Mutant	Anti-HS phage display antibody			
	AO4B08	EV3C3	HS4C3	RB4EA12
Ndst1$^{-/-}$	↓	↓	↓	↓
Ndst2$^{-/-}$	↓	↓	↓	↓
Ndst1$^{-/-}$;*2*$^{-/-}$	↓	↓	↓	↓
Glce$^{-/-}$	↓	↓	↓	↓
Hs2st$^{-/-}$	↓	↓	–	–
Hs6st1$^{-/-}$	↓	↓	↓	↓
Hs6st1$^{f/f}$;*2*$^{-/-}$	↓	↓	↓	↓
Hs6st1$^{-/-}$;*6*$^{-/-}$	↓	↓	↓	↓
Sulf1$^{-/-}$;*2*$^{-/-}$	↑	↑	↑	↑
Hs3st1-/-	↓	↓	↓	↓
Hs3st4$^{-/-}$	↓	↓	↓	↓
Hs3st1$^{-/-}$;*4*$^{-/-}$	↓	↓	↓	↓

Supplmentary Table 1. Summary of the effects of HS modification/remodeling gene deletion on cell surface anti-HS phage display antibody binding. The circles highlight the difference between the antibody binding on the HS mutant MLECs and reported biochemical studies using chemically modified heparins and synthesized HS oligosaccharides. The green arrows indicate no biochemical data reported in literature.

Supplementary Table 2. Genotyping Conditions and PCR Primers

1) PCR condition: Heat activated DNA polymerase was applied to amplify the extracted genomic DNA. The PCR condition was as following: DNA polymerase activation at 95 °C for 15 minutes; DNA amplification for 40 cycles (95 °C for 55 s, 55 °C for 55 s, 72 °C for 90 s), extension at 72 °C for 5 min. The reaction then was held at 4 °C.

2) Primers

Primer Name	Primer Sequence (5'->3')	Expected band Size
Cre3 Cre5	ACGTTCACCGGCATCAACGT CTGCATTACCGGTCGATGCA	355 bp
Ext1WTF Ext1WTR Ext1KOR	GGAGTGTGGATGAGTTGAAG CAACACTTTCAGCTCCAGTC GAGAACAGGTACCCATGTTC	*Ext1*^{f} : 460 bp *WT* : 389 bp *Ext1*$^{-}$: 500 bp
Ndst1WTF Ndst1WTR Ndst1KOR	TCCCACATGGCGAGACTGAGGTTC CCAGGGCGTCAGGGCCTCCTG CATCCTCTGAGGTGACCGC	*Ndst1*^{f} *:* 280 bp WT : 260 bp *Ndst*$^{-}$: 350 bp
Ndst2WTF Ndst2WTR Ndst2KOR	CCTGGCTGTTTGGTCTCTGT CGCTTTCAATACAGGAGAGG CTGCTCTTTACTGAAGGCTC	WT : 701 bp *Ndst2*$^{-}$: 602 bp
Hs2stWTF Hs2stWTR Hs2stKOR	ATGGGGCTCCTCAGGATTATGATGC TGCCCTAGGCTCAGGCATG GTGCGGCCGTGGGGTCC	Hs2stWTF/Hs2stWTR: WT : 609 bp, *Hs2st*^{f} : 747 bp Hs2stWTF/Hs2stKOR: WT 876 bp, *Hs2st*^{f} : 1178 bp *Hs2st*$^{-}$: 360 bp
Hs6st1WTF Hs6st1WTR Hs6st1hetTF Hs6st1KOF Hs6st1KOR	CCAGCCACAGAAGTGGAACA CACCAACAGAAACAGGGCTA GTGGGCTCTATGGCTTCTGA CAGTCAATGCTTTGGACCACT TCCACACCCACTTCCTAGCT	Hs6st1WTF/Hs6st1WTR/Hs6st1hetTF: WT : 210 bp Hs6st1^{f} : 320 bp Hs6st1KOF/Hs6st1KOR *Hs6st1* $^{-}$: 400 bp
Hs6st2WTF Hs6st2WTR Hs6st2KOF Hs6st2KOR	ATTTGCGGTGATCGTCCTCA TGAGCTCGGTCCAGTCGGAT GCCAGGTACGTGGTGAGCGAACG TGACCTCCAGGAACTGCCATAAC	WT : 375 bp *Ndst2*$^{-}$: 800 bp
Sulf1WTF Sulf1WTR Sulf1KOF Sulf1KOR	GCATAGAGTCAGTGGGTCAAAGTTG GCCTCCTGACAAGGTTACTAGG TCCCTCATATCAGAAAGTCTGG GCCTCCTGACAAGGTTACTAGG	Sulf1wt : 150 bp *Sulf1* ^{f}*:* 205 bp *Sulf1* $^{-}$: 400bp
Sulf2WTF Sulf2WTR Sulf2KOF Sulf2KOR	ATCTCAACAGCACAGGCTACCG ATGGCAACCCCTTCGTCATC GCAGGTTTGTACCCAACGC GGTTACTCCCACAATAAACTGGTG	Sulf2wt : 495 bp *Sulf2*^{f} *:* 550 bp *Sulf2*$^{-}$: 480 bp
FGFR1F FGFR1R FGFR2F FGFR2R FGFR3F FGFR3R FGFR4F FGFR4R	TCCTGATCTCCTGCATGTTG GGAAGTCGCTCTTCTTGGTG TGCTACCCAAGGAATCGTTC AGAGTGGATCGGGATGGAG TGGGCTAAGGATGGTACAGG TTAGCACTTGCAGCCTCTGA CCCTGAGGCCAGATACACAG GGAGCACAAGCAGAACCAGT	FGFR1: 71 bp FGFR2: 72 bp FGFR3: 72 bp FGFR4: 64 bp