Figure S1. Functional enrichment analysis of hub genes. (A) Significantly enriched Gene Ontology terms of the hub genes. (B) Significantly enriched Kyoto Encyclopedia of Genes and Genomes pathways of the hub genes. Th, T helper cell.
Table SI. List of metagenes for the 25 immune cell subpopulations.

| Metagene         | Immune cell type | Immunity |
|------------------|------------------|----------|
| ADAM28           | Activated B cell | Adaptive |
| CD180            | Activated B cell | Adaptive |
| CD79B            | Activated B cell | Adaptive |
| BLK              | Activated B cell | Adaptive |
| CD19             | Activated B cell | Adaptive |
| MS4A1            | Activated B cell | Adaptive |
| TNFRSF17         | Activated B cell | Adaptive |
| IGHM             | Activated B cell | Adaptive |
| GNG7             | Activated B cell | Adaptive |
| MICAL3           | Activated B cell | Adaptive |
| SPIB             | Activated B cell | Adaptive |
| HLA-DOB          | Activated B cell | Adaptive |
| IGKC             | Activated B cell | Adaptive |
| PNOC             | Activated B cell | Adaptive |
| FCRL2            | Activated B cell | Adaptive |
| BACH2            | Activated B cell | Adaptive |
| CR2              | Activated B cell | Adaptive |
| TCL1A            | Activated B cell | Adaptive |
| AKNA             | Activated B cell | Adaptive |
| ARHGAP25         | Activated B cell | Adaptive |
| CCL21            | Activated B cell | Adaptive |
| CD27             | Activated B cell | Adaptive |
| CD38             | Activated B cell | Adaptive |
| CLEC17A          | Activated B cell | Adaptive |
| CLEC9A           | Activated B cell | Adaptive |
| CLECL1           | Activated B cell | Adaptive |
| AIM2             | Activated CD4 T cell | Adaptive |
| BIRC3            | Activated CD4 T cell | Adaptive |
| BRIP1            | Activated CD4 T cell | Adaptive |
| CCL20            | Activated CD4 T cell | Adaptive |
| CCLA             | Activated CD4 T cell | Adaptive |
| CCL5             | Activated CD4 T cell | Adaptive |
| CCNB1            | Activated CD4 T cell | Adaptive |
| CCR7             | Activated CD4 T cell | Adaptive |
| DUSP2            | Activated CD4 T cell | Adaptive |
| ESCO2            | Activated CD4 T cell | Adaptive |
| ETS1             | Activated CD4 T cell | Adaptive |
| EXO1             | Activated CD4 T cell | Adaptive |
| EXOC6            | Activated CD4 T cell | Adaptive |
| IARS             | Activated CD4 T cell | Adaptive |
| ITK              | Activated CD4 T cell | Adaptive |
| KIF11            | Activated CD4 T cell | Adaptive |
| KNTC1            | Activated CD4 T cell | Adaptive |
| NUF2             | Activated CD4 T cell | Adaptive |
| PRC1             | Activated CD4 T cell | Adaptive |
| PSAT1            | Activated CD4 T cell | Adaptive |
| RGS1             | Activated CD4 T cell | Adaptive |
| RTKN2            | Activated CD4 T cell | Adaptive |
| SAMSN1           | Activated CD4 T cell | Adaptive |
| SELL             | Activated CD4 T cell | Adaptive |
| TRAT1            | Activated CD4 T cell | Adaptive |
| ADRM1            | Activated CD8 T cell | Adaptive |
| AHSA1            | Activated CD8 T cell | Adaptive |
| C1GALT1C1        | Activated CD8 T cell | Adaptive |
| CCT6B            | Activated CD8 T cell | Adaptive |
| CD37             | Activated CD8 T cell | Adaptive |
| Metagene | Immune cell type                  | Immunity      |
|----------|-----------------------------------|---------------|
| CD3D     | Activated CD8 T cell              | Adaptive      |
| CD3E     | Activated CD8 T cell              | Adaptive      |
| CD3G     | Activated CD8 T cell              | Adaptive      |
| CD69     | Activated CD8 T cell              | Adaptive      |
| CD8A     | Activated CD8 T cell              | Adaptive      |
| CETN3    | Activated CD8 T cell              | Adaptive      |
| CSE1L    | Activated CD8 T cell              | Adaptive      |
| GEMIN6   | Activated CD8 T cell              | Adaptive      |
| GNLY     | Activated CD8 T cell              | Adaptive      |
| GPT2     | Activated CD8 T cell              | Adaptive      |
| GZMA     | Activated CD8 T cell              | Adaptive      |
| GZMH     | Activated CD8 T cell              | Adaptive      |
| GZMK     | Activated CD8 T cell              | Adaptive      |
| IL2RB    | Activated CD8 T cell              | Adaptive      |
| LCK      | Activated CD8 T cell              | Adaptive      |
| MPZL1    | Activated CD8 T cell              | Adaptive      |
| NKG7     | Activated CD8 T cell              | Adaptive      |
| PIK3IP1  | Activated CD8 T cell              | Adaptive      |
| PTRH2    | Activated CD8 T cell              | Adaptive      |
| TIMM13   | Activated CD8 T cell              | Adaptive      |
| ZAP70    | Activated CD8 T cell              | Adaptive      |
| ABCD1    | Activated dendritic cell          | Innate        |
| C1QC     | Activated dendritic cell          | Innate        |
| CAPG     | Activated dendritic cell          | Innate        |
| CCL3L3   | Activated dendritic cell          | Innate        |
| CD207    | Activated dendritic cell          | Innate        |
| CD302    | Activated dendritic cell          | Innate        |
| ATP5B    | Activated dendritic cell          | Innate        |
| ATP5L    | Activated dendritic cell          | Innate        |
| ATP6V1A  | Activated dendritic cell          | Innate        |
| BCL2L1   | Activated dendritic cell          | Innate        |
| C1QB     | Activated dendritic cell          | Innate        |
| SNURF    | Activated dendritic cell          | Innate        |
| SPCS3    | Activated dendritic cell          | Innate        |
| CCNA1    | Activated dendritic cell          | Innate        |
| CEACAM8  | Activated dendritic cell          | Innate        |
| NOS2     | Activated dendritic cell          | Innate        |
| SRAI     | Activated dendritic cell          | Innate        |
| TNFRSF6B | Activated dendritic cell          | Innate        |
| TREM1    | Activated dendritic cell          | Innate        |
| TREML1   | Activated dendritic cell          | Innate        |
| RHOA     | Activated dendritic cell          | Innate        |
| SLC25A37 | Activated dendritic cell          | Innate        |
| TNFSF14  | Activated dendritic cell          | Innate        |
| TREML4   | Activated dendritic cell          | Innate        |
| VNN2     | Activated dendritic cell          | Innate        |
| XPO6     | Activated dendritic cell          | Innate        |
| CLEC4C   | Activated dendritic cell          | Innate        |
| TNFAIP2  | Activated dendritic cell          | Innate        |
| UBD      | Activated dendritic cell          | Innate        |
| ACTR3    | Activated dendritic cell          | Innate        |
| RAB1A    | Activated dendritic cell          | Innate        |
| SLA      | Activated dendritic cell          | Innate        |
| HLA-DQA2 | Activated dendritic cell          | Innate        |
| SIGLEC5  | Activated dendritic cell          | Innate        |
| SLAMF9   | Activated dendritic cell          | Innate        |
| CD56     | CD56bright natural killer cell    | Innate        |
| Metagene | Immune cell type | Immunity |
|----------|-----------------|----------|
| ABAT     | CD56<sup>bright</sup> natural killer cell | Innate |
| C1<sup>11</sup>orf75 | CD56<sup>bright</sup> natural killer cell | Innate |
| C5orf15  | CD56<sup>bright</sup> natural killer cell | Innate |
| CDHR1    | CD56<sup>bright</sup> natural killer cell | Innate |
| DCAF12   | CD56<sup>bright</sup> natural killer cell | Innate |
| DYNLL1   | CD56<sup>bright</sup> natural killer cell | Innate |
| GPR137B  | CD56<sup>bright</sup> natural killer cell | Innate |
| HCP5     | CD56<sup>bright</sup> natural killer cell | Innate |
| HDGFRP2  | CD56<sup>bright</sup> natural killer cell | Innate |
| KRT86    | CD56<sup>bright</sup> natural killer cell | Innate |
| MLST8    | CD56<sup>bright</sup> natural killer cell | Innate |
| ELMOD3   | CD56<sup>bright</sup> natural killer cell | Innate |
| ENTPD5   | CD56<sup>bright</sup> natural killer cell | Innate |
| FAM119A  | CD56<sup>bright</sup> natural killer cell | Innate |
| FAM179A  | CD56<sup>bright</sup> natural killer cell | Innate |
| C1<sup>2</sup>C2  | CD56<sup>bright</sup> natural killer cell | Innate |
| COX7A2L  | CD56<sup>bright</sup> natural killer cell | Innate |
| CREB3L4  | CD56<sup>bright</sup> natural killer cell | Innate |
| CSF1     | CD56<sup>bright</sup> natural killer cell | Innate |
| CSNK2A2  | CD56<sup>bright</sup> natural killer cell | Innate |
| CSTA     | CD56<sup>bright</sup> natural killer cell | Innate |
| CSTB     | CD56<sup>bright</sup> natural killer cell | Innate |
| CTPS     | CD56<sup>bright</sup> natural killer cell | Innate |
| CTSD     | CD56<sup>bright</sup> natural killer cell | Innate |
| FST      | CD56<sup>bright</sup> natural killer cell | Innate |
| GATA2    | CD56<sup>bright</sup> natural killer cell | Innate |
| GMPR     | CD56<sup>bright</sup> natural killer cell | Innate |
| HCO      | CD56<sup>bright</sup> natural killer cell | Innate |
| HOXA1    | CD56<sup>bright</sup> natural killer cell | Innate |
| H3ST1    | CD56<sup>bright</sup> natural killer cell | Innate |
| HS3ST1   | CD56<sup>bright</sup> natural killer cell | Innate |
| BCL11B   | CD56<sup>bright</sup> natural killer cell | Innate |
| CDH3     | CD56<sup>bright</sup> natural killer cell | Innate |
| MYL6B    | CD56<sup>bright</sup> natural killer cell | Innate |
| NAA16    | CD56<sup>bright</sup> natural killer cell | Innate |
| C1QA     | CD56<sup>bright</sup> natural killer cell | Innate |
| C1QB     | CD56<sup>bright</sup> natural killer cell | Innate |
| CYP27B1  | CD56<sup>bright</sup> natural killer cell | Innate |
| EIF3M    | CD56<sup>bright</sup> natural killer cell | Innate |
| CYP27A1  | CD56<sup>dim</sup> natural killer cell | Innate |
| DDX55    | CD56<sup>dim</sup> natural killer cell | Innate |
| DYRK2    | CD56<sup>dim</sup> natural killer cell | Innate |
| RPL37A   | CD56<sup>dim</sup> natural killer cell | Innate |
| NOTCH3   | CD56<sup>dim</sup> natural killer cell | Innate |
| AKR7A3   | CD56<sup>dim</sup> natural killer cell | Innate |
| GPRC5C   | CD56<sup>dim</sup> natural killer cell | Innate |
| GRIN1    | CD56<sup>dim</sup> natural killer cell | Innate |
| HLA-E    | CD56<sup>dim</sup> natural killer cell | Innate |
| PORCN    | CD56<sup>dim</sup> natural killer cell | Innate |
| PSMC4    | CD56<sup>dim</sup> natural killer cell | Innate |
| UPP1     | CD56<sup>dim</sup> natural killer cell | Innate |
| IL21R    | CD56<sup>dim</sup> natural killer cell | Innate |
| KIR2DS1  | CD56<sup>dim</sup> natural killer cell | Innate |
| KIR2DS2  | CD56<sup>dim</sup> natural killer cell | Innate |
| KIR2DS5  | CD56<sup>dim</sup> natural killer cell | Innate |
| ABHD3    | Central memory CD4 T cell | Adaptive |
| Metagene  | Immune cell type      | Immunity  |
|-----------|-----------------------|-----------|
| AHNAK     | Central memory CD4 T cell | Adaptive  |
| ANX2AP2   | Central memory CD4 T cell | Adaptive  |
| AQP3      | Central memory CD4 T cell | Adaptive  |
| ATHL1     | Central memory CD4 T cell | Adaptive  |
| BMI1      | Central memory CD4 T cell | Adaptive  |
| BZW2      | Central memory CD4 T cell | Adaptive  |
| CD63      | Central memory CD4 T cell | Adaptive  |
| COL4A1    | Central memory CD4 T cell | Adaptive  |
| CYLD      | Central memory CD4 T cell | Adaptive  |
| ELMO2     | Central memory CD4 T cell | Adaptive  |
| FYN       | Central memory CD4 T cell | Adaptive  |
| GLPR1     | Central memory CD4 T cell | Adaptive  |
| GSS       | Central memory CD4 T cell | Adaptive  |
| IFITM2    | Central memory CD4 T cell | Adaptive  |
| ITGB1     | Central memory CD4 T cell | Adaptive  |
| ITGB2     | Central memory CD4 T cell | Adaptive  |
| KLF5      | Central memory CD4 T cell | Adaptive  |
| LSP1      | Central memory CD4 T cell | Adaptive  |
| NDUF89    | Central memory CD4 T cell | Adaptive  |
| PKM2      | Central memory CD4 T cell | Adaptive  |
| SFXN3     | Central memory CD4 T cell | Adaptive  |
| SIRPG     | Central memory CD4 T cell | Adaptive  |
| SMAD4     | Central memory CD4 T cell | Adaptive  |
| STX4      | Central memory CD4 T cell | Adaptive  |
| TRADD     | Central memory CD4 T cell | Adaptive  |
| VIM       | Central memory CD4 T cell | Adaptive  |
| XRCC6     | Central memory CD4 T cell | Adaptive  |
| ACTN4     | Central memory CD8 T cell | Adaptive  |
| ADAM12    | Central memory CD8 T cell | Adaptive  |
| ADCY9     | Central memory CD8 T cell | Adaptive  |
| F13A1     | Central memory CD8 T cell | Adaptive  |
| FCER1G    | Central memory CD8 T cell | Adaptive  |
| FGFR3     | Central memory CD8 T cell | Adaptive  |
| FGF7      | Central memory CD8 T cell | Adaptive  |
| FKBP4     | Central memory CD8 T cell | Adaptive  |
| GLUD1     | Central memory CD8 T cell | Adaptive  |
| GM2A      | Central memory CD8 T cell | Adaptive  |
| GUSB      | Central memory CD8 T cell | Adaptive  |
| IL1RN     | Central memory CD8 T cell | Adaptive  |
| NOL11     | Central memory CD8 T cell | Adaptive  |
| NTRK1     | Central memory CD8 T cell | Adaptive  |
| RARA      | Central memory CD8 T cell | Adaptive  |
| RNF128    | Central memory CD8 T cell | Adaptive  |
| SIGLEC1   | Central memory CD8 T cell | Adaptive  |
| TNFRSF11A | Central memory CD8 T cell | Adaptive  |
| TOX4      | Central memory CD8 T cell | Adaptive  |
| UBA52     | Central memory CD8 T cell | Adaptive  |
| ULBP1     | Central memory CD8 T cell | Adaptive  |
| ATM       | Effector memory CD4 T cell | Adaptive  |
| CASP3     | Effector memory CD4 T cell | Adaptive  |
| CASQ1     | Effector memory CD4 T cell | Adaptive  |
| CD300E    | Effector memory CD4 T cell | Adaptive  |
| DARS      | Effector memory CD4 T cell | Adaptive  |
| DOCK9     | Effector memory CD4 T cell | Adaptive  |
| EXOSC9    | Effector memory CD4 T cell | Adaptive  |
| EZH2      | Effector memory CD4 T cell | Adaptive  |
| GDE1      | Effector memory CD4 T cell | Adaptive  |
| Metagene   | Immune cell type          | Immunity  |
|------------|---------------------------|-----------|
| IL34       | Effector memory CD4 T cell| Adaptive  |
| NCOA4      | Effector memory CD4 T cell| Adaptive  |
| NEFL       | Effector memory CD4 T cell| Adaptive  |
| PDGFRL     | Effector memory CD4 T cell| Adaptive  |
| PTGS1      | Effector memory CD4 T cell| Adaptive  |
| REPS1      | Effector memory CD4 T cell| Adaptive  |
| SCG2       | Effector memory CD4 T cell| Adaptive  |
| SDPR       | Effector memory CD4 T cell| Adaptive  |
| SIGLEC14   | Effector memory CD4 T cell| Adaptive  |
| SIGLEC6    | Effector memory CD4 T cell| Adaptive  |
| TAL1       | Effector memory CD4 T cell| Adaptive  |
| TFEC       | Effector memory CD4 T cell| Adaptive  |
| TIPIN      | Effector memory CD4 T cell| Adaptive  |
| TPK1       | Effector memory CD4 T cell| Adaptive  |
| UQCRB      | Effector memory CD4 T cell| Adaptive  |
| USP9Y      | Effector memory CD4 T cell| Adaptive  |
| WIPF1      | Effector memory CD4 T cell| Adaptive  |
| ZCRB1      | Effector memory CD4 T cell| Adaptive  |
| ACAP1      | Effector memory CD8 T cell| Adaptive  |
| APOL3      | Effector memory CD8 T cell| Adaptive  |
| ARHGAP10   | Effector memory CD8 T cell| Adaptive  |
| ATP10D     | Effector memory CD8 T cell| Adaptive  |
| C3AR1      | Effector memory CD8 T cell| Adaptive  |
| CCR5       | Effector memory CD8 T cell| Adaptive  |
| CD160      | Effector memory CD8 T cell| Adaptive  |
| CD55       | Effector memory CD8 T cell| Adaptive  |
| CFLAR       | Effector memory CD8 T cell| Adaptive  |
| CMKLR1     | Effector memory CD8 T cell| Adaptive  |
| DAPP1      | Effector memory CD8 T cell| Adaptive  |
| FCRL6      | Effector memory CD8 T cell| Adaptive  |
| FLT3LG     | Effector memory CD8 T cell| Adaptive  |
| GZMM       | Effector memory CD8 T cell| Adaptive  |
| HAPLN3     | Effector memory CD8 T cell| Adaptive  |
| HLA-DMA    | Effector memory CD8 T cell| Adaptive  |
| HLA-DPA1   | Effector memory CD8 T cell| Adaptive  |
| HLA-DPB1   | Effector memory CD8 T cell| Adaptive  |
| IFI16      | Effector memory CD8 T cell| Adaptive  |
| LIME1      | Effector memory CD8 T cell| Adaptive  |
| LTK        | Effector memory CD8 T cell| Adaptive  |
| NFKBIA     | Effector memory CD8 T cell| Adaptive  |
| SETD7      | Effector memory CD8 T cell| Adaptive  |
| SIK1       | Effector memory CD8 T cell| Adaptive  |
| TRIB2      | Effector memory CD8 T cell| Adaptive  |
| GIPR       | Eosinophil               | Innate    |
| KRT18P50   | Eosinophil               | Innate    |
| LRMP       | Eosinophil               | Innate    |
| FOSB       | Eosinophil               | Innate    |
| RRP12      | Eosinophil               | Innate    |
| GPR183     | Eosinophil               | Innate    |
| NR4A3      | Eosinophil               | Innate    |
| ST3GAL6    | Eosinophil               | Innate    |
| DEPC5      | Eosinophil               | Innate    |
| PDE6C      | Eosinophil               | Innate    |
| PKD2L2     | Eosinophil               | Innate    |
| GPR65      | Eosinophil               | Innate    |
| IL5RA      | Eosinophil               | Innate    |
| P2RY14     | Eosinophil               | Innate    |
Table SI. Continued.

| Metagene | Immune cell type | Immunity |
|----------|------------------|----------|
| DACH1    | Eosinophil       | Innate   |
| DAPK2    | Eosinophil       | Innate   |
| EMR3     | Eosinophil       | Innate   |
| ACP5     | γδ T cell        | Adaptive |
| AQP9     | γδ T cell        | Adaptive |
| BTN3A2   | γδ T cell        | Adaptive |
| C1orf54  | γδ T cell        | Adaptive |
| CARD8    | γδ T cell        | Adaptive |
| CCL18    | γδ T cell        | Adaptive |
| CD109    | γδ T cell        | Adaptive |
| CD33     | γδ T cell        | Adaptive |
| CD36     | γδ T cell        | Adaptive |
| CDK5     | γδ T cell        | Adaptive |
| IL10RB   | γδ T cell        | Adaptive |
| KLRF1    | γδ T cell        | Adaptive |
| LGALS1   | γδ T cell        | Adaptive |
| MAPK7    | γδ T cell        | Adaptive |
| KLHL7    | γδ T cell        | Adaptive |
| KRT80    | γδ T cell        | Adaptive |
| LAMC1    | γδ T cell        | Adaptive |
| LCORL    | γδ T cell        | Adaptive |
| LMNB1    | γδ T cell        | Adaptive |
| MEIS3P1  | γδ T cell        | Adaptive |
| MPL      | γδ T cell        | Adaptive |
| FABP1    | γδ T cell        | Adaptive |
| FABP5    | γδ T cell        | Adaptive |
| FADD     | γδ T cell        | Adaptive |
| MFAP3L   | γδ T cell        | Adaptive |
| MINPP1   | γδ T cell        | Adaptive |
| RPS24    | γδ T cell        | Adaptive |
| RPS7     | γδ T cell        | Adaptive |
| RPS9     | γδ T cell        | Adaptive |
| DBNL     | γδ T cell        | Adaptive |
| CCL13    | γδ T cell        | Adaptive |
| CD22     | Immature B cell  | Adaptive |
| CYBB     | Immature B cell  | Adaptive |
| FAM129C  | Immature B cell  | Adaptive |
| FCRL1    | Immature B cell  | Adaptive |
| FCRL3    | Immature B cell  | Adaptive |
| FCRL5    | Immature B cell  | Adaptive |
| FCRLA    | Immature B cell  | Adaptive |
| HDAC9    | Immature B cell  | Adaptive |
| HLA-DQA1 | Immature B cell  | Adaptive |
| HVNC1    | Immature B cell  | Adaptive |
| KIAA0226 | Immature B cell  | Adaptive |
| NCF1     | Immature B cell  | Adaptive |
| NCF1B    | Immature B cell  | Adaptive |
| P2RY10   | Immature B cell  | Adaptive |
| SP100    | Immature B cell  | Adaptive |
| TXNIP    | Immature B cell  | Adaptive |
| STAP1    | Immature B cell  | Adaptive |
| TAGAP    | Immature B cell  | Adaptive |
| ZCCHC2   | Immature B cell  | Adaptive |
| ACADM    | Immature dendritic cell | Innate |
| AHCYL1   | Immature dendritic cell | Innate |
| ALDH1A2  | Immature dendritic cell | Innate |
| ALDH3A2  | Immature dendritic cell | Innate |
Table SI. Continued.

| Metagene   | Immune cell type     | Immunity |
|------------|----------------------|----------|
| ALDH9A1    | Immature dendritic cell | Innate  |
| ALOX15     | Immature dendritic cell | Innate  |
| AMT        | Immature dendritic cell | Innate  |
| ARL1       | Immature dendritic cell | Innate  |
| ATIC       | Immature dendritic cell | Innate  |
| ATP5A1     | Immature dendritic cell | Innate  |
| CAPZA1     | Immature dendritic cell | Innate  |
| LILRA5     | Immature dendritic cell | Innate  |
| RDX        | Immature dendritic cell | Innate  |
| RRAGD      | Immature dendritic cell | Innate  |
| TACSTD2    | Immature dendritic cell | Innate  |
| INPP5F     | Immature dendritic cell | Innate  |
| RAB38      | Immature dendritic cell | Innate  |
| PLAU       | Immature dendritic cell | Innate  |
| CSF3R      | Immature dendritic cell | Innate  |
| SLC18A2    | Immature dendritic cell | Innate  |
| AMPD2      | Immature dendritic cell | Innate  |
| CLTB       | Immature dendritic cell | Innate  |
| C1orf162   | Immature dendritic cell | Innate  |
| iNOS       | M1 macrophage         | Innate  |
| IRF5       | M1 macrophage         | Innate  |
| CD8        | M1 macrophage         | Innate  |
| CD282      | M1 macrophage         | Innate  |
| CD284      | M1 macrophage         | Innate  |
| MHCII      | M1 macrophage         | Innate  |
| CD80       | M1 macrophage         | Innate  |
| TNF-α      | M1 macrophage         | Innate  |
| CD16       | M1 macrophage         | Innate  |
| CD32       | M1 macrophage         | Innate  |
| CD64       | M1 macrophage         | Innate  |
| MCP-1      | M1 macrophage         | Innate  |
| CD163      | M1 macrophage         | Innate  |
| VSIG4      | M1 macrophage         | Innate  |
| MS4A4A     | M1 macrophage         | Innate  |
| CD206      | M1 macrophage         | Innate  |
| Arg1       | M1 macrophage         | Innate  |
| CD200R     | M1 macrophage         | Innate  |
| CD301      | M1 macrophage         | Innate  |
| SLAM       | M1 macrophage         | Innate  |
| CD45       | M1 macrophage         | Innate  |
| CD23       | M1 macrophage         | Innate  |
| TGFβ       | M1 macrophage         | Innate  |
| ADAMTS3    | Mast cell             | Innate  |
| CPA3       | Mast cell             | Innate  |
| CMA1       | Mast cell             | Innate  |
| CTSG       | Mast cell             | Innate  |
| ARHGAP15   | Mast cell             | Innate  |
| CPM        | Mast cell             | Innate  |
| FCN1       | Mast cell             | Innate  |
| FTL        | Mast cell             | Innate  |
| HSPA6      | Mast cell             | Innate  |
| ITGA9      | Mast cell             | Innate  |
| RNASE3     | Mast cell             | Innate  |
| S100A4     | Mast cell             | Innate  |
| SIGLEC8    | Mast cell             | Innate  |
| SLC6A4     | Mast cell             | Innate  |
| PTGS2      | Mast cell             | Innate  |
| Metagene  | Immune cell type | Immunity |
|----------|------------------|----------|
| EGR3     | Mast cell        | Innate   |
| PILRA    | Mast cell        | Innate   |
| AICDA    | Memory B cell    | Adaptive |
| CCNA2    | Memory B cell    | Adaptive |
| CDKN3    | Memory B cell    | Adaptive |
| CLCN5    | Memory B cell    | Adaptive |
| ENPP1    | Memory B cell    | Adaptive |
| FCER1A   | Memory B cell    | Adaptive |
| FCRL4    | Memory B cell    | Adaptive |
| MYC      | Memory B cell    | Adaptive |
| RUNX2    | Memory B cell    | Adaptive |
| SORL1    | Memory B cell    | Adaptive |
| SOX5     | Memory B cell    | Adaptive |
| STAT5A   | Memory B cell    | Adaptive |
| STAT5B   | Memory B cell    | Adaptive |
| TLR9     | Memory B cell    | Adaptive |
| ASGR2    | Monocyte         | Innate   |
| CFP      | Monocyte         | Innate   |
| ASGR1    | Monocyte         | Innate   |
| CD1D     | Monocyte         | Innate   |
| UPK3A    | Monocyte         | Innate   |
| ACTG1    | Monocyte         | Innate   |
| ANXA5    | Monocyte         | Innate   |
| ATP6V1B2 | Monocyte         | Innate   |
| CFL1     | Monocyte         | Innate   |
| DAZAP2   | Monocyte         | Innate   |
| CTBS     | Monocyte         | Innate   |
| EMR4P    | Monocyte         | Innate   |
| HIVEP2   | Monocyte         | Innate   |
| MARCKSL1 | Monocyte         | Innate   |
| MBP      | Monocyte         | Innate   |
| MMP15    | Monocyte         | Innate   |
| PNPLA6   | Monocyte         | Innate   |
| TMBIM6   | Monocyte         | Innate   |
| PQBP1    | Monocyte         | Innate   |
| TEX264   | Monocyte         | Innate   |
| IKZF1    | Monocyte         | Innate   |
| AKT3     | Natural killer cell | Innate |
| AXL      | Natural killer cell | Innate |
| B2M2     | Natural killer cell | Innate |
| CDH2     | Natural killer cell | Innate |
| CRTAM    | Natural killer cell | Innate |
| CSF2RA   | Natural killer cell | Innate |
| CTSZ     | Natural killer cell | Innate |
| CXCL1    | Natural killer cell | Innate |
| CYTH1    | Natural killer cell | Innate |
| DAXX     | Natural killer cell | Innate |
| DGKH     | Natural killer cell | Innate |
| DLL4     | Natural killer cell | Innate |
| DPYD     | Natural killer cell | Innate |
| ERBB3    | Natural killer cell | Innate |
| F11R     | Natural killer cell | Innate |
| FAM27A   | Natural killer cell | Innate |
| FAM49A   | Natural killer cell | Innate |
| FASLG    | Natural killer cell | Innate |
| FASGR1A  | Natural killer cell | Innate |
| FN1      | Natural killer cell | Innate |
| Metagene | Immune cell type | Immunity |
|----------|------------------|----------|
| FSTL1    | Natural killer cell | Innate   |
| FUCA1    | Natural killer cell | Innate   |
| GBP3     | Natural killer cell | Innate   |
| GLS2     | Natural killer cell | Innate   |
| GRB2     | Natural killer cell | Innate   |
| LST1     | Natural killer cell | Innate   |
| BCL2     | Natural killer cell | Innate   |
| CDC5L    | Natural killer cell | Innate   |
| FGF18    | Natural killer cell | Innate   |
| FUT5     | Natural killer cell | Innate   |
| FZRI     | Natural killer cell | Innate   |
| GAGE2    | Natural killer cell | Innate   |
| IGFBP5   | Natural killer cell | Innate   |
| KANK2    | Natural killer cell | Innate   |
| LDB3     | Natural killer cell | Innate   |
| BTN2A2   | Natural killer T cell | Innate   |
| CD101    | Natural killer T cell | Innate   |
| CD109    | Natural killer T cell | Innate   |
| CNPY3    | Natural killer T cell | Innate   |
| CNPY4    | Natural killer T cell | Innate   |
| CREB1    | Natural killer T cell | Innate   |
| CRTC2    | Natural killer T cell | Innate   |
| CRTC3    | Natural killer T cell | Innate   |
| CSF2     | Natural killer T cell | Innate   |
| KLRCL1   | Natural killer T cell | Innate   |
| FUT4     | Natural killer T cell | Innate   |
| ICAM2    | Natural killer T cell | Innate   |
| IL32     | Natural killer T cell | Innate   |
| LAMP2    | Natural killer T cell | Innate   |
| LILRB5   | Natural killer T cell | Innate   |
| KLRG1    | Natural killer T cell | Innate   |
| HSPA4    | Natural killer T cell | Innate   |
| HSPB6    | Natural killer T cell | Innate   |
| ISM2     | Natural killer T cell | Innate   |
| ITIH2    | Natural killer T cell | Innate   |
| KDM4C    | Natural killer T cell | Innate   |
| KIR2DS4  | Natural killer T cell | Innate   |
| KIRREL3  | Natural killer T cell | Innate   |
| SDCBP    | Natural killer T cell | Innate   |
| NFATC2IP | Natural killer T cell | Innate   |
| MICB     | Natural killer T cell | Innate   |
| KIR2DL1  | Natural killer T cell | Innate   |
| KIR2DL3  | Natural killer T cell | Innate   |
| KIR3DL1  | Natural killer T cell | Innate   |
| KIR3DL2  | Natural killer T cell | Innate   |
| NCR1     | Natural killer T cell | Innate   |
| FOSL1    | Natural killer T cell | Innate   |
| TSLP     | Natural killer T cell | Innate   |
| SLC7A7   | Natural killer T cell | Innate   |
| SPP1     | Natural killer T cell | Innate   |
| TREM2    | Natural killer T cell | Innate   |
| UBAH3A   | Natural killer T cell | Innate   |
| YBX2     | Natural killer T cell | Innate   |
| CCDC88A  | Natural killer T cell | Innate   |
| CLEC1A   | Natural killer T cell | Innate   |
| THBD     | Natural killer T cell | Innate   |
| PDIPN    | Natural killer T cell | Innate   |
| Metagene  | Immune cell type                | Immunity   |
|-----------|---------------------------------|------------|
| VCAM1     | Natural killer T cell           | Innate     |
| EMR1      | Natural killer T cell           | Innate     |
| CD11B     | Neutrophil                      | Innate     |
| CREB5     | Neutrophil                      | Innate     |
| CDA       | Neutrophil                      | Innate     |
| CHST15    | Neutrophil                      | Innate     |
| S100A12   | Neutrophil                      | Innate     |
| APOBEC3A  | Neutrophil                      | Innate     |
| CASP5     | Neutrophil                      | Innate     |
| MMP25     | Neutrophil                      | Innate     |
| HAL       | Neutrophil                      | Innate     |
| C1orf183  | Neutrophil                      | Innate     |
| FFAR2     | Neutrophil                      | Innate     |
| MAK       | Neutrophil                      | Innate     |
| CXCR1     | Neutrophil                      | Innate     |
| STEAP4    | Neutrophil                      | Innate     |
| MGAM      | Neutrophil                      | Innate     |
| BTN1L8    | Neutrophil                      | Innate     |
| CXCR2     | Neutrophil                      | Innate     |
| TNFRSF10C | Neutrophil                      | Innate     |
| VNN3      | Neutrophil                      | Innate     |
| CDK5R1    | T follicular helper cell        | Adaptive   |
| PDCD1     | T follicular helper cell        | Adaptive   |
| BCL6      | T follicular helper cell        | Adaptive   |
| CD200     | T follicular helper cell        | Adaptive   |
| CD83      | T follicular helper cell        | Adaptive   |
| CD84      | T follicular helper cell        | Adaptive   |
| FGFR2     | T follicular helper cell        | Adaptive   |
| GPR18     | T follicular helper cell        | Adaptive   |
| CEBPA     | T follicular helper cell        | Adaptive   |
| CECR1     | T follicular helper cell        | Adaptive   |
| CLEC10A   | T follicular helper cell        | Adaptive   |
| CLEC4A    | T follicular helper cell        | Adaptive   |
| CSF1R     | T follicular helper cell        | Adaptive   |
| CTSS      | T follicular helper cell        | Adaptive   |
| DMN       | T follicular helper cell        | Adaptive   |
| DPP4      | T follicular helper cell        | Adaptive   |
| LRRRC32   | T follicular helper cell        | Adaptive   |
| MC5R      | T follicular helper cell        | Adaptive   |
| MICA      | T follicular helper cell        | Adaptive   |
| NCAM1     | T follicular helper cell        | Adaptive   |
| NCR2      | T follicular helper cell        | Adaptive   |
| NRP1      | T follicular helper cell        | Adaptive   |
| PDCD1LG2  | T follicular helper cell        | Adaptive   |
| PDCD6     | T follicular helper cell        | Adaptive   |
| PRDX1     | T follicular helper cell        | Adaptive   |
| RAE1      | T follicular helper cell        | Adaptive   |
| RAET1E    | T follicular helper cell        | Adaptive   |
| SIGLEC7   | T follicular helper cell        | Adaptive   |
| SIGLEC9   | T follicular helper cell        | Adaptive   |
| TYRO3     | T follicular helper cell        | Adaptive   |
| CHST12    | T follicular helper cell        | Adaptive   |
| CLEC3     | T follicular helper cell        | Adaptive   |
| IVNS1ABP  | T follicular helper cell        | Adaptive   |
| KIR2DL2   | T follicular helper cell        | Adaptive   |
| LGMN      | T follicular helper cell        | Adaptive   |
| CD70      | Type 1 T helper cell            | Adaptive   |
Table SI. Continued.

| Metagene  | Immune cell type      | Immunity |
|-----------|-----------------------|----------|
| TBX21     | Type 1 T helper cell  | Adaptive |
| ADAM8     | Type 1 T helper cell  | Adaptive |
| AHHCYL2   | Type 1 T helper cell  | Adaptive |
| ALCAM     | Type 1 T helper cell  | Adaptive |
| B3GALNT1  | Type 1 T helper cell  | Adaptive |
| BBS12     | Type 1 T helper cell  | Adaptive |
| BST1      | Type 1 T helper cell  | Adaptive |
| CD151     | Type 1 T helper cell  | Adaptive |
| CD47      | Type 1 T helper cell  | Adaptive |
| CD48      | Type 1 T helper cell  | Adaptive |
| CD52      | Type 1 T helper cell  | Adaptive |
| CD53      | Type 1 T helper cell  | Adaptive |
| CD59      | Type 1 T helper cell  | Adaptive |
| CD6       | Type 1 T helper cell  | Adaptive |
| CD68      | Type 1 T helper cell  | Adaptive |
| CD7       | Type 1 T helper cell  | Adaptive |
| CD96      | Type 1 T helper cell  | Adaptive |
| CFHR3     | Type 1 T helper cell  | Adaptive |
| CHRM3     | Type 1 T helper cell  | Adaptive |
| CLEC7A    | Type 1 T helper cell  | Adaptive |
| COL23A1   | Type 1 T helper cell  | Adaptive |
| COL4A4    | Type 1 T helper cell  | Adaptive |
| COL5A3    | Type 1 T helper cell  | Adaptive |
| DAB1      | Type 1 T helper cell  | Adaptive |
| DLEU7     | Type 1 T helper cell  | Adaptive |
| DOC2B     | Type 1 T helper cell  | Adaptive |
| EMP1      | Type 1 T helper cell  | Adaptive |
| F12       | Type 1 T helper cell  | Adaptive |
| FURIN     | Type 1 T helper cell  | Adaptive |
| GAB3      | Type 1 T helper cell  | Adaptive |
| GATM      | Type 1 T helper cell  | Adaptive |
| GFPT2     | Type 1 T helper cell  | Adaptive |
| GPR25     | Type 1 T helper cell  | Adaptive |
| GREM2     | Type 1 T helper cell  | Adaptive |
| HAVCR1    | Type 1 T helper cell  | Adaptive |
| HSD11B1   | Type 1 T helper cell  | Adaptive |
| HUNK      | Type 1 T helper cell  | Adaptive |
| IGF2      | Type 1 T helper cell  | Adaptive |
| RCS5D1    | Type 1 T helper cell  | Adaptive |
| RYR1      | Type 1 T helper cell  | Adaptive |
| SAV1      | Type 1 T helper cell  | Adaptive |
| SELE      | Type 1 T helper cell  | Adaptive |
| SELP      | Type 1 T helper cell  | Adaptive |
| SH3KBP1   | Type 1 T helper cell  | Adaptive |
| SIT1      | Type 1 T helper cell  | Adaptive |
| SLC35B3   | Type 1 T helper cell  | Adaptive |
| SIGLEC10  | Type 1 T helper cell  | Adaptive |
| SKAPI     | Type 1 T helper cell  | Adaptive |
| THUMPD2   | Type 1 T helper cell  | Adaptive |
| TIGIT     | Type 1 T helper cell  | Adaptive |
| ZEB2      | Type 1 T helper cell  | Adaptive |
| ENCI      | Type 1 T helper cell  | Adaptive |
| FAM134B   | Type 1 T helper cell  | Adaptive |
| FBXO30    | Type 1 T helper cell  | Adaptive |
| FCGR2C    | Type 1 T helper cell  | Adaptive |
| STAC      | Type 1 T helper cell  | Adaptive |
| LTC4S     | Type 1 T helper cell  | Adaptive |
| Metagene | Immune cell type        | Immunity |
|----------|-------------------------|----------|
| MAN1B1   | Type 1 T helper cell    | Adaptive |
| MDH1     | Type 1 T helper cell    | Adaptive |
| MMD      | Type 1 T helper cell    | Adaptive |
| RGS16    | Type 1 T helper cell    | Adaptive |
| IL12A    | Type 1 T helper cell    | Adaptive |
| P2RX5    | Type 1 T helper cell    | Adaptive |
| CD97     | Type 1 T helper cell    | Adaptive |
| ITGB4    | Type 1 T helper cell    | Adaptive |
| ICAM3    | Type 1 T helper cell    | Adaptive |
| METRN1L  | Type 1 T helper cell    | Adaptive |
| TNFRSF1A | Type 1 T helper cell    | Adaptive |
| IRF1     | Type 1 T helper cell    | Adaptive |
| HTR2B    | Type 1 T helper cell    | Adaptive |
| CALD1    | Type 1 T helper cell    | Adaptive |
| MOCOS    | Type 1 T helper cell    | Adaptive |
| TRAF3IP2 | Type 1 T helper cell    | Adaptive |
| TLR8     | Type 1 T helper cell    | Adaptive |
| TRAF1    | Type 1 T helper cell    | Adaptive |
| DUSP14   | Type 1 T helper cell    | Adaptive |
| ASB2     | Type 2 T helper cell    | Adaptive |
| CSRP2    | Type 2 T helper cell    | Adaptive |
| DAPK1    | Type 2 T helper cell    | Adaptive |
| DLC1     | Type 2 T helper cell    | Adaptive |
| DNAJC12  | Type 2 T helper cell    | Adaptive |
| DUSP6    | Type 2 T helper cell    | Adaptive |
| GNAI1    | Type 2 T helper cell    | Adaptive |
| LAMP3    | Type 2 T helper cell    | Adaptive |
| NRP2     | Type 2 T helper cell    | Adaptive |
| OSBPL1A  | Type 2 T helper cell    | Adaptive |
| PDE4B    | Type 2 T helper cell    | Adaptive |
| PHLDA1   | Type 2 T helper cell    | Adaptive |
| PLA2G4A  | Type 2 T helper cell    | Adaptive |
| RAB27B   | Type 2 T helper cell    | Adaptive |
| RBMS3    | Type 2 T helper cell    | Adaptive |
| RNF125   | Type 2 T helper cell    | Adaptive |
| TMPRSS3  | Type 2 T helper cell    | Adaptive |
| GATA3    | Type 2 T helper cell    | Adaptive |
| BIRC5    | Type 2 T helper cell    | Adaptive |
| CDC25C   | Type 2 T helper cell    | Adaptive |
| CDC7     | Type 2 T helper cell    | Adaptive |
| CENPF    | Type 2 T helper cell    | Adaptive |
| CXCR6    | Type 2 T helper cell    | Adaptive |
| DHFR     | Type 2 T helper cell    | Adaptive |
| EVI5     | Type 2 T helper cell    | Adaptive |
| GSTA4    | Type 2 T helper cell    | Adaptive |
| HELLS    | Type 2 T helper cell    | Adaptive |
| IL26     | Type 2 T helper cell    | Adaptive |
| LAIR2    | Type 2 T helper cell    | Adaptive |