

# MNS Blood Group System

## Number of antigens 46

Polymorphic	M, N, S, s
Low prevalence	He, Mi <sup>a</sup> , M <sup>c</sup> , Vw, Mur, M <sup>g</sup> , Vr, M <sup>e</sup> , Mt <sup>a</sup> , St <sup>a</sup> , Ri <sup>a</sup> , Cl <sup>a</sup> , Ny <sup>a</sup> , Hut, Hil, M <sup>v</sup> , Far, s <sup>D</sup> , Mit, Dantu, Hop, Nob, Or, DANE, TSEN, MINY, MUT, SAT, ERIK, Os <sup>a</sup> , HAG, MARS, MNTD
High prevalence	U, En <sup>a</sup> , ENKT, “N”, ENEP, ENEH, ENAV, ENDA, ENEV

SNM

## Terminology

ISBT symbol (number)	MNS (002)
CD number	CD235A (GPA); CD235B (GPB)
Obsolete name	MNSs
History	Discovered in 1927 by Landsteiner and Levine; named after the first three antigens identified in this system: M, N, and S.

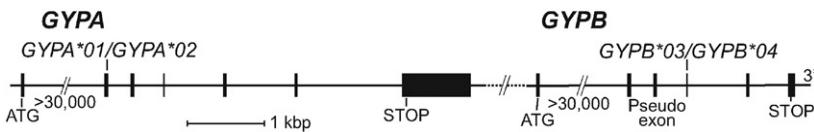
## Expression

Tissues	Renal endothelium and epithelium (the GPA may not be fully glycosylated, as only sialic acid independent anti-M and -N react)
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## Gene

Chromosome	4q31.21
Name	<i>GYPA</i> , <i>GYPB</i>
Organization	<i>GYPA</i> : 7 exons distributed over 60 kbp <i>GYPB</i> : 5 exons (and 1 pseudoexon) distributed over 58 kbp
Product	Glycophorin A (GPA; MN sialoglycoprotein; SGP $\alpha$ ) Glycophorin B (GPB; Ss sialoglycoprotein; SGP $\delta$ )

A third gene (*GYPE*), which is adjacent to *GYPB*, may not encode an RBC membrane component, but participates in gene rearrangements resulting in variant alleles.



## GenBank accession numbers

Database	<i>GYPA</i>	<i>GYPB</i>	<i>GYPE</i>
GenBank	NM_002099 and L31860	NM_002100 and J02982	NM_002102
Entrez Gene ID	2993	2994	2996

Exon numbering accounts for the presence of the pseudoexon(s) in *GYPB* and *GYPE*. Thus, *GYPB* pseudoexon 3 corresponds to the *GYPA* exon 3 sequence. This *GYPB* pseudoexon is involved in many gene rearrangements encoding hybrid glycophorins in this blood group system. Similarly, *GYPE* pseudoexons 3 and 4 correspond to *GYPA* exon 3 and 4 sequences. These *GYPE* pseudoexons are involved in gene rearrangements encoding hybrids.

## Molecular basis of MNS Phenotypes

MNS alleles with single nucleotide changes in *GYPA* that generate blood group antigens

Reference allele *GYPA\*01* or *GYPA\*M* (Accession number L31860) encodes M (MNS1), MNS28, MNS29, MNS39, MNS40, MNS42, MNS44, and MNS45. Nucleotide differences, and amino acids affected, are given. Note: In most cases, the nucleotide changes can also occur on a *GYPA\*N* allele.

Allele encodes	Allele name	Exon	Nucleotide	Amino acid <sup>‡</sup>	Ethnicity (prevalence)
N+ or MNS:2	<i>GYPA*02</i> or <i>GYPA*N</i>	2	59C>T; 71G>A; 72T>G	Ser20Leu, Gly24Glu	(Common)
M <sup>c</sup> + or MNS:1,-2,8 <sup>+</sup>	<i>GYPA*08</i> or <i>GYPA*Mc</i>	2	71G>A; 72T>G	Gly24Glu	(Several)

(Continued)

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Allele encodes	Allele name	Exon	Nucleotide	Amino acid <sup>‡</sup>	Ethnicity (prevalence)
Vw+ or GP.Vw MNS:7,9,-40	GYPA*09 or GYPA*Vw	3	140C>T	Thr47Met	Europeans, especially Swiss (Many)
M <sup>g</sup> + or MNS:-1, -2,11,32	GYPA*11 or GYPA*Mg	2	68C>A	Thr23Asn	Europeans, especially Swiss & Sicilians (Many)
Vr+ or MNS:12	GYPA*12 or GYPA*Vr	3	197C>A	Ser66Tyr	Dutch (Few)
Mt(a+) or MNS:14	GYPA*14 or GYPA*Mta	3	230C>T	Thr77Ile	(Many)
Ri(a+) or MNS:16	GYPA*16 or GYPA*Ria	3	226G>A	Glu76Lys	(Rare)
Ny(a+) or MNS:18	GYPA*18 or GYPA*Nya	3	138T>A	Asp46Glu	Norwegians (Many)
Hut+ or MNS:7,19,-40	GYPA*19 or GYPA*Hut	3	140C>A	Thr47Lys	(Many)
Or+ or MNS:31	GYPA*31 or GYPA*Or	3	148C>T	Arg50Trp	(Few)
ERIK+ or MNS:37	GYPA*37 or GYPA*ERIK <sup>^</sup>	4	232G>A	Gly78Arg	(Few)
Os(a+) or MNS:38	GYPA*38 or GYPA*Osa	3	217C>T	Pro73Ser	Japanese (Rare)
HAG+ or MNS:-39,41	GYPA*41 or GYPA*HAG	4	250G>C	Ala84Pro	Israeli (Rare)
MARS+ or MNS:-42,43	GYPA*43 or GYPA*MARS	4	244C>A	Gln82Lys	Choctaw Indians (Several)
ENEV- or MNS:-45	GYPA*-45	4	242T>G	Val81Gly	(Rare)
MNTD+ or MNS:46	GYPA*46 or GYPA*MNTD	3	107C>G	Thr36Arg	(Rare)

<sup>†</sup> = Most anti-M but only few anti-N react with M<sup>c+</sup> RBCs.<sup>^</sup> = Transcript 1; see also GYP\*EBH in hybrid table for transcript 2.<sup>‡</sup> = Amino acid #1 is the initiation methionine, which is +19 from the number given in earlier reports.

### MNS alleles with single nucleotide changes in *GYPB* that generate blood group antigens

Reference allele *GYPB\*04* or *GYPB\*s* (Accession number J02982) encodes “N” (**MNS30**), s (**MNS4**). Nucleotide differences from this reference allele, and amino acids affected, are given. Expression of the U antigen involves GPB and another protein, probably RhAG.

MNS

Allele encodes	Allele name	Exon (intron)	Nucleotide	Amino acid <sup>‡</sup>	Ethnicity (prevalence)	
S+ or MNS:3	<i>GYPB*03</i> or <i>GYPB*S</i>	4	143C>T	Thr48Met	(Common)	
s+He+ or MNS:4,6	<i>GYPB*06.01</i>	2	59T>G	Leu20Trp	Africans (Many)	
		2	60A>G			
		2	67A>T	Thr23Ser Glu24Gly		
		2	71A>G			
		2	72G>T			
S+He+ or MNS:3,6	<i>GYPB*06.02</i>	2	59T>G	Leu20Trp	Africans (Many)	
		2	60A>G	Thr23Ser Glu24Gly		
		2	67A>T			
		2	71A>G			
		2	72G>T			
		4	143C>T	Thr48Met		
M <sup>v</sup> + or MNS:21	<i>GYPB*21</i> or <i>GYPB*Mv</i>	2	65C>G	Thr22Ser	(Several)	
s <sup>D</sup> + or MNS:23	<i>GYPB*23</i> or <i>GYPB*sD</i>	4	173C>G	Pro58Arg	South African (Rare)	
Mit+ or MNS:24	<i>GYPB*24</i> or <i>GYPB*Mit</i>	4	161G>A	Arg54His	(Many)	
S-U+ <sup>w</sup> or MNS:-3,w5	<i>GYPB*03N.01</i> or <i>GYPB*NY</i>	4	143C>T	Thr48Met	Africans (Many)	
		5	208G>T	Silent		
		5	230C>T	Silent		
		5 (Intron 5)	251C>G +5g>t	Ser84Thr		
S-U+ <sup>w</sup> or MNS:-3,w5	<i>GYPB*03N.02</i> or <i>GYPB*He(NY)</i>	2	59T>G	Leu20Trp	Africans (Many)	
		2	60A>G	Thr23Ser Glu24Gly		
		2	67A>T			
		2	71A>G			
		2	72G>T			
		4	143C>T	Thr48Met Silent Silent Ser84Thr		
		5	208G>T			
		5	230C>T			
		5 (Intron 5)	251C>G +5g>t			

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Allele encodes	Allele name	Exon (intron)	Nucleotide	Amino acid <sup>‡</sup>	Ethnicity (prevalence)
S-U+w or MNS:-3,w5	<i>GYPB*03N.03</i> or <i>GYPB*P2</i>	4 (Intron 5)	143C>T +5g>t	Thr48Met	Africans (Many)
S-U+w or MNS:-3,w5	<i>GYPB*03N.04</i> or <i>GYP*He(P2)</i>	2	59T>G	Leu20Trp	Africans (Many)
		2	60A>G		
		2	67A>T		
		2	71A>G		
		2	72G>T		
		4 (Intron 5)	143C>T +5g>t	Thr48Met	

<sup>‡</sup> = Amino acid #1 is the initiation methionine, which is +19 from the number given in earlier reports.

MNS

## MNS alleles created by gene rearrangement events within the *GYP* gene family

Parent allele *GYPA*

Allele encodes	Allele name	Nucleotide	Protein	Comments
GYP(A-A) hybrid series				
MNS:15 or St(a+); GP.Zan	<i>GYP*101.01</i> or <i>GYP*Zan</i>	<i>GYPA</i> del exon 3	<i>GPA</i> del46-77	<i>GYP(A1–2-BΨ3–A4–7)</i> Africans (Many)
MNS:15, or St(a+); GP.EBH	<i>GYP*101.02</i> or <i>GYP*EBH<sup>Δ</sup></i>	<i>GYPA</i> 232G>A del exon 3	<i>GPA</i> del46-77	Nucleotide change at 232 destabilizes normal splicing. St <sup>a</sup> is encoded by a <i>GYPA</i> transcript that lacks exon 3. Full-length transcript encodes ERIK (MNS37).
MNS:15 or St(a+); GP.Mar	<i>GYP*101.03</i> or <i>GYP*Mar</i>	<i>GYPA</i> del exon 3	<i>GPA</i> del46-77	<i>GYP(A1–2-EΨ3–A4–7)</i>
MNS:6,15 or He+ St(a+); GP.Cal	<i>GYP*101.04</i> or <i>GYP*Cal</i>	<i>GYPA</i> 58G>T, 67A>T	<i>GPA</i> Ser20Trp, Thr23Ser <i>GPA</i> del 46-77	<i>GYP(A1–2-BΨ3–A4–7)</i>

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Allele encodes	Allele name	Nucleotide	Protein	Comments
GYP(A-B) hybrid series				
MNS:-3,4,20,34 or S-s+ Hil+ MINY+;GP.Hil	<i>GYP*201.01</i> or <i>GYP*Hil</i>	<i>GYP(A1–232–B233–312)</i>	GP(A1–77–B78–104)	
MNS:3,-4,32, 33,34 or S+s- TSEN+ MINY+;GP.JL	<i>GYP*202.01</i> or <i>GYP*JL</i>	<i>GYP(A1–232–B233–312)</i> 239C>T	GP(A1–77–B78–104) Thr80Met	
MNS:-1,2,-3,-4, -5,36 or M- N+ S-s-U- SAT+; GP.SAT	<i>GYP*203.01</i> or <i>GYP*SAT</i>	<i>GYP(A1–271–B272–369)</i> 59C>T; 71G>A; 72T>G	GP(A1–90–B91–123) Ser20Leu, Gly24Glu	Previously <i>GYP*TK</i>
GYP(A-B-A) hybrid series				
MNS:10,32 or Mur+ Dane+; GP.Dane	<i>GYP*301.01</i> or <i>GYP*Dane</i>	<i>GYP(A1–159–BΨ160–177–A178–450);</i> 191T>A	GP(A1–52–B53–58–A59–149) Ile65Asn	
MNS:10,32,-44 or Mur+ Dane+ ENDA-	<i>GYP*301.02</i>	<i>GYP(A1–159–BΨ160–177–A178–450)</i>	GP(A1–52–B53–58–A59–149)	Does not express ENDA
MNS:26,27 or Hop+ Nob+; GP.Joh	<i>GYP*302.01</i> or <i>GYP*Joh</i>	<i>GYP(A1–202–BΨ203–A204–450)</i>	GP(A1–67–B68–A69–150) Arg68Thr	Gene conversion in exon 3 replaces <i>GYPA</i> nucleotide 203 with the corresponding nucleotide from <i>GYPBΨ3</i>
MNS:-26,27,-29 or Hop-Nob+ ENKT-; GP.Nob	<i>GYP*302.02</i> or <i>GYP*Nob</i>	<i>GYP(A1–202–BΨ203–212–A213–450)</i> 203G>C 212A>C	GP(A1–67–B68–72–A73–150) Arg68Thr; Tyr71Ser	Gene conversion in exon 3 replaces <i>GYPA</i> nucleotides (203–212) with corresponding nucleotides from <i>GYPBΨ3</i>
MNS:20,-34 or Hil+ MINY-; GP.KI	<i>GYP*303</i> or <i>GYP*KI</i>	<i>GYP(A1–238–B239–242–A243–450)</i> 239G>C 242T>G	GP(A1–79–B80–81–A82–150) Arg80Thr Val81Gly	Gene conversion in exon 4 replaces <i>GYPA</i> nucleotides (239–242) with corresponding nucleotides from <i>GYPB</i>

^ = Transcript 2; see also *GYP\*ERIK* in table above for transcript 1.

**MNS alleles created by gene rearrangement events within the *GYP* gene family**

Parent allele *GYPB*

Allele encodes	Allele name	Nucleotide	Amino acid	Comments
<b>GYP(B-A) hybrid series</b>				
MNS:15 or St(a+); GP.Sch	<i>GYP*401</i> or <i>GYP*Sch</i>	<i>GYP(B1–136–A137–354)</i>	GP(B1–46–A47–118)	Reciprocal product is <i>GYP*Hil</i>
MNS:-3,4,25 or Dantu+; GP.Dantu	<i>GYP*402</i> or <i>GYP*Dantu</i>	<i>GYP(B1–175–A176–354)</i>	GPB(1–58)–A(59–118)	Reciprocal product is <i>GYP*Tk</i>
<b>GYP(B-A-B) hybrid series</b>				
MNS:-3,4,7, 10,20,34,35 or S- s+ Mi(a+) Mur+ Hil+ MINY+ MUT+; GP.Mur	<i>GYP*501</i> or <i>GYP*Mur</i>	<i>GYP(B1–136–Bψ137–204–A205–229–B230–366)</i>	GP(B1–69–A70–77–B78–122) GPB <sup>s</sup> ins 46–77 DKHKRDTYPAH TANEVSEISVRTV YPPEEET	Novel sequence derived from composite exon; <i>GYPB</i> 5' pseudoexon 3 + <i>GYPA</i> 3' exon 3
MNS:-3,-4,7,10, 26,33,34,35 or S+s- Mi(a+) Mur+ Hop+ TSEN+ MINY+ MUT+; GP.Hop	<i>GYP*502</i> or <i>GYP*Hop</i>	<i>GYP(B1–136–Bψ137–204–A205–229–B230–366)</i>	GP(B1–69–A70–77–B78–122) GPB <sup>s</sup> ins 46–77 DKHKRDTYPAH TANEVSEISVRTV YPPEEET	Novel sequence derived from composite exon; <i>GYPB</i> 5' pseudoexon 3 + <i>GYPA</i> 3' exon 3
MNS:-3,4,7,10, 20,26,34,35 or S- s+Mi(a+) Mur+ Hil+ MINY+ MUT+; GP.Bun	<i>GYP*503</i> or <i>GYP*Bun</i>	<i>GYP(B1–136–Bψ137–210–A211–229–B230–366)</i>	GP(B1–71–A72–77–B78–122) GPB <sup>s</sup> ins 46–77 DKHKRDTYPAH TANEVSEISVRTVY PPEEET	Novel sequence derived from composite exon; <i>GYPB</i> 5' pseudoexon 3 + <i>GYPA</i> 3' exon 3
MNS:-3,4,7,20,34,35 or S- s+ Mi(a+) Hil+ MINY+ MUT+; GP.HF	<i>GYP*504</i> or <i>GYP*HF</i>	<i>GYP(B1–136–Bψ137–159–A160–232–B233–369)</i>	GP(B1–53–A54–78–B79–123) in GPB <sup>s</sup> DKHKRDTYAAT PRAHEVSEISVRT VYPPEEET46–77ins	Novel sequence derived from composite exon; <i>GYPB</i> 5' pseudoexon 3 + <i>GYPA</i> 3' exon 3
MNS:-3,-4,-5,6 or S- s- U- He+; GP.GL	<i>GYP*505</i> or <i>GYP*He(GL)</i>	<i>GYP(B1–12–A13–78–B79–168)</i>	GP(B1–4–A5–26–B27–59)	Blacks (Rare)

For the molecular bases of other MNS antigens see dbRBC.

## Molecular basis of silencing *GYPA* or *GYPB* or *GYPA* and *GYPB*

Phenotype	Allele name	Nucleotide	Amino acid	Ethnicity (number)
MNS:-1,-2,-28 or M- N- En(a-)	<i>GYPA*01N</i>	Del <i>GYPA</i> exons 2-7; <i>GYPB</i> exon 1	GPA absent	(Rare)
MNS:-3,-4,-5 or S- s- U-	<i>GYPB*01N</i>	Del <i>GYPB</i> exons 2-5; <i>GYPE</i> exon 1	GPB absent	Blacks (Many)
MNS:-1,-2,-3,-4,-5 or M- N- S- s- or M <sup>k</sup> M <sup>k</sup>	<i>GYP*01N</i>	Del <i>GYPA</i> exons 2-7; <i>GYPB</i> exons 1-5 ; <i>GYPE</i> exon 1	GPA and GPB absent	(Rare)

MNS

## Amino acid sequence

Glycophorin A<sup>M</sup>:

MYGKIIIFVLL	LSEIVSISAS	STTGVAMHTS	TSSSVTKSYI	SSQTNDTHKR	50
DTYAATPRAH	EVSEISVRTV	YPPEEETGER	VQLAHHFSEP	EITLIIIFGVVM	100
<u>AGVIGTILLI</u>	<u>SYGIRRLIKK</u>	SPSDVKPLPS	PDTDVPLOSSV	EIENPETSDQ	150

Glycophorin B<sup>s</sup>:

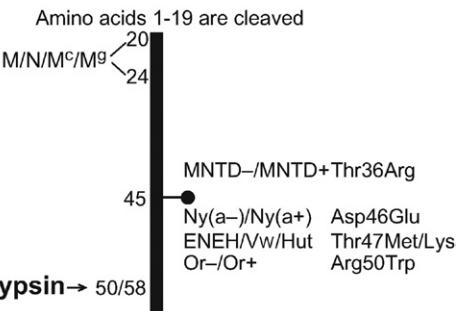
MYGKIIIFVLL	LSEIVSISAL	STTEVAMHTS	TSSSVTKSYI	SSQTNGETGQ	50
LVHRTVPPAP	<u>VVIILITILCV</u>	<u>MAGTIGTILL</u>	<u>ISYSIRRLIK</u>	A	91

Both *GYPA* and *GYPB* encode a signal peptide of 19 amino acids, which are cleaved from the membrane bound protein.

Amino acid numbers are now +19 from previous reports.

## Carrier molecule<sup>1,2</sup>

GPA and GPB are single-pass membrane sialoglycoproteins (type I).

**GPA**

**Ficin/Papain → 78/80**

ERIK-/ERIK+	Gly78Arg
ENEV+/ENEV-	Val81Gly
ENAV/MARS	Glu82Lys
ENEP/HAG	Ala84Pro

RBC lipid bilayer

COOH

**GPB**

Amino acids 1-19 are cleaved

'N'/He

20  
24

M<sup>V</sup>-/M<sup>V</sup>+ Thr22Ser

**α-chymotrypsin → 51**  
**Ficin/Papain →**

S/s	Met48Thr
Mit-/Mit+	Arg54His
s <sup>D</sup> -/s <sup>D</sup> +	Pro58Arg

RBC lipid bilayer

COOH

GPA is cleaved by trypsin at residues 50 and 58 on intact RBCs.  
 GPB is cleaved by  $\alpha$ -chymotrypsin at residue 51 on intact RBCs.

	GPA	GPB
$M_r$ (SDS-PAGE)	43,000	25,000
CHO: N-glycan	1 site	none
CHO: O-glycan	15 sites	11 sites
Copies per RBC	800,000	200,000

## Function

Chaperone for band 3 transport to RBC membrane. Major component contributing to the negatively-charged RBC glycocalyx.

## Disease association

Receptor for complement, bacteria, and viruses<sup>3,4</sup>. Involved in *Plasmodium falciparum* invasion of RBCs<sup>5-7</sup>.

## Phenotypes (% occurrence)

Phenotype	Caucasians	Blacks
M+N-S+s-	6	2
M+N-S+s+	14	7
M+N-S-s+	8	16
M+N+S+s-	4	2
M+N+S+s+	24	13
M+N+S-s+	22	33
M-N+S+s-	1	2
M-N+S+s+	6	5
M-N+S-s+	15	19
M+N-S-s-	0	0.4

(Continued)

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Phenotype	Caucasians	Blacks
M+N+S-s-	0	0.4
M-N+S-s-	0	0.7
Null:	M <sup>k</sup> M <sup>k</sup> . An absence of GPA=En(a-) and an absence of GPB=U-	
Unusual:	Various hybrids, GPB is decreased in Rh <sub>null</sub> and Rh <sub>mod</sub> RBCs	

## Glycophorin phenotypes and associated antigens [previously the Miltenberger (Mi) subsystem]

MNS antigen name and ISBT number (MNS#)											
Phenotype (Previous Name)	Mi <sup>a</sup> (7)	Vw (9)	Mur (10)	Hut (19)	Hil (20)	Hop (26)	Nob (27)	DANE (32)	TSEN (33)	MINY (34)	MUT (35)
GP.Vw (Mi.I)	+	+	0	0	0	0	0	0	0	0	0
GP.Hut (Mi.II)	+	0	0	+	0	0	0	0	0	0	+
GP.Mur (Mi.III)	+	0	+	0	+	0	0	0	0	+	+
GP.Hop (Mi.IV)	+	0	+	0	0	+	0	0	+	+	+
GP.Hil (Mi.V)	0	0	0	0	+	0	0	0	0	+	0
GP.Bun (Mi.VI)	+	0	+	0	+	+	0	0	0	+	+
GP.Nob (Mi.VII)	0	0	0	0	0	0	+	0	0	0	0
GP.Joh (Mi.VIII)	0	0	0	0	0	+	+	0	NT	0	0
GP.Dane (Mi.IX)	0	0	+	0	0	0	0	+	0	0	0
GP.HF (Mi.X)	+	0	0	0	+	0	0	0	0	+	+
GP.JL (Mi.XI)	0	0	0	0	0	0	0	0	+	+	0

## Hybrid glycophorin molecules, phenotypes, and associated low incidence antigens

Hybrid allele	Glycophorin	Phenotype symbol	Associated novel antigens
<i>GYP(A-B)</i>	GP(A-B)	GP.Hil (Mi.V) GP.JL (Mi.XI) GP.TK	Hil, MINY TSEN, MINY SAT
<i>GYP(B-A)</i>	GP(B-A)	GP.Sch (M <sup>f</sup> ) GP.Dantu	St <sup>a</sup> Dantu
<i>GYP(A-B-A)</i>	GP(A-B-A)	GP.Mg GP.KI	M <sup>g</sup> , DANE Hil
<i>GYP(B-A-B)</i>	GP(B-A-B)	GP.Mur (Mi.III) GP.Bun (Mi.VI)  GP.HF (Mi.X) GP.Hop (Mi.IV)	Mi <sup>a</sup> , Mur, MUT, Hil, MINY Mi <sup>a</sup> , Mur, MUT, Hop, Hil, MINY Mi <sup>a</sup> , MUT, Hil, MINY Mi <sup>a</sup> , Mur, MUT, Hop, TSEN, MINY
	GP(A-B)	GP.He; (P2, GL)	He
<i>GYP(B-A-ψB-A)</i>	GP(A-A)	GP.Cal	He, St <sup>a</sup>
<i>GYP(A-ψB-A)</i>	GP(A-B-A)	GP.Vw (Mi.I) GP.Hut (Mi.II) GP.Nob (Mi.VII) GP.Joh (Mi.VIII) GP.Dane (Mi.IX) GP.Zan (M <sup>Z</sup> )	Mi <sup>a</sup> , Vw Mi <sup>a</sup> , Hut, MUT Nob Nob, Hop Mur, DANE St <sup>a</sup>
<i>CYPA 179G&gt;A</i>	GPA GP(A-A)	GP.EBH GP.EBH	ERIK (from transcript 1) St <sup>a</sup> (from transcript 2)
<i>GYP(A-ψE-A)</i>	GPA-A	GP.Mar	St <sup>a</sup>

## Comments

Linkage disequilibrium exists with M/N and S/s antigens.

MNS antigens associated with atypical glycosylation have been placed into Collection 213 (MN CHO) and include: Hu, M<sub>1</sub>, Tm, Can, Sext, and Sj.

GPA and GPB are the major sialic acid-containing structures of the RBC membrane. The majority of the sialic acid is on the O-glycans.

GPA-deficient RBCs have a weak expression of Ch and Rg antigens.

## References

- <sup>1</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- <sup>2</sup> Reid, M.E., 1994. Some concepts relating to the molecular genetic basis of certain MNS blood group antigens. *Transf Med* 4, 99–111.
- <sup>3</sup> Daniels, G., 1999. Functional aspects of red cell antigens. *Blood Rev* 13, 14–35.
- <sup>4</sup> Moulds, J.M., et al., 1996. Human blood groups: incidental receptors for viruses and bacteria. *Transfusion* 36, 362–374.
- <sup>5</sup> Hadley, T.J., et al., 1991. Recognition of red cells by malaria parasites: the role of erythrocyte-binding proteins. *Transfusion Med Rev* 5, 108–113.
- <sup>6</sup> Ko, W.-Y., et al., 2011. Effects of natural selection and gene conversion on the evolution of human glycophorins coding for MNS blood polymorphisms in malaria-endemic African populations. *Am J Hum Genet* 88, 741–754.
- <sup>7</sup> Miller, L.H., 1994. Impact of malaria on genetic polymorphism and genetic diseases in Africans and African Americans. *Proc Natl Acad Sci USA* 91, 2415–2419.

## M Antigen

### Terminology

ISBT symbol (number)	MNS1 (002001 or 2.1)
History	M, identified in 1927, was the first antigen of the MNS system. It was named after “immune,” because anti-M was the result of immunizing rabbits with human RBCs.

### Occurrence

Caucasians	78%
Blacks	74%

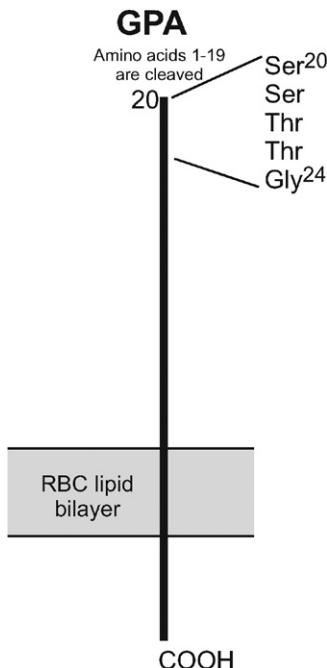
### Antithetical antigen

N (MNS2)

### Expression

Cord RBCs	Expressed
Altered	On some hybrid glycophorin molecules

## Molecular basis associated with M antigen<sup>1</sup>



Nucleotide C at bp 59, G at bp 71, and T at bp 72 in exon 2 of  
GYPA

Recognition of antigen by anti-M is usually dependent on O-glycans attached to amino acid residues 21, 22, and 23 (previously 2, 3, and 4).

### Effect of enzymes and chemicals on M antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
$\alpha$ -Chymotrypsin	Resistant
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-M

Immunoglobulin class IgG (cold reactive; many direct agglutinins) and IgM  
Optimal technique 4°C; RT; rarely also reactive by IAT

## Clinical significance of alloanti-M

Transfusion reactions	No (except in extremely rare cases)
HDFN	No (except in extremely rare cases)

## Autoanti-M

Rare; reactive at low temperatures.

## Comments

Many examples of anti-M are naturally-occurring.

Acidification of serum enhances the reactivity of some anti-M. Anti-M often react more strongly with M+N- RBCs than with M+N+ RBCs (i.e., they show dosage).

Anti-M is more common in children than adults, and in patients with bacterial infections. It is not uncommon for pregnant M- women to produce anti-M, but to give birth to an M- baby.

## Reference

- <sup>1</sup> Dahr, W., et al., 1977. Different N-terminal amino acids in the MN-glycoprotein from MM and NN erythrocytes. Hum Genet 35, 335–343.

## N Antigen

### Terminology

ISBT symbol (number)	MNS2 (002002 or 2.2)
History	Identified shortly after the M antigen in 1927. It was named as the next letter after M, and for the fifth letter of “immune” because anti-N was the result of immunizing rabbits with human RBCs.

### Occurrence

Caucasians	72%
Blacks	75%

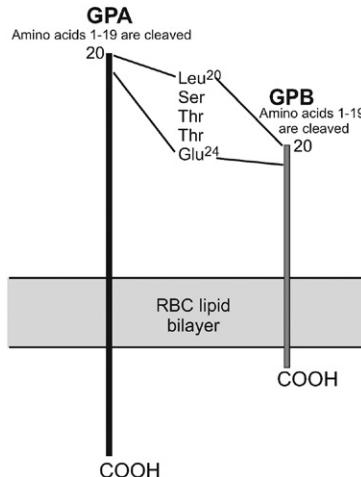
### Antithetical antigen

M (MNS1)

### Expression

Cord RBCs	Expressed
Altered	On some hybrid glycophorin molecules

## Molecular basis associated with N antigen<sup>1</sup>



Nucleotide

T at bp 59, A at bp 71, and G at bp 72 in exon 2 of *GYPA*

Recognition of antigen by anti-N is often also dependent on O-glycans attached to amino acid residues 21, 22, and 23 (previously 2, 3, and 4).

## Effect of enzymes and chemicals on N antigen on intact RBCs

	N on GPA	"N" on GPB
Ficin/Papain	Sensitive	Sensitive
Trypsin	Sensitive	Resistant
$\alpha$ -Chymotrypsin	Resistant	Sensitive
Sialidase	Variable	Variable
DTT 200 mM	Resistant	Resistant
Acid	Resistant	Resistant

## In vitro characteristics of alloanti-N

Immunoglobulin class

IgM; IgG (some direct agglutinins)

Optimal technique

4°C; RT; rarely also reactive by IAT

## Clinical significance of alloanti-N

Transfusion reaction      No  
HDFN                        No

Rare N–S–s–U– individuals make an antibody that reacts with N on GPA and GPB, and may be clinically significant.

## Autoanti-N

Rare; found in patients on dialysis when equipment was sterilized with formaldehyde (anti-Nf).

## Comments

Most examples of anti-N are naturally-occurring.

The N antigen on GPB is denoted as “N” (**MNS30**) to distinguish it from N on GPA.

Anti-N typing reagents are formulated to detect N antigen on GPA but not on GPB.

Monoclonal anti-N are more specific for the N on GPA at alkaline pH.

## Reference

<sup>1</sup> Dahr, W., et al., 1977. Different N-terminal amino acids in the MN-glycoprotein from MM and NN erythrocytes. *Hum Genet* 35, 335–343.

## S Antigen

### Terminology

ISBT symbol (number)    MNS3 (002003 or 2.3)  
History                       S was named after the city of Sydney (Australia), where the first example of anti-S was identified in 1947.

### Occurrence

Caucasians                    55%  
Blacks                        31%

### Antithetical antigen

s (**MNS4**)

### Expression

Cord RBCs                    Expressed  
Altered                        On Rh<sub>null</sub>, M<sup>v+</sup>, Mit+ and TSEN+ RBCs

## Molecular basis associated with S antigen<sup>1</sup>

Amino acid	Met48 (previously 29) of GPB
Nucleotide	T at bp 143 in exon 4 of <i>GYPB</i>

In addition to Met48, some anti-S also require Thr44 (previously 25) and/or the GalNAc attached to this residue, Glu47, His53, and Arg54 (previously 28, 34, and 35 respectively)<sup>2</sup>.

## Effect of enzymes and chemicals on S antigen on intact RBCs

Ficin/Papain	Variable
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Sensitive
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

## *In vitro* characteristics of alloanti-S

Immunoglobulin class	IgM less common than IgG
Optimal technique	RT; IAT
Complement binding	Some

## Clinical significance of alloanti-S

Transfusion reaction	No to moderate (rare)
HDFN	No to severe (rare)

## Autoanti-S

Rare

## Comments

Anti-S can be naturally-occurring.

There are approximately 1.5 times more copies of GPB in S+s- than in S-s+ RBCs. S+s+ RBCs have an intermediate amount of GPB<sup>2</sup>.

S antigen is sensitive to trace amounts of chlorine<sup>3,4</sup>.

Sera containing anti-S frequently contain antibodies to low prevalence antigens.

## References

- Dahr, W., et al., 1980. Structure of the Ss blood group antigens, II: a methionine/threonine polymorphism within the N-terminal sequence of the Ss glycoprotein. Hoppe-Seylers Z Physiol Chem 361, 895–906.

- <sup>2</sup> Dahr, W., 1986. Immunochemistry of sialoglycoproteins in human red blood cell membranes. In: Vengelen-Tyler, V., Judd, W.J. (Eds.), Recent Advances in Blood Group Biochemistry. American Association of Blood Banks, Arlington, VA, pp. 23–65.
- <sup>3</sup> Long, A., et al., 2002. Nondetection of the S antigen due to the presence of sodium hypochlorite. Immunohematology 18, 120–122.
- <sup>4</sup> Rygiel, S.A., et al., 1985. Destruction of the S antigen by sodium hypochlorite. Transfusion, 274–277.

## s Antigen

### Terminology

ISBT symbol (number)	MNS4 (002004 or 2.4)
History	Anti-s was identified in 1951; it reacted with an antigen antithetical to S.

### Occurrence

Caucasians	89%
Blacks	93%

### Antithetical antigen

#### S (MNS3)

### Expression

Cord RBCs	Expressed
Altered	Dantu+, Mit+, M <sup>v</sup> +, s <sup>D</sup> +, GP.Mur, GP.Hil, and some Rh <sub>null</sub> RBCs

### Molecular basis associated with s antigen<sup>1</sup>

Amino acid	Thr48 (previously 29) of GPB
Nucleotide	C at bp 143 in exon 4 in <i>GYPB</i>

In addition to Thr48, some anti-s also require Thr44 (previously 25) and/or GalNAc attached to this residue, Glu47, His53, and Arg54 (previously 28, 34, and 35, respectively)<sup>2</sup>.

### Effect of enzymes and chemicals on s antigen on intact RBCs

Ficin/Papain	Variable
Trypsin	Resistant
α-Chymotrypsin	Sensitive
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

### ***In vitro* characteristics of alloanti-s**

Immunoglobulin class	IgG; IgM
Optimal technique	IAT (often after incubation at RT or 4°C)
Complement binding	Rare

### **Clinical significance of alloanti-s**

Transfusion reaction	No to mild (rare)
HDFN	No to severe (rare)

### **Comments**

A pH of 6.0 enhances the reactivity of some anti-s.

### **References**

- <sup>1</sup> Dahr, W., et al., 1980. Structure of the Ss blood group antigens, II: a methionine/threonine polymorphism within the N-terminal sequence of the Ss glycoprotein. Hoppe-Seylers Z Physiol Chem 361, 895–906.
- <sup>2</sup> Dahr, W., 1986. Immunochemistry of sialoglycoproteins in human red blood cell membranes. In: Vengelen-Tyler, V., Judd, W.J. (Eds.), Recent Advances in Blood Group Biochemistry. American Association of Blood Banks, Arlington, VA, pp. 23–65.

## **U Antigen**

### **Terminology**

ISBT symbol (number)	MNS5 (002005 or 2.5)
History	Described in 1953 and named “U” from “the almost <u>universal distribution</u> ” of the antigen.

### **Occurrence**

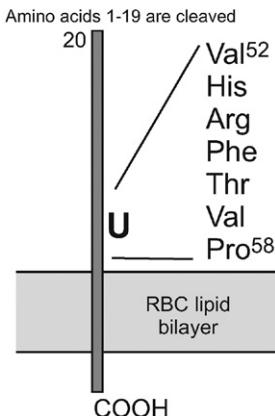
Caucasians	99.9%
Blacks	99%

### **Expression**

Cord RBCs	Expressed
Altered	GPB variants and on regulator type of Rh <sub>null</sub> , and on Rh <sub>mod</sub> RBCs

## Molecular basis associated with U antigen<sup>1</sup>

### GPB



Expression of U may require an interaction with another membrane protein, possibly the Rh associated glycoprotein (RhAG)<sup>2,3</sup>.

The U-negative phenotype is associated with an absence of GPB or with altered forms of GPB [see He (MNS 6)]<sup>4</sup>.

MNS

### Effect of enzymes and chemicals on U antigen on intact RBCs

Ficin/Papain	Resistant
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-U

Immunoglobulin class	IgG
Optimal technique	IAT

### Clinical significance of alloanti-U

Transfusion reaction	Mild to severe
HDFN	Mild to severe (one fetus required an intrauterine transfusion) <sup>5</sup>

### Autoanti-U

Yes

## Comments

U- RBCs (except Dantu+ and some Rh<sub>null</sub>/Rh<sub>mod</sub> RBCs) are S-s-. Of S-s-RBCs, approximately 16% are U+, albeit weakly (U+<sup>var</sup>), and are encoded by a hybrid glycophorin gene, of these approximately 23% are He+<sup>4,6</sup>). Antibodies that detect the altered protein should be more correctly called anti-U/GPB<sup>6</sup>.

## References

- <sup>1</sup> Dahr, W., Moulds, J.J., 1987. High-frequency antigens of human erythrocyte membrane sialoglycoproteins, IV. Molecular properties of the U antigen. Biol Chem Hoppe-Seyler 368, 659–667.
- <sup>2</sup> Ballas, S.K., et al., 1986. The blood group U antigen is not located on glycophorin B. Biochim Biophys Acta 884, 337–343.
- <sup>3</sup> Mallinson, G., et al., 1990. Murine monoclonal antibody MB-2D10 recognizes Rh-related glycoproteins in the human red cell membrane. Transfusion 30, 222–225.
- <sup>4</sup> Reid, M.E., et al., 1996. Expression and quantitative variation of the low incidence blood group antigen He on some S-s- RBCs. Transfusion 36, 719–724.
- <sup>5</sup> Win, N., et al., 1996. Severe haemolytic disease of the newborn due to anti-U requiring intrauterine transfusion [abstract]. Transfusion Medicine 6, (suupl 2):39.
- <sup>6</sup> Storry, JR, et al., 2003. Mutations in *GYPB* exon 5 drive the S-s-U+<sup>var</sup> phenotype in persons of African descent: implications for transfusion. Transfusion 43: 1738–177.

## He Antigen

### Terminology

ISBT symbol (number)	MNS6 (002006 or 2.6)
Obsolete name	Henshaw
History	Named for the first He+ proband, Mr. Henshaw; the original anti-He, present in a rabbit anti-M serum, was identified in 1951.

### Occurrence

African Americans	3%
Blacks in Natal	Up to 7%
Caucasians	Not found

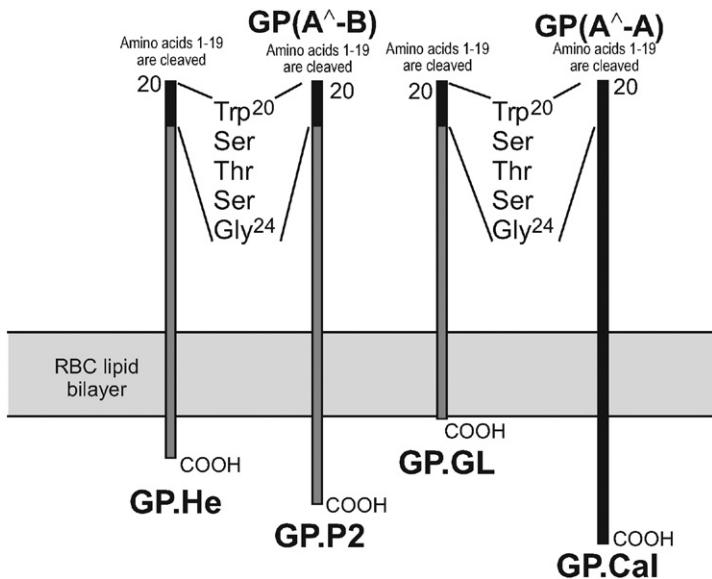
### Antithetical antigen

“N” (MNS30)

### Expression

Cord RBCs	Presumed expressed
Altered	On S-s- GPB variants <sup>1</sup>

## Molecular basis associated with He antigen<sup>1,2</sup>



MNS

### *Variant glycophorin*

GP.He                            GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-GPB(46–91)

GP.He(P2)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-B<sup>S</sup>(46–58)-  
                                  GPB(59–100<sup>^</sup>)

GP.He(GL)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-B(47–78)

GP.He(Cal)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–118)

<sup>^</sup>An altered sequence.

### *Contribution by parent glycophorin*

GP.He                            GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-GPB(46–91)

GP.He(P2)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-GPB<sup>S</sup>(46–58 then new  
                                  sequence 59–100)

GP.He(GL)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-GPB(59–91)

GP.He(Cal)                    GPB(20–23<sup>^</sup>)-GPA<sup>M</sup>(24–45)-GPA(78–150)

<sup>^</sup>An altered sequence.

## Gene arrangement

GP.He	<i>GYP(B-A-B)</i>	
GP.He(P2)	<i>GYP(B-A-B)</i>	The G>T change in intron 5 causes altered splicing and chain elongation with a novel transmembrane amino acid sequence. GP.He(P2) is hard to detect in the RBC membrane; the S-s- RBCs are He+ <sup>W</sup> due to expression of low levels of GP.He.
GP.He(GL)	<i>GYP(B-A-B)</i>	There are 4 transcripts: t1 is GP.He; t2 has a T>G change in the acceptor splice site (Intron 3 at nt -6) leading to skipping of exon 4 [GP.He(GL)]; t3 has a partial deletion of exon 5 due to a C>G change in exon 5, a frame-shift, and a premature stop codon; t4 has the T>G in intron 3 and deletion of exon 4, and the C>G in exon 5, which results in a partial deletion of exon 5. Products of t3 and t4 have not been demonstrated in the RBC membrane <sup>3</sup> .
GP.Cal	<i>GYP(B-A-ψB-A)</i>	The <i>GYPB</i> recombination site is in exon 2 so the mature protein, after cleavage of the leader peptide, is GP(A-A). The <i>GYPB</i> also contributes the pseudo exon, which is out-spliced. There are 2 He-specific transcripts: t1 has a junction of exon 2 to exon 4 and generates the amino acid sequence associated with the St <sup>a</sup> antigen [GP.He(Cal)]; t2 has a junction of exon 2 to exon 5, which is unlikely to be translated <sup>4</sup> .
GP.He (NY)	<i>GYP(B-A-B)</i>	Partial deletion of exon 5 alters the open reading frame, predicted to encode a protein of 43 amino acids, which has not been demonstrated in the RBC membrane. The S-s- RBCs are He+ <sup>W</sup> due to expression of low levels of GP.He <sup>5</sup> .

## Phenotype with antigen strength

Glycophorin	Antigens expressed		
	He	S/s	U
GP.He	Strong	S or s	Strong
GP.He(P2)	Weak/moderate <sup>^</sup>	No	Weak/moderate
GP.He(GL)	Strong <sup>^^</sup>	No	No
GP.He(Cal)	Weak/moderate	No	No
GP.He(NY)	Weak/moderate <sup>^</sup>	No	Weak/moderate

<sup>^</sup>The RBCs express He due to low levels of GP.He

<sup>^^</sup>The RBCs also express GP.He

## Effect of enzymes and chemicals on He antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Variable
Sialidase	Variable
DTT 200 mM	Resistant

## In vitro characteristics of alloanti-He

Immunoglobulin class	IgM; IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-He

No data are available because human anti-He is rare.

## Comments

Approximately 23% of S-s- RBCs express the He antigen<sup>6</sup>, and approximately half have an altered *GYPB* [see U (MNS 5)]. GPB carrying He does not express “N.”

## References

- Dahr, W., et al., 1984. Structural analysis of the Ss sialoglycoprotein specific for Henshaw blood group from human erythrocyte membranes. *Eur J Biochem* 141, 51–55.
- Huang, C.-H., et al., 1994. Remodeling of the transmembrane segment in human glycophorin by aberrant RNA splicing. *J Biol Chem* 269, 10804–10812.
- Huang, C.-H., et al., 1997. Alternative splicing of a novel glycophorin allele GPHe(GL) generates two protein isoforms in the human erythrocyte membrane. *Blood* 90, 391–397.
- Huang, C.-H., et al., 1994. Glycophorin He(St<sup>a</sup>) of the human red blood cell membrane is encoded by a complex hybrid gene resulting from two recombinational events. *Blood* 83, 3369–3376.
- Storry, J.R., et al., 2003. Mutations in *GYPB* exon 5 drive the S-s-U+<sup>var</sup> phenotype in persons of African descent: Implications for transfusion. *Transfusion* 43, 1738–1747.
- Reid, M.E., et al., 1996. Expression and quantitative variation of the low incidence blood group antigen He on some S-s- RBCs. *Transfusion* 36, 719–724.

## Mi<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS7 (002007 or 2.7)
Obsolete name	Miltenberger
History	In 1951, the serum of Mrs. Miltenberger revealed a “new” low-prevalence antigen, named Mi <sup>a</sup> . When other related antigens and antisera were found they formed a subsystem named Miltenberger. These antigens are in the MNS blood group system and a terminology based on glycophorin (e.g., GP.Vw, GP.Hop, etc.) is now commonly used <sup>1</sup> .

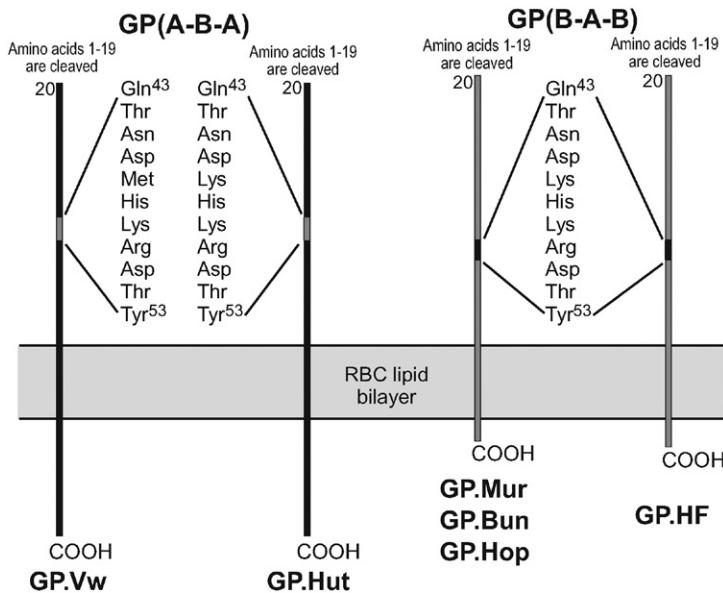
## Occurrence

Most populations <0.01%  
Chinese and SE Asians Up to 15%

## Expression

Cord RBCs Expressed

## Molecular basis associated with Mi<sup>a</sup> antigen<sup>2</sup>



Anti-Mi<sup>a</sup> recognizes the amino acid sequence QTND<sup>M</sup>KHKRD<sup>T</sup>TY<sup>53</sup>, but does not require residues C-terminal of the tyrosine at position 53 (previously 34)<sup>2</sup>.

## Effect of enzymes and chemicals on Mi<sup>a</sup> antigen on intact RBCs

	GP.Vw and GP.Hut	GP.Mur and GP.Hop	GP.Bun and GP.HF
Ficin/Papain	Sensitive	Sensitive/weakened	Sensitive/weakened
Trypsin	Sensitive	Resistant	Resistant
α-Chymotrypsin	Resistant	Sensitive	Sensitive/weakened

(Continued)

(Continued)

	GP.Vw and GP.Hut	GP.Mur and GP.Hop	GP.Bun and GP.HF
Sialidase	Sensitive	Variable	Variable
DTT 200 mM	Resistant	Resistant	Resistant
Acid	Resistant	Resistant	Resistant

### ***In vitro characteristics and clinical significance of alloanti-Mi<sup>a</sup>***

Transfusion reaction      Rare (because antigen is rare in most populations)  
 HDFN                      Mild to severe

### **Comments**

Anti-Mi<sup>a</sup> is often present in serum containing anti-Vw.

Production of monoclonal anti-Mi<sup>a</sup> (GAMA 210 and CBC-172) showed that anti-Mi<sup>a</sup> exists as a single specificity, and that Mi<sup>a</sup> is a discrete antigen<sup>3</sup>.

Due to the relatively high prevalence of some Mi(a+) phenotypes [(particularly GP.Mur (Mi.III), up to 15% in parts of Taiwan with a prevalence of 88% in some indigenous Taiwanese)<sup>4,5</sup> in Chinese and South East Asian populations, it is recommended by some to include GP.Mur phenotype RBCs in antibody investigations in these populations.

### **References**

- <sup>1</sup> Tippett, P., et al., 1992. The Miltenberger subsystem: Is it obsolescent? *Transfus Med Rev* 6, 170–182.
- <sup>2</sup> Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. *Vox Sang* 62, 129–135.
- <sup>3</sup> Chen, V., et al., 2001. Direct evidence for the existence of Miltenberger<sup>a</sup> antigen. *Vox Sang* 80, 230–233.
- <sup>4</sup> Broadberry, R.E., Lin, M., 1994. The incidence and significance of anti-“Mia” in Taiwan. *Transfusion* 34, 349–352.
- <sup>5</sup> Mak, K.H., et al., 1994. A survey of the incidence of Miltenberger antibodies among Hong Kong Chinese blood donors. *Transfusion* 34, 238–241.

## **M<sup>c</sup> Antigen**

### **Terminology**

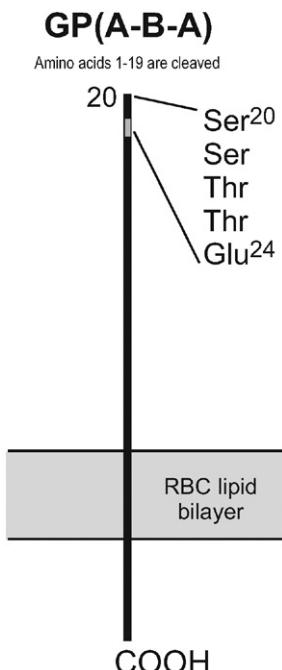
ISBT symbol (number)      MNS8 (002008 or 2.8)

History                      M<sup>c</sup> was described in 1953. The antigen appeared to be intermediate between M and N and, as such, was analogous to the situation described in 1948 for the Rh antigen c<sup>v</sup>; hence the name M<sup>c</sup> was used.

## Occurrence

Less than 0.01%; all probands are of European origin.

## Molecular basis associated with M<sup>c</sup> antigen<sup>1</sup>



O-glycosylation of residues 21, 22, and 23 (previously 2, 3, and 4) is normal.

Variant glycophorin	GPA <sup>M</sup> (20–23)-GPB(24)-GPA(25–150)
Gene arrangement	<i>GYP(A-B-A)</i>

## Comments

No alloanti-M<sup>c</sup> has been described. M<sup>c</sup> is defined by the reaction of certain anti-M and anti-N: a majority of anti-M and a minority of anti-N react with M<sup>c</sup>+ RBCs.

## Reference

- <sup>1</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.

## Vw Antigen

### Terminology

ISBT symbol (number)	MNS9 (002009 or 2.9)
Obsolete names	Gr; Verweyst; Mi.I
History	Identified in 1954; named for Mr. Verweyst; anti-Vw caused positive DAT on the RBCs in one of his children.

### Occurrence

Caucasians	0.06%
South East Swiss	Up to 1.4%

### Antithetical antigens

Hut (MNS19); ENEH (MNS40)

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with Vw antigen<sup>1,2</sup>

Amino acid	Met47 (previously 28) of GPA
Nucleotide	T at bp 140 in exon 3
Variant glycophorin	GPA(20–46)-GPB(47)-GPA(48–150)
Gene arrangement	<i>GYP(A-ψB-A)</i>

The N-glycosylation consensus sequence is changed so that Asn45 (previously 26) is not N-glycosylated, which results in a decreased  $M_r$  of about 3,000.

### Effect of enzymes and chemicals on Vw antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-Vw

Immunoglobulin class	IgM; IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-Vw

Transfusion reaction	No to severe
HDFN	Mild to severe

## Comments

The altered GPA carrying Vw usually carries N (**MNS2**).

One *GYP\*Vw* homozygote person has been described who made anti-En<sup>a</sup>TS (anti-ENEH)<sup>3</sup>.

Anti-Vw is found in 1% of sera and is a frequent component of multispecific sera.

Anti-Vw is commonly found in sera of patients with AIHA.

## References

- Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. *Vox Sang* 62, 129–135.
- Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), *Molecular Basis of Human Blood Group Antigens*. Plenum Press, New York, NY, pp. 153–188.
- Spruell, P., et al., 1993. An anti-En<sup>a</sup>TS detected in the serum of an MiI homozygote. *Transfusion* 33, 848–851.

## Mur Antigen

### Terminology

ISBT symbol (number)	MNS10 (002010 or 2.10)
Obsolete names	Murrell; Mu
History	Identified in 1961 as the cause of HDFN in the Murrell family.

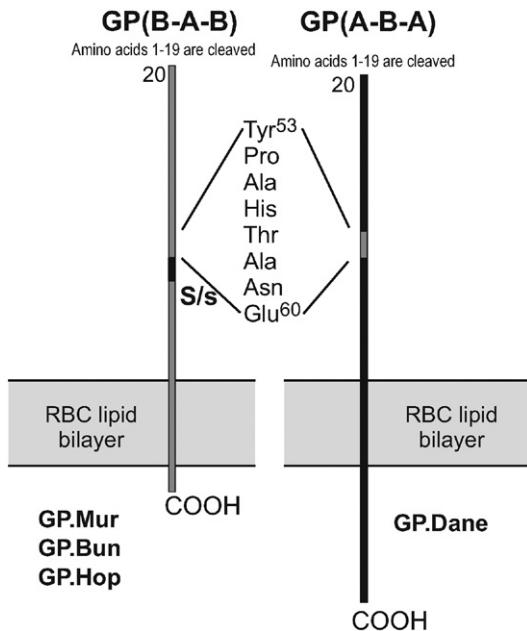
### Occurrence

Most populations	<0.1%
Chinese	6%
Taiwanese	7% (up to 88% in some indigenous people)
Thai	9%

### Expression

Cord RBCs	Expressed
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## Molecular basis associated with Mur antigen<sup>1,2</sup>



MNS

Mur antigen is expressed when a sequence of amino acids (<sup>53</sup>YPAHTANE<sup>60</sup>) is encoded by the pseudoexon 3 of *GPB*.

### Variant glycophorins

GP.Mur (Mi.III)	GPB(20-45)-GP $\psi$ B(46-67)-GPA(68-76)-GPB <sup>S</sup> (77-122)
GP.Bun (Mi.VI)	GPB(20-45)-GP $\psi$ B(46-69)-GPA(70-76)-GPB <sup>S</sup> (77-122)
GP.Hop (Mi.IV)	GPB(20-45)-GP $\psi$ B(46-69)-GPA(70-76)-GPB <sup>S</sup> (77-122)
GP.Dane (Mi.IX)	GPA(20-53)-GP $\psi$ B(54-59)-GPA(60-150)

### Contribution by parent glycophorins

GP.Mur	GPB(20-45)-GP $\psi$ B-GPA(68-76)-GPB(46-91)
GP.Bun, GP.Hop	GPB(20-45)-GP $\psi$ B-GPA(70-76)-GPB(46-91)
GP.Dane	GPA(20-53)-GP $\psi$ B-GPA(60-150)

### Gene arrangement

GP.Mur, GP.Bun, GP.Hop	<i>GYP(B-A-B)</i>
GP.Dane	<i>GYP(A-<math>\psi</math>B-A)</i>

## Effect of enzymes and chemicals on Mur antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Sensitive (resistant on GP.Dane)
Sialidase	Presumed resistant
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-Mur

Immunoglobulin class	IgM less common than IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-Mur

Transfusion reaction	No to severe
HDFN	No to severe

## Comments

Anti-Mur occurs as a single specificity and is often in sera containing anti-Mi<sup>a</sup>. Sera with inseparable anti-Mur and anti-Hut are now considered to contain an additional specificity, anti-MUT (anti-MNS35).

Anti-Mur is common in South East Asian and Chinese populations (0.2%, 0.28%, and 0.06% of patients in Thailand, Taiwan, and Hong Kong, respectively).

Mg<sup>+</sup>(MNS11) RBCs reacted with serum from Mrs. Murrell, but not with other anti-Mur<sup>3</sup>.

GP.Mur RBCs have increased levels (25 to 67%) of band 3 in the RBC membrane. This was correlated with functional changes including superior HCO<sub>3</sub><sup>-</sup> transport, acid-base homeostasis, and osmotic resistance<sup>4</sup>. GP.Mur may confer resistance to invasion by *Plasmodium falciparum* or the higher levels of band 3 could help to alleviate major malarial symptoms such as acidosis<sup>4</sup>.

## References

- Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- Storry, J.R., et al., 2000. Identification of a novel hybrid glycophorin gene encoding GP.Hop. Transfusion 40, 560–565.
- Green, C., et al., 1994. Mg<sup>+</sup> MNS blood group phenotype: further observations. Vox Sang 66, 237–241.
- Hsu, K., et al., 2009. Miltenberger blood group antigen type III (Mi.III) enhances the expression of band 3. Blood 114, 1919–1928.

## M<sup>g</sup> Antigen

### Terminology

ISBT symbol (number)	MNS11 (002011 or 2.11)
Obsolete name	Gilfeather
History	Identified in 1958; RBCs of a patient, Mr. Gilfeather, reacted with the serum of a donor.

### Occurrence

Most populations	<0.01%
Swiss and Sicilians	0.15%

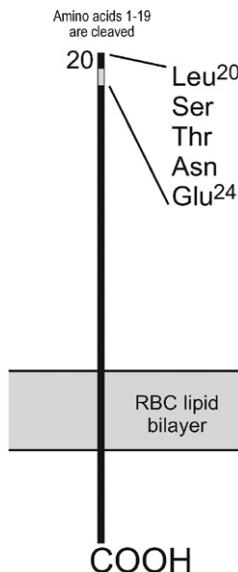
One  $M^gM^g$  homozygote person has been described.

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with M<sup>g</sup> antigen<sup>1</sup>

**GP(A-B-A)**



GP.Mg variant	GPA <sup>N</sup> (20–23)-GPB(24)-GPA(25–150)
Gene arrangement	<i>GYP(A<sup>N</sup>-B-A)</i>

The O-glycans attached to residues 21 and 22 are altered. There is no O-glycan attached to residue 23<sup>2</sup>. This causes a reduction in sialic acid content and decreased electrophoretic mobility.

## Effect of enzymes and chemicals on M<sup>g</sup> antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
Sialidase	Resistant (usually)
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-M<sup>g</sup>

Immunoglobulin class	IgM more common than IgG
Optimal technique	RT; 37°C; IAT

## Clinical significance of alloanti-M<sup>g</sup>

No data available.

## Comments

Human and rabbit anti-M and anti-N do not detect the M<sup>g</sup> antigen. Some monoclonal anti-M react with M – M<sup>g</sup>+ RBCs. Two of six anti-M<sup>g</sup> reacted with a variant M<sup>g</sup>+ RBC sample that had a higher level of glycosylation than other M<sup>g</sup>+ samples.

M<sup>g</sup> can travel with s and S, the latter combination may be indicative of a Sicilian background. M<sup>g</sup>+ RBCs carry DANE (**MNS32**) and were agglutinated by anti-Mur from Mrs. Murrell, but not with other anti-Mur<sup>3</sup>.

Anti-M<sup>g</sup> is present in 1–2% of sera.

## References

- Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- Dahr, W., et al., 1981. Amino acid sequence of the blood group M<sup>g</sup>-specific major human erythrocyte membrane sialoglycoprotein. Hoppe-Seylers Z Physiol Chem 362, 81–85.
- Green, C., et al., 1994. Mg+ MNS blood group phenotype: further observations. Vox Sang 66, 237–241.

## Vr Antigen

### Terminology

ISBT symbol (number)	MNS12 (002012 or 2.12)
Obsolete name	Verdegaal
History	Identified in 1958; named for the family in which the antigen and antibody were found.

## Occurrence

Only found in a few Dutch families.

## Expression

Cord RBCs                      Expressed

## Molecular basis associated with Vr antigen<sup>1</sup>

Amino acid	Tyr66 (previously 47) of GPA
Nucleotide	A at bp 197 in exon 3 of <i>GYPA</i>
Vr- (wild type)	Ser66 and C at position 197

## Effect of enzymes and chemicals on Vr antigen on intact RBCs<sup>1</sup>

Ficin/Papain	Sensitive
Trypsin	Resistant
α-Chymotrypsin	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-Vr

Immunoglobulin class	IgM and IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-Vr

Transfusion reaction	No data
HDFN	The original maker of anti-Vr had three Vr+ children; none had HDFN

## Comments

Inherited with Ms<sup>2</sup>.

Anti-Vr has been found in multispecific sera.

The Ser66Tyr substitution in GPA is predicted to introduce a novel α-chymotrypsin cleavage site, which would explain the (unexpected) sensitivity of the Vr antigen to α-chymotrypsin. Vr is located to the carboxyl side of the major trypsin cleavage site on GPA, thus making it resistant to trypsin treatment.

## References

<sup>1</sup> Storry, J.R., et al., 2000. The MNS blood group antigens, Vr (MNS 12) and Mta (MNS 14) each arise from an amino acid substitution on glycophorin A. Vox Sang 78, 52–56.

<sup>2</sup> van der Hart, M., et al., 1958. Vr, an antigen belonging to the MNSs blood group system. Vox Sang 3, 261–265.

## M<sup>e</sup> Antigen

### Terminology

ISBT symbol (number)	MNS13 (002013 or 2.13)
History	Anti-M <sup>e</sup> was identified in 1961; named M <sup>e</sup> because epitope expressed on M+ RBCs and on He+ RBCs, regardless of MN type.

### Molecular basis associated with M<sup>e</sup> antigen<sup>1</sup>

M<sup>e</sup> antigen is expressed when glycine occupies residue 24 (previously 5) of either GPA (M antigen [MNS1]) or GPB (He antigen [MNS6]).

### Comments

Some anti-M (anti-M<sup>e</sup>) have a component that reacts with glycine at residue 24 of GPA<sup>M</sup> or GPB<sup>He</sup>. The characteristics of these antibodies are the same as for anti-M (see MNS1).

M<sup>e</sup> on GPB<sup>He</sup> is resistant to trypsin treatment and sensitive to  $\alpha$ -chymotrypsin treatment.

### Reference

- <sup>1</sup> Dahr, W., 1986. Immunochemistry of sialoglycoproteins in human red blood cell membranes. In: Vengelen-Tyler, V., Judd, W.J. (Eds.), Recent Advances in Blood Group Biochemistry. American Association of Blood Banks, Arlington, VA, pp. 23–65.

## Mt<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS14 (002014 or 2.14)
Obsolete name	Martin
History	Reported in 1962; named for the first antigen-positive donor.

### Occurrence

Thai	1%
Swiss	0.35%
White Americans	0.24%
Black Americans	0.1%

### Expression

Cord RBCs	Expressed
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## Molecular basis associated with Mt<sup>a</sup> antigen<sup>1</sup>

Amino acid	Ile77 (previously 58) of GPA
Nucleotide	T at bp 230 in exon 3 in <i>GYPA</i>
Mt(a-) (wild type)	Thr77 and C at bp 230

## Effect of enzymes and chemicals on Mt<sup>a</sup> antigen on intact RBCs

Ficin/Papain	Variable
Trypsin	Resistant
α-Chymotrypsin	Resistant
Pronase	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant
Chloroquine	Sensitive

## In vitro characteristics of alloanti-Mt<sup>a</sup>

Immunoglobulin class	IgM; IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-Mt<sup>a</sup>

Transfusion reaction	No data
HDFN	No to severe <sup>2</sup>

## Comments

Inherited with Ns<sup>3,4</sup>.

The variable susceptibility of Mt<sup>a</sup> to ficin and papain treatment may reflect slight differences in the epitope recognized by certain anti-Mt<sup>a</sup> or may result from the proximity of residue 77 to Arg80, one of the two proteolytic sites on GPA.

Anti-Mt<sup>a</sup> is found as a single specificity and occasionally in multispecific sera.

## References

- 1 Storry, J.R., et al., 2000. The MNS blood group antigens, Vr (MNS 12) and Mta (MNS 14) each arise from an amino acid substitution on glycophorin A. Vox Sang 78, 52–56.
- 2 Cheung, C.C., et al., 2002. Anti-Mt<sup>a</sup> associated with three cases of hemolytic disease of the newborn. Immunohematology 18, 37–39.
- 3 Konugres, A.A., et al., 1965. Distribution and development of the blood factor Mt<sup>a</sup>. Vox Sang 10, 206–207.
- 4 Swanson, J., Matson, G.A., 1962. Mt<sup>a</sup>, a “new” antigen in the MNSs system. Vox Sang 7, 585–590.

## St<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS15 (002015 or 2.15)
Obsolete name	Stones
History	Antigen named in 1962 after the first producer of the antibody.

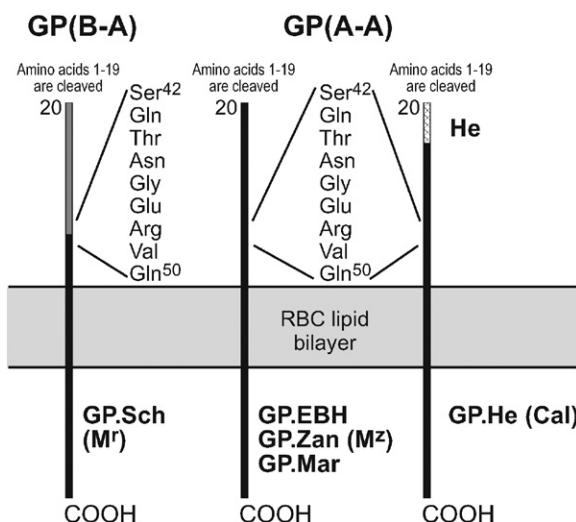
### Occurrence

Caucasians	<0.1%
Asians	2%
Japanese	6%

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with St<sup>a</sup> antigen<sup>1,2</sup>



The St<sup>a</sup> antigen arises when amino acid at residue 45 (previously 26) of GPB or GPA joins to GPA at residue 78 (previously 59).

### Variant glycophorins

GP.Sch (M <sup>r</sup> )	GPB(20-45)-GPA(46-118)
GP.Zan, GP.EBH t2	GPA(20-45)-GPA(46-118)
GP.Mar	GPA(20-45)-GPA(46-118)
GP.He (Cal)	GPA(20-24 <sup>^</sup> )-GPA(25-118)

<sup>^</sup>Altered sequence.

### *Contribution by parent glycophorins*

GP.Sch	GPB(20–45)-GPA(78–150)
GP.Zan, GP.EBH t2	GPA(20–45)-GPA(78–150)
GP.Mar	GPA(20–45)-GPA(78–150)
GP.He (Cal)	GPA(20–24 <sup>^</sup> )-GPA(25–45)-GPA(78–150)

<sup>^</sup>Altered sequence.

### *Gene arrangement*

GP.Sch	<i>GYP(B-A)</i>
GP.Zan	<i>GYP(A-ψB-A)</i>
GP.EBH	<i>GYP<sub>A</sub></i>
GP.Mar	<i>GYP(A-ψE-A)</i>
GP.He (Cal)	<i>GYP(B-A-ψB-A)</i>

### **Effect of enzymes and chemicals on St<sup>a</sup> antigen on intact RBCs**

Ficin/Papain	Variable
Trypsin	Resistant
α-Chymotrypsin	Resistant
Pronase	Sensitive
Sialidase	Presumed resistant
DTT 200 mM	Resistant
Acid	Resistant

### *In vitro characteristics of alloanti-St<sup>a</sup>*

Immunoglobulin class	IgM; IgG
Optimal technique	RT; IAT

### **Clinical significance of alloanti-St<sup>a</sup>**

No data are available because anti-St<sup>a</sup> is rare.

### **Comments**

*GYP\*Sch* is the reciprocal gene rearrangement product of *GYP\*Hil* (see Hil antigen [MNS20]) and *GYP\*JL* (see TSEN antigen [MNS33]).

The shortened product from transcript 2 (t2) of *GYP\*EBH*, which lacks amino acids encoded by exon 3, expresses St<sup>a</sup> but not ERIK antigen. The full length product (GP.EBH) expresses ERIK [MNS37] but not St<sup>a<sup>1</sup></sup> (see MNS system page).

GP.Zan and GP.Mar lack amino acids encoded by exon 3 and each has a trypsin-resistant M antigen.

One *GYP\*Sta/GYP\*Sta* homozygote person has been described. This person had decreased glycosylation on band 3.

Anti-St<sup>a</sup> is a rare specificity, and often occurs in sera containing anti-S and in multispecific sera. Anti-St<sup>a</sup> is notorious for deteriorating *in vitro*.

## References

- <sup>1</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- <sup>2</sup> Huang, C.-H., et al., 1994. Gene conversion between glycophorins A and E results in St<sup>a</sup> glycophorin in a family exhibiting the ERIK/St<sup>a</sup> blood group phenotype [abstract]. Blood 84 (Suppl. 1), 238a.

## Ri<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS16 (002016 or 2.16)
Obsolete name	Ridley
History	Identified in 1962; named for the original Ri(a+) person.

### Occurrence

Only found and studied in one large family<sup>1</sup>.

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with Ri<sup>a</sup> antigen<sup>2</sup>

Amino acid	Lys76 (previously 57) of GPA
Nucleotide	A at bp 226 in exon 3 in <i>GYP</i> A
Ri(a–) (wild type)	Glu76 and G at bp 226

### Effect of enzymes and chemicals on Ri<sup>a</sup> antigen on intact RBCs

Ficin/Papain	Partially sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
Pronase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-Ri<sup>a</sup>

Immunoglobulin class	IgM (12 of 13 anti-Ri <sup>a</sup> were IgM, one was IgG)
Optimal technique	RT; IAT
Complement binding	Some

### Clinical significance of alloanti-Ri<sup>a</sup>

No data are available because anti-Ri<sup>a</sup> is rare.

## Comments

The Glu76Lys substitution in GPA is predicted to introduce a novel trypsin cleavage site.

Anti-Ri<sup>a</sup>, likely to be naturally-occurring, was found in sera containing multiple antibodies to low prevalence antigens<sup>3</sup>. Anti-S [see **MNS3**] often contain anti-Ri<sup>a</sup>.

Inherited with MS<sup>3</sup>.

## References

- <sup>1</sup> Cleghorn, T.E., 1962. Two human blood group antigens, St<sup>a</sup> (Stones) and Ri<sup>a</sup> (Ridley), closely related to the MNSS system. *Nature* 195, 297–298.
- <sup>2</sup> Reid, M.E., Storry, J.R., 2001. Low-incidence MNS antigens associated with single amino acid changes and their susceptibility to enzyme treatment. *Immunohematology* 17, 76–81.
- <sup>3</sup> Contreras, M., et al., 1984. The MNSS antigen Ridley (Ri<sup>a</sup>). *Vox Sang* 46, 360–365.

## Cl<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS17 (002017 or 2.17)
Obsolete name	Caldwell
History	Identified in 1963; antibody found in an anti-B typing serum; named for the antigen-positive person.

### Occurrence

Only found in one Scottish and one Irish family.

### Expression

Cord RBCs	Presumed expressed
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### Effect of enzymes and chemicals on Cl<sup>a</sup> antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant

### In vitro characteristics of alloanti-Cl<sup>a</sup>

Immunoglobulin class	IgM
Optimal technique	RT

### Clinical significance of alloanti-Cl<sup>a</sup>

No data are available because antigen and antibody are rare.

## Comments

Anti-Cl<sup>a</sup> was found in serum samples from 24 of 5,000 British blood donors.  
Inherited with Ms<sup>1</sup>.

## Reference

- <sup>1</sup> Wallace, J., Izatt, M.M., 1963. The Cl<sup>a</sup> (Caldwell) antigen: a new and rare human blood group antigen related to the MNSs system. *Nature* 200, 689–690.

## Ny<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS18 (002018 or 2.18)
Obsolete name	Nyberg
History	Identified in 1964; named for Mr. Nyberg, the first Ny(a+) person.

MNS

### Occurrence

Found in 0.2% of Norwegians, in one Swiss family and an American of non-Scandinavian descent.

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with Ny<sup>a</sup> antigen<sup>1</sup>

Amino acid	Glu46 (previously 27) of GPA
Nucleotide	A at bp 138 in exon 3 in <i>GYPA</i>
Ny(a-) (wild type)	Asp46 and T at bp 138

### Effect of enzymes and chemicals on Ny<sup>a</sup> antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-Ny<sup>a</sup>

Immunoglobulin class	IgM
Optimal technique	RT

### Clinical significance of alloanti-Ny<sup>a</sup>

No data are available because antigen and antibody are rare.

## Comments

Inherited with Ns<sup>2,3</sup>.

Anti-Ny<sup>a</sup> appears to be naturally-occurring, found in about 0.1% of sera studied, and has been produced in rabbits.

## References

- <sup>1</sup> Daniels, G.L., et al., 2000. The low-frequency MNS blood group antigens Ny<sup>a</sup> (MNS18) and Os<sup>a</sup> (MNS38) are associated with GPA amino acid substitutions. *Transfusion* 40, 555–559.
- <sup>2</sup> Kornstad, L., et al., 1971. Further observations on the frequency of the Ny<sup>a</sup> blood-group antigen and its genetics. *Am J Hum Genet* 23, 612–613.
- <sup>3</sup> Örjasæter, H., et al., 1964. Studies on the Ny<sup>a</sup> blood group antigen and antibodies. *Vox Sang* 9, 673–683.

## Hut Antigen

### Terminology

ISBT symbol (number)	MNS19 (002019 or 2.19)
Obsolete name	Mi.II
History	Anti-Hut was reported in 1962 and redefined in 1982. It was first identified in 1958 as the cause of HDFN in the Hutchinson family. At the time, it was considered to be anti-Mi <sup>a</sup> .

### Occurrence

Most populations	<0.01%
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### Antithetical antigen

Vw (MNS9); ENEH (MNS40)

### Expression

Cord RBCs                      Expressed

### Molecular basis associated with Hut antigen<sup>1,2</sup>

Amino acid                      Lys47 (previously 28) of GPA

Nucleotide                      A at bp140 in exon 3

Variant glycophorin            GPA(20–46)-GPB(47)-GPA(48–150)

Gene arrangement                GYP(A-ψB-A)

The N-glycosylation consensus sequence is changed so that Asn45 (previously 26) is not N-glycosylated, which results in a decreased  $M_r$  of about 3,000.

### Effect of enzymes and chemicals on Hut antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
$\alpha$ -Chymotrypsin	Resistant
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-Hut

Immunoglobulin class	IgM more common than IgG
Optimal technique	RT; IAT

### Clinical significance of alloanti-Hut

Transfusion reaction	No data because antibody and antigen are rare
HDFN	No to moderate

### Comments

Hut has been aligned with MS, Ns and Ms in decreasing order of frequency but not with NS.

The specificity originally called anti-Hut is now called anti-MUT (see MNS35) since Hut+, Mur+ RBCs are reactive. Anti-Hut reacts with Hut+ RBCs only.

### References

- Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. *Vox Sang* 62, 129–135.
- Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), *Molecular Basis of Human Blood Group Antigens*. Plenum Press, New York, NY, pp. 153–188.

## Hil Antigen

### Terminology

ISBT symbol (number)	MNS20 (002020 or 2.20)
Obsolete name	Hill
History	Antibody identified in 1963 as the cause of HDFN in the Hill family; in 1966 named Hil.

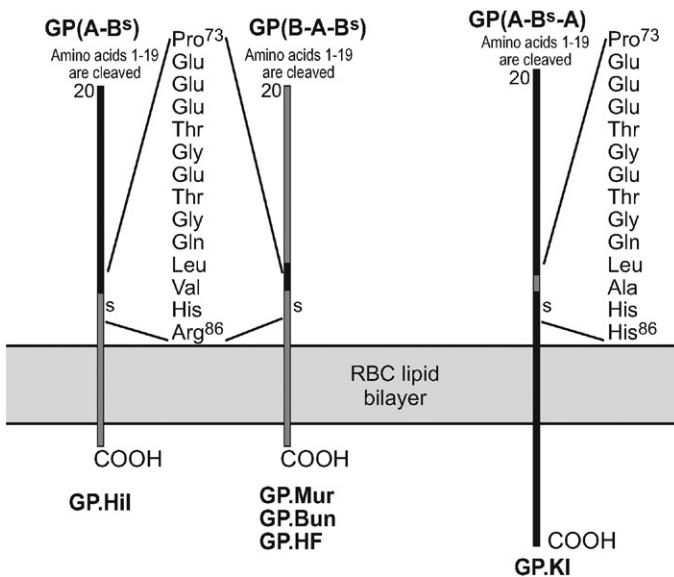
## Occurrence

Most populations <0.01%  
 Chinese 6%  
 One *GYP\*Hil/GYP\*Hil* homozygote has been described.

## Expression

Cord RBCs Expressed

## Molecular basis associated with Hil antigen<sup>1–4</sup>



## Variant glycophorins

GP.Hil (Mi.V)	GPA(20–77)-GPB <sup>s</sup> (78–123)
GP.Mur (Mi.III)	GPB(20–45)-GP $\psi$ B(46–67)-GPA(68–76)-GPB <sup>s</sup> (77–122)
GP.Bun (Mi.VI)	GPB(20–45)-GP $\psi$ B(46–69)-GPA(70–76)-GPB <sup>s</sup> (77–122)
GP.HF (Mi.X)	GPB(20–45)-GP $\psi$ B(46–53)-GPA(54–77)-GPB <sup>s</sup> (78–123)
GP.KI	GPA(20–79)-GPB(80–81)-GPA(82–150)

### *Contribution by parent glycophorins*

GP.Hil	GPA(20–77)-GPB(46–91)
GP.Mur	GPB(20–45)-GP $\psi$ B-GPA(68–76)-GPB(46–91)
GP.Bun	GPB(20–45)-GP $\psi$ B-GPA(70–76)-GPB(46–91)
GP.HF	GPB(20–45)-GP $\psi$ B-GPA(54–77)-GPB(46–91)
GP.KI	GPA(20–79)-GPB(48–49)-GPA(82–150)

### *Gene arrangement*

GP.Hil	<i>GYP(A-B)</i>
GP.Mur, GP.Bun, GP.HF	<i>GYP(B-A-B)</i>
GP.KI	<i>GYP(A-B-A)</i>

### **Effect of enzymes and chemicals on Hil antigen on intact RBCs**

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### *In vitro characteristics of alloanti-Hil*

Immunoglobulin class	IgM and IgG
Optimal technique	RT; IAT

### **Clinical significance of alloanti-Hil**

Transfusion reaction	No data
HDFN	No to moderate

### **Comments**

Reciprocal product to *GYP\*Hil* is *GYP\*Sch* (see *St<sup>a</sup>* antigen [MNS15]). Hil+ RBCs are s+ and, except those carrying GP.KI, are also MINY+.

### **References**

- Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. *Vox Sang* 62, 129–135.
- Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), *Molecular Basis of Human Blood Group Antigens*. Plenum Press, New York, NY, pp. 153–188.
- Poole, J., et al., 1998. Novel molecular basis for the Hil (MNS20) antigen [abstract]. *Transfusion* 38 (Suppl), 103S.
- Poole, J., 2000. Red cell antigens on band 3 and glycophorin A. *Blood Rev* 4, 31–43.

## M<sup>v</sup> Antigen

### Terminology

ISBT symbol (number)	MNS21 (002021 or 2.21)
Obsolete name	Armstrong
History	Found in 1961 when a serum containing anti-N agglutinated RBCs from 1 in 400 M+N– Caucasians and described in detail in 1966. The “v” is for “variant.”

### Occurrence

Most populations	<0.01%
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### Expression

Cord RBCs	Expressed
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### Molecular basis associated with M<sup>v</sup> antigen<sup>1</sup>

Amino acid	Ser22 (previously 3) of GPB
Nucleotide	G at bp 65 in exon 2 in <i>GYPB</i>
M <sup>v</sup> – (wild type)	Thr22 and C at bp 65

### Effect of enzymes and chemicals on M<sup>v</sup> antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
α-Chymotrypsin	Sensitive
Sialidase	Sensitive
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-M<sup>v</sup>

Immunoglobulin class	IgG and IgM
Optimal technique	IAT

### Clinical significance of alloanti-M<sup>v</sup>

Transfusion reaction	No data
HDFN	No to moderate

## Comments

$M^v+$  RBCs have a decreased level of GPB and a weak expression of s (MNS4), and may have a slight weakening of S when  $M^v$  is associated with MS<sup>1,2</sup>.

Inherited with Ms in 14 families, and with MS in 2 families.

GPB carrying  $M^v$  does not express 'N'.

## References

- <sup>1</sup> Storry, J.R., et al., 2001. The low incidence MNS antigens,  $M^v$ ,  $s^D$ , and Mit arise from single amino acid substitutions on glycophorin B. *Transfusion* 41, 269–275.
- <sup>2</sup> Dahr, W., Longster, G., 1984. Studies of  $M^v$  red cells. II. Immunochemical investigations. *Blut* 49, 299–306.

## Far Antigen

### Terminology

ISBT symbol (number)	MNS22 (002022 or 2.22)
Obsolete names	Kam; Kamhuber
History	The Kam antigen reported in 1966 and the Far antigen, reported in 1968, were shown to be the same in 1977. The name Far was chosen. Anti-'Kam' caused a severe transfusion reaction in a multiply-transfused hemophiliac; probably immunized following transfusion with blood of the same donor 11 years previously!

### Occurrence

Found in only two families.

### Expression

Cord RBCs	Expressed
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### Effect of enzymes and chemicals on Far antigen on intact RBCs

Ficin/Papain	Resistant
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Not known
DTT 200 mM	Resistant

## ***In vitro* characteristics of alloanti-Far**

Immunoglobulin class	IgG
Optimal technique	IAT

## **Clinical significance of alloanti-Far**

Transfusion reaction	Severe in one
HDFN	Severe in one

## **Comments**

Travels with Ns<sup>1</sup> and MS<sup>2</sup>.

Only two examples of anti-Far have been reported.

## **References**

- 1 Cregut, R., et al., 1974. A new rare blood group antigen, "FAR," probably linked to the MNSs system. Vox Sang 26, 194–198.
- 2 Speiser, P., et al., 1966. "Kamhuber" a new human blood group antigen of familial occurrence, revealed by a severe transfusion reaction. Vox Sang 11, 113–115.

## **s<sup>D</sup> Antigen**

### **Terminology**

ISBT symbol (number)	MNS23 (002023 or 2.23)
Obsolete name	Dreyer
History	Named in 1981; "s" was used because the s antigen is expressed weakly and "D" from the family name.

## **Occurrence**

Found only in one white South African family.

## **Expression**

Cord RBCs	Expressed
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## **Molecular basis associated with s<sup>D</sup> antigen<sup>1</sup>**

Amino acid	Arg58 (previously 39) of GPB
Nucleotide	G at bp 173 in exon 4 in <i>GPB</i>
s <sup>D</sup> – (wild type)	Pro58 and C at position 173

## **Effect of enzymes and chemicals on s<sup>D</sup> antigen on intact RBCs**

Ficin/Papain	Partially sensitive
Trypsin	Resistant
α-Chymotrypsin	Resistant
DTT 200 mM	Presumed resistant

### ***In vitro* characteristics of alloanti-s<sup>D</sup>**

Immunoglobulin class	IgG
Optimal technique	IAT

### **Clinical significance of alloanti-s<sup>D</sup>**

Transfusion reaction	No data
HDFN	No to severe

### **Comments**

S+s+s<sup>D</sup>+ RBCs have a weakened expression of the s antigen (**MNS4**)<sup>2</sup>. Inherited with Ms<sup>2</sup>.

The Pro58Arg introduces a novel papain cleavage site. However, the close proximity of the antigen to the lipid bilayer may make the site relatively inaccessible.

### **References**

- 1 Storry, J.R., et al., 2001. The low incidence MNS antigens, M<sup>v</sup>, s<sup>D</sup>, and Mit arise from single amino acid substitutions on glycoporphin B. Transfusion 41, 269–275.
- 2 Shapiro, M., Le Roux, M.E., 1981. Serology and genetics of a “new” red cell antigen: s<sup>D</sup> (the Dreyer antigen) [abstract]. Transfusion 21, 614.

## **Mit Antigen**

### **Terminology**

ISBT symbol (number)	MNS24 (002024 or 2.24)
Obsolete name	Mitchell
History	Named in 1980 after the family where the antigen (father’s RBCs) and antibody (mother’s serum) were found.

### **Occurrence**

Western Europeans	0.1%
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### **Expression**

Cord RBCs	Expressed
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### **Molecular basis associated with Mit antigen<sup>1</sup>**

Amino acid	His54 (previously 35) of GPB
Nucleotide	A at bp 161 in exon 4 in <i>GYPB</i>
Mit- (wild type)	Arg54 and G at bp 161

## Effect of enzymes and chemicals on Mit antigen on intact RBCs

Ficin	Resistant
Papain	Partially sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Resistant
Pronase	Weakened
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-Mit

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-Mit

Transfusion reaction	No data
HDFN	Positive DAT; no clinical HDFN

## Comments

Mit+ RBCs have weakened expression of S antigen<sup>2,3</sup> or s antigen<sup>1</sup>.  
Mit is usually associated with MS, and rarely with NS or Ms.

## References

- <sup>1</sup> Storry, J.R., et al., 2001. The low incidence MNS antigens, M<sup>v</sup>, s<sup>D</sup>, and Mit arise from single amino acid substitutions on glycophorin B. Transfusion 41, 269–275.
- <sup>2</sup> Eichhorn, M., et al., 1981. Suppression of the S antigen by the MIT antigen: Potential source of error in red cell typing [abstract]. Transfusion 21, 614.
- <sup>3</sup> Skradski, K.J., et al., 1983. Further investigation of the effect of Mitchell (Mit) antigen on S antigen expression [abstract]. Transfusion 23, 409.

## Dantu Antigen

### Terminology

ISBT symbol (number)	MNS25 (002025 or 2.25)
History	Named in 1984 after the first proband.

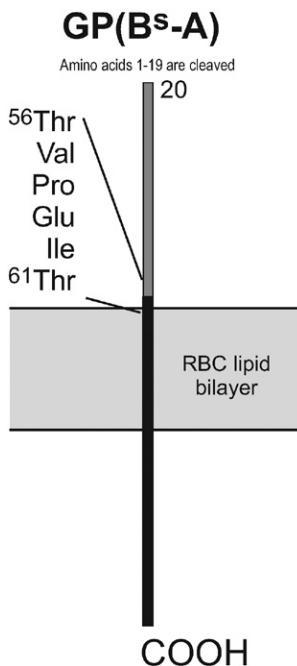
### Occurrence

Blacks	0.5%
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### Expression

Cord RBCs	Expressed
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## Molecular basis associated with Dantu antigen<sup>1,2</sup>



*Variant glycophorin*

GPB<sup>s</sup>(20-58)-GPA(59-118)

*Contribution by parent glycophorin*

GPB(20-58)-GPA(89-150)

*Gene arrangement*

*GYP(B-A)*

Three variants expressing Dantu have been reported:

The MD type is associated with a chromosome carrying *GYPA*, *GYP(B-A)* and *GYPB* genes.

The NE type is associated with a chromosome carrying *GYPA*, *GYP(B-A)* and a duplicated *GYP(B-A)*.

The Ph type may be associated with a chromosome carrying *GYPA*, *GYP(B-A)*.

### Effect of enzymes and chemicals on Dantu antigen on intact RBCs

Ficin/Papain

Resistant

Trypsin

Resistant

$\alpha$ -Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-Dantu

Immunoglobulin class	IgM and IgG
Optimal technique	RT; IAT

### Clinical significance of alloanti-Dantu

Transfusion reaction	No data
HDFN	Positive DAT; no clinical HDFN

### Comments

Dantu+ RBCs (NE type) have a weak expression of s and are U-; they have decreased glycosylation of band 3.

The reciprocal product of *GYP\*Dantu* is *GYP\*TK* (see SAT antigen MNS36).

### References

- <sup>1</sup> Blumenfeld, O.O., et al., 1987. Membrane glycophorins of Dantu blood group erythrocytes. *J Biol Chem* 262, 11864–11870.
- <sup>2</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), *Molecular Basis of Human Blood Group Antigens*. Plenum Press, New York, NY, pp. 153–188.

## Hop Antigen

### Terminology

ISBT symbol (number)	MNS26 (002026 or 2.26)
History	Reported in 1977 and named after the first donor whose RBCs expressed the antigen.

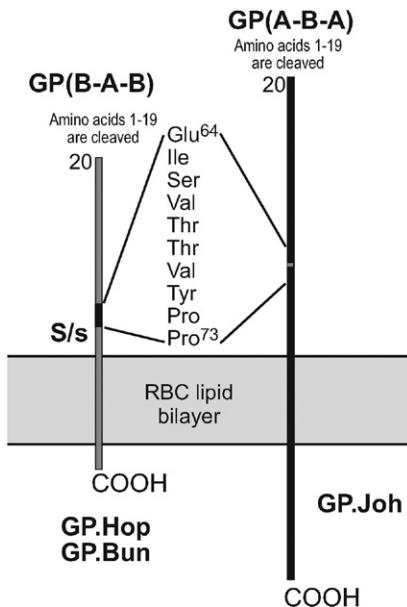
### Occurrence

Most populations	<0.01%
Thai	0.68%

### Expression

Cord RBCs	Presumed expressed
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## Molecular basis associated with Hop antigen<sup>1-3</sup>



### Variant glycophorins

GP.Hop (Mi.IV)	GPB(20-45)-GP $\psi$ B(46-69)-GPA(70-76)-GPB <sup>s</sup> (77-122)
GP.Bun (Mi.VI)	GPB(20-45)-GP $\psi$ B(46-69)-GPA(70-76)-GPB <sup>s</sup> (77-122)
GP.Joh (Mi.VIII)	GPA(20-67)-GP $\psi$ B(68)-GPA(69-150)

### Contribution by parent glycophorins

GP.Hop, GP.Bun	GPB(20-45)-GP $\psi$ B-GPA(70-76)-GPB(46-91)
GP.Joh	GPA(20-67)-GP $\psi$ B-GPA(69-150)

### Gene arrangement

GP.Hop, GP.Bun	<i>GYP(B-A-B)</i>
GP.Joh	<i>GYP(A-B-A)</i>

## Effect of enzymes and chemicals on Hop antigen on intact RBCs

	GP.Hop (Mi.IV)	GP.Bun (Mi.VI)	GP.Joh (Mi.VIII)
Ficin/Papain	Sensitive	Sensitive	Sensitive
Trypsin	Resistant	Resistant	Sensitive
$\alpha$ -Chymotrypsin	Sensitive	Variable	Resistant
Sialidase	Variable	Variable	Variable
DTT 200 mM	Resistant	Resistant	Resistant
Acid	Resistant	Resistant	Resistant

### In vitro characteristics of alloanti-Hop

Immunoglobulin class      IgG  
 Optimal technique      IAT

### Clinical significance of alloanti-Hop

No data are available because antibody is rare.

### Comments

Antigen is defined by the Anek serum (predominantly anti-Hop, weak anti-Nob). Sera which contain anti-Hop may also contain anti-Nob (see **MNS27**).

### References

- <sup>1</sup> Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. Vox Sang 62, 129–135.
- <sup>2</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- <sup>3</sup> Storry, J.R., et al., 2000. Identification of a novel hybrid glycophorin gene encoding GP.Hop. Transfusion 40, 560–565.

## Nob Antigen

### Terminology

- |                      |   |
|----------------------|---|
| ISBT symbol (number) | MNS27 (002027 or 2.27)  |
| History              | The antigen is defined by the Lane serum and was named Nob after the person whose RBCs carried the antigen. |

## Occurrence

Most populations      <0.01%

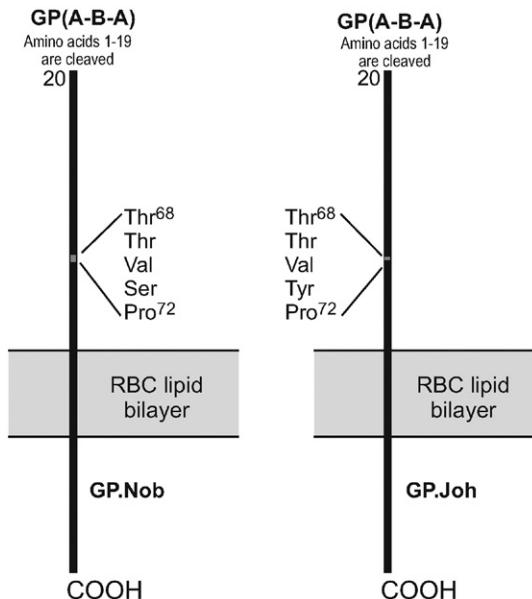
## Antithetical antigen

ENKT (MNS29)

## Expression

Cord RBCs      Presumed expressed

## Molecular basis associated with Nob antigen<sup>1,2</sup>



## Variant glycophorins

GP.Nob (Mi.VII)      GPA(20–67)-GPψB(68–71)-GPA(72–150)

GP.Joh (Mi.VIII)      GPA(20–67)-GPψB(68)-GPA(69–150)

## Contribution by parent glycophorins

GP.Nob      GPA(20–67)-GPψB-GPA(72–150)

GP.Joh      GPA(20–67)-GPψB-GPA(69–150)

## Gene arrangement

GP.Nob, GP.Joh      GYP(A-B-A)

## Effect of enzymes and chemicals on Nob antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Resistant
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-Nob

Immunoglobulin class	IgM; IgG
Optimal technique	RT; IAT

## Clinical significance of alloanti-Nob

Transfusion reaction	Mild in one case
HDFN	No data

## Comments

The Raddon serum is predominantly anti-Nob with a weak anti-Hop. Sera which contain anti-Nob may also contain anti-Hop (see **MNS26**).

## References

- <sup>1</sup> Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. Vox Sang 62, 129–135.
- <sup>2</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycoporphins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.

## En<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS28 (002028 or 2.28)
History	Named in 1965 when it was recognized that the antigen was carried on an important component of the <u>envelope</u> of the RBC. Joined the MNS system in 1985.

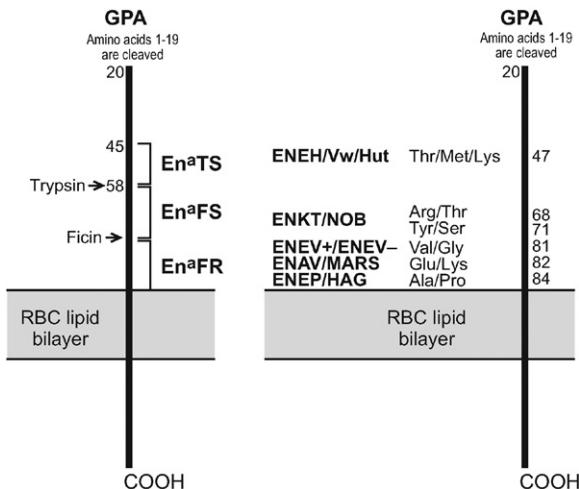
### Occurrence

All populations	100%
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### Expression

Cord RBCs	Expressed
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## Molecular basis associated with En<sup>a</sup> antigen<sup>1</sup>



Legend: TS = trypsin sensitive; FS = ficin sensitive; FR = ficin resistant

## Effect of enzymes and chemicals on En<sup>a</sup> antigen on intact RBCs

Ficin/Papain	See figure
Trypsin	See figure
α-Chymotrypsin	Resistant
Pronase	Most are sensitive
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-En<sup>a</sup>

Immunoglobulin class	IgM and IgG
Optimal technique	RT; IAT
Complement binding	Rare

## Clinical significance of alloanti-En<sup>a</sup>

Transfusion reaction	No to severe
HDFN	No to severe

## Autoantibody

Yes (Anti-En<sup>a</sup>TS, anti-En<sup>a</sup>FS, and anti-En<sup>a</sup>FR).

## Comments

RBCs that lack GPA lack all En<sup>a</sup> antigens, type as Wr(b-), and have reduced levels of sialic acid (40% of normal).

## Reference

<sup>1</sup> Issitt, P.D., et al., 1981. Proposed new terminology for En<sup>a</sup>. Transfusion 21, 473–474.

## ENKT Antigen

### Terminology

ISBT symbol (number)	MNS29 (002029 or 2.29)
Obsolete names	En <sup>a</sup> FS, En <sup>a</sup> KT
History	Reported as En <sup>a</sup> FS in 1985. In 1988, it was named “EN” because it is a high-prevalence antigen on GPA and “KT” for the initials of the first antigen-negative proband.

### Occurrence

All populations	100%
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### Antithetical antigen

Nob (MNS27)

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with ENKT antigen<sup>1</sup>

Amino acid	Arg68 (previously 49) and Tyr71 (previously 52) of GPA
Nucleotide	C at bp 203 and C at bp 212 of GYPA

### Effect of enzymes and chemicals on ENKT antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-ENKT

Immunoglobulin class	IgG
Optimal technique	IAT

### Clinical significance of alloanti-ENKT

No data are available because anti-ENKT is rare.

## Reference

- <sup>1</sup> Dahr, W., 1992. Miltenberger subsystem of the MNSs blood group system. Review and outlook. Vox Sang 62, 129–135.

## 'N' Antigen

### Terminology

ISBT symbol (number)	MNS30 (002030 or 2.30)
Other name	GPB <sup>N</sup>
History	Named when it was realized that the N-terminal amino acid sequence of GPB was the same as GPA carrying the N antigen. Quotation marks were used to distinguish N on GPB from N on GPA. Assigned an MNS number in 1985 by the ISBT.

MNS

### Occurrence

Present on all cells except those deficient in GPB or RBCs with GPB expressing He or M<sup>v</sup> antigen.

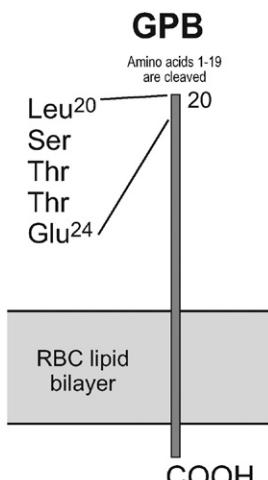
### Antithetical antigen

He (MNS6)

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with 'N' antigen<sup>1</sup>



## Effect of enzymes and chemicals on 'N' antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Sensitive
Sialidase	Variable
DTT 200 mM	Resistant
Acid	Resistant

## Comments

See N antigen (MNS2). Anti-'N' does not exist.

## Reference

- <sup>1</sup> Blanchard, D., et al., 1987. Glycophorins B and C from human erythrocyte membranes. Purification and sequence analysis. J Biol Chem 262, 5808–5811.

## Or Antigen

### Terminology

ISBT symbol (number)	MNS31 (002031 or 2.31)
Obsolete names	Orriss; Or <sup>a</sup>
History	Named in 1987 after the family in which the antigen was first found.

### Occurrence

Found in two Japanese, one Australian, one African American, and one Jamaican.

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with Or antigen<sup>1,2</sup>

Amino acid	Trp50 (previously 31) of GPA
Nucleotide	T at bp 148 in exon 3 in GYPA
Or- (wild type)	Arg50 and C at bp 148

## Effect of enzymes and chemicals on Or antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Variable
$\alpha$ -Chymotrypsin	Resistant
Sialidase	Sensitive
DTT 200 mM	Resistant
Acid	Resistant

### ***In vitro* characteristics of alloanti-Or**

Immunoglobulin class      IgM more common than IgG  
 Optimal technique            RT

### **Clinical significance of alloanti-Or**

Transfusion reactions      No data  
 HDFN                         No to moderate<sup>1</sup>

### **Comments**

The M (MNS1) antigen on Or+ RBCs is more resistant to trypsin treatment than normal M, presumably due to the close proximity of the amino acid change to the major trypsin cleavage site<sup>3</sup>.

### **References**

- <sup>1</sup> Reid, M.E., et al., 2000. First example of hemolytic disease of the newborn caused by anti-Or and confirmation of the molecular basis of Or. Vox Sang 79, 180–182.
- <sup>2</sup> Tsuneyama, H., et al., 1998. Molecular basis of Or in the MNS blood group system [abstract]. Vox Sang 74 (Suppl. 1), 1446.
- <sup>3</sup> Bacon, J.M., et al., 1987. Evidence that the low frequency antigen Orriss is part of the MN blood group system. Vox Sang 52, 330–334.

## **DANE Antigen**

### **Terminology**

ISBT symbol (number)      MNS32 (002032 or 2.32)  
 History                       Named in 1991 after it was found in four Danish families.

### **Occurrence**

Most populations            <0.01%  
 Danes                        0.43%

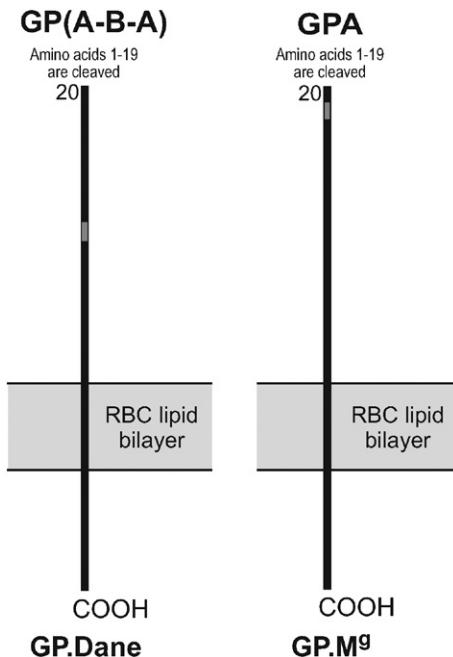
### **Antithetical antigen**

#### **ENDA (MNS44)**

### **Expression**

Cord RBCs                   Presumed expressed

## Molecular basis associated with DANE antigen<sup>1</sup>



MNS

### Variant glycophorin

GP.Dane (Mi.IX)                  GPA(20–53)-GPψB(54–59)-GPA(60–150)

### Contribution by parent glycophorin

GPA(20–53)-GPψB-GPA(60–150)

### Gene arrangement

*GYP(A-B-A)*. Found with an Ile65 (previously 46) change in GPA to Asn64 of GP.Dane in one case<sup>1</sup>, and without the Ile65 change in one case, which was ENDA – (**MNS44**)<sup>2</sup>.

### Effect of enzymes and chemicals on DANE antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

## ***In vitro* characteristics of alloanti-DANE**

Immunoglobulin class	IgG
Optimal technique	IAT

## **Clinical significance of alloanti-DANE**

Unknown since only one example, in an untransfused male, has been described.

## **Comments**

GP.Dane has trypsin resistant M (**MNS1**) and Mur (**MNS10**) antigens, but does not express other low prevalence MNS antigens<sup>3</sup>. Mg+ RBCs are DANE+, maybe due to the presence of Asn64 in the hybrid<sup>4</sup>.  
DANE is inherited with MS.

MNS

## **References**

- <sup>1</sup> Huang, C.-H., et al., 1992. Molecular analysis of human glycophorin MiIX gene shows a silent segment transfer and untemplated mutation resulting from gene conversion via sequence repeats. *Blood* 80, 2379–2387.
- <sup>2</sup> Velliquette, R.W., et al., 2008. Novel GYP(A-B-A) hybrid gene in a DANE+ person who made an antibody to a high prevalence MNS antigen. *Transfusion* 48, 2618–2623.
- <sup>3</sup> Skov, F., et al., 1991. Miltenberger class IX of the MNS blood group system. *Vox Sang* 61, 130–136.
- <sup>4</sup> Green, C., et al., 1994. Mg+ MNS blood group phenotype: further observations. *Vox Sang* 66, 237–241.

## **TSEN Antigen**

### **Terminology**

ISBT symbol (number)	MNS33 (002033 or 2.33)
History	Named in 1992 after the last name of the first antibody producer.

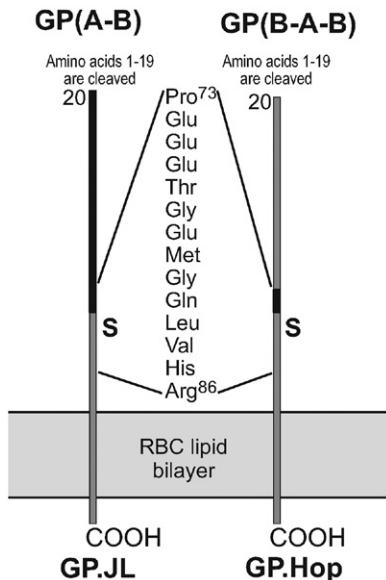
### **Occurrence**

Most populations	<0.01%
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### **Expression**

Cord RBCs	Expressed
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## Molecular basis associated with TSEN antigen<sup>1,2</sup>



MNS

### Variant glycophorins

GP.JL (Mi.XI)	GPA(20–77)-GPB <sup>S</sup> (78–123)
GP.Hop (Mi.IV)	GPB(20–45)-GP $\psi$ B(46–69)-GPA(70–76)-GPB <sup>S</sup> (77–123)

### Contribution by parent glycophorins

GP.JL	GPA(20–77)-GPB(46–91)
GP.Hop	GPB(20–45)-GP $\psi$ B-GPA(70–76)-GPB(46–91)

### Gene arrangement

GP.JL	GYP(A-B)
GP.Hop	GYP(B-A-B)

### Effect of enzymes and chemicals on TSEN antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### ***In vitro* characteristics of alloanti-TSEN**

Immunoglobulin class	IgM and IgG
Optimal technique	RT; IAT

### **Clinical significance of alloanti-TSEN**

Transfusion reactions	No
HDFN	No

### **Comments**

Reciprocal product of *GYP\*JL* is *GYP\*Sch* (see St<sup>a</sup> antigen [**MNS15**] ). TSEN+ RBCs are also MINY+ (**MNS34**).

Several examples of anti-TSEN have been described<sup>3</sup>.

Some anti-S do not agglutinate S+s+ TSEN+ RBCs.

### **References**

- <sup>1</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.
- <sup>2</sup> Reid, M.E., et al., 1992. TSEN: a novel MNS-related blood group antigen. Vox Sang 63, 122–128.
- <sup>3</sup> Storry, J.R., et al., 2000. Four examples of anti-TSEN and three of TSEN-positive erythrocytes. Vox Sang 79, 175–179.

## **MINY Antigen**

### **Terminology**

ISBT symbol (number)	MNS34 (002034 or 2.34)
History	Named in 1992 after the only producer of the antibody.

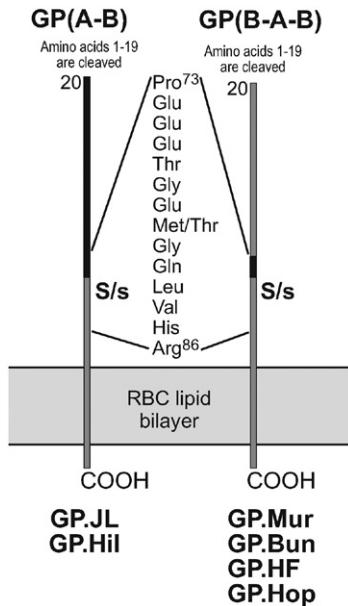
### **Occurrence**

Most populations	<0.01%
Chinese	6%

### **Expression**

Cord RBCs	Presumed expressed
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## Molecular basis associated with MINY antigen<sup>1</sup>



For details of variant glycophorin, contribution by parent glycophorin and gene arrangement, see Hil (MNS20) and TSEN (MNS33).

### Effect of enzymes and chemicals on MINY antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
α-Chymotrypsin	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-MINY

Immunoglobulin class	IgM
Optimal technique	RT

### Clinical significance of alloanti-MINY

No data because antibody is rare.

### Comments

All Hil+ (MNS20) and TSEN+ (MNS33) RBCs are MINY+ except when the Hil antigen is carried on GP.KI<sup>2</sup>.

## References

- <sup>1</sup> Reid, M.E., et al., 1992. MINY: A novel MNS-related blood group antigen. Vox Sang 63, 129–132.
- <sup>2</sup> Poole, J., et al., 1998. Novel molecular basis for the Hil (MNS20) antigen [abstract]. Transfusion 38 (Suppl), 103S.

## MUT Antigen

### Terminology

ISBT symbol (number) MNS35 (002035 or 2.35)

History The specificity originally called anti-Hut was renamed anti-MUT in 1984, because both Mur<sup>+</sup> and Hut<sup>+</sup> RBCs are reactive.

### Occurrence

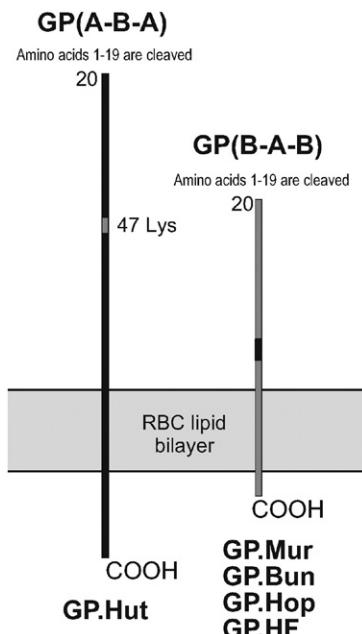
Most populations <0.01%

Chinese 6%

### Expression

Cord RBCs Presumed expressed

### Molecular basis associated with MUT antigen<sup>1</sup>



For details of variant glycophorin, contributions by parent glycophorin, and gene arrangement, see Hut (**MNS19**), Hil (**MNS20**), and Hop (**MNS26**).

## Effect of enzymes and chemicals on MUT antigen on intact RBCs

	GP(A-B-A)	GP(B-A-B)
Ficin/Papain	Sensitive	Sensitive
Trypsin	Sensitive	Resistant
$\alpha$ -Chymotrypsin	Resistant	Sensitive
DTT 200 mM	Resistant	Resistant
Acid	Resistant	Resistant

### *In vitro* characteristics of alloanti-MUT

Immunoglobulin class IgM and IgG

Optimal technique RT; IAT

### Clinical significance of alloanti-MUT

Transfusion reactions No data are available because antibody is rare

HDFN One case<sup>2</sup>

### Comments

Anti-MUT is often in serum with (and is separable from) anti-Hut (see **MNS19**).

### References

<sup>1</sup> Huang, C.-H., Blumenfeld, O.O., 1995. MNSs blood groups and major glycophorins: molecular basis for allelic variation. In: Cartron, J.-P., Rouger, P. (Eds.), Molecular Basis of Human Blood Group Antigens. Plenum Press, New York, NY, pp. 153–188.

<sup>2</sup> van den Bos, A.G., Steiner, K., 2004. Haemolytic disease of the newborn caused by anti-MUT (MNS 35). Vox Sang 87, 208–209.

## SAT Antigen

### Terminology

ISBT symbol (number) MNS36 (002036 or 2.36)

History Reported in 1991 and named after the first proband whose RBCs carried the antigen; joined the MNS system in 1994.

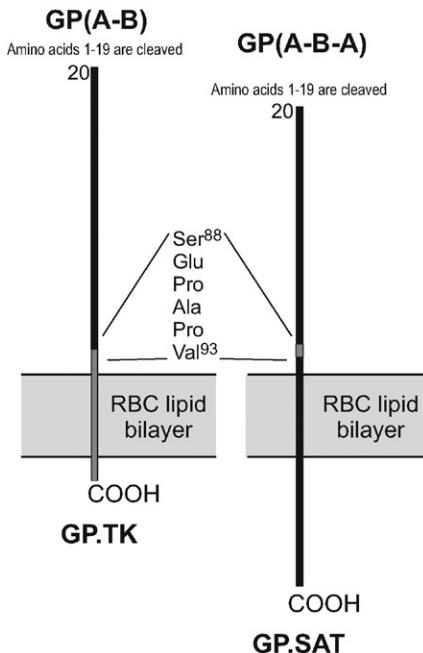
## Occurrence

Most populations <0.01%

## Expression

Cord RBCs Presumed expressed

## Molecular basis associated with SAT antigen<sup>1,2</sup>



## Variant glycophorins

GP.TK GPA(20–90)-GPB(91–123)

GP.SAT GPA(20–90)-GPB(91–93)-GPA(94–153)

## Contribution by parent glycophorins

GP.TK GPA(20–90)-GPB(59–91)

GP.SAT GPA(20–90)-GPB(59–61)-GPA(91–150)

## Gene arrangement

GP.TK *GYP(A-B)*

GP.SAT *GYP(A-B-A)*

## Effect of enzymes and chemicals on SAT antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive (GP.TK); resistant (GP.SAT)
$\alpha$ -Chymotrypsin	Sensitive
Sialidase	GP.SAT resistant
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-SAT

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-SAT

No data are available because anti-SAT is rare.

## Comments

The reciprocal product of *GYP\*TK* is *GYP\*Dantu* (see **MNS25**).

## References

- <sup>1</sup> Huang, C.-H., et al., 1995. Glycophorin SAT of the human erythrocyte membrane is specified by a hybrid gene reciprocal to glycophorin Dantu gene. *Blood* 85, 2222–2227.
- <sup>2</sup> Uchikawa, M., et al., 1994. A novel amino acid sequence result in the expression of the MNS related private antigen, SAT [abstract]. *Vox Sang* 67 (S2), 116.

## ERIK Antigen

### Terminology

ISBT symbol (number)	MNS37 (002037 or 2.37)
History	Named in 1993 after the proband whose St(a+) RBCs expressed another low-prevalence antigen.

### Occurrence

Most populations <0.01%

### Expression

Cord RBCs Presumed expressed

## Molecular basis associated with ERIK antigen<sup>1,2</sup>

Amino acid	Arg78 (previously 59) of GPA
Nucleotide	A at bp 232 in exon 4 in <i>GYPA</i>
ERIK- (wild type)	Gly78 and G at position 232

ERIK has been associated with a *GYP(A-E-A)*, which encodes a variant of GPA carrying St<sup>a</sup>.

### Effect of enzymes and chemicals on ERIK antigen on intact RBCs

Ficin/Papain	Variable/sensitive
Trypsin	Weakened
α-Chymotrypsin	Resistant
Pronase	Sensitive
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-ERIK

Immunoglobulin class	IgG
Optimal technique	IAT

### Clinical significance of alloanti-ERIK

Transfusion reaction	No data because the antibody is rare
HDFN	Positive DAT

### Comments

Alternative splicing of *GYP\*EBH* gives rise to a variant glycophorin GPEBH(t2) expressing the St<sup>a</sup> antigen (see **MNS15**). Thus, in ERIK+ RBCs, ERIK and St<sup>a</sup> antigens are carried on different glycophorin molecules (see table on MNS system page).

The Gly78Arg change introduces a trypsin cleavage site.

### References

- Huang, C.-H., et al., 1993. Alteration of splice site selection by an exon mutation in the human glycophorin A gene. *J Biol Chem* 268, 25902–25908.
- Huang, C.-H., et al., 1994. Gene conversion between glycophorins A and E results in St<sup>a</sup> glycophorin in a family exhibiting the ERIK/St<sup>a</sup> blood group phenotype [abstract]. *Blood* 84 (Suppl. 1), 238a.

## Os<sup>a</sup> Antigen

### Terminology

ISBT symbol (number)	MNS38 (002038 or 2.38)
Obsolete name	700033
History	Named in 1983 after Osaka, the town where the antibody and antigen were first found; joined the MNS system in 1994.

## Occurrence

Only studied in one Japanese family<sup>1</sup>.

## Expression

Cord RBCs                      Presumed expressed

## Molecular basis associated with Os<sup>a</sup> antigen<sup>2</sup>

Amino acid	Ser73 (previously 54) of GPA
Nucleotide	T at bp 217 in exon 3 in <i>GYPA</i>
Os(a–) (wild type)	Pro73 and C bp 217

## Effect of enzymes and chemicals on Os<sup>a</sup> antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Resistant
α-Chymotrypsin	Resistant
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

## In vitro characteristics of alloanti-Os<sup>a</sup>

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-Os<sup>a</sup>

No data are available.

## Comments

Anti-Os<sup>a</sup> found in several sera containing antibodies to multiple low-prevalence antigens.

## References

- 1 Seno, T., et al., 1983. OS<sup>a</sup>, a “new” low-frequency red cell antigen. Vox Sang 45, 60–61.
- 2 Daniels, G.L., et al., 2000. The low-frequency MNS blood group antigens Ny<sup>a</sup> (MNS18) and Os<sup>a</sup> (MNS38) are associated with GPA amino acid substitutions. Transfusion 40, 555–559.

## ENEP Antigen

### Terminology

ISBT symbol (number)	MNS39 (002039 or 2.39)
History	Reported in 1995 and named “EN” because it is a high-prevalence antigen on GPA, and “EP” for the name of the first antigen-negative proband.

## Occurrence

All populations 100%

## Antithetical antigen

HAG (MNS41)

## Expression

Cord RBCs Presumed expressed

## Molecular basis associated with ENEP antigen<sup>1</sup>

Amino acid Ala84 (previously 65) of GPA  
Nucleotide G at bp 250 in exon 4 in *GYP*A

## Effect of enzymes and chemicals on ENEP antigen on intact RBCs

Ficin/Papain	Ficin resistant/Papain sensitive
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Resistant
DTT 200 mM	Presumed resistant

## In vitro characteristics of alloanti-ENEP

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-ENEP

No data are available because antibody is rare.

## Comments

Anti-ENEP (anti-En<sup>a</sup>FR) was made by a person homozygous for *GYP*\*HAG. RBCs lacking ENEP (HAG+; MNS41) have an altered expression of Wr<sup>b</sup> (DI4) antigen<sup>1</sup>.

## Reference

<sup>1</sup> Poole, J., et al., 1999. Glycophorin A mutation Ala65 --> Pro gives rise to a novel pair of MNS alleles ENEP (MNS39) and HAG (MNS41) and altered Wr<sup>b</sup> expression: direct evidence for GPA/band 3 interaction necessary for normal Wr<sup>b</sup> expression. Transfus Med 9, 167–174.

## ENEH Antigen

### Terminology

ISBT symbol (number) MNS40 (002040 or 2.40)

History Named “EN” because it is a high-prevalence antigen on GPA, and “EH” from the initials of the first antigen-negative proband.

## Occurrence

All populations 100%

## Antithetical antigen

Vw (MNS9); Hut (MNS19)

## Expression

Cord RBCs Expressed

## Molecular basis associated with ENEH antigen<sup>1</sup>

Amino acid	Thr47 (previously 28) of GPA
Nucleotide	C at bp 140 in exon 3 in <i>GYPA</i>

## Effect of enzymes and chemicals on ENEH antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
Sialidase	Resistant
DTT 200 mM	Presumed resistant
Acid	Resistant

## In vitro characteristics of alloanti-ENEH

Immunoglobulin class	IgM and IgG is the only example of anti-ENEH described <sup>2</sup>
Optimal technique	RT; IAT

## Clinical significance of alloanti-ENEH

Transfusion reactions	No data are available
HDFN	The anti-ENEH (anti-En <sup>a</sup> TS) did not cause HDFN <sup>2</sup>

## Comment

ENEH– RBCs have an altered expression of Wr<sup>b</sup> (**DI4**).

## References

- <sup>1</sup> Huang, C.-H., et al., 1992. Molecular basis for the human erythrocyte glycophorin specifying the Miltenberger class I (MiI) phenotype. *Blood* 80, 257–263.
- <sup>2</sup> Spruell, P., et al., 1993. An anti-En<sup>a</sup>TS detected in the serum of an MiI homozygote. *Transfusion* 33, 848–851.

## HAG Antigen

### Terminology

ISBT symbol (number)	MNS41 (002041 or 2.41)
History	Reported in 1995 and named after the transfused man whose serum contained an antibody to a high-prevalence antigen (ENEП), and who's RBCs had a double dose of this low-prevalence antigen.

### Occurrence

Two probands, both Israeli.

### Antithetical antigen

ENEП (MNS39)

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with HAG antigen<sup>1</sup>

Amino acid	Pro84 (previously 65) of GPA
Nucleotide	C at bp 250 in exon 4 in <i>GYPA</i>

### Effect of enzymes and chemicals on HAG antigen on intact RBCs

Ficin/Papain	Resistant
Trypsin	Resistant
α-Chymotrypsin	Resistant
DTT 200 mM	Presumed resistant
Acid	Resistant

### In vitro characteristics of alloanti-HAG

Immunoglobulin class	IgG
Optimal technique	IAT

### Clinical significance of alloanti-HAG

No data are available because antibody is rare.

### Comments

RBCs with a double dose expression of HAG (ENEП-; [MNS39]) have an altered expression of Wr<sup>b</sup> (**DI4**)<sup>1</sup>.

## Reference

<sup>1</sup> Poole, J., et al., 1999. Glycophorin A mutation Ala65 --> Pro gives rise to a novel pair of MNS alleles ENEP (MNS39) and HAG (MNS41) and altered Wr<sup>b</sup> expression: direct evidence for GPA/band 3 interaction necessary for normal Wr<sup>b</sup> expression. Transfus Med 9, 167–174.

## ENAV Antigen

### Terminology

ISBT symbol (number)	MNS42 (002042 or 2.42)
Obsolete names	Avis
History	Reported in 1996; named “EN” because it is a high-prevalence antigen on GPA, and “AV” after the name of the proband whose serum contained the antibody.

### Occurrence

All populations	100%
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### Antithetical antigen

MARS (MNS43)

### Expression

Cord RBCs	Expressed
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### Molecular basis associated with ENAV antigen<sup>1</sup>

Amino acid	Gln82 (previously 63) of GPA
Nucleotide	C at bp 244 in exon 4 in GYPA

### Effect of enzymes and chemicals on ENAV antigen on intact RBCs

Ficin/Papain	Resistant
Trypsin	Resistant
α-Chymotrypsin	Resistant
Sialidase	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-ENAV

Immunoglobulin class	IgG
Optimal technique	IAT

### Clinical significance of alloanti-ENAV

No data are available because antibody is rare.

## Comments

ENAV– RBCs have a weak expression of Wr<sup>b</sup> (see **DI4**).

## Reference

- <sup>1</sup> Jarolim, P., et al., 1997. Molecular basis of the MARS and AVIS blood group antigens [abstract]. Transfusion 37 (Suppl), 90S.

## MARS Antigen

### Terminology

ISBT symbol (number)	MNS43 (002043 or 2.43)
History	Reported in 1996 and named after the Native American proband (Marsden) whose serum contained antibodies to several low-prevalence antigens and reacted with ENAV– RBCs ( <b>MNS42</b> ).

### Occurrence

Most populations	None found
Choctaw Indians	15%

### Antithetical antigen

ENAV (**MNS42**)

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with MARS antigen<sup>1</sup>

Amino acid	Lys82 (previously 63) of GPA
Nucleotide	A at bp 244 in exon 4 in <i>GYP</i> A

### Effect of enzymes and chemicals on MARS antigen on intact RBCs

Ficin/Papain	Resistant
Trypsin	Resistant
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant
Acid	Resistant

### In vitro characteristics of alloanti-MARS

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-MARS

No data are available because antibody is rare.

## Comments

RBCs with a double dose of the MARS antigen (ENAV-) have a weak expression of Wr<sup>b</sup> (see **DI4**).

## Reference

- <sup>1</sup> Jarolim, P., et al., 1997. Molecular basis of the MARS and AVIS blood group antigens [abstract]. Transfusion 37 (Suppl), 90S.

## ENDA Antigen

### Terminology

ISBT symbol (number)	MNS44 (002044 or 2.44)
History	Reported in 2008; named “EN” because it is a high-prevalence antigen on GPA, and “DA” for the association with DANE.

### Occurrence

Only one ENDA– proband and her ENDA– brother, have been reported.

### Antithetical antigen

DANE (MNS32)

### Expression

Cord RBCs	Presumed expressed
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### Molecular basis associated with ENDA antigen<sup>1</sup>

*Variant glycophorin*

GP.Dane: GPA(20–53)-GPψB(54–59)-GPA(60–150)

*Contribution by parent glycophorin*

GPA(20–53)-GPψB-GPA(60–150)

*Gene arrangement*

*GYP(A-B-A)*

### Effect of enzymes and chemicals on ENDA antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
α-Chymotrypsin	Resistant
DTT 200 mM	Resistant

## ***In vitro* characteristics of alloanti-ENDA**

Immunoglobulin class      IgM; IgG (see Comments)  
 Optimal technique            RT; 37°C; IAT

## **Clinical significance of alloanti-ENDA**

No data are available because antibody is rare.

## **Comments**

The only known example of anti-ENDA was found in the serum of an untransfused woman during her first pregnancy. The antibody was IgM, but after the birth of the proband's baby a trace of IgG was found. In this proband, the novel *GYP(A-B-A)* was in trans to  $M^k$ .

## **Reference**

- <sup>1</sup> Velliquette, R.W., et al., 2008. Novel GYP(A-B-A) hybrid gene in a DANE+ person who made an antibody to a high prevalence MNS antigen. Transfusion 48, 2618–2623.

## **ENEV Antigen**

### **Terminology**

ISBT symbol (number)    MNS45 (002045 or 2.45)  
 History                    Reported in 2010; named “EN” because it is a high-prevalence antigen on GPA, and “EV” from the ENEV– proband’s name.

### **Occurrence**

One ENEV– proband has been reported.

### **Expression**

Cord RBCs                Presumed expressed

### **Molecular basis associated with ENEV antigen<sup>1</sup>**

Amino acid                Val81 (previously 62) of GPA  
 Nucleotide                T at bp 242 in exon 4 in *GYP*  
 ENEV–                    Gly81 and G at bp 242

### **Effect of enzymes and chemicals on ENEV antigen on intact RBCs**

Ficin/Papain	Resistant
Trypsin	Resistant
$\alpha$ -Chymotrypsin	Resistant
DTT 200 mM	Resistant

## ***In vitro characteristics of alloanti-ENEV***

Immunoglobulin class	IgM; IgG
Optimal technique	IAT; RT; 37°C

## **Clinical significance of alloanti-ENEV**

Only one example of anti-ENEV has been reported. The proband, who had a history of three pregnancies, received four units of crossmatch-compatible RBCs. Ten days after transfusion she presented with a drop in hemoglobin. Testing of her RBCs suggested that no transfused RBCs remained in her circulation.

## **Comments**

ENEV– RBCs have an altered expression of the Wr<sup>b</sup> (**D14**) antigen. Anti-ENEV gave marginally weaker reactions with ENEP– and ENAV– RBCs.

## **Reference**

- <sup>1</sup> Velliquette, R.W., et al., 2010. Novel single nucleotide change in *GYP\*A* in a person who made an alloantibody to a new high prevalence MNS antigen called ENEV. Transfusion 50, 856–860.

## **MNTD Antigen**

### **Terminology**

ISBT symbol (number)	MNS46 (002046 or 2.46)
History	Reported in 2006; named “MN” for the system, and “TD” from the name of the antigen-positive index case.

### **Occurrence**

Most populations	None found
Japanese	0.02%

### **Expression**

Cord RBCs	Presumed expressed
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### **Molecular basis associated with MNTD antigen<sup>1</sup>**

Amino acid	Arg36 (previously 17) on GPA
Nucleotide	G at bp 107 in exon 3 of <i>GYP*A</i>
MNTD– (wild type)	Thr36 and C at bp107

## Effect of enzymes and chemicals on MNTD antigen on intact RBCs

Ficin/Papain	Sensitive
Trypsin	Sensitive
$\alpha$ -Chymotrypsin	Sensitive
DTT 200 mM	Presumed resistant

## *In vitro* characteristics of alloanti-MNTD

Immunoglobulin class	IgG
Optimal technique	IAT

## Clinical significance of alloanti-MNTD

No data are available because antibody and antigen are rare.

## Reference

- <sup>1</sup> Uchikawa, M, et al., 2006. Molecular basis for a novel low frequency antigen in the MNS blood group system, Td [abstract]. Vox Sang 91 (Suppl. 3), 133.