~~18, wherein said polynucleotide sequence is operably linked to a control sequence.

~~26~~20. The polynucleotide sequence of any one of Claims ~~22~~16-~~25~~19, wherein said polynucleotide sequence is codon optimized.

~~27~~21. The polynucleotide sequence of any one of Claims ~~22~~16-~~26~~20, wherein said polynucleotide sequence comprises a polynucleotide sequence forth in the odd numbered sequences of SEQ ID NOS: 351~~7~~ 545.

~~28~~22. An expression vector comprising at least one polynucleotide sequence of any one of Claims ~~22~~16-~~27~~21.

~~29~~23. A host cell comprising at least one expression vector of Claim ~~28~~22.

~~30~~24. A host cell comprising at least one polynucleotide sequence of any one of Claims ~~22~~16-~~27~~21.

~~31~~25. A method of producing an engineered phosphopentomutase in a host cell, comprising culturing the host cell of Claim ~~29~~ 23 ~~and/~~or ~~30~~24, under suitable conditions, such that at least one engineered phosphopentomutase is produced.

~~32~~26. The method of Claim ~~31~~25, further comprising recovering at least one engineered phosphopentomutase from the culture and/or host cell.

~~33~~27. The method of Claim ~~31~~ 25 ~~and/~~or ~~32~~26, further comprising the step of purifying said at least one engineered phosphopentomutase.