# Investigating the positive and negative selection of B cell development




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# Abstract

Understanding the mechanisms that control the positive and negative selection of B cells by self and foreign antigens and the generation of B cell subsets, are two important questions in B cell immunology. In this thesis, I described a bimodal switch, consisting of an RNA binding protein/microRNA suppressor Lin28b and a microRNA family let-7, which converts B cell negative selection in late ontogeny into positive selection and helps B1 B cell generation in adult life.

In this project, I used the anti-HEL (hen egg lysozyme) transgenic mouse model to show how an intracellular self-antigen positively select B1 cells in early ontogeny but is tolerogenic to B cells in later life. I used this model to investigate the transcriptional profiles of antigen-specific B cells at different stages in ontogeny, in the presence and absence of cognate self-antigens.

I have found that immature anti-HEL-specific B cells in fetal and neonatal life with intrinisic capacity for positive selection by self-antigen, have a transcriptional profile characterized by expression of Lin28b. In contrast, immature anti-HEL B cells from adult marrow, which are unable to undergo positive selection, show the reciprocal expression of the let-7 family. Expression of transgenic Lin28b reconstitutes the fetal B1 lineage in adult BM chimeras and rescues positive selection. This is inducible by transient expression of Lin28b suggesting that the switch is not hard-wired or specific to a precursor lineage.

I have used genetic and functional approaches to identify pathways downstream of the Lin28b/let-7 switch, including some proteins that have already been shown to be involved in B cell selection. It is highly likely that similar functions will operate in

humans, where fetal B1-like cells may be similarly self-renewing and Lin28b is involved in stem cell maintenance, development in early ontogeny and oncogenesis.

# List of Abbreviations

| | |
|---|---|
| **Ab** | Antibody |
| **Ag** | Antigen |
| **APC** | Allophycocyanin |
| **BAFF** | B-cell activating factor |
| **BCR** | B cell receptor |
| **BM** | Bone marrow |
| **bp** | Base pairs |
| **CAG** | Chicken actin gene promoter |
| **CLL** | Chronic lymphocytic leukemia |
| **DNA** | Deoxyribonucleic acid |
| **ER** | Endoplasmic reticulum |
| **ES** | Embryonic stem |
| **FITC** | Flurorescein isothiocyanate |
| **FL** | Fetal liver |
| **FO** | Follicular B cells |
| **Fr** | Fraction |
| **FSC** | Forward scatter |
| **GC** | Germinal Centre |
| **HEL** | Hen egg lysozyme |
| **HSA** | Heat-stable antigen |
| **HSC** | Haematopoietic stem cell |
| **Ig** | Immunoglobulin |
| **Igh** | Ig heavy-chain |

| | |
|---|---|
| **$Ig^{HEL}$** | Transgenic mice expressing rearranged Ig chains specific for HEL |
| **IL** | Interleukin |
| **IRES** | Internal ribosome entry site |
| **ITAM** | Immunoreceptor tyrosine-based activation motifs |
| **ITIM** | Immunoreceptor tyrosine-based inhibitory motifs |
| **LPS** | Lipopolysaccharide |
| **MFI** | Median fluorescence intensity |
| **MHC** | Major histocompatibility complex |
| **mHEL** | Membrane bound HEL |
| **mHELKK** | ER-retained HEL |
| **MLN** | Mesenteric lymph node |
| **MZ** | Marginal zone B cells |
| **NK** | Natural killer |
| **NL** | Neonatal liver |
| **PBL** | Peripheral blood leukocytes |
| **PBS** | Phosphate-buffered saline |
| **PC** | Phosphorylcholine |
| **PCR** | Polymerase chain reaction |
| **PE** | Phycoerythrin |
| **PerC** | Peritoneal cavity |
| **PI3K** | Phosphatidylinositol 3-kinase |
| **PLCγ2** | Phospholipase Cγ2 |
| **PPS** | Pneumococcal polysaccharide |
| **PTK** | Protein tyrosine kinase |
| **RA** | Rheumatoid arthritis |
| **RAG** | Recombinase activating gene |
| **RANK** | Receptor activator of nuclear factor-κB |

| | |
|---|---|
| **RCME** | Recombinase mediated cassette exchange |
| **RT** | Room temperature |
| **sHEL** | Soluble HEL |
| **SHIP** | SH2-domain-containing inositol polyphosphate 5' phosphatase |
| **SHP1** | SH2-domain-containing protein tyrosine phosphatase |
| **SLE** | Systemic lupus erythematosus |
| **SSC** | Side scatter |
| **TdT** | Terminal deoxyribonucleotidyltransferase |
| **Tg** | Transgenic |
| **WT** | Wild type |

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# Chapter 1. Introduction

## 1.1 B cell development – the generation of subsets

It is well known that B cells make several essential contributions to adaptive immunity, including multiple functions that are protective against foreign pathogens. These functions include antigen presentation, the generation of antibody-secreting plasma cells and the secretion of cytokines. At the same time, there is increasing evidence that B cells may also play roles in cellular homeostasis and protection against inflammatory and autoimmune reactions. The dissection of these functions requires a clearer understanding of B cell differentiation and the role of specialised subsets.

Conventional, postnatal B cell development begins in bone marrow (BM). After common lymphoid precursor cells commit to B cell lineage, they undergo sequential heavy chain and light chain rearrangement to give rise to immature B cells that express a functional B cell receptor (BCR) with other co-receptors on cell surface.

The generation of a large and diverse B cell repertoire with minimal risk of attacking normal components, requires strict checkpoints during development. Selection against self-antigens occurs at the immature B cells stage in the BM, when self-reactive B cells undergo negative selection, with receptor editing, clonal deletion or the induction of anergy.

B cells passing the negative selection checkpoint become transitional B cells, leaving the BM and recirculating in the periphery. They eventually differentiate into a series of downstream B cell populations, including follicular (FO), marginal zone (MZ) - collectively known as B2 B cells - and B1 B cells(1).

In contrast to B2 B cells, some B1 B cells seem to undergo positive selection by antigen at the immature B cell stage. They form an innate-like B cell subset, with distinct phenotype and functions. Their generation is largely restricted to the fetal and neonatal liver stage; they have a biased BCR repertoire(2); and secrete natural IgM antibody and produce cytokines such as interleukin(IL) -10(3); and they have been associated with autoimmune disease(4,5).

Broadly speaking, there are two predominant theories regarding B1 B cell generation. The first lineage model proposes that B1 and B2 B cells develop from separate precursors. The second proposes that B1 and B2 B cells are generated from the same precursor but via separate selection processes.

### 1.1.1 Conventional B cell development - the formation of the pre-immune B cell repertoire

As already described, in the classical model and for most of life, B cell development occurs in the BM. Early B cell development depends on the non-lymphoid stromal cells of the BM, which form specific adhesive contacts with the developing B-lineage cells and provide soluble factors that control lymphocyte differentiation and proliferation. Late B cell development depends additionally on positive and negative selection via BCR signalling.

The distinct stages of B cell development are characterised by expression of surface molecules. Based on this principle, Hardy established a method for delineating mouse B cell development into seven discrete stages in the BM(6).

Fraction A, pre-pro-B cells, is the starting point when common lymphoid precursors commit to B cell lineage. At this stage they have a surface marker pattern as $B220^{+}CD43^{+}CD93^{+}CD24^{lo}$. Pre-pro-B cells bind to the adhesion molecule VCAM-1 on stromal cells through the integrin VLA-4, alongside other cell-adhesion molecules.

These interactions help the binding between the receptor tyrosine kinase Kit (CD117) on the surface of pre-pro B cell and stem-cell factor (SCF) on the stromal cell, which activates the kinase and induces the proliferation of the B-cell progenitors. The receptor for IL-7 (IL-7R CD127/CD132) is present from the common lymphoid progenitor stage, and is required for B cell proliferation and further development. IL-7 is produced by stromal cells in the BM and elicits a survival and proliferative response from pre-B cells. IL-7 does not act upon more mature B-lineage cells (7,8). Accordingly, the expression of the IL-7Rα is restricted to cell lines representing the pre-B stage of B cell development.

Fraction B and C, pro-B cells, represent the first irreversibly committed B cell precursor. Pro-B cells have a surface pattern as $B220^{+}CD43^{+}CD24^{+}CD19^{+}$. Immunoglobulin (Ig) heavy chain rearrangement is initiated. DH-JH rearrangement occurs at the early pro-B stage (Fraction B) and V-DJ rearrangements commence at the late pro-B stage (Fraction C). The development of the pro-B cell is BCR independent but relies on the intrinsic expression of the E2A family transcription factors, and the transcription factor EBF, which have been shown to up-regulate expression of the B-cell receptor specific genes *λ5, VpreB, Igα and Igβ*, as well as the lymphoid-specific recombinase-activated genes *Rag1* and *Rag2* and the B-cell-specific transcription factor *Pax5*(9). The IL-7 receptor is required for the generation of pro-B cells and up-regulates the expression of *CD19* and *Pax5* (10).

Successful expression of the surrogate light chain with the rearranged Ig heavy chain forms the pre-BCR on cell surface (11). Fraction C', large pre-B cells, is a rapidly proliferating stage when the cells are highly responsive to IL-7. B cells at this stage have a surface pattern as $B220^{+}CD43^{+}CD24^{hi}BP\text{-}1^{+}$. They undergo 4-5 rounds of proliferation.

Following expansion, the pre-B cells enter fraction D (late pre-B cell) stage, down-regulating CD24, CD43 and IL-7Rα. The surface pattern becomes $B220^{+}CD43^{-}$ $CD24^{+}$. They also become IL-7 independent from this stage. At this point, pre-B cells start light chain rearrangement in kappa and lambda loci, to replace the surrogate light chain.

Successful light-chain rearrangement leads to co-expression of heavy and light chains on the cell surface, which forms a functional BCR in association with Igα (CD79α) and Igβ (CD79β). Constitutive BCR signaling is sufficient to turn off RAG genes and upregulate the B-cell activating factor (BAFF) receptor, which replaces IL7R in mediating survival signals to the naïve B cell. Immature B cells express a nascent intact BCR on the cell surface (Hardy Fraction E) and are identified by surface expression of $B220^{+}CD43^{-}CD24^{mid}IgM^{+}IgD^{-}$. Immature B cells will undergo a negative selection process to remove auto-reactive B cells from the B cell pool. This negative selection will induce receptor editing or, rarely, deletion, or anergy. On average, about 20 million immature B cells are produced daily, only 10-20% of which survive to exit the BM and enter periphery and only 1-3% finally enter the mature B cell pool(1).

Cells that survive negative selection migrate to the periphery, start expressing surface IgD, and are first defined as transitional B cells (see later). These cells recirculate and mature in the periphery into well-defined mature subsets, typically FO B cells expressing both IgM and IgD (9). In contrast to immature B cells, which only survive for 3-4 days, mature FO B cells are long-lived cells, with a life-span of 8 weeks, and recirculate continuously. In the BM they are known as Fraction F. The mature B cell subsets form the preimmune B cell repertoire (12-14).

### 1.1.2 Peripheral B cell subsets and their function

Immature B cells emerging from the BM into the blood and secondary lymphoid organs develop into specialised subsets. FO B cells recirculate through the secondary lymphoid organs as part of a long-lived pool, whilst others join more static compartments enriched in specific locations. Other subsets include the MZ B cells of the spleen, and the B1 B cells which are enriched in the peritoneal and pleural cavities (12). These different subsets of B cells vary in terms of their location, their ability to migrate, and in the likelihood that they will be activated in a T-dependent or a T-independent manner. It is assumed that the development of the different subsets depends on selection or lineage specific events, but these are incompletely defined.

Downstream B cell subsets have a wide range of function. As already mentioned, they can mediate humoral immune responses, secrete cytokines and present antigen to naive T cells. Other functions of B cells that are less well understood include: the potential for some B cell populations to act as regulatory cells inhibiting tissue-specific inflammation; the putative role of activated cytokine-producing B cell in the activation of T cells that drive inflammation; and the probable role of B cells in the induction of tertiary lymphoid organs, at sites of disease-related inflammation(15).

#### 1.1.2.1 Transitional B cells

In terms of the differentiation of subsets, Carsetti et al. first proposed that there is a window of differentiation between immature and mature B cells. They named this as a discrete population, the transitional B cells(16). This population makes up 15-20% of total B cells in BM, 10-15% of total B cells in spleen and 15-20% of total B cells in blood. In the lymph node, however, transitional B cells are not found(17). In transitional B cells, the expression level of later differentiation markers such as CD23 and IgD, and the expression of MHCII gradually increase. However, unlike mature B cells, transitional B cells still express the B-lineage precursor marker CD93.

Transitional B cells in the adult spleen may be subdivided into two distinct subsets, T1 and T2, based on the expression of IgD and CD21(17). Transitional B cells of type 1 (T1) are recent immigrants from the BM. They are $IgM^{bright}IgD^{-}CD21^{-}$. They develop into the transitional B cells of type 2 (T2), which are $IgM^{+}IgD^{+}$ $CD21^{bright}CD23^{+}$. T2 cells are found exclusively in the primary follicles of the spleen. Mature B cells can be generated from T1 or T2 B cells.

Mice with genetic deletions of *Cd45* and *Btk* genes display developmental arrest at the T1 or T2 stage. The analysis of these defects showed that the development of T2 and mature B cells from T1 precursors requires defined BCR signals and different signals lead to the induction of longevity and maturation(17).

Later Hardy and colleagues divided transitional B cells in to three stages(18). They used CD93, IgM and CD23 as markers to distinguish T1 ($CD93^{+}CD23^{-}IgM^{high}$), T2 ($CD93^{+}CD23^{+}IgM^{high}$) and T3 ($CD93^{+}CD23^{+}IgM^{low}$). These cells are functionally immature as they don't proliferate following IgM cross-linking in vitro, and they have a rapid turnover rate as measured by BrdU in vivo. Consistent with data from Loder et al.(17), cells in T1 also lack expression of MEL-14/CD62L, suggesting that cells within the T1 population do not effectively migrate into lymph nodes. They also found that there is cell loss at both T1 to T2 and T2 to T3 transition stages, indicating that multiple selections happened during this transitional stage. They found that BTK-deficient mice exhibit an incomplete developmental block at the T2-T3 transition within the immature B cell pool. Collectively, these data provide evidence for the possibility of multiple selection events within the immature/transitional peripheral B cell pool(18).

#### 1.1.2.2 Follicular B cells (Conventional B2)

Naive, mature follicular B cells (FO) reside in spleen, lymph nodes and BM. Once the transitional B cells mature and attain the ability to recirculate, they migrate repeatedly

through the blood and the lymph to B cell areas of lymph nodes, Peyer's patches, and the spleen (15). In the normal mouse, only mature B cells are long-lived, able to recirculate with the lymph and the blood, and able to enter the lymphoid follicles of spleen and lymph nodes. These abilities are vital for accumulating an efficient immune response. Only B cells that can enter the follicle have access to antigen deposited on the follicular dendritic cells and are able to initiate the germinal centre (GC) reaction and then rapidly produce antigen-specific, high-affinity antibodies in collaboration with cognate T cells(17).

Naïve FO B cells stay in follicular niches in the lymphoid organs and play essential roles in T-dependent immune response. Follicular B cells respond to a TD antigen with a second signal from CD40 ligation. They can be recruited to a GC, are able to somatically mutate, and give rise to memory cells as well as plasma cells (19). Early in a T-dependent immune response, FO B cells can also differentiate into short-lived plasma cells without long site migration. In contrast, long-lived plasma cells often arise from GCs and can migrate to the BM where they can be sustained by interaction between APRIL and/or BAFF produced by stromal cells and the plasma cell specific BAFFR family receptor, BCMA(20).

The precise contribution of B cell Toll-like receptor(TLR) ligands to T-dependent B cell activation is obscure, but FO B cells activated by T-dependent antigens of microbial origin receive synergistic signals delivered via the BCR, CD40 and TLRs. Differentiation of activated B cells into antibody-secreting cells is facilitated by TLR activation on FO B cells, given it has been primed by BCR and CD40. While MZ B cells and B1 B cells can be induced to proliferate after TLR ligation, FO B cells are resistant to sole stimulation by TLR ligands(21).

In a normal rodent spleen, FO B cells circulate through the white pulp, where they migrate over the processes of specialised macrophages and follicular dendritic cells

(FDCs) in search of antigen. Follicular stromal cells are also a source of B lymphocyte chemoattractant (BLC; also called CXCL13), a chemokine that attracts B cells to follicles by engaging the receptor CXCR5 (22).

#### 1.1.2.3 Marginal Zone B cells (MZ B cells)

Marginal zone B cells, as one of the major B cell populations in spleen, reside in the marginal zone (MZ) area between white and red pulp(22). The MZ is a highly transited place with extensive blood flow. The topography of the MZ is highly organized and separated from the white pulp by the marginal sinuses, where terminal arterioles open and release blood. The marginal zone macrophages and the metalophillic macrophages which border the porous marginal sinus are involved in capturing blood-borne particulate antigens which are carried into the spleen via the central arteriole(23), and may also be involved in the processing and presentation of antigen.

$IgM^{hi}CD21^{hi}CD23^{lo}IgD^{lo}CD1d^{+}$ MZ B cells are absent until 2-3 weeks after birth in rodents and 1-2 years in humans(23). MZ B cells share innate-like features with B1 B cells. MZ B cells can be induced to differentiate into short-lived plasma cells without BCR stimulation and they are able to self-renew. It has also been suggested that BCR signalling is also involved in the positive-selection signals that generate and maintain the MZ B cell phenotype (24). MZ B cells are also able to mediate the transport of antigen in immune complexes into spleen follicles, showing participation in T-dependent B cell responses. They also express the nonclassical major histocompatibility complex (MHC) I molecule CD1d for presentation of lipid antigens, showing participation in immune responses to lipid antigens(15).

MZ B cells are non-recirculating B cells. The positioning of MZ B cells is promoted by sphingosine-1-phosphate (S1P), which signals mainly through S1P receptor, S1PR1(22,25). MZ B cells lacking S1PR1 fail to reside in MZ(22). Further research

shows that MZ B cells constitutively shuttle between marginal zone and follicle even in the absence of immunization and independently of BCR specificity or complement receptor expression. This shuttling is determined by the balance of the signalling through CXCR5 and S1PR1/S1PR3 receptors. S1P also signals through S1PR1 and S1PR3 to overcome CXCL13 signal via CXCR5(22). In addition, Muppidi et al. have shown that the cannabinoid receptor 2 (CB2) is important in the positioning MZ B cells. CB2 helps MZ B cells retaining in spleen. Overexpressing of CB2 is also sufficient to position B cells to MZ (25).

#### 1.1.2.4 B1 B cells

B1 B cells were identified in the mouse in the early 1980s but their developmental origin has remained unresolved for nearly three decades. B1 B cells are predominant in the peritoneal and pleural cavities, but can also be detected in the spleen. Experiments using parabiotic mice have shown that B1 B cells retain the capacity to recirculate through the secondary lymphoid organs(26), although they don't express CD11b (Mac-1) and are difficult to distinguish from large $B220^{lo}IgD^{-/lo}IgM^{bright}$ transitional B cells. B1 B cells are innate-like lymphocytes that develop primarily during fetal and neonatal life. B1 B cells can be identified with surface phenotype: $B220^{lo}IgM^{hi}CD23^{-}CD43^{+}IgD^{lo}$, and are further subdivided on the expression of CD5: B1a B cells are $CD5^{+}$, while B1b B cells are $CD5^{-}$. B1 B cells are larger and exhibit more side scatter compared to B2 B cells. Peritoneal B1 B cells also express CD11b while splenic B1 B cells don't.

In contrast to conventional B2 B cells, B1 B cells have unique developmental, phenotypical, tissue distribution, and functional characteristics. B1 B cells are long-lived cells and self-replenished. B1 B cells progenitors do not express terminal deoxynucleotidyl transferase (TdT), which might explain the reduced diversity in their antibody specificity. B1 B cell immunoglobulin genes have fewer N insertions and

usually do not contain somatic mutations(19). B1 B cells have a limited repertoire that is skewed toward reactivity with common bacterial and self-antigens.

Unlike B2 B cells, B1 B cells are refractory to activation through BCR ligation but can be induced to proliferate by treatment with phorbol esters. They are reported to less efficiently mobilize intracellular calcium upon BCR cross-linking. B1 B cells also have consitutively active basal tonic signalling downstream of the BCR such as phosphorylated Syk, PLC$\gamma$2 and STAT3(27,28). In contrast, these signalling molecules only become phosphorylated upon BCR stimulation in B2 B cells(27).

It is likely that B1 B cells are more frequently involved in TI-2 (Thymus independent type2) responses, since their repertoire is skewed toward reactivity with TI-2 antigen and because they lack the somatic mutations that are the hallmark of affinity maturation in GC. BTK-deficient xid mice, which lack B1 B cells, are unable to respond to TI-2 antigen. B1 B cells also produce IgM and IgG3, the major isotypes produced in response to TI-2 antigen(19).

B1 B cell-derived plasma cells secrete a class of soluble IgM, known as natural antibody because it appears to be produced without exogenous antigen stimulation(29,30). This natural antibody is polyreactive, weakly autoreactive, and reactive with many common pathogen-associated carbohydrate antigens. It has been reported to play an important role in protection from bacterial infection and autoimmunity(19). Natural IgM antibodies that recognize phosphorylcholine(PC) and malondialdehyde (MDA) determinants exposed on the cell membranes of apoptotic cells promote complement deposition and phagocytosis of apoptotic corpses by immature DCs(31). They may functions as a “mopping” antibody that reduces the load of antigens and up-regulates the clearance of apoptotic cells.

Since B1 B cells produce autoreactive antibodies, although non-pathogenic and of a low affinity, it has been speculated that they may also function as a source of the

high affinity, pathogenic autoantibodies seen in systemic autoimmune disease. Natural IgM has been shown to promote inflammation by activating the classical complement cascade, and causing tissue destruction by binding to epithelial antigens exposed upon ischemia-reperfusion injury(32). There are also examples, in both human and mouse, of an association between autoimmune disease and B1 B cells. In humans, elevated numbers of B1-like cells have been reported in patients with Sjogren's syndrome and rheumatoid arthritis. In mice, increased numbers of B1 B cells have been observed in a number of naturally occurring and genetically manipulated strains that develop autoimmune manifestations.

Early on, it was discovered that B1 B cells are a principal source of IL-10(3), and can also cause suppression by the killing of the $CD4^+$ T cell target population by FasL/Fas-dependent mechanism(33). At the same time, B1 B cells can also augment immune response because of the expression of high basal levels of the co-stimulatory molecule CD86, which can modulate T cells activation(34).

Alongside the functional differences between B1 and B2 B cell, it has long been reported that substantial developmental differences separate these B-cell lineages. It is well known that B2 B cells development is IL-7 dependent and all B2 B cell progenitors express IL-7R. In contrast, most B1 B cell progenitors do not express IL-7R and B1 B cell development is IL-7-independent, since this population is found in $IL\text{-}7^{-/-}$ mice(35). However, the mechanisms underlying the differences in development are unknown.

Apart from $CD5^+$ B1 B cells in mouse, CD5 expression was also observed in human B cells and chronic lymphocytic leukemia (CLL) cells. Similar to mouse B1 B cells, B-CLL are self-reactive, activated cells, secreting poly-reactive natural antibodies, including antibodies with reactivity to self-antigen(36). The CD5 expression level varies among CLL patients, although 95% of B-CLL cells are $CD5^+$. In humans, the

CD5 marker does not define specific B cell subsets. The majority of cord blood and neonatal B cells in human are $CD5^+$, although this percentage decreases to 10-20% in peripheral blood with age(37).

Griffin et al. identified a population of $CD20^+CD27^+CD43^+CD70^-$ cells in umbilical cord and adult peripheral blood leukocytes (PBL) that they propose share functional characteristics with murine B1 B cells(38). The $CD20^+CD70^+CD43^+$ B cells differed from activated human B cells by the lack of expression of activation markers CD69 and CD70. They are able to spontaneously secrete IgM and efficiently stimulate T cell proliferation in vitro. They have tonic intracellular signalling via phosphorylated PLC$\gamma$2 and SYK, and enriched immunoglobulin specificities to phosphorylcholine (PC) and an aspartate-tryptophan-glutamate-tyrosine-serine (DWEYS) tetramer DNA mimetope (38).

#### 1.1.2.5 Regulatory B cells

Regulatory B cells are another group of B cells that may have a distinct function compared to conventional B cells. A group of suppressive B cells inhibiting hypersensitive inflammation response was first described in 1974(39,40). In 1992, B1 B cells expressing IL10 were identified by O'Garra(3). In 2002, Bhan and colleagues found a group of $CD19^+CD1d^{hi}$ IL-10 producing B cells that can suppress chronic intestinal inflammatory conditions by downregulating inflammatory cascades associated with IL-1 upregulation and STAT3 activation rather than by altering polarized T helper responses. They named this group of B cells, Bregs (41).

Unlike conventional B cells, whose main function is positive regulation of immune responses and the pathogenesis of immune related diseases, Bregs contribute to the maintenance of tolerance. They are required to restrain "overreactive" inflammatory responses. In contrast to conventional B cells producing antibody, they produce a wide range of cytokines, particularly IL10 (41,42), which counters proinflammatory

cytokines and support regulatory T cell differentiation(41,43,44). Breg B cells are essential for the inhibition of Th1/Th17 responses, induction of T regulatory type 1 cells and reduction of collagen-induced arthritis(45).

However, the precise definition of Bregs remains controversial and obscure. This is particularly because no specific markers or transcription factors have been identified which can define the population. IL-10, apart from the suppression function, is also a growth factor promoting B cell maturation into antibody secreting plasma cells. In autoimmune diseases such as rheumatoid arthritis (RA) and systemic lupus erythematosus (SLE), there are large number of autoantibody secreting plasma cells(46,47). Moreover, B1 B cells are also a main source of IL10 production(3). A rare population of $CD5^{+}CD1d^{hi}$ IL10 producing splenic Bregs, termed as B10 B cells, is quite similar to B1 B cells. $CD19^{+}$ Bregs reportedly express high levels of CD1d(41), but $CD1d^{hi}$ B cells comprise both MZ and transitional 2 MZ precursor B cells. MZ B cells can produce IL-10 in vitro upon stimulation with anti-CD40 mAb or CpG, although transfer of unmanipulated MZ B cells fails to protect mice from developing either CIA or lupus like disease(48,49). Bregs require activation via CD40, which also contributes to B cell maturation and antibody production(50). CD40 has long been considered to have a dual role in B cell development - it can cause positive or negative selection depending upon the BCR signal.

**Table 1-1. B cell peripheral populations phenotype summary (adapted from Martin F. et al.** (23,51)**)**

| | **B1** | **MZ** | **FO** |
|---|---|---|---|
| Half-life | 6-8 weeks | 6-8 weeks | 6-8 weeks |
| Self-renew | Yes | Yes | No |
| Blood circulation | Yes | No | Yes |
| Lymph recirculation | No | No | Yes |
| TI response | +++ | +++ | + |
| TD response | +/- | + | + |
| Typical Isotypes | IgM, $IgG_3$, IgA | IgM, $IgG_3$ | $IgG_1$ |
| Ag presentation in vitro | +++ | +++ | + |
| Apoptosis after anti-IgM | - | +++ | + |
| **Proliferation** | | | |
| LPS | +++ | +++ | + |
| CD40 | ++ | ++ | + |
| IgM | - | - | + |
| IgM+CD40 | ++ | ++ | ++ |
| **TNF/TNFR-family dependence** | | | |
| BAFF | - | + | + |
| Lymphotoxin | - | + | +/- |

**Table 1-2. Surface phenotypes of B cell subpopulations.**

| Faction | Population | Surface Marker | Location |
|---|---|---|---|
| Fraction A | Pre-pro B cell | $B220^{+}CD43^{+}CD93^{+}CD24^{lo}BP\text{-}1^{-}$ $IgM^{-}IgD^{-}IL7R\alpha^{+}Kit^{+}$ | BM/ FL |
| Fraction B/C | Pro B cell | $B220^{+}CD19^{+}CD43^{+}CD93^{+}CD24^{mi}$ $^{d}BP\text{-}1^{-}IgM^{-}IgD^{-}$ | BM/ FL |
| Fraction C' | Large Pre B cell (Proliferating) | $B220^{+}CD19^{+}CD43^{+}CD93^{+}CD24^{hi}$ $BP\text{-}1^{+}IgM^{-}IgD^{-}$ | BM / FL |
| Fraction D | Pre B cell | $B220^{+}CD19^{+}CD43^{-}$ $CD93^{+}CD24^{hi}BP\text{-}1^{+}IgM^{-}IgD^{-}$ | BM / FL |
| Fraction E | Immature B cell | $B220^{+}CD19^{+}CD43^{-}$ $CD93^{+}CD24^{mid}BAFFR^{+}IgM^{+}IgD^{-}$ | BM / FL |
| Fraction F | Mature B cell | $B220^{+}CD19^{+}CD43^{-}CD93^{+}CD24^{lo}$ $BAFFR^{+}IgM^{+}IgD^{+}$ | BM / FL |
| T1 | Transtional B cell stage 1 | $B220^{+}CD19^{+}CD93^{+}IgM^{+}CD23^{-}$ | BM / FL / Spleen |
| T2 | Transtional B cell stage 2 | $B220^{+}CD19^{+}CD93^{+}IgM^{+}CD23^{+}$ | BM/ FL / Spleen |
| T3 | Transtional B cell stage 3 | $B220^{+}CD19^{+}CD93^{+}IgM^{lo}CD23^{+}$ | BM /FL / Spleen |
| FO | Follicular B cell | $B220^{+}CD19^{+}CD93^{-}$ $CD23^{+}CD21^{mid}IgM^{+/lo}IgD^{+/lo}$ | Spleen |
| GC | Germinal Centre B cell | $B220^{+}CD19^{+}$ $IgM^{+}IgD^{-}GL7^{+}PNA^{+}$ | GC |
| MZ | Marginal Zone B cell | $B220^{+}CD19^{+}CD93^{-}CD23^{+}CD21^{+}$ $IgM^{+}IgD^{-}$ | Spleen |
| B1a | B1a B cell | $FSC^{hi}B220^{lo}CD19^{+}IgM^{+}IgD^{-}$ $CD5^{+}CD11b^{+}CD9^{+}$ | PerC |
| B1b | B1b B cell | $FSC^{hi}B220^{lo}CD19^{+}IgM^{+}IgD^{-}CD5^{-}$ $CD11b^{+}$ | PerC |

## 1.2 B cell development during ontogeny

### 1.2.1 Differential development of B1 and B2 B cells – the lineage hypothesis

Although, conventional B cell development has been well studied and illustrated by a series of functional knockout mice, the origin and development of the innate-like B1 B cells is still largely a mystery. The two hypotheses, centred around separate lineages and positive selection, have dominated our thinking; although they are not mutually exclusive.

In its purest form, the lineage model proposed that B1 and B2 cells actually develop from distinct B cell precursors. It differs from the conventional model of B cell development, in which a homogenous self-renewing population of hematopoietic stem cells (HSCs) generates all lineages. It was based on the early observation that B cell progenitors from the fetal liver (FL) repopulated both B1 and B2 compartments of an immunodeficient host, while adult BM precursors only efficiently reconstituted the B2 population(52,53). On this basis it was proposed that B1 and B2 cells must derive from different progenitors whose lineage commitment was established early in development and maintained even when the progenitors were forced to develop in the same environment(54).

An important test of the lineage hypothesis is that the capacity to generate different populations is cell intrinsic. The failure to derive significant numbers of B1 B cells from adult BM was not due to extrinsic regulatory mechanisms that obscure B1 progenitor activity, since BM cells do not affect the reconstitution of B1 B cells from FL B cell progenitors. Likewise, the presence of FL cells does not induce BM progenitors to reconstitute B1 B cell in mixed chimeras experiments(54).

The fact that the capacity to generate different populations changes during ontogeny was seen as further support for separate lineages. Thus, embryonic splanchnopleura and fetal omentum contain progenitors that reconstitute B1 B cells only in adoptive

recipients(55-57). However, progenitors that reconstitute both B1 and B2 cells are found in FL and at neonatal sites. The B1 progenitors in neonatal animals are largely gone by the time the animals are weaned (2-3 weeks of age); but the progenitors for B2 cells, in contrast, persist or increase in frequency in BM as animals mature after weaning. Thus, while B1 B cells are poorly reconstituted by adult BM, progenitors for B2 B cells are abundant at this site and readily reconstitute the full adult B2 B cell populations (58,59).

### 1.2.2 The Layered Immune System

Following the lineage model, Herzenberg et al. proposed the "layered immune system hypothesis"(59).

"If ontogeny is taken as a guide, and the most primitive lineage appears earliest in development, then the most primitive lineage generates B1a B cells, which differentiate from immunoglobulin-negative progenitors during prenatal and early neonatal life and persist as a self-replenishing population thereafter. Stem cells for this lineage may also give rise to fetal erythrocytes and certain $\gamma\delta$ T cells."(53) In this model, the next lineage gives rises to the B1b B cells, $\gamma\delta$ T cells and $\alpha\beta$ T cells. The third and fourth lineages collectively generate the conventional B and T cell populations(53). The extent to which the separate lineages could be over-lapping was not defined, nor the molecular basis of their distinction.

### 1.2.3 Identification of B1 B cell progenitors and development waves

One piece of evidence in support of a separate lineage, which does depend on understanding the molecular underpinning, is the isolation of distinct precursors. In 2006, Dorshkind reported pre-pro $Lin^-CD93^+B220^{-/lo}CD19^+$ B cell progenitors in mice as precursors that preferentially generate B1 but not B2 cells, which derive from $Lin^-CD93^+B220^+CD19^-CD43^+$cells. Earlier precursors have not been identified. Transplantation experiments showed that these progenitors efficiently generated

functional sIgM$^{hi}$CD11b$^{+}$CD5$^{+}$ or sIgM$^{hi}$CD11b$^{+}$CD5$^{-}$ B1 B cells but not sIgM$^{+}$CD11b$^{-}$ B2 B cells. The B1-like B cells expressed $V_H11$ Ig genes known to be utilized by B1 B cells and secreted IgM with reactivity towards the B1 antigen phosphorylcholine(60). The same group went on to show that similar progenitors can be isolated from mouse embryonic day 9 yolk sac and intra-embryonic haemogenic endothelium giving rise to B1 and MZ B cells, but not B2 B cells(61). These B220$^{lo\text{-}neg}$CD19$^{+}$ population with B1 but no B2 B cell potential were present in high numbers in FL, peaking in number at around day 17 of gestation, and then declined in both frequency and total number in the weeks after birth. They were the earliest recognizable B lineage progenitors that arose in fetal BM and FL (60,62-66).

Differences in the transcriptional profiles of CD93$^{+}$B220$^{-/lo}$CD19$^{+}$ and CD93$^{+}$B220$^{+}$CD19$^{-}$CD43$^{+}$ cells from FL (embryonic day (E) 15.5), neonatal liver (d2, day 2) and adult BM during ontogeny were used to support the model of three waves of B cell development (**Fig. 1-1**). Early B cell development depends on the co-ordinated expression of a series of transcription factors, which prime the upregulation of B cell specific transcription factors like Ebf1 and Pax5(67). Mice deficient in one of these transcription factors, PU.1, which is expressed in conventional HSC and their progeny and encoded by the gene *Sfpi1*, were found to lack B2 B cells but have relative preservation of B1 B cells (68,69). On this basis and the reduced expression of *Sfpi1* in the putative CD93$^{+}$B220$^{-/lo}$CD19$^{+}$ B1 B cells, it was suggested that PU.1 may be a factor required for B2 cell generation (69).

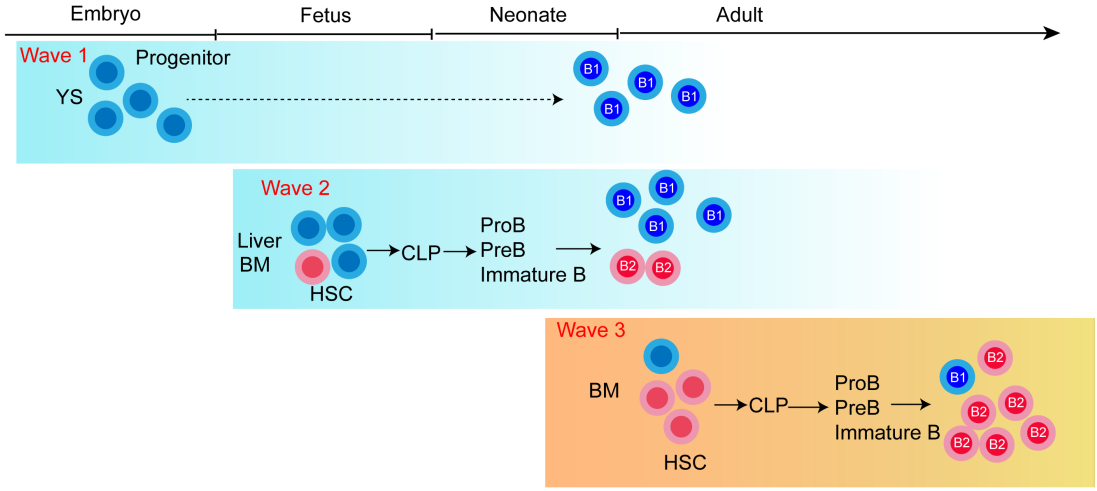



**Figure 1-1. Developmental Waves of B1 and B2 B cells**(58,69) The first wave of B1 B cells happens before the emergence of definitive HSCs. In the fetal and neonatal stage, second wave of B1 B cell and B2 B cell is initiated. After birth, B1 B cells contribute subtly to wave 3 but B2 B cells are the major subset at this point.

Whilst the concept of waves of different lineages is attractive, the evidence for differences depends critically on the accurate sorting of the different putative B cell precursor populations. It has not been shown that PU.1 is able to rescue B2 B cell development, as might be expected if it is a master-regulator. Notably, however, both fetal and neonatal cells express higher levels of Lin28b, and this was enriched in putative B1 B cell precursors at E15.5 and d2 (69).

### 1.2.4 A bimodal switch – Lin28b and let-7

Lin28 was first identified in the nematode *C. elegans* through screens for lineage-modifying genes that alter developmental timing or heterochrony(70). Two other prominent heterochronic genes, lin-4 and let-7, were the first microRNA (miRNAs) to be discovered, and both miRNAs directly repress Lin28 to suppress heterochronic reiteration in cell lineages. Heterochronic "reiteration" of nematode stem cells, first demonstrated in *C. elegans*, is strongly reminiscent of mammalian stem cell self-renewal(70). This connection was reinforced by the discovery that mouse embryonic

stem cells (ESCs) express high levels of mammalian Lin28, which decreases upon differentiation(71). Successful reprogramming of human fibroblasts into induced pluripotent stem cells (iPSCs) with the use of Lin28, along with Oct4, Sox2, and Nanog, further corroborated its role in pluripotent stem cells(72).

Lin28 has two evolutionary conserved paralogs in mammals, Lin28a and Lin28b. Both *Lin28a* and *Lin28b* are highly expressed in early murine embryos until E10.5. Thereafter, their patterns diverges: *Lin28b* is expressed in the FL, blood and brain, whereas *Lin28a* is expressed in the intestinal crypts, muscle, heart, testes and ovary(73). Lin28a and Lin28b block the biogenesis of let-7 miRNAs posttranscriptionally by binding to the terminal loop region of the let-7 primary of precursor miRNAs (pri- or pre-miRNA) (74-77). Lin28a binds pre-let-7 at the terminal loop and at the bulge GGAG motif where Dicer cleaves(78). Lin28a also recruits Tut4(*Zcchc11*), a cytoplasmic terminal uridylyl transferase, to oligo-uridylate pre-let-7 and prevent its processing by Dicer(79,80). Recent studies have further elaborated on this mechanism, suggesting that Tut7(*Zcchc6*) is a redundant homolog of Tut4 that can also oligo-uridylate pre-let-7 in the presence of Lin28a(81,82). In contrast, when Lin28a is absent, Tut4, Tut7, or Tut2 (*Papd4/Gld2*) monouridylates pre-let-7s at their 3' 1nt overhang to generate a 2nt overhang, thereby enabling their processing by Dicer (82). On the basis of these findings, one would expect oligo-uridylated pre-let-7 to accumulate when pri-let-7, Lin28a, and Tut4 and Tut7 are present. But this was not observed, suggesting that an unknown nuclease must exist to degrade oligo-uridylated pre-let-7s (76,79) and/or that Lin28 can sequester pri-let-7s to prevent further processing (77,83). Indeed, a study suggested that Lin28b is predominantly localized in the nucleolus where it can sequester pri-let-7 away from Drosha and DGCR8 processing, whereas Lin28a is predominantly localized in the cytoplasm, where it can recruit Tut4 to oligo-uridylate pre-let-7 and prevent Dicer processing (84). However, mammalian Lin28a and Lin28b and *C. elegans* Lin28 can all enter the

nucleus as well as cytoplasm (76,84-88). Moreover, all three proteins possess a putative nucleolar localization signal, and all three proteins can bind both pri- and pre-let-7 (75-77,83,87).

In counter regulation, *let-7* binding itself contributes to *lin28* repression and this underlies the opposing roles of the two factors in regulating differentiation. In *C. elegans*, mutation of the *let-7* binding site in the *lin28* 3' UTR also led to an increase in *lin28* 3' UTR lacZ reporter expression(89). Thus, Lin28 and let-7 acts in a binary fashion with Lin28b preventing the processing of let-7 microRNA to its mature and active form, and let-7 promoting the degradation of Lin28 RNA.

**1.2.5 Lin28b/let-7 function in lineage plasticity**

Joan Yuan and her colleagues found let-7 miRNA is highly expressed in adult BM progenitor B (pro-B and pre-pro-B) cells in mouse and it was largely absent in FL progenitor B cells(90). In contrast, *Lin28b* mRNA was abundant in all stages of FL B cell development (90). As in mice, *Lin28b* mRNA expression was exclusively detected in fetal human hematopoietic tissues, whereas mature let-7 was more abundant in the adult (90). This leads to the hypothesis that the Lin28/let-7 axis may be important in regulating haematopoiesis during mammalian ontogeny, and the sequential timing of generation of first B1 then B2 B cells is due to this "ontological switch" in development. This was demonstrated to be correct by ectopic expression of Lin28 in murine adult BM hematopoietic stem cells and allowing multi-lineage reconstitution (90,91).

The ectopic expression of Lin28b can also induce the development of murine adult BM hematopoietic precursors into innate lymphoid lineages, including the B1a, MZ B cells, γδ T cells, (90) and CD8 T cells in the adult that are phenotypically and functionally similar to those in neonate(92). The ectopic expression of Lin28 converts adult hematopoietic precursors into fetal-like stage, including independence from

IL7Rα-mediated signalling. Thus, the fetal/adult switch in B (and T) cell development is regulated by the Lin28b/let-7 axis (**Fig. 1-2**).

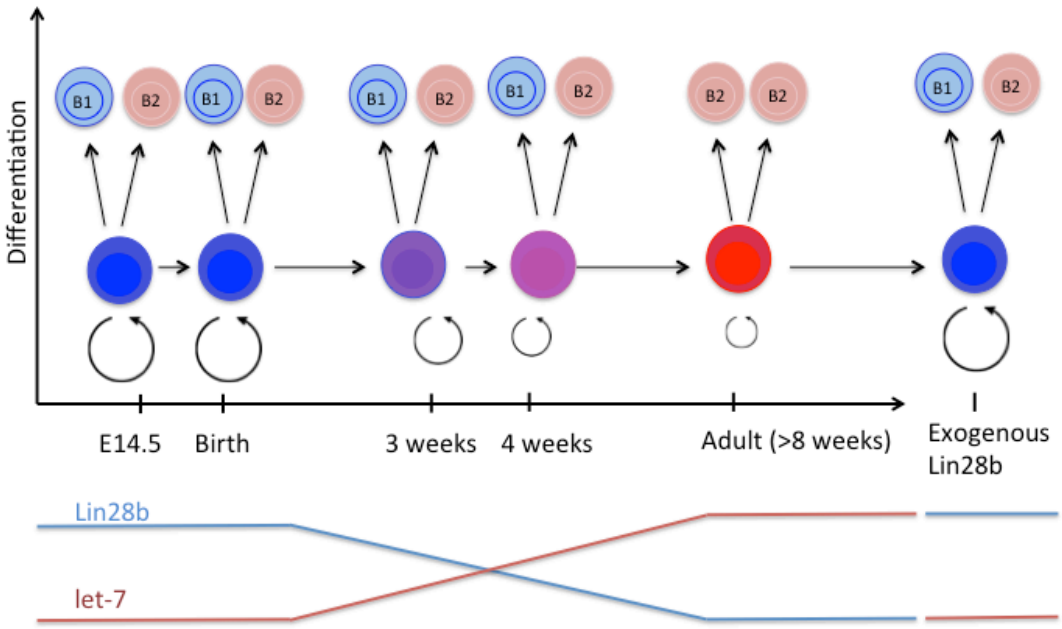



**Figure 1-2. Lin28b/let-7 function in HSC plasticity**(93).

Coincidentally, the Lin28b/let-7 axis also functions to regulate a variety of metabolic, proliferation, and differentiation pathways(94,95). For example, the Lin28b blocking of let-7 function releases repression of a network of proto-oncogenes, including the insulin-PI3K-mTOR pathway, Ras, Myc, Hmga2, and Igf2bp, resulting in increased metabolism and growth(96,97). Such reprogramming of metabolism also enhances tissue repair(98). Let-7 targets genes are involved in cellular proliferation, so expression of the Lin28b protein can result in increased proliferation and even malignancy(99-101). Differential Lin28b expression in fetal and adult human B-cell precursors showed that human B-cell development may resemble mouse, with self-

reactive “innate-like” B cells generated early in life. It remains to be determined whether such human B cells have a higher propensity to leukemic progression(102).

Following these findings, Yuan and colleagues used cellular barcoding to re-address the lineage question. Among 200 precursor barcodes found in B1a population, 108 progenitors gave rise to both B1a and B2 B cells and these contributed to 91% of B1a B cell population (93). The 92 barcodes detected only in B1a B cells amounted to 9% of the total contribution to B1a pool (93). This result shows that FL definitive hematopoietic stem cells (HSCs) initially give rise to both B1a and B2 B cells, but gradually lose B1a potential. The findings suggest that B1a B cell output is linked to HSC regenerative potential(93).

The results agree with the idea that B1a B cells lie downstream of definitive FL HSCs(103) but demonstrate that the single HSC can give rise to both B1a and B2 cells. Although their results don’t preclude the parallel existence of primitive B cell lineages prior to the emergence of definitive HSCs, they contradict the notion that definitive HSCs lack B1a potential(104). Instead they suggest that initially B1a potent FL HSCs become B2 restricted over time.

The loss of B1a potential correlates with molecular changes intrinsic to HSCs. Lin28b/let-7 and their downstream targets such as *Hmga2* and *Igf2bp1-3* were co-regulated with this loss of B1 potential during ontogeny. This provides evidence for the Lin28b/let-7 axis being a vital molecular switch on a single cell level during ontogeny(93). Lin28b enhances HSC clone size and longevity with a proportional increase in activity, thereby promoting HSC self-renewal. Ectopic expression of Lin28b reinitiates fetal-like state in a significant fraction of adult HSCs characterized by paralleled reacquisition of B1a plasticity, an overall increase in multi-lineage output, and enhanced HSC self-renewal(93).

As well as identifying Lin28b as a genetically accessible switch, these findings should encourage us to explore Lin28b's ability to rejuvenate adult HSC function and improve the outcome of immune regenerative treatments(93), though this may be at the risk of increased malignancy.

### 1.2.6 Lin28b/Let-7 function in B1a cell generation

In complementation experiments, Yuan et al., Copley et al. and Zhou et al. investigated Lin28b function by transfecting Lin28b-lentivirus into HSCs or pro-B cells(90,105,106). The results showed that Lin28b, or its homologue Lin28a, was able to reverse adult HSC or adult pro-B cells back to fetal stage, and this contributed to B1 B cell generation in cell transfer experiments. Lin28b homologue Lin28a was also used in transduction experiments because its ectopic overexpression is higher than Lin28b. Lin28a is not itself highly expressed in fetal liver after E10.5.

Copley et al. investigated the Lin28b/let-7 mechanism by looking at the Ki-67$^{+}$ populations and showed that there is no significant up-regulation of the proliferative activity(105). They investigated the downstream protein Hmga2, which is positively regulated by Lin28b and negatively regulated by let-7. They observed increased rate of expansion of Lin28- or Hmga2- overexpressing adult HSCs, which could be explained by an ability to execute symmetric self-renewal at a higher frequency. They also found that overexpression of Hmga2 itself in adult HSCs does not activate fetal lymphoid differentiation programs in their progeny. Overall, these findings show that Lin28b has indispensible role in regulating HSCs plasticity, as well as lineage potential (105).

Zhou et al. found that modulation of Let-7 in fetal pro-B cells was sufficient to alter fetal B1 B cell development and produce B cells resembling the progeny of adult B2 development(106). This result along with modulation of Lin28b in adult pro-B cells

appear to confirm the theory that Lin28b/let-7 axis is essential and sufficient in regulating lymphopoeisis plasticity. They also identified the Arid3a transcription factor as a key target negatively regulated by Let-7, whose ectopic expression is sufficient to induce B1a B cell development in adult pro-B cells and whose silencing by knockdown blocks B1 development in fetal pro-B cells(106). These experiments also showed that Lin28b represses normal FO B cell development while let-7 miRNAs have the opposite function. Lin28b/let-7 axis' function in MZ B cells is still obscure.

Recently, Kreslavsky et al. found that transcription factor Bhlhe41, downstream of Lin28/let-7, also plays an important role in the regulation of B1a B cell development, self-renewal and BCR repertoire generation(107). Bhlhe41 directly repressed the expression of cell-cycle regulators and inhibitors of BCR signalling, while enabling pro-survival cytokine signalling(107). Bhlhe41$^{-/-}$ mice have a significant reduction of B1a cells, while B1b and B2 cells are not affected. These findings also suggest that the BCR repertoire, BCR signalling and cytokine signalling play a role in B1 B cell maintenance.

Collectively these results appear to show that separate lineages are controlled by a Lin28b/let-7 switch and downstream transcription regulators, which include Arid3a and Bhlhe41, and possibly other metabolic modifiers. Plasticity exists at the level of HSCs. Lineage specific B cell intermediates may exist and be more or less detectable at different stages in development and the opportunity exists to see if these exist more or less in the context of specific transcriptional regulators. What is not certain is whether additional factors are required for the positive or negative selection of specific subsets.

However, apart from lineage potential, it is also found that intact BCR signal is required for the generation of B1a B cells from Lin28b-transduced BM progenitors,

supporting a requirement for ligand-dependent selection as in the case of normal B1a B cells. The VH repertoire of Lin28b-induced BM or Bhlhe41-knock out B1a B cells differs from that of normal B1a, suggesting persistent differences at the fetal progenitor stage(93,107).

## 1.3 B cell positive and negative selection in the pre-immune repertoire

### 1.3.1 Immunological tolerance, autoimmunity and selection

Antigen receptor specificity, which may affect intrinsic signalling or the interaction with antigens on self or common pathogens, is a factor that may influence the selection of B cell subsets within a mixed repertoire. We have already seen how certain specificities are more associated with B1 B cell selection, for example phosphorylcholine-specificity.

Most of what we know about the interaction of immature B cells and antigen comes from the study of negative selection. Tolerance is crucial for the maintaining a non self-reactive repertoire for both B cell and T cells. Of course, B cells have the potential to develop autoreactive specificity at two stages in their development: in the BM and in the periphery, during somatic hypermutation (SHM) within germinal centres (GCs). In both cases, the need to generate a pool of diverse B-cell specificities against foreign antigens, through random V(D)J recombination and SHM inevitably leads to the appearance of cells expressing autoreactive BCRs. A series of tolerance-inducing mechanisms at these two stages reduce the risk of autoimmune disease. These mechanisms depend on a range of factors, which accommodate variable risks, including the time of exposure to antigen during ontogeny, the tissue site of expression, concentration and the structure of the self-antigen(1,108-110).

A key unresolved issue is the extent to which self-reactivity or the selection of particular BCRs may also play a role in the generation of B1 B cells in early ontogeny. Study of the Ig heavy and light chains of B1 B cells has shown that they constitute a biased set of BCRs (111-113), which appear to be encoded by distinctive germline genes, possibly with preferential heavy-chain–light-chain combinations. The fact that fetal pro-B cells lack TdT or express lower TdT levels than adult pro-B cells, also acts to restrict (or maintain the focus) of the initial μ-heavy chain diversity (114). These restrictions support the idea that B1 cell generation is a part of innate immunity, genetically reserved for reactivity to common pathogens or self/natural antigens, therefore with no necessity for affinity maturation normally associated with immune responses.

The manner in which positive selection can operate to provide survival advantage is described in the VH12 B-cell repertoire (115). Anti-phosphatidylcholine(PtC) and anti-phosphocholine(PC) natural antibodies recognize the PC epitope of the cell-wall polysaccharide of *Streptococcus pneumoniae* and protect mice from lethal infection with this microorganism. Anti-PtC BCR, which is encoded by either $V_H$11/Vκ9 or by $V_H$12/Vκ4/5H, comprise 5-8% of the B1 B cell repertoire. From the pre-B cell stage onwards, B cell progenitors undergo a series of positive selections, which enriches B cells with a $V_H$CDR3 and L chain specific for PtC binding and eliminating the majority of $V_H$12 B cells that lack the ability to bind PtC (115).

How these particular BCRs are selected, through natural selection and the germline or as a result of reaction with self- or commensual antigens, is unclear. It is also unknown whether changes in the BCR signalling threshold or other lineage-specific features of B cells at an early stage in their development may lead to positive rather than negative selection.

### 1.3.2 B cell repertoire cellular selection – mouse models

Animal models, particularly Ig transgenic mice, have been used extensively to explore aspects of B cell selection. It is notable that the expression of BCR transgenes derived from B1 B cells which are specific for self-antigens – including anti-erythrocyte(116) and anti-Thy1(117) – has been sufficient to recapitulate B1 B cell lineages in vivo. Likewise, the selection of Ig transgenes derived from conventional B2 cells usually recapitulates follicular and MZ B cell lineages, but not B1 B cells, in vivo. The way in which specificity of the receptor determines the lineage has been taken as evidence of selection. This principle has been explored in more detail in two models, where the expression of self-antigen has been also been manipulated: in one case by gene targeting a natural antigen Thy1, and in the other by varying the expression of a transgenic (Tg) neo-self antigen, hen egg lysozyme (HEL).

#### 1.3.2.1 Anti-Thy-1 Autoreactive (ATA) mouse model

Anti-thymocyte autoantibody (ATA) is another natural antibody produced by B1 B cells, which was identified by Randy Hardy and Kyoko Hayakawa from hybridomas made from sorted $CD5^+$ B1 B cells. Multiple hybridomas producing antibody staining thymocytes shared a recurrent rearranged Ig heavy chain from the $V_H3609$ family. They subsequently found a specific clone 6C10, from hybridoma SM6C10, that bound Thy-1 (CD90), and used it in a novel approach for studying the development of natural autoreactive B cells. Since the normal frequency of B cells with the prototypic ATA rearrangement ($V_H3609$/6C10) is low, they generated Tg mice bearing the specific 6C10 $V_H3609$ μ heavy chain (μ Hc) and mice bearing both 6C10 $V_H3609$ μ Hc and Vκ21c light chain (Lc) and studied the development of B cells in wild-type and *Thy-1*$^{-/-}$ mice(2,117). This model provided an opportunity to study the selection of antigen specific B1 B cells in the presence or absence of specific antigen.

Hardy and Hayakawa discovered that B cells that pair the Vκ21 chain with the ATA-μ Tg Hc were positively selected into the B1 B cell pool when Thy-1 antigen is present and secreted high level of serum ATA IgM. When Thy-1 was absent, there was no B1 B cell selection and most BM-derived B cells that express the ATA BCR were deleted or underwent receptor editing to a different specificity. Similarly in the ATA μκ Hc+Lc transgenic model system, when Thy-1 antigen is around, most conventional B cells developing from BM of adult mice were blocked at an immature stage in spleen and only rarely escaped apoptosis by editing their BCR to eliminate the ATA specificity. However, there was ATA IgM in serum, derived from differentiation of B1 type cells during foetal/neonatal development, and many ATA-secreting plasma cells were observed in spleen. When Thy-1 antigen was absent, ATA B cells did not enter the B1 B cell pool and serum ATA levels were low but conventional B cell maturation was efficient in BM, generating a follicular B cell pool, with most cells expressing the ATA BCR. Intermediate levels of Thy1 antigen, inducing different levels of BCR signalling, induced MZ B cell generation(117).

#### 1.3.2.2 The hen-egg-lysozyme-specific model

One of the most widely studied Ig Tg B cell mouse models of selection was generated by Chris Goodnow and uses HEL as a neo-self antigen. The biochemistry and antigenic structure of HEL is well defined and it is not toxic in vivo in mice(118).The original model comprises MD4 ($Ig^{HEL}$) Tg mice, which express Hc (both $IgM^a$ and $IgD^a$ heavy chains) and Lc from the high affinity anti-HEL HyHEL-10 BALB/c hybridoma (affinity $2 \times 10^{-9}$ M) (118). The second series of Tg strains express HEL in different forms and tissues. The principal strains for understanding B cell selection are: ML5, which expresses a soluble HEL (sHEL) under the metallothionein promoter (118); KLK, which expresses a chimeric form of HEL coupled to the transmembrane portion of MHC class I under the MHC class 1 promoter (mHEL) (119,120); and mHEL-KK, an intracellular variant of mHEL, which

differs from the latter by inclusion of a dilysine ER-retention motif (118,121,122). Crossing the two kinds of Tg mice creates “double-transgenic (Dbl Tg)” offspring carrying both anti-HEL BCR and different forms of HEL as self-antigen (**Fig. 1-3**).

This generates a model for studying the effect of nature, amount and location of self-antigen on B cell fate in the pre-immune repertoire with a single BCR. The different antigenic forms have profound effects on both positive and negative selection of B cells.

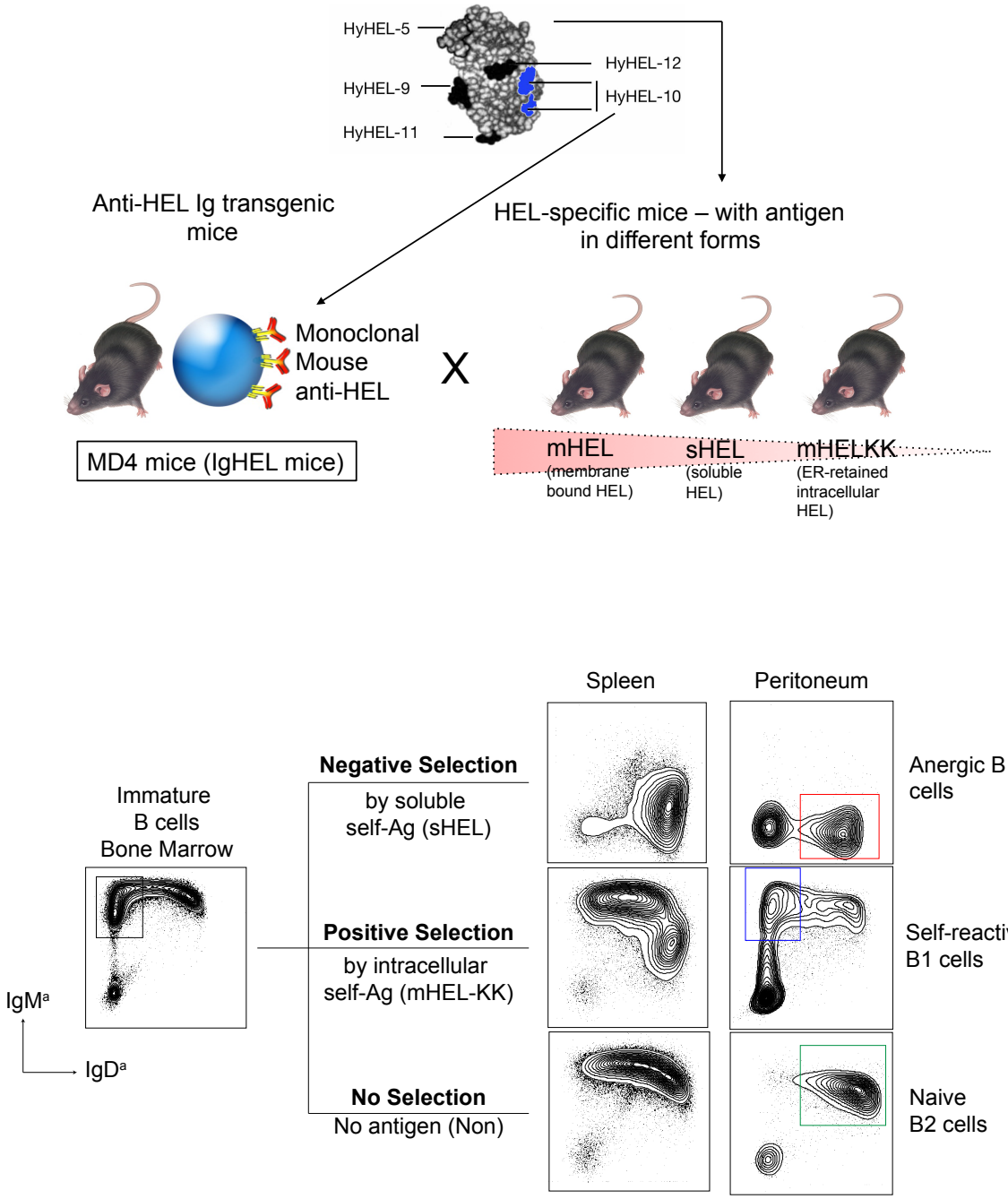



**Figure 1-3. MD4 mouse model.** Upper panel shows the IgHEL binding site and those two kinds of transgenic mice. Lower panel shows positve and negative selection in periphery, when $Ig^{HEL}$ mice mated with different forms of HEL expressing mice.

***$Ig^{HEL}$/sHEL:***

Single ML5 Tg mice expressing sHEL at a serum level around 10-20 ng/ml showed tolerance to HEL, and this was magnified in the $Ig^{HEL}$/sHEL Dbl Tg, by expanding the high affinity $Ig^{HEL}$ B cells in the periphery to about 90%(118). Chronic exposure of the peripheral B cells in these mice to sHEL results in anergy and the absolute number of mature recirculating B cells is ~50% less than that observed in $Ig^{HEL}$ mice. The anergic phenotype is characterised by a series of changes including a 10-20 fold reduction of $sIgM^a$ with no change on $sIgD^a$ level. The Dbl Tg mice have extremely low level of anti-HEL serum titres compared to $Ig^{HEL}$ mice.

In a mixed repertoire the reduced lifespan of anergic B cells is further reduced by their inability to compete with naïve B cells for BAFF, which is required for their survival(123). In the absence of autoantigen, the anti-HEL B cells follow the normal route into the primary follicles from the T-cell zones but under competitive conditions, HEL-binding B cells continuously exposed to sHEL are restricted to the outer T cell zone and, in the absence of T cell help, die within less than three days. Exclusion from the follicles is a competitive phenomenon rather than a result of binding of autoantigen alone, because sHEL-bound Tg B cells could recirculate and survive normally in the absence of a sufficient number of unbound competitors(124).

ML5/sHEL mice fail to mount adaptive responses (as determined by serum antibody titres) following immunization with HEL conjugated with horse red blood cells (HEL-HRBC)(125), and they exhibit a reduced capacity to generate antibody-secreting cells in response to the Toll-like receptor (TLR) agonists CpG-containing DNA and lipopolysaccharide (LPS) (118,125-128). In anergic B cells, continued exposure to self-antigen triggers only low $Ca^{2+}$ oscillations, NF-AT and ERK, leading to pathways associated with decreased survival (induction of Bim) and migration (decreased expression of CXCR5). Anergic B cells exhibit a proximal block in the sIg signaling

pathway, which prevents activation of receptor-associated tyrosine kinases in response to the binding of soluble HEL(128), and an ERK-dependent inhibition of the NFkB pathways, which mediates the resistance to TLR signalling. After removal from sHEL environment, the BCRs on tolerant B cells reacquire the ability to stimulate a biphasic $Ca^{2+}$ flux and to promote proliferation (129). Tolerant self-reactive B cells from $Ig^{HEL}$/sHEL Dbl Tg mice responded poorly to the combination of allogeneic T cells and sHEL, but present antigen to T cells and can respond normally to stimulation with IL-4 and anti-CD40 Abs in vitro, showing that they retain the capacity to respond to mediators of T cell help.

***$Ig^{HEL}$/mHEL:***

More stringent tolerance is generated in $Ig^{HEL}$/mHEL Dbl Tg mice expressing the higher avidity self-antigen. Numerous other models have also shown that this form of antigen primarily induces immature B cell arrest(130), BCR degradation, reactivation of Rag, Lc editing(131) and, in a majority of cases, escape as a non-self-reactive clone(130). In the anti-HEL transgenic model, the concatemerised Hc and Lc Tg prevents effective editing and so arrested cells apoptose (119,120).

To study the affinity effect on negative selection, the same phenotype has been studied in Tg mice that express an anti-HEL Hc Tg only. These mice develop a small subset of HEL-binding B cells with a range of binding affinities. Exposure to mHEL during development eliminates even the lowest affinity cells in these mice(132,133).

***$Ig^{HEL}$/mHELKK:***

In order to investigate tolerance to intracellular antigens, typical of systemic autoimmune disease, the Cornall laboratory modified the mHEL Tg by addition of a two amino acid COP1 dilysine endoplasmic reticulum (ER) retention signal. With the exception of dilysine motif, the antigen was the same as mHEL, expressed under the

class I promoter with the same extracytoplasmic lysozyme domain and transmembrane segment.

In contrast to mHEL, which causes the deletion of autoreactive $Ig^{HEL}$ B cells, the intracellular sequestered self-antigen positively selected antigen-binding B cells to differentiate into B1 B cells and induced a 25-fold T-independent increase in IgM autoantibody-secreting plasma cells(121,122,134,135). Follicular B cell development and function was broadly normal in the presence of the positively selected B1 B cells and high titres of anti-HEL IgM antibody, with minimal reduction in B cell numbers in the mesenteric lymph nodes and BM and IgM modulation. The follicular $Ig^{HEL}$ B cells were functionally naïve. The serum sHEL released by cleavage from mHEL-KK mice was in a range of 2-10 ng/ml in single Tg mice, below the 10-20 ng/ml threshold required to induce B cell anergy. In $Ig^{HEL}$/mHEL-KK Dbl Tg mice the antigen was further complexed with the autoantibody (121,122,134,135).

### 1.3.3 Two-pathway model: lineage and selection are both essential in B1 B cell fate

Distinctions in B cell development between fetal/neonatal and adult can be due to differences in initial repertoire generation, the process of cellular selection, or a combination of the two. The lineage hypothesis and the selection models are not mutually exclusive (136) (102). A two-pathway model proposes that B1 B cells develop initially, and primarily, from B1 restricted precursors during fetal life, and undergo some positive selection for reactivity to self-antigens and/or strong intrinsic BCR signaling. The B1 B cells are maintained in the adult mainly through the process of self-renewal; though B1 precursors in the adult BM also contribute to the B1 pool (particularly B1b cells) over time (136).

In B lymphopoiesis, Lin28b may play important roles in modulating B cell repertoire and generating $CD5^+$ B cells by a process that positively selects for self-reactive

cells(102,137). It has been suggested that this may occur through changes that modify the threshold for BCR signalling, a hypothesis supported by the effect on B cell development of a variety of mutations that alter the level of BCR activation.

## 1.4 Signal threshold affecting B cell lineage and selection

### 1.4.1 BCR signal

The fate of B cells is most importantly determined by signaling through the surface BCR, which comprises the two Ig Hc and Lc assembled in a signaling complex with Igα-Igβ heterodimers. After BCR stimulation by antigen, downstream enzymes such as the protein tyrosine kinase (PTK) SYK and *Src*-family PTKs, such as LYN, are activated initially. PTK phosphorylated immunoreceptor tyrosine-based activation motifs (ITAMs) in the cytoplasmic tails of Igα-Igβ, recruit and facilitate the activation of SYK and the TEC-family PTK BTK(138). B cells express multiple *src*-family kinases, including LYN, FYN, BLK, and FGR. The fact that mutations of *Fyn, Blk*(139) and *Fgr*(140) have little effect on B cell function may be due to redundancy.

Analysis of B cell lymphomas and other transformed cell lines have identified SYK as essential for the BCR to activate downstream signalling events such as intracellular calcium(141,142). In *Syk* knockout mice, B cells have development deficiency in BM. They are blocked at the $CD43^{high}$ proB cell stage and only few cells become $CD43^{low}$ preB cells or surface IgM-bearing immature B cells(143). They also fail to express complement receptors and other markers. In the MD4 mouse model (**section 1.3.2.2**), binding of low or high avidity forms of auto-antigen had no effect on maturation of the $Syk^{-/-}$ MD4 B cells but did induce IgM modulation in an exaggerated manner, indicating that antigen-receptor signaling is at least partially intact(143).

The VAV family of RHO GTPases is the downstream of the BCR and is also important for BCR signal. It consists of at least three forms – VAV1, VAV2 and VAV3 (144). BCR-induced proliferation is defective in VAV1-deficient B cells. VAV1 and

VAV2 double deficient mice have a defect in calcium mobilization (145). They have been proposed to function downstream of phosphatidylinositol 3-kinase (PI3K) owing to their possession of a phospholipid-binding pleckstrin-homology (PH) domain. Nevertheless, VAV3 may also regulate activation of PI3K in B cells(144).

Bruton's tyrosine kinase (BTK) plays a complex role in BCR signalling(146). It is rapidly activated by *Src*-family kinases after BCR cross-linking and interacts with a number of ligands participating in the BCR signalling cascade. It has a PH domain that interacts with the PI3K product phosphatidylinositol (3,4,5) triphosphate ($PtdInsP_3$) and with other signalling molecules, like protein kinase C (PKC)(147) and G proteins(148). The interaction with $PtdInsP_3$ regulates the recruitment of BTK to the cell membrane and thus the intensity and duration of extracellular calcium fluxes(149). The interaction with PKC also affects the localization of BTK to the cell membrane, and in turn BTK modulates PKC activity. The association with G proteins results in an increase of the catalytic activity of BTK(17,150). The PH domain is essential for the function of BTK. B cell development is blocked at an immature stage in the spleens of mice with PH domain mutation and the same defect is observed in mice with a complete deletion of the BTK domain(151). BTK and SYK phosphorylate and activate phospholipase Cγ2 (PLCγ2) after stimulation.

PI3K and PLCγ2 are both crucial effector enzymes that generate key second messagers in BCR signalling(152).

Blocking PI3K increases BCR-induced cell death. PI3K activates Akt via its p110δ subunit(153), and Akt phosphorylates cellular targets that are involved in cell survival. Akt inhibits the activation of the pro-apoptotic BCL-2 family member BCL-2 antagonist of cell death (BAD)(154), and glycogen synthase kinase 3(GSK3) in B cells. In unstimulated cells, GSK3 is active constitutively to phosphorylate and

destabilize MYC and cyclin D, both of which are required for cell-cycle progression(155).

PLCγ2 processes phosphatidylinositol-4,5-biphosphate ($PtdInsP_2$) to generate inositol-1,4,5-trisphosphate ($InsP_3$) and diacylglycerol (DAG), which are required for the release of intracellular calcium ($Ca^{2+}$) and activation of protein kinase C (PKC) (141). $Ca^{2+}$ flux and PKC activation induce the activation of mitogen-activated protein kinase (MAPK) family kinase – extracellular signal-regulated kinase (ERK), c-JUN NH2-terminal kinase (JNK) and p38 MAPK – and transcription factors, including nuclear factor-κB (NFκB) and nuclear factor of activated T cells (NFAT).

The NF-κB pathway is an important pathway for B cell survival. It protects cells from apoptotic signals. In mice that are deficient for inhibitor of NF-κB kinase-α (IKKα), IKKβ and the regulatory subunit NF-κB essential modulator (NEMO), B cell apoptosis is upregulated(156,157).

Non-enzymatic adaptor proteins are also important for regulation of BCR signalling. Among them, the B-cell linker (BLNK) efficiently connects SYK and BTK with PLCγ2(158,159). BLNK also associates with VAV, which regulates cytoskeletal organization in B cells. B-cell adaptor for PI3K (BCAP) was isolated originally as a new molecule that associates with the SRC-homology 2 (SH2) domain of PI3K p85 subunits, and disruption of BCAP leads to impaired BCR-induced activation of PI3K and the protein serine/threonine kinase Akt(158,160).

The details of the how the BCR engages antigen remains uncertain, including whether it exists in monomeric or oligomeric form in the resting, unstimulated state. One model, proposed by Michael Reth and his colleagues, postulates that in the absence of antigen binding, the BCR is pre-assembled into oligomeric receptor complex, which generate a basal level of signalling that is essential for B-cell maintenance. Components such as Btk, Blnk, Vav, PI3K and PLCγ2 may form

complexes in lipid rafts, referred to as 'signalosomes'(161). Other models propose that the BCR is normally a monomer and is subject to structural modification on antigen engagement or re-modelling that changes the balance of kinase and phosphatase in the immunological synapse with antigen (M. Wilcock and S. Davis, personal communication). In the case of B cells, several model maybe compatible with each other, depending on the form of antigen.

### 1.4.2 Other receptors intersect with the BCR signal

Core B cell signalling is also modified by the activity of receptors, such as CD19 and CD22, that tune the cell to its environment and developmental stage. For example, CD19 is a positive regulator of BCR that functions as adaptor for PI3K in B cells as well(162). Paired immunoglobulin-like receptor B (PIRB) and FcγRIIB are negative regulators, which have immunoreceptor tyrosine-based inhibitory motifs (ITIMs) in their cytoplasmic tails that recruit SH2-domain-containing protein tyrosine phosphatase (SHP1) and SH2-domain-containing inositol polyphosphate 5' phosphatase (SHIP). Many coreceptors have several function – the cytoplasmic tail of CD22, for example, recruits GRB2, leading to MAPK activation, but also recruits SHP1 via ITIM motifs to block BCR signalling(163-165). LYN can also function as a negative effector in B cells. In fact, *lyn*$^{-/-}$ B cells have increased signalling and increased numbers of B1a B cells and plasma cells(166,167).

BCR mediated survival signals intersect with those received via the BAFF receptor. The precise mechanism by which BAFF-R mediates survival of B cells, particularly transitional cells, is incompletely defined due to its complex interplay with the BCR. Current evidence supports a theory that BAFF-R activates the alternative NFκB pathway, leading to the upregulation of pro-survival factors including BCL2 and PIM2(168) and post-transcriptional modification of the pro-apoptotic member, BIM(169). This may help to rescue B cells receiving 'ineffective' BCR signals(170).

### 1.4.3 BCR signalling influences B cell fate

Several studies have reported that strong BCR signalling induces the development of B1 B cells, while weaker signalling leads to the development of B2 cells. Mice lacking negative regulators of BCR signalling, such as the phosphatase SHP1(171), tyrosine kinase LYN and co-receptor CD22(172), CD72(173), Siglec-G(174) or overexpressing of positive regulators, such as CD19, CD81(175), develop increased numbers of B1 B cells. Similarly, in two independent BCR transgenic systems, increasing BCR surface expression promoted B1 B cell development (176,177).

However, the interpretation of these results is sometimes ambiguous, because these experimental systems do not usually dissociate BCR signaling strength from BCR specificity. Nevertheless SHP1 deficient (motheaten) MD4 Tg B cells with increased BCR signalling do develop into B1-like cells(178). Likewise, if the nature of the selecting antigen is essential for B1 B cell positive selection, then the simultaneous engagement of immunoglobulin co-receptors such as the CD19-CD21 complex, CD22 or CD72 on the B cell surface may be critical in the selection process. Several of the positive (for example, PLCγ2) and negative (SHP-1 and Lyn) regulators participate in multiple signaling cascades, some of which may influence B1 versus follicular B cell differentiation independently of their effect on BCR signaling(179).

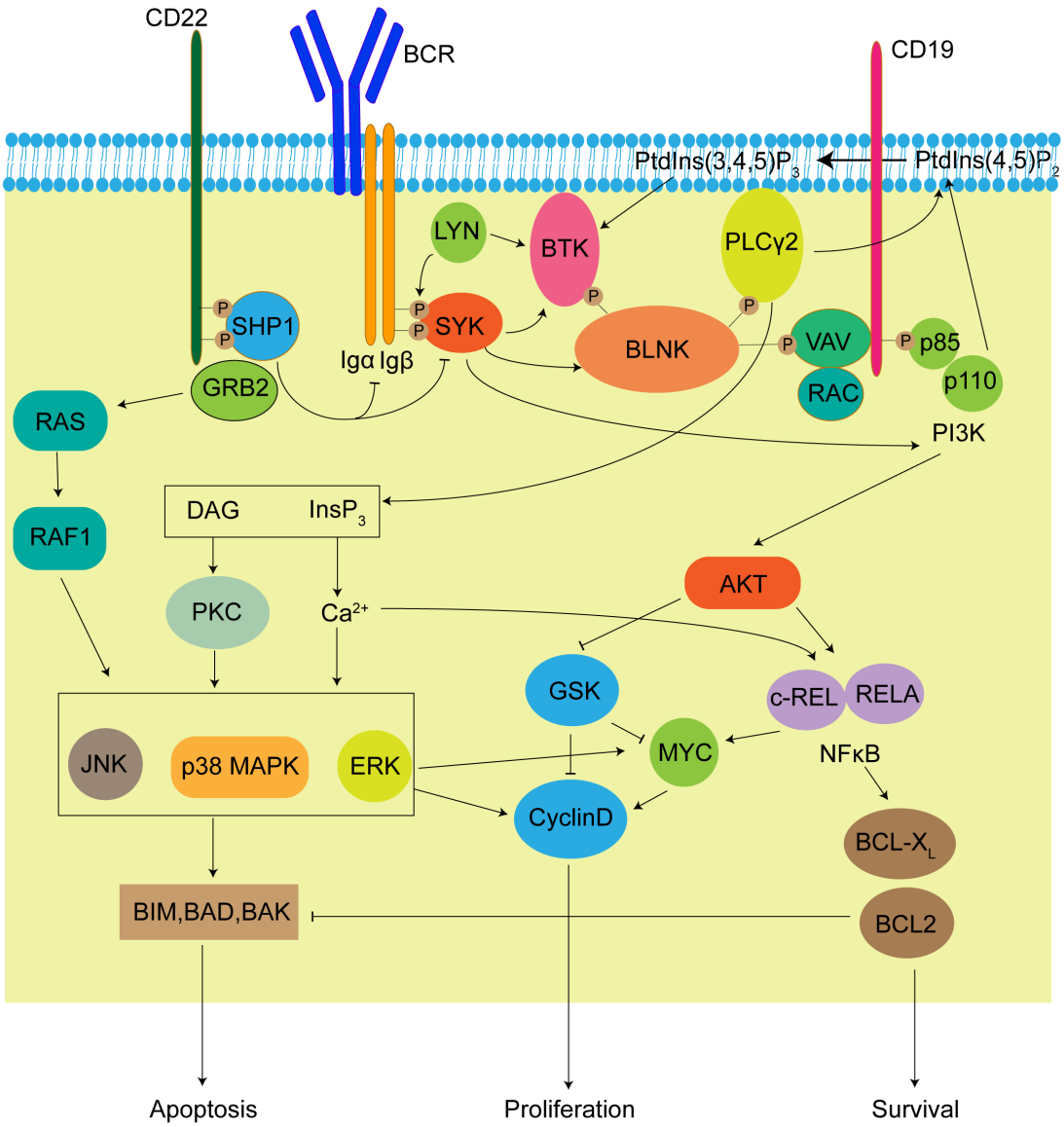



**Figure 1-4. BCR signal regulates cell fate** (180). BCR and other coreceptor signals together to control the apoptosis, proliferation and survival fate of B cells.

## 1.5 Aim of study

The overall aim of this project was to identify the factors underpining positive and negative selection. The initial approach was to use Ig and antigen specific models, genetic approaches and next generation sequencing tools to build a transcriptomic map of B cell development.

A particular focus was to determine the factors leading to B1 B cell selection. This was based on the rationale that understanding B1 B cell development, especially from the aspect of both lineage and selection, may provide answers to fundamental questions about selection in establishing B cell tolerance and immunity. Understanding how selection is controlled in the normal situations may provide insight into autoimmune disease such as SLE. The processes that control B1 B cell selection and survival may also provide insight into the causes of cancers, like CLL, that are likely to be derived from this subset of cells in humans.

Experimentally the project uses several tools. It builds on the extensive literature defining B cell populations. The MD4 $Ig^{HEL}$ transgenic mouse model provides an effective platform for investigating tolerance and immunity, which controls for both antigen and Ig specificity. Finally, rapidly developing techniques of high throughput sequencing and single cell transcriptomic analyses make it increasingly possible to investigate lineage and selection questions from a molecular basis.

# Chapter2. Materials and Methods

## 2.1 Reagents

**Ear punch buffer:** 50mM Tris HCl pH 8.0, 10mM EDTA, 1% SDS, 2mM NaCl

**Foetal calf serum (FCS)**: European origin (First Link). Heat inactivated at 55°C for 40 minutes, then stored in 10ml and 50ml aliquots at -20°C

**R2:** RPMI 1640 (Sigma) plus 2% FCS, 20mM HEPES (Invitrogen)

**R10:** RPMI 1640(Sigma) plus 10% FSC, 20mM HEPES (Invitrogen), 2mM L-glutamine (Sigma), 105 U/L penicillin (Sigma) and 10mg/L streptomycin (Sigma)

**Staining Buffer (FACS buffer):** DPBS(1x), 2% Heat inactivated FCS, 20mM HEPES (1M, pH 7.0-7.6), 0.05% Sodium Azide

**Phosphate Buffered Saline (PBS):** 137 mM NaCl, 2.7 mM KCl, 10.1mM Na2HPO4, 1.76mM $KH_2PO_4$

**1% BSA/PBS**: 10mg/ml BSA in sterile 1x PBS; 0.2µm filter-sterilised.

**Carbonate buffer**: 10mM $Na_2CO_3$ 35mM $NaHCO_3$ pH 9.6

**ICE-T**: 1%FCS, 1%milk powder (w/v), 0.1% Tween 20, 0.1% $NaN_3$ in 1XPBS

**NPP buffer**: 50mM $Na_2CO_3$, 0.5 mM $MgCl_2$ pH9.8

**PBS/Tw:** 137mM NaCl, 2.7mM KCl, 10.1mM $Na_2HPO_4$, 1.76mM $KH_2PO_4$, 0.05% (v/v) Tween 20(Sigma).

**White blood cell counting fluid:** 1.5% acetic acid, 0.5% methyl violet in water

**Tris-EDTA (TE) buffer**: (Invitrogen) 10 mM Tris-HCl (pH 8.0), 0.1 mM EDTA

## 2.2 Animal Work

### 2.2.1 Animal facilities and procedures

Mice were kept in specific pathogen free conditions. All experiments performed at the University of Oxford were approved by the Oxford University Ethical Review Committee and were performed under UK Home Office project licence P79A4C5BA and personal licence I434A9E14.

### 2.2.2 Breeding of mice

Non-transgenic C57BL/6, B6SJL-CD45.1 mice were supplied by Biomedical Services (BMS), Oxford University. The providers of all other mouse lines used are detailed below.

#### 2.2.2.1 MD4 model transgenic mice

After confirming that the transgene was being expressed as desired, double-transgenic mice were produced by mating mHEL-KK(121) and sHEL (kind gift C.C. Goodnow(125)) transgenic lines with MD4 transgenic lines (kind gift of C.C.Goodnow(125)). All lines were backcrossed to C57BL/6 for a minimum of twelve generations before analysis (>99% C57BL/6).

#### 2.2.2.2 Lin28b transgenic strain

Lin28b transgenic mouse strain was obtained from Dr. Johannes Schulte (Charité Hospital, Berlin) (181). Lin28b cDNA had been introduced between FLP recombinase sites via a proprietary plasmid compatible with recombinase mediated cassette exchange (RCME). This plasmid had been transfected into B6S6F1 embryonic stem (ES) cells containing F3/FLP recombinase sites compatible for RCME at the *ROSA26* locus (**Fig. 2-1**). Mice were generated by injection of ES cells into tetraploid blastocysts(181). $Lin28b^{fl/+}$ mice were crossed with CD79a-cre (mb1-cre, M. Reth)

mice to produce mice expressing a B cell specific Lin28b strain. Lin28b$^{fl/+}$Mb1cre mice were then bred with Ig$^{HEL}$ and Ig$^{HEL}$/mHELKK transgenic mice to generate Ig$^{HEL}$Lin28b.Mb1cre and Ig$^{HEL}$mHELKK.Lin28b.Mb1cre transgenic mice. Lin28b transgenic mice were backcrossed to C57BL/6 for a minimum of four generations before analysis.

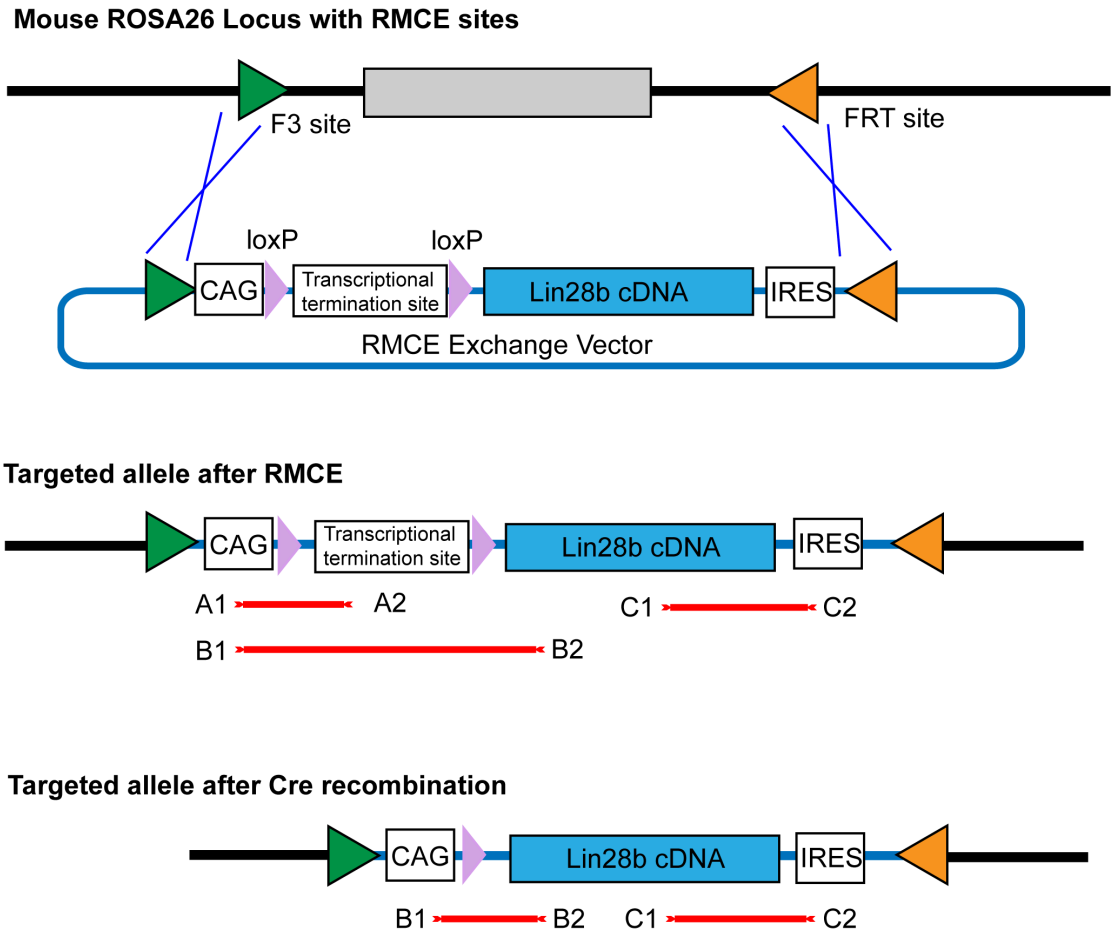



**Figure 2-1. Lin28b transgenic mouse design**(181,182)**.**

The chicken actin gene promoter (CAG), transcriptional termination site, murine Lin28b open reading frame (Lin28b cDNA) and internal ribosome entry site (IRES) were inserted between FLP recombinase sites via RMCE exchange vector. Cre recombination mediated the excision of the transcriptional termination site thus allowing Lin28b expression. A1, A2, B1, B2, C1 and C2 show PCR primer binding sites.

### 2.2.3 Ear punch DNA extraction for genotyping

Ear punches were used to identify and genotype individual mice at the time of weaning. DNA was extracted from ear punches by incubating the tissue with 1mg/ml proteinase K (Sigma) in ear punch buffer at 55°C for 40mins, vortexing the samples once after 20mins. DNA samples were then diluted 1/10 with PCR grade water and heated to 100°C for 5mins to inactivate the proteinase K. DNA was then stored at -20°C before PCR screens were carried out.

### 2.2.4 Genotyping and screening of mice by PCR

Mice were screened by PCR with 0.3μM of each primer (**Table 2-1**), 3.125μM of dNTPs, 2.5mM $MgCl_2$ and 0.025U/μl Taq DNA polymerase in 1x PCR buffer. The total volume was adjusted to 24μl using PCR grade water plus 1μl DNA template. PCR program was set as follow (**Table 2-1**).

For $Ig^{HEL}$/HEL screening, the Ig transgene band was 460bp, endogenous control band was 264bp and HEL band was smaller than endogenous band. For Lin28b screening, the A1A2 band was ~500bp, the B1B2 non-recombined band was 1836bp, the recombined band was 298bp, and C1C2 band was ~600bp. For Mb1cre screening, the wildtype band was ~400bp and Mb1cre band ~500bp(**Fig. 2-1**). Except in the case of A1A2 B1B2 and C1C2, which involved three separate reactions, all other primers were used together in the screening.

**Table 2-1. Details of primers and PCR programs used to screen transgenic and mutant mice.**

| Screen | Oligonucleotide Primers | | | |
|---|---|---|---|---|
| | primer | | sequence | [µM] |
| IgHEL/HEL | IgHEL primer | IgH F1 | 5'-gcgactccatcaccagcgat-3' | 10 |
| | | IgH F2 | 5'-ctggagccctagccaaggat-3' | 10 |
| | | IgHR1 | 5'-accacagaccagcaggcaga-3' | 10 |
| | HEL primer | HEL 3F | 5'-gagcgtgaactgcgcgaaga-3' | 10 |
| | | HEL 4R | 5'-tcggtacccttgcagcggtt-3' | 10 |
| Lin28b | PCR Genotyping Lin28b Mouse | A1 | 5'- gtgacattgacatccactttgc-3' | 10 |
| | | A2 | 5'-cccaaggcacacaaaaaacc-3' | 10 |
| | PCR to prove Cre-recombination | B1 | 5'- gcccgcggtgatgcctttgagg-3' | 10 |
| | | B2 | 5'-ggttcgtcctctgccagcccg-3' | 10 |
| | PCR amplification -/ sequecing of Lin28b Transgene | C1 | 5'-atgcagctctgcggcaccaa-3' | 10 |
| | | C2 | 5'-tccgctgcctgcaaagggtc-3' | 10 |
| Mb1Cre | | Mb-1 F | 5'-ctgcgggtagaaggggtc-3' | 10 |
| | | Mb-1 R | 5'-ccttgccaggtcagggagcc-3' | 10 |
| | | hCre F | 5'-acctctgatgaagtcaggaagaac-3' | 10 |
| | | hCre R | 5'-ggagatgtccttcactctgcttct-3' | 10 |

| Screen | PCR Conditions | | Cycle |
|---|---|---|---|
| IgHEL/HEL | Step1 | 95°C 5min | 1 |
| | Step2 | 95°C 10sec --> 60°C 30sec --> 72 °C 30sec | 35 |
| | Step3 | 72°C 10min --> 4 °C | 1 |
| Lin28b | Step1 | 95°C 5min | 1 |
| | Step2 | 95°C 10s --> 66°C 30s --> 72 °C 30s | 34 |
| | Step3 | 72°C 10min --> 4°C | 1 |
| Mb1cre | Step1 | 94°C 3min | 1 |
| | Step2 | 94°C 60sec --> 55°C 60sec --> 72 °C 60sec | 35 |
| | Step3 | 72°C 7min --> 4°C | 1 |

### 2.2.5 Preparation of radiation chimeras

All recipient mice were lethally irradiated with two doses of 4.5Gy gamma-irradiation separated by 3 hours, and received antibiotics (Baytril 0.04% in water bottles) for the first 3 weeks of their reconstitution.

Foetal liver cells were harvested at day 18.5 of gestation from embryos expressing the $Ig^{HEL}$ transgenic; neonatal liver cells were harvested at day 0-3 post-partum from pups expressing $Ig^{HEL}$ transgene. Adult BM cells were harvested when mice were 8 weeks or older. $1x10^7$ cells resuspended in 100-200 µl of sterile PBS were injected into the lateral tail vein of irradiated mHEL-KK and non-transgenic recipients. The animals were sacrificed at 8-10 weeks after reconstitution.

After collecting from organs, cells were counted and centrifuged at 1200rpm 4°C for 7mins before removal media. If cells were used fresh, cells would be re-suspended in sterile PBS. If cells were stored at -80°C, cells would be re-suspended in freezing media (90%FCS+10%DMSO) and stored in freezing container for -80°C, before transfer to liquid nitrogen. When needed, cells were taken out from the freezer, and thawed gently in 37°C water bath. 1ml thawed cells were added slowly to 9ml R10, centrifuged at 1200rpm 4°C for 7mins , resuspended in sterile medium and counts adjusted ready for injection.

### 2.2.6 Preparation of primary lymphocytes

Peritoneal lymphocytes were collected by carefully injecting (25 gauge needle) ~5ml of ice-cold cell medium (above) into the peritoneal cavity of euthanized mice. The fluid containing lymphocytes was collected using plastic pipettes and the peritoneal cavity was washed with more medium (up to 10ml total) to extract the remaining cells.

Spleens were cut in half, added to 10ml ice cold medium, and then mashed gently through a sieve to separate cells from stroma. BM samples were taken from one femur and tibia (after picking off all the fat and muscle with a tissue) and added to 5ml medium. A 25 gauge needle was used to flush the BM in ice cold medium. The cells were then passed through the needle until a unicellular cell suspension was obtained.

All tubes were topped up to 10ml final volume on ice, spun at 1700rpm for 5min at 4°C and resuspended in the following volumes of 2% medium: 10ml for spleen, 1ml for peritoneum, 5ml for BM. Cells were counted and kept on ice overnight if necessary.

## 2.3 Cellular Based Immunology Assays

### 2.3.1 Flow cytometry staining

The volume of each sample equivalent to $1x10^6$ cells was transferred to a round-bottomed 96-well plate (Falcon), and the wells were filled to a volume of 200µl with staining buffer. The plates were spun at 2000rpm 4°C for 2mins, and the media flicked-off. Then, cells were re-suspended with 25µl of staining mix, and incubated on ice, in the dark, for 30mins. Cells were washed twice by adding 200µl of staining buffer, spinning 2000rpm 4°C for 2mins and flicking-off media. Cells were re-suspended in 200µl staining buffer, transferred to a FACS tube (Falcon), and stored in the dark at 4°C before acquiring data with as little delay as possible. All antibodies used were titrated to optimize staining, and diluted in staining buffer immediately prior to use.

### 2.3.2 Intracellular flow cytometry staining

The volume of each sample equivalent to $10^6$ cells was transferred to a round-bottomed 96-well plate (Falcon), and the wells were filled to a volume of 200µl with

staining buffer. The plates were spun at 2000rpm 4°C for 2mins, and the media flicked-off. Cells were stained with surface marker cocktail and left on ice for 30mins in dark. Cells were washed twice by adding 200µl of staining buffer, spinning at 2000rpm 4°C for 2mins and flicking-off media. 100µl Cytofix/CytoPerm (BD) was then added per well, left for 20mins on ice in dark. 100µl perm/wash was then added to each well, spinning for 2000 rpm 4°C for 2mins and flicking-off media. Plates were washed in 200µl perm/wash, spinning 2000 rpm 4°C for 2mins and flicking-off media. Next of the 50ul intracellular staining cocktail was added to each well, left on ice for 30mins in dark (or 4°C overnight). Cells were washed twice with 200µl Perm/wash (BD). Cells were re-suspended in 200µl Perm/wash, transferred to a FACS tube (Falcon), and stored in the dark at 4°C before acquiring data.

**Table 2-2. Antibodies for Flow cytometry**

| Specificity | | Clone | Source |
|---|---|---|---|
| B220 | CD45R | RA3-6B2 | Biolegend |
| BAFFR | | 7H22-E16 | BD |
| BP-1 | Ly-51 | 6C3 | Biolegend |
| CD3e | | 145-2C11 | eBioscience |
| CD4 | | GK1.5 | eBioscience |
| CD5 | Ly-1 | 53-7.3 | Biolegend |
| CD8 | | 53-6.7 | Biolegend |
| CD9 | | MZ3 | Biolegend |
| CD11b | Mac-1 | M1/70 | eBioscience |
| CD19 | | 6D5, 1D3 | Biolegend |
| CD21/CD35 | CR2/CR1 | 7E9 | Biolegend |
| CD23 | FcεRII | B3B4 | Biolegend |
| CD24 | HSA | M1/69 | Biolegend |
| CD25 | IL2RA | PC61 | Biolegend |
| CD43 | Leukosialin | S7 | Biolegend |
| CD44 | | IM7 | Biolegend |
| CD45.1 | Ly-5.1 | A20 | Biolegend |
| CD45.2 | Ly-5.2 | 104 | Biolegend |
| CD69 | | H1.2F3 | Biolegend |
| CD80 | B7.1 | 16-10A1 | Biolegend |
| CD86 | B7.2 | GL1 | Biolegend |
| CD93 | AA4.1 | AA4.1 | Biolegend |
| DAPI | | | BIOTIUM |
| Gr-1 | Ly-6G | RB6-8C5 | eBioscience |
| HEL | | HyHEL9 | S.J. Gill-Smith |
| $IgD^a$ | $Igh\text{-}5^a$ | AMS-9.1 | Biolegend |
| IgD | $Igh\text{-}5^{pan}$ | 11-26c | Biolegend |
| $IgM^a$ | $Igh\text{-}6^a$ | DS-1,MA-69 | Biolegend |
| IgM | $Igh\text{-}6^{pan}$ | II/41 or RMM-1 | Biolegend |
| TCRγδ | | GL3 | Biolegend |
| Live dead dye | Zombie Aqua Dye | | Biolegend |
| Live dead dye | Zombie NIR | | Biolegend |

### 2.3.3 Cell sorting experiment

Samples were collected fresh and stained using the normal flow cytometry protocol (section 2.3.1). Single colour controls and Fluorescence Minus One (FMO) controls were prepared for each sorting panel. Cells were sorted with a FACS sorter (AriaIII), and collected in ice-cold medium (50% R10 + 50% FCS) or lysis buffer (in single cell RNAseq experiment) for further assays. I gratefully acknowledge Dr. Craig Waugh in the flow cytometry facility at Weatherall Institute of Molecular Medicine, for help with the cell sorting.

### 2.3.4 Enzyme-Linked Immunsorbance Assay (ELISA)

#### 2.3.4.1 IgM Sandwich ELISA

a. 96-well half-area flat-bottomed ELISA plates (Greiner) were coated with 25µl of 5µg/ml anti-mouse IgM in carbonate buffer pH 9.6 (0.2µm filter-sterilised), and incubated overnight at 4°C.

b. Plates were washed twice with PBS/Tw and once with PBS, before blocking with 50µl 5% milk (2.5g dehydrated fat-free milk per 50ml PBS) per well and incubating at 37°C for 1-3 hours.

c. During the incubation, serum dilutions were prepared in 1% milk (1% milk is made with 5% milk and PBS), as follows: 1/500,1/1000,1/2000,1/4000

d. Plates were incubated at 37°C for 1.5 hour and washed 6 times with PBS/Tw.

e. Plates were added with 25 µl/well of diluted AP(alkaline phosphatase)-conjugated goat anti-mouse IgM (1:2000 in 1% milk) and incubate at 37°C for 1 hour.

f. Plates were washed 6 times with PBS/Tw and before the addition of 50 µl phosphatase substrate (add 1 tablet of phosphatase substrate per 5ml NPP buffer).

After incubation at RT in the dark for around 10 mins, absorbance was measured at 405 nm with a model 550 Microplates Reader (BIO-RAD).

#### 2.3.4.2 Anti-HEL IgMa Capture ELISA

a. 96-well half-area flat-bottomed ELISA plates (Greiner) were coated with 25µl of 10ug/ml HEL in carbonate buffer pH 9.6 (0.2um filter-sterilised), and incubated overnight at 4°C.

b. Plates were washed 3xPBS/Tw, blocked with 50 µl of 1% BSA/PBS (0.2um filter-sterilised), and incubated 1h at RT.

c. Samples were added to 0.1% BSA/PBS and serially diluted 1 in 4.

d. After washing plates 3xPBS/Tw, 25ul diluted samples were added to each well. Plates were incubated for 2 hours at 37°C.

e. Plates were washed 5xPBS/Tw and then 25ul (0.5ug/ml) biotinylated anti-IgM$^a$ (DS-1;BD Pharmingen) diluted in ICE-T added to each well, and incubated 2 hours at 37°C.

f. Plates were washed 5xPBS/Tw,then 25ul/well 1/3000 dilution of avidin-alkaline phosphatase (Sigma A7294) diluted in 0.1% BSA/PBS added and incubated at 37°C for 1 hour.

g. Plates were washed 5xPBS/Tw, 2x 1XPBS, 1x TDW, and 1xNPP buffer. Plates were developed with 50ul/well 1mg/ml SIGMA104/NPP buffer, and absorbance measured at 405 nm with a model 550 Microplates Reader (BIO-RAD).

### 2.3.5 Enzyme-Linked ImmunoSpot Assay (ELISpot)

a. MultiScreenHTS-HA filter plates (MSHAS4510) were rinsed with 50µl freshly made 35% ethanol for 30s. Plates were washed 3 times with PBS.

b. Plates were coated with 50µl 5µg/mL anti-mouse IgM in PBS and incubated overnight at 4°C. Plates were washed 3 times with PBS.

c. Plates were blocked with 100µl R10 for 2h at RT or 30mins at 37°C.

d. Media were removed and to each well was added 100µl R10 followed by cells in 100ul R10. Samples were in duplicate.

e. Plates were incubated at 37°C overnight without disturbing.

f. Plates were washed 3 times with PBS+0.05% Tween 20, twice with PBS, and once more with distilled water, and were left in water for 5mins. Then plates were rinsed once more with PBS.

g. 50ul detection antibody (AP-conjugated anti-mouse IgM, 1:2000 in PBS-1%FCS) was added and plates incubated for 1h at 37°C or 2h at RT.

h. Plates were inverted to remove buffer and washed 5 times with PBS-0.05% Tween20 and once with PBS.

i. Plates were inverted and flicked firmly on tissue paper to dry. 50ul AP ELISpot substrate was added to each well and incubated at RT in the dark for typically 10 min (5-20 min) until spots were visible, before plates were washed thoroughly in tap water and dried for counting.

### 2.3.6 Calcium Flux

a. Samples from control and test cases were differently stained with APC-Cy7-B220 and Alexa Fluro®700-B220, and combined in each numbers.

b. Cells were re-suspended at $10^7$ cell/ml in HBSS with 0.01% Pluronic acid, 1 μM Fura Red, and incubate for 30 minutes at 37°C.

c. Cells were washed with HEPES saline solution H-HBSS (HBSS with 0.1% BSA, 1 mM $CaCl_2$, 0.5 mM $MgCl_2$ and 10 mM HEPES) and re-suspended at $10^7$ cells/ml in H-HBSS with surface marker (FITC-CD24, APC-CD43) and incubated for 30mins on ice.

d. Cells were washed and re-suspend at $10^7$ cells/ml and equilibrated 10-15 mins at 37°C in water bath.

e. 10x stimulants (10μg/ml anti-IgM, 100ng/ml sHEL and 5 μg/ml Ionomycin) were prepared in H-HBSS in FACS tube at 37°C in water bath.

f. The baseline signal of the cells was recorded for 20s before removing the tube and adding 180μl of the cells to 20μl 10X stimulant. The tube was replaced as quickly as possible recording made for a fixed period, typically 2-3min.

h. FlowJo was used for full analysis.

## 2.4 Molecular Based Assays

### 2.4.1 RNA isolation with RNA-queous® micro Kit (Ambion)

a. Samples were aliquoted to less than 500,000 cells/tube, spinning at 2000rpm for 10min at 4°C, and supernatant removed. Cells were washed with 500µl PBS, and were centrifuged at 2000rpm for 5min at 4°C, and supernatant again removed.

c. 100µl lysis buffer was added to each tube and cells were re-suspended by vortexing vigorously for ~2mins.

d. 50µl 100% ethanol was then added to each tube (note, fresh ethanol was needed, as ethanol absorbs moisture from the environment, thus changing the final concerntration) and vortexed briefly but thoroughly.

e. 150µl lysate/ethanol was transferred to a Micro Filter Cartridge. The tube was assembled and centrifuged at max speed for 10min at 4°C.

f. 180µl Wash Solution1 was added to the same tube, was centrifuged at 12,000rpm for 30sec at 4°C. The Micro Elution Tube was then replaced.

g. 180µl Wash Solution2/3 was added and the cartridge centrifuged at 12,000rpm for 30sec at 4°C.

h. Step g was repeated. The Micro Elution Tube was again replaced. The tube was centrifuged at 13,000rpm for 1min at 4°C. The Micro Filter cartridge was transferred into a new micro Elution tube.

i. 10µl of Elution Solution(Rnase-free DEPC-treated water) (75°C) was applied to the center of the filter. The tube was stood at RT for 1min, then centrifuged at maximum speed for 1 min at RT. This was repeated with a second 10µl Elution Solution

j. Sample quality was checked on a RNA nanodrop.

k. (Optional DNase treatment): 2µl DNaseI reaction buffer (Invitrogen) and 2µl DNaseI (Amplification Grade, 1U/2µl) were added to 18µl RNA. The mix was incubated for 15 mins at 25°C. Then to inactivate the DNaseI, 2ul of 25mM EDTA solution was added to the reaction mix. The mix was incubated for 10 mins at 65°C.

**2.4.2 First-strand cDNA synthesis using random primers**

a. The reaction mix was made with 1ng-5ug total RNA or 50-500ng polyA RNA, 1µl of 10mM dNTPs and 1µl of 50ng/µl random hexamers in a 0.5ml tube. DEPC treated water was added to adjust the reaction mix into 10µl. The reaction mix was incubated at 65°C for 5 mins, then put on ice for at least 1min.

b. In a separate tube, 2x reaction mix was prepared, including 2µl 10xRT buffer, 4µl 25mM Mg, 2 µl 0.1M DTT, 1µl 40 units/µl RNase OUT and 1µl of SuperScript III RT.

c. 10µl of 2x reaction mix was added to the previous tube on ice, mixed gently, and collected by brief centrifuge. (**Control:** 1ul DEPC-water was added instead of the RT) The reaction mix was incubated at 25°C for 10mins, at 50°C for 50mins, at 85°C for 5mins and then chilled on ice. The reaction was collected by brief centrifugation. 1 µl of RNaseH was added to each tube and incubated for 20mins at 37°C.

d. The cDNA sample was tested using nanodrop and stored at -20°C or used for qPCR assay immediately.

### 2.4.3 Real-time PCR

a. Each cDNA sample was diluted 1 in 4 (60 µl $H_2O$ was added to a 20 µl sample).

b. 20 µl was taken from each tube, and pooled into standard 1.

c. Standards were diluted 1 in 4 to make St 1, 2, 3, 4, 5.

d. The remaining 60 µl sample was diluted 1 in 4.

e. The master mix was made with 10 µl of SYBR Green, 0.4 µl of 10 µM forward primer, 0.4 µl of 10 µM reverse primer, 1.2 µl of $H_2O$ and 8 µl of cDNA.

f. The reaction mix was put on real-time PCR machine with a program of 94 °C for 15mins, 40 cycles of 94°C for 15s, 60°C for 30s, 72°C for 30s.

g. Data was collected and analyzed after the program finished.

**Table 2-3. real-time PCR primers for SYBR Green system.**

| **Primer** | **Sequence (5'-3')** |
|---|---|
| CD19_mRNA_F | TCATCACCCCTTGCCTAAGA |
| CD19_mRNA_R | AGTAGGTTCACAGGTCCCAA |
| Lin28b_mRNA_F | GCACCAAGAGAAGTGGGAGG |
| Lin28b_mRNA_R | CTGCAAACGCTTTCGTGGAA |
| Lin28b_exon3-4_F | AGCCCCTGCTTAGGAAGTGA |
| Lin28b_exon3-4_R | TTCTTCTCGCACAGTCCACA |
| Lin28b_exon2-3_F | CGAGAGGGAAATCCCTTGGA |
| Lin28b_exon2-3_R | CTCAAGGCCTTTGGGGGATT |

### 2.4.4 Microarray experiment

RNA was isolated using the Ambion kit/RNA-queous micro Kit (**section 2.4.1**). I gratefully acknowledge the staff at the High-Throughput Genomics Group at the Wellcome Trust Centre for Human Genetics who processed the samples and performed microarray experiment using Mouse WG6v2.0 Expression Beadchip (Illumina). Briefly, RNA was QC'ed using a Bioanalyser and 500ng of total RNA was reverse transcribed to synthesize first and second strand complementary DNA (cDNA), followed by *in vitro* transcription to synthesize biotin-labelled complementary RNA (cRNA) using a TotalPrerp-96 RNA amplification kit from Ambion (Ambion). A total of 1500ng of biotin-labelled cRNA from each sample was used in the hybridization process at 58°C for 18h. The hybridized BeadChip was washed and labeled with streptavidin-Cy3, according to the manufacturer's protocol. The chip was scanned using Illumina's iScan Scanner to generate IDAT files. A gene expression dataset was created using Illumina's GenomeStudio® software using generated IDAT files to carry out QC checks of the procedure and to provide files including QC_Sample Table Control, Control Probe/Gene Profile, and Sample Probe/Gene Profile.

### 2.4.5 RNA sequencing

RNA was isolated with Ambion kit/RNA-queous micro Kit (**section 2.4.1**). Again I acknowledge the High-Throughput Genomics Group at the Wellcome Trust Centre for Human Genetics for processing the RNA samples and performing the RNA sequencing. Briefly, the mRNA libraries were prepared with the Illumina TruSeq Stranded mRNA Sample Prep Kit (Illumina Inc, San Diego, California, USA). For polyA selection assays, the mRNA fraction was selected from the total RNA provided before conversion to cDNA. For ribosome depletion assays, the ribo-depleted fraction was isolated from the total RNA provided before conversion to cDNA. After

that, second strand cDNA synthesis incorporated dUTP. The cDNA was end-repaired, A-tailed and adapter-ligated. Prior to amplification, samples underwent uridine digestion. The prepared libraries were size selected, multiplexed and QC'ed before paired end sequencing over one lane of a flow cell on HiSeq2500 or HiSeq4000. Data were collected as fastq files.

### 2.4.6 Large-scale single cell qPCR (Biomark) on NL and BM

**Pre-amplification (in clean room hood)**

a. The mastermix was made with 1µl of each TaqMan assay (Invitrogen) and topped up to 100 µl with TE buffer (Invitrogen). This master mix was prepared a few days before the sort and stored in a -20°C freezer. It can be kept for up to 6 weeks.

b. RT-STA mix was freshly prepared before sorting. This contained 2x cells direct reaction mix(Invitrogen), 0.2U/µl SUPERase (Ambion), 0.2x assay mix, 0.12x SuperScript® III RT/Platinum® Taq Mix (with RNaseOUTTM Ribonuclease Inhibitor) and topped up with TE buffer (Invitrogen). Aliquots of the RT-STA mix (5µl for single cell and 10µl for 100 cells) were transferred to a 96-well PCR plate.

c. FL and BM cells were freshly harvested and processed. Cells were stained with $IgD^a$-FITC, $IgM^a$-PE, CD24-PerCPCy5.5, PE-Cy7CD23- PE-Cy7, B220-APC, Gr1-Alexa Fluro®700, CD3e- APC-Cy7, DAPI and CD21-BV605. Single cells were sorted into wells with 5µl RT-STA mix directly without a lysis step. 20 NL live $B220^+Gr1^-CD3e^-CD24^{mid}IgMa^+IgDa^-CD23^-CD21^-$ immature B cells and 20 BM live $B220^+Gr1^-CD3e^-CD24^{mid}IgMa^+IgDa^-CD23^-CD21^-$ immature B cells were sorted into 40 wells. In addition, 100 FL immature B cells, 100 BM immature B cells, 100 BM live $B220^+Gr1^-CD3e^-CD24^{lo}IgMa^+IgDa^+CD23^+CD21^+$ mature B cells, 100 live $B220^-Gr1^-CD3e^+$ T cells, and 100 BM live $B220^-Gr1^+CD3e^-$ myeloid cells were sorted into 5 wells, as

control samples with 100cells into 10µl RT-STA mix. Three wells without template were used as a negative control.

d. The PCR wells were then sealed using PCR tube lids and spun down at 4600rpm for 30 sec. The reaction mix was placed in a PCR machine for pre-amplification, with 50°C for 15min, 95°C for 2min and 20 cycles of 95°C for 15sec, 60°C for 4min.

e. After pre-amplification, the cDNA was diluted with 4x vol TE (i.e. 10µl sample were added with 40µl TE), vortexed and briefly spun down. Samples could then be stored at -20°C for up to 3 months.

**Real-time PCR using a Fluidigm 48.48 real-time PCR chip**

Samples were processed following the Fluidigm 48.48 Fast Real-Time PCR Workflow Quick Reference:

a. The assay mix plate was made by adding 3µl of each individual assay and 3µl of sample loading reagent to 48 wells of a 96 well plate in a DNA-free hood.

b. The sample mix plate was made by adding 3µl 2x Taqman Universal PCR Master Mix, 0.3µl 20x GE sample loading reagent and 2.7µl cDNA to 48 wells of a 96 well plate in a DNA-free hood.

c. The 48.48 dynamic arrays were injected with control line fluid and primed into the Integrated Fluidic Circuit (IFC) Controller MX.

d. Assays and samples were added into the plate without bubbles. The plate was loaded on the IFC to collect data.

### 2.4.7 Smart-Seq of 4hr sHEL stimulated BM and FL immature B cells

**Cell stimulation and sorting**

a. FL and BM samples were taken from $Ig^{HEL}$ 3-6 days old and 10-13 weeks old mice. Samples were processed and counted for white blood cells. Cells were aliquoted into 1million cells per well in a 96 well plate, and spun at 2000rpm for 2min at 4°C.

b. Cells were re-suspended in 200µl warm R10 medium with/without 100ng/ml sHEL. Cells were incubated at 37°C for 4 hours.

c. Cells were washed in ice-cold FACS staining buffer twice, spinning at 2000rpm for 2min at 4°C. Cells were stained with BAFFR-PE, CD43- PerCPCy5.5, B220-APC, IgD- APC-Cy7, DAPI and CD24-BV605 and $B220^{+}CD43^{-}BAFFR^{+}IgD^{-}CD24^{mid}$ immature B cells were sorted by flow cytometry.

d. 100 cells/sample were sorted directly into ice-cold cell lysis buffer (0.4% (vol/vol) Triton X-100 and 2 U/µl RNase inhibitor, 2.5mM dNTPs (Thermo-Fisher), 2.5µM Oligo (Oligo-dT30VN)) and immediately frozen in dry ice.

**RNA library preparation**

Sorted cells were processed using the Smart-Seq v4 Ultra Low Input RNA kit (Clontech), following the Smart-seq2 protocol with minor changes(183).

a. The cell reaction was mixed with 2µM 3' SMART-Seq CDS Primer II A, preheated at 72°C for 3mins. To make the first strand synthesis mix, 1xUltra Low First-strand Buffer, 1.2µM SMART-Seqv4 Oligonucleotide, 1U/ml RNase Inhibitor and 10U/µl SMARTScribeTM Reverse Transcriptase to the tubes. The tubes were incubated at 42°C for 90mins, 70°C for 10mins and 4°C on hold.

b. The PCR product was then amplified for 15 cycles by adding 1x SeqAmp PCR buffer, 0.24μM PCR PrimerII A, 0.025U/μl SeqAmp DNA Polymerase. The tubes were incubated at 95°C for 1mins, 15 cycles of 98°C for 10 sec, 65°C for 30 sec and 68°C for 3 mins, 72°C for 10mins and 4°C on hold.

c. The cDNA product was purified with AMPure XP beads and quantified using the Agilent 2100 Bioanalyzer.

d. The tagmentation and library building was performed by the High-Throughput Genomics Group at the Wellcome Trust Centre for Human Genetics. In brief, 1 ng of pre-amplified cDNA was tagmented and indexed using the Nextera XT DNA Sample Preparation Index kit (24 index primers, manufacturer (Illumina)), according to manufacturer's instructions. Following library preparation, the samples were sequenced on an Illumina HiSeq 4000 instrument as 75 bp paired-end reads.

## 2.5 Bioinformatic Analysis

### 2.5.1 Microarray data analysis

I am very grateful to Dr. Helen Lockstone (WTCHG), who helped me to analyze the microarray data. The data was processed in R. Data were QC'ed using ggplot, background corrected and normalized using VSN package version 3.47.1 (variance stabilization and calibration for microarray data). VSN data were analyzed using limma package version 3.35.12 (Linear Models for Microarray and RNA-Seq Data). Differentially expressed probes were annotated using both the original Illumina and updated annotations from BioConductor package illuminaMousev2.db.

### 2.5.2 RNA sequencing data analysis

RNA sequencing analysis was performed using CGAT Pipelines and tools (https://github.com/CGATOxford/CGATPipelines and(184)). Briefly, reads were aligned to the mm10 mouse genome using hisat2 version 2.1.0(185), and reads were quantified over feature annotations (ensemble81) using featureCounts program version 1.4.6 within the Subread software package(186). DESeq2 was used for statistical analysis of the differential expression for each gene between groups. Typically a gene was considered differentially expressed if the log2 fold change was +/- 1 and significance value was adjusted P value < 0.01, adjusted for FDR due to multiple testing procedures to control for type I error. Clustering and heat maps were generated in R with pheatmap package version 1.0.8. For heat maps, expression values were scaled per gene. Venn graphs were plotted in R with VennDiagram package version 1.6.17.

# Chapter3. Identification of the Lin28b/let-7 bimodal switch in B cell ontogeny

## 3.1 Introduction

Understanding how B cells are positively and negatively selected by self and foreign antigens is of fundamental importance in the field of adaptive immunity. In this respect, B1 and B2 B cells have distinct development pathways and functions. B1 B cells are mainly generated in the early ontogeny, after which they are renewed by proliferation, particularly in the body cavities. B1 B cells also provide a bridge between the innate and adaptive immune systems by expressing a preselected antibody repertoire against common pathogens, or generate autoantibodies that appear to protect against autoimmunity. However, the underlying differences between B1 B and conventional B2 B cells, and what determines the switch in positive and negative selection during life, are obscure.

In this project, I use the MD4 $Ig^{HEL}$ transgenic mouse model(118), which I have already described in the introduction section 1.3.2.2, to study B1 B cell generation. In 2003, Ferry et al. generated a transgenic mouse strain (mHEL-KK), in which HEL functions as a neo-self antigen and retained intracellularly(121). Instead of negative selection and tolerance generation, which is observed in $Ig^{HEL}$/mHEL and $Ig^{HEL}$/sHEL mice, autoreactive B cells in $Ig^{HEL}$/mHEL-KK double transgenic mice undergo positive selection to form B1 B cells (**Fig. 1-4**). B1 B cells, especially B1b B cells are enriched in peritoneal cavity in $Ig^{HEL}$/mHEL-KK mice, with a high level of serum natural $IgM^a$ antibody and anti-HEL specific $IgM^a$ secreting plasma cells(121). This mouse model

provides a useful platform to study B1 B cell positive selection, since the B cells can be observed as a clone and the mHEL-KK neo-self antigen is well controlled.

Using neonatal liver (NL) and adult bone marrow (BM) cell transfer experiment, I confirm that the occurrence of positive and negative selection largely coincides with early and late ontogeny. I report a genomic and bioinformatic approach to investigate the key regulator for this positive/negative selection, including gene expression microarray, RNA-seq, microRNA-seq, single cell qPCR and open source online database. The results identify an oncological switch in the Lin28b/let-7 axis, which has been reported to be a negative loop essential for stem cell proliferation and differentiation, and has more recently been found to be important in B1 B cell generation.

## 3.2 Results

### 3.2.1 B1 B cell get positive selection in $Ig^{HEL}$/mHEL-KK model but restrict to fetal/neonatal stage

Previous BM reconstitution experiments revealed a poor yield of B1 B cells in adult recipients(52) whereas fetal/neonatal liver (FL/NL) cells are able to generate good numbers of B1 B cells. This has been reported to define a developmental switch between early and late ontogeny(91). The $Ig^{HEL}$/mHEL-KK model shows that this developmental switch also affects positive and negative selection, since it has been reported that neonatal liver is more able than adult BM to reconstitute B1 B cells in the $Ig^{HEL}$/mHEL-KK mouse model.

To confirm the reports of the ontological change in the $Ig^{HEL}$/mHEL-KK mouse model, I reconstituted lethally irradiated adult mHEL-KK transgenic or WT mice with $Ig^{HEL}$ NL or adult BM cells. The recipient mice were sacrificed 8 weeks after reconstitution. Flow cytometry showed that the $Ig^{HEL}$ NL donors generated B2 B cell population in the absence of self-antigen, and B1 B cell population in the presence of the mHEL-KK self-antigen. In contrast, $Ig^{HEL}$ adult BM donors also generated B2 population in the absence of self-antigen, but a reduction of both B1 and B2 B cells in the presence of self-antigen (**Fig. 3-1**).

This result confirmed that positive selection is largely restricted in early ontogeny. The difference between FL/NL and adult BM cells may be due to different mechanism of selection between early and late ontogeny immature B cells.

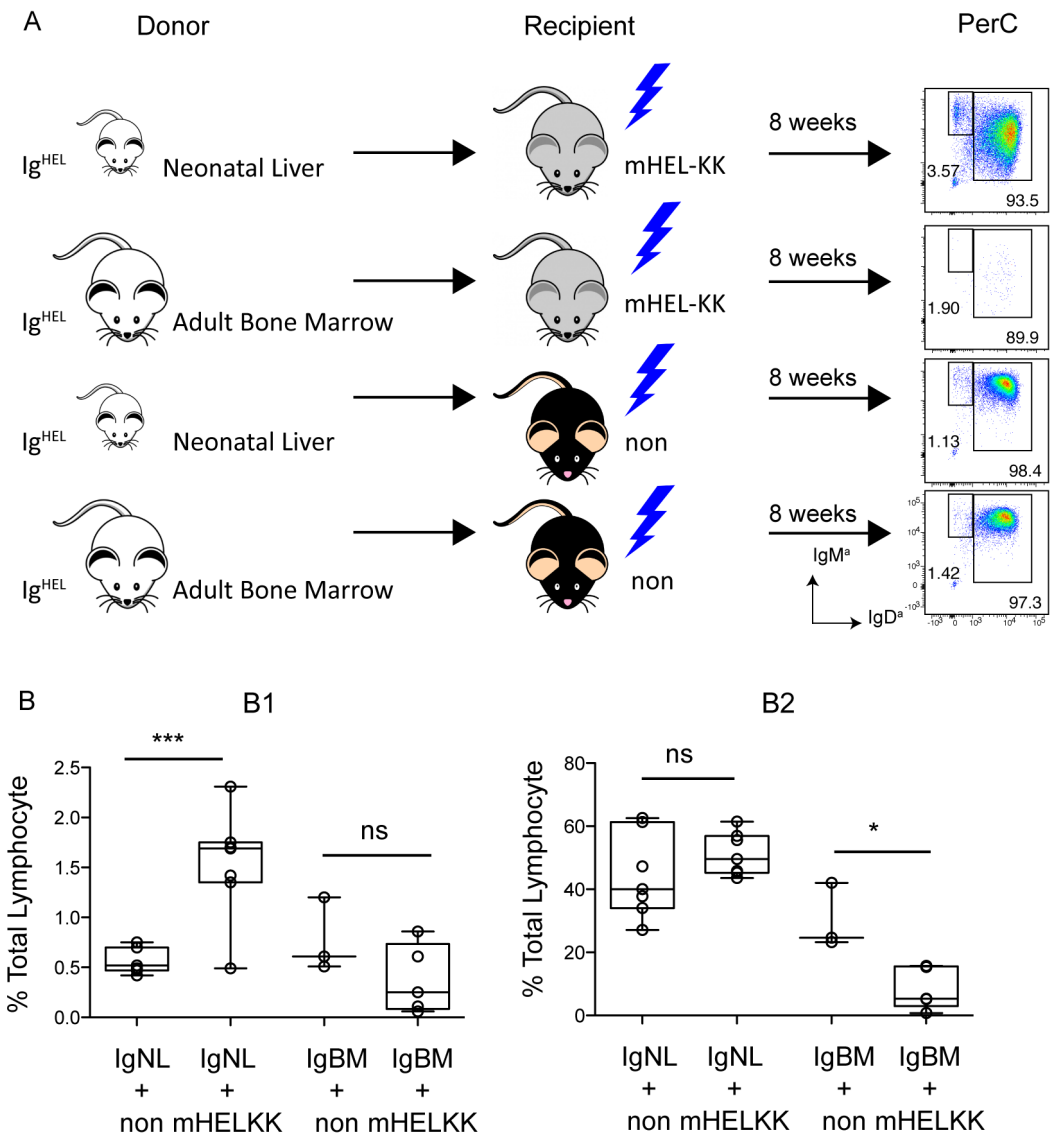



**Figure 3-1. B1 B cell positive selection with mHEL-KK self-antigen is restricted to early ontogeny.** Around 5x10$^6$ cells, from Ig$^{HEL}$ FL/NL or Ig$^{HEL}$ adult BM (CD45.2$^+$) were i.v. injected into lethally irradiated mHEL-KK/B6SJL CD45.1(Ly5) or WT CD45.1 mice to reconstitute B cell populations. B cell populations were phenotyped by flow cytometry. (A) Representative flow cytometry plots of peritoneum, gated on CD45.2$^+$B220$^{lo/+}$CD19$^+$, stained for IgM$^a$ and IgD$^a$, showing B1 (IgM$^{a+}$IgD$^{a-}$) and B2 (IgM$^{alo/+}$IgD$^{a+}$) B cells. (B) Peritoneal B1 and B2 B cells percentage of total lymphocytes. Columns show the mean, bars represent the 95% confidence and dots show individual data points (*p<0.5, *p<0.01, ***p<0.001, unpaired t-test).

### 3.2.2 The transcriptomic signature of $Ig^{HEL}$ neonatal liver and adult bone marrow immature B cells reveals a Lin28b/let-7 bimodal switch

The occurrence in the switch in positive selection during ontogeny led me next to look for an underlying mechanism. Initially my approach was to try to find a biochemical signature correlating with the change in development. Since immature B cells are the first to bear intact surface BCR and be liable to selection, I started by focusing on this sub-population.

To compare $Ig^{HEL}$ NL and $Ig^{HEL}$ BM immature B cells, I flow-sorted $5x10^5$ immature B cells aliquot from 3 day old NL samples and 8 weeks old adult BM samples, gated on $B220^{+}IgM^{a+}IgD^{a-}$ (**Fig. 3-2A**). Total RNA was isolated and quality controlled before sending for Illumina whole genome microarray, RNA sequencing and microRNA sequencing.

#### 3.2.2.1 Illumina Microarray

To initiate the study, I analysed RNA samples using probes on Illumina MouseWG-6_V2 chips. Data were processed in R. The list of differentially expressd genes included 304 genes with adjusted P-value less than 0.05, including 124 upregulated in NL(**Fig. 3-2B and Table 3-1)** and 180 upregulated in BM(**Fig. 3-2B and Table 3-2**). Genes such as Igf2bp3 and H19 were detected with several different probes, and were highly expressed in NL, but nearly absent in BM.

#### 3.2.2.2 RNA-seq

Samples from the same immature populations were also sent for RNA-seq. The libraries were built by poly-A selection, and sequenced for 50bp, paired end reads, with 35million/sample on HiSeq2500. Genes that were differentially expressed between NL and BM were filtered by adjusted P value under 0.05 and fold change over 2. Among these genes, 264 were upregulated in NL and 240 upregulated in BM

(**Fig. 3-2C**). Genes including Lin28b, Igf2bp3, Igf2, Hmga2, H19, Arid3a and Bhlhe41 were again highly expressed in NL compared to BM.

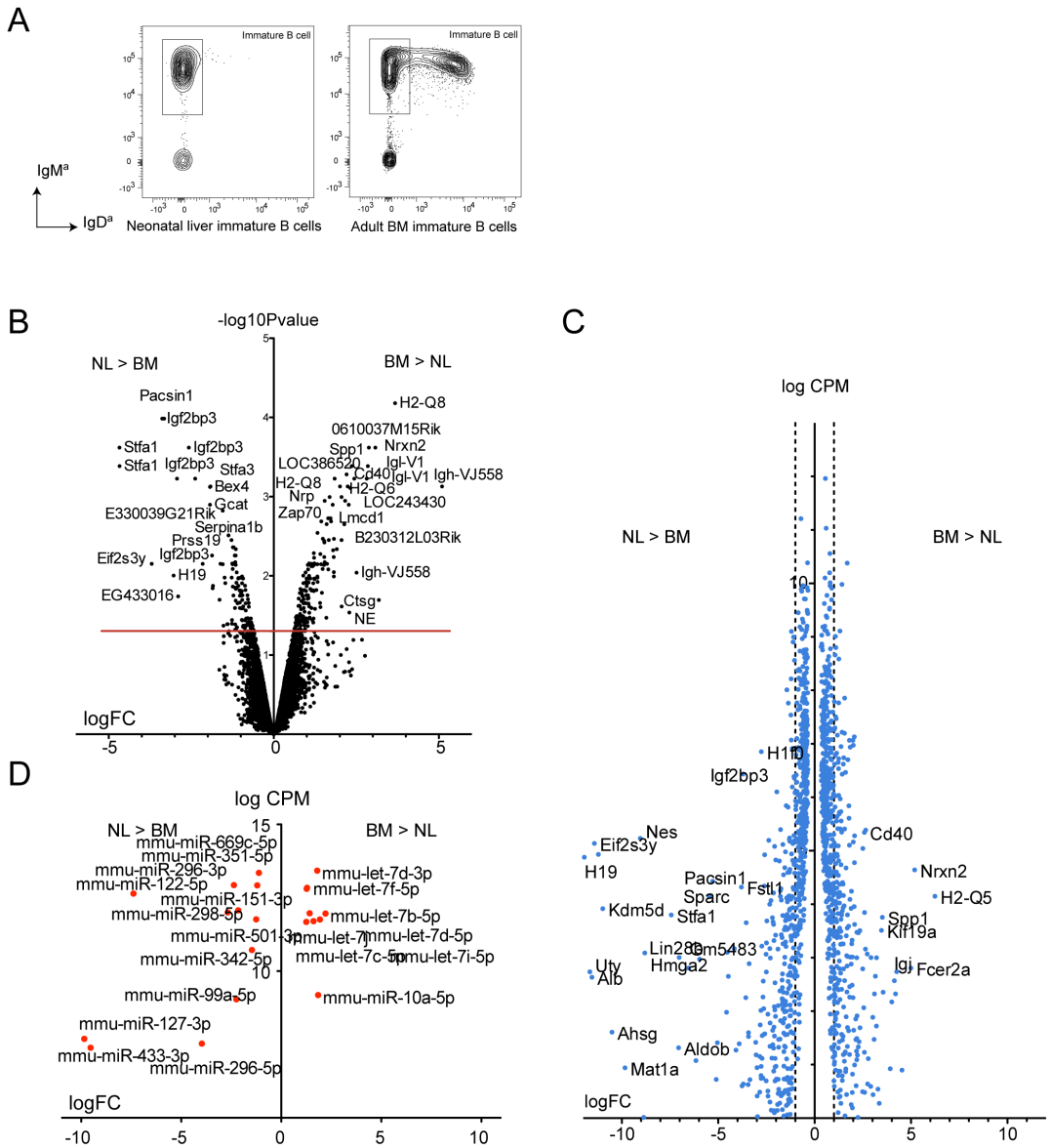



**Figure 3-2. Transcriptomic analysis of NL and BM. (**A) Sorting gate for immature B cells from NL and BM. B220$^{+}$ B cells were stained for IgM$^{a}$ and IgD$^{a}$ and gated on IgM$^{a+}$IgD$^{a-}$(n=3). (B) Volcano plot shows logFC(x-axix) against –log10 of adjusted P-value(y-axis) of all data points (probes) in microarray dataset. Red lines show threshold of adjusted-P-value = 0.05(n=3). The left and right panels show genes with higher expression level in NL and BM respectively. (C) Volcano plot shows all data points with adjusted P value over 0.05 in RNA-seq. Dash lines shows logFC=1/-1

(n=3); (D) Volcano plots shows all data points with adjusted P value over 0.05 in microRNA-seq(n=3).

#### 3.2.2.3 MicroRNA Sequencing

Since Lin28b is a RNA binding protein that blocks the biogenesis of let-7 miRNAs posttranscriptionally(84), I proceeded to check the miRNA expression pattern in NL and BM immature B cells. To do this, I sent the same samples for microRNA sequencing (50bp, paired end, ~8 million reads/sample on HiSeq2500). The result shows that let-7 family miRNAs are highly expressed in BM immature B cells but not in NL, which is in agreement with a switch from FL/NL (Lin28b$^{+}$) to adult BM (let-7$^{+}$) (**Fig. 3-2D and Table 3-5**).

#### 3.2.2.4 QPCR and protein level validation

To further validate Lin28b/let-7 bimodal switch in individual immature B cells in early and late ontogeny, I performed a qPCR on up to 20 flow sorted single immature B cells from NL and BM. The qPCR result identified 2 cells from NL that were detectably expressing Lin28b, but no expression was found in adult BM. All 19 cells from NL expressed the Lin28b target, Igf2bp3, compared to only 3 cells from BM. Six NL cells expressed Myc, but no cells from BM. In slight contrast, 18 cells from NL expressed Arid3a, which was subsequently found to be a transcriptional regulator of B1 B cell development(106), and 10 cells from BM (**Fig. 3-3A**).

Alongside the transcriptomic data, the Lin28b expression pattern was also different when evaluated at a protein level using flow cytometry. By this assay, Lin28b was strictly expressed in liver in early ontogeny (**Fig. 3-3B**).

Collectively, these data show that Lin28b and its definite or probable targets Igf2bp3, Hmga2, H19, Arid3a and Bhlhe41 are highly expressed in NL immature B cells; while

let-7 family miRNAs are highly expressed in BM immature B cells. Lin28b and let-7 expressing in the opposite trend, are likely to regulate different downstream targets.

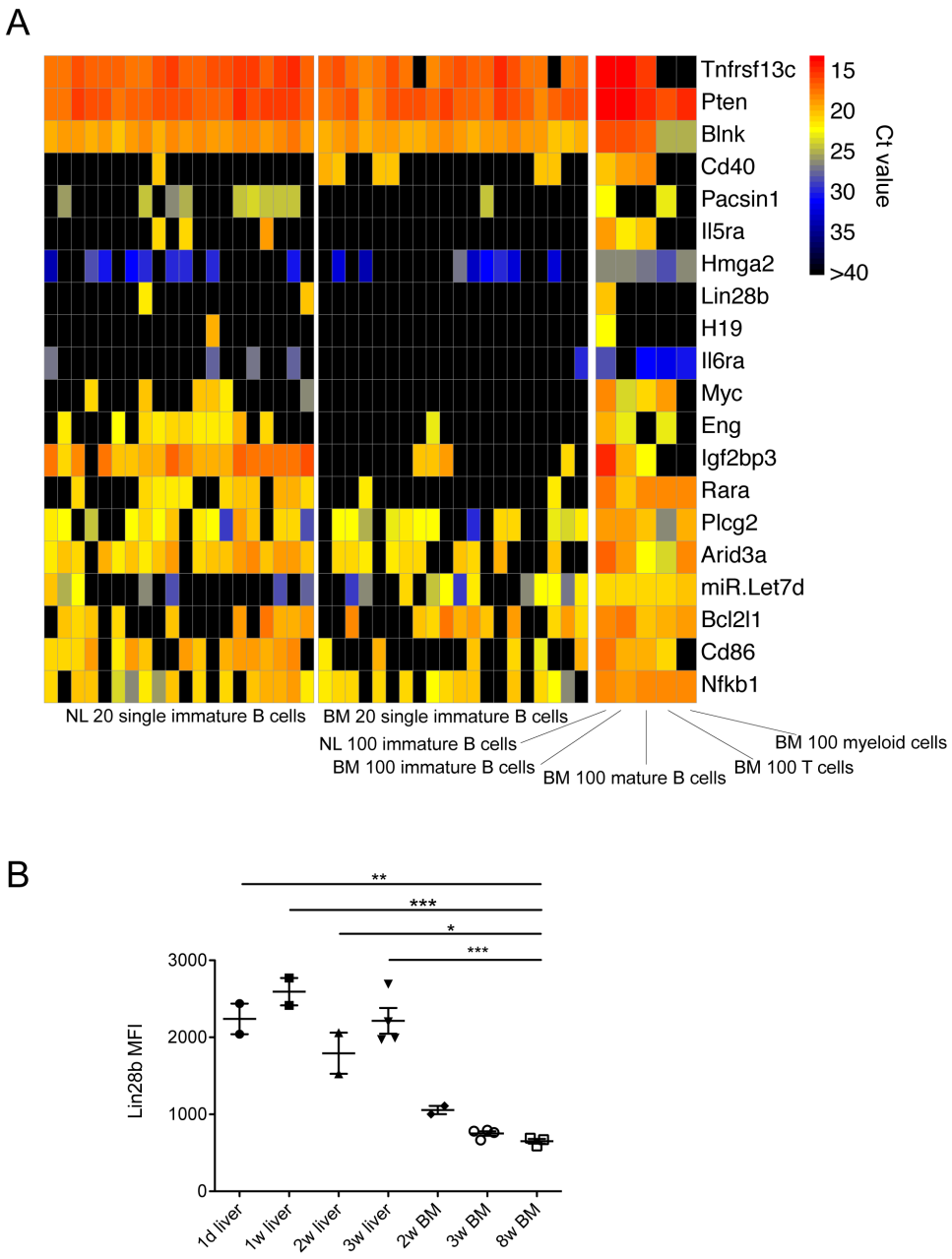



**Figure 3-3. Lin28b/let-7 axis validation.** (A) Biomark single cell qPCR for selected genes. RNA samples were collected from flow-sorted individual $Ig^{HEL}$ NL and $Ig^{HEL}$ BM single immature B cells (20 each), and bulk populations (100 cells each) from $Ig^{HEL}$ NL and BM immature B cells, $Ig^{HEL}$ BM mature B cells, $Ig^{HEL}$ BM T cells, and

$Ig^{HEL}$ BM myeloid cells. The heatmap shows Ct Values. (B) Intracellular staining of Lin28b on $Ig^{HEL}$ immature B cells, gated on $B220^{+}IgM^{a+}IgD^{a-}$.

### 3.2.3 The timing of the Lin28b/let-7 switch ontogeny

Since the Lin28b-let-7 axis was observed to be differentially regulated in NL and adult BM, I wanted to explore at what stage immature B cells lose Lin28b expression. To investigate this, I picked a 3 week time point, when B cell progenitors have almost finished transferring from NL to BM. It also marks weaning and the switch point from neonatal to adult stages.

I sorted immature B cells from the BM of 3 week old $Ig^{HEL}$ mice, generated total RNA and sent these samples with NL and adult BM immature B cell RNA for RNA sequencing. $5x10^5$ $B220^{+}IgM^{a+}IgD^{a-}$ immature B cells were taken from 3w and 10w mice BM, with 3 biological replicates. The libraries were built by ribosome depletion and sequenced for 75bp, paired end, ~40 million reads/ sample on a HiSeq4000.

Data were analyzed using CGAT pipeline. There were 67 genes are significantly different between 3w and 10w BM, with adjusted P value less than 0.05 and more than 2-fold change (log2FC > 1). Amongst these genes, 39 were more highly expressed in 3 week BM (**Table 3-7**) and 28 genes in 10 week BM(**Table 3-8**).

Within the 39 genes highly expressed in 3w BM immature B cells, 27 were also found highly expressed in NL immature B cells: for example, Igf2bp3 is still detectably expressed at 3w, but Lin28b is not (**Fig. 3-4**). Of 28 genes under-expressed in 3w BM immature B cells, 19 of them were also under-expressed in NL immature B cells compared to adult BM (**Fig. 3-4**). This Lin28b expression pattern is in agreement with Lin28b protein level in NL, 2w BM, 3w BM and 8w BM, which is detected by flow cytometry (**Fig. 3-3B**).

To summarize these data, the Lin28b expression level gradually decreased in whole populations during ontogeny. This may account for progressive phenotypic changes in immature B cells during relatively early ontogeny. The presence of positive feedback loops within the Lin28b/Let7 axis, means it is likely that this switch will be binary.

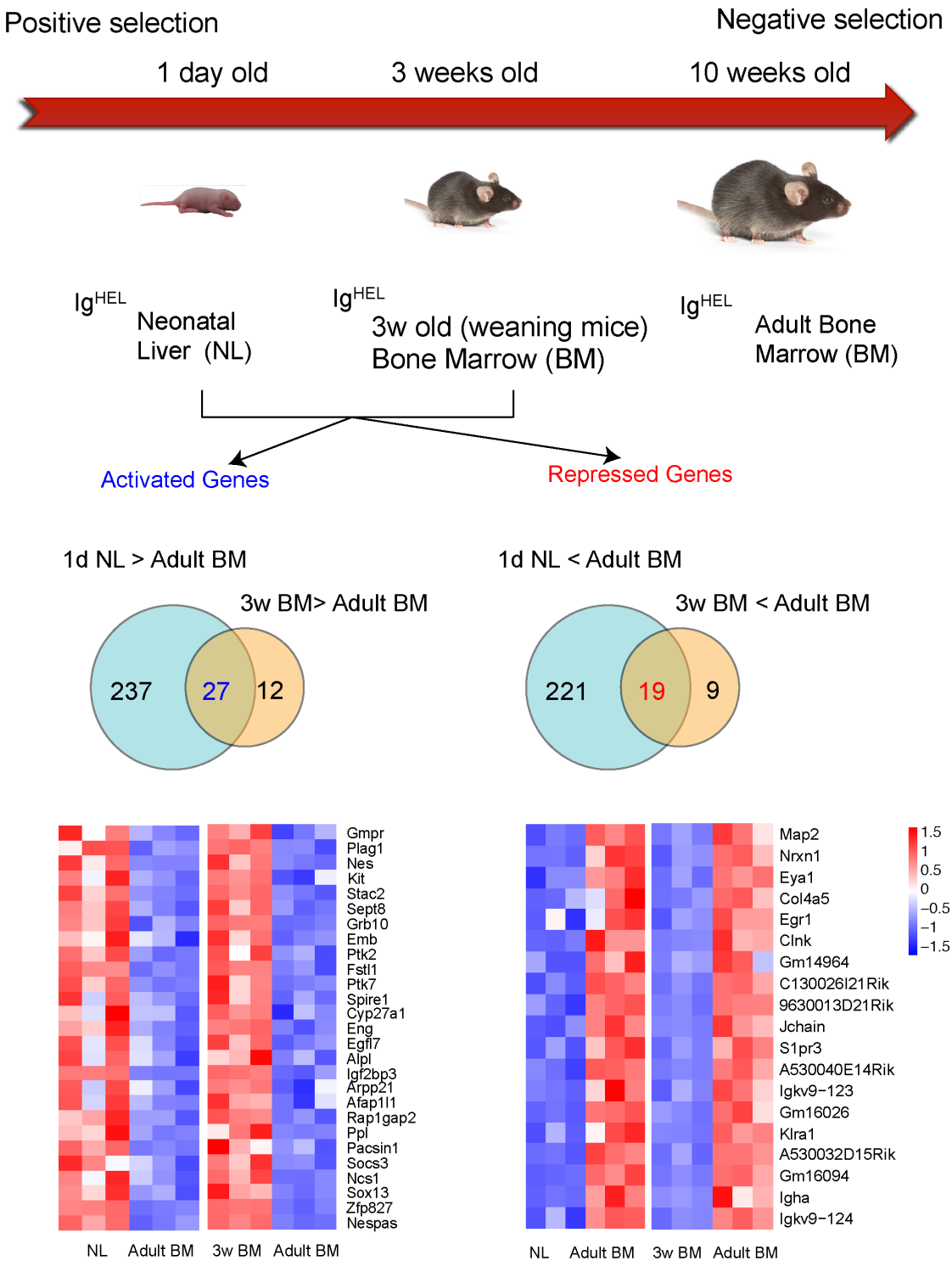



**Figure 3-4. Immature B cell transcriptome during different ontogeny stages.** Diagram shows NL, and 3w and adult BM RNA-seq. Venn graphs and heatmaps show common activated and repressed genes in early ontogeny compared to late ontogeny.

### 3.2.4 A hierarchy of differences during ontogeny: the Lin28b/let-7 balance is maintained during B cell development, but some targets are immature B cell specific

After identifying differences in the expression of genes in immature B cells during ontogeny, an important secondary question was to what extent these varied during B cell development and whether any were specific to the immature cell stage when the BCR was first expressed.

To address this question, I compared the subsets of transcripts that are differentially regulated in FL/NL versus adult BM transcriptomes, focusing on genes that are differentially expressed in immature $Ig^{HEL}$ B cells (MD4 Hardy Fraction E), immature non-transgenic B cells (NonTg Hardy Fraction E) and non-transgenic Pro B cell precursors (B6 Hardy Fraction ABC), all in C57BL/6 mice (**Fig. 3-5A**). The first dataset was generated from the RNAseq data described in section 3.2.1 (**Fig. 3-2C**), the latter whole genome microarray datasets (GSE15907) downloaded from ImmGen website (www.immgen.org).

This analysis revealed 13 transcripts that were higher in FL/NL compared to adult BM and common across all three datasets (**Fig. 3-5B**). In addition to *Lin28b, Igf2bp3, H19* and *Arid3a, Fstl1* and *Chd7* are also activated in NL B cells. Arid3a has recently been identified as master-regulator of B1a B cell development(106). Fstl1 (Follistatin-like 1), has an important function in development. It is negatively regulated by miR-27a and it can activate the TLR4/NFκB pathway(187). Chd7 (Chromodomain-helicase-DNA-binding protein 7) is a master regulator in neurogenesis. It works as chromatin remodeler, stimulating gene by modulate their promoter region to an open state(188).

Genes repressed in all groups from FL/NL included Casp1 (caspase 1), Esr1 (estrogen receptor, regulating cell proliferation and differentiation), Chd3

(Chromodomain-helicase-DNA-binding protein 3) and Neurl3 (E3 ubiquitin-protein ligase) may also play essential role in early ontogeny B1 B cell positive selection.

The fact that the differential expression of genes like *Lin28b, Igf2bp3, H19 and Arid3a* is shared between different Hardy fractions is interesting and possibly puts them upstream of targets more directly involved in positive selection by self-antigen. The implication is that Lin28b and downstream targets may have multiple and early roles during the different stages of B cell development stages.

In contrast, there are 49 genes that are only differentially expressed in the $Ig^{HEL}$ and non-transgenic immature B cell datasets (NonTg FrE and MD4 FrE datasets), implying that the effects of these genes may be more immature-B cell specific (**Fig. 3-5C**). Notably within this subset, Bhlhe41 has been reported encoding a key transcription factor for B1 B cell generation(107). In addition, we now identify: Plag1, which encodes a transcription factor whose activation results in up-regulation of Igf2, leading to cell proliferation(189); Yes1 (Tyrosine-protein kinase YES), which is essential in CD95L induced PI3K/Akt signaling, leading to cell migration; Stac2 (SH3 and cysteine-rich domain-containing protein 2), which is positively regulated by Pax5, and may function for intracellular signal transduction(190).

Genes such as Cr2 (CD21) and Fcer2a (CD23) are all mature B cell markers. They have higher expression level in BM sample, which is likely to be due to contamination from mature B cell population (which is absent in NL stage).

To summarize this experiment, differential expression in early ontogeny of Lin28b expression is maintained throughout B cell development stages, consistent with it's role as a master-regulator of B cell development. Hypothetically, other genes that are differentially expressed in ontogeny, but limited to the immature B cell stage, may be downstream of Lin28b and associated regulators like Arid3a, but have more specific roles in B cell selection.

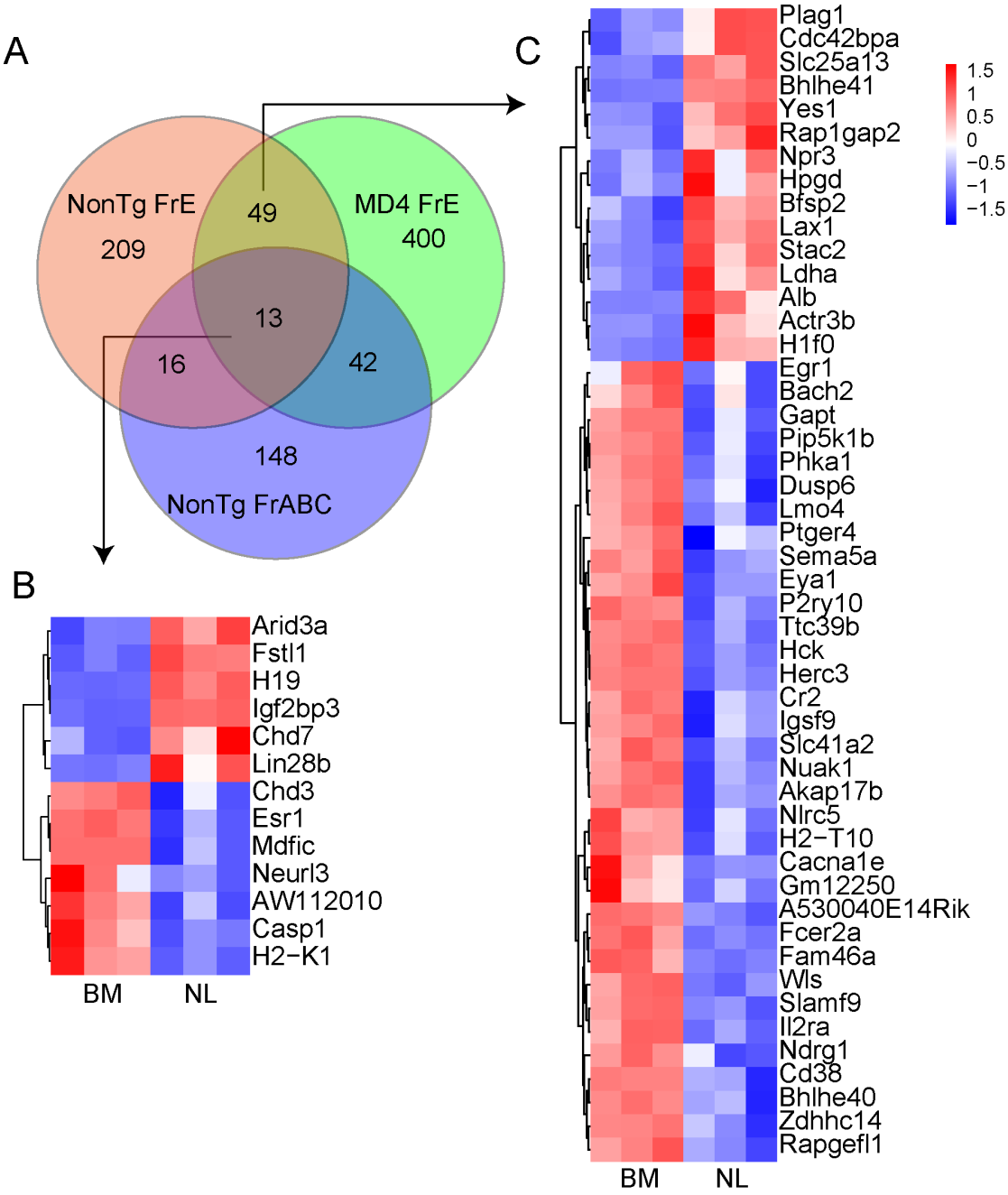



**Figure 3-5. Lin28b is highly expressed in NL across different B cell development datasets.** (A) Venn graph shows common genes between $Ig^{HEL}$ immature NL/BM dataset (MD4 FrE), B6 immature NL/BM dataset (NonTg FrE) and B6 B cell precursor NL/BM dataset (NonTg FrABC). (B) Common genes between three datasets. (C) Common genes between $Ig^{HEL}$ immature NL/BM dataset (MD4 FrE) and B6 immature NL/BM dataset (NonTg FrE), but not exists in B6 B cell precursor NL/BM dataset (NonTg FrABC).

## 3.3 Discussion

B1 B cells are mainly generated from FL/NL precursors, whilst precursors in adult BM largely lose their B1 B cell potential. The lineage theory proposes that adult BM lose B1 B cell precursors or B1 B cell precursors get diluted during ontogeny(93). In this chapter, I have confirmed that positive selection occurs in FL/NL, rather than adult BM. This result implies that an ontogeny switch could change B cell selection process as well.

Using a bioinformatics approach, I have found a Lin28b/let-7 switch between NL and BM. Overall Lin28b expression falls gradually during ontogeny, while let-7 has the opposite trend. These results agree with previous research, which reported that Lin28b and let-7 works as a bimodal switch in stem cell differentiation(75,191)(**Fig. 3-6**). The molecular mechanism behind this bimodal switch is in accordance with transcriptomic analysis as well. This is likely to be binary at the level of single cells because of positive feedback mechanisms that reinforce the alternative states. Where there are differences between samples, these are likely to be due to the limits of detection with current technology – for example in the detection of Lin28 in single cell analysis.

Lin28b sequesters pri-let-7 RNA away from Drosha and DGCR8 processing(84); whilst let-7 miRNA directly targets Lin28b transcript to repress its protein translation(95,191). Primary targets of Let-7 include Igf2bp3, Hmga2 and Igf2, which are reported to enhance cell proliferation, and whose transcripts have let-7 binding sites on 3'UTRs(95). Lin28b promotes Igf2bp3, Igf2 and Hmga2 mRNA translation by repressing let-7, but also promote these genes translation by direct binding to mRNA. Alongside this mechanism, H19 works as a molecular sponge, wiping out let-7 miRNAs(192). There is also evidence showing H19 is repressed by let-7 and promoted by Lin28b, although the mechanism is not clear(193)(**Fig. 3-6**). Arid3a and

Bhlhe41 are transcriptional factors that have both been reported to positively regulate B1 B cell generation(106,107).

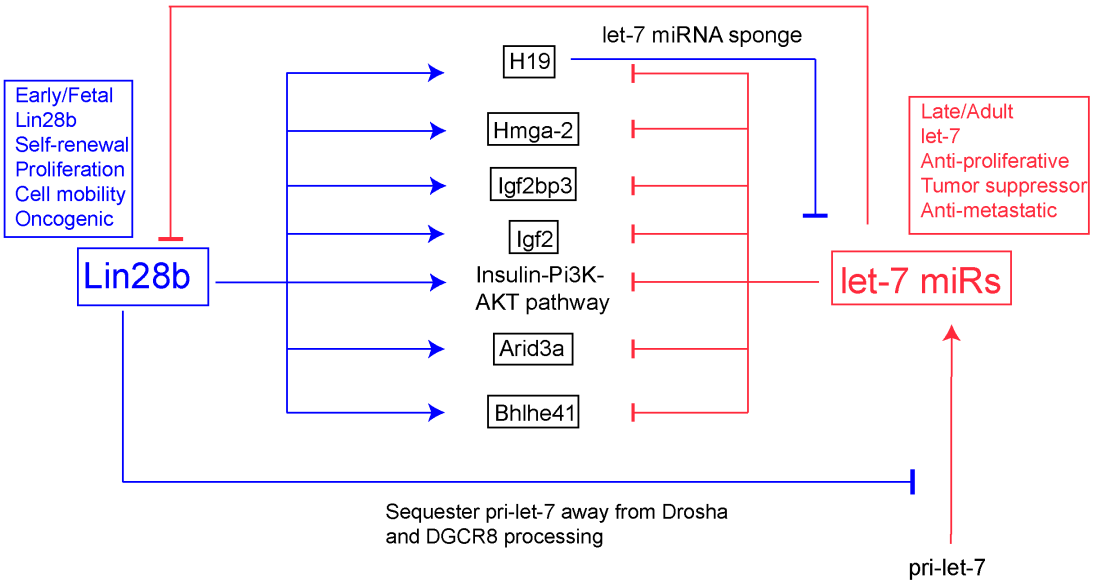



**Figure 3-6. Lin28b/let-7 bimodal switch.** Red showing genes upregulated in late ontogeny and blue showing genes upregulated in early ontogeny.

# Chapter 4. The function of Lin28b function in B1 B cell positive selection

## 4.1 Introduction

I have described in the previous chapter how a transcriptomic analysis reveals a Lin28b/let-7 bimodal switch, which is an essential difference between FL/NL and adult BM. This leads to the hypothesis that this bimodal switch orchestrates B cell development in early and late ontogeny stages.

Lin28 family members are small (<30kDa) proteins containing two CCHC-type zinc fingers and a Cold-Shock Domain (CSD), both implicated in RNA binding. Because Lin28a and Lin28b mRNAs are themselves let-7 targets, this Lin28b/let-7 axis establishes a double-negative feedback loop whereby either let-7 or Lin28 is expressed at high levels, promoting a differentiated or a proliferative cell fate, respectively(75). Ranging from embryonic development to cancer, inflammation, and metabolic processes, the Lin28/let-7 axis is now recognized as central to maintain proper cell fate and coordinate proliferation, growth, and energy utilization at the cellular level, as well as growth, developmental timing, tissue homeostasis, and metabolism in whole organisms.

Differential Lin28b expression in fetal and adult human B-cell precursors showed that human B-cell development might resemble that in the mouse, with self-reactive “innate-like” B cells generated early in life(102). Research by others has shown how Lin28b functions in lineage development and plasticity (90,106); but it is unknown whether Lin28b regulates the selection process by antigen or constitutive BCR signalling.

In this chapter, I describe how I have used the $Ig^{HEL}$/mHELKK mouse model to investigate the role of Lin28b in positive selection. The objective was that the findings would also generate an approach that could shed light on the molecular functions of Lin28b and its downstream pathways in developing B cells.

## 4.2 Results

### 4.2.1 Expression of Lin28b/mb1-cre reconstitutes the fetal lineages in BM chimeras, increasing B1a B cell numbers and decreasing BCR down-modulation

To test the role of Lin28b in vivo genetically, I next obtained a Lin28b transgenic mouse strain created by Dr. Johannes Schulte (Charité Hospital, Berlin). The mice were crossbred to Mb1-Cre mice, generating Lin28b$^{flox/+}$Mb1cre mice (Lin28b mice) and WT siblings for further phenotyping and experiments (**section 2.2.2.2** and **Fig. 2-1**). Mb1-cre mice express Cre recombinase gene under the control of the endogenous CD79a (BCR complex-associated protein α chain) promoter/enhance elements. Hence, Lin28b is specifically overexpressed in B cells. The mice had normal performance, litter size, breeding life span and growth rate.

In order to investigate Lin28b function in development, I next proceeded to generate series of BM chimeras. WT C57BL/6 (CD45.2) NL cells, WT CD45.2 adult BM cells, and CD45.2 Lin28b adult BM cells were injected intravenously into lethally irradiated WT B6SJL (CD45.1) recipient mice. Eight weeks after reconstitution, B cell populations were analysed using flow cytometry.

The results of this experiment confirmed the results of previous reports, in which over-expression of Lin28b was able to convert adult BM to FL, and generate a fetal-like phenotype. Compared to mice reconstituted with WT BM, mice reconstituted with Lin28b BM had increased immature B cells in BM, increased transitional B cells in

the spleen and greatly increased B1a B cells in peritoneum (**Fig. 4-1 and Fig. 4-2**), similar to mice reconstituted with FL. There was a trend towards an increase in MZ B cells but this not statistically significant (**Fig. 4-1 and Fig. 4-2**). Importantly, B1b B cells were not increased in numbers (**Fig. 4-2**).

Moreover, I also noticed that B cells in mice expressing the Lin28b-transgene were similar to B cells normally emerging from the fetal lineage in terms of surface IgM expression (**Fig. 4-3**). Adult BM reconstituted mice have lower surface IgM across immature, mature, transitional, follicular, marginal zone and B1 B cell subsets compared to FL. Overexpression of Lin28b in adult BM, led to higher surface IgM expression. I speculated that this may due to increased of BCR expression or decrease of BCR down-regulation, and both can be associated with changes in the selection threshold, B cell tolerance and deletion(172).

In immature, transitional and MZ B cell populations, the BAFFR expression level in Lin28b transgenic BM group is similar to FL (**Fig. 4-4A**). However, in mature, FO, B1 B cell populations, the BAFFR expression level of Lin28b transgenic BM group is similar to adult BM (**Fig. 4-4B**).

In conclusion, previous research has reported that Lin28b/let-7 axis is essential for controlling cell proliferation and differentiation; and Lin28b and let-7 dominate fetal and adult stages respectively. Lin28b overexpression is sufficient to redirect adult BM to a fetal lineage phenotype.

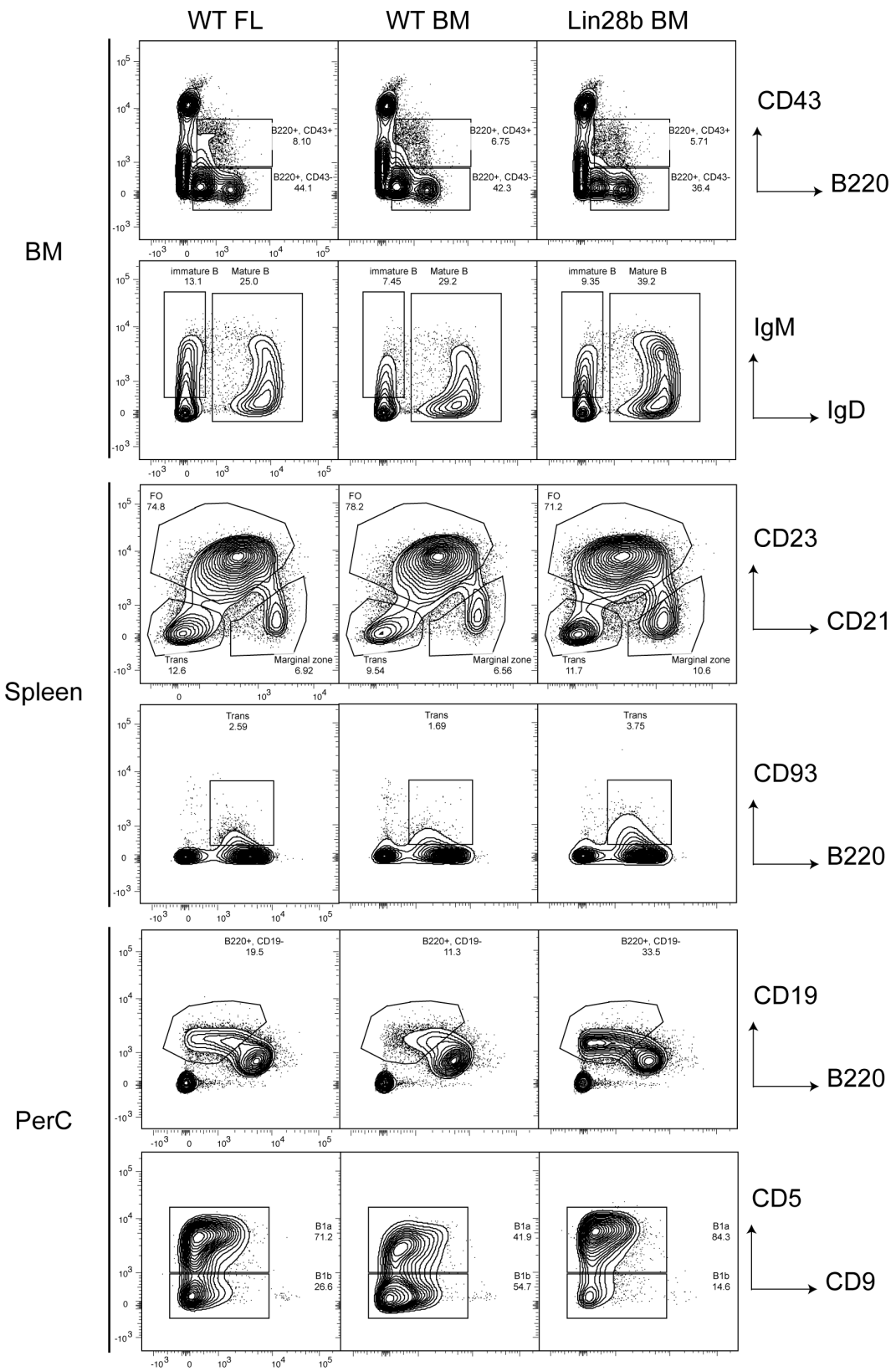



**Figure 4-1. The effect of Lin28b on the development of B cells in Adult BM.**

Representative flow cytometry of BM, splenic and peritoneal cells from indicated BM chimeras. BM upper panel gated on $CD45.2^+$, stained with CD43 and B220, and lower panel gated on $CD45.2^+B220^+CD43^-$, stained with IgM and IgD. Spleen upper panel gated on $CD45.2^+B220^+CD19^+$, stained with CD23 and CD21, and lower panel gated on $CD45.2^+$, stained with CD93 and B220. Peritoneum upper panel gated on $CD45.2^+$, stained with CD19 and B220, and lower panel gated on $CD45.2^+B220^{lo}CD19^+CD21^-IgD^-$ cells, stained with CD5 and CD9.

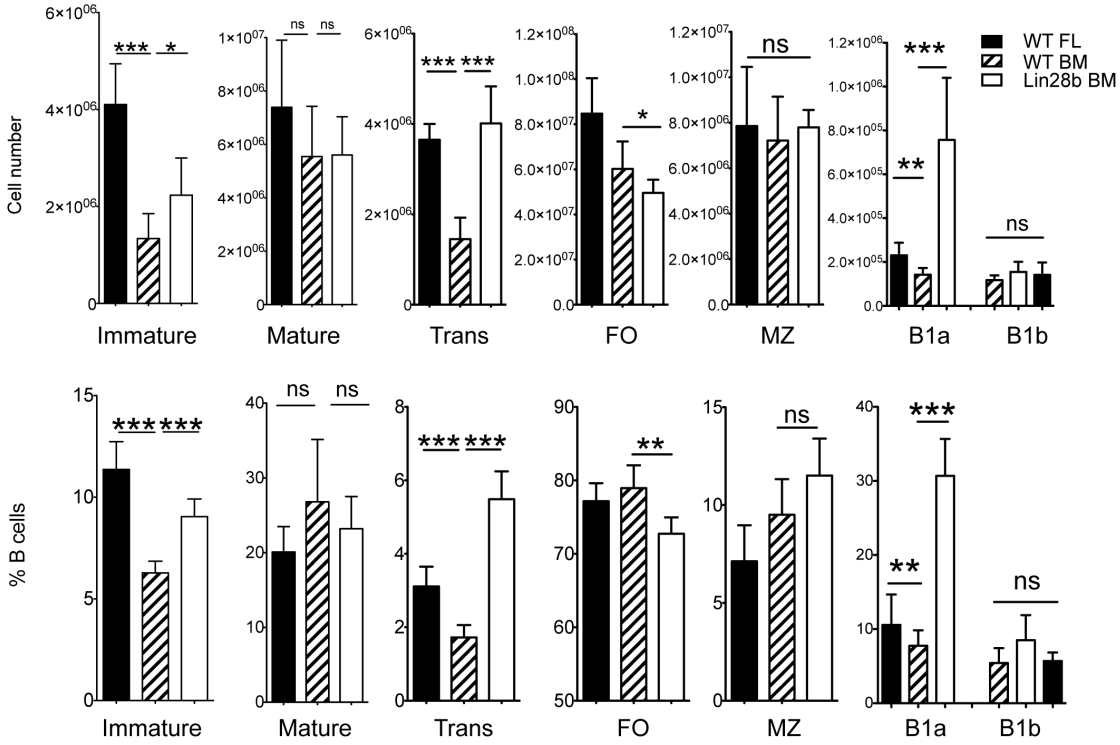



**Figure 4-2. The effect of Lin28b on B cell populations in adult BM.**

Upper panel: Absolute cell number of donor ($CD45.2^+$) immature and mature B cell in BM, transitional, follicular and marginal zone B cells in spleen, and B1a and B1b cell in peritoneum (n=5). Lower panel: Percentage of total donor ($CD45.2^+$) B cells that are immature and mature B cells in BM, transitional, follicular and marginal zone B cell in spleen, and B1a and B1b cell in peritoneum (n=5). Columns show mean and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test).

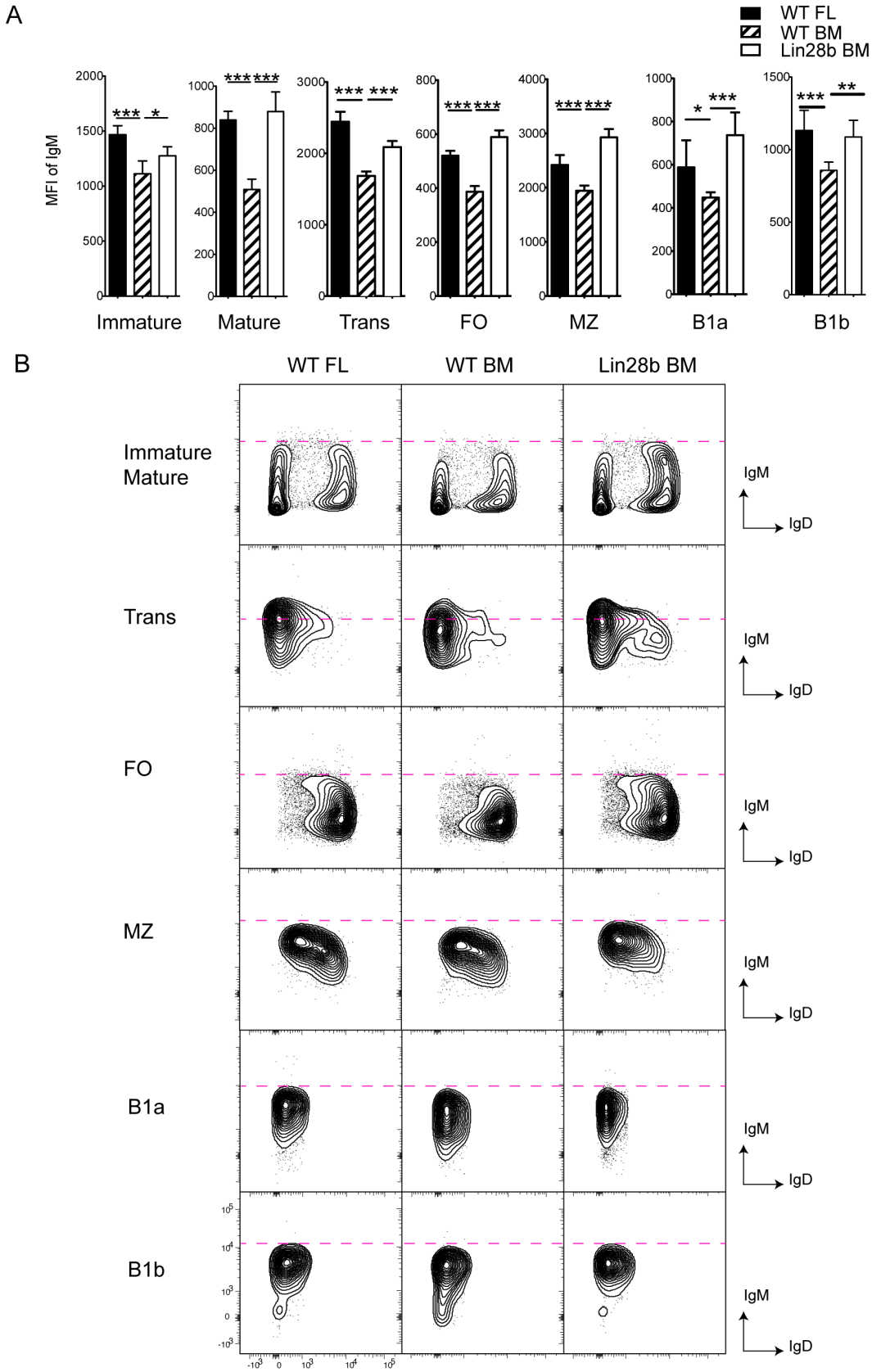



**Figure 4-3. Changes in IgM expression induced by Lin28b**

(A) Median Fluorescence Intensity (MFI) of surface IgM on $CD45.1^{-}CD45.2^{+}$ $B220^{+}CD43^{-}IgM^{+}IgD^{-}$ immature B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD43^{-}IgM^{+}IgD^{-}$ mature B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD93^{+}$ transitional B cells, $CD45.1^{-}CD45.2^{+}B220^{+}$ $CD93^{+}CD21^{mid}CD23^{+}$ follicular B cells, $CD45.1^{-}CD45.2^{+}$ $B220^{+}$ $CD93^{+}$ $CD21^{+}CD23^{-}$ marginal zone B cells and $CD45.1^{-}CD45.2^{+}B220^{lo}CD19^{+}IgM^{+}IgD^{-}CD5^{+}$ B1a B cells and $CD45.1^{-}CD45.2^{+}B220^{lo}CD19^{+}IgM^{+}IgD^{-}CD5^{-}$ B1b B cells in WT FL, WT BM and Lin28b BM (n=5). Columns show mean and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test). (B) Representative flow cytometry plots of immature, mature, transitional, follicular and marginal zone B cells in WT FL, WT BM and Lin28b BM (n=5).

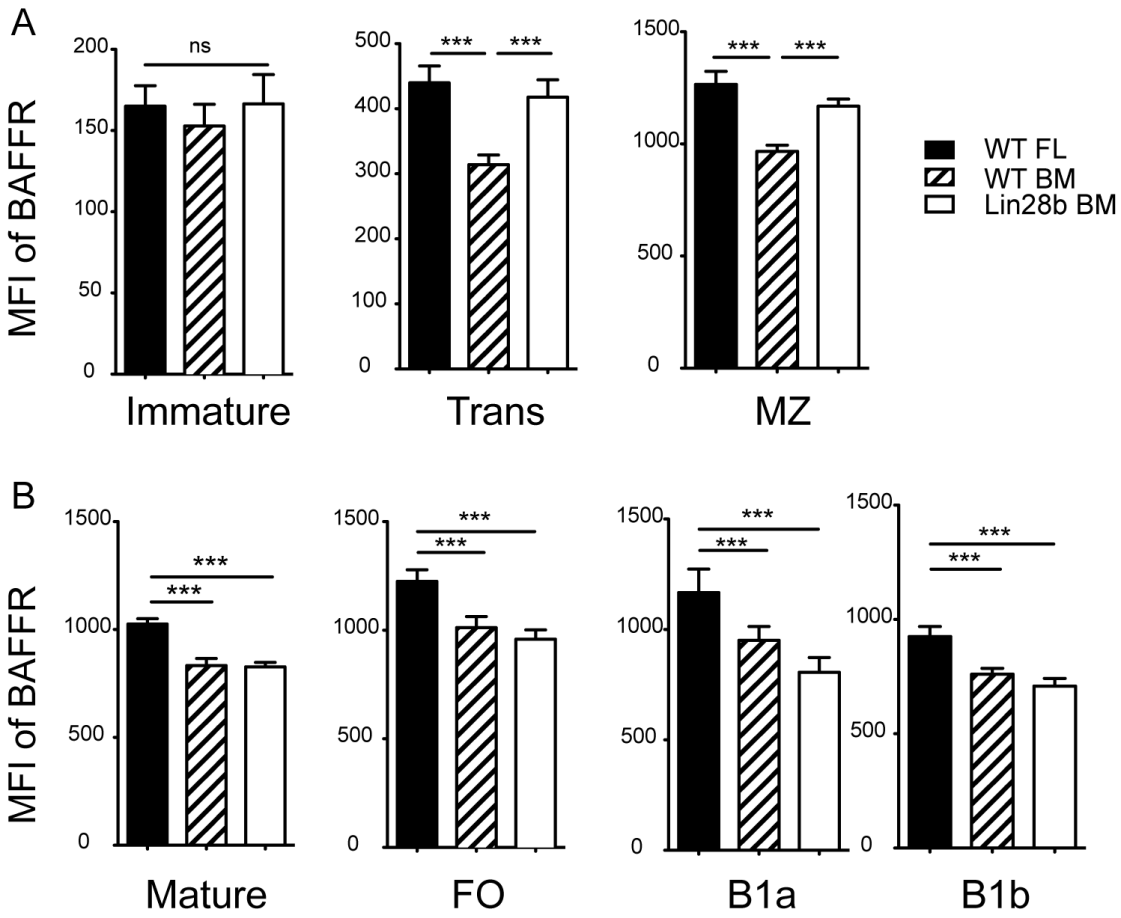



**Figure 4-4. BAFFR expression in the presence or absence of Lin28b.**

Median Fluorescence Intensity (MFI) of surface BAFFR on (A) immature, transitional, marginal zone, (B) $CD45.1^{-}CD45.2^{+}B220^{+}CD43^{-}IgM^{+}IgD^{-}$ immature B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD43^{-}IgM^{+}IgD^{-}$ mature B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD93^{+}$ transitional B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD93^{+}CD21^{mid}CD23^{+}$ follicular B cells, $CD45.1^{-}CD45.2^{+}B220^{+}CD93^{+}CD21^{+}CD23^{-}$ marginal zone B cells and $CD45.1^{-}CD45.2^{+}B220^{lo}CD19^{+}IgM^{+}IgD^{-}CD5^{+}$ B1a B cells and $CD45.1^{-}CD45.2^{+}B220^{lo}CD19^{+}IgM^{+}IgD^{-}CD5^{-}$ B1b B cells in WT FL, WT BM and Lin28b BM Columns show means and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test).

### 4.2.2 The expression of Lin28b/Mb1-cre reconstitutes positive selection to self-Ag in the Ig/mHEL-KK model

Results in the previous section showed that Lin28b alone was able to convert B cells back to a fetal lineage. However, whether Lin28b also affected the antigen-driven selection process was unknown. To investigate this, I tested the effect of Lin28b in the Ig/mHEL-KK model. As described in chapter 3, it is already known that when $Ig^{HEL}$ B cells are transferred to mHEL-KK recipient mice, positive selection is restricted in early ontogeny. I next wanted to ask if expression of Lin28b was able to convert negative to positive selection in late ontogeny.

In this chimera experiment, $CD45.2^+$ MD4 $Ig^{HEL}$ transgenic NL, adult BM and Lin28b adult BM was used to reconstitute series of lethally irradiated $CD45.1^+$ mHEL-KK recipient mice. Eight weeks after transfer, B cell populations were again analysed using flow cytometry.

In contrast to $Ig^{HEL}$ adult BM B cells, which underwent negative selection in mHEL-KK recipients, $Ig^{HEL}$Lin28b adult BM B cells were now positively selected into the B1 compartment in the peritoneum, by exposure to the self-antigen mHEL-KK (**Fig. 4-5 and Fig. 4-6A**). Whist non-HEL binding B1a cells were also induced by Lin28b, the positively selected HEL binding B1 B cells were from the B1b subset, in agreement with the previously described Ig/mHELKK Dbl transgenic mouse phenotype (**Fig. 4-5**).

Analysis of anti-HEL IgM$^a$ titres also showed the presence of more HEL specific IgM$^a$ antibodies and HEL specific IgM$^a$ secreting plasma cells in IgNL-mHELKK and IgLin28bBM-mHELKK mice than in IgBM-mHELKK mice (**Fig. 4-6B** and **Fig. 4-6C**).

Since serum anti-HEL IgM$^a$ antibodies can mask self-antigen and protect B2 B cells from self-antigen induced negative selection (135), B2 B cells were partially rescued in IgNL-mHELKK and IgLin28bBM-mHELKK mice (**Fig. 4-5 and Fig. 4-6A**). The reduction of B2 B cells in peritoneum and BM of IgBM-mHELKK mice indicated ongoing B cell negative selection of B cells by antigen in the absence of antibody (**Fig. 4-5 and Fig. 4-6A**).

The situation was more complicated in the spleen, where there were more transitional B cells in Lin28b transgenic B cells, but in a self-antigen independent manner (**Fig. 4-6A**). In contrast MZ B cells seemed to be positively selected by self-antigen, but in a Lin28b independent manner (**Fig. 4-5 and Fig. 4-6A**).

To assess the BCR, I went on to check surface IgM$^a$ expression level in B cell subsets. IgNL and IgLin28bBM generated B cells with significantly higher sIgM$^a$ levels than IgBM in non HEL transgenic recipients, though all other subsets have minor differences. In the presence of 'mHELKK' recipients, IgNL and IgLin28bBM B cell subsets, including immature, mature, transitional, FO, MZ and B1 B cells, displayed significantly higher sIgM$^a$ level than IgBM (**Fig. 4-7 and Fig. 4-3**). Together with the results using non-transgenic donor BM (**section 4.2.1)**, these results

suggest that one action of Lin28b may be to change BCR signalling in an antigen-dependent manner.

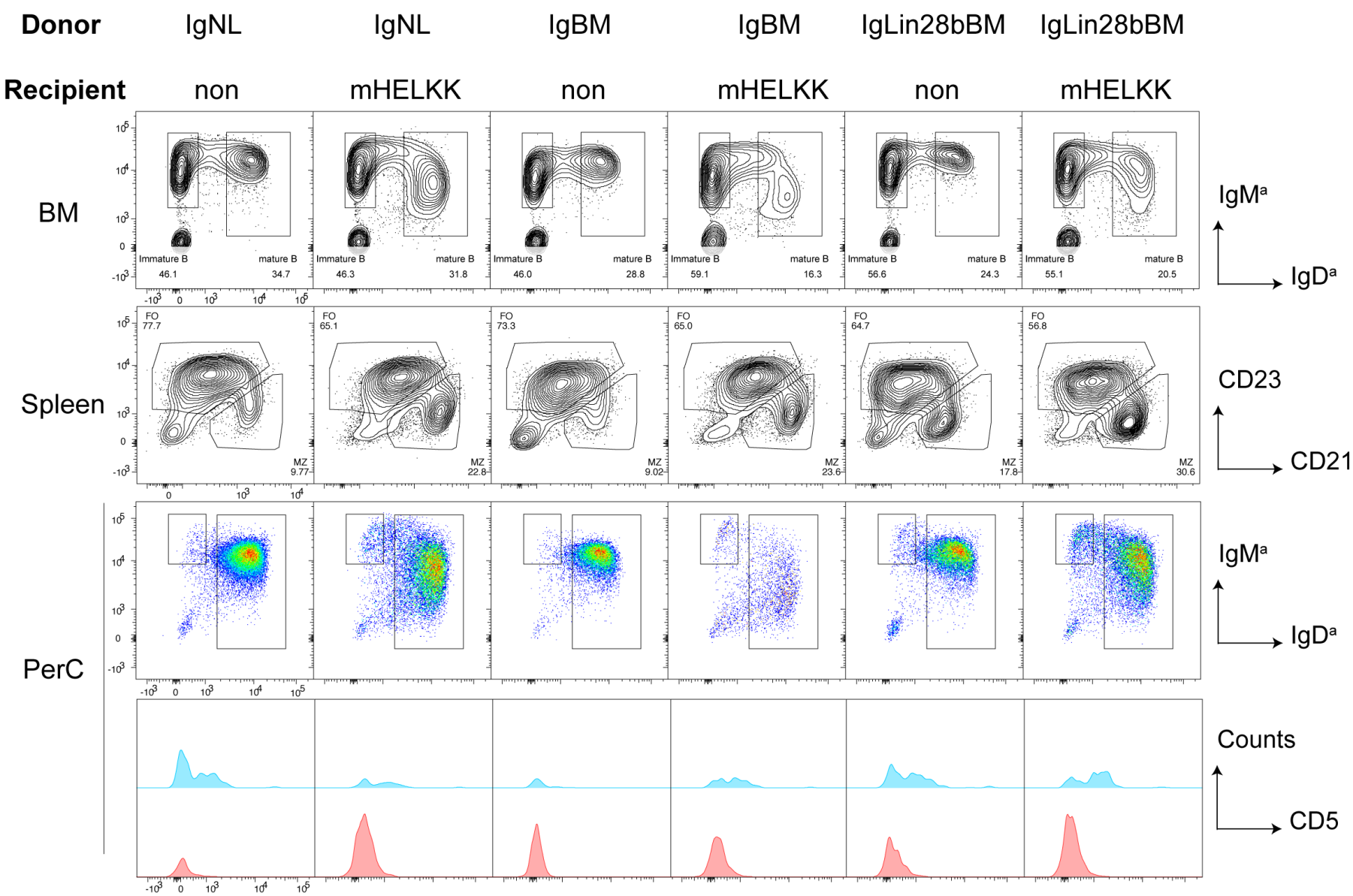



**Figure 4-5. Lin28b converts negative to positive selection in adult BM.**

Flow cytometry analysis of BM, spleen and peritoneum (PerC) B cells from IgNL, IgBM or IgLin28bBM transferred into irradiated non or mHELKK recipients (after 8-10 weeks reconstitution). Experiments were performed three times, with 5 mice in each group. Here shows the representative plots. BM panel gated on $CD45.2^{+}B220^{+}$ cells, stained for $IgM^{a}$ and $IgD^{a}$, shows immature ($IgM^{a+}IgD^{a-}$) and mature B cells ($IgM^{alo/+}IgD^{a+}$). Spleen panel gated on $CD45.2^{+}HEL^{+}CD93^{-}B220^{+}CD19^{+}$, stained for CD23 and CD21, shows FO ($CD21^{mid}CD23^{hi}$) and MZ ($CD21^{hi}CD23^{lo}$) B cells. PerC upper panel, gated on $CD45.2^{+}B220^{+}CD19^{+}$, stained for $IgM^{a}$ and $IgD^{a}$, shows B1 ($IgM^{a+}IgD^{a-}$) and B2 ($IgM^{alo/+}IgD^{a+}$) B cell. PerC lower panel, blue plots shows non-HEL binding B1 B cells, gated on $CD45.2^{+}HEL^{-}B220^{lo}CD19^{hi}$, stained for CD5 expression; red plots shows HEL binding B1 B cell, gated on $CD45.2^{+}HEL^{+}B220^{lo/+}CD19^{+}IgM^{a+}IgD^{a-}$, stained for CD5 expression.

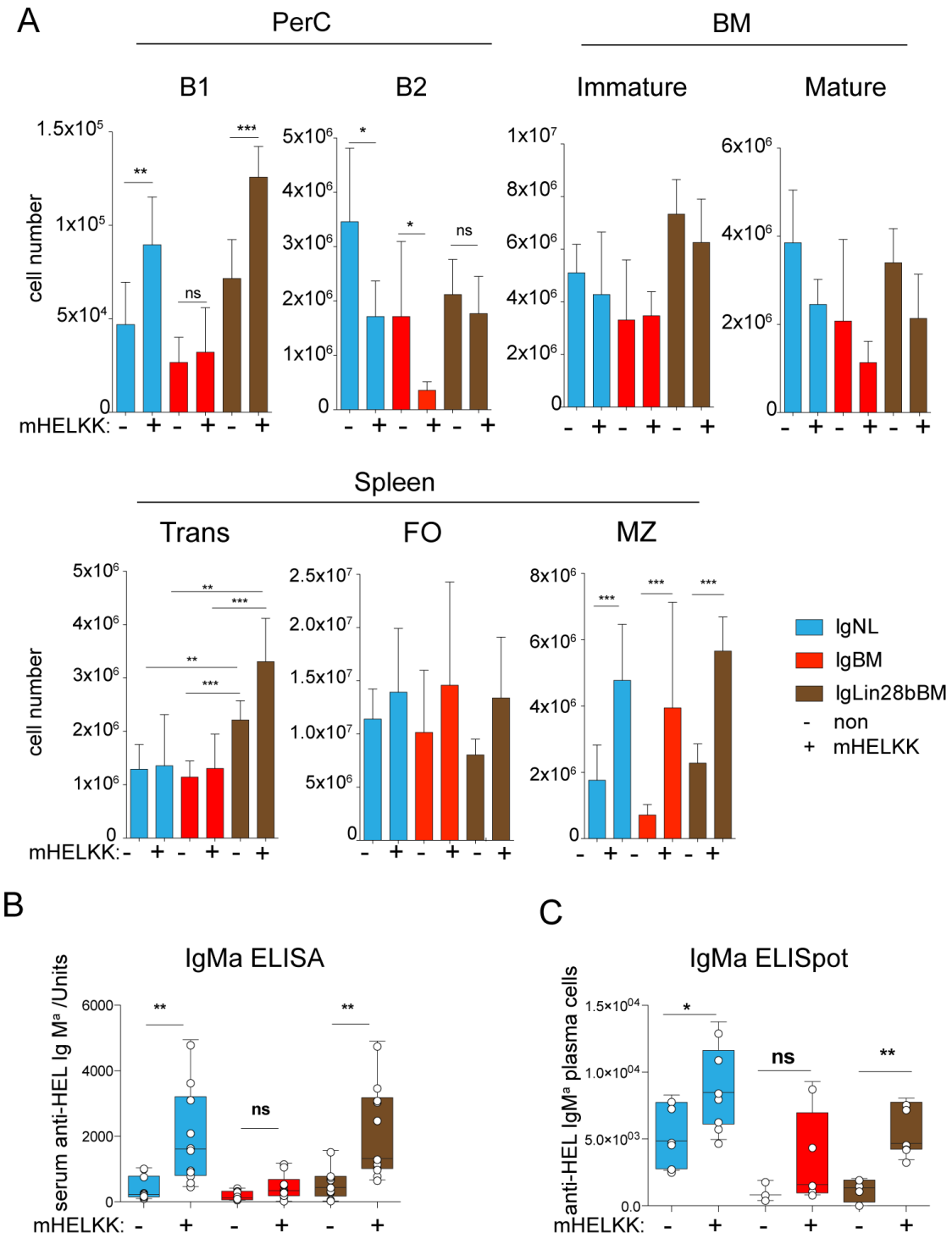



**Figure 4-6. B1 B cells undergo positive selection in IgLin28b/mHELKK chimeras.** (A) Cell numbers of B1, B2 B cells in PerC, immature, mature B cells in BM, Trans, FO, MZ B cells in spleens from IgNL-non (n=5), IgNL-mHELKK (n=4),

IgBM-non (n=5), IgBM-mHELKK (n=5), IgLin28bBM-non (n=5) or IgLin28bBM-mHELKK (n=6) mice. Columns show the mean and bars represent the 95% confidence limits. Gating identified $CD45.1^{-}CD45.2^{+}B220^{+}CD19^{+}IgM^{a+}IgD^{a-}$ B1 and $CD45.1^{-}CD45.2^{+}B220^{+}CD19^{+}IgM^{alo/+}IgD^{a+}$ B2 B cells in the PerC; $CD45.1^{-}CD45.2^{+}B220^{+}IgM^{a+}IgD^{a-}CD21^{-}CD23^{-}$ immature and $CD45.1^{-}CD45.2^{+}B220^{+}$ $IgM^{a-/+}IgD^{a+}CD21^{+}CD23^{+}$ mature in the BM; $CD45.1^{-}CD45.2^{+}HEL^{+}B220^{+}CD93^{+}$ transitional, $CD45.1^{-}CD45.2^{+}HEL^{+}B220^{+}CD93^{-}CD21^{mid}CD23^{+}$ FO and $CD45.1^{-}CD45.2^{+}HEL^{+}B220^{+}CD93^{-}CD21^{+}CD23^{-}$ MZ B cells in the spleen. (B) Pooled data of serum anti-HEL $IgM^{a}$ titres in IgNL-non (n=11), IgNL-mHELKK (n=11), IgBM-non (n=8), IgBM-mHELKK (n=10), IgLin28bBM-non (n=9) and IgLin28bBM-mHELKK (n=12) mice. Columns show the means, bars represent the 95% confidence limits and dots show individual data points. (C) Anti-HEL $IgM^{a}$ secreting splenic plasma cells in IgNL-non (n=7), IgNL-mHELKK (n=7), IgBM-non (n=3), IgBM-mHELKK (n=5), IgLin28bBM-non (n=4) or IgLin28bBM-mHELKK (n=6) mice. Columns show the mean, bars represent the 95% confidence limits and dots show individual data points.

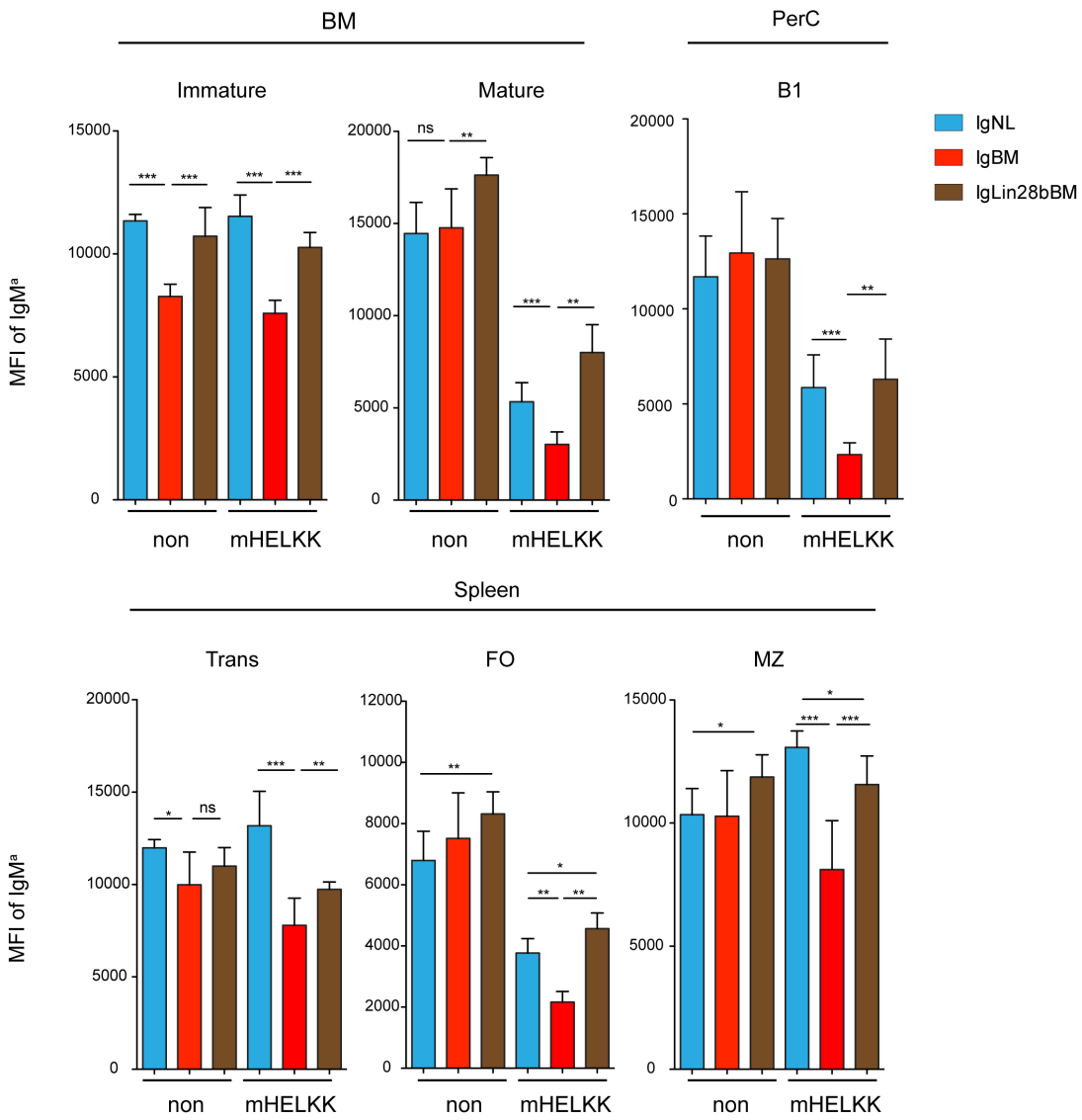



**Figure 4-7. Lin28b increases IgMa level.** MFI of surface IgM$^a$ on immature, mature, B1, transitional, FO and MZ B cells in IgNL, IgBM and IgLin28bBM/mHELKK chimeras (n=5 per group). Columns show means and bars represent the 95% confidence limits.

### 4.2.3 Lin28b functions affect B cell development, independent of selection

Overexpression of Lin28b in adult BM also led to abnormal maturation marker expression on FO and MZ B cells, as evidenced by changes in CD21 (CR2) expression in both Lin28bBM-WT and IgLin28bBM-non/mHELKK experiments (**Fig. 4-1, Fig. 4-2, Fig. 4-6A, Fig. 4-8 and Fig. 4-9**). CD21 is a BCR co-receptor expressed at high levels on mature B cells. The absence of CD21 may result in weaker signalling by antigens complexed to complement or simply be a marker of less maturation. The fact that CD21 down-modulated in the FO compartment was partially rescued by mHELKK self-antigen, suggested that this phenotype may indeed relate with abnormal B cell signaling. Since CD21 is not a direct target of either Lin28b or let-7, it is likely that there is separate regulator between Lin28b/let-7 switch and CD21.

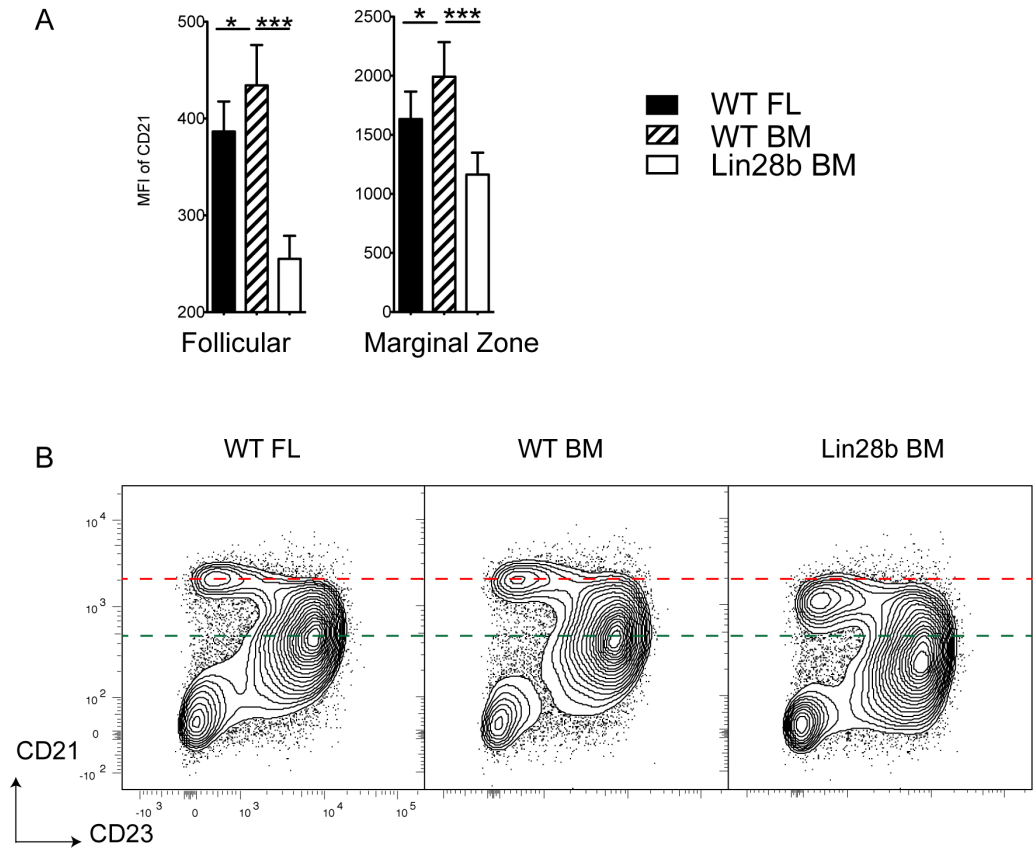



**Figure 4-8. Lin28b/Mb1-cre transgene leads to CD21 down-modulation.**

(A) MFI of surface CD21 on FO and MZ B cells in WT FL, WT BM and Lin28b BM transferred mice (n=5). Columns show mean and bars represent the 95% confidence limits(*p<0.05, **p<0.01, ***p<0.001, unpaired t-test). (b) Splenic B cells in WT FL, WT BM and Lin28b BM transferred mice, stained with CD21 and CD23 (n=5).

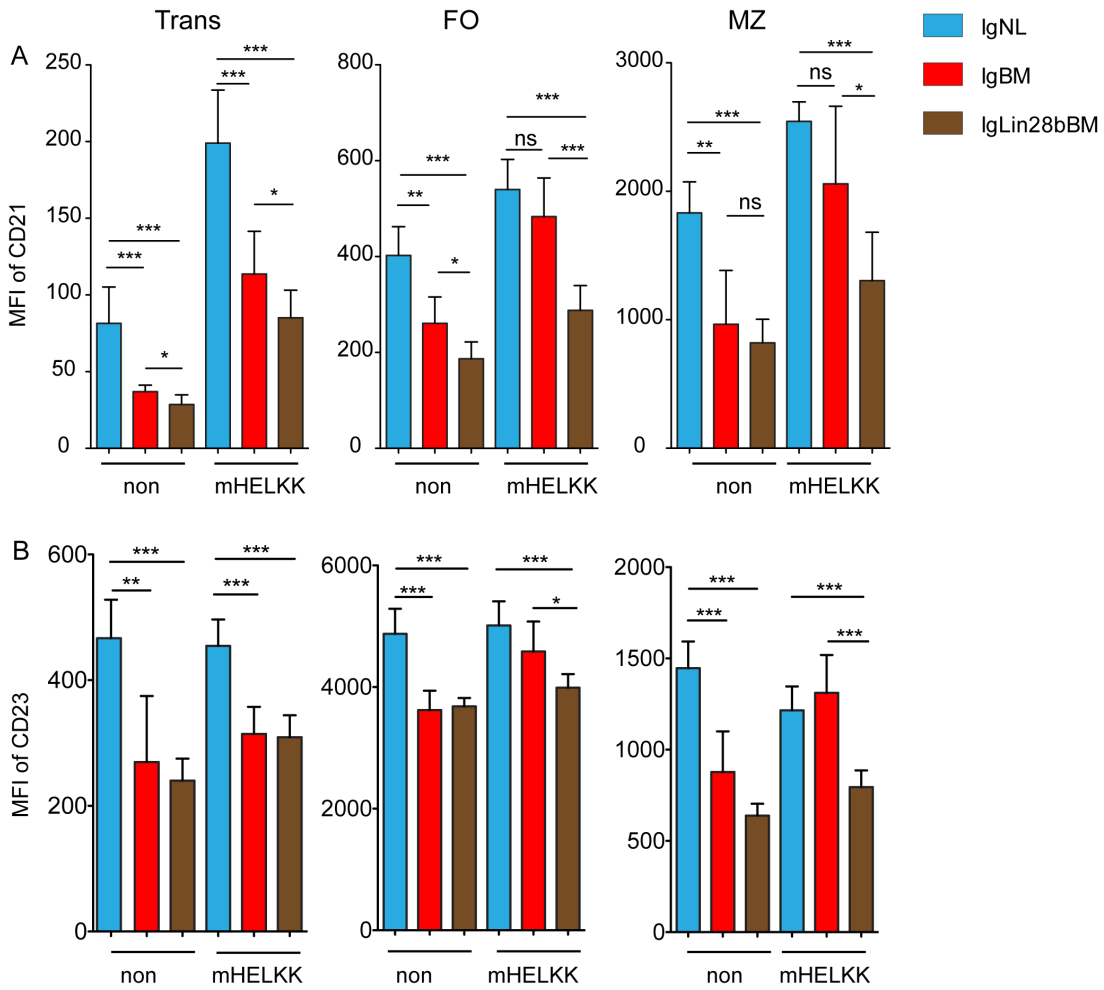



**Figure 4-9. Mature IgLin28bBM B2 B cells show developmental arrest in the presence and absence of self-antigen.** (a) MFI of surface CD21 on Trans, FO and MZ B cells in IgNL, IgBM and IgLin28bBM transferred into non and mHELKK mice (n=5). Columns show means and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test). (b) MFI of surface CD23 on Trans, FO and MZ B cells in IgNL, IgBM and IgLin28bBM transferred non and mHELKK mice (n=5). Columns show mean and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test).

### 4.2.4 Continuous expression of Lin28b throughout life does not increase B1 B cells above those selected by shorter expression during neonatal development.

The BM reconstitution experiment shows that expression of Lin28b is able to convert B cell to a fetal/neonatal stage which is susceptible to positive selection. To investigate the effect on Lin28b function on positive selection model over a longer term, I generated a triple transgenic mouse strain, Lin28bMb1cre/$Ig^{HEL}$/mHEL-KK. Interestingly, there was no cumulative effect of Lin28b expression on positive selection, beyond the effect seen in $Ig^{HEL}$/mHEL-KK (**Fig. 4-10**).

Consistent with the chimera data, there was increased number of transitional B cells, and decreased number of FO B cell in both Lin28b/$Ig^{HEL}$/mHEL-KK and Lin28b/$Ig^{HEL}$ (**Fig. 4-10**).

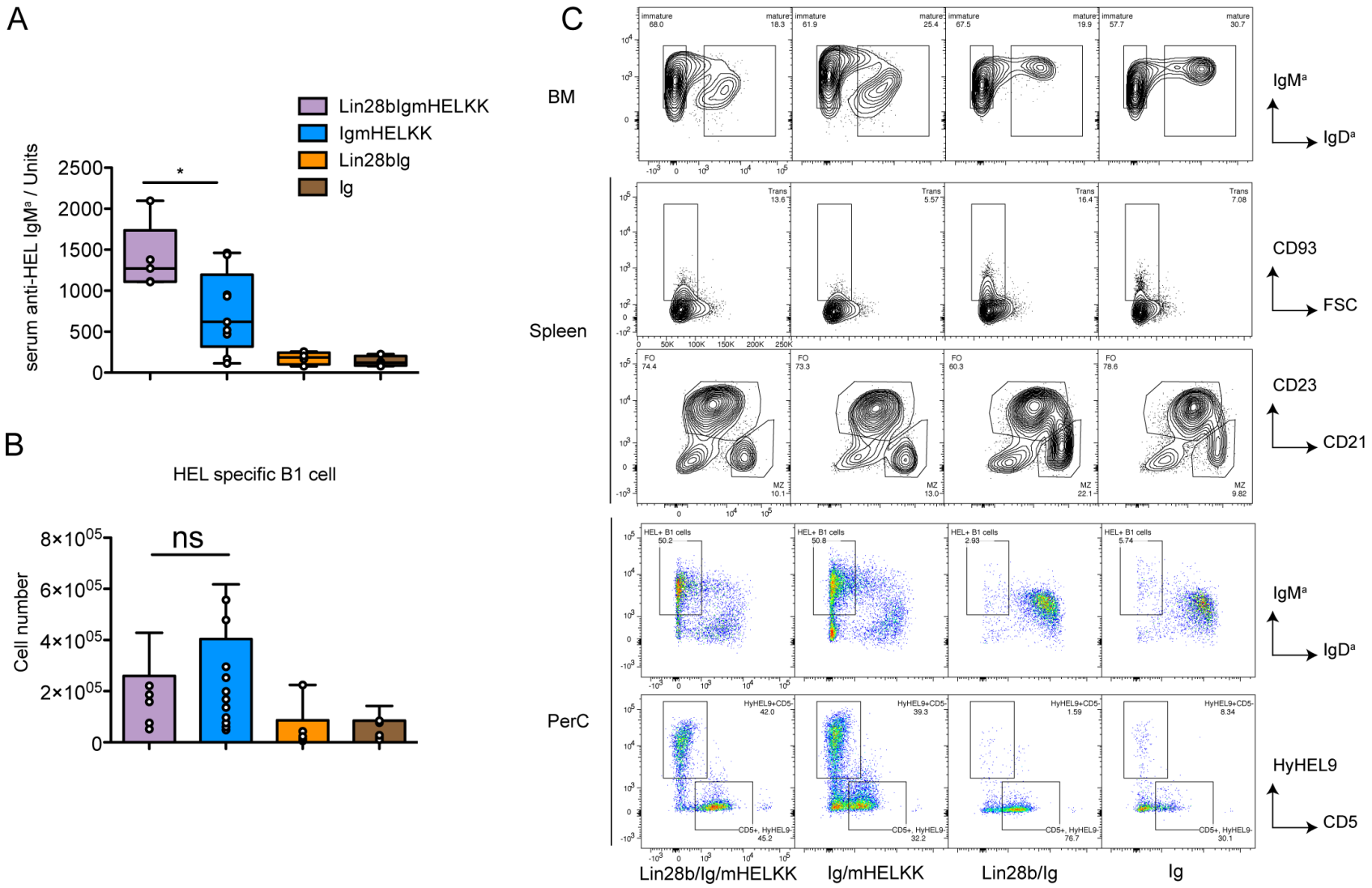



**Figure 4-10. Continuous expression of Lin28b throughout life does not further increase B1 B cell numbers.**

(a) Serum anti-HEL IgM$^{a}$ titres in Lin28bIg$^{HEL}$mHELKK (n=5), Ig$^{HEL}$mHELKK (n=9), Lin28bIg$^{HEL}$ (n=4) and Ig$^{HEL}$ (n=4) mice. Columns show the means, bars represent the 95% confidence limits and dots show individual data points. (b) HEL specific B1 B cell numbers in Lin28bIg$^{HEL}$mHELKK (n=5), Ig$^{HEL}$mHELKK (n=11), Lin28bIg$^{HEL}$ (n=7) and Ig$^{HEL}$ (n=7) mice. Columns show the mean, bars represent the 95% confidence limits and dots show individual data points. (c) Representative flow cytometric analysis of BM, spleen and peritoneum (PerC) B cells from different mice. BM panel gated on B220$^{+}$HEL$^{+}$ cells, stained for IgM$^{a}$ and IgD$^{a}$, and showing immature (IgM$^{a+}$IgD$^{a-}$) and mature B cells (IgM$^{alo/+}$IgD$^{a+}$). Spleen (upper panel) gated on B220$^{+}$CD19$^{+}$HEL$^{+}$ cells, showing transitional B cells (CD93$^{+}$); (lower panel) gated on HEL$^{+}$ B220$^{+}$CD19$^{+}$CD93$^{-}$, stained for CD23 and CD21, showing FO (CD21$^{mid}$CD23$^{hi}$) and MZ (CD21$^{hi}$CD23$^{lo}$) B cells. PerC (upper panel), gated on B220$^{lo/+}$CD19$^{+}$HEL$^{+}$, stained for IgM$^{a}$ and IgD$^{a}$, shows HEL specific B1 (IgM$^{a+}$IgD$^{a-}$) B cell. PerC (lower panel) gated on B220$^{lo}$CD19$^{hi}$, stained for HEL and CD5 expression. HEL$^{+}$CD5$^{-}$ are HEL specific B1b cells and HEL$^{-}$CD5$^{+}$ are background B1a cells.

## 4.3 Discussion

The Lin28b/let-7 switch is correlated with positive and negative selection during ontogeny. In this chapter, I confirmed previous findings that Lin28b promotes fetal lymphopoiesis and also found that Lin28b is important in B1 B cell positive selection.

In Lin28b adult BM only chimeras, Lin28b adult BM regained fetal/neonatal liver phenotypes, in which B1a B cells are highly increased in PerC. This result showed Lin28b is important for fetal lymphopoiesis, but it was hard to conclude that was involved in the positive selection of B1 B cells, without controlling for BCR specificity and self-antigen in this system.

In $Ig^{HEL}$Lin28b adult BM with mHELKK recipient chimeras, in which BCR and self-antigen were controlled, overexpression Lin28b in adult BM reversed $Ig^{HEL}$ negative selection to positive selection in mHELKK recipient mice. There were also increased B1b cells in $Ig^{HEL}$BM-mHELKK PerC, along with increased serum anti-HEL $IgM^a$ level, increased numbers of anti-HEL $IgM^a$ secreting plasma cells and less negative selection of B2 B cells.

Although these findings increased our understanding of the role of Lin28b in B1 selection, it remains hard to end the controversy surrounding lineage and selection theories. The B1 B cells increased in WT recipients were B1a subsets, whereas B1 B cells increased in mHELKK recipient were B1b subsets. Whilst Lin28bMb1cre mice have more B1a cells, the presence of the transgene in Lin28b$Ig^{HEL}$/mHELKK mice did not have an additive function in terms of generating B1b cells, it only switched on positive selection. This leads me to speculate that there may be two distinct B1 B cell development pathways, in which B1a cells rely on precursor and B1b cells rely on selection. This would also fit with two-pathway model described in the introduction (**section 1.4.4**).

As far as the mechanism of positive selection is concerned, Lin28b overexpression generates several possible clues of positive selection. For example, the increased number of immature and transitional B cells suggests that Lin28b overexpression may generate a bigger B cell repertoire for selection. In this scenario we can speculate that auto-reactive B cells are more likely to pass through the strict selection checkpoints at immature stage.

Lin28b also affects the level of BCR expression. This may be due to more expression or less modulation of surface BCR. Since this phenotype is also observed in cells derived from NL, altered BCR signal may correlate with positive selection – for example by reducing the signal threshold.

However, since Lin28b is not normally expressed in mature cells, there may be other non-physiological effects on FO and other mature B cells. There is, for example, significantly less CD21 expression of mature B cell subsets compared to WT. This leads to a change of FO/MZ ratio in spleen and may, speculatively, affect further tolerance and immunogenic functions. The Lin28b/let-7 switch itself may regulate negative transcription factor of CD21 or other checkpoints of FO B cell development. The role of let-7 in normal function needs to be elucidated as well. The precise mechanisms will require further experiments and analysis.

# Chapter 5. Lin28b exaggerates B cell tolerance

## 5.1 Introduction

I have shown how Lin28b functions in early ontogeny to create conditions for positive selection, using $Ig^{HEL}$/mHELKK model. Lin28b overexpression in adult BM (late ontogeny) converts negative selection to positive selection. This effect from the Lin28b transgene could be due to enhanced positive selection and/or diminished negative selection.

To explore whether Lin28b has a direct effect on negative selection, I turned to its function in the $Ig^{HEL}$/sHEL (ML5) model, in which B cell tolerance (anergy) is induced by the presence of soluble antigen. In this situation, negative selection occurs regardless of ontogeny stage.

Differences between sHEL and mHELKK relate to the form of HEL self-antigen. ML5 mice express a soluble low avidity form of self antigen, with higher serum level of HEL (10-20 ng/ml); in contrast to the mHELKK mice, which express an high avidity intracellular form of membrane bound self antigen with lower level of serum free HEL (2-10 ng/ml), which is presumably cleaved from the membrane protein (121).

This $Ig^{HEL}$/sHEL model provides a different environment for selection and the aim of this chapter was to understand Lin28b function in B cell tolerance and negative selection.

## 5.2 Results

### 5.2.1 Anergy is induced in both NL and adult BM $Ig^{HEL}$ B cells exposed to sHEL

To assess the induction of anergy, $CD45.2^+$ MD4 $Ig^{HEL}$ transgenic NL, adult BM and Lin28b adult BM were used to reconstitute lethally irradiated $CD45.1^+$ sHEL (ML5) recipient mice. Eight weeks after BM transfer, B cell populations were analysed using flow cytometry.

In contrast to the age-related differences observed in Ig/mHELKK chimeras, the outcome of transferring IgNL and IgBM into sHEL chimeras was similar. Both IgNL and IgBM B cells were induced into a state of tolerance and became anergic in sHEL recipients (**Fig. 5-1**). There was a ~70% reduction of mature recirculating $Ig^{HEL}$ B cells in BM and ~50% reduction of FO B cells in spleen compared to $Ig^{HEL}$ single transgenic mice (**Fig. 5-2A**). The B1 and MZ B cell populations were absent or diminished in sHEL recipients, compatible with negative selection of the latter in the presence of sHEL as well (**Fig. 5-1**). In agreement with the anergic phenotype, follicular B cell populations had 10-20 fold reduction of $sIgM^a$ but no change on $sIgD^a$ level (**Fig. 5-2B**) and reduced CD21 expression (**Fig. 5-4**). Low levels of serum anti-HEL $IgM^a$ antibody in sHEL recipients compared to non recipients (**Fig. 5-3**), showed that B cells were in an anergic state.

### 5.2.2 Lin28b exaggerates sHEL induced negative selection

Surprisingly, Lin28b appeared to exaggerate negative selection in adults BM. Transgene expression resulted in ~80% reduction of recirculating mature B cells in BM and ~50% reduction of FO B cells in spleen (**Fig. 5-1 and Fig. 5-2A**). MZ and B1 B cell populations were not rescued. Moreover, when judged by CD21 expression level, FO B cells showed new developmental arrest in the absence of self-antigen and even more severe arrest in the presence of self-antigen (**Fig. 5-4**). Compatible

with developmental arrest, transitional B cell numbers were increased with overexpression of Lin28b (**Fig. 5-2A**).

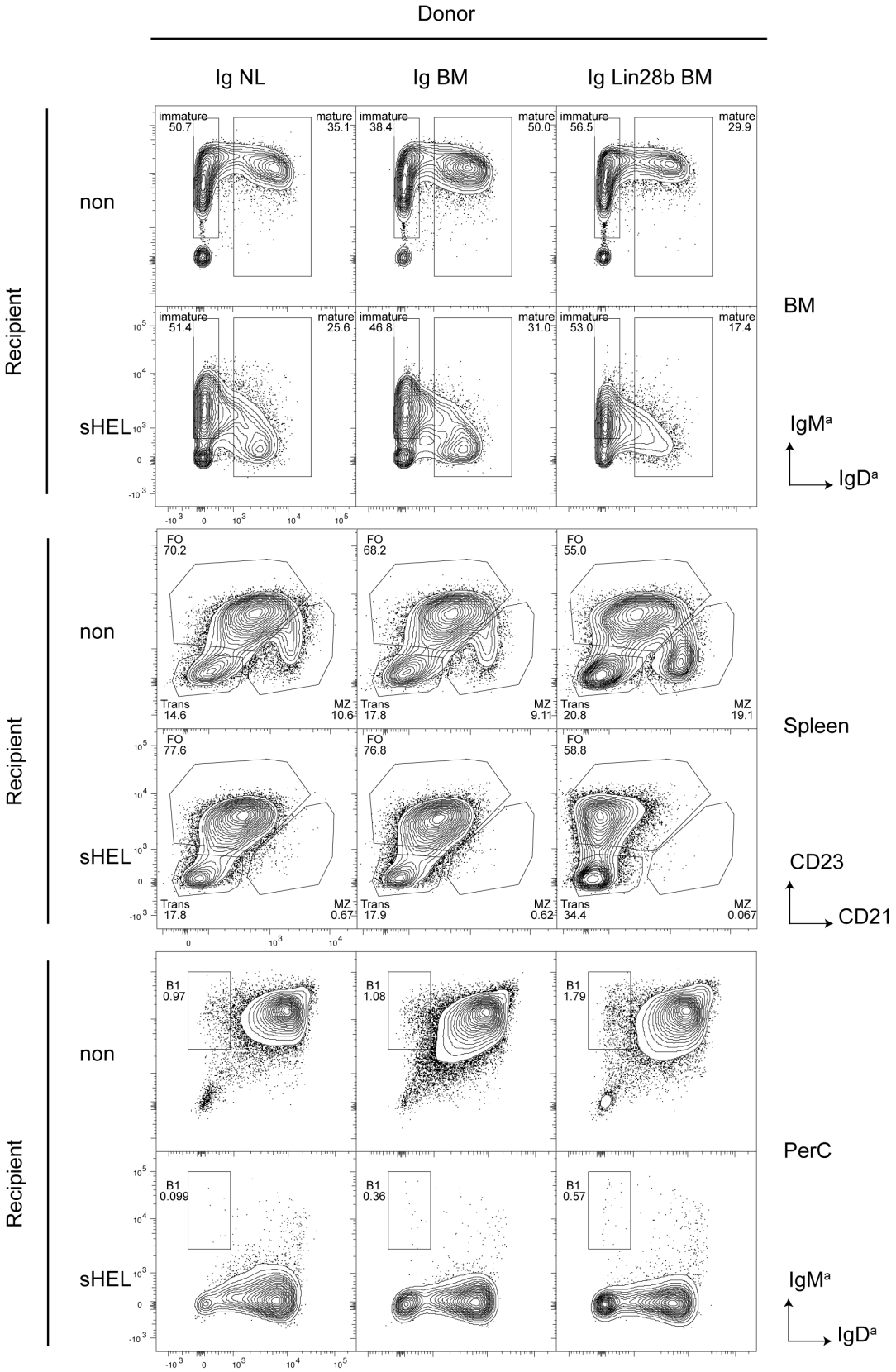


**Figure 5-1. Lin28b function in the $Ig^{HEL}$/sHEL model.**

Flow cytometric analysis performed on BM, spleen and PerC B cells from IgNL, IgBM or IgLin28bBM, transferred into irradiated non or sHEL recipients. Experiments were performed with 5 mice in each group (here showing representative plots). The BM panel is gated on $CD45.1^{-}CD45.2^{+}B220^{+}CD43^{-}$ cells, stained for $IgM^{a}$ and $IgD^{a}$, shows immature ($IgM^{a+}IgD^{a-}$) and mature B cells ($IgM^{alo/+}IgD^{a+}$). Spleen panel gated on $CD45.1^{-}CD45.2^{+}HEL^{+}B220^{+}CD19^{+}$, stained for CD23 and CD21, shows FO ($CD21^{mid}CD23^{hi}$), MZ ($CD21^{hi}CD23^{lo}$) and transitional ($CD23^{-}CD21^{-}$) B cells. PerC panel gated on $CD45.1^{-}CD45.2^{+}B220^{lo/+}CD19^{+}$, stained for $IgM^{a}$ and $IgD^{a}$, shows B1 ($IgM^{a+}IgD^{a-}$) B cells.

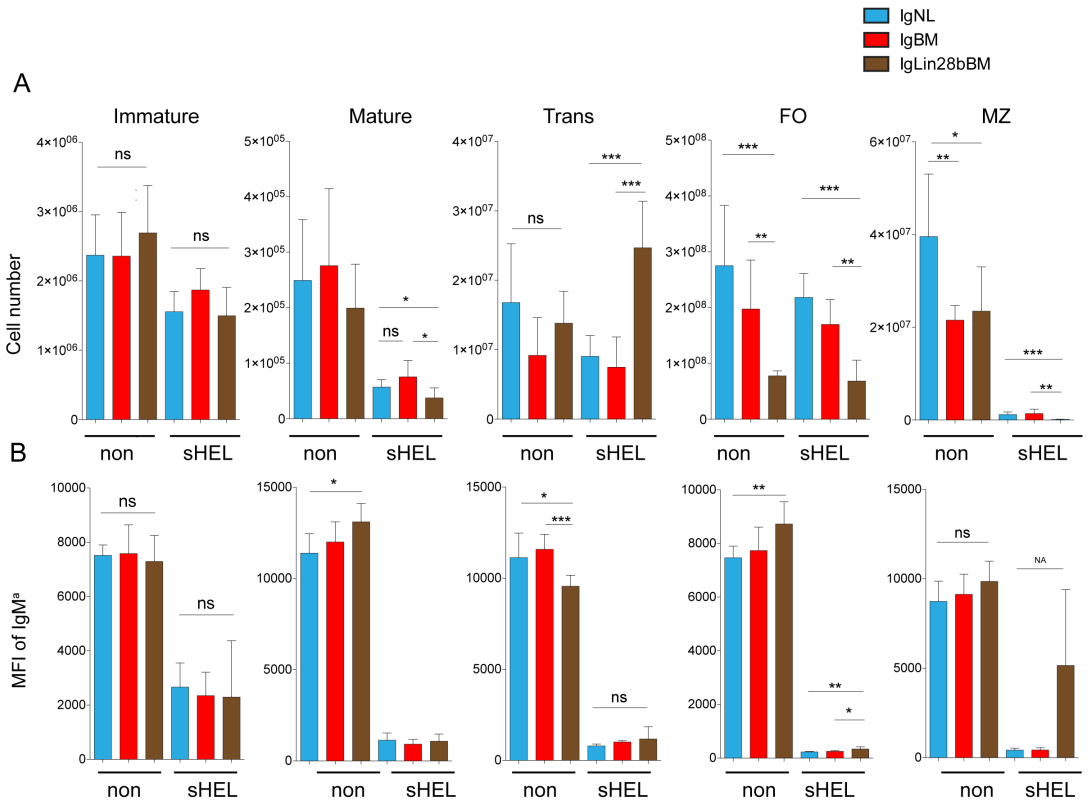



**Figure 5-2. The effect of Lin28b on B cell populations in Ig$^{HEL}$/sHEL model.** (A) Cell number of immature, mature B cells in BM, Trans, FO, MZ B cells in spleens from IgNL, IgBM or IgLin28bBM transferred into irradiated non or sHEL recipients (n=5 per group) (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test). Columns show the mean and bars represent the 95% confidence limits. Gating identified CD45.1$^-$ CD45.2$^+$B220$^+$IgM$^{a+}$IgD$^{a-}$CD21$^-$CD23$^-$ immature and CD45.1$^-$CD45.2$^+$B220$^+$IgM$^{a-/+}$ IgD$^{a+}$CD21$^+$CD23$^+$ mature in the BM; CD45.1$^-$CD45.2$^+$HEL$^+$ B220$^+$CD93$^+$ transitional, CD45.1$^-$CD45.2$^+$HEL$^+$B220$^+$CD93$^-$CD21$^{mid}$CD23$^+$ FO and CD45.1$^-$ CD45.2$^+$HEL$^+$ B220$^+$CD93$^-$CD21$^+$CD23$^-$ MZ B cells in the spleen. (B) MFI of surface IgM$^a$ on immature, mature, transitional, FO and MZ B cells in IgNL, IgBM and IgLin28bBM/sHEL chimeras (n=5 per group). Columns show means and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test). Gating strategy as above.

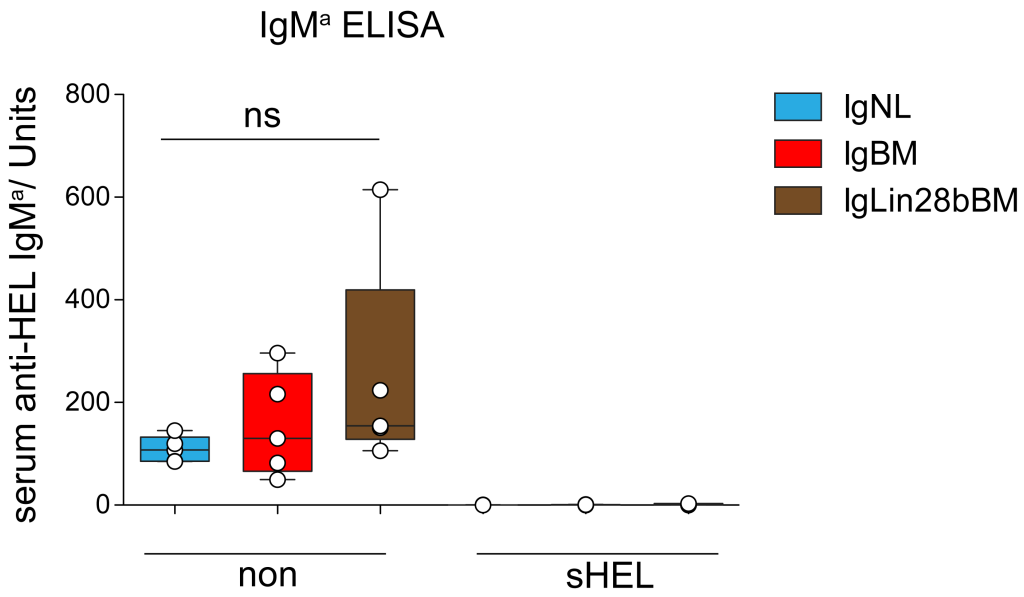



**Figure 5-3. Anti-HEL serum IgMa shows anergy of B cells in sHEL recipients.** Serum anti-HEL IgM$^a$ titres in IgNL-non, IgNL-sHEL, IgBM-non, IgBM-sHEL, IgLin28bBM-non and IgLin28bBM-sHEL mice (n=5). Columns show the means, bars represent the 95% confidence limits and dots show individual data points (unpaired t-test).

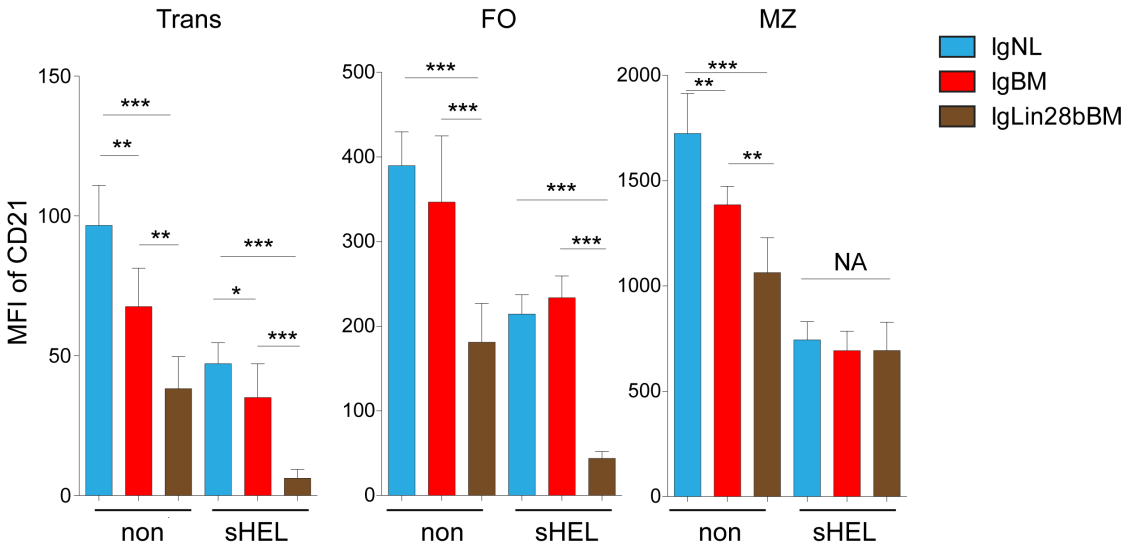



**Figure 5-4. Mature B2 B cells overexpressing Lin28b show developmental arrest.**

MFI of surface CD21 on Trans, FO and MZ B cells from IgNL, IgBM and IgLin28bBM transferred into non and mHELKK mice (n=5). Columns show means and bars represent the 95% confidence limits (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test).

## 5.3 Discussion

These results reveal effects of Lin28b, which are separate from its effects at different stages of ontogeny and likely to be due to its abnormal expression late in B cell development.

Lin28b overexpression in adult BM may cause abnormal blockade of FO B cell development.

The fact that B1 and MZ B cells are not rescued in BM over-expressing IgLin28b and recirculating mature B cells are more reduced, suggests that Lin28b may exaggerate negative selection in this scenario.

This raises the question of the mechanism of Lin28b action in positive and negative selection. In previous chapter, we found that Lin28b affects the level of BCR expression and this may due to changes in expression of surface BCR (**Fig. 4-3 and Fig. 4-8**). In the sHEL model where self-antigen induces a stronger signal, it is reasonable to expect stronger negative selection in Lin28b transgenic group. A similar titratable effect could also explain the cumulative effect on FO B cells.

# Chapter 6. Insight into the mechanism of Lin28b control

## 6.1 Introduction

Chapters 4 and 5 described how Lin28b is able to convert negative to positive selection. I have also shown that the expression of a Lin28b transgene has novel effects that are independent of ontogeny, blocking FO B cell development and hence causing the accumulation of transitional B cells. These effects may be due to suppression of normal let-7 dependent functions in late stage B cell development, caused by the continued expression of the Lin28b transgene beyond the immature B cell stage of development. Nevertheless, the fact that Lin28b appears to induce high levels of sIgM, and reduce CD21 level in a manner that is additive with antigen, suggests the possibility that Lin28b may also regulate the threshold for BCR signalling. This regulation of signalling may illustrate the mechanism of Lin28b function in positive selection.

As already discussed, there is a large body of literature supporting an instructive role of BCR signalling in B1 B cell development and lineage commitment(194). Previous reports have suggested that the positive selection of B1 B cells depends on a stronger BCR signal, and mice lacking negative regulators (such as SHP-1, Lyn, and CD22) or transgenic for positive regulators of BCR signalling (such as CD19) showed an enrichment in B1 B cells(19).

Stimulation of the BCR leads to the induced activation of the three major classes of mitogen-activated protein kinase (MAPKs), ERK, JNK, and p38 MAPK, as well as the Akt kinase and the transcription factor nuclear factor of activated T cells (NF-AT) and

NF-κB in B2 B cells. In contrast, B1 B cells have been reported as displaying constitutive activation of ERK and NF-AT but exhibit delayed JNK and absent p38 MAPK and NF-κB induction upon BCR cross-linking(195). B1 B cells are also reported to be less efficient at mobilizing intracellular calcium upon BCR cross-linking (19,171,174,196).

Comparison of immature and mature B cell signalling has suggested that immature B cells have a lower threshold for BCR triggered protein tyrosine phosphorylation than mature cells, but data were controversial in terms of intracellular calcium response(197,198). The BCR induced phosphorylation of Gab1/2 is similar but the kinetics of Erk activation is different. A sustained Erk activation enhancing survival and cell activation operates in mature B cells, while a transient Erk phosphorylation and transient activation of the Erk-dependent transcription factors may be associated with a tendency to apoptosis in immature B cells(197,198). Whether this difference determines cell fate, and whether there is similar signalling difference between FL and adult BM immature B cells is unknown.

To investigate further the role of Lin28b and ontogeny on B cell fate decision and signalling downstream of antigen engagement, I explored BCR signalling in MD4 B cells from early, medium and late stages of ontogeny and development and used transcriptional profiling of immature and differentiated cells to identify downstream targets.

## 6.2 Results

### 6.2.1 Lin28b regulation in immature B cells

To identify the transcriptional profile in immature B cells downstream of Lin28b, I sorted 5x$10^5$ immature B cells from $Ig^{HEL}$ BM and $Ig^{HEL}$ Lin28b BM for RNA-seq. The libraries were built by poly-A selection, and sequenced for 75bp, paired end reads, with 40 million reads/sample on HiSeq4000. Genes differentially expressed between $Ig^{HEL}$ BM and $Ig^{HEL}$ Lin28b BM were filtered by an adjusted P value under 0.05. Among these genes, 39 were upregulated in the presence of Lin28b and 42 in its absence (**Fig. 6-1 and Table. 6-1**).

Lin28b was itself highly expressed in Lin28b transgenic sample, which validated the assay. Other transcripts that have been reported as downstream of Lin28b, including Igf2bp3(90), Arid3a(106), Bhlhe41(107), were all induced by Lin28b in immature B cells. The transcripts of calcium related genes, such as Cacna1i (calcium channel, voltage-dependent, alpha 1I subunit) and Camkk1 (Calcium/calmodulin-dependent protein kinase kinase 1) were also higher in the presence of Lin28b. Other transcripts higher in the presence of Lin28b included: chemokine receptors, such as Klrb1c (killer cell lectin-like receptor subfamily B member 1C), Plaur (plasminogen activator, urokinase receptor) and Ccr6 (chemokine receptor 6); transcription factors, such as Arid3b and Pou2f2; and signal transducers, such as Stac2 (SH3 and cysteine rich domain 2) (**Fig. 6-1**).

Transcripts including Il2ra, Igkv9-124 (Immnogloblin light chain variable region), Vpreb1 (CD179a), Igll1 (CD179b) were repressed by Lin28b (**Fig. 6-1**).

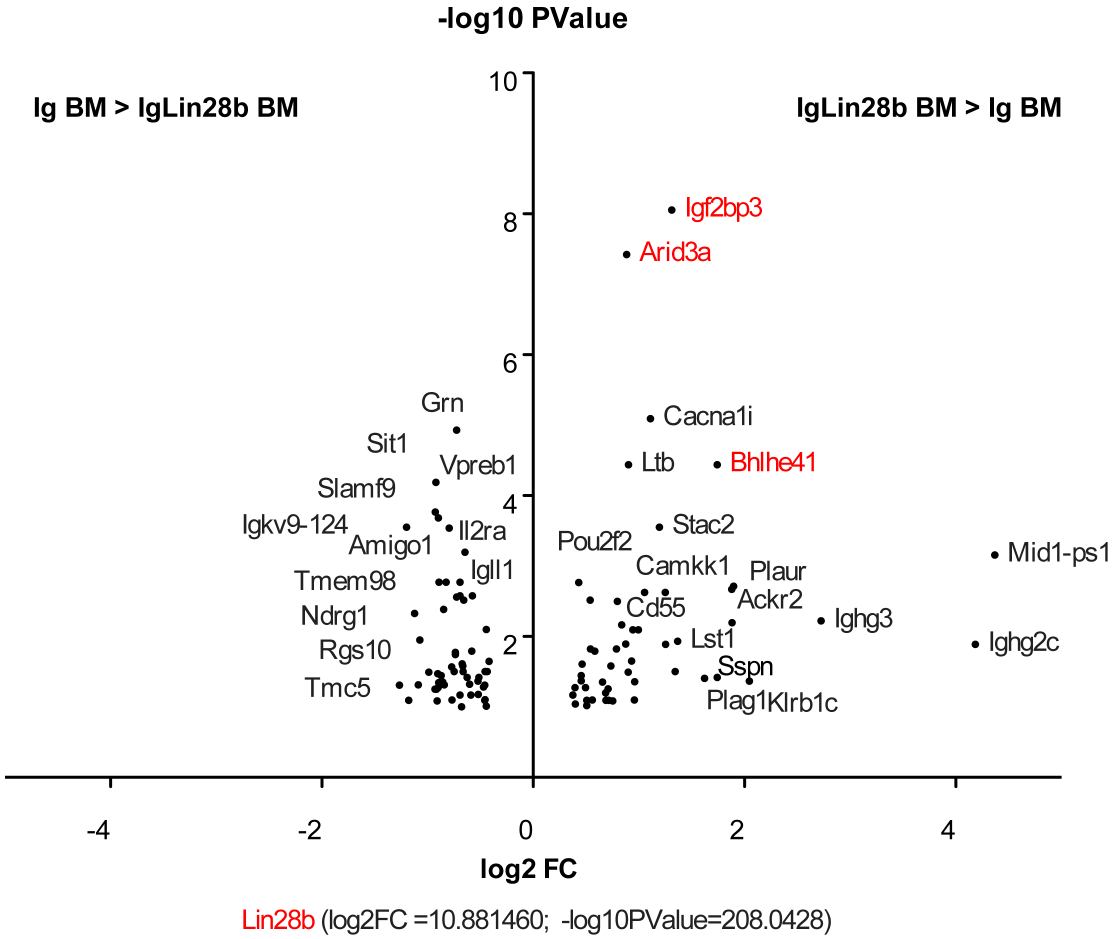



**Figure 6-1. Transcription analysis of IgLin28b BM.** Volcano plot shows logFC(x-axix) against –log10 of adjusted P-value(y-axis) of all data points in RNAseq dataset (n=3, adjusted P value<0.05). The left and right panels show genes with higher expression level in MD4 $Ig^{HEL}$ BM and $Ig^{HEL}$ Lin28bBM respectively. Lin28b transcript as listed red at the bottom is beyond the plot scale.

### 6.2.2 BCR signal in immature B cells of early and late ontogeny

To compare B cell signalling in immature B cells from early and late ontogeny, I next stimulated $Ig^{HEL}$ NL (0 day old) and $Ig^{HEL}$ adult BM (8-10 weeks old) immature B cells with cognate antigen, sHEL, or anti-IgM antibody ex vivo.

$Ig^{HEL}$ NL and $Ig^{HEL}$ adult BM cells were treated with a range of sHEL or anti-IgM concentrations for 3mins (for measuring pSyk, pBLNK and pPLCγ2) or 5mins (for measuring pERK). The cells were fixed and surface stained for B220, CD24, CD43, $IgM^a$, $IgD^a$ and then intracellularly for phosphorylated enzymes. Flow cytometry analysis showed no significant differences in pSyk, pBLNK, pPLCγ2 (**Fig. 6-2a**), but a higher basal and anti-IgM-induced pERK in $Ig^{HEL}$ FL immature B cells compared to $Ig^{HEL}$ adult BM counterparts (**Fig. 6-2a,c**).

$Ig^{HEL}$ NL immature B cells also showed a higher basal and anti-IgM stimulated higher median $Ca^{2+}$ flux, compared to $Ig^{HEL}$ immature adult B cells. In these experiments, $Ig^{HEL}$ FL and BM cell were labelled with B220-PerCP-Cy5.5 and B220-Alexa Fluro®700 respectively (in both ways) and mixed in the same tube and stimulated with 10ug/ml anti-IgM F(ab')2 (**Fig. 6-2b**).

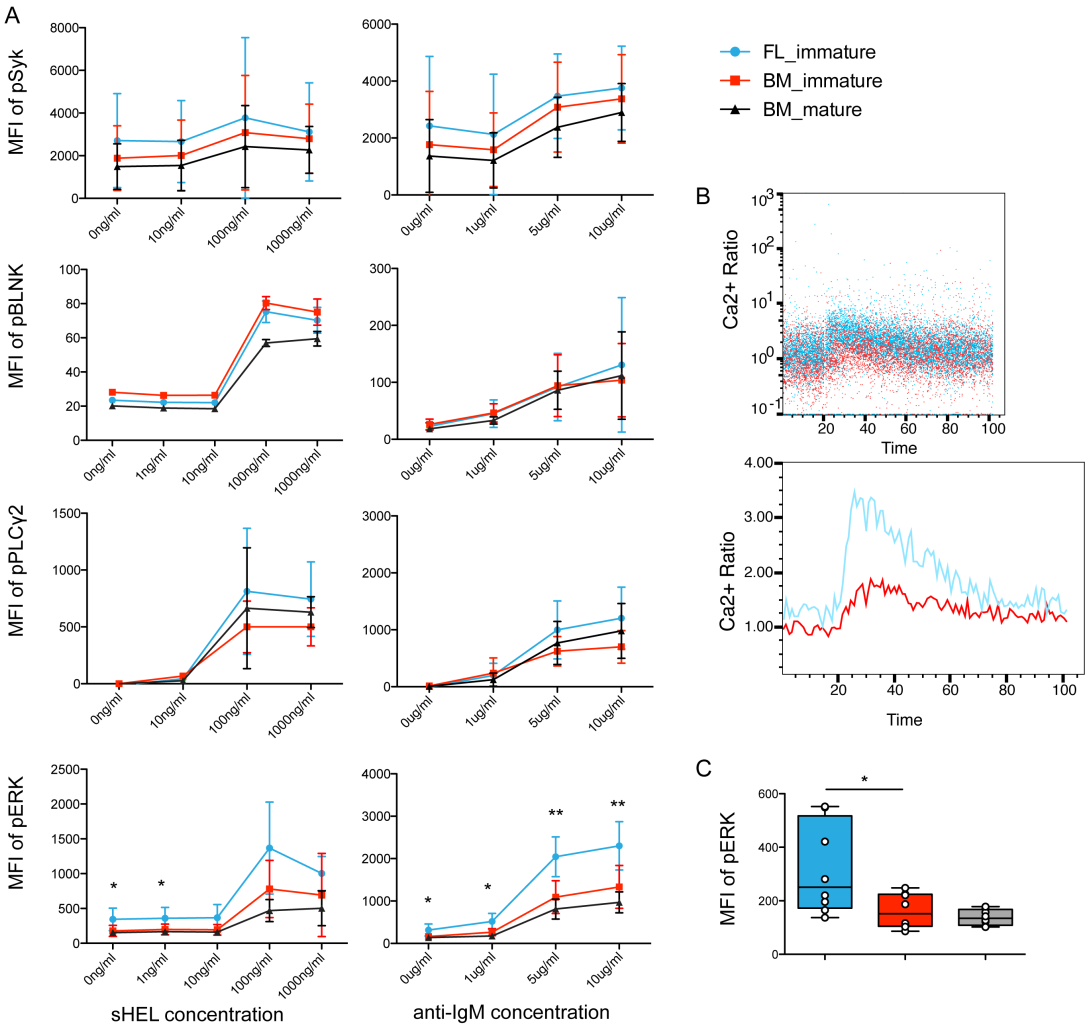



**Figure 6-2. Immature B cell BCR signalling in early and late ontogeny.** (a) ICS staining for pSYK, pBLNK, pPLCγ2 after 3mins sHEL or anti-IgM stimulation (n=3) and ICS staining for pERK after 5mins sHEL or anti-IgM stimulation (n=8). Blue shows FL/NL immature $Ig^{HEL}$ B cells ($B220^{mid}CD24^{hi}CD43^{-}IgD^{-}$), red shows adult $Ig^{HEL}$ BM immature B cells ($B220^{mid}CD24^{hi}CD43^{-}IgD^{-}$), and black shows adult $Ig^{HEL}$ BM mature B cells ($B220^{hi}CD24^{lo}CD43^{-}IgD^{-}$). (b) Dot plot and median value of calcium flux ratio in mixed $Ig^{HEL}$ FL and $Ig^{HEL}$ adult BM immature B cells in response to stimulation with anti-IgM F(ab')2. (c) Basal level of pERK on FL immature B cell, adult BM immature B cell and adult BM mature B cells (*p<0.05, **p<0.01, ***p<0.001, unpaired t-test)(n=8).

### 6.2.3 Pathways downstream of the BCR signal

To investigate BCR signalling more broadly, I decided to compare next the transcriptomic profile in NL and BM after stimulation. In this experiment, $Ig^{HEL}$ NL and $Ig^{HEL}$ adult BM were stimulated with the cognate antigen sHEL for 4 hours. I then flow-sorted one hundred $B220^{+}CD43^{-}CD21^{-}CD23^{-}CD24^{hi}IgD^{-}$ immature B cells in each sample.

I generated and compared samples from four groups, with 5 biological replicates of each: (i) stimulated $Ig^{HEL}$ NL immature B cells stimulated (NL-sHEL); (ii) unstimulated $Ig^{HEL}$ NL immature B cells (NL-R10); (iii) stimulated $Ig^{HEL}$ adult BM immature B cells (BM-sHEL); and (iv) unstimulated adult BM immature B cells (BM-R10). The sequencing library was prepared using smartseq2 and sequenced for 75bp, pair end reads, with ~35million reads/sample on HiSeq4000. Genes that were differentially expressed between those four groups were filtered for an adjusted P value under 0.01 and fold change over 2.

The results show an induction of 545 transcripts (**Table 6-7**) and repression of 388 transcripts (**Table 6-8**) in stimulated $Ig^{HEL}$ NL immature B cells (**Fig. 6-3a**). In comparison, there was induction of 128 transcripts (**Table 6-9**) and repression of 103 transcripts (**Table 6-10**) in stimulated adult $Ig^{HEL}$ BM immature B cells (**Fig. 6-3b**). There were 199 differentially up-regulated (**Table 6-3**) and 152 down-regulated transcripts (**Table 6-4**) in NL-sHEL compared to BM-sHEL (**Fig. 6-3c**); and there were 243 up-regulated (**Table 6-5**) and 185 down-regulated transcripts (**Table 6-6**) in NL-R10 compared to BM-sHEL (**Fig. 6-3d**).

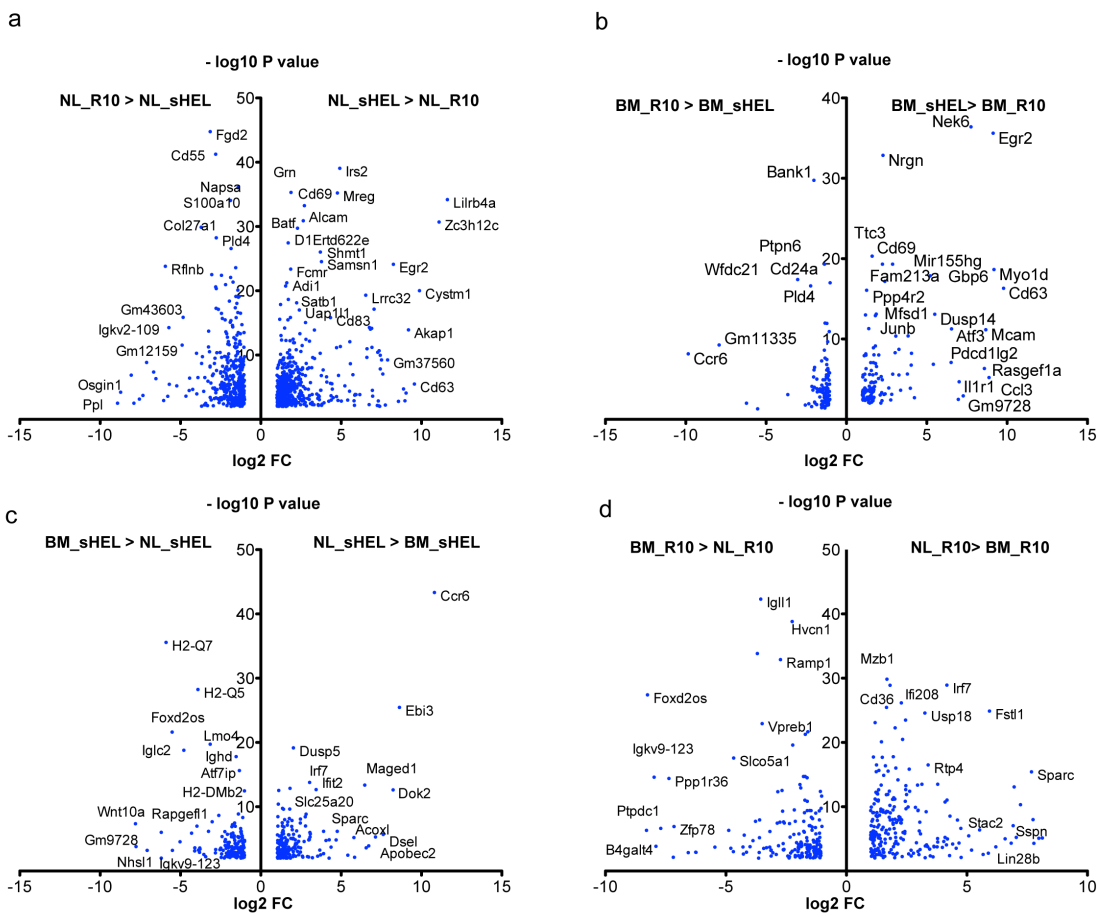



**Figure 6-3. Transcriptional analysis of Ig$^{HEL}$ NL and BM immature B cells after stimulation with antigen.** (a) mRNA transcripts significantly induced or repressed in immature B cell subsets in Ig$^{HEL}$ NL upon sHEL stimulation (n=5, adjusted P value<0.01, log2FC>1 or log2FC<-1). (b) mRNA transcripts significantly activated or repressed in immature B cell subsets in Ig$^{HEL}$ adult BM upon stimulation with sHEL (n=5, adjusted P value<0.01, log2FC>1 or log2FC<-1). (c) mRNA transcripts differentially expressed in immature B cell subsets in Ig$^{HEL}$ NL compared to Ig$^{HEL}$ adult BM stimulated with sHEL (n=5, adjusted P value<0.01, log2FC>1 or log2FC<-1). One transcript beyond the scale of the plot is H2-Q6 (log2FC = -7.33, -log10Pvalue = 198). (d) Transcripts differentially expressed in immature B cell subsets in Ig NL and Ig adult BM (n=5, adjusted P value<0.01, log2FC>1 or log2FC<-1). Two transcripts beyond the scale of the plot are H2-Q6 (log2FC = -6.6870, -log10Pvalue = 88) and H2-Q7 (log2FC= -6.033, -log10Pvalue = 88).

### 6.2.4 The transcriptional profile of B cell subsets

To link the early events following antigen stimulation with B cell selection, I decided next to investigate whether there was any transcriptional signature common to these early events and the differentiated B cell subsets.

To pursue this strategy, I decided first to profile differentiated B cell subsets generate in the $Ig^{HEL}$ MD4 model. I sorted $5x10^5$ cells from different $Ig^{HEL}$ (MD4) B cell populations including: splenic $B220^+CD19^+CD21^{mid}CD23^{hi}$ FO B cells and $B220^+CD19^+$ $CD21^{hi}CD23^-$ MZ B cells from $Ig^{HEL}$ single transgenic mice; splenic $B220^+IgMa^{lo}IgDa^+$ anergic B cells from $Ig^{HEL}$/sHEL (MD4/ML5) double transgenic mice; and peritoneal $B220^{lo}CD19^{hi}IgMa^+IgDa^-CD21^-CD23^-$ B1 B cells from $Ig^{HEL}$/mHELKK double transgenic mice. RNA-seq libraries were built by ribosome depletion, and sequenced for 75bp, paired end reads, with ~35million reads/sample on HiSeq4000.

Using FO B cells as a reference population, I compared MZ, anergic and B1 B cells with FO B cells. Differentially expressed genes were filtered by an adjusted P value under 0.05 and fold change over 2.

The results of this analysis showed the greatest similarity between follicular and anergic B cells: 300 transcripts had a higher expression level in anergic B cells compared to FO B cells (**Table 6-11**) and 188 genes were repressed (**Table 6-12 and Fig. 6-4a**). In comparison, 681 transcripts has a higher expression level in MZ B cells compared to FO B cells (**Table 6-13**) and 505 genes were repressed (**Table 6-14 and Fig. 6-4b**); and 886 transcripts were more highly expressed in B1 B cells compared to FO B cells (**Table 6-15**) and 446 genes repressed (**Table 6-16 and Fig. 6-4c**).

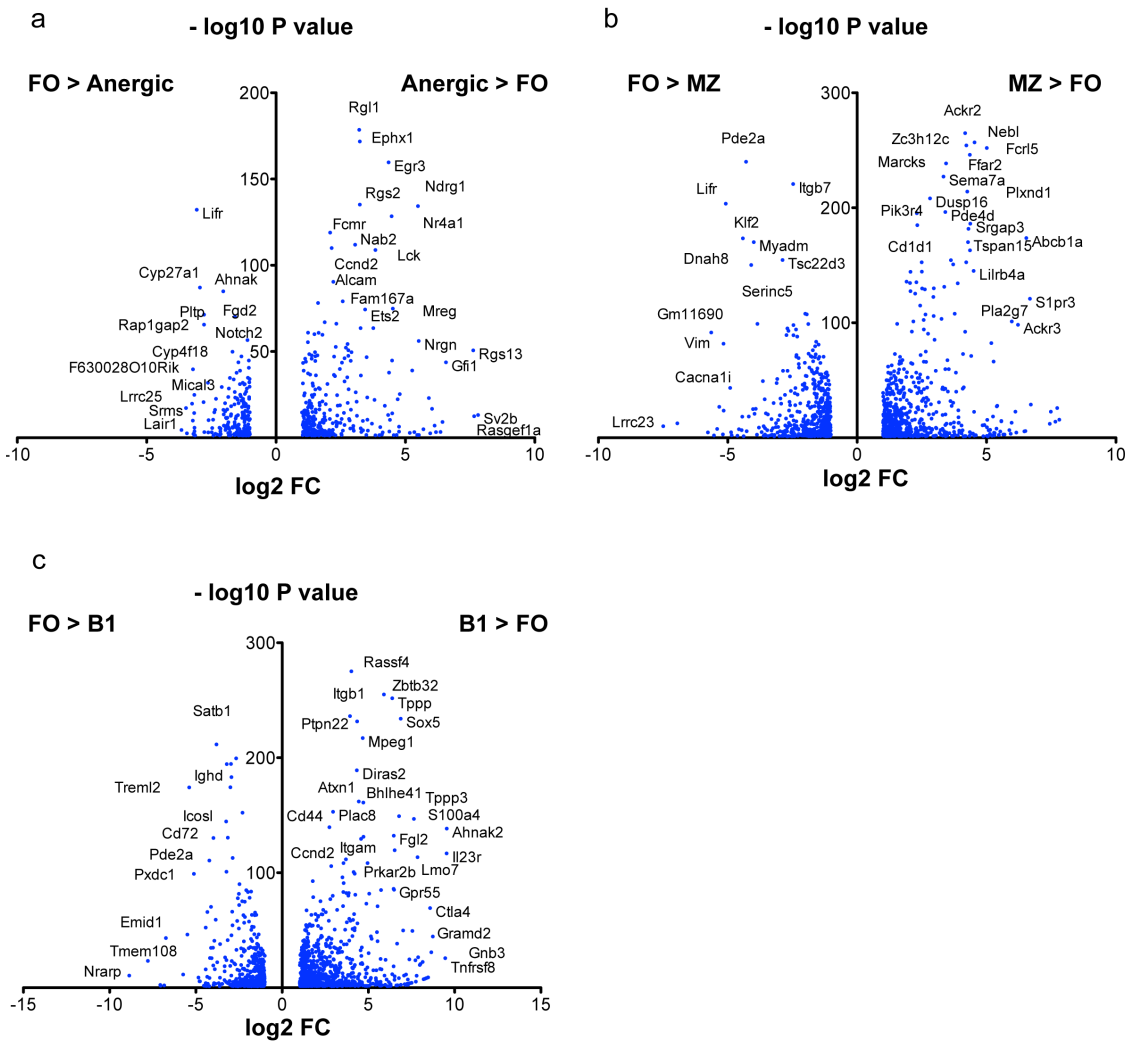



**Figure 6-4. Transcriptional analysis of FO, MZ, Anergic and B1 Ig$^{HEL}$ B cell subsets.** (a) Genes differentially expressed between FO and anergic B cell subsets (n=3, adjusted P value<0.05, log2FC>1 or log2FC<-1). (b) Genes differentially expressed between FO and MZ B cells (n=3, adjusted P value<0.05, log2FC>1 or log2FC<-1). (c) Genes differentially expressed between FO and B1 B cell subsets (FO: n=3, B1: one pool sample from 11 mice, adjusted P value<0.05, log2FC>1 or log2FC<-1).

### 6.2.5 Genes associated with Lin28b regulation and positive selection of B1 B cells.

#### 6.2.5.1 Lin28b regulated B1 B cell development

To identify transcripts that might be associated with B1 B cell development, I searched next for transcriptional signatures common to early cells in ontogeny, Lin28b and the differentiated cells.

I began by looking for common factors in three RNAseq datasets comprising (i) transcripts higher in $Ig^{HEL}$ NL vs $Ig^{HEL}$ Adult BM immature B cells; (ii) transcripts higher in $Ig^{HEL}$ Lin28b transgenic vs non-transgenic $Ig^{HEL}$ BM immature B cells; and (iii) transcripts higher in $Ig^{HEL}$ B1 vs $Ig^{HEL}$ FO B cells. Interestingly, only two genes were common between these three datasets, Sspn and Bhlhe41 (**Fig. 6-5a**).

It has recently been shown that Bhlhe41 is an important transcription factor required for B1 B cell development(107). Sspn (sarcospan) is an integral membrane component of the dystrophin-glycoprotein complex (DGC) found at the sarcolemma of striated and smooth muscle.

There were 8 genes up-regulated in early ontogeny and positively regulated by Lin28b, including Lin28b, Igf2bp3 and Arid3a (**Fig. 6-5b**). Hypothetically, these genes may all be important in the early stages of B1 B cell development.

There were 44 genes shared between Ig NL immature B cells and B1 B cells, but not common to Lin28b. This finding may highlight a series of Lin28b independent pathways in B1 B cell development (**Fig. 6-5c**).

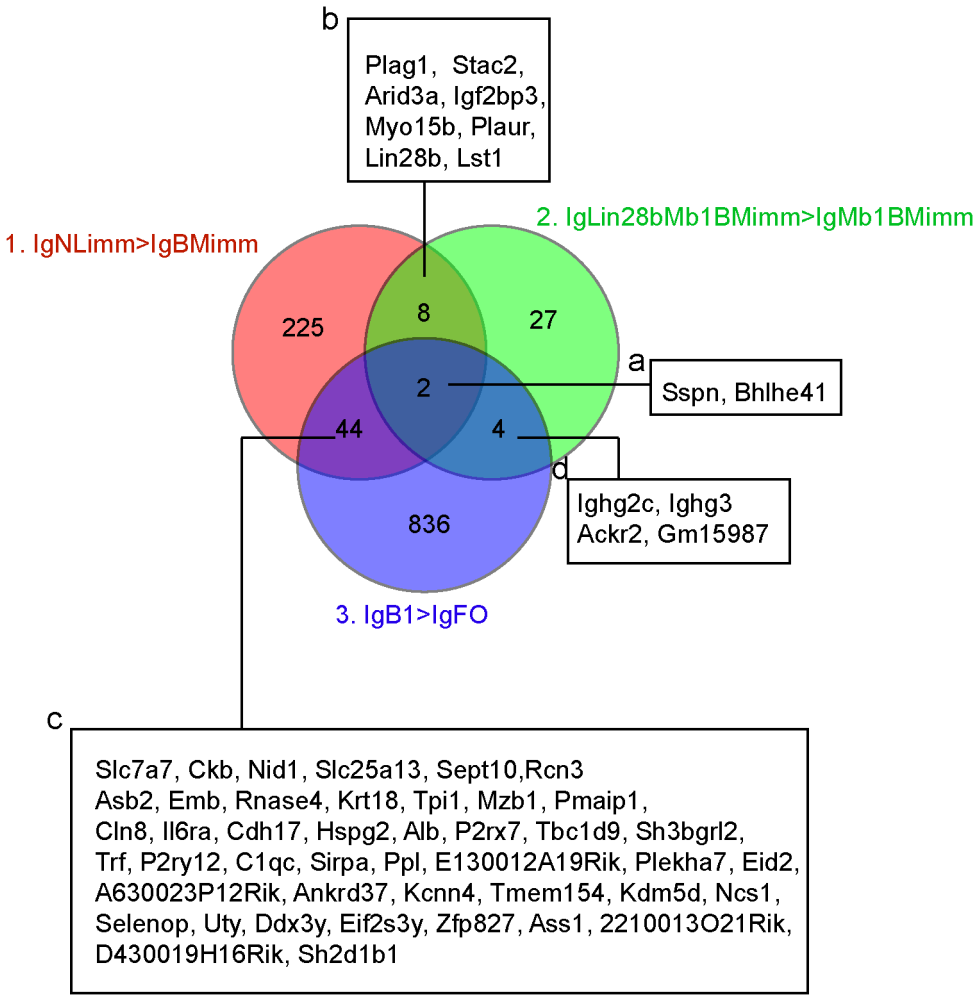



**Figure 6-5. Venn Graph of common genes across $Ig^{HEL}$ NL immature, Lin28b BM and B1 B cell population.**

#### 6.2.5.2 Positive and negative selection

Since immature $Ig^{HEL}$ NL and adult BM B cells differ in their susceptibility to positive and negative selection by mHEL-KK, and B1 and anergic B cells lie downstream of positive and negative selection events, I hypothesized that a comparison of these four groups might reveal genes important for these processes.

First, I identified transcripts that were elevated in $Ig^{HEL}$ NL immature B cells (**Fig. 6-3a**) and $Ig^{HEL}$ adult BM immature B cells (**Fig. 6-3b**) following 4hr sHEL stimulation. Second, I identified transcripts that were elevated in B1 B cells (**Fig. 6-4c**) and anergic B cells (**Fig. 6-4a**) compared to FO B cells. There were 43 transcripts shared exclusively between antigen-stimulated $Ig^{HEL}$ NL immature B cells and B1 B cells, which might be important for positive selection; and 5 transcripts were shared exclusively between antigen-stimulated $Ig^{HEL}$ adult immature B cells and anergic B cell subsets, which might be implicated in negative selection (**Fig. 6-6a**).

Similarly, I also compared genes repressed in those four groups and found 24 repressed genes shared exclusively between $Ig^{HEL}$ NL and B1 B cells (**Fig. 6-4b**).

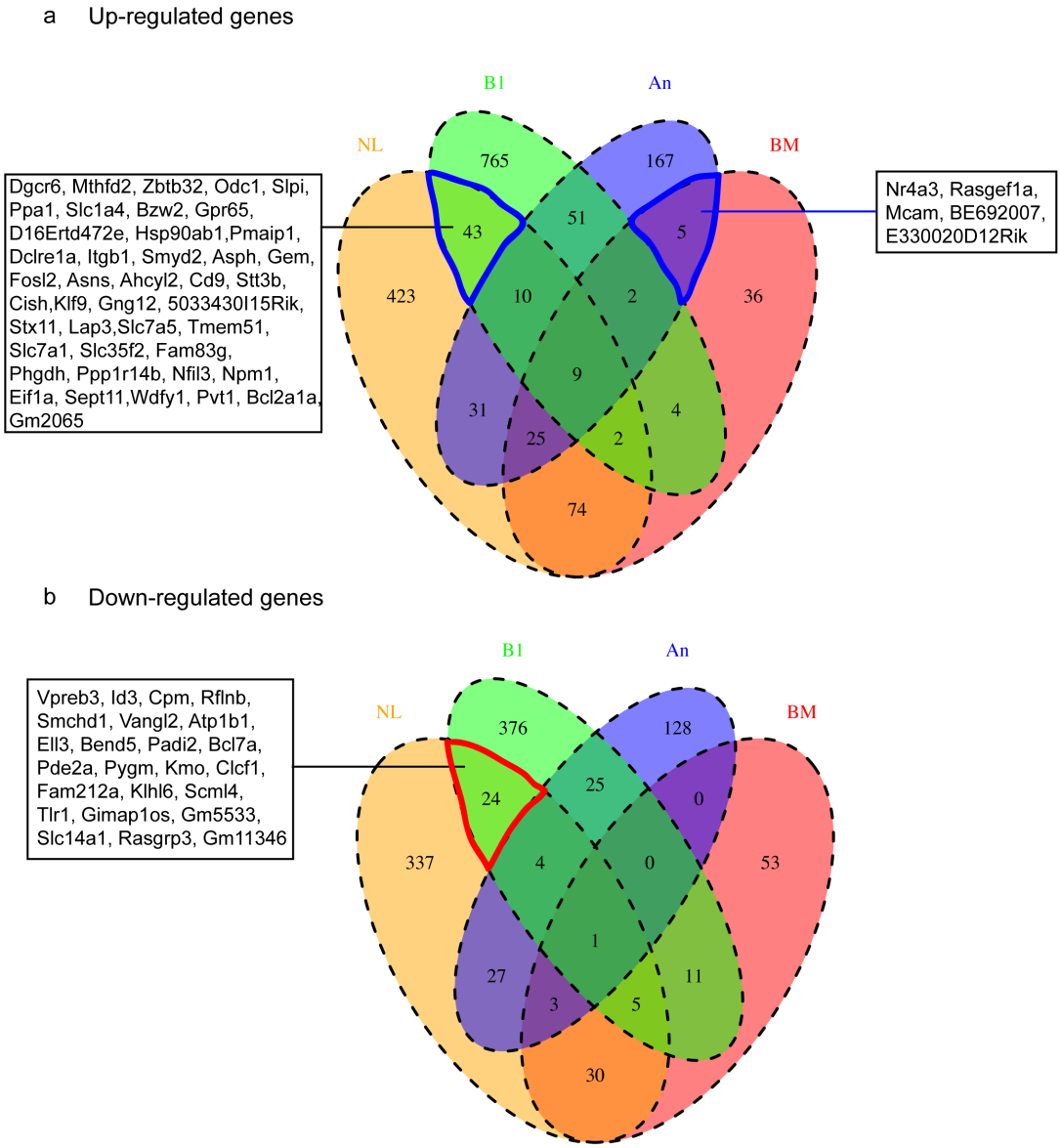



**Figure 6-6. Venn Graph of common genes for positive and negative selection.**

## 6.3 Discussion

This chapter investigated Lin28b/let-7 downstream pathways in multiple dimensions. Transcriptomic analysis was used to gain insights into the possible molecular mechanisms of Lin28b regulated positive selection at the immature B cell level. Immediate BCR signalling was compared in $Ig^{HEL}$ NL and adult BM immature B cells using flow cytometry; and antigen-induced transcriptional changes were measured 4 hours later. Finally, downstream B cell populations were profiled using RNASeq and a B cell transcriptional development map was built.

Many candidate genes arise from this pool of data. The identification of BHLHE41 as a Lin28b-dependent target associated with B1 B cell selection is a good validation of this approach. Among other genes downstream of *Lin28b* that might be involved in B1 B cell selection, *Sspn* and *Stac2* are of particular interest.

*Sspn* encodes sarcospan, a membrane protein with a similar structure to CD20. CD20 localizes to lipid rafts where it may play a role in regulating cell cycle progression, tyrosine kinase-dependent signalling, and B-cell differentiation(199). SSPN has been reported to regulate signalling thresholds (AKT), which hypothetically might also affect B cell migration, integrin activation and/or survival(200). We have now formed a collaboration with Rachelle Crosbie-Watson (UCLA) to investigate B cell development in $Sspn^{-/-}$ mice.

Stac2 is highly expressed in NL immature B cell and Lin28b induced immature B cells. It encodes STAC2, which is Src homology 3 domain and cysteine-rich domain-containing protein 2. STAC2 protein physically interacts with the receptor activator of nuclear factor-κB (RANK) and inhibits the formation of the RANK signaling complex, which contains Grb-2-associated binder 2 (Gab2) and PLCγ2, leading to the suppression of RANK-mediated NF-κB and MAPK activation. Overexpressing

STAC2 limits Btk/Tec-mediated PLCγ2 phosphorylation(201). This protein also belongs to a newly identified family of regulators of voltage-gated calcium channel (CaV) trafficking and function. STAC proteins associate with the CaV1.2 C terminus at the IQ domain and thus inhibit calcium-dependent feedback regulation of CaV1.2 currents(202).

Hypothetically, negative regulation of downstream BCR signalling by proteins like STAC2 could explain why immature B cells in early ontogeny respond to some antigenic signals with positive rather than negative selection, and perhaps why surviving cells are associated with higher levels of constitutive signalling in the absence of antigens. Lin28b activates *Stac2*, as well as calcium related genes, *Cacna1i* and *Camkk1*. Future experiments could usefully compare signaling in $Ig^{HEL}$ Lin28b transgenic and non-transgenic immature BM B cells.

As well as seeking to address the mechanism of positive selection mechanism, the transcriptomic analysis builds a development map of B cell development into subsets within a single BCR specificity, which may guide other future investigations.

# Chapter 7. General Discussion

## 7.1 Thesis Summary

Immature anti-HEL B cells in fetal and neonatal life, with an intrinsic capacity for positive selection by self-antigen, have a transcriptional profile characterized by expression of RNA binding protein and let-7 micro-RNA suppressor, Lin28b. In contrast, immature anti-HEL B cells from adult bone marrow, which are unable to undergo positive selection, show the reciprocal expression of the let-7 family. The use of a HEL specific BCR transgenic model shows that the change is independent of antigen specificity.

This primary observation has led to a hypothesis that Lin28b and let-7 may form a bimodal switch, which is important to B cell positive and negative selection. In support, expression of transgenic Lin28b reconstituted the fetal B1 lineage in adult BM chimeras and rescued positive selection. Furthermore, since the developmental switch is inducible by transient expression of Lin28b, these data also support other reports showing that the switch is not hard-wired or specific to a precursor lineage (106).

These findings have encouraged me to explore the pathways downstream of Lin28b/let-7 that encode susceptibility to positive and negative selection. Data from early, intermediate and late time points following the stimulation of B cells with cognate antigen have highlighted the possibility that higher level of calcium mobilization and pERK may help B cell positive selection. Expression of transgenic Lin28b induced transcription factor such as Arid3a and Bhlhe41 – which have already been shown to have roles in B1 B cell selection - and other factors such as Sspn and Stac2 with unknown functions. My data help to build a network downstream Lin28b, in regulating B cell positive and negative selection.

In summary, I reported that Lin28b/let-7 switch is able to convert B cell negative selection to positive selection. In part this may be due to Lin28b-dependent regulation of the transcription network and other factors that change BCR signalling and response to antigen during ontogeny (**Fig. 7-1**).

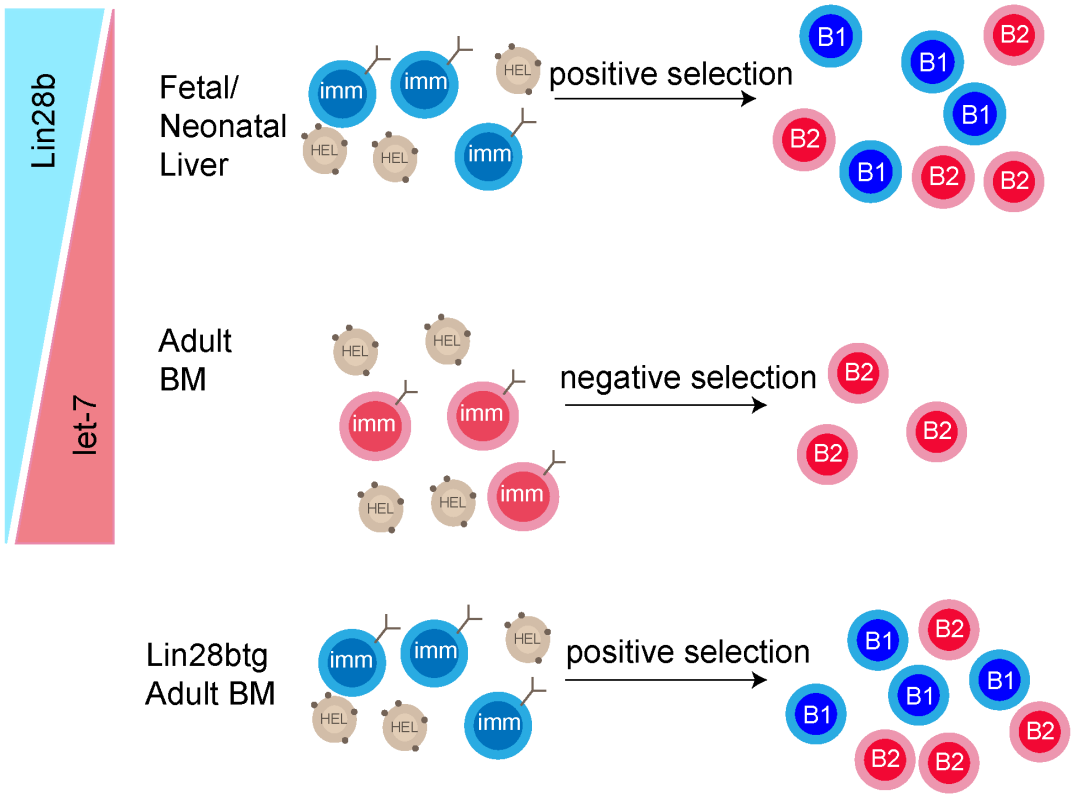



**Figure 7-1. Lin28b/let-7 in B cell positive and negative selection.** Lin28b level is decreasing during ontogeny while let-7 level increase accordingly. Immature B cells are positively selected by self-antigen when cells have high level of Lin28b but negatively selected b the same antigen when cells have high level of let-7. In the $Ig^{HEL}$/mHELKK mouse model, the self-antigen HEL is retained in ER but exposed to immature B cells on apoptotic blebs(122), shown in brown in diagram.

## 7.2 Further discussion and future plans

### 7.2.1 Innate like lymphocytes may share similar regulation mechanism

Previous research has shown that HSCs over-expressing Lin28b not only produce B1 B cells, but also give rise to MZ B cells, γδT cells and natural killer T (NKT) cells. It has been argued that this form of fetal lymphopoiesis meets a higher requirement for innate immunity in early ontogeny, when the first line of immune defence is important.

Among these cells, γδT cells and B1 B cells are both reported to be self-reactive. The fact that a Lin28b/let-7 switch could facilitate the positive selection of B1 B cells may also apply to γδT cells. This could be explored in future work.

Apart from Lin28b, other RNA binding protein such as ZFP36L1 and ZFP36L2 are also reported as regulating lymphocyte development. It has been reported that ZFP36L1 and ZFP36L2 regulate B cell development by maintaining cell quiescence before and after pre-BCR B cell stages(203). They also enforce the β-selection checkpoint during thymopoiesis(204). They repress the activity of the E2F pathway by binding to AU-rich elements(AURE) in the 3' UTR of cell-cycle-related mRNAs(205). Alongside these effects, ZFP36L1 regulates the transcription factors KLF2 and IRF8, to retain MZ B cells(206).

Collectively these results show how RNA binding proteins and microRNAs regulates a comprehensive network during development. Transcription factors downstream work synergistically to keep the immune system in a steady state.

### 7.2.2 BCR rearrangement and B cell repertoire shaping -- Lin28b/let-7 function in B1a B cell development

In B2 B cell development, IL-7R signalling activates the transcription factor STAT5, leading to the activation of rearrangement at the immunoglobulin heavy-chain (*Igh*) locus and suppression of rearrangement at the immunoglobulin light-chain *Igk* locus(207). This mechanism does not exist in FL/NL B cells, where pro-B cells are IL7 independent and have low level of pSTAT5. Hence, it has been suggested that the rearrangement of Igh and Igk loci both take place in pro B stage and bypassing the pre-BCR checkpoint(208).

Recently, a transcription factor Arid3a has been reported that is able to form a complex with Bruton's tyrosine kinase (BTK) and transcription factor TFII-I, binding to A+T-rich regions of the immunoglobulin heavy chain (Igh) intronic enhancer (Eμ) and selecting Igh promoters to activate Igh transcription(209). Deficiency in Arid3a significantly reduces B1a B cell and serum IgM antibody production(106,209,210).

In addition, early in 1998, Richard Hardy showed that the fetal-associated $V_H11\mu$ heavy chain does not associate efficiently with a surrogate light chain(211). The number of B1a cells and their BCR repertoire are mainly unchanged in the pre-BCR deficient mice.

Although the mechanism has not been fully determined, deletion of the transcription factor Bhlhe41 in a mouse model also leads to an altered BCR repertoire, including large reduction of $V_H12^+$ and PtC-specific B1a cells in *Bhlhe41*$^{-/-}$ mice(107).

Together, we may speculate that B1a cell development is regulated by Lin28b/let-7 switch and downstream transcription factors. B cells in early ontogeny may have distinct a BCR rearrangment mechanism to bypass the pre-BCR selection (**Fig. 7-2**) leading to skewed BCR repertoire. This may also explain why we see B1a cell

dramatically regulated in Lin28b/mb-1 BM transferred mice(**Chapter 4, Fig. 4-1 and Fig. 4-2**). The possibility that Lin28b helps B cells to bypass the pre-BCR checkpoint could lead to an increase of immature and transitional B cells in this scenario as well (**Chapter4, Fig. 4-1 and Fig. 4-2**).

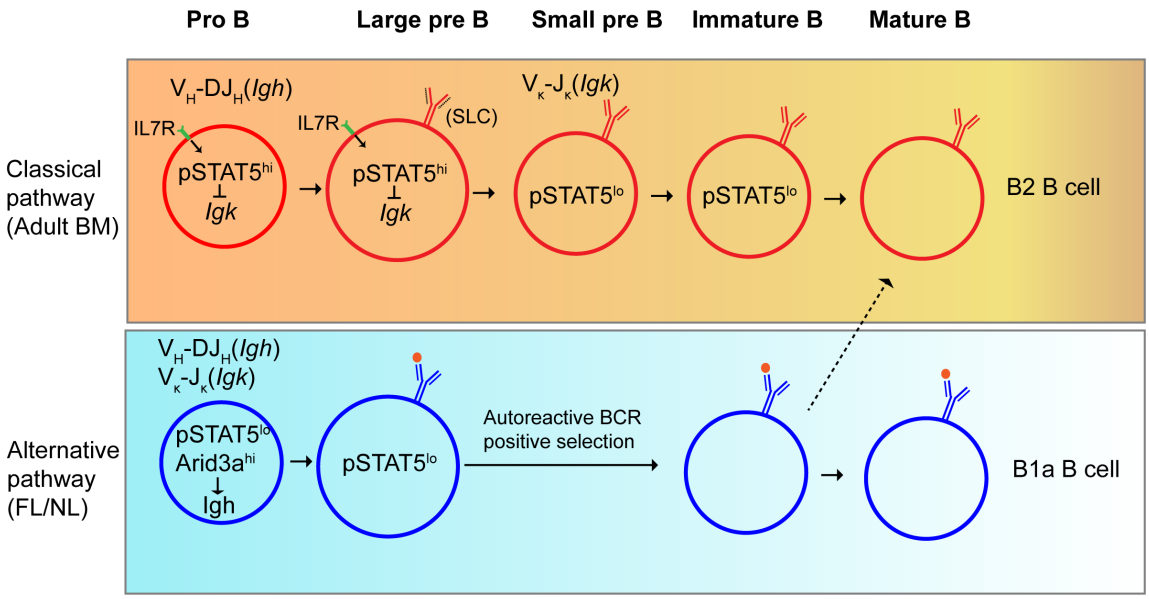



**Figure 7-2**. **Hypothetical outline of B1a cell development**(208). Upper panel shows classical pathway of B cell development in adult BM; lower panel shows alternative pathway of B cell development in FL and NL.

### 7.2.3 B1b cells development – Lin28b/let-7 function in self-antigen selection

B1a and B1b B cells were first defined with similar surface markers, and distinguished by the presence or absence of CD5; however, further studies have indicated that B1a and B1b B cells are not identical cell populations. There are differences in the pathways underlying B cell generation. For example, $CD19^{-/-}$ mice have deficiency of B1a cell generation but B1b cell development is relatively normal, while in CD19 overexpressing mice, B1a cell generation is significantly increased(212).

I have previously described a pre-BCR selection model for B1a B cell generation. Because B cells in the MD4 model have tandem repeats of rearranged heavy and light chains, allelic exclusion is strong and editing of the Ig locus is difficult. Therefore, B1a B cells are not normally enriched in this model (**Chapter 4, Fig. 4-6 and Fig. 4-7**) in contrast to B1b B cells. The selection of B1b B cells is a unique feature to $Ig^{HEL}$ transgenic mice with intracellular HEL self-antigen(121). The rarity and avidity of self-antigen is another factor thought to be important for this positive selection(135), and it is important to note that B1 B cell selection is not hard wired and not accumulative. Instead of bypassing early pre-BCR checkpoint, which may be typical of most B1a cells, B1b cells may be more likely to be positively selected at immature B cell stage or later by antigen.

### 7.2.4 B1b B cell function and therapeutic importance

B1a and B1b B cells are also functionally diverged. B1a cells are able to generate IgM and IgA antibodies in the steady state. These antibodies are mostly poly-reactive and with modest affinity, showing B1a cells are likely to be responsible for the innate immune response in early ontogeny(213).

B1b B cells, in contrast, undergo TI response to bacterial pathogens(212). Haas et al. have demonstrated that pneumococcal polysaccharide (PPS) is a B1b antigen. B1b B cells are able to provide antibody against *Streptococcus pneumonia* infection(212) and these potential is maintained throughout life(214). Other studies including Alugupallie et al. reported B1b function in immunity to *Borrelia hermsii*(215) and Foote et al. using α-1,3 Dextran expressed on *Enterobacter cloacae*(216), also demonstrated that B1b B cells are the principal reservoir of memory to bacterial polysaccharide antigens.

The theory that B1a and B1b B cells are biased towards innate and adaptive immunity respectively is controversial. There is a report that B1a B cells generate an antigen-specific response to the glycolipid (FtL) from *Francisella tularensis*(217). Thus B1b (and B1a) B cell may have important role in vaccine development., and studying targets of B1b (and B1a) B cells may help in developing novel vaccination strategies(218).

### 7.2.5 Human B1 B cells and clinical relevance

Although it has not yet been possible to define a set of markers that clearly identify a B1 B cell population in humans and CD5 would not function as an exclusive marker, there are cells in human meet the key criteria of B1 B cells as found in mouse. These features include natural IgM secretion, efficient T cell stimulation and chronic intracellular signalling(219). As discussed in previous section, identification of human B1 B cells might provide the opportunity to advance immune therapy against microbial pathogens and other human disease.

There are several diseases associated with B1 like B cells in humans, including chronic lymphocytic leukemia (CLL), which is a disease of monoclonal B cells with $CD5^+$ phenotype. It is a common form of adult leukaemia with an incidence that increases with advancing age. Studies of CLL show that BCR signalling plays critical role in CLL cell growth. The receptor of CLL B cells is often polyreactive and sometimes autoreactive. Like B1b B cells, CLL B cells have been shown to respond to stimulation by both autoantigens and microbial antigens.

In this context, understanding B1b B cell positive selection mechanism may help to discover the mechanism of CLL disease generation. Future understanding of how

changes in BCR signalling are linked to B cell development and loss of tolerance to self-antigen will provide insights into autoimmune disease.

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# Appendix: Gene lists

## Table 3-1. Genes significantly up-regulated in NL in microarray sequencing.

| Symbol | Probe_Id | logFC(NL/BM) | adj.P.Val | Annotation |
|---|---|---|---|---|
| Stfa1 | ILMN_2988931 | 4.676449908 | 0.000240634 | stefin A1 |
| Stfa1 | ILMN_2774410 | 4.673338791 | 0.000411984 | stefin A1 |
| Eif2s3y | ILMN_1241001 | 3.697381898 | 0.007050641 | eukaryotic translation initiation factor 2, subunit 3, structural gene Y-linked |
| Igf2bp3 | ILMN_1226175 | 3.379131441 | 0.000103461 | insulin-like growth factor 2 mRNA binding protein 3 |
| Pacsin1 | ILMN_2644415 | 3.319876702 | 0.000103461 | protein kinase C and casein kinase substrate in neurons 1 |
| H19 | ILMN_1256343 | 3.035598838 | 0.009904673 | H19, imprinted maternally expressed transcript |
| Igf2bp3 | ILMN_1218913 | 2.93041243 | 0.000592428 | insulin-like growth factor 2 mRNA binding protein 3 |
| EG433016 | ILMN_2995688 | 2.8972298 | 0.018179604 | predicted gene 5483 |
| Igf2bp3 | ILMN_1259757 | 2.573428039 | 0.000240634 | NA |
| Stfa3 | ILMN_1260585 | 2.378970396 | 0.000592428 | stefin A2 |
| Igf2bp3 | ILMN_1245610 | 2.151540616 | 0.007050641 | NA |
| Bex4 | ILMN_3118584 | 1.9326965 | 0.000754343 | brain expressed gene 4 |
| Gcat | ILMN_2777696 | 1.930616644 | 0.001264406 | glycine C-acetyltransferase (2-amino-3-ketobutyrate-coenzyme A ligase) |
| Sparc | ILMN_3136561 | 1.9154645 | 0.000742734 | secreted acidic cysteine rich glycoprotein |
| Prss19 | ILMN_2675232 | 1.868702909 | 0.00553125 | kallikrein related-peptidase 8 |
| Pacsin1 | ILMN_1244892 | 1.851518718 | 0.014367371 | protein kinase C and casein kinase substrate in neurons 1 |
| Tcrb-V13 | ILMN_2417926 | 1.842937719 | 0.013352356 | NA |
| D230007K08Rik | ILMN_1217913 | 1.641449591 | 0.020074841 | NA |
| Tnni2 | ILMN_2481133 | 1.614337332 | 0.007045251 | troponin I, skeletal, fast 2 |
| E330039G21Rik | ILMN_2667190 | 1.545740365 | 0.001503883 | NA |
| P2ry13 | ILMN_2640346 | 1.545273801 | 0.007145263 | purinergic receptor P2Y, G-protein coupled 13 |
| C230050J15Rik | ILMN_1256771 | 1.522963769 | 0.042542346 | adrenergic receptor kinase, beta 2 |
| Lst1 | ILMN_2609323 | 1.489544406 | 0.010538951 | leukocyte specific transcript 1 |
| Ahsg | ILMN_2993745 | 1.468329634 | 0.012358278 | alpha-2-HS-glycoprotein |
| Serpina1b | ILMN_2659680 | 1.409673715 | 0.040727962 | serine (or cysteine) preptidase inhibitor, clade A, member 1B |
| Apoa2 | ILMN_1247156 | 1.396853208 | 0.040727962 | apolipoprotein A-II |
| Serpina1b | ILMN_1215859 | 1.371092225 | 0.003084768 | serine (or cysteine) preptidase inhibitor, clade A, member 1B |
| H19 | ILMN_2906728 | 1.359827488 | 0.049980191 | H19, imprinted maternally expressed transcript |
| Tceal8 | ILMN_2861493 | 1.281194371 | 0.0035401 | transcription elongation factor A (SII)-like 8 |
| Zcchc3 | ILMN_1248465 | 1.276029592 | 0.010538951 | zinc finger, CCHC domain containing 3 |
| LOC382691 | ILMN_2535566 | 1.267233418 | 0.04026074 | NA |
| Dok2 | ILMN_3160659 | 1.264162207 | 0.0361747 | docking protein 2 |
| 1300002F13Rik | ILMN_2714031 | 1.256941248 | 0.006999673 | ERBB receptor feedback inhibitor 1 |
| Tcrb-V8.2 | ILMN_2431390 | 1.25362198 | 0.007050641 | NA |
| Stfa1 | ILMN_2700239 | 1.246799931 | 0.007145263 | NA |
| Garnl4 | ILMN_2940713 | 1.245007117 | 0.008185316 | RAP1 GTPase activating protein 2 |
| Serpina1b | ILMN_1252899 | 1.240977012 | 0.013674273 | serine (or cysteine) preptidase inhibitor, clade A, member 1B |
| Mlf1 | ILMN_3112219 | 1.236393935 | 0.004355465 | myeloid leukemia factor 1 |
| Ahsg | ILMN_2764036 | 1.221488716 | 0.017710746 | alpha-2-HS-glycoprotein |
| Rem2 | ILMN_1222084 | 1.217058633 | 0.004358914 | rad and gem related GTP binding protein 2 |
| C130091E20 | ILMN_2513922 | 1.181134761 | 0.00553125 | PR domain containing 16 |
| Ptk2 | ILMN_2615901 | 1.176442076 | 0.025478885 | PTK2 protein tyrosine kinase 2 |
| Serpina1d | ILMN_1225570 | 1.167276349 | 0.006732309 | serine (or cysteine) peptidase inhibitor, clade A, member 1D |
| Tnnt1 | ILMN_2460136 | 1.166858317 | 0.047772505 | troponin T1, skeletal, slow |
| Jarid1d | ILMN_1224210 | 1.164748458 | 0.041114708 | lysine (K)-specific demethylase 5D |
| Fkbp11 | ILMN_1224635 | 1.163962644 | 0.014120014 | FK506 binding protein 11 |
| Trf | ILMN_2485323 | 1.154589276 | 0.007264381 | transferrin |
| 2010005H15Rik | ILMN_1234774 | 1.153229417 | 0.020546288 | RIKEN cDNA 2010005H15 gene |
| Lrig3 | ILMN_1213273 | 1.152783433 | 0.00553125 | leucine-rich repeats and immunoglobulin-like domains 3 |
| Dlk1 | ILMN_2771738 | 1.150088631 | 0.004599568 | delta-like 1 homolog (Drosophila) |
| Stac2 | ILMN_2703563 | 1.150018185 | 0.014589194 | SH3 and cysteine rich domain 2 |
| Gpr174 | ILMN_2836855 | 1.144309168 | 0.048302652 | G protein-coupled receptor 174 |
| 9930117H01Rik | ILMN_1237114 | 1.130297465 | 0.012208696 | transmembrane protein 154 |
| Fbln1 | ILMN_2870672 | 1.122339911 | 0.014120014 | fibulin 1 |
| LOC386405 | ILMN_2538597 | 1.121337069 | 0.009029492 | NA |
| Cyp27a1 | ILMN_2960114 | 1.114661011 | 0.044702562 | cytochrome P450, family 27, subfamily a, polypeptide 1 |
| Cgef2-pending | ILMN_1247893 | 1.097298326 | 0.02223733 | Rap guanine nucleotide exchange factor (GEF) 4 |
| Myo7a | ILMN_1251839 | 1.07483108 | 0.010820663 | myosin VIIA |
| Gmpr | ILMN_2602581 | 1.07157866 | 0.013352356 | guanosine monophosphate reductase |
| Iqcf5 | ILMN_2637839 | 1.068720896 | 0.010649604 | IQ motif containing F5 |
| H1f0 | ILMN_1259559 | 1.033971706 | 0.015245641 | H1 histone family, member 0 |
| Uhrf1 | ILMN_2497581 | 1.030456485 | 0.015338907 | ubiquitin-like, containing PHD and RING finger domains, 1 |
| Slc16a6 | ILMN_3073406 | 1.030037191 | 0.021771029 | solute carrier family 16 (monocarboxylic acid transporters), member 6 |
| Plag1 | ILMN_2830811 | 1.026962584 | 0.025461929 | pleiomorphic adenoma gene 1 |
| Kcnmb4 | ILMN_2639207 | 1.026677132 | 0.017783729 | potassium large conductance calcium-activated channel, subfamily M, beta member 4 |

(Continue next page)

| | | | | |
|---|---|---|---|---|
| LOC269531 | ILMN_1228909 | 1.005007929 | 0.015338907 | RIKEN cDNA E230008N13 gene |
| Kng1 | ILMN_2788223 | 1.000047664 | 0.010539933 | NA |
| 4930524J08Rik | ILMN_2425557 | 0.990789435 | 0.016314407 | NA |
| Rnase4 | ILMN_1235657 | 0.984553631 | 0.010538951 | ribonuclease, RNase A family 4 |
| Trim27 | ILMN_2556209 | 0.983060083 | 0.017783729 | NA |
| Cmah | ILMN_2626252 | 0.976188677 | 0.0257106 | cytidine monophospho-N-acetylneuraminic acid hydroxylase |
| LOC233529 | ILMN_2533104 | 0.974971592 | 0.010539933 | potassium channel tetramerisation domain containing 14 |
| Stat4 | ILMN_1236059 | 0.971403812 | 0.015605393 | signal transducer and activator of transcription 4 |
| Kcnmb4 | ILMN_3101339 | 0.966386544 | 0.036042642 | potassium large conductance calcium-activated channel, subfamily M, beta member 4 |
| Zcchc3 | ILMN_2951955 | 0.961000082 | 0.010179612 | zinc finger, CCHC domain containing 3 |
| Pdk1 | ILMN_1229318 | 0.959028102 | 0.012396791 | pyruvate dehydrogenase kinase, isoenzyme 1 |
| Bfsp2 | ILMN_2731774 | 0.955172081 | 0.020177627 | beaded filament structural protein 2, phakinin |
| Cd86 | ILMN_1216386 | 0.951036444 | 0.036516544 | CD86 antigen |
| Ng23 | ILMN_1239632 | 0.947233488 | 0.017574475 | suppressor APC domain containing 1 |
| Cirbp | ILMN_2761594 | 0.939934058 | 0.0257106 | cold inducible RNA binding protein |
| St5 | ILMN_3154820 | 0.933096693 | 0.044013889 | suppression of tumorigenicity 5 |
| Robo3 | ILMN_1247463 | 0.928634136 | 0.010819498 | roundabout homolog 3 (Drosophila) |
| Pscd3 | ILMN_2791746 | 0.927222203 | 0.024346924 | cytohesin 3 |
| Egfl7 | ILMN_3163288 | 0.923438094 | 0.042542346 | EGF-like domain 7 |
| Ptpns1 | ILMN_2722996 | 0.875369689 | 0.045895801 | signal-regulatory protein alpha |
| Sh2d2a | ILMN_1228404 | 0.870775337 | 0.013329857 | SH2 domain protein 2A |
| Tpi1 | ILMN_1231447 | 0.869459619 | 0.03614994 | triosephosphate isomerase 1 |
| Igsf10 | ILMN_2445658 | 0.868511923 | 0.04352496 | mediator complex subunit 12-like |
| Kit | ILMN_1246876 | 0.864388201 | 0.036516544 | kit oncogene |
| 1700048O20Rik | ILMN_2479690 | 0.863196549 | 0.042256323 | RIKEN cDNA 1700048O20 gene |
| AI448196 | ILMN_1246006 | 0.858475794 | 0.015118839 | armadillo repeat containing, X-linked 4 |
| D0Kist3 | ILMN_1235602 | 0.856722524 | 0.036232022 | NA |
| Ass1 | ILMN_1247811 | 0.853749424 | 0.042615466 | argininosuccinate synthetase 1 |
| 7420404O03Rik | ILMN_1239863 | 0.850111615 | 0.02223733 | Mab-21 domain containing 1 |
| A430106B04Rik | ILMN_1255676 | 0.847876705 | 0.027386873 | NA |
| Zfp64 | ILMN_2515349 | 0.835500522 | 0.034545438 | zinc finger protein 64 |
| Zcchc3 | ILMN_2437173 | 0.823674157 | 0.042238958 | zinc finger, CCHC domain containing 3 |
| Mkrn3 | ILMN_2754447 | 0.79817619 | 0.034545438 | makorin, ring finger protein, 3 |
| Nipsnap1 | ILMN_2619861 | 0.795444013 | 0.017574475 | 4-nitrophenylphosphatase domain and non-neuronal SNAP25-like protein homolog 1 (C. elegans) |
| LOC212390 | ILMN_1240069 | 0.787120416 | 0.034545438 | kelch-like 32 |
| Syt11 | ILMN_1233402 | 0.786847922 | 0.034219148 | synaptotagmin XI |
| Ephb2 | ILMN_2622255 | 0.786147609 | 0.039233702 | Eph receptor B2 |
| I830077J02Rik | ILMN_3161500 | 0.784342359 | 0.019774647 | RIKEN cDNA I830077J02 gene |
| Cte1 | ILMN_3139875 | 0.759701732 | 0.021983904 | acyl-CoA thioesterase 1 |
| Phgdh | ILMN_2790181 | 0.755890812 | 0.024565367 | 3-phosphoglycerate dehydrogenase |
| Impa2 | ILMN_1244086 | 0.742449913 | 0.038253299 | NA |
| Atic | ILMN_2606567 | 0.735718573 | 0.040589742 | 5-aminoimidazole-4-carboxamide ribonucleotide formyltransferase/IMP cyclohydrolase |
| 3110054C06Rik | ILMN_1231506 | 0.716080478 | 0.040727962 | cannabinoid receptor interacting protein 1 |
| H1fx | ILMN_1247646 | 0.716038447 | 0.043120727 | H1 histone family, member X |
| Mreg | ILMN_2976159 | 0.709931917 | 0.040589742 | melanoregulin |
| E130012A19Rik | ILMN_2963091 | 0.708201734 | 0.04026074 | RIKEN cDNA E130012A19 gene |
| Dsg2 | ILMN_1221153 | 0.699193097 | 0.045653766 | desmoglein 2 |
| Sept8 | ILMN_1218866 | 0.693422589 | 0.034545438 | septin 8 |
| Ase1 | ILMN_1246695 | 0.681353456 | 0.038686732 | CD3E antigen, epsilon polypeptide associated protein |
| Uchl1 | ILMN_1225261 | 0.675143532 | 0.042238958 | ubiquitin carboxy-terminal hydrolase L1 |
| Eno1 | ILMN_2628271 | 0.671596782 | 0.040589742 | NA |
| LOC244710 | ILMN_1221874 | 0.657682787 | 0.047089682 | NA |
| 2210013O21Rik | ILMN_2750864 | 0.650716751 | 0.042542346 | NA |
| 2310057G13Rik | ILMN_2638781 | 0.649387761 | 0.045399877 | HD domain containing 2 |
| LOC381678 | ILMN_1222627 | 0.643178983 | 0.042615466 | zinc finger, CW type with PWWP domain 1 |
| Gapd | ILMN_1377924 | 0.62434812 | 0.047452585 | glyceraldehyde-3-phosphate dehydrogenase |
| LOC209182 | ILMN_1244101 | 0.618016009 | 0.049860694 | predicted gene 3993 |
| Eno1 | ILMN_2958159 | 0.613094274 | 0.048767171 | predicted gene 5506 |
| Zfp26 | ILMN_2945607 | 0.609373566 | 0.048767171 | zinc finger protein 26 |

(adj.P value <= 0.05)

## Table 3-2. Genes significantly up-regulated in BM in microarray sequencing.

| Symbol | Probe_Id | logFC(BM/NL) | adj.P.Val | Annotation |
|---|---|---|---|---|
| Igh-VJ558 | ILMN_2635272 | 5.09708452 | 0.000742734 | NA |
| H2-Q8 | ILMN_2771182 | 3.674334774 | 6.54E-05 | NA |
| Mpo | ILMN_1249030 | 3.184438866 | 0.020177627 | myeloperoxidase |
| Nrxn2 | ILMN_2418389 | 3.077043512 | 0.000240634 | NA |
| 0610037M15Rik | ILMN_2495446 | 2.880696852 | 0.000240634 | NA |
| Igl-V1 | ILMN_1230696 | 2.851866092 | 0.000411984 | NA |
| Igl-V1 | ILMN_1245146 | 2.814950461 | 0.000592428 | NA |
| Igh-VJ558 | ILMN_2772264 | 2.507544449 | 0.00910808 | NA |
| Nrxn2 | ILMN_3015003 | 2.44086403 | 0.000592428 | neurexin II |
| Spp1 | ILMN_2690603 | 2.362022998 | 0.000411984 | secreted phosphoprotein 1 |
| LOC381276 | ILMN_1213824 | 2.320809627 | 0.000779895 | NA |
| NE | ILMN_1221700 | 2.289719147 | 0.029040741 | elastase, neutrophil expressed |
| LOC243430 | ILMN_2649286 | 2.271757151 | 0.001264406 | NA |
| B230105J10 | ILMN_1250569 | 2.240572379 | 0.000742734 | Rap guanine nucleotide exchange factor (GEF)-like 1 |
| LOC386520 | ILMN_1231522 | 2.2051437 | 0.000523666 | NA |
| H2-Q6 | ILMN_2675337 | 2.162146997 | 0.001129115 | NA |
| B230312L03Rik | ILMN_1251968 | 2.137688899 | 0.002234203 | predicted gene 14964 |
| Ctsg | ILMN_1220236 | 2.056836078 | 0.024355752 | cathepsin G |
| IGLC2_J00595_Ig_lambda_constant_2_14 | ILMN_2450155 | 2.05483764 | 0.0035401 | NA |
| AA467197 | ILMN_3160750 | 2.054423785 | 0.001010643 | expressed sequence AA467197 |
| H2-Q8 | ILMN_2951592 | 2.005964104 | 0.000742734 | histocompatibility 2, Q region locus 8 |
| Slc34a1 | ILMN_2598639 | 1.909746594 | 0.004599568 | solute carrier family 34 (sodium phosphate), member 1 |
| Cd40 | ILMN_3115796 | 1.84463689 | 0.000592428 | CD40 antigen |
| IGKV9-128_AJ231245_Ig_kappa_variable_9-128_15 | ILMN_1232948 | 1.823538861 | 0.003414651 | NA |
| Scin | ILMN_1259174 | 1.820408564 | 0.010179612 | scinderin |
| Angptl4 | ILMN_2759365 | 1.819620577 | 0.008985687 | angiopoietin-like 4 |
| B230343A10Rik | ILMN_2468473 | 1.817659559 | 0.005797166 | growth arrest specific 7 |
| Cldn10 | ILMN_2515816 | 1.797937819 | 0.00475478 | claudin 10 |
| Lmcd1 | ILMN_2907540 | 1.786386594 | 0.001264406 | LIM and cysteine-rich domains 1 |
| B230104P22Rik | ILMN_1227458 | 1.735105643 | 0.002052853 | NUAK family, SNF1-like kinase, 1 |
| Cldn10 | ILMN_1214954 | 1.720408184 | 0.0018771 | claudin 10 |
| Nrp | ILMN_2669912 | 1.693651592 | 0.001010643 | neuropilin 1 |
| Insl6 | ILMN_2677859 | 1.668180107 | 0.0035401 | insulin-like 6 |
| Tle6 | ILMN_2900617 | 1.651004431 | 0.008284679 | transducin-like enhancer of split 6, homolog of Drosophila E(spl) |
| Mist1 | ILMN_2651388 | 1.647889759 | 0.0018771 | basic helix-loop-helix family, member a15 |
| LOC243431 | ILMN_2639196 | 1.613362067 | 0.007050641 | NA |
| Lmcd1 | ILMN_1247343 | 1.601566996 | 0.002223324 | LIM and cysteine-rich domains 1 |
| LOC381287 | ILMN_1238357 | 1.591655657 | 0.033869119 | RIKEN cDNA A530032D15Rik gene |
| 6330403M23Rik | ILMN_1222351 | 1.542563116 | 0.006732309 | NA |
| Zap70 | ILMN_2513870 | 1.54253444 | 0.001129115 | zeta-chain (TCR) associated protein kinase |
| 1700028N11Rik | ILMN_2764466 | 1.532508434 | 0.003792613 | calcyphosine-like |
| Mist1 | ILMN_2651389 | 1.530608282 | 0.005797166 | basic helix-loop-helix family, member a15 |
| Cpne2 | ILMN_2870487 | 1.528339438 | 0.003620632 | copine II |
| Gas7 | ILMN_2924831 | 1.519881367 | 0.007293308 | growth arrest specific 7 |
| Tnfrsf5 | ILMN_2502136 | 1.48568866 | 0.003397873 | CD40 antigen |
| Socs5 | ILMN_1240346 | 1.481751493 | 0.00819812 | suppressor of cytokine signaling 5 |
| Zap70 | ILMN_3005740 | 1.459743651 | 0.016351009 | zeta-chain (TCR) associated protein kinase |
| EG630499 | ILMN_2810539 | 1.439019795 | 0.002052853 | NA |
| Klra1 | ILMN_1228875 | 1.435388203 | 0.007145263 | killer cell lectin-like receptor, subfamily A, member 1 |
| G630019A19Rik | ILMN_1252611 | 1.414620661 | 0.024775363 | NA |
| Nrp | ILMN_1237197 | 1.412889294 | 0.005316898 | neuropilin 1 |
| Mtap2 | ILMN_3137552 | 1.401767123 | 0.021983904 | microtubule-associated protein 2 |
| Gas7 | ILMN_2776850 | 1.327591197 | 0.011931635 | growth arrest specific 7 |
| LOC382177 | ILMN_1234106 | 1.325805626 | 0.002872729 | NA |
| Tnfrsf5 | ILMN_2503129 | 1.323846399 | 0.010538951 | CD40 antigen |
| H2-gs17 | ILMN_2835683 | 1.323254331 | 0.010179612 | predicted gene 8909 |
| Bhlhb2 | ILMN_1249378 | 1.322685547 | 0.007145263 | basic helix-loop-helix family, member e40 |
| Slamf9 | ILMN_2663249 | 1.289125704 | 0.015118839 | SLAM family member 9 |
| H2-K1 | ILMN_2795520 | 1.250242392 | 0.026093306 | NA |
| 4833444G19Rik | ILMN_2693934 | 1.235881888 | 0.01101257 | NA |
| Grn | ILMN_2595973 | 1.232782343 | 0.006960594 | granulin |
| Nrxn2 | ILMN_2723541 | 1.232203077 | 0.010805192 | neurexin II |
| Bteb1 | ILMN_1254031 | 1.229055246 | 0.010820663 | Kruppel-like factor 9 |
| 1110060I01Rik | ILMN_2476452 | 1.223281707 | 0.007264381 | carboxypeptidase M |
| Cldn10 | ILMN_2723576 | 1.220584303 | 0.005921031 | claudin 10 |
| Fcer2a | ILMN_2975312 | 1.214124187 | 0.005169795 | Fc receptor, IgE, low affinity II, alpha polypeptide |
| Lmo4 | ILMN_2642403 | 1.213962765 | 0.015585494 | LIM domain only 4 |
| Myo1e | ILMN_2522127 | 1.207892996 | 0.034545438 | myosin IE |
| 9130206I24Rik | ILMN_2647898 | 1.199191863 | 0.007293308 | forkhead box D2, opposite strand |
| Slpi | ILMN_1256817 | 1.198063031 | 0.015245239 | secretory leukocyte peptidase inhibitor |
| Tspan17 | ILMN_2817714 | 1.196875737 | 0.012396791 | tetraspanin 17 |
| Tor3a | ILMN_2437513 | 1.19584427 | 0.038778008 | torsin family 3, member A |
| Aatk | ILMN_1231439 | 1.178953522 | 0.007564225 | apoptosis-associated tyrosine kinase |
| Csf3r | ILMN_2806180 | 1.169383415 | 0.0361747 | colony stimulating factor 3 receptor (granulocyte) |
| Cd2 | ILMN_2753697 | 1.152849001 | 0.007045251 | CD2 antigen |
| Cnp1 | ILMN_2802263 | 1.144030931 | 0.015338907 | 2',3'-cyclic nucleotide 3' phosphodiesterase |
| LOC243451 | ILMN_2615739 | 1.141954737 | 0.025461929 | NA |
| Zdhhc14 | ILMN_1240332 | 1.140193629 | 0.007564225 | zinc finger, DHHC domain containing 14 |
| Dtx1 | ILMN_2641793 | 1.109327134 | 0.014649875 | deltex 1 homolog (Drosophila) |
| Tsga2 | ILMN_2441534 | 1.109174206 | 0.010820663 | radial spoke head 1 homolog (Chlamydomonas) |
| Usp18 | ILMN_3131679 | 1.087996183 | 0.033624817 | ubiquitin specific peptidase 18 |

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| | | | | |
|---|---|---|---|---|
| Car13 | ILMN_1249727 | 1.083524498 | 0.010539933 | carbonic anhydrase 13 |
| Aicda | ILMN_2624986 | 1.076250394 | 0.024355752 | activation-induced cytidine deaminase |
| H2-K1 | ILMN_2588139 | 1.075324729 | 0.029256275 | histocompatibility 2, K1, K region |
| H2-Q7 | ILMN_2924419 | 1.071131806 | 0.006960594 | NA |
| Klra16 | ILMN_3005175 | 1.07055854 | 0.010010451 | killer cell lectin-like receptor, subfamily A, member 16 |
| Ccnd2 | ILMN_2700168 | 1.062933332 | 0.034545438 | cyclin D2 |
| 1190002H23Rik | ILMN_2593774 | 1.058275968 | 0.019043735 | regulator of cell cycle |
| Polm | ILMN_2621761 | 1.056294625 | 0.012157331 | polymerase (DNA directed), mu |
| Ccnd2 | ILMN_2700166 | 1.055425831 | 0.022427792 | cyclin D2 |
| A830039N02Rik | ILMN_1213378 | 1.053966464 | 0.010805192 | LON peptidase N-terminal domain and ring finger 3 |
| 2810410A03Rik | ILMN_1243249 | 1.049783503 | 0.010820663 | NA |
| H2-T10 | ILMN_2665266 | 1.041391942 | 0.008284679 | histocompatibility 2, T region locus 10 |
| D11Ertd759e | ILMN_1229455 | 1.040688566 | 0.010820663 | NA |
| Esr1 | ILMN_2726412 | 1.03700072 | 0.017574475 | estrogen receptor 1 (alpha) |
| Amica1 | ILMN_3160218 | 1.033480668 | 0.007293308 | adhesion molecule, interacts with CXADR antigen 1 |
| A630085E16Rik | ILMN_1260366 | 1.028799937 | 0.043120727 | NA |
| Ndrl | ILMN_2646166 | 1.02611628 | 0.019474708 | N-myc downstream regulated gene 1 |
| Car2 | ILMN_2606746 | 1.019750493 | 0.03837057 | carbonic anhydrase 2 |
| Ppap2b | ILMN_2630993 | 0.999990398 | 0.012527282 | phosphatidic acid phosphatase type 2B |
| A730062O07Rik | ILMN_1248556 | 0.999371787 | 0.010820663 | NA |
| 1810037B05Rik | ILMN_1221820 | 0.997670035 | 0.013478105 | Fas apoptotic inhibitory molecule 3 |
| Ppm1e | ILMN_2702374 | 0.993805752 | 0.010820663 | protein phosphatase 1E (PP2C domain containing) |
| Mxd4 | ILMN_2760417 | 0.989100913 | 0.017574475 | Max dimerization protein 4 |
| 5031439A09Rik | ILMN_2704184 | 0.983887561 | 0.012004755 | NA |
| Mst1r | ILMN_2757671 | 0.980679051 | 0.015585494 | macrophage stimulating 1 receptor (c-met-related tyrosine kinase) |
| IGKV3-2_X16954_Ig_kappa_variable_3- | ILMN_1251011 | 0.97802632 | 0.034409586 | NA |
| D830013M18Rik | ILMN_2580601 | 0.976973761 | 0.038686732 | NA |
| 4933439C20Rik | ILMN_2944601 | 0.973784692 | 0.02223733 | NA |
| Khdrbs3 | ILMN_2590488 | 0.964743487 | 0.00906151 | KH domain containing, RNA binding, signal transduction associated 3 |
| AA536717 | ILMN_2492284 | 0.963726584 | 0.038160287 | NA |
| B230333C21Rik | ILMN_1236157 | 0.959250399 | 0.012208696 | A kinase (PRKA) anchor protein 17B |
| 9830130M13 | ILMN_1231000 | 0.958056945 | 0.03614994 | Grb2-binding adaptor, transmembrane |
| Gpr177 | ILMN_2996561 | 0.947569098 | 0.046992925 | wntless homolog (Drosophila) |
| Gpr12 | ILMN_1221410 | 0.94732526 | 0.049682797 | G-protein coupled receptor 12 |
| Pcyt1b | ILMN_3132186 | 0.946015406 | 0.021983904 | phosphate cytidylyltransferase 1, choline, beta isoform |
| Polm | ILMN_2621762 | 0.945491057 | 0.039233702 | polymerase (DNA directed), mu |
| Dntt | ILMN_1232383 | 0.932600036 | 0.028346495 | deoxynucleotidyltransferase, terminal |
| Itpr2 | ILMN_3155180 | 0.930094661 | 0.015118839 | inositol 1,4,5-triphosphate receptor 2 |
| 1500031H04Rik | ILMN_2649172 | 0.927216415 | 0.042256323 | zinc finger, CCHC domain containing 18 |
| B930008A12Rik | ILMN_1258704 | 0.924869004 | 0.042238958 | NA |
| scl000460.1_17 | ILMN_1259060 | 0.9246909 | 0.042256323 | fibroblast growth factor 8 |
| Pip5k1a | ILMN_2711562 | 0.92312423 | 0.039233702 | phosphatidylinositol-4-phosphate 5-kinase, type 1 beta |
| Hspa2 | ILMN_3140383 | 0.909057625 | 0.025461929 | heat shock protein 2 |
| scl0001464.1_6 | ILMN_2477946 | 0.90469667 | 0.01970933 | phosphatidylserine decarboxylase, pseudogene 1 |
| Cpm | ILMN_2629191 | 0.901899489 | 0.02223733 | carboxypeptidase M |
| Asb13 | ILMN_3104025 | 0.899441938 | 0.012358278 | ankyrin repeat and SOCS box-containing 13 |
| B230333C21Rik | ILMN_2716719 | 0.895622723 | 0.009937122 | A kinase (PRKA) anchor protein 17B |
| Capn5 | ILMN_2627566 | 0.894523248 | 0.032605929 | calpain 5 |
| Igsf9 | ILMN_2804166 | 0.88971407 | 0.015245641 | immunoglobulin superfamily, member 9 |
| Gpr155 | ILMN_1249003 | 0.879904846 | 0.018179604 | G protein-coupled receptor 155 |
| 4931426K16Rik | ILMN_2701129 | 0.877565938 | 0.037429759 | sperm flagellar 1 |
| Kdt1 | ILMN_2704637 | 0.871135782 | 0.034545438 | MyoD family inhibitor domain containing |
| Ddc | ILMN_2628647 | 0.870015205 | 0.03219325 | dopa decarboxylase |
| Cnr2 | ILMN_2794526 | 0.867715904 | 0.049535321 | cannabinoid receptor 2 (macrophage) |
| Lhfp | ILMN_2879588 | 0.863112868 | 0.017574765 | lipoma HMGIC fusion partner |
| Ddc | ILMN_1260450 | 0.862036595 | 0.03219325 | dopa decarboxylase |
| Rassf4 | ILMN_2686244 | 0.856754242 | 0.015199953 | Ras association (RalGDS/AF-6) domain family member 4 |
| Lmcd1 | ILMN_2628940 | 0.851936745 | 0.016964483 | LIM and cysteine-rich domains 1 |
| Wdr9 | ILMN_1252496 | 0.838852733 | 0.020889181 | bromodomain and WD repeat domain containing 1 |
| Pfc | ILMN_1228320 | 0.834495443 | 0.036516544 | complement factor properdin |
| Dyrk1b | ILMN_3053158 | 0.82781569 | 0.026441636 | dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 1b |
| Myo18b | ILMN_2675785 | 0.812623465 | 0.04214904 | myosin XVIIIb |
| A630085K21 | ILMN_2638431 | 0.811352588 | 0.038253299 | NA |
| BC023892 | ILMN_2502471 | 0.807494633 | 0.014649875 | family with sequence similarity 46, member A |
| Tlr1 | ILMN_1236908 | 0.804724648 | 0.046396553 | toll-like receptor 1 |
| Hoxb4 | ILMN_1241077 | 0.802915457 | 0.036516544 | homeobox B4 |
| Psen2 | ILMN_2941992 | 0.79816727 | 0.030273615 | presenilin 2 |
| F730031O20Rik | ILMN_2603976 | 0.794543766 | 0.036516544 | NA |
| H2-Q2 | ILMN_2732816 | 0.78995643 | 0.024095076 | NA |
| Dnahc8 | ILMN_2602341 | 0.788971558 | 0.016468495 | dynein, axonemal, heavy chain 8 |
| Dnajb10 | ILMN_2725428 | 0.780800627 | 0.023837253 | DnaJ (Hsp40) homolog, subfamily B, member 2 |
| F13a1 | ILMN_2914938 | 0.776857408 | 0.032605929 | coagulation factor XIII, A1 subunit |
| F730017E11Rik | ILMN_1213707 | 0.775058762 | 0.03219325 | NA |
| A130019H11Rik | ILMN_2567962 | 0.770932262 | 0.040727962 | NA |
| Hspa2 | ILMN_1223285 | 0.763812617 | 0.032605929 | heat shock protein 2 |
| Fer1l3 | ILMN_1223416 | 0.762454558 | 0.048130412 | myoferlin |
| LOC56628 | ILMN_2588130 | 0.755196028 | 0.019372388 | NA |
| Il7r | ILMN_1237567 | 0.75354492 | 0.047772505 | NA |
| Epb4.1l4b | ILMN_2775064 | 0.749087974 | 0.024030001 | erythrocyte protein band 4.1-like 4b |
| 9130422G05Rik | ILMN_1215670 | 0.746087006 | 0.037191672 | tetratricopeptide repeat domain 39B |
| Tdrd7 | ILMN_2818678 | 0.745422963 | 0.036232022 | tudor domain containing 7 |
| Ankrd12 | ILMN_3072676 | 0.737108552 | 0.036516544 | ankyrin repeat domain 12 |
| Sipa1l1 | ILMN_2763679 | 0.730226826 | 0.039564102 | signal-induced proliferation-associated 1 like 1 |
| Al875142 | ILMN_1256967 | 0.715268234 | 0.035888163 | protein kinase C, alpha |
| LOC381135 | ILMN_1251205 | 0.712966899 | 0.042122605 | ectopic P-granules autophagy protein 5 homolog (C. elegans) |
| 2810410P22Rik | ILMN_1221102 | 0.702905506 | 0.042542346 | ADP-ribosylation factor-like 5A |
| Ncan | ILMN_2648883 | 0.696020204 | 0.03219325 | neurocan |
| 2810410P22Rik | ILMN_2692986 | 0.693557617 | 0.043120727 | ADP-ribosylation factor-like 5A |
| H2-L | ILMN_2462745 | 0.686259392 | 0.039457855 | histocompatibility 2, D region locus 1 |

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| | | | | |
|---|---|---|---|---|
| 2510009E07Rik | ILMN_3052390 | 0.686055679 | 0.036003335 | RIKEN cDNA 2510009E07 gene |
| 2810410P22Rik | ILMN_2692989 | 0.684645428 | 0.040589742 | ADP-ribosylation factor-like 5A |
| BC006779 | ILMN_1226639 | 0.670168878 | 0.033445135 | helicase with zinc finger 2, transcriptional coactivator |
| 9930004G02Rik | ILMN_1249945 | 0.660413311 | 0.048130412 | NA |
| Cnp1 | ILMN_1257097 | 0.657736028 | 0.04352496 | 2',3'-cyclic nucleotide 3' phosphodiesterase |
| LOC385940 | ILMN_2537948 | 0.657514171 | 0.039132419 | NA |
| LOC631002 | ILMN_2985249 | 0.650861438 | 0.047801346 | synovial sarcoma, X member B, breakpoint 8 |
| Parp14 | ILMN_2825803 | 0.634490239 | 0.049535321 | poly (ADP-ribose) polymerase family, member 14 |
| Irak3 | ILMN_1253972 | 0.63403499 | 0.046992925 | interleukin-1 receptor-associated kinase 3 |
| Cd72 | ILMN_2675669 | 0.627065963 | 0.046396553 | CD72 antigen |

(adj.P value <= 0.05)

## Table 3-3. Genes significantly up-regulated in NL in RNA sequencing.

| Symbol | Ensembl gene id | logFC (NL/BM) | adj.P.val | Annotation |
|---|---|---|---|---|
| H19 | ENSMUSG00000000031 | 12.30668071 | 1.40E-102 | H19, imprinted maternally expressed transcript [Source:MGI Symbol;Acc:MGI:95891] |
| Eif2s3y | ENSMUSG00000069049 | 11.645365 | 4.84E-98 | eukaryotic translation initiation factor 2, subunit 3, structural gene Y-linked [Source:MGI Symbol;Acc:MGI:1349430] |
| Alb | ENSMUSG00000029368 | 10.02883687 | 0.010970315 | albumin [Source:MGI Symbol;Acc:MGI:87991] |
| Ddx3y | ENSMUSG00000069045 | 9.866452959 | 1.50E-82 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 3, Y-linked [Source:MGI Symbol;Acc:MGI:1349406] |
| Nes | ENSMUSG00000004891 | 9.015869687 | 0.042040362 | nestin [Source:MGI Symbol;Acc:MGI:101784] |
| Ahsg | ENSMUSG00000022868 | 8.896850522 | 1.13E-13 | alpha-2-HS-glycoprotein [Source:MGI Symbol;Acc:MGI:107189] |
| Aldob | ENSMUSG00000028307 | 8.778095701 | 6.58E-20 | aldolase B, fructose-bisphosphate [Source:MGI Symbol;Acc:MGI:87995] |
| Lin28b | ENSMUSG00000063804 | 8.636823712 | 1.13E-13 | lin-28 homolog B (C. elegans) [Source:MGI Symbol;Acc:MGI:3584032] |
| Bhmt | ENSMUSG00000074768 | 8.577167204 | 5.04E-07 | betaine-homocysteine methyltransferase [Source:MGI Symbol;Acc:MGI:1339972] |
| Mat1a | ENSMUSG00000037798 | 8.300976175 | 1.51E-13 | methionine adenosyltransferase I, alpha [Source:MGI Symbol;Acc:MGI:88017] |
| Apoa1 | ENSMUSG00000032083 | 7.407799256 | 0.000146802 | apolipoprotein A-I [Source:MGI Symbol;Acc:MGI:88049] |
| Serpina1b | ENSMUSG00000071178 | 7.361973934 | 0.001053309 | serine (or cysteine) preptidase inhibitor, clade A, member 1B [Source:MGI Symbol;Acc:MGI:891970] |
| Gm29650 | ENSMUSG00000099876 | 7.230017163 | 2.82E-06 | predicted gene 29650 [Source:MGI Symbol;Acc:MGI:5580356] |
| Ttr | ENSMUSG00000061808 | 7.111253761 | 0.000199271 | transthyretin [Source:MGI Symbol;Acc:MGI:98865] |
| Spats2 | ENSMUSG00000051934 | 7.078684854 | 0.002561876 | spermatogenesis associated, serine-rich 2 [Source:MGI Symbol;Acc:MGI:1919822] |
| Marco | ENSMUSG00000026390 | 6.883887768 | 0.001646662 | macrophage receptor with collagenous structure [Source:MGI Symbol;Acc:MGI:1309998] |
| Hpd | ENSMUSG00000029445 | 6.710975331 | 0.001228505 | 4-hydroxyphenylpyruvic acid dioxygenase [Source:MGI Symbol;Acc:MGI:96213] |
| Rgn | ENSMUSG00000023070 | 6.70732084 | 0.036490738 | regucalcin [Source:MGI Symbol;Acc:MGI:108024] |
| Apoc1 | ENSMUSG00000040564 | 6.62104653 | 0.005469434 | apolipoprotein C-I [Source:MGI Symbol;Acc:MGI:88053] |
| Hmga2 | ENSMUSG00000056758 | 6.59948016 | 1.94E-17 | high mobility group AT-hook 2 [Source:MGI Symbol;Acc:MGI:101761] |
| Peg3 | ENSMUSG00000002265 | 6.594506284 | 4.24E-06 | paternally expressed 3 [Source:MGI Symbol;Acc:MGI:104748] |
| Fabp1 | ENSMUSG00000054422 | 6.443038689 | 0.013657679 | fatty acid binding protein 1, liver [Source:MGI Symbol;Acc:MGI:95479] |
| Adh1 | ENSMUSG00000074207 | 6.241530239 | 0.015650794 | alcohol dehydrogenase 1 (class I) [Source:MGI Symbol;Acc:MGI:87921] |
| Rps6ka6 | ENSMUSG00000025665 | 6.146108958 | 0.005281525 | ribosomal protein S6 kinase polypeptide 6 [Source:MGI Symbol;Acc:MGI:1914321] |
| Hnf4a | ENSMUSG00000017950 | 6.056046142 | 0.029405157 | hepatic nuclear factor 4, alpha [Source:MGI Symbol;Acc:MGI:109128] |
| Apobec2 | ENSMUSG00000040694 | 5.975662047 | 0.010970315 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide 2 [Source:MGI Symbol;Acc:MGI:1343178] |
| Qrfp | ENSMUSG00000043102 | 5.912234254 | 0.00197479 | pyroglutamylated RFamide peptide [Source:MGI Symbol;Acc:MGI:3630329] |
| Serpina1d | ENSMUSG00000071177 | 5.878640626 | 0.046258631 | serine (or cysteine) peptidase inhibitor, clade A, member 1D [Source:MGI Symbol;Acc:MGI:891968] |
| Uox | ENSMUSG00000028186 | 5.769672575 | 0.002134038 | urate oxidase [Source:MGI Symbol;Acc:MGI:98907] |
| Hmgcs2 | ENSMUSG00000027875 | 5.616279208 | 7.58E-09 | 3-hydroxy-3-methylglutaryl-Coenzyme A synthase 2 [Source:MGI Symbol;Acc:MGI:101939] |
| Clec4f | ENSMUSG00000014542 | 5.521444348 | 1.38E-05 | C-type lectin domain family 4, member f [Source:MGI Symbol;Acc:MGI:1859834] |
| Igf2 | ENSMUSG00000048583 | 5.487266115 | 8.63E-06 | insulin-like growth factor 2 [Source:MGI Symbol;Acc:MGI:96434] |
| Pck1 | ENSMUSG00000027513 | 5.48339974 | 9.23E-05 | phosphoenolpyruvate carboxykinase 1, cytosolic [Source:MGI Symbol;Acc:MGI:97501] |
| Sparc | ENSMUSG00000018593 | 5.266209283 | 3.54E-06 | secreted acidic cysteine rich glycoprotein [Source:MGI Symbol;Acc:MGI:98373] |
| Pacsin1 | ENSMUSG00000040276 | 5.260853114 | 1.51E-31 | protein kinase C and casein kinase substrate in neurons 1 [Source:MGI Symbol;Acc:MGI:1345181] |
| Afp | ENSMUSG00000054932 | 5.152900572 | 2.76E-06 | alpha fetoprotein [Source:MGI Symbol;Acc:MGI:87951] |
| A630023P12 | ENSMUSG00000048215 | 5.038498721 | 8.72E-08 | RIKEN cDNA A630023P12 gene [Source:MGI Symbol;Acc:MGI:2445162] |
| Igsf10 | ENSMUSG00000036334 | 4.892914937 | 0.004016433 | immunoglobulin superfamily, member 10 [Source:MGI Symbol;Acc:MGI:1923481] |
| Klk8 | ENSMUSG00000064023 | 4.72809017 | 2.43E-06 | kallikrein related-peptidase 8 [Source:MGI Symbol;Acc:MGI:1343327] |
| Ndn | ENSMUSG00000033585 | 4.65261101 | 0.010961579 | necdin [Source:MGI Symbol;Acc:MGI:97290] |
| Dlk1 | ENSMUSG00000040856 | 4.603356726 | 5.54E-08 | delta-like 1 homolog (Drosophila) [Source:MGI Symbol;Acc:MGI:94900] |
| Nrep | ENSMUSG00000042834 | 4.592153934 | 0.016554135 | neuronal regeneration related protein [Source:MGI Symbol;Acc:MGI:99444] |
| Fbln1 | ENSMUSG00000006369 | 4.337137789 | 2.89E-09 | fibulin 1 [Source:MGI Symbol;Acc:MGI:95487] |
| Bex4 | ENSMUSG00000047844 | 4.310898384 | 0.000335053 | brain expressed X-linked 4 [Source:MGI Symbol;Acc:MGI:3606746] |
| Rtkn | ENSMUSG00000034930 | 4.219881121 | 2.20E-07 | rhotekin [Source:MGI Symbol;Acc:MGI:107371] |
| Ptk7 | ENSMUSG00000023972 | 4.140117185 | 6.09E-16 | PTK7 protein tyrosine kinase 7 [Source:MGI Symbol;Acc:MGI:1918711] |
| Shisa8 | ENSMUSG00000096883 | 4.092942602 | 4.95E-15 | shisa family member 8 [Source:MGI Symbol;Acc:MGI:2146080] |
| Uty | ENSMUSG00000068457 | 4.087300929 | 4.66E-19 | ubiquitously transcribed tetratricopeptide repeat gene, Y chromosome [Source:MGI Symbol;Acc:MGI:894810] |
| Trbc2 | ENSMUSG00000076498 | 4.073990398 | 0.004680237 | T cell receptor beta, constant 2 [Source:MGI Symbol;Acc:MGI:4835227] |
| Acsbg1 | ENSMUSG00000032281 | 4.068726925 | 2.27E-08 | acyl-CoA synthetase bubblegum family member 1 [Source:MGI Symbol;Acc:MGI:2385656] |
| Igf2bp3 | ENSMUSG00000029814 | 3.933156968 | 1.45E-162 | insulin-like growth factor 2 mRNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1890359] |
| Fzd10 | ENSMUSG00000081683 | 3.845036274 | 0.002535935 | frizzled class receptor 10 [Source:MGI Symbol;Acc:MGI:2136761] |
| Alpk3 | ENSMUSG00000038763 | 3.841592996 | 4.90E-06 | alpha-kinase 3 [Source:MGI Symbol;Acc:MGI:2151224] |
| Morn4 | ENSMUSG00000049670 | 3.757870493 | 0.008078405 | MORN repeat containing 4 [Source:MGI Symbol;Acc:MGI:2449568] |
| Fstl1 | ENSMUSG00000022816 | 3.636852338 | 2.86E-34 | follistatin-like 1 [Source:MGI Symbol;Acc:MGI:102793] |
| Kdm5d | ENSMUSG00000056673 | 3.613900282 | 5.85E-24 | lysine (K)-specific demethylase 5D [Source:MGI Symbol;Acc:MGI:99780] |
| Ppl | ENSMUSG00000039457 | 3.563101187 | 2.17E-05 | periplakin [Source:MGI Symbol;Acc:MGI:1194898] |
| Adora2b | ENSMUSG00000018500 | 3.544600485 | 0.029405157 | adenosine A2b receptor [Source:MGI Symbol;Acc:MGI:99403] |
| Mum1l1 | ENSMUSG00000042515 | 3.521178119 | 2.88E-07 | melanoma associated antigen (mutated) 1-like 1 [Source:MGI Symbol;Acc:MGI:2445062] |
| D430019H16 | ENSMUSG00000094910 | 3.519561729 | 0.022402757 | RIKEN cDNA D430019H16 gene [Source:MGI Symbol;Acc:MGI:2443127] |
| Zfp827 | ENSMUSG00000071064 | 3.477081872 | 3.13E-31 | zinc finger protein 827 [Source:MGI Symbol;Acc:MGI:2444807] |
| Lyplal1 | ENSMUSG00000039246 | 3.457567501 | 6.36E-05 | lysophospholipase-like 1 [Source:MGI Symbol;Acc:MGI:2385115] |
| Skida1 | ENSMUSG00000054074 | 3.450622021 | 0.000193219 | SKI/DACH domain containing 1 [Source:MGI Symbol;Acc:MGI:1919918] |
| Pkp2 | ENSMUSG00000041957 | 3.430234188 | 0.043914982 | plakophilin 2 [Source:MGI Symbol;Acc:MGI:1914701] |
| Rasd1 | ENSMUSG00000049892 | 3.369296654 | 1.46E-11 | RAS, dexamethasone-induced 1 [Source:MGI Symbol;Acc:MGI:1270848] |
| Crmp1 | ENSMUSG00000029121 | 3.227913889 | 0.000211308 | collapsin response mediator protein 1 [Source:MGI Symbol;Acc:MGI:107793] |
| Gm37552 | ENSMUSG00000102941 | 3.2250225 | 0.000459692 | predicted gene, 37552 [Source:MGI Symbol;Acc:MGI:5610780] |
| Obsl1 | ENSMUSG00000026211 | 3.198837104 | 0.023453763 | obscurin-like 1 [Source:MGI Symbol;Acc:MGI:2138628] |
| Pdgfrb | ENSMUSG00000024620 | 3.17638039 | 0.012597382 | platelet derived growth factor receptor, beta polypeptide [Source:MGI Symbol;Acc:MGI:97531] |
| Nid1 | ENSMUSG00000005397 | 3.160554137 | 0.0079175 | nidogen 1 [Source:MGI Symbol;Acc:MGI:97342] |
| Dsg2 | ENSMUSG00000044393 | 3.125234599 | 0.006385947 | desmoglein 2 [Source:MGI Symbol;Acc:MGI:1196466] |

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| | | | | |
|---|---|---|---|---|
| Fam109b | ENSMUSG00000049687 | 3.04947805 | 1.21E-07 | family with sequence similarity 109, member B [Source:MGI Symbol;Acc:MGI:2443609] |
| Pald1 | ENSMUSG00000020092 | 2.927821071 | 6.14E-05 | phosphatase domain containing, paladin 1 [Source:MGI Symbol;Acc:MGI:1351623] |
| Kif7 | ENSMUSG00000050382 | 2.914965178 | 4.08E-05 | kinesin family member 7 [Source:MGI Symbol;Acc:MGI:1098239] |
| Phactr1 | ENSMUSG00000054728 | 2.886360635 | 0.013628524 | phosphatase and actin regulator 1 [Source:MGI Symbol;Acc:MGI:2659021] |
| Snai3 | ENSMUSG00000006587 | 2.808546831 | 0.01793578 | snail family zinc finger 3 [Source:MGI Symbol;Acc:MGI:1353563] |
| Hnf1b | ENSMUSG00000020679 | 2.806884366 | 0.005314391 | HNF1 homeobox B [Source:MGI Symbol;Acc:MGI:98505] |
| Bex1 | ENSMUSG00000050071 | 2.804243877 | 0.000853242 | brain expressed X-linked 1 [Source:MGI Symbol;Acc:MGI:1328321] |
| Rnft2 | ENSMUSG00000032850 | 2.774198757 | 0.044764599 | ring finger protein, transmembrane 2 [Source:MGI Symbol;Acc:MGI:2442859] |
| H1f0 | ENSMUSG00000096210 | 2.767484295 | 7.14E-14 | H1 histone family, member 0 [Source:MGI Symbol;Acc:MGI:95893] |
| Gcat | ENSMUSG00000006378 | 2.758187739 | 7.80E-14 | glycine C-acetyltransferase (2-amino-3-ketobutyrate-coenzyme A ligase) [Source:MGI Symbol;Acc:MGI:1349389] |
| Sox13 | ENSMUSG00000070643 | 2.705502341 | 0.000249885 | SRY (sex determining region Y)-box 13 [Source:MGI Symbol;Acc:MGI:98361] |
| Sh2d1b1 | ENSMUSG00000102418 | 2.658594755 | 5.55E-05 | SH2 domain containing 1B1 [Source:MGI Symbol;Acc:MGI:1349420] |
| Sh2b2 | ENSMUSG00000005057 | 2.656664613 | 0.000471469 | SH2B adaptor protein 2 [Source:MGI Symbol;Acc:MGI:1345171] |
| Npr3 | ENSMUSG00000022206 | 2.654983791 | 0.029405157 | natriuretic peptide receptor 3 [Source:MGI Symbol;Acc:MGI:97373] |
| Spire1 | ENSMUSG00000024533 | 2.613912986 | 0.026608018 | spire homolog 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:1915416] |
| Plag1 | ENSMUSG00000003282 | 2.606743424 | 4.22E-06 | pleiomorphic adenoma gene 1 [Source:MGI Symbol;Acc:MGI:1891916] |
| Eid2 | ENSMUSG00000046058 | 2.557134036 | 0.000637309 | EP300 interacting inhibitor of differentiation 2 [Source:MGI Symbol;Acc:MGI:2681174] |
| Cav2 | ENSMUSG00000000058 | 2.542851997 | 0.004484058 | caveolin 2 [Source:MGI Symbol;Acc:MGI:107571] |
| Fbp1 | ENSMUSG00000069805 | 2.519361944 | 0.000340998 | fructose bisphosphatase 1 [Source:MGI Symbol;Acc:MGI:95492] |
| Ptgs1 | ENSMUSG00000047250 | 2.513722977 | 0.000633023 | prostaglandin-endoperoxide synthase 1 [Source:MGI Symbol;Acc:MGI:97797] |
| 2310075C17I | ENSMUSG00000089718 | 2.507087682 | 0.009057552 | RIKEN cDNA 2310075C17 gene [Source:MGI Symbol;Acc:MGI:1917444] |
| Nespas | ENSMUSG00000086537 | 2.502987079 | 0.000811474 | neuroendocrine secretory protein antisense [Source:MGI Symbol;Acc:MGI:1861674] |
| Myo15b | ENSMUSG00000034427 | 2.461845033 | 6.89E-14 | myosin XVB [Source:MGI Symbol;Acc:MGI:2685534] |
| Sept8 | ENSMUSG00000018398 | 2.449973065 | 3.53E-07 | septin 8 [Source:MGI Symbol;Acc:MGI:894310] |
| Hspg2 | ENSMUSG00000028763 | 2.436791115 | 0.04719676 | perlecan (heparan sulfate proteoglycan 2) [Source:MGI Symbol;Acc:MGI:96257] |
| Kcnmb4os2 | ENSMUSG00000085837 | 2.435910537 | 0.000496046 | potassium large conductance calcium-activated channel, subfamily M, beta member 4, opposite strand 2 [Source:MGI Symbol;Acc:MGI:1918263] |
| Rab4a | ENSMUSG00000019478 | 2.421517259 | 0.001194283 | RAB4A, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:105069] |
| Ptk2 | ENSMUSG00000022607 | 2.402436625 | 1.50E-11 | PTK2 protein tyrosine kinase 2 [Source:MGI Symbol;Acc:MGI:95481] |
| Dok2 | ENSMUSG00000022102 | 2.396654033 | 1.56E-05 | docking protein 2 [Source:MGI Symbol;Acc:MGI:1332623] |
| Ckb | ENSMUSG00000001270 | 2.373352968 | 0.002026833 | creatine kinase, brain [Source:MGI Symbol;Acc:MGI:88407] |
| Mfsd6l | ENSMUSG00000048329 | 2.363793852 | 0.027188366 | major facilitator superfamily domain containing 6-like [Source:MGI Symbol;Acc:MGI:2384904] |
| Ranbp17 | ENSMUSG00000040594 | 2.358901904 | 6.83E-08 | RAN binding protein 17 [Source:MGI Symbol;Acc:MGI:1929706] |
| Glis2 | ENSMUSG00000014303 | 2.356504474 | 4.69E-06 | GLIS family zinc finger 2 [Source:MGI Symbol;Acc:MGI:1932535] |
| Stac2 | ENSMUSG00000017400 | 2.35324326 | 1.93E-14 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Gmpr | ENSMUSG00000000253 | 2.32894838 | 3.68E-06 | guanosine monophosphate reductase [Source:MGI Symbol;Acc:MGI:1913605] |
| Afap1l1 | ENSMUSG00000033032 | 2.304535878 | 0.006691653 | actin filament associated protein 1-like 1 [Source:MGI Symbol;Acc:MGI:2147199] |
| Rcn3 | ENSMUSG00000019539 | 2.298294911 | 1.75E-06 | reticulocalbin 3, EF-hand calcium binding domain [Source:MGI Symbol;Acc:MGI:1277122] |
| Cacnb2 | ENSMUSG00000057914 | 2.294608113 | 7.21E-05 | calcium channel, voltage-dependent, beta 2 subunit [Source:MGI Symbol;Acc:MGI:894644] |
| Bhlhe41 | ENSMUSG00000030256 | 2.275428335 | 9.06E-30 | basic helix-loop-helix family, member e41 [Source:MGI Symbol;Acc:MGI:1930704] |
| Slc7a8 | ENSMUSG00000022180 | 2.273557419 | 0.020262442 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 8 [Source:MGI Symbol;Acc:MGI:1355323] |
| Tbc1d9 | ENSMUSG00000031709 | 2.268226771 | 0.026433018 | TBC1 domain family, member 9 [Source:MGI Symbol;Acc:MGI:1918560] |
| Cdh17 | ENSMUSG00000028217 | 2.229659055 | 6.92E-06 | cadherin 17 [Source:MGI Symbol;Acc:MGI:1095414] |
| Zfp580 | ENSMUSG00000055633 | 2.212269335 | 0.000548517 | zinc finger protein 580 [Source:MGI Symbol;Acc:MGI:1916242] |
| Rapgef4 | ENSMUSG00000049044 | 2.205124423 | 0.000269044 | Rap guanine nucleotide exchange factor (GEF) 4 [Source:MGI Symbol;Acc:MGI:1917723] |
| Zdhhc2 | ENSMUSG00000039470 | 2.193495152 | 6.55E-05 | zinc finger, DHHC domain containing 2 [Source:MGI Symbol;Acc:MGI:1923452] |
| Nek6 | ENSMUSG00000026749 | 2.192974208 | 3.93E-09 | NIMA (never in mitosis gene a)-related expressed kinase 6 [Source:MGI Symbol;Acc:MGI:1891638] |
| Smo | ENSMUSG00000001761 | 2.184895138 | 4.81E-08 | smoothened, frizzled class receptor [Source:MGI Symbol;Acc:MGI:108075] |
| Flt3 | ENSMUSG00000042817 | 2.183295105 | 0.000508587 | FMS-like tyrosine kinase 3 [Source:MGI Symbol;Acc:MGI:95559] |
| Trf | ENSMUSG00000032554 | 2.179551384 | 0.0006168 | transferrin [Source:MGI Symbol;Acc:MGI:98821] |
| Tnni2 | ENSMUSG00000031097 | 2.178023613 | 6.86E-11 | troponin I, skeletal, fast 2 [Source:MGI Symbol;Acc:MGI:105070] |
| I830077J02R | ENSMUSG00000074342 | 2.172739063 | 0.004512254 | RIKEN cDNA I830077J02 gene [Source:MGI Symbol;Acc:MGI:3588284] |
| Prdm16 | ENSMUSG00000039410 | 2.150701825 | 4.69E-06 | PR domain containing 16 [Source:MGI Symbol;Acc:MGI:1917923] |
| Kit | ENSMUSG00000005672 | 2.102207007 | 4.90E-05 | KIT proto-oncogene receptor tyrosine kinase [Source:MGI Symbol;Acc:MGI:96677] |
| Rbp1 | ENSMUSG00000046402 | 2.100703656 | 0.008821555 | retinol binding protein 1, cellular [Source:MGI Symbol;Acc:MGI:97876] |
| 2410018L13F | ENSMUSG00000073164 | 2.087639235 | 1.04E-08 | RIKEN cDNA 2410018L13 gene [Source:MGI Symbol;Acc:MGI:1916982] |
| Cd5l | ENSMUSG00000015854 | 2.072194743 | 0.043867005 | CD5 antigen-like [Source:MGI Symbol;Acc:MGI:1334419] |
| Fam135a | ENSMUSG00000026153 | 2.04152435 | 0.003510966 | family with sequence similarity 135, member A [Source:MGI Symbol;Acc:MGI:1915437] |
| C1qc | ENSMUSG00000036896 | 2.0302797 | 0.036406836 | complement component 1, q subcomponent, C chain [Source:MGI Symbol;Acc:MGI:88225] |
| H2afy2 | ENSMUSG00000020086 | 2.02827902 | 0.008552036 | H2A histone family, member Y2 [Source:MGI Symbol;Acc:MGI:3037658] |
| Mkrn3 | ENSMUSG00000070527 | 2.020274012 | 0.017422891 | makorin, ring finger protein, 3 [Source:MGI Symbol;Acc:MGI:2181178] |
| Atp2a1 | ENSMUSG00000030730 | 2.018159725 | 0.035689221 | ATPase, Ca++ transporting, cardiac muscle, fast twitch 1 [Source:MGI Symbol;Acc:MGI:105058] |
| P2ry12 | ENSMUSG00000036353 | 2.017767427 | 0.00048894 | purinergic receptor P2Y, G-protein coupled 12 [Source:MGI Symbol;Acc:MGI:1918089] |
| Tnfsf11 | ENSMUSG00000022015 | 2.009736527 | 0.021349934 | tumor necrosis factor (ligand) superfamily, member 11 [Source:MGI Symbol;Acc:MGI:1100089] |
| Tceal8 | ENSMUSG00000051579 | 1.995857312 | 3.98E-08 | transcription elongation factor A (SII)-like 8 [Source:MGI Symbol;Acc:MGI:1913934] |
| Rap1gap2 | ENSMUSG00000038807 | 1.980693314 | 3.92E-08 | RAP1 GTPase activating protein 2 [Source:MGI Symbol;Acc:MGI:3028623] |
| Lax1 | ENSMUSG00000051998 | 1.977255257 | 2.86E-15 | lymphocyte transmembrane adaptor 1 [Source:MGI Symbol;Acc:MGI:2443362] |
| Ccdc40 | ENSMUSG00000039963 | 1.970163239 | 0.017413138 | coiled-coil domain containing 40 [Source:MGI Symbol;Acc:MGI:2443893] |
| Eng | ENSMUSG00000026814 | 1.963413946 | 6.83E-08 | endoglin [Source:MGI Symbol;Acc:MGI:95392] |
| Hif3a | ENSMUSG00000004328 | 1.944917459 | 0.014484005 | hypoxia inducible factor 3, alpha subunit [Source:MGI Symbol;Acc:MGI:1859778] |
| Camk2a | ENSMUSG00000024617 | 1.935403888 | 2.66E-09 | calcium/calmodulin-dependent protein kinase II alpha [Source:MGI Symbol;Acc:MGI:88256] |
| Lst1 | ENSMUSG00000073412 | 1.912372415 | 6.74E-05 | leukocyte specific transcript 1 [Source:MGI Symbol;Acc:MGI:1096324] |
| Acy3 | ENSMUSG00000024866 | 1.903539274 | 0.003047015 | aspartoacylase (aminoacylase) 3 [Source:MGI Symbol;Acc:MGI:1918920] |
| Cln8 | ENSMUSG00000026317 | 1.89718514 | 0.022491441 | ceroid-lipofuscinosis, neuronal 8 [Source:MGI Symbol;Acc:MGI:1349447] |

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| | | | | |
|---|---|---|---|---|
| Tfpi | ENSMUSG00000027082 | 1.884483689 | 5.81E-05 | tissue factor pathway inhibitor [Source:MGI Symbol;Acc:MGI:1095418] |
| Zbtb7b | ENSMUSG00000028042 | 1.881038645 | 2.05E-05 | zinc finger and BTB domain containing 7B [Source:MGI Symbol;Acc:MGI:102755] |
| Lrig3 | ENSMUSG00000020105 | 1.873236396 | 0.024298738 | leucine-rich repeats and immunoglobulin-like domains 3 [Source:MGI Symbol;Acc:MGI:2443955] |
| Rps4l | ENSMUSG00000063171 | 1.873026825 | 5.98E-06 | ribosomal protein S4-like [Source:MGI Symbol;Acc:MGI:1913434] |
| Peg12 | ENSMUSG00000070526 | 1.863658709 | 2.66E-05 | paternally expressed 12 [Source:MGI Symbol;Acc:MGI:1351637] |
| Tpm2 | ENSMUSG00000028464 | 1.862350316 | 0.021216521 | tropomyosin 2, beta [Source:MGI Symbol;Acc:MGI:98810] |
| Plekha7 | ENSMUSG00000045659 | 1.803823719 | 0.000340998 | pleckstrin homology domain containing, family A member 7 [Source:MGI Symbol;Acc:MGI:2445094] |
| Egfl7 | ENSMUSG00000026921 | 1.80109275 | 0.000248791 | EGF-like domain 7 [Source:MGI Symbol;Acc:MGI:2449923] |
| Ephb2 | ENSMUSG00000028664 | 1.795890605 | 4.50E-06 | Eph receptor B2 [Source:MGI Symbol;Acc:MGI:99611] |
| 1700086O06 | ENSMUSG00000097080 | 1.793703107 | 0.000385668 | RIKEN cDNA 1700086O06 gene [Source:MGI Symbol;Acc:MGI:1920766] |
| Colq | ENSMUSG00000057606 | 1.787515111 | 1.53E-09 | collagen-like tail subunit (single strand of homotrimer) of asymmetric acetylcholinesterase [Source:MGI Symbol;Acc:MGI:1338761] |
| Angptl2 | ENSMUSG00000004105 | 1.784194712 | 0.007630298 | angiopoietin-like 2 [Source:MGI Symbol;Acc:MGI:1347002] |
| Adgra3 | ENSMUSG00000029090 | 1.77914296 | 0.002370813 | adhesion G protein-coupled receptor A3 [Source:MGI Symbol;Acc:MGI:1917943] |
| Errfi1 | ENSMUSG00000028967 | 1.776862732 | 9.40E-05 | ERBB receptor feedback inhibitor 1 [Source:MGI Symbol;Acc:MGI:1921405] |
| Tnnt1 | ENSMUSG00000064179 | 1.776363768 | 0.001935929 | troponin T1, skeletal, slow [Source:MGI Symbol;Acc:MGI:1333868] |
| Il6ra | ENSMUSG00000027947 | 1.767445838 | 0.000293287 | interleukin 6 receptor, alpha [Source:MGI Symbol;Acc:MGI:105304] |
| Tln2 | ENSMUSG00000052698 | 1.756731292 | 0.042040362 | talin 2 [Source:MGI Symbol;Acc:MGI:1917799] |
| Kifc3 | ENSMUSG00000031788 | 1.754277598 | 0.029730942 | kinesin family member C3 [Source:MGI Symbol;Acc:MGI:109202] |
| Bpifb3 | ENSMUSG00000068008 | 1.745147102 | 2.04E-06 | BPI fold containing family B, member 3 [Source:MGI Symbol;Acc:MGI:2675077] |
| Tnnt3 | ENSMUSG00000061723 | 1.744932482 | 0.000402221 | troponin T3, skeletal, fast [Source:MGI Symbol;Acc:MGI:109550] |
| P2rx7 | ENSMUSG00000029468 | 1.728045903 | 0.021114099 | purinergic receptor P2X, ligand-gated ion channel, 7 [Source:MGI Symbol;Acc:MGI:1339957] |
| Kcnn4 | ENSMUSG00000054342 | 1.720601459 | 8.00E-05 | potassium intermediate/small conductance calcium-activated channel, subfamily N, member 4 [Source:MGI Symbol;Acc:MGI:1277957] |
| Plaur | ENSMUSG00000046223 | 1.715277776 | 0.004808271 | plasminogen activator, urokinase receptor [Source:MGI Symbol;Acc:MGI:97612] |
| Fzd6 | ENSMUSG00000022297 | 1.715180255 | 0.000491699 | frizzled class receptor 6 [Source:MGI Symbol;Acc:MGI:108474] |
| Nlrc3 | ENSMUSG00000049871 | 1.704092401 | 7.43E-06 | NLR family, CARD domain containing 3 [Source:MGI Symbol;Acc:MGI:2444070] |
| Bend5 | ENSMUSG00000028545 | 1.703619142 | 5.57E-10 | BEN domain containing 5 [Source:MGI Symbol;Acc:MGI:1914871] |
| Tbc1d16 | ENSMUSG00000039976 | 1.687759565 | 0.000293249 | TBC1 domain family, member 16 [Source:MGI Symbol;Acc:MGI:2652878] |
| Kctd14 | ENSMUSG00000051727 | 1.67704647 | 6.40E-05 | potassium channel tetramerisation domain containing 14 [Source:MGI Symbol;Acc:MGI:1289222] |
| Lrrc9 | ENSMUSG00000021090 | 1.671594819 | 0.033297214 | leucine rich repeat containing 9 [Source:MGI Symbol;Acc:MGI:1925507] |
| Nynrin | ENSMUSG00000075592 | 1.670566594 | 0.003799963 | NYN domain and retroviral integrase containing [Source:MGI Symbol;Acc:MGI:2652872] |
| Sspn | ENSMUSG00000030255 | 1.654231731 | 3.94E-06 | sarcospan [Source:MGI Symbol;Acc:MGI:1353511] |
| Prf1 | ENSMUSG00000037202 | 1.65336526 | 9.83E-06 | perforin 1 (pore forming protein) [Source:MGI Symbol;Acc:MGI:97551] |
| Tmem121 | ENSMUSG00000049036 | 1.651181377 | 0.003712414 | transmembrane protein 121 [Source:MGI Symbol;Acc:MGI:1916445] |
| Cadm4 | ENSMUSG00000054793 | 1.649790865 | 0.005988021 | cell adhesion molecule 4 [Source:MGI Symbol;Acc:MGI:2449088] |
| Csf1r | ENSMUSG00000024621 | 1.642571847 | 0.021006127 | colony stimulating factor 1 receptor [Source:MGI Symbol;Acc:MGI:1339758] |
| Krt18 | ENSMUSG00000023043 | 1.610856506 | 0.010049529 | keratin 18 [Source:MGI Symbol;Acc:MGI:96692] |
| Ncs1 | ENSMUSG00000062661 | 1.575850276 | 0.004866741 | neuronal calcium sensor 1 [Source:MGI Symbol;Acc:MGI:109166] |
| Yes1 | ENSMUSG00000014932 | 1.57027145 | 0.000402221 | YES proto-oncogene 1, Src family tyrosine kinase [Source:MGI Symbol;Acc:MGI:99147] |
| Gtf2ird1 | ENSMUSG00000023079 | 1.558165142 | 0.000214781 | general transcription factor II I repeat domain-containing 1 [Source:MGI Symbol;Acc:MGI:1861942] |
| Uchl1 | ENSMUSG00000029223 | 1.534225689 | 8.63E-06 | ubiquitin carboxy-terminal hydrolase L1 [Source:MGI Symbol;Acc:MGI:103149] |
| Sh2d2a | ENSMUSG00000028071 | 1.527438865 | 9.95E-06 | SH2 domain containing 2A [Source:MGI Symbol;Acc:MGI:1351596] |
| 5730559C18I | ENSMUSG00000041605 | 1.518681093 | 0.000322206 | RIKEN cDNA 5730559C18 gene [Source:MGI Symbol;Acc:MGI:1921579] |
| Sfmbt2 | ENSMUSG00000061186 | 1.508268693 | 2.21E-05 | Scm-like with four mbt domains 2 [Source:MGI Symbol;Acc:MGI:2447794] |
| Ccdc180 | ENSMUSG00000035539 | 1.502312228 | 0.027696731 | coiled-coil domain containing 180 [Source:MGI Symbol;Acc:MGI:2685871] |
| Rnase4 | ENSMUSG00000021876 | 1.492434307 | 2.39E-06 | ribonuclease, RNase A family 4 [Source:MGI Symbol;Acc:MGI:1926217] |
| Cyp27a1 | ENSMUSG00000026170 | 1.490534087 | 0.034687259 | cytochrome P450, family 27, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:88594] |
| Alpl | ENSMUSG00000028766 | 1.483457154 | 0.010881611 | alkaline phosphatase, liver/bone/kidney [Source:MGI Symbol;Acc:MGI:87983] |
| Art4 | ENSMUSG00000030217 | 1.481756472 | 0.016047165 | ADP-ribosyltransferase 4 [Source:MGI Symbol;Acc:MGI:1202710] |
| Actr3b | ENSMUSG00000056367 | 1.472104841 | 9.15E-05 | ARP3 actin-related protein 3B [Source:MGI Symbol;Acc:MGI:2661120] |
| Grk3 | ENSMUSG00000042249 | 1.461081917 | 5.26E-10 | G protein-coupled receptor kinase 3 [Source:MGI Symbol;Acc:MGI:87941] |
| Mgmt | ENSMUSG00000054612 | 1.452750029 | 0.031100703 | O-6-methylguanine-DNA methyltransferase [Source:MGI Symbol;Acc:MGI:96977] |
| Sh3bgrl2 | ENSMUSG00000032261 | 1.447075528 | 0.004344134 | SH3 domain binding glutamic acid-rich protein like 2 [Source:MGI Symbol;Acc:MGI:1915350] |
| Tpi1 | ENSMUSG00000023456 | 1.43935569 | 3.37E-06 | triosephosphate isomerase 1 [Source:MGI Symbol;Acc:MGI:98797] |
| Slc7a7 | ENSMUSG00000000958 | 1.434805249 | 7.92E-05 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 7 [Source:MGI Symbol;Acc:MGI:1337120] |
| Emb | ENSMUSG00000021728 | 1.432179211 | 0.004560402 | embigin [Source:MGI Symbol;Acc:MGI:95321] |
| P2ry13 | ENSMUSG00000036362 | 1.416880751 | 0.000901315 | purinergic receptor P2Y, G-protein coupled 13 [Source:MGI Symbol;Acc:MGI:1921441] |
| Mlf1 | ENSMUSG00000048416 | 1.411528368 | 0.012465056 | myeloid leukemia factor 1 [Source:MGI Symbol;Acc:MGI:1341819] |
| Lamb2 | ENSMUSG00000052911 | 1.401412444 | 0.005548341 | laminin, beta 2 [Source:MGI Symbol;Acc:MGI:99916] |
| Ass1 | ENSMUSG00000076441 | 1.391188057 | 3.01E-05 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Pdk1 | ENSMUSG00000006494 | 1.37186069 | 4.19E-08 | pyruvate dehydrogenase kinase, isoenzyme 1 [Source:MGI Symbol;Acc:MGI:1926119] |
| Nbdy | ENSMUSG00000086316 | 1.368580173 | 0.013383829 | negative regulator of P-body association [Source:MGI Symbol;Acc:MGI:1917373] |
| Socs3 | ENSMUSG00000053113 | 1.364567601 | 0.006972032 | suppressor of cytokine signaling 3 [Source:MGI Symbol;Acc:MGI:1201791] |
| Armcx4 | ENSMUSG00000049804 | 1.362459019 | 5.79E-07 | armadillo repeat containing, X-linked 4 [Source:MGI Symbol;Acc:MGI:2147887] |
| Pear1 | ENSMUSG00000028073 | 1.348447138 | 1.61E-13 | platelet endothelial aggregation receptor 1 [Source:MGI Symbol;Acc:MGI:1920432] |
| Zyx | ENSMUSG00000029860 | 1.344269327 | 0.000343421 | zyxin [Source:MGI Symbol;Acc:MGI:103072] |
| Rara | ENSMUSG00000037992 | 1.34253467 | 2.20E-05 | retinoic acid receptor, alpha [Source:MGI Symbol;Acc:MGI:97856] |
| Tctn2 | ENSMUSG00000029386 | 1.336550725 | 0.015646574 | tectonic family member 2 [Source:MGI Symbol;Acc:MGI:1915228] |
| Cul7 | ENSMUSG00000038545 | 1.313039294 | 9.19E-09 | cullin 7 [Source:MGI Symbol;Acc:MGI:1913765] |
| Cdc42bpa | ENSMUSG00000026490 | 1.30971089 | 0.000459692 | CDC42 binding protein kinase alpha [Source:MGI Symbol;Acc:MGI:2441841] |
| Ankrd37 | ENSMUSG00000050914 | 1.30514112 | 8.42E-08 | ankyrin repeat domain 37 [Source:MGI Symbol;Acc:MGI:3603444] |
| Arpp21 | ENSMUSG00000032503 | 1.294795451 | 0.023772738 | cyclic AMP-regulated phosphoprotein, 21 [Source:MGI Symbol;Acc:MGI:107562] |
| Kcnmb4 | ENSMUSG00000054934 | 1.291097046 | 4.38E-05 | potassium large conductance calcium-activated channel, subfamily M, beta member 4 [Source:MGI Symbol;Acc:MGI:1913272] |
| Stat4 | ENSMUSG00000062939 | 1.290560395 | 0.00029072 | signal transducer and activator of transcription 4 [Source:MGI Symbol;Acc:MGI:103062] |

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|---|---|---|---|---|
| Klhl23 | ENSMUSG00000042155 | 1.290008554 | 0.000148838 | kelch-like 23 [Source:MGI Symbol;Acc:MGI:2683536] |
| Jup | ENSMUSG00000001552 | 1.285863945 | 5.25E-06 | junction plakoglobin [Source:MGI Symbol;Acc:MGI:96650] |
| Eno1 | ENSMUSG00000063524 | 1.278488678 | 3.19E-06 | enolase 1, alpha non-neuron [Source:MGI Symbol;Acc:MGI:95393] |
| Bfsp2 | ENSMUSG00000032556 | 1.277125085 | 2.52E-06 | beaded filament structural protein 2, phakinin [Source:MGI Symbol;Acc:MGI:1333828] |
| Zcchc3 | ENSMUSG00000074682 | 1.270517713 | 3.14E-12 | zinc finger, CCHC domain containing 3 [Source:MGI Symbol;Acc:MGI:1915167] |
| Pmaip1 | ENSMUSG00000024521 | 1.263474705 | 0.017421052 | phorbol-12-myristate-13-acetate-induced protein 1 [Source:MGI Symbol;Acc:MGI:1930146] |
| Med12l | ENSMUSG00000056476 | 1.260344171 | 0.001337686 | mediator complex subunit 12-like [Source:MGI Symbol;Acc:MGI:2139916] |
| Epop | ENSMUSG00000043439 | 1.259672819 | 0.003226467 | elongin BC and polycomb repressive complex 2 associated protein [Source:MGI Symbol;Acc:MGI:2143991] |
| Fhl3 | ENSMUSG00000032643 | 1.251441003 | 0.001761883 | four and a half LIM domains 3 [Source:MGI Symbol;Acc:MGI:1341092] |
| Nlgn2 | ENSMUSG00000051790 | 1.241062651 | 0.001256068 | neuroligin 2 [Source:MGI Symbol;Acc:MGI:2681835] |
| Tbc1d2 | ENSMUSG00000039813 | 1.238451895 | 0.035420982 | TBC1 domain family, member 2 [Source:MGI Symbol;Acc:MGI:2652885] |
| Ptgr1 | ENSMUSG00000028378 | 1.233662208 | 1.38E-06 | prostaglandin reductase 1 [Source:MGI Symbol;Acc:MGI:1914353] |
| Cd86 | ENSMUSG00000022901 | 1.23113661 | 2.59E-05 | CD86 antigen [Source:MGI Symbol;Acc:MGI:101773] |
| Hmga1b | ENSMUSG00000078249 | 1.226240497 | 0.006864725 | high mobility group AT-hook 1B [Source:MGI Symbol;Acc:MGI:96161] |
| Hmga1 | ENSMUSG00000046711 | 1.22523837 | 4.74E-06 | high mobility group AT-hook 1 [Source:MGI Symbol;Acc:MGI:96160] |
| Ldha | ENSMUSG00000063229 | 1.224191932 | 7.14E-06 | lactate dehydrogenase A [Source:MGI Symbol;Acc:MGI:96759] |
| Cercam | ENSMUSG00000039787 | 1.221715379 | 0.012065842 | cerebral endothelial cell adhesion molecule [Source:MGI Symbol;Acc:MGI:2139134] |
| Fabp5 | ENSMUSG00000027533 | 1.203943076 | 0.018771989 | fatty acid binding protein 5, epidermal [Source:MGI Symbol;Acc:MGI:101790] |
| Tmem154 | ENSMUSG00000056498 | 1.203460868 | 1.88E-05 | transmembrane protein 154 [Source:MGI Symbol;Acc:MGI:2444725] |
| Dennd2c | ENSMUSG00000007379 | 1.203028292 | 0.005912351 | DENN/MADD domain containing 2C [Source:MGI Symbol;Acc:MGI:3036254] |
| Aldh7a1 | ENSMUSG00000053644 | 1.202988059 | 0.000631954 | aldehyde dehydrogenase family 7, member A1 [Source:MGI Symbol;Acc:MGI:108186] |
| Asb2 | ENSMUSG00000021200 | 1.193755988 | 9.40E-06 | ankyrin repeat and SOCS box-containing 2 [Source:MGI Symbol;Acc:MGI:1929743] |
| Emilin1 | ENSMUSG00000029163 | 1.192105422 | 0.007450599 | elastin microfibril interfacer 1 [Source:MGI Symbol;Acc:MGI:1926189] |
| Grb10 | ENSMUSG00000020176 | 1.184705544 | 0.001112514 | growth factor receptor bound protein 10 [Source:MGI Symbol;Acc:MGI:103232] |
| Nme4 | ENSMUSG00000024177 | 1.1829178 | 0.015056745 | NME/NM23 nucleoside diphosphate kinase 4 [Source:MGI Symbol;Acc:MGI:1931148] |
| Rbpms | ENSMUSG00000031586 | 1.181516817 | 0.000195173 | RNA binding protein gene with multiple splicing [Source:MGI Symbol;Acc:MGI:1334446] |
| Slc25a13 | ENSMUSG00000015112 | 1.180625484 | 4.09E-07 | solute carrier family 25 (mitochondrial carrier, adenine nucleotide translocator), member 13 [Source:MGI Symbol;Acc:MGI:1354721] |
| Selenop | ENSMUSG00000064373 | 1.176692884 | 7.31E-05 | selenoprotein P [Source:MGI Symbol;Acc:MGI:894288] |
| Pcbp4 | ENSMUSG00000023495 | 1.170047802 | 0.00404421 | poly(rC) binding protein 4 [Source:MGI Symbol;Acc:MGI:1890471] |
| Myo7a | ENSMUSG00000030761 | 1.167792509 | 3.42E-20 | myosin VIIA [Source:MGI Symbol;Acc:MGI:104510] |
| Tmem98 | ENSMUSG00000035413 | 1.155900911 | 0.000627612 | transmembrane protein 98 [Source:MGI Symbol;Acc:MGI:1923457] |
| Cd5 | ENSMUSG00000024669 | 1.146226523 | 0.003193997 | CD5 antigen [Source:MGI Symbol;Acc:MGI:88340] |
| Chd7 | ENSMUSG00000041235 | 1.14550007 | 0.000417848 | chromodomain helicase DNA binding protein 7 [Source:MGI Symbol;Acc:MGI:2444748] |
| Fam212a | ENSMUSG00000042106 | 1.142190261 | 0.001600339 | family with sequence similarity 212, member A [Source:MGI Symbol;Acc:MGI:1915426] |
| Pkm | ENSMUSG00000032294 | 1.141879008 | 0.000533995 | pyruvate kinase, muscle [Source:MGI Symbol;Acc:MGI:97591] |
| Mif | ENSMUSG00000033307 | 1.125623842 | 0.009972233 | macrophage migration inhibitory factor (glycosylation-inhibiting factor) [Source:MGI Symbol;Acc:MGI:96982] |
| Arid3a | ENSMUSG00000019564 | 1.1064222 | 2.81E-11 | AT rich interactive domain 3A (BRIGHT-like) [Source:MGI Symbol;Acc:MGI:1328360] |
| Dnmt3b | ENSMUSG00000027478 | 1.103592636 | 5.54E-06 | DNA methyltransferase 3B [Source:MGI Symbol;Acc:MGI:1261819] |
| Hpse | ENSMUSG00000035273 | 1.091510008 | 1.11E-05 | heparanase [Source:MGI Symbol;Acc:MGI:1343124] |
| Serpinf1 | ENSMUSG00000000753 | 1.067476322 | 0.004085674 | serine (or cysteine) peptidase inhibitor, clade F, member 1 [Source:MGI Symbol;Acc:MGI:108080] |
| Bcat1 | ENSMUSG00000030268 | 1.066669244 | 0.002912594 | branched chain aminotransferase 1, cytosolic [Source:MGI Symbol;Acc:MGI:104861] |
| Pik3r6 | ENSMUSG00000046207 | 1.065075901 | 0.006744824 | phosphoinositide-3-kinase regulatory subunit 5 [Source:MGI Symbol;Acc:MGI:2144613] |
| Mzb1 | ENSMUSG00000024353 | 1.063273298 | 4.54E-06 | marginal zone B and B1 cell-specific protein 1 [Source:MGI Symbol;Acc:MGI:1917066] |
| Sirpa | ENSMUSG00000037902 | 1.058143584 | 0.020065555 | signal-regulatory protein alpha [Source:MGI Symbol;Acc:MGI:108563] |
| Sept10 | ENSMUSG00000019917 | 1.057609809 | 0.000411063 | septin 10 [Source:MGI Symbol;Acc:MGI:1918110] |
| Pfkl | ENSMUSG00000020277 | 1.057113935 | 2.39E-06 | phosphofructokinase, liver, B-type [Source:MGI Symbol;Acc:MGI:97547] |
| Cdc42ep4 | ENSMUSG00000041598 | 1.013113645 | 0.004601851 | CDC42 effector protein (Rho GTPase binding) 4 [Source:MGI Symbol;Acc:MGI:1929760] |

(adj.P value <= 0.05, $\log_2$FC>1)

## Table 3-4. Genes significantly up-regulated in BM in RNA sequencing.

| Symbol | Ensembl gene id | logFC (BM/NL) | adj.P.val | Annotation |
|---|---|---|---|---|
| Igha | ENSMUSG00000095079 | 6.343034741 | 4.31E-34 | immunoglobulin heavy constant alpha [Source:MGI Symbol;Acc:MGI:96444] |
| Ighv10-1 | ENSMUSG00000095981 | 5.973582758 | 0.039501614 | immunoglobulin heavy variable 10-1 [Source:MGI Symbol;Acc:MGI:4439620] |
| Il1b | ENSMUSG00000027398 | 5.443709644 | 0.027181669 | interleukin 1 beta [Source:MGI Symbol;Acc:MGI:96543] |
| Dnajc6 | ENSMUSG00000028528 | 5.231479538 | 0.01050805 | DnaJ heat shock protein family (Hsp40) member C6 [Source:MGI Symbol;Acc:MGI:1919935] |
| Iglc2 | ENSMUSG00000076937 | 5.173808232 | 1.51E-11 | immunoglobulin lambda constant 2 [Source:MGI Symbol;Acc:MGI:99547] |
| 9330182L06F | ENSMUSG00000056004 | 4.933512972 | 9.07E-07 | RIKEN cDNA 9330182L06 gene [Source:MGI Symbol;Acc:MGI:2443264] |
| Fcer2a | ENSMUSG00000005540 | 4.913163372 | 2.78E-21 | Fc receptor, IgE, low affinity II, alpha polypeptide [Source:MGI Symbol;Acc:MGI:95497] |
| Frmpd1 | ENSMUSG00000035615 | 4.850199528 | 0.001500202 | FERM and PDZ domain containing 1 [Source:MGI Symbol;Acc:MGI:2446274] |
| Nrxn2 | ENSMUSG00000033768 | 4.818200787 | 2.15E-28 | neurexin II [Source:MGI Symbol;Acc:MGI:1096362] |
| Nrxn1 | ENSMUSG00000024109 | 4.599692922 | 9.10E-10 | neurexin I [Source:MGI Symbol;Acc:MGI:1096391] |
| Lrrn3 | ENSMUSG00000036295 | 4.46232021 | 0.000911167 | leucine rich repeat protein 3, neuronal [Source:MGI Symbol;Acc:MGI:106036] |
| Lonrf3 | ENSMUSG00000016239 | 4.434140404 | 3.45E-08 | LON peptidase N-terminal domain and ring finger 3 [Source:MGI Symbol;Acc:MGI:1921615] |
| Slc9a2 | ENSMUSG00000026062 | 4.222234959 | 0.009428918 | solute carrier family 9 (sodium/hydrogen exchanger), member 2 [Source:MGI Symbol;Acc:MGI:105075] |
| 9630013D21I | ENSMUSG00000059027 | 4.213590375 | 4.61E-12 | RIKEN cDNA 9630013D21 gene [Source:MGI Symbol;Acc:MGI:2442649] |
| Jchain | ENSMUSG00000067149 | 4.121893924 | 3.01E-13 | immunoglobulin joining chain [Source:MGI Symbol;Acc:MGI:96493] |
| Igkv9-123 | ENSMUSG00000076512 | 4.047406503 | 0.046337938 | immunoglobulin kappa variable 9-123 [Source:MGI Symbol;Acc:MGI:3643848] |
| Col4a5 | ENSMUSG00000031274 | 4.019422335 | 0.045431556 | collagen, type IV, alpha 5 [Source:MGI Symbol;Acc:MGI:88456] |
| Ankrd33b | ENSMUSG00000022237 | 3.997870449 | 3.52E-20 | ankyrin repeat domain 33B [Source:MGI Symbol;Acc:MGI:1917904] |
| Mmp25 | ENSMUSG00000023903 | 3.849370119 | 0.022402757 | matrix metallopeptidase 25 [Source:MGI Symbol;Acc:MGI:2443938] |
| Igkv14-118-2 | ENSMUSG00000106098 | 3.767180954 | 0.027039923 | immunoglobulin kappa chain variable 14-118-2 [Source:MGI Symbol;Acc:MGI:5009880] |
| Igkv13-85 | ENSMUSG00000079543 | 3.710128105 | 0.039120368 | immunoglobulin kappa chain variable 13-85 [Source:MGI Symbol;Acc:MGI:4439827] |
| Kcne1 | ENSMUSG00000039639 | 3.677742482 | 3.01E-05 | potassium voltage-gated channel, Isk-related subfamily, member 1 [Source:MGI Symbol;Acc:MGI:96673] |
| Clec7a | ENSMUSG00000079293 | 3.621513358 | 0.028125602 | C-type lectin domain family 7, member a [Source:MGI Symbol;Acc:MGI:1861431] |
| Spp1 | ENSMUSG00000029304 | 3.560279447 | 2.81E-43 | secreted phosphoprotein 1 [Source:MGI Symbol;Acc:MGI:98389] |
| H2-Q5 | ENSMUSG00000055413 | 3.523566469 | 8.19E-17 | histocompatibility 2, Q region locus 5 [Source:MGI Symbol;Acc:MGI:95934] |
| A530032D15 | ENSMUSG00000089844 | 3.512685098 | 5.26E-22 | RIKEN cDNA A530032D15Rik gene [Source:MGI Symbol;Acc:MGI:3037746] |
| Sh3d19 | ENSMUSG00000028082 | 3.507375564 | 7.06E-09 | SH3 domain protein D19 [Source:MGI Symbol;Acc:MGI:1350923] |
| Clnk | ENSMUSG00000039315 | 3.457052159 | 0.01918403 | cytokine-dependent hematopoietic cell linker [Source:MGI Symbol;Acc:MGI:1351468] |
| Gm16094 | ENSMUSG00000090103 | 3.456944615 | 7.10E-12 | predicted gene 16094 [Source:MGI Symbol;Acc:MGI:3801967] |
| Shank1 | ENSMUSG00000038738 | 3.429564592 | 0.004354741 | SH3 and multiple ankyrin repeat domains 1 [Source:MGI Symbol;Acc:MGI:3613677] |
| Ntng2 | ENSMUSG00000035513 | 3.411482896 | 1.87E-07 | netrin G2 [Source:MGI Symbol;Acc:MGI:2159341] |
| 6530402F18I | ENSMUSG00000079499 | 3.383506217 | 2.10E-31 | RIKEN cDNA 6530402F18 gene [Source:MGI Symbol;Acc:MGI:1923470] |
| Gm14964 | ENSMUSG00000052188 | 3.352710345 | 0.003893481 | predicted gene 14964 [Source:MGI Symbol;Acc:MGI:3641621] |
| Map3k19 | ENSMUSG00000051590 | 3.321022353 | 1.47E-13 | mitogen-activated protein kinase kinase kinase 19 [Source:MGI Symbol;Acc:MGI:1203481] |
| Igkv4-92 | ENSMUSG00000076531 | 3.291145761 | 0.024750856 | immunoglobulin kappa variable 4-92 [Source:MGI Symbol;Acc:MGI:2686254] |
| Gm16026 | ENSMUSG00000079455 | 3.22212353 | 1.21E-08 | predicted pseudogene 16026 [Source:MGI Symbol;Acc:MGI:3783243] |
| Klra1 | ENSMUSG00000079853 | 3.210021365 | 0.048328181 | killer cell lectin-like receptor, subfamily A, member 1 [Source:MGI Symbol;Acc:MGI:101907] |
| Cd300lb | ENSMUSG00000063193 | 3.179009938 | 0.038271294 | CD300 molecule like family member B [Source:MGI Symbol;Acc:MGI:2685099] |
| Iglc1 | ENSMUSG00000105906 | 3.176397029 | 4.60E-18 | immunoglobulin lambda constant 1 [Source:MGI Symbol;Acc:MGI:99546] |
| Foxd2 | ENSMUSG00000055210 | 3.105881227 | 0.000378064 | forkhead box D2 [Source:MGI Symbol;Acc:MGI:1347471] |
| Map2 | ENSMUSG00000015222 | 3.099545032 | 7.85E-20 | microtubule-associated protein 2 [Source:MGI Symbol;Acc:MGI:97175] |
| Gm15848 | ENSMUSG00000086706 | 3.099202625 | 0.000558063 | predicted gene 15848 [Source:MGI Symbol;Acc:MGI:3802054] |
| Il2ra | ENSMUSG00000026770 | 3.081269513 | 6.89E-12 | interleukin 2 receptor, alpha chain [Source:MGI Symbol;Acc:MGI:96549] |
| Igkv9-124 | ENSMUSG00000096632 | 3.040467972 | 2.48E-05 | immunoglobulin kappa chain variable 9-124 [Source:MGI Symbol;Acc:MGI:3646892] |
| Lmcd1 | ENSMUSG00000057604 | 3.011164824 | 5.49E-14 | LIM and cysteine-rich domains 1 [Source:MGI Symbol;Acc:MGI:1353635] |
| C130026I21F | ENSMUSG00000052477 | 2.973515343 | 5.23E-32 | RIKEN cDNA C130026I21 gene [Source:MGI Symbol;Acc:MGI:3612702] |
| Gm6264 | ENSMUSG00000089716 | 2.971376581 | 0.000502669 | predicted gene 6264 [Source:MGI Symbol;Acc:MGI:3779580] |
| A530040E14 | ENSMUSG00000072109 | 2.873755273 | 4.13E-38 | RIKEN cDNA A530040E14 gene [Source:MGI Symbol;Acc:MGI:3612703] |
| Esr1 | ENSMUSG00000019768 | 2.848466483 | 7.58E-09 | estrogen receptor 1 (alpha) [Source:MGI Symbol;Acc:MGI:1352467] |
| Ighv5-6 | ENSMUSG00000094951 | 2.830443486 | 0.028081841 | immunoglobulin heavy variable 5-6 [Source:MGI Symbol;Acc:MGI:4439815] |
| Celf4 | ENSMUSG00000024268 | 2.799433748 | 0.000359935 | CUGBP, Elav-like family member 4 [Source:MGI Symbol;Acc:MGI:1932407] |
| Foxd2os | ENSMUSG00000085399 | 2.780322525 | 6.36E-15 | forkhead box D2, opposite strand [Source:MGI Symbol;Acc:MGI:2444065] |
| Gm42870 | ENSMUSG00000105128 | 2.767840029 | 0.018602115 | predicted gene 42870 [Source:MGI Symbol;Acc:MGI:5663007] |
| Slc34a1 | ENSMUSG00000021490 | 2.752078713 | 1.97E-09 | solute carrier family 34 (sodium phosphate), member 1 [Source:MGI Symbol;Acc:MGI:1345284] |
| Eya1 | ENSMUSG00000025932 | 2.733851477 | 0.000210231 | EYA transcriptional coactivator and phosphatase 1 [Source:MGI Symbol;Acc:MGI:109344] |
| Clgn | ENSMUSG00000002190 | 2.73255044 | 0.031775191 | calmegin [Source:MGI Symbol;Acc:MGI:107472] |
| Carmil3 | ENSMUSG00000022211 | 2.728708046 | 0.008006004 | capping protein regulator and myosin 1 linker 3 [Source:MGI Symbol;Acc:MGI:2448573] |
| Rapgefl1 | ENSMUSG00000038020 | 2.676341524 | 2.40E-14 | Rap guanine nucleotide exchange factor (GEF)-like 1 [Source:MGI Symbol;Acc:MGI:3611446] |
| Cpne2 | ENSMUSG00000034361 | 2.66250128 | 1.58E-14 | copine II [Source:MGI Symbol;Acc:MGI:2387578] |
| Lhfp | ENSMUSG00000048332 | 2.638712893 | 0.001989838 | lipoma HMGIC fusion partner [Source:MGI Symbol;Acc:MGI:1920048] |
| Klf4 | ENSMUSG00000003032 | 2.528171419 | 9.42E-10 | Kruppel-like factor 4 (gut) [Source:MGI Symbol;Acc:MGI:1342287] |
| Nuak1 | ENSMUSG00000020032 | 2.5063387 | 9.75E-12 | NUAK family, SNF1-like kinase, 1 [Source:MGI Symbol;Acc:MGI:1925226] |
| S1pr3 | ENSMUSG00000067586 | 2.498575023 | 7.26E-09 | sphingosine-1-phosphate receptor 3 [Source:MGI Symbol;Acc:MGI:1339365] |
| Tle2 | ENSMUSG00000034771 | 2.492164864 | 3.93E-09 | transducin-like enhancer of split 2 [Source:MGI Symbol;Acc:MGI:104635] |
| Cd40 | ENSMUSG00000017652 | 2.446538535 | 1.44E-21 | CD40 antigen [Source:MGI Symbol;Acc:MGI:88336] |
| Mcf2l | ENSMUSG00000031442 | 2.445855658 | 6.72E-05 | mcf.2 transforming sequence-like [Source:MGI Symbol;Acc:MGI:103263] |
| Msantd3 | ENSMUSG00000039693 | 2.428514546 | 0.038501213 | Myb/SANT-like DNA-binding domain containing 3 [Source:MGI Symbol;Acc:MGI:1913915] |
| AA467197 | ENSMUSG00000033213 | 2.38168943 | 0.001745833 | expressed sequence AA467197 [Source:MGI Symbol;Acc:MGI:3034182] |
| H2-Q10 | ENSMUSG00000067235 | 2.372212742 | 1.41E-08 | histocompatibility 2, Q region locus 10 [Source:MGI Symbol;Acc:MGI:95929] |
| Scin | ENSMUSG00000002565 | 2.317239331 | 1.70E-11 | scinderin [Source:MGI Symbol;Acc:MGI:1306794] |
| Mdfic | ENSMUSG00000041390 | 2.304954385 | 1.24E-08 | MyoD family inhibitor domain containing [Source:MGI Symbol;Acc:MGI:104611] |
| Plpp3 | ENSMUSG00000028517 | 2.297984799 | 1.14E-05 | phospholipid phosphatase 3 [Source:MGI Symbol;Acc:MGI:1915166] |
| Cldn10 | ENSMUSG00000022132 | 2.254306405 | 5.66E-06 | claudin 10 [Source:MGI Symbol;Acc:MGI:1913101] |

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|---|---|---|---|---|
| Zap70 | ENSMUSG00000026117 | 2.248392342 | 7.95E-06 | zeta-chain (TCR) associated protein kinase [Source:MGI Symbol;Acc:MGI:99613] |
| Iglc3 | ENSMUSG00000105547 | 2.245734906 | 8.75E-10 | immunoglobulin lambda constant 3 [Source:MGI Symbol;Acc:MGI:99886] |
| Insl6 | ENSMUSG00000050957 | 2.220818235 | 4.16E-05 | insulin-like 6 [Source:MGI Symbol;Acc:MGI:1351595] |
| Cr2 | ENSMUSG00000026616 | 2.220186396 | 6.92E-06 | complement receptor 2 [Source:MGI Symbol;Acc:MGI:88489] |
| Slc41a2 | ENSMUSG00000034591 | 2.182727743 | 0.000400235 | solute carrier family 41, member 2 [Source:MGI Symbol;Acc:MGI:2442940] |
| Vegfc | ENSMUSG00000031520 | 2.178766311 | 0.00405403 | vascular endothelial growth factor C [Source:MGI Symbol;Acc:MGI:109124] |
| Cd83 | ENSMUSG00000015396 | 2.111565541 | 1.22E-07 | CD83 antigen [Source:MGI Symbol;Acc:MGI:1328316] |
| Synpo2 | ENSMUSG00000050315 | 2.089200535 | 0.000267411 | synaptopodin 2 [Source:MGI Symbol;Acc:MGI:2153070] |
| Socs5 | ENSMUSG00000037104 | 2.075737711 | 3.37E-06 | suppressor of cytokine signaling 5 [Source:MGI Symbol;Acc:MGI:2385459] |
| AW112010 | ENSMUSG00000075010 | 2.059861782 | 3.57E-07 | expressed sequence AW112010 [Source:MGI Symbol;Acc:MGI:2147706] |
| Tspan17 | ENSMUSG00000025875 | 2.058780518 | 0.002860873 | tetraspanin 17 [Source:MGI Symbol;Acc:MGI:1921507] |
| Rgs18 | ENSMUSG00000026357 | 2.036615339 | 1.06E-07 | regulator of G-protein signaling 18 [Source:MGI Symbol;Acc:MGI:1927498] |
| Bhlhe40 | ENSMUSG00000030103 | 2.033480651 | 0.031084953 | basic helix-loop-helix family, member e40 [Source:MGI Symbol;Acc:MGI:1097714] |
| Tle6 | ENSMUSG00000034758 | 2.028631091 | 1.38E-09 | transducin-like enhancer of split 6 [Source:MGI Symbol;Acc:MGI:2149593] |
| Gas7 | ENSMUSG00000033066 | 2.018717976 | 5.16E-22 | growth arrest specific 7 [Source:MGI Symbol;Acc:MGI:1202388] |
| P2ry10 | ENSMUSG00000050921 | 2.002497891 | 1.51E-07 | purinergic receptor P2Y, G-protein coupled 10 [Source:MGI Symbol;Acc:MGI:1926076] |
| Hck | ENSMUSG00000003283 | 1.994952818 | 3.70E-26 | hemopoietic cell kinase [Source:MGI Symbol;Acc:MGI:96052] |
| Chd3 | ENSMUSG00000018474 | 1.989655948 | 0.008336274 | chromodomain helicase DNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1344395] |
| A530030E21 | ENSMUSG00000105160 | 1.981197553 | 3.79E-11 | RIKEN cDNA A530030E21 gene [Source:MGI Symbol;Acc:MGI:2444617] |
| Hspa12a | ENSMUSG00000025092 | 1.97298926 | 2.17E-06 | heat shock protein 12A [Source:MGI Symbol;Acc:MGI:1920692] |
| 2010309G21 | ENSMUSG00000106567 | 1.971003879 | 1.98E-06 | RIKEN cDNA 2010309G21 gene [Source:MGI Symbol;Acc:MGI:1917268] |
| Iglv1 | ENSMUSG00000076934 | 1.966204367 | 2.17E-05 | immunoglobulin lambda variable 1 [Source:MGI Symbol;Acc:MGI:96530] |
| Angptl4 | ENSMUSG00000002289 | 1.962585877 | 3.67E-06 | angiopoietin-like 4 [Source:MGI Symbol;Acc:MGI:1888999] |
| Slamf9 | ENSMUSG00000026548 | 1.953557016 | 2.53E-10 | SLAM family member 9 [Source:MGI Symbol;Acc:MGI:1923692] |
| Cyp46a1 | ENSMUSG00000021259 | 1.91808821 | 0.001477893 | cytochrome P450, family 46, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:1341877] |
| Bhlha15 | ENSMUSG00000052271 | 1.916757401 | 1.06E-17 | basic helix-loop-helix family, member a15 [Source:MGI Symbol;Acc:MGI:891976] |
| Ndrg1 | ENSMUSG00000005125 | 1.878534305 | 0.000548517 | N-myc downstream regulated gene 1 [Source:MGI Symbol;Acc:MGI:1341799] |
| Trim30b | ENSMUSG00000052749 | 1.863837569 | 5.09E-05 | tripartite motif-containing 30B [Source:MGI Symbol;Acc:MGI:4821256] |
| Gapt | ENSMUSG00000046006 | 1.85023061 | 3.63E-06 | Grb2-binding adaptor, transmembrane [Source:MGI Symbol;Acc:MGI:3608341] |
| Slc30a4 | ENSMUSG00000005802 | 1.83889346 | 5.70E-06 | solute carrier family 30 (zinc transporter), member 4 [Source:MGI Symbol;Acc:MGI:1345282] |
| Clic5 | ENSMUSG00000023959 | 1.816169366 | 8.43E-06 | chloride intracellular channel 5 [Source:MGI Symbol;Acc:MGI:1917912] |
| Cacna1e | ENSMUSG00000004110 | 1.798606411 | 0.030753127 | calcium channel, voltage-dependent, R type, alpha 1E subunit [Source:MGI Symbol;Acc:MGI:106217] |
| Trim2 | ENSMUSG00000027993 | 1.785787624 | 0.001053309 | tripartite motif-containing 2 [Source:MGI Symbol;Acc:MGI:1933163] |
| Phka1 | ENSMUSG00000034055 | 1.783216612 | 1.04E-06 | phosphorylase kinase alpha 1 [Source:MGI Symbol;Acc:MGI:97576] |
| Khdrbs3 | ENSMUSG00000022332 | 1.763327852 | 1.55E-05 | KH domain containing, RNA binding, signal transduction associated 3 [Source:MGI Symbol;Acc:MGI:1313312] |
| Aph1b | ENSMUSG00000032375 | 1.75950415 | 0.005474823 | aph1 homolog B, gamma secretase subunit [Source:MGI Symbol;Acc:MGI:3522097] |
| H2-T10 | ENSMUSG00000079491 | 1.745322764 | 1.93E-07 | histocompatibility 2, T region locus 10 [Source:MGI Symbol;Acc:MGI:95942] |
| Car3 | ENSMUSG00000027559 | 1.718777032 | 0.000528319 | carbonic anhydrase 3 [Source:MGI Symbol;Acc:MGI:88270] |
| Trim7 | ENSMUSG00000040350 | 1.707162989 | 2.05E-05 | tripartite motif-containing 7 [Source:MGI Symbol;Acc:MGI:2137353] |
| Pcyt1b | ENSMUSG00000035246 | 1.692686723 | 1.33E-05 | phosphate cytidylyltransferase 1, choline, beta isoform [Source:MGI Symbol;Acc:MGI:2147987] |
| Cd1d2 | ENSMUSG00000041750 | 1.681674883 | 0.011234885 | CD1d2 antigen [Source:MGI Symbol;Acc:MGI:107675] |
| Prkcg | ENSMUSG00000078816 | 1.673927996 | 3.03E-11 | protein kinase C, gamma [Source:MGI Symbol;Acc:MGI:97597] |
| Gabbr1 | ENSMUSG00000024462 | 1.673514848 | 9.39E-15 | gamma-aminobutyric acid (GABA) B receptor, 1 [Source:MGI Symbol;Acc:MGI:1860139] |
| Igsf9 | ENSMUSG00000037995 | 1.664962657 | 6.76E-06 | immunoglobulin superfamily, member 9 [Source:MGI Symbol;Acc:MGI:2135283] |
| Tanc1 | ENSMUSG00000035168 | 1.661068414 | 0.001053428 | tetratricopeptide repeat, ankyrin repeat and coiled-coil containing 1 [Source:MGI Symbol;Acc:MGI:1914110] |
| Gm15406 | ENSMUSG00000085237 | 1.660203464 | 1.66E-07 | predicted gene 15406 [Source:MGI Symbol;Acc:MGI:3705112] |
| Lefty1 | ENSMUSG00000038793 | 1.655255113 | 0.007889101 | left right determination factor 1 [Source:MGI Symbol;Acc:MGI:107405] |
| Enpep | ENSMUSG00000028024 | 1.652724912 | 0.013645133 | glutamyl aminopeptidase [Source:MGI Symbol;Acc:MGI:106645] |
| Nab2 | ENSMUSG00000025402 | 1.644463844 | 0.023053541 | Ngfi-A binding protein 2 [Source:MGI Symbol;Acc:MGI:107563] |
| Mgll | ENSMUSG00000033174 | 1.638089165 | 0.015585776 | monoglyceride lipase [Source:MGI Symbol;Acc:MGI:1346042] |
| Nav1 | ENSMUSG00000009418 | 1.638015159 | 0.00485726 | neuron navigator 1 [Source:MGI Symbol;Acc:MGI:2183683] |
| Sox5 | ENSMUSG00000041540 | 1.623361583 | 0.003712414 | SRY (sex determining region Y)-box 5 [Source:MGI Symbol;Acc:MGI:98367] |
| Nav2 | ENSMUSG00000052512 | 1.610003391 | 1.34E-06 | neuron navigator 2 [Source:MGI Symbol;Acc:MGI:2183691] |
| Ttc39b | ENSMUSG00000038172 | 1.591100607 | 1.47E-07 | tetratricopeptide repeat domain 39B [Source:MGI Symbol;Acc:MGI:1917113] |
| Lmo4 | ENSMUSG00000028266 | 1.580517381 | 1.57E-07 | LIM domain only 4 [Source:MGI Symbol;Acc:MGI:109360] |
| Zbtb20 | ENSMUSG00000022708 | 1.57483068 | 0.000491699 | zinc finger and BTB domain containing 20 [Source:MGI Symbol;Acc:MGI:1929213] |
| Akap17b | ENSMUSG00000059708 | 1.57349441 | 2.93E-09 | A kinase (PRKA) anchor protein 17B [Source:MGI Symbol;Acc:MGI:2443758] |
| Pip5k1b | ENSMUSG00000024867 | 1.562154031 | 0.000273705 | phosphatidylinositol-4-phosphate 5-kinase, type 1 beta [Source:MGI Symbol;Acc:MGI:107930] |
| Neurl3 | ENSMUSG00000047180 | 1.544288065 | 0.014755795 | neuralized E3 ubiquitin protein ligase 3 [Source:MGI Symbol;Acc:MGI:2429944] |
| Plcxd2 | ENSMUSG00000087141 | 1.541407637 | 5.09E-05 | phosphatidylinositol-specific phospholipase C, X domain containing 2 [Source:MGI Symbol;Acc:MGI:3647874] |
| H2-Q4 | ENSMUSG00000035929 | 1.52940307 | 1.22E-07 | histocompatibility 2, Q region locus 4 [Source:MGI Symbol;Acc:MGI:95933] |
| Lrtm2 | ENSMUSG00000055003 | 1.520898526 | 0.004659768 | leucine-rich repeats and transmembrane domains 2 [Source:MGI Symbol;Acc:MGI:2141485] |
| Ltk | ENSMUSG00000027297 | 1.51869151 | 0.00076296 | leukocyte tyrosine kinase [Source:MGI Symbol;Acc:MGI:96840] |
| Wls | ENSMUSG00000028173 | 1.513266031 | 7.40E-13 | wntless homolog (Drosophila) [Source:MGI Symbol;Acc:MGI:1915401] |
| Hoxb4 | ENSMUSG00000038692 | 1.510503662 | 0.004745317 | homeobox B4 [Source:MGI Symbol;Acc:MGI:96185] |
| H2-K2 | ENSMUSG00000067203 | 1.497850191 | 1.74E-07 | histocompatibility 2, K region locus 2 [Source:MGI Symbol;Acc:MGI:95906] |
| Pisd-ps1 | ENSMUSG00000082286 | 1.494072396 | 5.31E-17 | phosphatidylserine decarboxylase, pseudogene 1 [Source:MGI Symbol;Acc:MGI:3842428] |
| Cdkl1 | ENSMUSG00000020990 | 1.486702316 | 8.74E-05 | cyclin-dependent kinase-like 1 (CDC2-related kinase) [Source:MGI Symbol;Acc:MGI:1918341] |
| Pura | ENSMUSG00000043991 | 1.481615662 | 3.91E-05 | purine rich element binding protein A [Source:MGI Symbol;Acc:MGI:103079] |
| Gm10552 | ENSMUSG00000073628 | 1.478566568 | 0.005290356 | predicted gene 10552 [Source:MGI Symbol;Acc:MGI:3642083] |
| Reep2 | ENSMUSG00000038555 | 1.459167145 | 6.49E-07 | receptor accessory protein 2 [Source:MGI Symbol;Acc:MGI:2385070] |
| Klf9 | ENSMUSG00000033863 | 1.457927922 | 0.00029126 | Kruppel-like factor 9 [Source:MGI Symbol;Acc:MGI:1333856] |
| Tnnt2 | ENSMUSG00000026414 | 1.452216464 | 0.000122183 | troponin T2, cardiac [Source:MGI Symbol;Acc:MGI:104597] |
| Gm6525 | ENSMUSG00000104043 | 1.450624201 | 0.000496046 | predicted pseudogene 6525 [Source:MGI Symbol;Acc:MGI:3648757] |
| Rapgef3 | ENSMUSG00000022469 | 1.4445818 | 9.95E-05 | Rap guanine nucleotide exchange factor (GEF) 3 [Source:MGI Symbol;Acc:MGI:2441741] |

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|---|---|---|---|---|
| Wfdc21 | ENSMUSG00000051748 | 1.442415004 | 0.003127825 | WAP four-disulfide core domain 21 [Source:MGI Symbol;Acc:MGI:1913357] |
| Gm26947 | ENSMUSG00000098055 | 1.438546736 | 0.000445061 | predicted gene, 26947 [Source:MGI Symbol;Acc:MGI:5504062] |
| Dusp6 | ENSMUSG00000019960 | 1.435675682 | 0.000142293 | dual specificity phosphatase 6 [Source:MGI Symbol;Acc:MGI:1914853] |
| Ly6k | ENSMUSG00000044678 | 1.43476807 | 0.00792864 | lymphocyte antigen 6 complex, locus K [Source:MGI Symbol;Acc:MGI:1923736] |
| Cd38 | ENSMUSG00000029084 | 1.4322102 | 7.56E-06 | CD38 antigen [Source:MGI Symbol;Acc:MGI:107474] |
| Casp1 | ENSMUSG00000025888 | 1.430267944 | 1.75E-05 | caspase 1 [Source:MGI Symbol;Acc:MGI:96544] |
| H2-K1 | ENSMUSG00000061232 | 1.42158997 | 6.51E-11 | histocompatibility 2, K1, K region [Source:MGI Symbol;Acc:MGI:95904] |
| Hspa2 | ENSMUSG00000059970 | 1.414786457 | 0.001196643 | heat shock protein 2 [Source:MGI Symbol;Acc:MGI:96243] |
| Cfp | ENSMUSG00000001128 | 1.392120259 | 3.99E-08 | complement factor properdin [Source:MGI Symbol;Acc:MGI:97545] |
| Cyp2d22 | ENSMUSG00000061740 | 1.380670543 | 9.03E-05 | cytochrome P450, family 2, subfamily d, polypeptide 22 [Source:MGI Symbol;Acc:MGI:1929474] |
| Pltp | ENSMUSG00000017754 | 1.378399389 | 0.013733351 | phospholipid transfer protein [Source:MGI Symbol;Acc:MGI:103151] |
| Zdhhc14 | ENSMUSG00000034265 | 1.365790674 | 3.60E-05 | zinc finger, DHHC domain containing 14 [Source:MGI Symbol;Acc:MGI:2653229] |
| Trp53inp2 | ENSMUSG00000038375 | 1.364972714 | 7.93E-06 | transformation related protein 53 inducible nuclear protein 2 [Source:MGI Symbol;Acc:MGI:1915978] |
| Egr1 | ENSMUSG00000038418 | 1.362412528 | 0.046839207 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Fcmr | ENSMUSG00000042474 | 1.351477332 | 0.000202036 | Fc fragment of IgM receptor [Source:MGI Symbol;Acc:MGI:1916419] |
| Nlrc5 | ENSMUSG00000074151 | 1.335034175 | 7.61E-05 | NLR family, CARD domain containing 5 [Source:MGI Symbol;Acc:MGI:3612191] |
| Gm11131 | ENSMUSG00000079505 | 1.334780826 | 0.000159961 | predicted gene 11131 [Source:MGI Symbol;Acc:MGI:3779386] |
| Tlr1 | ENSMUSG00000044827 | 1.331288232 | 3.83E-05 | toll-like receptor 1 [Source:MGI Symbol;Acc:MGI:1341295] |
| Slpi | ENSMUSG00000017002 | 1.325053012 | 0.000746326 | secretory leukocyte peptidase inhibitor [Source:MGI Symbol;Acc:MGI:109297] |
| Basp1 | ENSMUSG00000045763 | 1.319722821 | 0.001908537 | brain abundant, membrane attached signal protein 1 [Source:MGI Symbol;Acc:MGI:1917600] |
| Gm12250 | ENSMUSG00000082292 | 1.319698042 | 0.008219313 | predicted gene 12250 [Source:MGI Symbol;Acc:MGI:3649299] |
| H2-M3 | ENSMUSG00000016206 | 1.310289403 | 7.94E-10 | histocompatibility 2, M region locus 3 [Source:MGI Symbol;Acc:MGI:95915] |
| Pla2g16 | ENSMUSG00000060675 | 1.308370967 | 0.004452451 | phospholipase A2, group XVI [Source:MGI Symbol;Acc:MGI:2179715] |
| Ap1s2 | ENSMUSG00000031367 | 1.307489174 | 2.05E-05 | adaptor-related protein complex 1, sigma 2 subunit [Source:MGI Symbol;Acc:MGI:1889383] |
| Dstyk | ENSMUSG00000042046 | 1.306126862 | 0.000304446 | dual serine/threonine and tyrosine protein kinase [Source:MGI Symbol;Acc:MGI:1925064] |
| Cd72 | ENSMUSG00000028459 | 1.291866165 | 0.001724294 | CD72 antigen [Source:MGI Symbol;Acc:MGI:88345] |
| Igkv1-88 | ENSMUSG00000076535 | 1.286029796 | 0.01793578 | immunoglobulin kappa chain variable 1-88 [Source:MGI Symbol;Acc:MGI:4439828] |
| Klhl14 | ENSMUSG00000042514 | 1.285961656 | 3.53E-05 | kelch-like 14 [Source:MGI Symbol;Acc:MGI:1921249] |
| Syne2 | ENSMUSG00000063450 | 1.281388217 | 0.000686215 | spectrin repeat containing, nuclear envelope 2 [Source:MGI Symbol;Acc:MGI:2449316] |
| Zbp1 | ENSMUSG00000027514 | 1.278914831 | 0.007546547 | Z-DNA binding protein 1 [Source:MGI Symbol;Acc:MGI:1927449] |
| Itpr2 | ENSMUSG00000030287 | 1.262349372 | 8.00E-05 | inositol 1,4,5-triphosphate receptor 2 [Source:MGI Symbol;Acc:MGI:99418] |
| Synj2 | ENSMUSG00000023805 | 1.252176171 | 0.000540344 | synaptojanin 2 [Source:MGI Symbol;Acc:MGI:1201671] |
| Neat1 | ENSMUSG00000092274 | 1.2510776 | 2.93E-09 | nuclear paraspeckle assembly transcript 1 (non-protein coding) [Source:MGI Symbol;Acc:MGI:1914211] |
| Malat1 | ENSMUSG00000092341 | 1.241787829 | 5.20E-05 | metastasis associated lung adenocarcinoma transcript 1 (non-coding RNA) [Source:MGI Symbol;Acc:MGI:1919539] |
| 2510009E07I | ENSMUSG00000043391 | 1.237152534 | 0.01794716 | RIKEN cDNA 2510009E07 gene [Source:MGI Symbol;Acc:MGI:1919440] |
| 9330175E14I | ENSMUSG00000097194 | 1.235203641 | 3.01E-05 | RIKEN cDNA 9330175E14 gene [Source:MGI Symbol;Acc:MGI:2443913] |
| Grn | ENSMUSG00000034708 | 1.217304842 | 1.23E-08 | granulin [Source:MGI Symbol;Acc:MGI:95832] |
| Pisd-ps2 | ENSMUSG00000023795 | 1.215845924 | 5.11E-06 | phosphatidylserine decarboxylase, pseudogene 2 [Source:MGI Symbol;Acc:MGI:3612472] |
| Alpk1 | ENSMUSG00000028028 | 1.203136361 | 0.00159062 | alpha-kinase 1 [Source:MGI Symbol;Acc:MGI:1918731] |
| Afap1 | ENSMUSG00000029094 | 1.200007442 | 0.000124209 | actin filament associated protein 1 [Source:MGI Symbol;Acc:MGI:1917542] |
| Gpr155 | ENSMUSG00000041762 | 1.189931654 | 6.40E-05 | G protein-coupled receptor 155 [Source:MGI Symbol;Acc:MGI:1915776] |
| Slco5a1 | ENSMUSG00000025938 | 1.18507411 | 0.046258631 | solute carrier organic anion transporter family, member 5A1 [Source:MGI Symbol;Acc:MGI:2443431] |
| Bace1 | ENSMUSG00000032086 | 1.179944663 | 0.005631765 | beta-site APP cleaving enzyme 1 [Source:MGI Symbol;Acc:MGI:1346542] |
| Tmc5 | ENSMUSG00000030650 | 1.178419903 | 0.002970958 | transmembrane channel-like gene family 5 [Source:MGI Symbol;Acc:MGI:1921674] |
| Iqsec2 | ENSMUSG00000041115 | 1.178207909 | 0.000802455 | IQ motif and Sec7 domain 2 [Source:MGI Symbol;Acc:MGI:3528396] |
| Ypel2 | ENSMUSG00000018427 | 1.17509655 | 0.000223153 | yippee-like 2 (Drosophila) [Source:MGI Symbol;Acc:MGI:1925114] |
| Vps13c | ENSMUSG00000035284 | 1.173977737 | 0.015307819 | vacuolar protein sorting 13C [Source:MGI Symbol;Acc:MGI:2444207] |
| Slc28a2 | ENSMUSG00000027219 | 1.17249577 | 2.68E-09 | solute carrier family 28 (sodium-coupled nucleoside transporter), member 2 [Source:MGI Symbol;Acc:MGI:1913105] |
| Icosl | ENSMUSG00000000732 | 1.167412998 | 0.007598536 | icos ligand [Source:MGI Symbol;Acc:MGI:1354701] |
| Naip5 | ENSMUSG00000071203 | 1.163610984 | 4.49E-05 | NLR family, apoptosis inhibitory protein 5 [Source:MGI Symbol;Acc:MGI:1298220] |
| Mllt3 | ENSMUSG00000028496 | 1.162986459 | 3.57E-07 | myeloid/lymphoid or mixed-lineage leukemia; translocated to, 3 [Source:MGI Symbol;Acc:MGI:1917372] |
| Klf8 | ENSMUSG00000041649 | 1.15906774 | 0.004041729 | Kruppel-like factor 8 [Source:MGI Symbol;Acc:MGI:2442430] |
| Dnah8 | ENSMUSG00000033826 | 1.153103018 | 0.000548517 | dynein, axonemal, heavy chain 8 [Source:MGI Symbol;Acc:MGI:107714] |
| Cpeb2 | ENSMUSG00000039782 | 1.150648729 | 0.002863718 | cytoplasmic polyadenylation element binding protein 2 [Source:MGI Symbol;Acc:MGI:2442640] |
| Itgam | ENSMUSG00000030786 | 1.149924463 | 0.004865503 | integrin alpha M [Source:MGI Symbol;Acc:MGI:96607] |
| Ell2 | ENSMUSG00000001542 | 1.144645629 | 2.34E-07 | elongation factor RNA polymerase II 2 [Source:MGI Symbol;Acc:MGI:2183438] |
| Ptger4 | ENSMUSG00000039942 | 1.14145456 | 0.013474989 | prostaglandin E receptor 4 (subtype EP4) [Source:MGI Symbol;Acc:MGI:104311] |
| Psd3 | ENSMUSG00000030465 | 1.139257388 | 0.00245901 | pleckstrin and Sec7 domain containing 3 [Source:MGI Symbol;Acc:MGI:1918215] |
| Creb3l2 | ENSMUSG00000038648 | 1.136022427 | 0.000193274 | cAMP responsive element binding protein 3-like 2 [Source:MGI Symbol;Acc:MGI:2442695] |
| Osbpl8 | ENSMUSG00000020189 | 1.135068731 | 0.000188107 | oxysterol binding protein-like 8 [Source:MGI Symbol;Acc:MGI:2443807] |
| Derl3 | ENSMUSG00000009092 | 1.129929882 | 0.004096151 | Der1-like domain family, member 3 [Source:MGI Symbol;Acc:MGI:1917627] |
| Arl5a | ENSMUSG00000036093 | 1.126975453 | 1.83E-11 | ADP-ribosylation factor-like 5A [Source:MGI Symbol;Acc:MGI:1922673] |
| Lta | ENSMUSG00000024402 | 1.12653746 | 0.026123472 | lymphotoxin A [Source:MGI Symbol;Acc:MGI:104797] |
| H2-D1 | ENSMUSG00000073411 | 1.124297538 | 3.18E-09 | histocompatibility 2, D region locus 1 [Source:MGI Symbol;Acc:MGI:95896] |
| Rtl5 | ENSMUSG00000049191 | 1.122419518 | 0.0002979 | retrotransposon Gag like 5 [Source:MGI Symbol;Acc:MGI:3045324] |
| Fam46a | ENSMUSG00000032265 | 1.120350294 | 6.96E-05 | family with sequence similarity 46, member A [Source:MGI Symbol;Acc:MGI:2670964] |
| Ankrd12 | ENSMUSG00000034647 | 1.113037812 | 1.79E-06 | ankyrin repeat domain 12 [Source:MGI Symbol;Acc:MGI:1914357] |
| Kalrn | ENSMUSG00000061751 | 1.112527417 | 0.000263368 | kalirin, RhoGEF kinase [Source:MGI Symbol;Acc:MGI:2685385] |
| Rab44 | ENSMUSG00000064147 | 1.111706049 | 0.032835321 | RAB44, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:3045302] |
| Trim36 | ENSMUSG00000033949 | 1.107463707 | 0.00485726 | tripartite motif-containing 36 [Source:MGI Symbol;Acc:MGI:106264] |
| Herc3 | ENSMUSG00000029804 | 1.100430125 | 1.03E-08 | hect domain and RLD 3 [Source:MGI Symbol;Acc:MGI:1921248] |
| Bach2 | ENSMUSG00000040270 | 1.096732165 | 0.008458954 | BTB and CNC homology, basic leucine zipper transcription factor 2 [Source:MGI Symbol;Acc:MGI:894679] |

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| | | | | |
|---|---|---|---|---|
| Irak3 | ENSMUSG00000020227 | 1.087061848 | 0.003753853 | interleukin-1 receptor-associated kinase 3 [Source:MGI Symbol;Acc:MGI:1921164] |
| Ero1lb | ENSMUSG00000057069 | 1.086087266 | 0.006892275 | ERO1-like beta (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1914725] |
| 4930426D05I | ENSMUSG00000043168 | 1.084639149 | 2.77E-13 | RIKEN cDNA 4930426D05 gene [Source:MGI Symbol;Acc:MGI:1921894] |
| Il18 | ENSMUSG00000039217 | 1.083625567 | 0.008570231 | interleukin 18 [Source:MGI Symbol;Acc:MGI:107936] |
| Ggnbp1 | ENSMUSG00000048731 | 1.082553532 | 0.000290342 | gametogenetin binding protein 1 [Source:MGI Symbol;Acc:MGI:3055306] |
| Atp8a1 | ENSMUSG00000037685 | 1.070170103 | 9.11E-05 | ATPase, aminophospholipid transporter (APLT), class I, type 8A, member 1 [Source:MGI Symbol;Acc:MGI:1330848] |
| Tmem123 | ENSMUSG00000050912 | 1.058701671 | 7.29E-11 | transmembrane protein 123 [Source:MGI Symbol;Acc:MGI:1919179] |
| Ly75 | ENSMUSG00000026980 | 1.055973862 | 0.00021812 | lymphocyte antigen 75 [Source:MGI Symbol;Acc:MGI:106662] |
| Tlr6 | ENSMUSG00000051498 | 1.054960016 | 0.003532126 | toll-like receptor 6 [Source:MGI Symbol;Acc:MGI:1341296] |
| Sema5a | ENSMUSG00000022231 | 1.052995687 | 3.83E-05 | sema domain, seven thrombospondin repeats (type 1 and type 1-like), transmembrane domain (TM) and short cytoplasmic domain, (semaphorin) 5A [Source:MGI Symbol;Acc:MGI:107556] |
| Slc25a35 | ENSMUSG00000018740 | 1.047951705 | 0.010961579 | solute carrier family 25, member 35 [Source:MGI Symbol;Acc:MGI:1919248] |
| Neurl1b | ENSMUSG00000034413 | 1.047020961 | 0.001657726 | neuralized E3 ubiquitin protein ligase 1B [Source:MGI Symbol;Acc:MGI:3643092] |
| Man1a | ENSMUSG00000003746 | 1.040291178 | 0.000105442 | mannosidase 1, alpha [Source:MGI Symbol;Acc:MGI:104677] |
| Mxd4 | ENSMUSG00000037235 | 1.037554767 | 0.000202053 | Max dimerization protein 4 [Source:MGI Symbol;Acc:MGI:104991] |
| H2-DMb1 | ENSMUSG00000079547 | 1.035369496 | 9.19E-09 | histocompatibility 2, class II, locus Mb1 [Source:MGI Symbol;Acc:MGI:95922] |
| Ciita | ENSMUSG00000022504 | 1.03431045 | 0.019903204 | class II transactivator [Source:MGI Symbol;Acc:MGI:108445] |
| Mfhas1 | ENSMUSG00000070056 | 1.031937353 | 0.002815831 | malignant fibrous histiocytoma amplified sequence 1 [Source:MGI Symbol;Acc:MGI:1098644] |
| Trim16 | ENSMUSG00000047821 | 1.03030738 | 4.28E-06 | tripartite motif-containing 16 [Source:MGI Symbol;Acc:MGI:2137356] |
| Cnr2 | ENSMUSG00000062585 | 1.016799725 | 6.19E-08 | cannabinoid receptor 2 (macrophage) [Source:MGI Symbol;Acc:MGI:104650] |
| Gbp5 | ENSMUSG00000105504 | 1.009062497 | 0.011311379 | guanylate binding protein 5 [Source:MGI Symbol;Acc:MGI:2429943] |

(adj.P value <= 0.05, $\log_2$FC>1)

**Table 3-5. Genes significantly up-regulated in NL in microRNA sequencing.**

| Symbol | ID | logFC(NL/BM) | PValue | FDR |
|---|---|---|---|---|
| mmu-miR-127-3p | MIMAT0000139 | 9.84588727 | 3.44E-10 | 3.75E-08 |
| mmu-miR-433-3p | MIMAT0001420 | 9.52858239 | 1.31E-06 | 6.10E-05 |
| mmu-miR-122-5p | MIMAT0000246 | 7.38712448 | 2.45E-49 | 8.01E-47 |
| mmu-miR-296-5p | MIMAT0000374 | 3.97024509 | 0.00242572 | 0.04174791 |
| mmu-miR-298-5p | MIMAT0000376 | 2.67125336 | 5.60E-09 | 4.58E-07 |
| mmu-miR-296-3p | MIMAT0004576 | 2.36545246 | 2.27E-10 | 3.71E-08 |
| mmu-miR-99a-5p | MIMAT0000131 | 2.24378493 | 0.00154777 | 0.03163265 |
| mmu-miR-151-3p | MIMAT0000161 | 2.14509993 | 4.81E-07 | 2.84E-05 |
| mmu-miR-342-5p | MIMAT0004653 | 1.46630765 | 0.00054634 | 0.0148878 |
| mmu-miR-501-3p | MIMAT0003509 | 1.25242827 | 0.00269666 | 0.04409035 |
| mmu-miR-351-5p | MIMAT0000609 | 1.19771602 | 0.00083547 | 0.01951417 |
| mmu-miR-669c-5p | MIMAT0003479 | 1.11698766 | 0.00290905 | 0.04529805 |

**Table 3-6. Genes significantly up-regulated in BM in microRNA sequencing.**

| Symbol | ID | logFC(BM/NL) | PValue | FDR |
|---|---|---|---|---|
| mmu-let-7b-5p | MIMAT0000522 | 2.21388074 | 5.21E-07 | 2.84E-05 |
| mmu-let-7i-5p | MIMAT0000122 | 1.93697219 | 2.64E-06 | 0.00010794 |
| mmu-miR-10a-5p | MIMAT0000648 | 1.84578606 | 0.00201354 | 0.03873096 |
| mmu-let-7d-3p | MIMAT0000384 | 1.80149758 | 0.00073287 | 0.01843458 |
| mmu-let-7j | MIMAT0025123 | 1.61175209 | 9.34E-05 | 0.00339404 |
| mmu-let-7d-5p | MIMAT0000383 | 1.41642463 | 0.00114008 | 0.02485365 |
| mmu-let-7f-5p | MIMAT0000525_1 | 1.29111824 | 0.00028723 | 0.00939226 |
| mmu-let-7f-5p | MIMAT0000525 | 1.26825499 | 0.00036473 | 0.01084251 |
| mmu-let-7c-5p | MIMAT0000523_1 | 1.25138262 | 0.00236306 | 0.04174791 |

(FDR<= 0.05, $\log_2$FC>1)

## Table 3-7. Genes significantly up-regulated in 3w BM in RNA sequencing.

| Symbol | Ensembl gene id | logFC (3w/Adult) | adj.P.val | Annotation |
|---|---|---|---|---|
| Nespas | ENSMUSG00000086537 | 2.436587158 | 2.33E-63 | neuroendocrine secretory protein antisense [Source:MGI Symbol;Acc:MGI:1861674] |
| Igf2bp3 | ENSMUSG00000029814 | 2.339019277 | 4.21E-57 | insulin-like growth factor 2 mRNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1890359] |
| Ptk7 | ENSMUSG00000023972 | 2.22664764 | 1.02E-06 | PTK7 protein tyrosine kinase 7 [Source:MGI Symbol;Acc:MGI:1918711] |
| Nes | ENSMUSG00000004891 | 2.224500848 | 0.00343001 | nestin [Source:MGI Symbol;Acc:MGI:101784] |
| D130058E05Rik | ENSMUSG00000092627 | 2.062461971 | 0.02673191 | RIKEN cDNA D130058E05 gene [Source:MGI Symbol;Acc:MGI:2444614] |
| Spire1 | ENSMUSG00000024533 | 1.900411859 | 0.01926399 | spire homolog 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:1915416] |
| Ifitm6 | ENSMUSG00000059108 | 1.818667555 | 0.01869941 | interferon induced transmembrane protein 6 [Source:MGI Symbol;Acc:MGI:2686976] |
| Rap1gap2 | ENSMUSG00000038807 | 1.721452749 | 8.28E-27 | RAP1 GTPase activating protein 2 [Source:MGI Symbol;Acc:MGI:3028623] |
| Lcn2 | ENSMUSG00000026822 | 1.5949258 | 0.00031445 | lipocalin 2 [Source:MGI Symbol;Acc:MGI:96757] |
| Afap1l1 | ENSMUSG00000033032 | 1.584314788 | 0.02633531 | actin filament associated protein 1-like 1 [Source:MGI Symbol;Acc:MGI:2147199] |
| Asns | ENSMUSG00000029752 | 1.528761774 | 0.00227801 | asparagine synthetase [Source:MGI Symbol;Acc:MGI:1350929] |
| Plag1 | ENSMUSG00000003282 | 1.518956093 | 3.05E-20 | pleiomorphic adenoma gene 1 [Source:MGI Symbol;Acc:MGI:1891916] |
| Pacsin1 | ENSMUSG00000040276 | 1.47156069 | 0.03266971 | protein kinase C and casein kinase substrate in neurons 1 [Source:MGI Symbol;Acc:MGI:1345181] |
| Cyp27a1 | ENSMUSG00000026170 | 1.43894691 | 0.00034538 | cytochrome P450, family 27, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:88594] |
| Sox13 | ENSMUSG00000070643 | 1.418931413 | 0.01670733 | SRY (sex determining region Y)-box 13 [Source:MGI Symbol;Acc:MGI:98361] |
| Ncs1 | ENSMUSG00000062661 | 1.404204212 | 2.53E-08 | neuronal calcium sensor 1 [Source:MGI Symbol;Acc:MGI:109166] |
| Kit | ENSMUSG00000005672 | 1.404186902 | 2.07E-05 | KIT proto-oncogene receptor tyrosine kinase [Source:MGI Symbol;Acc:MGI:96677] |
| Gimap4 | ENSMUSG00000054435 | 1.402122532 | 1.15E-06 | GTPase, IMAP family member 4 [Source:MGI Symbol;Acc:MGI:1349656] |
| Zfp827 | ENSMUSG00000071064 | 1.392958975 | 3.05E-20 | zinc finger protein 827 [Source:MGI Symbol;Acc:MGI:2444807] |
| Cst7 | ENSMUSG00000068129 | 1.342540886 | 0.00178582 | cystatin F (leukocystatin) [Source:MGI Symbol;Acc:MGI:1298217] |
| Camp | ENSMUSG00000038357 | 1.319337924 | 0.00099686 | cathelicidin antimicrobial peptide [Source:MGI Symbol;Acc:MGI:108443] |
| Fstl1 | ENSMUSG00000022816 | 1.273786408 | 1.40E-10 | follistatin-like 1 [Source:MGI Symbol;Acc:MGI:102793] |
| Arpp21 | ENSMUSG00000032503 | 1.266342867 | 0.00824567 | cyclic AMP-regulated phosphoprotein, 21 [Source:MGI Symbol;Acc:MGI:107562] |
| Cd177 | ENSMUSG00000052212 | 1.248721317 | 0.01190826 | CD177 antigen [Source:MGI Symbol;Acc:MGI:1916141] |
| Socs3 | ENSMUSG00000053113 | 1.236535877 | 2.11E-07 | suppressor of cytokine signaling 3 [Source:MGI Symbol;Acc:MGI:1201791] |
| Gmpr | ENSMUSG00000000253 | 1.213444068 | 8.27E-05 | guanosine monophosphate reductase [Source:MGI Symbol;Acc:MGI:1913605] |
| Sept8 | ENSMUSG00000018398 | 1.182062012 | 0.01545397 | septin 8 [Source:MGI Symbol;Acc:MGI:894310] |
| Ptk2 | ENSMUSG00000022607 | 1.159619041 | 0.00010665 | PTK2 protein tyrosine kinase 2 [Source:MGI Symbol;Acc:MGI:95481] |
| Alpl | ENSMUSG00000028766 | 1.157212715 | 0.00236303 | alkaline phosphatase, liver/bone/kidney [Source:MGI Symbol;Acc:MGI:87983] |
| Egfl7 | ENSMUSG00000026921 | 1.155888582 | 8.14E-08 | EGF-like domain 7 [Source:MGI Symbol;Acc:MGI:2449923] |
| Cyp2j6 | ENSMUSG00000052914 | 1.143955367 | 0.04795442 | cytochrome P450, family 2, subfamily j, polypeptide 6 [Source:MGI Symbol;Acc:MGI:1270148] |
| Ppl | ENSMUSG00000039457 | 1.14149612 | 0.04292238 | periplakin [Source:MGI Symbol;Acc:MGI:1194898] |
| Grb10 | ENSMUSG00000020176 | 1.139938304 | 7.68E-07 | growth factor receptor bound protein 10 [Source:MGI Symbol;Acc:MGI:103232] |
| Stac2 | ENSMUSG00000017400 | 1.101083282 | 2.70E-06 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Tsc22d3 | ENSMUSG00000031431 | 1.077065905 | 0.00554004 | TSC22 domain family, member 3 [Source:MGI Symbol;Acc:MGI:1196284] |
| Emb | ENSMUSG00000021728 | 1.072565666 | 5.19E-07 | embigin [Source:MGI Symbol;Acc:MGI:95321] |
| Eng | ENSMUSG00000026814 | 1.065257272 | 1.62E-09 | endoglin [Source:MGI Symbol;Acc:MGI:95392] |
| Sash1 | ENSMUSG00000015305 | 1.039079854 | 1.40E-05 | SAM and SH3 domain containing 1 [Source:MGI Symbol;Acc:MGI:1917347] |
| Card9 | ENSMUSG00000026928 | 1.017820408 | 8.34E-08 | caspase recruitment domain family, member 9 [Source:MGI Symbol;Acc:MGI:2685628] |

(adj.P value <= 0.05, $\log_2$FC>1)

## Table 3-8. Genes significantly up-regulated in adult(10w) BM in RNA sequencing.

| Symbol | Ensembl gene id | logFC (Adult/3w) | adj.P.val | Annotation |
|---|---|---|---|---|
| Igha | ENSMUSG00000095079 | 3.526274175 | 1.59E-13 | immunoglobulin heavy constant alpha [Source:MGI Symbol;Acc:MGI:96444] |
| H2-Q6 | ENSMUSG00000073409 | 3.24500409 | 1.19E-138 | histocompatibility 2, Q region locus 6 [Source:MGI Symbol;Acc:MGI:95935] |
| Gm18342 | ENSMUSG00000101279 | 3.083160023 | 0.04268624 | predicted gene, 18342 [Source:MGI Symbol;Acc:MGI:5010527] |
| Gm14964 | ENSMUSG00000052188 | 2.916515031 | 0.00699495 | predicted gene 14964 [Source:MGI Symbol;Acc:MGI:3641621] |
| Clnk | ENSMUSG00000039315 | 2.446150411 | 3.72E-05 | cytokine-dependent hematopoietic cell linker [Source:MGI Symbol;Acc:MGI:1351468] |
| Col4a5 | ENSMUSG00000031274 | 2.218916244 | 0.00405943 | collagen, type IV, alpha 5 [Source:MGI Symbol;Acc:MGI:88456] |
| H2-Q7 | ENSMUSG00000060550 | 2.069960132 | 4.01E-140 | histocompatibility 2, Q region locus 7 [Source:MGI Symbol;Acc:MGI:95936] |
| 9630013D21Rik | ENSMUSG00000059027 | 1.902690376 | 1.06E-39 | RIKEN cDNA 9630013D21 gene [Source:MGI Symbol;Acc:MGI:2442649] |
| Map2 | ENSMUSG00000015222 | 1.763216509 | 2.08E-14 | microtubule-associated protein 2 [Source:MGI Symbol;Acc:MGI:97175] |
| Myo18b | ENSMUSG00000072720 | 1.749261689 | 4.04E-07 | myosin XVIIIb [Source:MGI Symbol;Acc:MGI:1921626] |
| Nrxn1 | ENSMUSG00000024109 | 1.649027509 | 6.84E-21 | neurexin I [Source:MGI Symbol;Acc:MGI:1096391] |
| Gm16026 | ENSMUSG00000079455 | 1.57481893 | 1.64E-12 | predicted pseudogene 16026 [Source:MGI Symbol;Acc:MGI:3783243] |
| Egr1 | ENSMUSG00000038418 | 1.50544846 | 1.21E-12 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Jchain | ENSMUSG00000067149 | 1.471890764 | 0.00010335 | immunoglobulin joining chain [Source:MGI Symbol;Acc:MGI:96493] |
| Gbp6 | ENSMUSG00000104713 | 1.464530939 | 3.43E-07 | guanylate binding protein 6 [Source:MGI Symbol;Acc:MGI:2140937] |
| Aldh1l1 | ENSMUSG00000030088 | 1.399195651 | 0.00720672 | aldehyde dehydrogenase 1 family, member L1 [Source:MGI Symbol;Acc:MGI:1340024] |
| Klra1 | ENSMUSG00000079853 | 1.399176956 | 0.00039541 | killer cell lectin-like receptor, subfamily A, member 1 [Source:MGI Symbol;Acc:MGI:101907] |
| Ppp1r36 | ENSMUSG00000052221 | 1.334642735 | 1.61E-06 | protein phosphatase 1, regulatory subunit 36 [Source:MGI Symbol;Acc:MGI:2684916] |
| Igkv9-123 | ENSMUSG00000076512 | 1.306039769 | 0.01403839 | immunoglobulin kappa variable 9-123 [Source:MGI Symbol;Acc:MGI:3643848] |
| Gm16094 | ENSMUSG00000090103 | 1.305665536 | 1.96E-16 | predicted gene 16094 [Source:MGI Symbol;Acc:MGI:3801967] |
| A530032D15Rik | ENSMUSG00000089844 | 1.262077822 | 4.33E-21 | RIKEN cDNA A530032D15Rik gene [Source:MGI Symbol;Acc:MGI:3037746] |
| Igkv9-124 | ENSMUSG00000096632 | 1.185455873 | 3.95E-07 | immunoglobulin kappa chain variable 9-124 [Source:MGI Symbol;Acc:MGI:3646892] |
| A530040E14Rik | ENSMUSG00000072109 | 1.154259946 | 1.07E-33 | RIKEN cDNA A530040E14 gene [Source:MGI Symbol;Acc:MGI:3612703] |
| Agbl1 | ENSMUSG00000025754 | 1.1098123 | 0.02505297 | ATP/GTP binding protein-like 1 [Source:MGI Symbol;Acc:MGI:3646469] |
| S1pr3 | ENSMUSG00000067586 | 1.099425003 | 5.75E-09 | sphingosine-1-phosphate receptor 3 [Source:MGI Symbol;Acc:MGI:1339365] |
| Eya1 | ENSMUSG00000025932 | 1.021463704 | 7.74E-08 | EYA transcriptional coactivator and phosphatase 1 [Source:MGI Symbol;Acc:MGI:109344] |
| Gm6377 | ENSMUSG00000048621 | 1.019504297 | 0.00025857 | predicted gene 6377 [Source:MGI Symbol;Acc:MGI:3647255] |
| C130026I21Rik | ENSMUSG00000052477 | 1.00503635 | 3.14E-12 | RIKEN cDNA C130026I21 gene [Source:MGI Symbol;Acc:MGI:3612702] |

(adj.P value <= 0.05, $\log_2$FC>1)

## Table 6-1. Genes significantly up-regulated in immature B cell subsets in IgLin28bBM compared to IgBM.

| Symbol | Ensembl gene id | logFC (IgLin28bBM /IgBM) | adj.P.val | Annotation |
|---|---|---|---|---|
| Lin28b | ENSMUSG00000063804 | 10.8814619 | 9.06E-209 | lin-28 homolog B (C. elegans) [Source:MGI Symbol;Acc:MGI:3584032] |
| Mid1-ps1 | ENSMUSG00000095134 | 4.36971633 | 0.000693444 | midline 1, pseudogene 1 [Source:MGI Symbol;Acc:MGI:5780070] |
| Ighg2c | ENSMUSG00000076612 | 4.18638095 | 0.012885697 | immunoglobulin heavy constant gamma 2C [Source:MGI Symbol;Acc:MGI:2686979] |
| Ighg3 | ENSMUSG00000076615 | 2.7264152 | 0.006011187 | Immunoglobulin heavy constant gamma 3 [Source:MGI Symbol;Acc:MGI:2144790] |
| Klrb1c | ENSMUSG00000030325 | 2.04665604 | 0.043010202 | killer cell lectin-like receptor subfamily B member 1C [Source:MGI Symbol;Acc:MGI:107538] |
| Plaur | ENSMUSG00000046223 | 1.89702868 | 0.001923759 | plasminogen activator, urokinase receptor [Source:MGI Symbol;Acc:MGI:97612] |
| Gm7967 | ENSMUSG00000100009 | 1.88412846 | 0.006342556 | predicted gene 7967 [Source:MGI Symbol;Acc:MGI:3644984] |
| Ackr2 | ENSMUSG00000044534 | 1.87893442 | 0.002147506 | atypical chemokine receptor 2 [Source:MGI Symbol;Acc:MGI:1891697] |
| Sspn | ENSMUSG00000030255 | 1.74129592 | 0.038065383 | sarcospan [Source:MGI Symbol;Acc:MGI:1353511] |
| Bhlhe41 | ENSMUSG00000030256 | 1.74110033 | 3.63E-05 | basic helix-loop-helix family, member e41 [Source:MGI Symbol;Acc:MGI:1930704] |
| Plag1 | ENSMUSG00000003282 | 1.6213185 | 0.039047894 | pleiomorphic adenoma gene 1 [Source:MGI Symbol;Acc:MGI:1891916] |
| Lst1 | ENSMUSG00000073412 | 1.36880488 | 0.01168666 | leukocyte specific transcript 1 [Source:MGI Symbol;Acc:MGI:1096324] |
| Lrrc32 | ENSMUSG00000090958 | 1.34370965 | 0.031420339 | leucine rich repeat containing 32 [Source:MGI Symbol;Acc:MGI:93882] |
| Igf2bp3 | ENSMUSG00000029814 | 1.31267525 | 8.84E-09 | insulin-like growth factor 2 mRNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1890359] |
| Gimap4 | ENSMUSG00000054435 | 1.25264393 | 0.012885697 | GTPase, IMAP family member 4 [Source:MGI Symbol;Acc:MGI:1349656] |
| Gm11690 | ENSMUSG00000085844 | 1.24956907 | 0.002366342 | predicted gene 11690 [Source:MGI Symbol;Acc:MGI:3652329] |
| Stac2 | ENSMUSG00000017400 | 1.19453355 | 0.000281052 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Cacna1i | ENSMUSG00000022416 | 1.10975409 | 8.08E-06 | calcium channel, voltage-dependent, alpha 1I subunit [Source:MGI Symbol;Acc:MGI:2178051] |
| Camkk1 | ENSMUSG00000020785 | 1.05569445 | 0.002366342 | calcium/calmodulin-dependent protein kinase kinase 1, alpha [Source:MGI Symbol;Acc:MGI:1891766] |
| Ccr6 | ENSMUSG00000040899 | 0.99662729 | 0.008048072 | chemokine (C-C motif) receptor 6 [Source:MGI Symbol;Acc:MGI:1333797] |
| March | ENSMUSG00000036469 | 0.96011721 | 0.044067659 | membrane-associated ring finger (C3HC4) 1 [Source:MGI Symbol;Acc:MGI:1920175] |
| F730311O21Rik | ENSMUSG00000100658 | 0.94306501 | 0.008057094 | RIKEN cDNA F730311O21 gene [Source:MGI Symbol;Acc:MGI:3643355] |
| Itgb7 | ENSMUSG00000001281 | 0.93181046 | 0.022302435 | integrin beta 7 [Source:MGI Symbol;Acc:MGI:96616] |
| Ltb | ENSMUSG00000024399 | 0.90187021 | 3.63E-05 | lymphotoxin B [Source:MGI Symbol;Acc:MGI:104796] |
| Myo15b | ENSMUSG00000034427 | 0.89849638 | 0.03212056 | myosin XVB [Source:MGI Symbol;Acc:MGI:2685534] |
| Arid3a | ENSMUSG00000019564 | 0.88607328 | 3.78E-08 | AT rich interactive domain 3A (BRIGHT-like) [Source:MGI Symbol;Acc:MGI:1328360] |
| Dnah17 | ENSMUSG00000033987 | 0.87769908 | 0.012738112 | dynein, axonemal, heavy chain 17 [Source:MGI Symbol;Acc:MGI:1917176] |
| Slamf1 | ENSMUSG00000015316 | 0.83750937 | 0.006813422 | signaling lymphocytic activation molecule family member 1 [Source:MGI Symbol;Acc:MGI:1351314] |
| Cd55 | ENSMUSG00000026399 | 0.79680952 | 0.003155697 | CD55 molecule, decay accelerating factor for complement [Source:MGI Symbol;Acc:MGI:104850] |
| Gimap3 | ENSMUSG00000039264 | 0.78824195 | 0.014992757 | GTPase, IMAP family member 3 [Source:MGI Symbol;Acc:MGI:1932723] |
| Klf3 | ENSMUSG00000029178 | 0.73665563 | 0.026155613 | Kruppel-like factor 3 (basic) [Source:MGI Symbol;Acc:MGI:1342773] |
| Nlrc4 | ENSMUSG00000039193 | 0.65809821 | 0.044236989 | NLR family, CARD domain containing 4 [Source:MGI Symbol;Acc:MGI:3036243] |
| Pitpnm2 | ENSMUSG00000029406 | 0.58306745 | 0.01617326 | phosphatidylinositol transfer protein, membrane-associated 2 [Source:MGI Symbol;Acc:MGI:1336192] |
| Pik3c2b | ENSMUSG00000026447 | 0.54233717 | 0.014992757 | phosphatidylinositol-4-phosphate 3-kinase catalytic subunit type 2 beta [Source:MGI Symbol;Acc:MGI:2685045] |
| Myo1g | ENSMUSG00000020437 | 0.53915018 | 0.003059195 | myosin IG [Source:MGI Symbol;Acc:MGI:1927091] |
| Arid3b | ENSMUSG00000004661 | 0.46269743 | 0.024558456 | AT rich interactive domain 3B (BRIGHT-like) [Source:MGI Symbol;Acc:MGI:1930768] |
| Pde4c | ENSMUSG00000031842 | 0.45424974 | 0.042639195 | phosphodiesterase 4C, cAMP specific [Source:MGI Symbol;Acc:MGI:99556] |
| Rassf2 | ENSMUSG00000027339 | 0.4536109 | 0.035968066 | Ras association (RalGDS/AF-6) domain family member 2 [Source:MGI Symbol;Acc:MGI:2442060] |
| Pou2f2 | ENSMUSG00000008496 | 0.43077013 | 0.001719839 | POU domain, class 2, transcription factor 2 [Source:MGI Symbol;Acc:MGI:101897] |

(adj.P value <= 0.05)

**Table 6-2. Genes significantly up-regulated in immature B cell subsets in IgBM compare to IgLin28bBM.**

| Symbol | Ensembl gene id | logFC (IgBM/ IgLin28bBM) | adj.P.val | Annotation |
|---|---|---|---|---|
| Tmc5 | ENSMUSG00000030650 | 1.26502506 | 0.049005656 | transmembrane channel-like gene family 5 [Source:MGI Symbol;Acc:MGI:1921674] |
| Igkv9-124 | ENSMUSG00000096632 | 1.19676568 | 0.000281052 | immunoglobulin kappa chain variable 9-124 [Source:MGI Symbol;Acc:MGI:3646892] |
| Ndrg1 | ENSMUSG00000005125 | 1.12334694 | 0.004717726 | N-myc downstream regulated gene 1 [Source:MGI Symbol;Acc:MGI:1341799] |
| Tmc7 | ENSMUSG00000042246 | 1.0866157 | 0.048368257 | transmembrane channel-like gene family 7 [Source:MGI Symbol;Acc:MGI:2443317] |
| Rgs10 | ENSMUSG00000030844 | 1.07214454 | 0.01122072 | regulator of G-protein signalling 10 [Source:MGI Symbol;Acc:MGI:1915115] |
| Car3 | ENSMUSG00000027559 | 0.98844367 | 0.03212056 | carbonic anhydrase 3 [Source:MGI Symbol;Acc:MGI:88270] |
| Vpreb1 | ENSMUSG00000059305 | 0.92558502 | 0.000171587 | pre-B lymphocyte gene 1 [Source:MGI Symbol;Acc:MGI:98936] |
| Sit1 | ENSMUSG00000028460 | 0.9200784 | 0.0000645 | suppression inducing transmembrane adaptor 1 [Source:MGI Symbol;Acc:MGI:1889342] |
| Hmgcll1 | ENSMUSG00000007908 | 0.90255346 | 0.033717501 | 3-hydroxymethyl-3-methylglutaryl-Coenzyme A lyase-like 1 [Source:MGI Symbol;Acc:MGI:2446108] |
| Slamf9 | ENSMUSG00000026548 | 0.89572784 | 0.000206628 | SLAM family member 9 [Source:MGI Symbol;Acc:MGI:1923692] |
| Eya1 | ENSMUSG00000025932 | 0.89477543 | 0.045228242 | EYA transcriptional coactivator and phosphatase 1 [Source:MGI Symbol;Acc:MGI:109344] |
| Kif19a | ENSMUSG00000010021 | 0.89114094 | 0.001686333 | kinesin family member 19A [Source:MGI Symbol;Acc:MGI:2447024] |
| Lmcd1 | ENSMUSG00000057604 | 0.8702877 | 0.035968066 | LIM and cysteine-rich domains 1 [Source:MGI Symbol;Acc:MGI:1353635] |
| Tsc22d1 | ENSMUSG00000022010 | 0.855968 | 0.044236989 | TSC22 domain family, member 1 [Source:MGI Symbol;Acc:MGI:109127] |
| Tmem98 | ENSMUSG00000035413 | 0.84801926 | 0.004107469 | transmembrane protein 98 [Source:MGI Symbol;Acc:MGI:1923457] |
| Pla2g12a | ENSMUSG00000027999 | 0.83996839 | 0.048368257 | phospholipase A2, group XIIA [Source:MGI Symbol;Acc:MGI:1913600] |
| AW112010 | ENSMUSG00000075010 | 0.82219683 | 0.001686333 | expressed sequence AW112010 [Source:MGI Symbol;Acc:MGI:2147706] |
| Il2ra | ENSMUSG00000026770 | 0.79401634 | 0.000288467 | interleukin 2 receptor, alpha chain [Source:MGI Symbol;Acc:MGI:96549] |
| Sulf2 | ENSMUSG00000006800 | 0.77214462 | 0.027092492 | sulfatase 2 [Source:MGI Symbol;Acc:MGI:1919293] |
| Slc25a20 | ENSMUSG00000032602 | 0.74682927 | 0.031420339 | solute carrier family 25 (mitochondrial carnitine/acylcarnitine translocase), member 20 [Source:MGI Symbol;Acc:MGI:1928738] |
| Uchl1 | ENSMUSG00000029223 | 0.73540904 | 0.01680708 | ubiquitin carboxy-terminal hydrolase L1 [Source:MGI Symbol;Acc:MGI:103149] |
| Srgap3 | ENSMUSG00000030257 | 0.73511897 | 0.018087175 | SLIT-ROBO Rho GTPase activating protein 3 [Source:MGI Symbol;Acc:MGI:2152938] |
| Car2 | ENSMUSG00000027562 | 0.72549542 | 0.002749001 | carbonic anhydrase 2 [Source:MGI Symbol;Acc:MGI:88269] |
| Grn | ENSMUSG00000034708 | 0.72413413 | 0.0000117 | granulin [Source:MGI Symbol;Acc:MGI:95832] |
| Igll1 | ENSMUSG00000075370 | 0.69287166 | 0.001686333 | immunoglobulin lambda-like polypeptide 1 [Source:MGI Symbol;Acc:MGI:96529] |
| S1pr3 | ENSMUSG00000067586 | 0.69072078 | 0.002634113 | sphingosine-1-phosphate receptor 3 [Source:MGI Symbol;Acc:MGI:1339365] |
| Tnnt2 | ENSMUSG00000026414 | 0.67215407 | 0.024306062 | troponin T2, cardiac [Source:MGI Symbol;Acc:MGI:104597] |
| Klf4 | ENSMUSG00000003032 | 0.66682692 | 0.026155613 | Kruppel-like factor 4 (gut) [Source:MGI Symbol;Acc:MGI:1342287] |
| Coq7 | ENSMUSG00000030652 | 0.66365493 | 0.031420339 | demethyl-Q 7 [Source:MGI Symbol;Acc:MGI:107207] |
| Cacna1h | ENSMUSG00000024112 | 0.65629335 | 0.003029914 | calcium channel, voltage-dependent, T type, alpha 1H subunit [Source:MGI Symbol;Acc:MGI:1928842] |
| Amigo1 | ENSMUSG00000050947 | 0.64559226 | 0.000638456 | adhesion molecule with Ig like domain 1 [Source:MGI Symbol;Acc:MGI:2653612] |
| Pla2g16 | ENSMUSG00000060675 | 0.62319097 | 0.038065383 | phospholipase A2, group XVI [Source:MGI Symbol;Acc:MGI:2179715] |
| Cplx2 | ENSMUSG00000025867 | 0.60194526 | 0.047675584 | complexin 2 [Source:MGI Symbol;Acc:MGI:104726] |
| Pfn2 | ENSMUSG00000027805 | 0.58115942 | 0.01617326 | profilin 2 [Source:MGI Symbol;Acc:MGI:97550] |
| Zdhhc14 | ENSMUSG00000034265 | 0.57418717 | 0.002633454 | zinc finger, DHHC domain containing 14 [Source:MGI Symbol;Acc:MGI:2653229] |
| Slc12a3 | ENSMUSG00000031766 | 0.52121902 | 0.043010202 | solute carrier family 12, member 3 [Source:MGI Symbol;Acc:MGI:108114] |
| Sapcd1 | ENSMUSG00000036185 | 0.51313784 | 0.038065383 | suppressor APC domain containing 1 [Source:MGI Symbol;Acc:MGI:2388100] |
| Zhx2 | ENSMUSG00000071757 | 0.45713852 | 0.049005656 | zinc fingers and homeoboxes 2 [Source:MGI Symbol;Acc:MGI:2683087] |
| Zfp219 | ENSMUSG00000049295 | 0.45477039 | 0.031420339 | zinc finger protein 219 [Source:MGI Symbol;Acc:MGI:1917140] |
| Epb41l4b | ENSMUSG00000028434 | 0.44222143 | 0.007913415 | erythrocyte membrane protein band 4.1 like 4b [Source:MGI Symbol;Acc:MGI:1859149] |
| Spns3 | ENSMUSG00000020798 | 0.43540247 | 0.031420339 | spinster homolog 3 [Source:MGI Symbol;Acc:MGI:1924827] |
| Zkscan17 | ENSMUSG00000020472 | 0.41615245 | 0.02261991 | zinc finger with KRAB and SCAN domains 17 [Source:MGI Symbol;Acc:MGI:2679270] |

(adj.P value <= 0.05)

**Table 6-3. Genes significantly up-regulated in immature B cell subsets in IgNL treated with sHEL compare to IgBM treated with sHEL.**

| Symbol | Ensembl gene id | logFC (NL-sHEL/BM-sHEL) | adj.P.val | Annotation |
|---|---|---|---|---|
| Ccr6 | ENSMUSG00000040899 | 10.81240706 | 4.52632E-44 | chemokine (C-C motif) receptor 6 [Source:MGI Symbol;Acc:MGI:1333797] |
| Ebi3 | ENSMUSG00000003206 | 8.63115647 | 3.50985E-26 | Epstein-Barr virus induced gene 3 [Source:MGI Symbol;Acc:MGI:1354171] |
| Dusp5 | ENSMUSG00000034765 | 2.035824828 | 6.80925E-20 | dual specificity phosphatase 5 [Source:MGI Symbol;Acc:MGI:2685183] |
| Irf7 | ENSMUSG00000025498 | 3.043920559 | 1.60192E-14 | interferon regulatory factor 7 [Source:MGI Symbol;Acc:MGI:1859212] |
| Maged1 | ENSMUSG00000025151 | 6.472627889 | 4.25159E-14 | melanoma antigen, family D, 1 [Source:MGI Symbol;Acc:MGI:1930187] |
| Slc25a20 | ENSMUSG00000032602 | 1.818251027 | 1.35348E-13 | solute carrier family 25 (mitochondrial carnitine/acylcarnitine translocase), member 20 [Source:MGI Symbol;Acc:MGI:1928738] |
| Ifit2 | ENSMUSG00000045932 | 3.448534907 | 2.12557E-13 | interferon-induced protein with tetratricopeptide repeats 2 [Source:MGI Symbol;Acc:MGI:99449] |
| Dok2 | ENSMUSG00000022102 | 8.235383013 | 2.33629E-13 | docking protein 2 [Source:MGI Symbol;Acc:MGI:1332623] |
| Rnaset2a | ENSMUSG00000095687 | 1.120153492 | 2.8652E-13 | ribonuclease T2A [Source:MGI Symbol;Acc:MGI:1915445] |
| Rpn1 | ENSMUSG00000030062 | 1.094111043 | 3.81482E-11 | ribophorin I [Source:MGI Symbol;Acc:MGI:98084] |
| Sp110 | ENSMUSG00000070034 | 1.352662534 | 1.74646E-10 | Sp110 nuclear body protein [Source:MGI Symbol;Acc:MGI:1923364] |
| Crem | ENSMUSG00000063889 | 1.803334073 | 2.2548E-10 | cAMP responsive element modulator [Source:MGI Symbol;Acc:MGI:88495] |
| Hspa5 | ENSMUSG00000026864 | 1.419082848 | 2.41104E-10 | heat shock protein 5 [Source:MGI Symbol;Acc:MGI:95835] |
| Usp18 | ENSMUSG00000030107 | 2.825234237 | 1.38896E-09 | ubiquitin specific peptidase 18 [Source:MGI Symbol;Acc:MGI:1344364] |
| Pnpt1 | ENSMUSG00000020464 | 1.062881363 | 3.48051E-09 | polyribonucleotide nucleotidyltransferase 1 [Source:MGI Symbol;Acc:MGI:1918951] |
| Lgals3bp | ENSMUSG00000033880 | 2.771702398 | 3.61895E-09 | lectin, galactoside-binding, soluble, 3 binding protein [Source:MGI Symbol;Acc:MGI:99554] |
| Evi2a | ENSMUSG00000078771 | 1.781597686 | 6.77506E-09 | ecotropic viral integration site 2a [Source:MGI Symbol;Acc:MGI:95458] |
| Cybb | ENSMUSG00000015340 | 2.47400389 | 8.14925E-09 | cytochrome b-245, beta polypeptide [Source:MGI Symbol;Acc:MGI:88574] |
| Ncf1 | ENSMUSG00000015950 | 1.48811518 | 1.00041E-08 | neutrophil cytosolic factor 1 [Source:MGI Symbol;Acc:MGI:97283] |
| Bst2 | ENSMUSG00000046718 | 1.946523829 | 1.3598E-08 | bone marrow stromal cell antigen 2 [Source:MGI Symbol;Acc:MGI:1916800] |
| Irgm1 | ENSMUSG00000046879 | 1.68025022 | 2.20435E-08 | immunity-related GTPase family M member 1 [Source:MGI Symbol;Acc:MGI:107567] |
| Mrps6 | ENSMUSG00000039680 | 1.336866929 | 3.12384E-08 | mitochondrial ribosomal protein S6 [Source:MGI Symbol;Acc:MGI:2153111] |
| Pmaip1 | ENSMUSG00000024521 | 2.460146761 | 3.44255E-08 | phorbol-12-myristate-13-acetate-induced protein 1 [Source:MGI Symbol;Acc:MGI:1930146] |
| Uck2 | ENSMUSG00000026558 | 1.652908752 | 7.35706E-08 | uridine-cytidine kinase 2 [Source:MGI Symbol;Acc:MGI:1931744] |
| Cd5 | ENSMUSG00000024669 | 2.786800199 | 9.73887E-08 | CD5 antigen [Source:MGI Symbol;Acc:MGI:88340] |
| Slfn2 | ENSMUSG00000072620 | 1.350628978 | 9.98859E-08 | schlafen 2 [Source:MGI Symbol;Acc:MGI:1313258] |
| Tor1aip2 | ENSMUSG00000050565 | 1.063761137 | 1.02934E-07 | torsin A interacting protein 2 [Source:MGI Symbol;Acc:MGI:3582695] |
| Rps4l | ENSMUSG00000063171 | 1.929638981 | 1.15475E-07 | ribosomal protein S4-like [Source:MGI Symbol;Acc:MGI:1913434] |
| Rilpl2 | ENSMUSG00000029401 | 1.446841589 | 1.37895E-07 | Rab interacting lysosomal protein-like 2 [Source:MGI Symbol;Acc:MGI:1933112] |
| Igtp | ENSMUSG00000078853 | 1.958657726 | 3.88462E-07 | interferon gamma induced GTPase [Source:MGI Symbol;Acc:MGI:107729] |
| Tma16 | ENSMUSG00000025591 | 1.382372166 | 4.80433E-07 | translation machinery associated 16 [Source:MGI Symbol;Acc:MGI:1913532] |
| Slc15a3 | ENSMUSG00000024737 | 2.235107169 | 5.84484E-07 | solute carrier family 15, member 3 [Source:MGI Symbol;Acc:MGI:1929691] |
| Mitd1 | ENSMUSG00000026088 | 1.400380168 | 6.05501E-07 | MIT, microtubule interacting and transport, domain containing 1 [Source:MGI Symbol;Acc:MGI:1916278] |
| Sparc | ENSMUSG00000018593 | 4.757287166 | 6.50556E-07 | secreted acidic cysteine rich glycoprotein [Source:MGI Symbol;Acc:MGI:98373] |
| Ifitm3 | ENSMUSG00000025492 | 3.912164899 | 6.81336E-07 | interferon induced transmembrane protein 3 [Source:MGI Symbol;Acc:MGI:1913391] |
| Adar | ENSMUSG00000027951 | 1.38015735 | 9.4636E-07 | adenosine deaminase, RNA-specific [Source:MGI Symbol;Acc:MGI:1889575] |
| Trim30d | ENSMUSG00000057596 | 3.061168326 | 1.02085E-06 | tripartite motif-containing 30D [Source:MGI Symbol;Acc:MGI:3035181] |
| Bysl | ENSMUSG00000023988 | 1.337958441 | 1.06162E-06 | bystin-like [Source:MGI Symbol;Acc:MGI:1858419] |
| Syngr2 | ENSMUSG00000048277 | 1.415808418 | 1.57017E-06 | synaptogyrin 2 [Source:MGI Symbol;Acc:MGI:1328324] |
| Rtp4 | ENSMUSG00000033355 | 3.082460622 | 1.68904E-06 | receptor transporter protein 4 [Source:MGI Symbol;Acc:MGI:1915025] |
| Gm1966 | ENSMUSG00000073902 | 2.042925189 | 1.92535E-06 | predicted gene 1966 [Source:MGI Symbol;Acc:MGI:3584360] |
| Dsel | ENSMUSG00000038702 | 7.622419516 | 2.06946E-06 | dermatan sulfate epimerase-like [Source:MGI Symbol;Acc:MGI:2442948] |
| Arhgap39 | ENSMUSG00000033697 | 1.734303725 | 2.25025E-06 | Rho GTPase activating protein 39 [Source:MGI Symbol;Acc:MGI:107858] |
| Stat3 | ENSMUSG00000004040 | 1.044272791 | 2.36518E-06 | signal transducer and activator of transcription 3 [Source:MGI Symbol;Acc:MGI:103038] |
| Cd86 | ENSMUSG00000022901 | 1.750836134 | 2.37481E-06 | CD86 antigen [Source:MGI Symbol;Acc:MGI:101773] |
| H2-T24 | ENSMUSG00000053835 | 1.304594186 | 2.70418E-06 | histocompatibility 2, T region locus 24 [Source:MGI Symbol;Acc:MGI:95958] |
| Nsun5 | ENSMUSG00000000916 | 1.167249274 | 3.5971E-06 | NOL1/NOP2/Sun domain family, member 5 [Source:MGI Symbol;Acc:MGI:2140844] |
| Fam46c | ENSMUSG00000044468 | 2.400804356 | 3.73403E-06 | family with sequence similarity 46, member C [Source:MGI Symbol;Acc:MGI:1921895] |
| Apobec2 | ENSMUSG00000040694 | 7.138455168 | 4.93875E-06 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide 2 [Source:MGI Symbol;Acc:MGI:1343178] |
| Mpeg1 | ENSMUSG00000046805 | 3.06574148 | 5.13668E-06 | macrophage expressed gene 1 [Source:MGI Symbol;Acc:MGI:1333743] |
| Acoxl | ENSMUSG00000027380 | 5.794934588 | 6.01748E-06 | acyl-Coenzyme A oxidase-like [Source:MGI Symbol;Acc:MGI:1921371] |
| Slc25a22 | ENSMUSG00000019082 | 1.510038032 | 6.36014E-06 | solute carrier family 25 (mitochondrial carrier, glutamate), member 22 [Source:MGI Symbol;Acc:MGI:1915517] |
| Srm | ENSMUSG00000006442 | 2.015801369 | 8.06488E-06 | spermidine synthase [Source:MGI Symbol;Acc:MGI:102690] |
| Nop58 | ENSMUSG00000026020 | 1.341414769 | 8.13313E-06 | NOP58 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1933184] |
| Gm26637 | ENSMUSG00000097567 | 1.875920295 | 8.28988E-06 | predicted gene, 26637 [Source:MGI Symbol;Acc:MGI:5477131] |
| Sdf2l1 | ENSMUSG00000022769 | 1.306637776 | 9.37744E-06 | stromal cell-derived factor 2-like 1 [Source:MGI Symbol;Acc:MGI:2149842] |
| Gpr65 | ENSMUSG00000021886 | 1.979950721 | 9.81508E-06 | G-protein coupled receptor 65 [Source:MGI Symbol;Acc:MGI:108031] |
| Isg15 | ENSMUSG00000035692 | 3.014501531 | 1.10053E-05 | ISG15 ubiquitin-like modifier [Source:MGI Symbol;Acc:MGI:1855694] |
| Rem2 | ENSMUSG00000022176 | 3.022838393 | 1.25672E-05 | rad and gem related GTP binding protein 2 [Source:MGI Symbol;Acc:MGI:2155260] |
| Gm16062 | ENSMUSG00000087249 | 2.146526161 | 1.39759E-05 | predicted gene 16062 [Source:MGI Symbol;Acc:MGI:3802162] |
| Rsad2 | ENSMUSG00000020641 | 4.263336508 | 1.41136E-05 | radical S-adenosyl methionine domain containing 2 [Source:MGI Symbol;Acc:MGI:1929628] |
| Mx1 | ENSMUSG00000000386 | 2.99105908 | 1.44539E-05 | MX dynamin-like GTPase 1 [Source:MGI Symbol;Acc:MGI:97243] |
| Igf2bp3 | ENSMUSG00000029814 | 4.686961154 | 1.47944E-05 | insulin-like growth factor 2 mRNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1890359] |
| Samsn1 | ENSMUSG00000022876 | 1.658031229 | 1.56149E-05 | SAM domain, SH3 domain and nuclear localization signals, 1 [Source:MGI Symbol;Acc:MGI:1914992] |
| Prdx6 | ENSMUSG00000026701 | 1.225000674 | 1.56149E-05 | peroxiredoxin 6 [Source:MGI Symbol;Acc:MGI:894320] |
| Gspt1 | ENSMUSG00000062203 | 1.054353908 | 1.75652E-05 | G1 to S phase transition 1 [Source:MGI Symbol;Acc:MGI:1316728] |
| Hspa8 | ENSMUSG00000015656 | 1.666002676 | 1.76187E-05 | heat shock protein 8 [Source:MGI Symbol;Acc:MGI:105384] |
| Gm5431 | ENSMUSG00000058163 | 4.056855113 | 1.77588E-05 | predicted gene 5431 [Source:MGI Symbol;Acc:MGI:3645205] |
| Setdb2 | ENSMUSG00000071350 | 1.289291279 | 1.94122E-05 | SET domain, bifurcated 2 [Source:MGI Symbol;Acc:MGI:2685139] |

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|---|---|---|---|---|
| Bmyc | ENSMUSG00000049086 | 1.575291384 | 2.14829E-05 | brain expressed myelocytomatosis oncogene [Source:MGI Symbol;Acc:MGI:88184] |
| Hk2 | ENSMUSG00000000628 | 2.356116056 | 2.38885E-05 | hexokinase 2 [Source:MGI Symbol;Acc:MGI:1315197] |
| Tmem51 | ENSMUSG00000040616 | 2.697942867 | 2.50201E-05 | transmembrane protein 51 [Source:MGI Symbol;Acc:MGI:2384874] |
| Tsen54 | ENSMUSG00000020781 | 1.2338696 | 2.66591E-05 | tRNA splicing endonuclease subunit 54 [Source:MGI Symbol;Acc:MGI:1923515] |
| Stat1 | ENSMUSG00000026104 | 1.616040531 | 2.69568E-05 | signal transducer and activator of transcription 1 [Source:MGI Symbol;Acc:MGI:103063] |
| Parp14 | ENSMUSG00000034422 | 1.619430807 | 3.02728E-05 | poly (ADP-ribose) polymerase family, member 14 [Source:MGI Symbol;Acc:MGI:1919489] |
| Pgam1 | ENSMUSG00000011752 | 1.272513191 | 4.04201E-05 | phosphoglycerate mutase 1 [Source:MGI Symbol;Acc:MGI:97552] |
| Map2k1 | ENSMUSG00000004936 | 1.061973523 | 4.04201E-05 | mitogen-activated protein kinase kinase 1 [Source:MGI Symbol;Acc:MGI:1346866] |
| C230085N15Rik | ENSMUSG00000102212 | 1.379094867 | 4.7612E-05 | RIKEN cDNA C230085N15 gene [Source:MGI Symbol;Acc:MGI:2444267] |
| Rrs1 | ENSMUSG00000061024 | 1.438392033 | 4.79394E-05 | ribosome biogenesis regulator 1 [Source:MGI Symbol;Acc:MGI:1929721] |
| Mx2 | ENSMUSG00000023341 | 2.243736764 | 4.83234E-05 | MX dynamin-like GTPase 2 [Source:MGI Symbol;Acc:MGI:97244] |
| 1600014C10Rik | ENSMUSG00000054676 | 1.163800313 | 5.18582E-05 | RIKEN cDNA 1600014C10 gene [Source:MGI Symbol;Acc:MGI:1919494] |
| Zmynd8 | ENSMUSG00000039671 | 1.148160896 | 5.44344E-05 | zinc finger, MYND-type containing 8 [Source:MGI Symbol;Acc:MGI:1918025] |
| Matk | ENSMUSG00000004933 | 2.165867524 | 5.50213E-05 | megakaryocyte-associated tyrosine kinase [Source:MGI Symbol;Acc:MGI:99259] |
| Trim30a | ENSMUSG00000030921 | 2.220640143 | 5.82541E-05 | tripartite motif-containing 30A [Source:MGI Symbol;Acc:MGI:98178] |
| Cd83 | ENSMUSG00000015396 | 1.596095279 | 6.22696E-05 | CD83 antigen [Source:MGI Symbol;Acc:MGI:1328316] |
| Fam136a | ENSMUSG00000057497 | 1.215937592 | 7.94823E-05 | family with sequence similarity 136, member A [Source:MGI Symbol;Acc:MGI:1913738] |
| Nhp2 | ENSMUSG00000001056 | 1.388521731 | 9.87212E-05 | NHP2 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1098547] |
| Ifi213 | ENSMUSG00000073491 | 2.138412036 | 0.000101966 | interferon activated gene 213 [Source:MGI Symbol;Acc:MGI:3695276] |
| Dkc1 | ENSMUSG00000031403 | 1.346726889 | 0.000109516 | dyskeratosis congenita 1, dyskerin [Source:MGI Symbol;Acc:MGI:1861727] |
| Ifi35 | ENSMUSG00000010358 | 1.529405952 | 0.00011569 | interferon-induced protein 35 [Source:MGI Symbol;Acc:MGI:1917360] |
| Fabp1 | ENSMUSG00000054422 | 6.717921835 | 0.000119923 | fatty acid binding protein 1, liver [Source:MGI Symbol;Acc:MGI:95479] |
| Nop16 | ENSMUSG00000025869 | 1.48693174 | 0.000163445 | NOP16 nucleolar protein [Source:MGI Symbol;Acc:MGI:107862] |
| Cmpk2 | ENSMUSG00000020638 | 2.338899726 | 0.000187852 | cytidine monophosphate (UMP-CMP) kinase 2, mitochondrial [Source:MGI Symbol;Acc:MGI:99830] |
| Xaf1 | ENSMUSG00000040483 | 1.733732284 | 0.000192062 | XIAP associated factor 1 [Source:MGI Symbol;Acc:MGI:3772572] |
| Ifit3 | ENSMUSG00000074896 | 4.377779034 | 0.000192979 | interferon-induced protein with tetratricopeptide repeats 3 [Source:MGI Symbol;Acc:MGI:1101055] |
| Nolc1 | ENSMUSG00000015176 | 1.514010759 | 0.000197128 | nucleolar and coiled-body phosphoprotein 1 [Source:MGI Symbol;Acc:MGI:1918019] |
| Rsl1d1 | ENSMUSG00000005846 | 1.102786396 | 0.000220933 | ribosomal L1 domain containing 1 [Source:MGI Symbol;Acc:MGI:1913659] |
| Ppa1 | ENSMUSG00000020089 | 2.04292311 | 0.000232055 | pyrophosphatase (inorganic) 1 [Source:MGI Symbol;Acc:MGI:97831] |
| Tpst1 | ENSMUSG00000034118 | 1.053622985 | 0.000240383 | protein-tyrosine sulfotransferase 1 [Source:MGI Symbol;Acc:MGI:1298231] |
| Ifitm2 | ENSMUSG00000060591 | 2.477691589 | 0.000241487 | interferon induced transmembrane protein 2 [Source:MGI Symbol;Acc:MGI:1933382] |
| A730015C16Rik | ENSMUSG00000090551 | 6.558731429 | 0.00024421 | RIKEN cDNA A730015C16 gene [Source:MGI Symbol;Acc:MGI:3704235] |
| Ldha | ENSMUSG00000063229 | 1.395683293 | 0.000279045 | lactate dehydrogenase A [Source:MGI Symbol;Acc:MGI:96759] |
| Myc | ENSMUSG00000022346 | 2.146902666 | 0.000326597 | myelocytomatosis oncogene [Source:MGI Symbol;Acc:MGI:97250] |
| Pgd | ENSMUSG00000028961 | 1.029311722 | 0.000347465 | phosphogluconate dehydrogenase [Source:MGI Symbol;Acc:MGI:97553] |
| S100a6 | ENSMUSG00000001025 | 1.902089598 | 0.000380992 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Parp9 | ENSMUSG00000022906 | 1.490483715 | 0.00039353 | poly (ADP-ribose) polymerase family, member 9 [Source:MGI Symbol;Acc:MGI:1933117] |
| Tmem97 | ENSMUSG00000037278 | 1.33655914 | 0.000434485 | transmembrane protein 97 [Source:MGI Symbol;Acc:MGI:1916321] |
| Pno1 | ENSMUSG00000020116 | 1.078608906 | 0.000440681 | partner of NOB1 homolog [Source:MGI Symbol;Acc:MGI:1913499] |
| Noc4l | ENSMUSG00000033294 | 1.335259121 | 0.00045478 | NOC4 like [Source:MGI Symbol;Acc:MGI:2140843] |
| Cd36 | ENSMUSG00000002944 | 1.173513591 | 0.000476907 | CD36 molecule [Source:MGI Symbol;Acc:MGI:107899] |
| Ppan | ENSMUSG00000004100 | 1.482732121 | 0.000491491 | peter pan homolog (Drosophila) [Source:MGI Symbol;Acc:MGI:2178445] |
| 2410016O06Rik | ENSMUSG00000046791 | 1.62103313 | 0.000494675 | ribosomal oxygenase 1 [Source:MGI Symbol;Acc:MGI:1919202] |
| Oas3 | ENSMUSG00000032661 | 3.673517522 | 0.00054043 | 2'-5' oligoadenylate synthetase 3 [Source:MGI Symbol;Acc:MGI:2180850] |
| Eef1e1 | ENSMUSG00000001707 | 1.074027837 | 0.000618004 | eukaryotic translation elongation factor 1 epsilon 1 [Source:MGI Symbol;Acc:MGI:1913393] |
| Phf11b | ENSMUSG00000091649 | 1.75207151 | 0.000618393 | PHD finger protein 11B [Source:MGI Symbol;Acc:MGI:3645789] |
| Phb2 | ENSMUSG00000004264 | 1.190613938 | 0.000712084 | prohibitin 2 [Source:MGI Symbol;Acc:MGI:102520] |
| Atp1a1 | ENSMUSG00000033161 | 1.118378869 | 0.000762858 | ATPase, Na+/K+ transporting, alpha 1 polypeptide [Source:MGI Symbol;Acc:MGI:88105] |
| Jak3 | ENSMUSG00000031805 | 1.066623417 | 0.0008275 | Janus kinase 3 [Source:MGI Symbol;Acc:MGI:99928] |
| Tgtp2 | ENSMUSG00000078921 | 2.286384267 | 0.000890489 | T cell specific GTPase 2 [Source:MGI Symbol;Acc:MGI:3710083] |
| Tor3a | ENSMUSG00000060519 | 1.342014963 | 0.000890489 | torsin family 3, member A [Source:MGI Symbol;Acc:MGI:1353652] |
| Zbp1 | ENSMUSG00000027514 | 1.665613585 | 0.000947182 | Z-DNA binding protein 1 [Source:MGI Symbol;Acc:MGI:1927449] |
| Gem | ENSMUSG00000028214 | 1.392306364 | 0.000952976 | GTP binding protein (gene overexpressed in skeletal muscle) [Source:MGI Symbol;Acc:MGI:99844] |
| Snapc4 | ENSMUSG00000036281 | 2.021643545 | 0.000956234 | small nuclear RNA activating complex, polypeptide 4 [Source:MGI Symbol;Acc:MGI:2443935] |
| Isyna1 | ENSMUSG00000019139 | 1.565212994 | 0.000999929 | myo-inositol 1-phosphate synthase A1 [Source:MGI Symbol;Acc:MGI:1919030] |
| Oasl1 | ENSMUSG00000041827 | 2.472504634 | 0.001130538 | 2'-5' oligoadenylate synthetase-like 1 [Source:MGI Symbol;Acc:MGI:2180849] |
| Cd3eap | ENSMUSG00000047649 | 1.444927728 | 0.001147361 | CD3E antigen, epsilon polypeptide associated protein [Source:MGI Symbol;Acc:MGI:1917583] |
| Rab8b | ENSMUSG00000036943 | 1.168527817 | 0.001328861 | RAB8B, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:2442982] |
| D16Ertd472e | ENSMUSG00000022864 | 1.195026685 | 0.001352721 | DNA segment, Chr 16, ERATO Doi 472, expressed [Source:MGI Symbol;Acc:MGI:1196400] |
| Hspe1 | ENSMUSG00000073676 | 1.324375503 | 0.001398532 | heat shock protein 1 (chaperonin 10) [Source:MGI Symbol;Acc:MGI:104680] |
| Cct3 | ENSMUSG00000001416 | 1.143633487 | 0.001526777 | chaperonin containing Tcp1, subunit 3 (gamma) [Source:MGI Symbol;Acc:MGI:104708] |
| Polr1c | ENSMUSG00000067148 | 1.043584492 | 0.001526872 | polymerase (RNA) I polypeptide C [Source:MGI Symbol;Acc:MGI:103288] |
| Nif3l1 | ENSMUSG00000026036 | 1.146277179 | 0.001573076 | Ngg1 interacting factor 3-like 1 (S. pombe) [Source:MGI Symbol;Acc:MGI:1929485] |
| C1qbp | ENSMUSG00000018446 | 1.139358283 | 0.001764231 | complement component 1, q subcomponent binding protein [Source:MGI Symbol;Acc:MGI:1194505] |
| Lfng | ENSMUSG00000029570 | 1.270769695 | 0.001786384 | LFNG O-fucosylpeptide 3-beta-N-acetylglucosaminyltransferase [Source:MGI Symbol;Acc:MGI:1095413] |
| Gnl3 | ENSMUSG00000042354 | 1.396715089 | 0.001803341 | guanine nucleotide binding protein-like 3 (nucleolar) [Source:MGI Symbol;Acc:MGI:1353651] |
| Bex1 | ENSMUSG00000050071 | 3.911191443 | 0.001934549 | brain expressed X-linked 1 [Source:MGI Symbol;Acc:MGI:1328321] |
| Dhx58 | ENSMUSG00000017830 | 1.511865932 | 0.001968079 | DEXH (Asp-Glu-X-His) box polypeptide 58 [Source:MGI Symbol;Acc:MGI:1931560] |
| Rrad | ENSMUSG00000031880 | 1.287039232 | 0.001968105 | Ras-related associated with diabetes [Source:MGI Symbol;Acc:MGI:1930943] |
| Ndufaf4 | ENSMUSG00000028261 | 1.142313971 | 0.001981315 | NADH dehydrogenase (ubiquinone) 1 alpha subcomplex, assembly factor 4 [Source:MGI Symbol;Acc:MGI:1915743] |
| Ppat | ENSMUSG00000029246 | 1.724589728 | 0.001999026 | phosphoribosyl pyrophosphate amidotransferase [Source:MGI Symbol;Acc:MGI:2387203] |
| Snhg4 | ENSMUSG00000097769 | 1.358196753 | 0.002077308 | small nucleolar RNA host gene 4 [Source:MGI Symbol;Acc:MGI:4937091] |
| Apex1 | ENSMUSG00000035960 | 1.083916797 | 0.002116571 | apurinic/apyrimidinic endonuclease 1 [Source:MGI Symbol;Acc:MGI:88042] |
| Bcl2l11 | ENSMUSG00000027381 | 1.342073022 | 0.002271576 | BCL2-like 11 (apoptosis facilitator) [Source:MGI Symbol;Acc:MGI:1197519] |
| Psmg1 | ENSMUSG00000022913 | 1.25891128 | 0.002271576 | proteasome (prosome, macropain) assembly chaperone 1 [Source:MGI Symbol;Acc:MGI:1860263] |

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|---|---|---|---|---|
| Timm9 | ENSMUSG00000021079 | 1.100343327 | 0.002374653 | translocase of inner mitochondrial membrane 9 [Source:MGI Symbol;Acc:MGI:1353436] |
| Siah2 | ENSMUSG00000036432 | 1.169033566 | 0.002794704 | seven in absentia 2 [Source:MGI Symbol;Acc:MGI:108062] |
| Wdr43 | ENSMUSG00000041057 | 1.104904193 | 0.002839595 | WD repeat domain 43 [Source:MGI Symbol;Acc:MGI:1919765] |
| Ahr | ENSMUSG00000019256 | 2.362877633 | 0.002863528 | aryl-hydrocarbon receptor [Source:MGI Symbol;Acc:MGI:105043] |
| Ncl | ENSMUSG00000026234 | 1.300917662 | 0.003026958 | nucleolin [Source:MGI Symbol;Acc:MGI:97286] |
| Mov10 | ENSMUSG00000002227 | 2.038088107 | 0.003027119 | Moloney leukemia virus 10 [Source:MGI Symbol;Acc:MGI:97054] |
| Rrp1b | ENSMUSG00000058392 | 1.800443797 | 0.003047669 | ribosomal RNA processing 1 homolog B (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1919712] |
| Smyd2 | ENSMUSG00000026603 | 3.722752197 | 0.003122642 | SET and MYND domain containing 2 [Source:MGI Symbol;Acc:MGI:1915889] |
| Eif2ak2 | ENSMUSG00000024079 | 1.425942455 | 0.003153254 | eukaryotic translation initiation factor 2-alpha kinase 2 [Source:MGI Symbol;Acc:MGI:1353449] |
| Wdr77 | ENSMUSG00000000561 | 1.280578774 | 0.003256782 | WD repeat domain 77 [Source:MGI Symbol;Acc:MGI:1917715] |
| Gm15624 | ENSMUSG00000085782 | 5.42376897 | 0.003487674 | predicted gene 15624 [Source:MGI Symbol;Acc:MGI:3783068] |
| BC147527 | ENSMUSG00000094796 | 1.567399632 | 0.004296251 | cDNA sequence BC147527 [Source:MGI Symbol;Acc:MGI:4840510] |
| Trafd1 | ENSMUSG00000042726 | 1.343180365 | 0.004309667 | TRAF type zinc finger domain containing 1 [Source:MGI Symbol;Acc:MGI:1923551] |
| Aatf | ENSMUSG00000018697 | 1.175343355 | 0.004370691 | apoptosis antagonizing transcription factor [Source:MGI Symbol;Acc:MGI:1929608] |
| Ero1l | ENSMUSG00000021831 | 1.385850207 | 0.004400439 | ERO1-like (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1354385] |
| Helz2 | ENSMUSG00000027580 | 1.255119147 | 0.004453778 | helicase with zinc finger 2, transcriptional coactivator [Source:MGI Symbol;Acc:MGI:2385169] |
| Timm10 | ENSMUSG00000027076 | 1.133570507 | 0.004685733 | translocase of inner mitochondrial membrane 10 [Source:MGI Symbol;Acc:MGI:1353429] |
| Ifit1 | ENSMUSG00000034459 | 3.545732096 | 0.004743787 | interferon-induced protein with tetratricopeptide repeats 1 [Source:MGI Symbol;Acc:MGI:99450] |
| Rrp12 | ENSMUSG00000035049 | 2.175646685 | 0.004775715 | ribosomal RNA processing 12 homolog (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:2147437] |
| Stat4 | ENSMUSG00000062939 | 2.592392203 | 0.004958367 | signal transducer and activator of transcription 4 [Source:MGI Symbol;Acc:MGI:103062] |
| Grwd1 | ENSMUSG00000053801 | 1.455621285 | 0.00533241 | glutamate-rich WD repeat containing 1 [Source:MGI Symbol;Acc:MGI:2141989] |
| Agpat5 | ENSMUSG00000031467 | 1.134416858 | 0.005375683 | 1-acylglycerol-3-phosphate O-acyltransferase 5 (lysophosphatidic acid acyltransferase, epsilon) [Source:MGI Symbol;Acc:MGI:1196345] |
| Cirh1a | ENSMUSG00000041438 | 1.117221235 | 0.005375683 | UTP4 small subunit processome component [Source:MGI Symbol;Acc:MGI:1096573] |
| Rrp9 | ENSMUSG00000041506 | 1.411063166 | 0.005441863 | RRP9, small subunit (SSU) processome component, homolog (yeast) [Source:MGI Symbol;Acc:MGI:2384313] |
| Il1r2 | ENSMUSG00000026073 | 2.912877542 | 0.005613568 | interleukin 1 receptor, type II [Source:MGI Symbol;Acc:MGI:96546] |
| Cct6a | ENSMUSG00000029447 | 1.074538412 | 0.005719034 | chaperonin containing Tcp1, subunit 6a (zeta) [Source:MGI Symbol;Acc:MGI:107943] |
| Polr1b | ENSMUSG00000027395 | 2.003430219 | 0.005745797 | polymerase (RNA) I polypeptide B [Source:MGI Symbol;Acc:MGI:108014] |
| Ece2 | ENSMUSG00000022842 | 1.592350473 | 0.005745797 | endothelin converting enzyme 2 [Source:MGI Symbol;Acc:MGI:1101356] |
| Ctps | ENSMUSG00000028633 | 1.186664574 | 0.005931277 | cytidine 5'-triphosphate synthase [Source:MGI Symbol;Acc:MGI:1858304] |
| Mrto4 | ENSMUSG00000028741 | 1.116790483 | 0.006394364 | mRNA turnover 4, ribosome maturation factor [Source:MGI Symbol;Acc:MGI:1917152] |
| Ccdc86 | ENSMUSG00000024732 | 1.084743669 | 0.006394364 | coiled-coil domain containing 86 [Source:MGI Symbol;Acc:MGI:1277220] |
| Tspan4 | ENSMUSG00000025511 | 2.98415477 | 0.006458025 | tetraspanin 4 [Source:MGI Symbol;Acc:MGI:1928097] |
| St6galnac4 | ENSMUSG00000079442 | 1.103786973 | 0.006516495 | ST6 (alpha-N-acetyl-neuraminyl-2,3-beta-galactosyl-1,3)-N-acetylgalactosaminide alpha-2,6-sialyltransferase 4 [Source:MGI Symbol;Acc:MGI:1341894] |
| Nifk | ENSMUSG00000026377 | 1.084439974 | 0.006629668 | nucleolar protein interacting with the FHA domain of MKI67 [Source:MGI Symbol;Acc:MGI:1915199] |
| Hspd1 | ENSMUSG00000025980 | 1.226219025 | 0.006715384 | heat shock protein 1 (chaperonin) [Source:MGI Symbol;Acc:MGI:96242] |
| Nek6 | ENSMUSG00000026749 | 1.505913024 | 0.006823767 | NIMA (never in mitosis gene a)-related expressed kinase 6 [Source:MGI Symbol;Acc:MGI:1891638] |
| Shisa8 | ENSMUSG00000096883 | 2.616410094 | 0.006903497 | shisa family member 8 [Source:MGI Symbol;Acc:MGI:2146080] |
| Wdr12 | ENSMUSG00000026019 | 1.047800739 | 0.006944839 | WD repeat domain 12 [Source:MGI Symbol;Acc:MGI:1927241] |
| A630023P12Rik | ENSMUSG00000048215 | 5.840339963 | 0.007129024 | RIKEN cDNA A630023P12 gene [Source:MGI Symbol;Acc:MGI:2445162] |
| Glrx5 | ENSMUSG00000021102 | 1.036354329 | 0.007293171 | glutaredoxin 5 [Source:MGI Symbol;Acc:MGI:1920296] |
| Isg20 | ENSMUSG00000039236 | 1.814997629 | 0.007542034 | interferon-stimulated protein [Source:MGI Symbol;Acc:MGI:1928895] |
| Oas1a | ENSMUSG00000052776 | 1.807238853 | 0.007626175 | 2'-5' oligoadenylate synthetase 1A [Source:MGI Symbol;Acc:MGI:2180860] |
| Apoe | ENSMUSG00000002985 | 3.217373321 | 0.008352394 | apolipoprotein E [Source:MGI Symbol;Acc:MGI:88057] |
| Slc35f2 | ENSMUSG00000042195 | 1.660993973 | 0.00865432 | solute carrier family 35, member F2 [Source:MGI Symbol;Acc:MGI:1919272] |
| Pusl1 | ENSMUSG00000051557 | 1.636305898 | 0.008743358 | pseudouridylate synthase-like 1 [Source:MGI Symbol;Acc:MGI:3047787] |
| Chchd4 | ENSMUSG00000034203 | 1.408671942 | 0.008759797 | coiled-coil-helix-coiled-coil-helix domain containing 4 [Source:MGI Symbol;Acc:MGI:1919420] |
| Oasl2 | ENSMUSG00000029561 | 1.849010212 | 0.008770305 | 2'-5' oligoadenylate synthetase-like 2 [Source:MGI Symbol;Acc:MGI:1344390] |
| Ftsj3 | ENSMUSG00000020706 | 1.109969432 | 0.00897438 | FtsJ RNA methyltransferase homolog 3 (E. coli) [Source:MGI Symbol;Acc:MGI:1860295] |
| Mreg | ENSMUSG00000039395 | 1.132330392 | 0.009570129 | melanoregulin [Source:MGI Symbol;Acc:MGI:2151839] |
| Slc7a7 | ENSMUSG00000000958 | 1.85076358 | 0.009649138 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 7 [Source:MGI Symbol;Acc:MGI:1337120] |
| Heatr3 | ENSMUSG00000031657 | 1.573378764 | 0.009709095 | HEAT repeat containing 3 [Source:MGI Symbol;Acc:MGI:2444491] |
| Mcts2 | ENSMUSG00000042814 | 4.252783798 | 0.009796012 | malignant T cell amplified sequence 2 [Source:MGI Symbol;Acc:MGI:1913655] |
| Rnf213 | ENSMUSG00000070327 | 1.632856863 | 0.009898336 | ring finger protein 213 [Source:MGI Symbol;Acc:MGI:1289196] |
| Fbl | ENSMUSG00000046865 | 1.232687929 | 0.009898336 | fibrillarin [Source:MGI Symbol;Acc:MGI:95486] |
| Rrp15 | ENSMUSG00000001305 | 1.060750709 | 0.009898336 | ribosomal RNA processing 15 homolog (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1914473] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-4. Genes significantly up-regulated in immature B cell subsets in IgBM treated with sHEL compare to IgNL treated with sHEL.

| Symbol | Ensembl gene id | logFC (BM-sHEL/ NL-sHEL) | adj.P.val | Annotation |
|---|---|---|---|---|
| H2-Q6 | ENSMUSG00000073409 | 7.330300045 | 2.589E-199 | histocompatibility 2, Q region locus 6 [Source:MGI Symbol;Acc:MGI:95935] |
| H2-Q7 | ENSMUSG00000060550 | 5.890433879 | 2.64605E-36 | histocompatibility 2, Q region locus 7 [Source:MGI Symbol;Acc:MGI:95936] |
| H2-Q5 | ENSMUSG00000055413 | 3.909920195 | 5.76147E-29 | histocompatibility 2, Q region locus 5 [Source:MGI Symbol;Acc:MGI:95934] |
| Foxd2os | ENSMUSG00000085399 | 5.516289357 | 2.36953E-22 | forkhead box D2, opposite strand [Source:MGI Symbol;Acc:MGI:2444065] |
| Lmo4 | ENSMUSG00000028266 | 3.143253659 | 1.88365E-20 | LIM domain only 4 [Source:MGI Symbol;Acc:MGI:109360] |
| Iglc2 | ENSMUSG00000076937 | 4.785332341 | 1.58877E-19 | immunoglobulin lambda constant 2 [Source:MGI Symbol;Acc:MGI:99547] |
| Ighd | ENSMUSG00000104213 | 1.532540175 | 1.5974E-18 | immunoglobulin heavy constant delta [Source:MGI Symbol;Acc:MGI:96447] |
| Atf7ip | ENSMUSG00000030213 | 1.333924441 | 2.39021E-16 | activating transcription factor 7 interacting protein [Source:MGI Symbol;Acc:MGI:1858965] |
| H2-DMb2 | ENSMUSG00000037548 | 1.011320834 | 3.40367E-13 | histocompatibility 2, class II, locus Mb2 [Source:MGI Symbol;Acc:MGI:95923] |
| Cd38 | ENSMUSG00000029084 | 1.389958895 | 1.35471E-09 | CD38 antigen [Source:MGI Symbol;Acc:MGI:107474] |
| Hdac9 | ENSMUSG00000004698 | 2.611829265 | 2.19115E-09 | histone deacetylase 9 [Source:MGI Symbol;Acc:MGI:1931221] |
| Add1 | ENSMUSG00000029106 | 1.117871883 | 4.68003E-09 | adducin 1 (alpha) [Source:MGI Symbol;Acc:MGI:87918] |
| Chd3 | ENSMUSG00000018474 | 3.028039778 | 2.1491E-08 | chromodomain helicase DNA binding protein 3 [Source:MGI Symbol;Acc:MGI:1344395] |
| Rreb1 | ENSMUSG00000039087 | 1.628048585 | 3.38348E-08 | ras responsive element binding protein 1 [Source:MGI Symbol;Acc:MGI:2443664] |
| Wnt10a | ENSMUSG00000026167 | 7.801476005 | 4.40296E-08 | wingless-type MMTV integration site family, member 10A [Source:MGI Symbol;Acc:MGI:108071] |
| Lef1 | ENSMUSG00000027985 | 1.763847259 | 6.36493E-08 | lymphoid enhancer binding factor 1 [Source:MGI Symbol;Acc:MGI:96770] |
| Gnb4 | ENSMUSG00000027669 | 3.971085543 | 1.02934E-07 | guanine nucleotide binding protein (G protein), beta 4 [Source:MGI Symbol;Acc:MGI:104581] |
| 2010309G21Rik | ENSMUSG00000106567 | 1.586089377 | 1.0767E-07 | RIKEN cDNA 2010309G21 gene [Source:MGI Symbol;Acc:MGI:1917268] |
| Slamf9 | ENSMUSG00000026548 | 1.797586306 | 1.28907E-07 | SLAM family member 9 [Source:MGI Symbol;Acc:MGI:1923692] |
| Arhgap24 | ENSMUSG00000057315 | 1.251746195 | 2.38508E-07 | Rho GTPase activating protein 24 [Source:MGI Symbol;Acc:MGI:1922647] |
| Abcg1 | ENSMUSG00000024030 | 3.255320856 | 6.50556E-07 | ATP binding cassette subfamily G member 1 [Source:MGI Symbol;Acc:MGI:107704] |
| Carhsp1 | ENSMUSG00000008393 | 1.211332163 | 6.57371E-07 | calcium regulated heat stable protein 1 [Source:MGI Symbol;Acc:MGI:1196368] |
| Mapk3 | ENSMUSG00000063065 | 1.239490177 | 7.37132E-07 | mitogen-activated protein kinase 3 [Source:MGI Symbol;Acc:MGI:1346859] |
| Slain1 | ENSMUSG00000055717 | 2.233317592 | 7.52911E-07 | SLAIN motif family, member 1 [Source:MGI Symbol;Acc:MGI:2145578] |
| Rapgefl1 | ENSMUSG00000038020 | 6.191919414 | 9.53878E-07 | Rap guanine nucleotide exchange factor (GEF)-like 1 [Source:MGI Symbol;Acc:MGI:3611446] |
| H2-DMb1 | ENSMUSG00000079547 | 1.733171891 | 1.20165E-06 | histocompatibility 2, class II, locus Mb1 [Source:MGI Symbol;Acc:MGI:95922] |
| Cercam | ENSMUSG00000039787 | 4.303750022 | 1.29281E-06 | cerebral endothelial cell adhesion molecule [Source:MGI Symbol;Acc:MGI:2139134] |
| Mterf2 | ENSMUSG00000049038 | 1.204728433 | 1.46478E-06 | mitochondrial transcription termination factor 2 [Source:MGI Symbol;Acc:MGI:1921488] |
| Irak3 | ENSMUSG00000020227 | 1.85124644 | 1.76639E-06 | interleukin-1 receptor-associated kinase 3 [Source:MGI Symbol;Acc:MGI:1921164] |
| Hes5 | ENSMUSG00000048001 | 2.077718717 | 1.92535E-06 | hairy and enhancer of split 5 (Drosophila) [Source:MGI Symbol;Acc:MGI:104876] |
| Bach2 | ENSMUSG00000040270 | 1.155293952 | 3.32737E-06 | BTB and CNC homology, basic leucine zipper transcription factor 2 [Source:MGI Symbol;Acc:MGI:894679] |
| Lhpp | ENSMUSG00000030946 | 1.643743785 | 3.43036E-06 | phospholysine phosphohistidine inorganic pyrophosphate phosphatase [Source:MGI Symbol;Acc:MGI:1923679] |
| Iglc3 | ENSMUSG00000105547 | 2.406070779 | 4.36927E-06 | immunoglobulin lambda constant 3 [Source:MGI Symbol;Acc:MGI:99886] |
| Pld3 | ENSMUSG00000003363 | 1.424633527 | 4.58814E-06 | phospholipase D family, member 3 [Source:MGI Symbol;Acc:MGI:1333782] |
| Sgk1 | ENSMUSG00000019970 | 1.81764799 | 4.77289E-06 | serum/glucocorticoid regulated kinase 1 [Source:MGI Symbol;Acc:MGI:1340062] |
| Pknox1 | ENSMUSG00000006705 | 1.352460598 | 5.07354E-06 | Pbx/knotted 1 homeobox [Source:MGI Symbol;Acc:MGI:1201409] |
| Cd72 | ENSMUSG00000028459 | 1.370748828 | 6.31058E-06 | CD72 antigen [Source:MGI Symbol;Acc:MGI:88345] |
| H2-DMa | ENSMUSG00000037649 | 1.143531985 | 6.44982E-06 | histocompatibility 2, class II, locus DMa [Source:MGI Symbol;Acc:MGI:95921] |
| Trp53i13 | ENSMUSG00000044328 | 1.665026604 | 6.79596E-06 | transformation related protein 53 inducible protein 13 [Source:MGI Symbol;Acc:MGI:1915125] |
| Sbk1 | ENSMUSG00000042978 | 2.198660728 | 1.25163E-05 | SH3-binding kinase 1 [Source:MGI Symbol;Acc:MGI:2135937] |
| Ero1lb | ENSMUSG00000057069 | 1.616432324 | 1.65037E-05 | ERO1-like beta (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1914725] |
| Osbpl8 | ENSMUSG00000020189 | 1.032178598 | 1.65037E-05 | oxysterol binding protein-like 8 [Source:MGI Symbol;Acc:MGI:2443807] |
| Rab43 | ENSMUSG00000030055 | 1.00734097 | 1.78009E-05 | RAB43, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:1917084] |
| Fcho1 | ENSMUSG00000070000 | 1.23458902 | 1.97339E-05 | FCH domain only 1 [Source:MGI Symbol;Acc:MGI:1921265] |
| Tubgcp2 | ENSMUSG00000025474 | 1.001558631 | 2.43881E-05 | tubulin, gamma complex associated protein 2 [Source:MGI Symbol;Acc:MGI:1921487] |
| Fbxo32 | ENSMUSG00000022358 | 2.231696142 | 2.55347E-05 | F-box protein 32 [Source:MGI Symbol;Acc:MGI:1914981] |
| Rcan3 | ENSMUSG00000059713 | 5.02689496 | 2.75816E-05 | regulator of calcineurin 3 [Source:MGI Symbol;Acc:MGI:1858220] |
| Sgsh | ENSMUSG00000005043 | 1.36296578 | 2.80309E-05 | N-sulfoglucosamine sulfohydrolase (sulfamidase) [Source:MGI Symbol;Acc:MGI:1350341] |
| Mxi1 | ENSMUSG00000025025 | 1.097971057 | 2.88543E-05 | MAX interactor 1, dimerization protein [Source:MGI Symbol;Acc:MGI:97245] |
| Baiap2 | ENSMUSG00000025372 | 1.960617574 | 3.48794E-05 | brain-specific angiogenesis inhibitor 1-associated protein 2 [Source:MGI Symbol;Acc:MGI:2137336] |
| Mgst1 | ENSMUSG00000008540 | 2.05086481 | 3.53524E-05 | microsomal glutathione S-transferase 1 [Source:MGI Symbol;Acc:MGI:1913850] |
| Cecr2 | ENSMUSG00000071226 | 1.098566922 | 4.95578E-05 | CECR2, histone acetyl-lysine reader [Source:MGI Symbol;Acc:MGI:1923799] |
| Bnip3 | ENSMUSG00000078566 | 1.558276547 | 5.07198E-05 | BCL2/adenovirus E1B interacting protein 3 [Source:MGI Symbol;Acc:MGI:109326] |
| Gstm1 | ENSMUSG00000058135 | 1.602237982 | 5.11544E-05 | glutathione S-transferase, mu 1 [Source:MGI Symbol;Acc:MGI:95860] |
| Hmces | ENSMUSG00000030060 | 1.44462455 | 6.19109E-05 | 5-hydroxymethylcytosine (hmC) binding, ES cell specific [Source:MGI Symbol;Acc:MGI:1914053] |
| D3Ertd751e | ENSMUSG00000025766 | 2.015829734 | 6.67486E-05 | DNA segment, Chr 3, ERATO Doi 751, expressed [Source:MGI Symbol;Acc:MGI:1289213] |
| Spidr | ENSMUSG00000041974 | 1.513247355 | 7.94823E-05 | scaffolding protein involved in DNA repair [Source:MGI Symbol;Acc:MGI:1924834] |
| Aes | ENSMUSG00000054452 | 1.078004508 | 0.00010346 | amino-terminal enhancer of split [Source:MGI Symbol;Acc:MGI:95806] |
| Cpm | ENSMUSG00000020183 | 2.212577956 | 0.000106481 | carboxypeptidase M [Source:MGI Symbol;Acc:MGI:1917824] |
| Gm42870 | ENSMUSG00000105128 | 2.099331066 | 0.000109404 | predicted gene 42870 [Source:MGI Symbol;Acc:MGI:5663007] |
| 5830418P13Rik | ENSMUSG00000086236 | 1.532495214 | 0.000133199 | RIKEN cDNA 5830418P13 gene [Source:MGI Symbol;Acc:MGI:3604110] |
| Gm9728 | ENSMUSG00000106248 | 7.759733594 | 0.0001531 | predicted gene 9728 [Source:MGI Symbol;Acc:MGI:3780132] |
| Casp7 | ENSMUSG00000025076 | 1.782705961 | 0.000168018 | caspase 7 [Source:MGI Symbol;Acc:MGI:109383] |
| Arhgef6 | ENSMUSG00000031133 | 1.222590151 | 0.000168018 | Rac/Cdc42 guanine nucleotide exchange factor (GEF) 6 [Source:MGI Symbol;Acc:MGI:1920591] |
| Dhx35 | ENSMUSG00000027655 | 1.547265409 | 0.000168972 | DEAH (Asp-Glu-Ala-His) box polypeptide 35 [Source:MGI Symbol;Acc:MGI:1918965] |
| Slc14a1 | ENSMUSG00000059336 | 1.918364158 | 0.00016966 | solute carrier family 14 (urea transporter), member 1 [Source:MGI Symbol;Acc:MGI:1351654] |

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|---|---|---|---|---|
| Desi1 | ENSMUSG00000022472 | 1.179695793 | 0.000195607 | desumoylating isopeptidase 1 [Source:MGI Symbol;Acc:MGI:106313] |
| Adgrg1 | ENSMUSG00000031785 | 1.554298647 | 0.000199105 | adhesion G protein-coupled receptor G1 [Source:MGI Symbol;Acc:MGI:1340051] |
| Tuba1a | ENSMUSG00000072235 | 1.042077329 | 0.000217978 | tubulin, alpha 1A [Source:MGI Symbol;Acc:MGI:98869] |
| Tm6sf1 | ENSMUSG00000038623 | 1.606063681 | 0.000219448 | transmembrane 6 superfamily member 1 [Source:MGI Symbol;Acc:MGI:1933209] |
| Ramp1 | ENSMUSG00000034353 | 1.494005307 | 0.000229409 | receptor (calcitonin) activity modifying protein 1 [Source:MGI Symbol;Acc:MGI:1858418] |
| Pdk2 | ENSMUSG00000038967 | 2.010057051 | 0.000235473 | pyruvate dehydrogenase kinase, isoenzyme 2 [Source:MGI Symbol;Acc:MGI:1343087] |
| Mical1 | ENSMUSG00000019823 | 1.44345609 | 0.000241487 | microtubule associated monooxygenase, calponin and LIM domain containing 1 [Source:MGI Symbol;Acc:MGI:2385847] |
| Pura | ENSMUSG00000043991 | 1.37302629 | 0.000242458 | purine rich element binding protein A [Source:MGI Symbol;Acc:MGI:103079] |
| Rab3a | ENSMUSG00000031840 | 4.105635293 | 0.000246175 | RAB3A, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:97843] |
| Mturn | ENSMUSG00000038065 | 3.79413194 | 0.000257572 | maturin, neural progenitor differentiation regulator homolog (Xenopus) [Source:MGI Symbol;Acc:MGI:1915485] |
| Iglc1 | ENSMUSG00000105906 | 2.48746192 | 0.000267803 | immunoglobulin lambda constant 1 [Source:MGI Symbol;Acc:MGI:99546] |
| Cd2 | ENSMUSG00000027863 | 2.152099472 | 0.000288751 | CD2 antigen [Source:MGI Symbol;Acc:MGI:88320] |
| Syk | ENSMUSG00000021457 | 1.280220192 | 0.000315218 | spleen tyrosine kinase [Source:MGI Symbol;Acc:MGI:99515] |
| Polm | ENSMUSG00000020474 | 1.658408383 | 0.000347465 | polymerase (DNA directed), mu [Source:MGI Symbol;Acc:MGI:1860191] |
| Dbp | ENSMUSG00000059824 | 1.420600636 | 0.000361352 | D site albumin promoter binding protein [Source:MGI Symbol;Acc:MGI:94866] |
| Prkag2 | ENSMUSG00000028944 | 1.76282076 | 0.000365228 | protein kinase, AMP-activated, gamma 2 non-catalytic subunit [Source:MGI Symbol;Acc:MGI:1336153] |
| Glipr2 | ENSMUSG00000028480 | 1.356962406 | 0.000370346 | GLI pathogenesis-related 2 [Source:MGI Symbol;Acc:MGI:1917770] |
| Kcnh4 | ENSMUSG00000035355 | 3.780240715 | 0.000379171 | potassium voltage-gated channel, subfamily H (eag-related), member 4 [Source:MGI Symbol;Acc:MGI:2156184] |
| Trim16 | ENSMUSG00000047821 | 2.80456493 | 0.000440752 | tripartite motif-containing 16 [Source:MGI Symbol;Acc:MGI:2137356] |
| Ubash3b | ENSMUSG00000032020 | 2.545100825 | 0.000468764 | ubiquitin associated and SH3 domain containing, B [Source:MGI Symbol;Acc:MGI:1920078] |
| Chtf18 | ENSMUSG00000019214 | 1.804783989 | 0.000516322 | CTF18, chromosome transmission fidelity factor 18 [Source:MGI Symbol;Acc:MGI:2384887] |
| Lat2 | ENSMUSG00000040751 | 1.135777839 | 0.000528754 | linker for activation of T cells family, member 2 [Source:MGI Symbol;Acc:MGI:1926479] |
| 2010315B03Rik | ENSMUSG00000074829 | 1.267653741 | 0.00054043 | RIKEN cDNA 2010315B03 gene [Source:MGI Symbol;Acc:MGI:1919321] |
| Spp1 | ENSMUSG00000029304 | 3.876148342 | 0.000552071 | secreted phosphoprotein 1 [Source:MGI Symbol;Acc:MGI:98389] |
| Nhsl1 | ENSMUSG00000039835 | 7.066048412 | 0.000596011 | NHS-like 1 [Source:MGI Symbol;Acc:MGI:106390] |
| Gmcl1 | ENSMUSG00000001157 | 1.130523438 | 0.000599267 | germ cell-less, spermatogenesis associated 1 [Source:MGI Symbol;Acc:MGI:1345156] |
| Insl6 | ENSMUSG00000050957 | 2.339740383 | 0.000607947 | insulin-like 6 [Source:MGI Symbol;Acc:MGI:1351595] |
| Lmcd1 | ENSMUSG00000057604 | 5.501456478 | 0.000609352 | LIM and cysteine-rich domains 1 [Source:MGI Symbol;Acc:MGI:1353635] |
| Sdc1 | ENSMUSG00000020592 | 4.107993408 | 0.000762858 | syndecan 1 [Source:MGI Symbol;Acc:MGI:1349162] |
| Pik3ip1 | ENSMUSG00000034614 | 1.858362361 | 0.0008275 | phosphoinositide-3-kinase interacting protein 1 [Source:MGI Symbol;Acc:MGI:1917016] |
| Parp8 | ENSMUSG00000021725 | 2.004382189 | 0.000882973 | poly (ADP-ribose) polymerase family, member 8 [Source:MGI Symbol;Acc:MGI:1098713] |
| Fcer2a | ENSMUSG00000005540 | 3.811273085 | 0.001230358 | Fc receptor, IgE, low affinity II, alpha polypeptide [Source:MGI Symbol;Acc:MGI:95497] |
| Smpd1 | ENSMUSG00000037049 | 1.400798947 | 0.001234699 | sphingomyelin phosphodiesterase 1, acid lysosomal [Source:MGI Symbol;Acc:MGI:98325] |
| Map7 | ENSMUSG00000019996 | 1.691710524 | 0.001257729 | microtubule-associated protein 7 [Source:MGI Symbol;Acc:MGI:1328328] |
| Pla2g16 | ENSMUSG00000060675 | 1.569852053 | 0.001352721 | phospholipase A2, group XVI [Source:MGI Symbol;Acc:MGI:2179715] |
| Rnf38 | ENSMUSG00000035696 | 1.329285563 | 0.001357413 | ring finger protein 38 [Source:MGI Symbol;Acc:MGI:1920719] |
| Rfc1 | ENSMUSG00000029191 | 1.03825914 | 0.001428774 | replication factor C (activator 1) 1 [Source:MGI Symbol;Acc:MGI:97891] |
| BC029214 | ENSMUSG00000047617 | 1.086049249 | 0.001468713 | non-homologous end joining factor [Source:MGI Symbol;Acc:MGI:2442831] |
| AW112010 | ENSMUSG00000075010 | 2.822763291 | 0.001495477 | expressed sequence AW112010 [Source:MGI Symbol;Acc:MGI:2147706] |
| Hist2h2be | ENSMUSG00000068854 | 1.42749859 | 0.001495477 | histone cluster 2, H2be [Source:MGI Symbol;Acc:MGI:2448415] |
| Nxt2 | ENSMUSG00000042271 | 1.379587071 | 0.001518556 | nuclear transport factor 2-like export factor 2 [Source:MGI Symbol;Acc:MGI:2147914] |
| Ttc7 | ENSMUSG00000036918 | 1.919165965 | 0.001546548 | tetratricopeptide repeat domain 7 [Source:MGI Symbol;Acc:MGI:1920999] |
| Oxct1 | ENSMUSG00000022186 | 1.25181632 | 0.001573076 | 3-oxoacid CoA transferase 1 [Source:MGI Symbol;Acc:MGI:1914291] |
| BC064078 | ENSMUSG00000087150 | 2.139575555 | 0.001637664 | cDNA sequence BC064078 [Source:MGI Symbol;Acc:MGI:3040692] |
| Tmem107 | ENSMUSG00000020895 | 1.983337976 | 0.001777801 | transmembrane protein 107 [Source:MGI Symbol;Acc:MGI:1914160] |
| AI504432 | ENSMUSG00000056145 | 1.771312432 | 0.00178087 | expressed sequence AI504432 [Source:MGI Symbol;Acc:MGI:2139742] |
| Nr1d1 | ENSMUSG00000020889 | 2.092784345 | 0.00179431 | nuclear receptor subfamily 1, group D, member 1 [Source:MGI Symbol;Acc:MGI:2444210] |
| Bmf | ENSMUSG00000040093 | 1.568995743 | 0.001891813 | BCL2 modifying factor [Source:MGI Symbol;Acc:MGI:2176433] |
| Ccdc88a | ENSMUSG00000032740 | 1.935773932 | 0.001982449 | coiled coil domain containing 88A [Source:MGI Symbol;Acc:MGI:1925177] |
| Enpp1 | ENSMUSG00000037370 | 2.435551011 | 0.00214655 | ectonucleotide pyrophosphatase/phosphodiesterase 1 [Source:MGI Symbol;Acc:MGI:97370] |
| Sox5 | ENSMUSG00000041540 | 3.545713628 | 0.002595382 | SRY (sex determining region Y)-box 5 [Source:MGI Symbol;Acc:MGI:98367] |
| Dyrk1b | ENSMUSG00000002409 | 2.056600447 | 0.002839058 | dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 1b [Source:MGI Symbol;Acc:MGI:1330302] |
| Slc25a10 | ENSMUSG00000025792 | 1.553605873 | 0.00298295 | solute carrier family 25 (mitochondrial carrier, dicarboxylate transporter), member 10 [Source:MGI Symbol;Acc:MGI:1353497] |
| Nnt | ENSMUSG00000025453 | 1.181123428 | 0.003026958 | nicotinamide nucleotide transhydrogenase [Source:MGI Symbol;Acc:MGI:109279] |
| Hspa4l | ENSMUSG00000025757 | 1.164116859 | 0.003087225 | heat shock protein 4 like [Source:MGI Symbol;Acc:MGI:107422] |
| Dnajc14 | ENSMUSG00000025354 | 1.072763875 | 0.003092547 | DnaJ heat shock protein family (Hsp40) member C14 [Source:MGI Symbol;Acc:MGI:1921580] |
| Arhgap18 | ENSMUSG00000039031 | 1.64050451 | 0.003122642 | Rho GTPase activating protein 18 [Source:MGI Symbol;Acc:MGI:1921160] |
| Nrgn | ENSMUSG00000053310 | 1.055621795 | 0.003374348 | neurogranin [Source:MGI Symbol;Acc:MGI:1927184] |
| Faap20 | ENSMUSG00000073684 | 1.148221681 | 0.003431277 | Fanconi anemia core complex associated protein 20 [Source:MGI Symbol;Acc:MGI:1914763] |
| Cdc42ep3 | ENSMUSG00000036533 | 2.026949801 | 0.003551913 | CDC42 effector protein (Rho GTPase binding) 3 [Source:MGI Symbol;Acc:MGI:2384718] |
| Amz2 | ENSMUSG00000020610 | 1.012833757 | 0.003564662 | archaelysin family metallopeptidase 2 [Source:MGI Symbol;Acc:MGI:104837] |
| Tfeb | ENSMUSG00000023990 | 1.143382361 | 0.003566782 | transcription factor EB [Source:MGI Symbol;Acc:MGI:103270] |
| Arid1b | ENSMUSG00000069729 | 1.075905873 | 0.003573099 | AT rich interactive domain 1B (SWI-like) [Source:MGI Symbol;Acc:MGI:1926129] |
| Gfra1 | ENSMUSG00000025089 | 1.628890783 | 0.003654315 | glial cell line derived neurotrophic factor family receptor alpha 1 [Source:MGI Symbol;Acc:MGI:1100842] |
| Ddah2 | ENSMUSG00000007039 | 2.105861219 | 0.003842686 | dimethylarginine dimethylaminohydrolase 2 [Source:MGI Symbol;Acc:MGI:1859016] |
| B3gnt8 | ENSMUSG00000059479 | 1.702683127 | 0.004523917 | UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 8 [Source:MGI Symbol;Acc:MGI:2385269] |
| E330020D12Rik | ENSMUSG00000073538 | 1.171343543 | 0.004681853 | Riken cDNA E330020D12 gene [Source:MGI Symbol;Acc:MGI:3761270] |

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|---|---|---|---|---|
| Edaradd | ENSMUSG00000095105 | 1.812819168 | 0.004775715 | EDAR (ectodysplasin-A receptor)-associated death domain [Source:MGI Symbol;Acc:MGI:1931001] |
| 2610035D17Rik | ENSMUSG00000087259 | 1.421255877 | 0.005081006 | RIKEN cDNA 2610035D17 gene [Source:MGI Symbol;Acc:MGI:1919636] |
| Tubg1 | ENSMUSG00000035198 | 1.070766593 | 0.00515587 | tubulin, gamma 1 [Source:MGI Symbol;Acc:MGI:101834] |
| Id3 | ENSMUSG00000007872 | 1.215538994 | 0.005745797 | inhibitor of DNA binding 3 [Source:MGI Symbol;Acc:MGI:96398] |
| Gm37893 | ENSMUSG00000103928 | 3.431034629 | 0.005798913 | predicted gene, 37893 [Source:MGI Symbol;Acc:MGI:5611121] |
| Cox6a2 | ENSMUSG00000030785 | 2.206165743 | 0.005977377 | cytochrome c oxidase subunit VIa polypeptide 2 [Source:MGI Symbol;Acc:MGI:104649] |
| Dusp6 | ENSMUSG00000019960 | 2.031618373 | 0.006101558 | dual specificity phosphatase 6 [Source:MGI Symbol;Acc:MGI:1914853] |
| Atp8a1 | ENSMUSG00000037685 | 1.552648642 | 0.006715384 | ATPase, aminophospholipid transporter (APLT), class I, type 8A, member 1 [Source:MGI Symbol;Acc:MGI:1330848] |
| Ano10 | ENSMUSG00000037949 | 1.557375098 | 0.006767067 | anoctamin 10 [Source:MGI Symbol;Acc:MGI:2143103] |
| Rnf157 | ENSMUSG00000052949 | 1.031276477 | 0.006944839 | ring finger protein 157 [Source:MGI Symbol;Acc:MGI:2442484] |
| Trmt2b | ENSMUSG00000067369 | 1.189288281 | 0.00716346 | TRM2 tRNA methyltransferase 2B [Source:MGI Symbol;Acc:MGI:2442530] |
| Neurl3 | ENSMUSG00000047180 | 1.914257764 | 0.007542034 | neuralized E3 ubiquitin protein ligase 3 [Source:MGI Symbol;Acc:MGI:2429944] |
| Socs5 | ENSMUSG00000037104 | 2.465667356 | 0.007604619 | suppressor of cytokine signaling 5 [Source:MGI Symbol;Acc:MGI:2385459] |
| Ift22 | ENSMUSG00000007987 | 1.150015955 | 0.008099274 | intraflagellar transport 22 [Source:MGI Symbol;Acc:MGI:1914536] |
| Adgre5 | ENSMUSG00000002885 | 1.18689781 | 0.008155786 | adhesion G protein-coupled receptor E5 [Source:MGI Symbol;Acc:MGI:1347095] |
| Sfxn3 | ENSMUSG00000025212 | 1.498141687 | 0.008370932 | sideroflexin 3 [Source:MGI Symbol;Acc:MGI:2137679] |
| Tnfaip8l2 | ENSMUSG00000013707 | 1.114796058 | 0.008416953 | tumor necrosis factor, alpha-induced protein 8-like 2 [Source:MGI Symbol;Acc:MGI:1917019] |
| Cr2 | ENSMUSG00000026616 | 2.268028362 | 0.009527034 | complement receptor 2 [Source:MGI Symbol;Acc:MGI:88489] |
| Igkv9-123 | ENSMUSG00000076512 | 6.188781676 | 0.00962392 | immunoglobulin kappa variable 9-123 [Source:MGI Symbol;Acc:MGI:3643848] |
| Tifa | ENSMUSG00000046688 | 1.231751008 | 0.009936202 | TRAF-interacting protein with forkhead-associated domain [Source:MGI Symbol;Acc:MGI:2182965] |

adjusted P value <=0.01

Fold change >= 2

**Table 6-5. Genes significantly up-regulated in immature B cell subsets in IgNL without stimuli compare to IgBM without stimuli.**

| Symbol | Ensembl gene id | logFC (NL-R10/BM-R10) | adj.P.val | Annotation |
|---|---|---|---|---|
| Mzb1 | ENSMUSG00000024353 | 1.68216621 | 1.39E-30 | marginal zone B and B1 cell-specific protein 1 [Source:MGI Symbol;Acc:MGI:1917066] |
| Irf7 | ENSMUSG00000025498 | 4.16909749 | 1.19E-29 | interferon regulatory factor 7 [Source:MGI Symbol;Acc:MGI:1859212] |
| Rasa3 | ENSMUSG00000031453 | 1.81031627 | 1.25E-29 | RAS p21 protein activator 3 [Source:MGI Symbol;Acc:MGI:1197013] |
| Ifi208 | ENSMUSG00000066677 | 2.28077092 | 6.93E-27 | interferon activated gene 208 [Source:MGI Symbol;Acc:MGI:2442822] |
| Cd36 | ENSMUSG00000002944 | 1.66290112 | 3.45E-26 | CD36 molecule [Source:MGI Symbol;Acc:MGI:107899] |
| Fstl1 | ENSMUSG00000022816 | 5.93596621 | 1.32E-25 | follistatin-like 1 [Source:MGI Symbol;Acc:MGI:102793] |
| Usp18 | ENSMUSG00000030107 | 3.2536046 | 2.67E-25 | ubiquitin specific peptidase 18 [Source:MGI Symbol;Acc:MGI:1344364] |
| Ifi206 | ENSMUSG00000037849 | 2.45227942 | 3.35E-24 | interferon activated gene 206 [Source:MGI Symbol;Acc:MGI:3646410] |
| Mndal | ENSMUSG00000090272 | 1.1919967 | 8.29E-24 | myeloid nuclear differentiation antigen like [Source:MGI Symbol;Acc:MGI:3780953] |
| Mitd1 | ENSMUSG00000026088 | 2.02289716 | 5.24E-23 | MIT, microtubule interacting and transport, domain containing 1 [Source:MGI Symbol;Acc:MGI:1916278] |
| 1600014C10Rik | ENSMUSG00000054676 | 2.33379239 | 3.32E-21 | RIKEN cDNA 1600014C10 gene [Source:MGI Symbol;Acc:MGI:1919494] |
| Acp5 | ENSMUSG00000001348 | 1.45417968 | 7.88E-21 | acid phosphatase 5, tartrate resistant [Source:MGI Symbol;Acc:MGI:87883] |
| Traf5 | ENSMUSG00000026637 | 1.94821546 | 1.64E-18 | TNF receptor-associated factor 5 [Source:MGI Symbol;Acc:MGI:107548] |
| Hspa8 | ENSMUSG00000015656 | 1.1203729 | 1.87E-18 | heat shock protein 8 [Source:MGI Symbol;Acc:MGI:105384] |
| Arl5c | ENSMUSG00000038352 | 1.49084401 | 1.98E-18 | ADP-ribosylation factor-like 5C [Source:MGI Symbol;Acc:MGI:3028577] |
| Rtp4 | ENSMUSG00000033355 | 3.39329904 | 3.12E-17 | receptor transporter protein 4 [Source:MGI Symbol;Acc:MGI:1915025] |
| Trim25 | ENSMUSG00000000275 | 1.2482828 | 3.12E-17 | tripartite motif-containing 25 [Source:MGI Symbol;Acc:MGI:102749] |
| Parp9 | ENSMUSG00000022906 | 1.61523806 | 4.16E-17 | poly (ADP-ribose) polymerase family, member 9 [Source:MGI Symbol;Acc:MGI:1933117] |
| Slc25a20 | ENSMUSG00000032602 | 2.05228748 | 9.30E-17 | solute carrier family 25 (mitochondrial carnitine/acylcarnitine translocase), member 20 [Source:MGI Symbol;Acc:MGI:1928738] |
| Gm1966 | ENSMUSG00000073902 | 2.60642341 | 1.44E-16 | predicted gene 1966 [Source:MGI Symbol;Acc:MGI:3584360] |
| Cst3 | ENSMUSG00000027447 | 1.34608102 | 2.25E-16 | cystatin C [Source:MGI Symbol;Acc:MGI:102519] |
| Ifi214 | ENSMUSG00000070501 | 1.73000143 | 2.82E-16 | interferon activated gene 214 [Source:MGI Symbol;Acc:MGI:3584522] |
| S100a11 | ENSMUSG00000027907 | 1.23850137 | 3.56E-16 | S100 calcium binding protein A11 [Source:MGI Symbol;Acc:MGI:1338798] |
| Sparc | ENSMUSG00000018593 | 7.68237745 | 3.65E-16 | secreted acidic cysteine rich glycoprotein [Source:MGI Symbol;Acc:MGI:98373] |
| Ifi35 | ENSMUSG00000010358 | 1.54839264 | 1.29E-15 | interferon-induced protein 35 [Source:MGI Symbol;Acc:MGI:1917360] |
| Xaf1 | ENSMUSG00000040483 | 2.13814812 | 6.71E-15 | XIAP associated factor 1 [Source:MGI Symbol;Acc:MGI:3772572] |
| Ifitm3 | ENSMUSG00000025492 | 3.78651702 | 3.08E-14 | interferon induced transmembrane protein 3 [Source:MGI Symbol;Acc:MGI:1913391] |
| Ifit2 | ENSMUSG00000045932 | 3.13120218 | 3.08E-14 | interferon-induced protein with tetratricopeptide repeats 2 [Source:MGI Symbol;Acc:MGI:99449] |
| Ifi213 | ENSMUSG00000073491 | 2.95417955 | 4.24E-14 | interferon activated gene 213 [Source:MGI Symbol;Acc:MGI:3695276] |
| Zufsp | ENSMUSG00000039531 | 1.44017325 | 4.24E-14 | zinc finger with UFM1-specific peptidase domain [Source:MGI Symbol;Acc:MGI:1919830] |
| Trim30a | ENSMUSG00000030921 | 2.46746757 | 5.11E-14 | tripartite motif-containing 30A [Source:MGI Symbol;Acc:MGI:98178] |
| BC049715 | ENSMUSG00000047515 | 6.95955986 | 8.25E-14 | cDNA sequence BC049715 [Source:MGI Symbol;Acc:MGI:3605234] |
| Cmpk2 | ENSMUSG00000020638 | 2.45780944 | 2.14E-13 | cytidine monophosphate (UMP-CMP) kinase 2, mitochondrial [Source:MGI Symbol;Acc:MGI:99830] |
| Sh2d3c | ENSMUSG00000059013 | 1.33724531 | 2.19E-13 | SH2 domain containing 3C [Source:MGI Symbol;Acc:MGI:1351631] |
| Ptgr1 | ENSMUSG00000028378 | 1.77959633 | 3.81E-13 | prostaglandin reductase 1 [Source:MGI Symbol;Acc:MGI:1914353] |
| Mgst2 | ENSMUSG00000074604 | 2.62682651 | 3.97E-13 | microsomal glutathione S-transferase 2 [Source:MGI Symbol;Acc:MGI:2448481] |
| Ifi209 | ENSMUSG00000043263 | 1.22679612 | 5.51E-13 | interferon activated gene 209 [Source:MGI Symbol;Acc:MGI:2138243] |
| BC147527 | ENSMUSG00000094796 | 1.26639086 | 5.85E-13 | cDNA sequence BC147527 [Source:MGI Symbol;Acc:MGI:4840510] |
| Zc3hav1 | ENSMUSG00000029826 | 1.27401123 | 9.01E-13 | zinc finger CCCH type, antiviral 1 [Source:MGI Symbol;Acc:MGI:1926031] |
| S100a10 | ENSMUSG00000041959 | 1.29430839 | 1.01E-12 | S100 calcium binding protein A10 (calpactin) [Source:MGI Symbol;Acc:MGI:1339468] |
| Stat1 | ENSMUSG00000026104 | 1.71940525 | 1.17E-12 | signal transducer and activator of transcription 1 [Source:MGI Symbol;Acc:MGI:103063] |
| Gvin1 | ENSMUSG00000045868 | 2.49696857 | 1.25E-12 | GTPase, very large interferon inducible 1 [Source:MGI Symbol;Acc:MGI:1921808] |
| Klf3 | ENSMUSG00000029178 | 1.65837729 | 1.30E-12 | Kruppel-like factor 3 (basic) [Source:MGI Symbol;Acc:MGI:1342773] |
| Cd86 | ENSMUSG00000022901 | 1.96152207 | 3.97E-12 | CD86 antigen [Source:MGI Symbol;Acc:MGI:101773] |
| Gm15987 | ENSMUSG00000085786 | 2.00753658 | 6.17E-12 | predicted gene 15987 [Source:MGI Symbol;Acc:MGI:3801849] |
| Tcp11l2 | ENSMUSG00000020034 | 1.19149657 | 6.17E-12 | t-complex 11 (mouse) like 2 [Source:MGI Symbol;Acc:MGI:2444679] |
| Evl | ENSMUSG00000021262 | 1.97061325 | 6.70E-12 | Ena-vasodilator stimulated phosphoprotein [Source:MGI Symbol;Acc:MGI:1194884] |
| Irgm1 | ENSMUSG00000046879 | 1.91721887 | 6.99E-12 | immunity-related GTPase family M member 1 [Source:MGI Symbol;Acc:MGI:107567] |
| Cotl1 | ENSMUSG00000031827 | 1.32755188 | 8.98E-12 | coactosin-like 1 (Dictyostelium) [Source:MGI Symbol;Acc:MGI:1919292] |
| Gimap4 | ENSMUSG00000054435 | 4.17701707 | 9.12E-12 | GTPase, IMAP family member 4 [Source:MGI Symbol;Acc:MGI:1349656] |
| Sp110 | ENSMUSG00000070034 | 1.2671096 | 1.01E-11 | Sp110 nuclear body protein [Source:MGI Symbol;Acc:MGI:1923364] |
| Tmem184b | ENSMUSG00000009035 | 1.32233243 | 1.31E-11 | transmembrane protein 184b [Source:MGI Symbol;Acc:MGI:2445179] |
| Lfng | ENSMUSG00000029570 | 2.44307481 | 1.42E-11 | LFNG O-fucosylpeptide 3-beta-N-acetylglucosaminyltransferase [Source:MGI Symbol;Acc:MGI:1095413] |
| Gm4070 | ENSMUSG00000078606 | 4.09050936 | 1.82E-11 | predicted gene 4070 [Source:MGI Symbol;Acc:MGI:3782245] |
| Gmfg | ENSMUSG00000060791 | 1.15143532 | 3.55E-11 | glia maturation factor, gamma [Source:MGI Symbol;Acc:MGI:1927135] |
| Vsir | ENSMUSG00000020101 | 7.22321984 | 4.77E-11 | V-set immunoregulatory receptor [Source:MGI Symbol;Acc:MGI:1921298] |
| Ass1 | ENSMUSG00000076441 | 1.8055888 | 6.13E-11 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Ifi47 | ENSMUSG00000078920 | 1.98753579 | 1.03E-10 | interferon gamma inducible protein 47 [Source:MGI Symbol;Acc:MGI:99448] |
| Lax1 | ENSMUSG00000051998 | 2.55891133 | 1.06E-10 | lymphocyte transmembrane adaptor 1 [Source:MGI Symbol;Acc:MGI:2443362] |
| Cd55 | ENSMUSG00000026399 | 1.03088377 | 1.10E-10 | CD55 molecule, decay accelerating factor for complement [Source:MGI Symbol;Acc:MGI:104850] |
| Rnf213 | ENSMUSG00000070327 | 2.86250957 | 1.22E-10 | ring finger protein 213 [Source:MGI Symbol;Acc:MGI:1289196] |
| Eif2ak2 | ENSMUSG00000024079 | 2.47272584 | 2.01E-10 | eukaryotic translation initiation factor 2-alpha kinase 2 [Source:MGI Symbol;Acc:MGI:1353449] |
| Pld4 | ENSMUSG00000052160 | 1.4282929 | 2.33E-10 | phospholipase D family, member 4 [Source:MGI Symbol;Acc:MGI:2144765] |
| Evi2a | ENSMUSG00000078771 | 1.93534853 | 3.06E-10 | ecotropic viral integration site 2a [Source:MGI Symbol;Acc:MGI:95458] |
| Tpst1 | ENSMUSG00000034118 | 1.51188255 | 3.46E-10 | protein-tyrosine sulfotransferase 1 [Source:MGI Symbol;Acc:MGI:1298231] |
| Chd7 | ENSMUSG00000041235 | 2.97657677 | 3.50E-10 | chromodomain helicase DNA binding protein 7 [Source:MGI Symbol;Acc:MGI:2444748] |
| Oas1a | ENSMUSG00000052776 | 2.96950166 | 4.01E-10 | 2'-5' oligoadenylate synthetase 1A [Source:MGI Symbol;Acc:MGI:2180860] |
| Fh1 | ENSMUSG00000026526 | 1.01005092 | 4.01E-10 | fumarate hydratase 1 [Source:MGI Symbol;Acc:MGI:95530] |
| Tmsb4x | ENSMUSG00000049775 | 1.42413262 | 5.08E-10 | thymosin, beta 4, X chromosome [Source:MGI Symbol;Acc:MGI:99510] |
| Rrbp1 | ENSMUSG00000027422 | 1.66843691 | 5.18E-10 | ribosome binding protein 1 [Source:MGI Symbol;Acc:MGI:1932395] |
| Tmem173 | ENSMUSG00000024349 | 1.71863216 | 5.69E-10 | transmembrane protein 173 [Source:MGI Symbol;Acc:MGI:1919762] |
| Lgals3bp | ENSMUSG00000033880 | 3.30916462 | 5.82E-10 | lectin, galactoside-binding, soluble, 3 binding protein [Source:MGI Symbol;Acc:MGI:99554] |
| Phf11b | ENSMUSG00000091649 | 1.52177415 | 6.54E-10 | PHD finger protein 11B [Source:MGI Symbol;Acc:MGI:3645789] |
| Irf9 | ENSMUSG00000002325 | 1.26609473 | 8.00E-10 | interferon regulatory factor 9 [Source:MGI Symbol;Acc:MGI:107587] |
| Pml | ENSMUSG00000036986 | 1.12374064 | 8.00E-10 | promyelocytic leukemia [Source:MGI Symbol;Acc:MGI:104662] |
| Hsh2d | ENSMUSG00000062007 | 1.63194465 | 8.31E-10 | hematopoietic SH2 domain containing [Source:MGI Symbol;Acc:MGI:2676364] |
| Bptf | ENSMUSG00000040481 | 1.09497278 | 8.32E-10 | bromodomain PHD finger transcription factor [Source:MGI Symbol;Acc:MGI:2444008] |
| Zbp1 | ENSMUSG00000027514 | 1.8197893 | 9.10E-10 | Z-DNA binding protein 1 [Source:MGI Symbol;Acc:MGI:1927449] |
| Ifi203 | ENSMUSG00000039997 | 1.37414244 | 2.11E-09 | interferon activated gene 203 [Source:MGI Symbol;Acc:MGI:96428] |

(Continue next page)

| | | | | |
|---|---|---|---|---|
| Susd3 | ENSMUSG00000021384 | 1.22982874 | 2.48E-09 | sushi domain containing 3 [Source:MGI Symbol;Acc:MGI:1913579] |
| S100a6 | ENSMUSG00000001025 | 4.29605915 | 2.78E-09 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Itga4 | ENSMUSG00000027009 | 1.27584088 | 3.42E-09 | integrin alpha 4 [Source:MGI Symbol;Acc:MGI:96603] |
| Dhx58 | ENSMUSG00000017830 | 2.17773993 | 3.44E-09 | DEXH (Asp-Glu-X-His) box polypeptide 58 [Source:MGI Symbol;Acc:MGI:1931560] |
| Cisd3 | ENSMUSG00000078695 | 1.77389723 | 4.35E-09 | CDGSH iron sulfur domain 3 [Source:MGI Symbol;Acc:MGI:101788] |
| Irgm2 | ENSMUSG00000069874 | 2.21968618 | 4.49E-09 | immunity-related GTPase family M member 2 [Source:MGI Symbol;Acc:MGI:1926262] |
| Parp14 | ENSMUSG00000034422 | 2.01743844 | 8.61E-09 | poly (ADP-ribose) polymerase family, member 14 [Source:MGI Symbol;Acc:MGI:1919489] |
| Bst2 | ENSMUSG00000046718 | 2.26954927 | 9.56E-09 | bone marrow stromal cell antigen 2 [Source:MGI Symbol;Acc:MGI:1916800] |
| S1pr4 | ENSMUSG00000044199 | 1.09181681 | 9.56E-09 | sphingosine-1-phosphate receptor 4 [Source:MGI Symbol;Acc:MGI:1333809] |
| Ifi27l2a | ENSMUSG00000079017 | 1.91102946 | 9.83E-09 | interferon, alpha-inducible protein 27 like 2A [Source:MGI Symbol;Acc:MGI:1924183] |
| Ckb | ENSMUSG00000001270 | 7.74270725 | 1.03E-08 | creatine kinase, brain [Source:MGI Symbol;Acc:MGI:88407] |
| Tnni2 | ENSMUSG00000031097 | 2.29342219 | 1.05E-08 | troponin I, skeletal, fast 2 [Source:MGI Symbol;Acc:MGI:105070] |
| Ifit1bl1 | ENSMUSG00000079339 | 4.60850146 | 1.15E-08 | interferon induced protein with tetratricpeptide repeats 1B like 1 [Source:MGI Symbol;Acc:MGI:3650685] |
| Slfn2 | ENSMUSG00000072620 | 2.15164143 | 1.17E-08 | schlafen 2 [Source:MGI Symbol;Acc:MGI:1313258] |
| Cep164 | ENSMUSG00000043987 | 1.81563377 | 1.19E-08 | centrosomal protein 164 [Source:MGI Symbol;Acc:MGI:2384878] |
| Rasal3 | ENSMUSG00000052142 | 1.28152727 | 1.36E-08 | RAS protein activator like 3 [Source:MGI Symbol;Acc:MGI:2444128] |
| Id3 | ENSMUSG00000007872 | 1.06278491 | 1.79E-08 | inhibitor of DNA binding 3 [Source:MGI Symbol;Acc:MGI:96398] |
| Agl | ENSMUSG00000033400 | 3.04388931 | 2.44E-08 | amylo-1,6-glucosidase, 4-alpha-glucanotransferase [Source:MGI Symbol;Acc:MGI:1924809] |
| Dusp5 | ENSMUSG00000034765 | 2.07573254 | 2.78E-08 | dual specificity phosphatase 5 [Source:MGI Symbol;Acc:MGI:2685183] |
| Cplx2 | ENSMUSG00000025867 | 2.25354671 | 3.28E-08 | complexin 2 [Source:MGI Symbol;Acc:MGI:104726] |
| Isg20 | ENSMUSG00000039236 | 2.27544802 | 3.32E-08 | interferon-stimulated protein [Source:MGI Symbol;Acc:MGI:1928895] |
| Bhlhe41 | ENSMUSG00000030256 | 1.93641568 | 3.41E-08 | basic helix-loop-helix family, member e41 [Source:MGI Symbol;Acc:MGI:1930704] |
| Arid3a | ENSMUSG00000019564 | 1.93811593 | 5.26E-08 | AT rich interactive domain 3A (BRIGHT-like) [Source:MGI Symbol;Acc:MGI:1328360] |
| Daxx | ENSMUSG00000002307 | 1.35162568 | 6.77E-08 | Fas death domain-associated protein [Source:MGI Symbol;Acc:MGI:1197015] |
| Twf2 | ENSMUSG00000023277 | 1.02473623 | 8.50E-08 | twinfilin actin binding protein 2 [Source:MGI Symbol;Acc:MGI:1346078] |
| Bex4 | ENSMUSG00000047844 | 6.91718379 | 8.86E-08 | brain expressed X-linked 4 [Source:MGI Symbol;Acc:MGI:3606746] |
| Lsp1 | ENSMUSG00000018819 | 1.15095395 | 1.18E-07 | lymphocyte specific 1 [Source:MGI Symbol;Acc:MGI:96832] |
| Btg2 | ENSMUSG00000020423 | 1.29853366 | 1.49E-07 | B cell translocation gene 2, anti-proliferative [Source:MGI Symbol;Acc:MGI:108384] |
| Cep89 | ENSMUSG00000023072 | 1.52577716 | 1.57E-07 | centrosomal protein 89 [Source:MGI Symbol;Acc:MGI:1919390] |
| Stac2 | ENSMUSG00000017400 | 4.74685421 | 2.36E-07 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Tor3a | ENSMUSG00000060519 | 1.98157 | 2.41E-07 | torsin family 3, member A [Source:MGI Symbol;Acc:MGI:1353652] |
| Fgd2 | ENSMUSG00000024013 | 1.79322717 | 3.03E-07 | FYVE, RhoGEF and PH domain containing 2 [Source:MGI Symbol;Acc:MGI:1347084] |
| Vangl2 | ENSMUSG00000026556 | 1.47060806 | 3.37E-07 | vang-like 2 (van gogh, Drosophila) [Source:MGI Symbol;Acc:MGI:2135272] |
| Gm5431 | ENSMUSG00000058163 | 5.52858844 | 4.01E-07 | predicted gene 5431 [Source:MGI Symbol;Acc:MGI:3645205] |
| Dgka | ENSMUSG00000025357 | 1.65341529 | 4.67E-07 | diacylglycerol kinase, alpha [Source:MGI Symbol;Acc:MGI:102952] |
| Sfn | ENSMUSG00000047281 | 3.02169928 | 5.83E-07 | stratifin [Source:MGI Symbol;Acc:MGI:1891831] |
| Mrpl30 | ENSMUSG00000026087 | 1.1083015 | 5.83E-07 | mitochondrial ribosomal protein L30 [Source:MGI Symbol;Acc:MGI:1333820] |
| Arhgap9 | ENSMUSG00000040345 | 1.14674356 | 6.42E-07 | Rho GTPase activating protein 9 [Source:MGI Symbol;Acc:MGI:2143764] |
| Gm26637 | ENSMUSG00000097567 | 2.42264635 | 6.96E-07 | predicted gene, 26637 [Source:MGI Symbol;Acc:MGI:5477131] |
| 4833407H14Rik | ENSMUSG00000097779 | 1.21903225 | 9.72E-07 | RIKEN cDNA 4833407H14 gene [Source:MGI Symbol;Acc:MGI:1921149] |
| Gimap3 | ENSMUSG00000039264 | 2.35173747 | 9.86E-07 | GTPase, IMAP family member 3 [Source:MGI Symbol;Acc:MGI:1932723] |
| Gpr137b | ENSMUSG00000021306 | 1.02155338 | 1.01E-06 | G protein-coupled receptor 137B [Source:MGI Symbol;Acc:MGI:1891463] |
| Lpxn | ENSMUSG00000024696 | 1.14508246 | 1.11E-06 | leupaxin [Source:MGI Symbol;Acc:MGI:2147677] |
| Dtx3l | ENSMUSG00000049502 | 1.6323153 | 1.16E-06 | deltex 3-like, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:2656973] |
| Igtp | ENSMUSG00000078853 | 2.03316459 | 1.23E-06 | interferon gamma induced GTPase [Source:MGI Symbol;Acc:MGI:107729] |
| Lst1 | ENSMUSG00000073412 | 2.41686988 | 1.38E-06 | leukocyte specific transcript 1 [Source:MGI Symbol;Acc:MGI:1096324] |
| Trim30d | ENSMUSG00000057596 | 3.0756052 | 1.67E-06 | tripartite motif-containing 30D [Source:MGI Symbol;Acc:MGI:3035181] |
| Trafd1 | ENSMUSG00000042726 | 1.73701446 | 1.74E-06 | TRAF type zinc finger domain containing 1 [Source:MGI Symbol;Acc:MGI:1923551] |
| Nampt | ENSMUSG00000020572 | 1.26778777 | 1.94E-06 | nicotinamide phosphoribosyltransferase [Source:MGI Symbol;Acc:MGI:1929865] |
| Vasp | ENSMUSG00000030403 | 1.10456934 | 1.96E-06 | vasodilator-stimulated phosphoprotein [Source:MGI Symbol;Acc:MGI:109268] |
| Tor1aip1 | ENSMUSG00000026466 | 1.04934112 | 2.27E-06 | torsin A interacting protein 1 [Source:MGI Symbol;Acc:MGI:3582693] |
| Samd9l | ENSMUSG00000047735 | 1.18726319 | 2.44E-06 | sterile alpha motif domain containing 9-like [Source:MGI Symbol;Acc:MGI:1343184] |
| Sp140 | ENSMUSG00000070031 | 1.00820995 | 2.52E-06 | Sp140 nuclear body protein [Source:MGI Symbol;Acc:MGI:3702467] |
| Sell | ENSMUSG00000026581 | 1.37325315 | 2.65E-06 | selectin, lymphocyte [Source:MGI Symbol;Acc:MGI:98279] |
| Bcl11a | ENSMUSG00000000861 | 1.3226021 | 3.13E-06 | B cell CLL/lymphoma 11A (zinc finger protein) [Source:MGI Symbol;Acc:MGI:106190] |
| Kcnn4 | ENSMUSG00000054342 | 5.07779873 | 3.33E-06 | potassium intermediate/small conductance calcium-activated channel, subfamily N, member 4 [Source:MGI Symbol;Acc:MGI:1277957] |
| Vim | ENSMUSG00000026728 | 1.0336296 | 3.35E-06 | vimentin [Source:MGI Symbol;Acc:MGI:98932] |
| Lrrc8c | ENSMUSG00000054720 | 1.07676963 | 3.47E-06 | leucine rich repeat containing 8 family, member C [Source:MGI Symbol;Acc:MGI:2140839] |
| Gm13919 | ENSMUSG00000085417 | 1.17743734 | 4.66E-06 | predicted gene 13919 [Source:MGI Symbol;Acc:MGI:3651616] |
| Selenop | ENSMUSG00000064373 | 2.04241271 | 5.90E-06 | selenoprotein P [Source:MGI Symbol;Acc:MGI:894288] |
| 2900092N22Rik | ENSMUSG00000104034 | 7.04947932 | 5.99E-06 | RIKEN cDNA 2900092N22 gene [Source:MGI Symbol;Acc:MGI:1920357] |
| Ebi3 | ENSMUSG00000003206 | 4.09461429 | 5.99E-06 | Epstein-Barr virus induced gene 3 [Source:MGI Symbol;Acc:MGI:1354171] |
| Tnfaip8l2 | ENSMUSG00000013707 | 1.01240915 | 6.06E-06 | tumor necrosis factor, alpha-induced protein 8-like 2 [Source:MGI Symbol;Acc:MGI:1917019] |
| Snx20 | ENSMUSG00000031662 | 1.0398626 | 7.16E-06 | sorting nexin 20 [Source:MGI Symbol;Acc:MGI:1918857] |
| Smpdl3a | ENSMUSG00000019872 | 1.3292765 | 7.17E-06 | sphingomyelin phosphodiesterase, acid-like 3A [Source:MGI Symbol;Acc:MGI:1931437] |
| 1700016K19Rik | ENSMUSG00000053783 | 8.13080793 | 7.20E-06 | RIKEN cDNA 1700016K19 gene [Source:MGI Symbol;Acc:MGI:1921480] |
| Fam46a | ENSMUSG00000032265 | 2.26125805 | 7.61E-06 | family with sequence similarity 46, member A [Source:MGI Symbol;Acc:MGI:2670964] |
| Tmem144 | ENSMUSG00000027956 | 7.98570598 | 7.96E-06 | transmembrane protein 144 [Source:MGI Symbol;Acc:MGI:1917902] |
| Entpd1 | ENSMUSG00000048120 | 1.82530019 | 8.35E-06 | ectonucleoside triphosphate diphosphohydrolase 1 [Source:MGI Symbol;Acc:MGI:102805] |
| Lipa | ENSMUSG00000024781 | 1.4044045 | 8.72E-06 | lysosomal acid lipase A [Source:MGI Symbol;Acc:MGI:96789] |
| Oasl1 | ENSMUSG00000041827 | 3.78066663 | 8.77E-06 | 2'-5' oligoadenylate synthetase-like 1 [Source:MGI Symbol;Acc:MGI:2180849] |
| Inpp5k | ENSMUSG00000006127 | 1.09008227 | 8.92E-06 | inositol polyphosphate 5-phosphatase K [Source:MGI Symbol;Acc:MGI:1194899] |
| Epsti1 | ENSMUSG00000022014 | 1.03286996 | 9.46E-06 | epithelial stromal interaction 1 (breast) [Source:MGI Symbol;Acc:MGI:1915168] |
| Sspn | ENSMUSG00000030255 | 6.5864676 | 9.54E-06 | sarcospan [Source:MGI Symbol;Acc:MGI:1353511] |
| Ifi30 | ENSMUSG00000031838 | 1.00453977 | 1.01E-05 | interferon gamma inducible protein 30 [Source:MGI Symbol;Acc:MGI:2137648] |
| Fkbp11 | ENSMUSG00000003355 | 4.19485595 | 1.02E-05 | FK506 binding protein 11 [Source:MGI Symbol;Acc:MGI:1913370] |
| Gm8995 | ENSMUSG00000063286 | 1.14612991 | 1.04E-05 | predicted gene 8995 [Source:MGI Symbol;Acc:MGI:3644223] |
| Hipk3 | ENSMUSG00000027177 | 1.60579445 | 1.15E-05 | homeodomain interacting protein kinase 3 [Source:MGI Symbol;Acc:MGI:1314882] |
| Plaur | ENSMUSG00000046223 | 2.36347112 | 1.32E-05 | plasminogen activator, urokinase receptor [Source:MGI Symbol;Acc:MGI:97612] |
| Bin2 | ENSMUSG00000098112 | 1.07423691 | 1.45E-05 | bridging integrator 2 [Source:MGI Symbol;Acc:MGI:3611448] |
| 9930111J21Rik2 | ENSMUSG00000069892 | 1.15831754 | 1.51E-05 | RIKEN cDNA 9930111J21 gene 2 [Source:MGI Symbol;Acc:MGI:3711310] |
| Fam212a | ENSMUSG00000042106 | 2.05547675 | 2.47E-05 | family with sequence similarity 212, member A [Source:MGI Symbol;Acc:MGI:1915426] |
| Cdh23 | ENSMUSG00000012819 | 4.0387848 | 2.58E-05 | cadherin 23 (otocadherin) [Source:MGI Symbol;Acc:MGI:1890219] |
| Pqlc1 | ENSMUSG00000034006 | 1.44936391 | 2.92E-05 | PQ loop repeat containing 1 [Source:MGI Symbol;Acc:MGI:1914193] |
| Kctd14 | ENSMUSG00000051727 | 3.7887855 | 3.05E-05 | potassium channel tetramerisation domain containing 14 [Source:MGI Symbol;Acc:MGI:1289222] |
| Scimp | ENSMUSG00000057135 | 2.90563465 | 3.91E-05 | SLP adaptor and CSK interacting membrane protein [Source:MGI Symbol;Acc:MGI:3610314] |
| Mpeg1 | ENSMUSG00000046805 | 4.67123744 | 4.35E-05 | macrophage expressed gene 1 [Source:MGI Symbol;Acc:MGI:1333743] |
| Shisa5 | ENSMUSG00000025647 | 1.61465345 | 4.49E-05 | shisa family member 5 [Source:MGI Symbol;Acc:MGI:1915044] |
| Apobec2 | ENSMUSG00000040694 | 6.83554139 | 4.65E-05 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide 2 [Source:MGI Symbol;Acc:MGI:1343178] |
| Atp1b1 | ENSMUSG00000026576 | 1.10024389 | 4.65E-05 | ATPase, Na+/K+ transporting, beta 1 polypeptide [Source:MGI Symbol;Acc:MGI:88108] |

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| | | | | |
|---|---|---|---|---|
| Fabp1 | ENSMUSG00000054422 | 7.77841177 | 4.93E-05 | fatty acid binding protein 1, liver [Source:MGI Symbol;Acc:MGI:95479] |
| Slfn8 | ENSMUSG00000035208 | 2.0044834 | 5.75E-05 | schlafen 8 [Source:MGI Symbol;Acc:MGI:2672859] |
| Itgb7 | ENSMUSG00000001281 | 2.14084435 | 6.23E-05 | integrin beta 7 [Source:MGI Symbol;Acc:MGI:96616] |
| Eng | ENSMUSG00000026814 | 4.40767238 | 6.36E-05 | endoglin [Source:MGI Symbol;Acc:MGI:95392] |
| Gm4759 | ENSMUSG00000053541 | 1.37755372 | 7.23E-05 | predicted gene 4759 [Source:MGI Symbol;Acc:MGI:3647753] |
| Socs3 | ENSMUSG00000053113 | 3.32607237 | 8.39E-05 | suppressor of cytokine signaling 3 [Source:MGI Symbol;Acc:MGI:1201791] |
| Gmpr | ENSMUSG00000000253 | 4.15223954 | 8.44E-05 | guanosine monophosphate reductase [Source:MGI Symbol;Acc:MGI:1913605] |
| BE692007 | ENSMUSG00000099757 | 1.40619943 | 8.49E-05 | expressed sequence BE692007 [Source:MGI Symbol;Acc:MGI:3035348] |
| Cd52 | ENSMUSG00000000682 | 1.42033309 | 0.00011387 | CD52 antigen [Source:MGI Symbol;Acc:MGI:1346088] |
| Bbx | ENSMUSG00000022641 | 1.1551312 | 0.00011639 | bobby sox HMG box containing [Source:MGI Symbol;Acc:MGI:1917758] |
| Krtcap3 | ENSMUSG00000029149 | 3.27163396 | 0.00012556 | keratinocyte associated protein 3 [Source:MGI Symbol;Acc:MGI:1917065] |
| Isg15 | ENSMUSG00000035692 | 3.63281759 | 0.00014335 | ISG15 ubiquitin-like modifier [Source:MGI Symbol;Acc:MGI:1855694] |
| Gimap8 | ENSMUSG00000064262 | 1.95205755 | 0.00016433 | GTPase, IMAP family member 8 [Source:MGI Symbol;Acc:MGI:2685303] |
| Olfr56 | ENSMUSG00000040328 | 3.3749074 | 0.00016827 | olfactory receptor 56 [Source:MGI Symbol;Acc:MGI:1333785] |
| Gsap | ENSMUSG00000039934 | 3.76278055 | 0.00017148 | gamma-secretase activating protein [Source:MGI Symbol;Acc:MGI:2442259] |
| Ly6c2 | ENSMUSG00000022584 | 3.63931809 | 0.00017187 | lymphocyte antigen 6 complex, locus C2 [Source:MGI Symbol;Acc:MGI:3712069] |
| Fam234a | ENSMUSG00000024187 | 6.20132331 | 0.00017337 | family with sequence similarity 234, member A [Source:MGI Symbol;Acc:MGI:2146854] |
| Ifit1 | ENSMUSG00000034459 | 3.97920787 | 0.00020738 | interferon-induced protein with tetratricopeptide repeats 1 [Source:MGI Symbol;Acc:MGI:99450] |
| Syngr2 | ENSMUSG00000048277 | 1.31356279 | 0.00028632 | synaptogyrin 2 [Source:MGI Symbol;Acc:MGI:1328324] |
| Rflnb | ENSMUSG00000020846 | 4.55713029 | 0.00029033 | refilin B [Source:MGI Symbol;Acc:MGI:1923816] |
| Tor1aip2 | ENSMUSG00000050565 | 1.02176918 | 0.00035744 | torsin A interacting protein 2 [Source:MGI Symbol;Acc:MGI:3582695] |
| Ermap | ENSMUSG00000028644 | 3.45760206 | 0.00039133 | erythroblast membrane-associated protein [Source:MGI Symbol;Acc:MGI:1349816] |
| March1 | ENSMUSG00000036469 | 1.52978651 | 0.00041856 | membrane-associated ring finger (C3HC4) 1 [Source:MGI Symbol;Acc:MGI:1920175] |
| Adgrl2 | ENSMUSG00000028184 | 3.05916029 | 0.0004473 | adhesion G protein-coupled receptor L2 [Source:MGI Symbol;Acc:MGI:2139714] |
| Samhd1 | ENSMUSG00000027639 | 1.19561157 | 0.00044794 | SAM domain and HD domain, 1 [Source:MGI Symbol;Acc:MGI:1927468] |
| Helz2 | ENSMUSG00000027580 | 1.85545517 | 0.00047161 | helicase with zinc finger 2, transcriptional coactivator [Source:MGI Symbol;Acc:MGI:2385169] |
| Hpse | ENSMUSG00000035273 | 1.51911253 | 0.00048207 | heparanase [Source:MGI Symbol;Acc:MGI:1343124] |
| Txnip | ENSMUSG00000038393 | 1.21948792 | 0.00052799 | thioredoxin interacting protein [Source:MGI Symbol;Acc:MGI:1889549] |
| Rhobtb1 | ENSMUSG00000019944 | 5.19047722 | 0.00055109 | Rho-related BTB domain containing 1 [Source:MGI Symbol;Acc:MGI:1916538] |
| Ddx58 | ENSMUSG00000040296 | 1.17798204 | 0.00055109 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 58 [Source:MGI Symbol;Acc:MGI:2442858] |
| Oasl2 | ENSMUSG00000029561 | 2.68450421 | 0.00059252 | 2'-5' oligoadenylate synthetase-like 2 [Source:MGI Symbol;Acc:MGI:1344390] |
| Def6 | ENSMUSG00000002257 | 1.05717451 | 0.00064752 | differentially expressed in FDCP 6 [Source:MGI Symbol;Acc:MGI:1346328] |
| Prkd2 | ENSMUSG00000041187 | 1.21822113 | 0.00066588 | protein kinase D2 [Source:MGI Symbol;Acc:MGI:2141917] |
| Plac8 | ENSMUSG00000029322 | 1.35445492 | 0.00077617 | placenta-specific 8 [Source:MGI Symbol;Acc:MGI:2445289] |
| Adrb2 | ENSMUSG00000045730 | 1.06216424 | 0.00086304 | adrenergic receptor, beta 2 [Source:MGI Symbol;Acc:MGI:87938] |
| Oas3 | ENSMUSG00000032661 | 2.96857707 | 0.0008658 | 2'-5' oligoadenylate synthetase 3 [Source:MGI Symbol;Acc:MGI:2180850] |
| Gbp9 | ENSMUSG00000029298 | 1.02075642 | 0.00101482 | guanylate-binding protein 9 [Source:MGI Symbol;Acc:MGI:3605620] |
| Rras2 | ENSMUSG00000055723 | 1.15643783 | 0.00106835 | related RAS viral (r-ras) oncogene 2 [Source:MGI Symbol;Acc:MGI:1914172] |
| Gna15 | ENSMUSG00000034792 | 1.52223731 | 0.00111169 | guanine nucleotide binding protein, alpha 15 [Source:MGI Symbol;Acc:MGI:95770] |
| Fanca | ENSMUSG00000032815 | 1.36811726 | 0.00120799 | Fanconi anemia, complementation group A [Source:MGI Symbol;Acc:MGI:1341823] |
| Slc4a7 | ENSMUSG00000021733 | 1.55076169 | 0.00126975 | solute carrier family 4, sodium bicarbonate cotransporter, member 7 [Source:MGI Symbol;Acc:MGI:2443878] |
| Ighg2b | ENSMUSG00000076613 | 1.79192544 | 0.00129895 | immunoglobulin heavy constant gamma 2B [Source:MGI Symbol;Acc:MGI:96445] |
| Gimap6 | ENSMUSG00000047867 | 1.13261583 | 0.00152414 | GTPase, IMAP family member 6 [Source:MGI Symbol;Acc:MGI:1918876] |
| Tlr7 | ENSMUSG00000044583 | 2.10385676 | 0.00164864 | toll-like receptor 7 [Source:MGI Symbol;Acc:MGI:2176882] |
| Lin28b | ENSMUSG00000063804 | 5.89166897 | 0.00165808 | lin-28 homolog B (C. elegans) [Source:MGI Symbol;Acc:MGI:3584032] |
| Spata13 | ENSMUSG00000021990 | 2.78315154 | 0.00168217 | spermatogenesis associated 13 [Source:MGI Symbol;Acc:MGI:104838] |
| Ltb | ENSMUSG00000024399 | 1.92985295 | 0.00204296 | lymphotoxin B [Source:MGI Symbol;Acc:MGI:104796] |
| Dus2 | ENSMUSG00000031901 | 1.08592556 | 0.00213984 | dihydrouridine synthase 2 [Source:MGI Symbol;Acc:MGI:1913619] |
| Ifih1 | ENSMUSG00000026896 | 2.58483925 | 0.00215095 | interferon induced with helicase C domain 1 [Source:MGI Symbol;Acc:MGI:1918836] |
| Trim34a | ENSMUSG00000056144 | 1.38883311 | 0.00244839 | tripartite motif-containing 34A [Source:MGI Symbol;Acc:MGI:2137359] |
| Nek6 | ENSMUSG00000026749 | 5.67190326 | 0.00260036 | NIMA (never in mitosis gene a)-related expressed kinase 6 [Source:MGI Symbol;Acc:MGI:1891638] |
| Sufu | ENSMUSG00000025231 | 1.33476214 | 0.00264535 | suppressor of fused homolog (Drosophila) [Source:MGI Symbol;Acc:MGI:1345643] |
| Akna | ENSMUSG00000039158 | 1.40051516 | 0.00278253 | AT-hook transcription factor [Source:MGI Symbol;Acc:MGI:2140340] |
| Mx1 | ENSMUSG00000000386 | 3.01291814 | 0.00280552 | MX dynamin-like GTPase 1 [Source:MGI Symbol;Acc:MGI:97243] |
| Amica1 | ENSMUSG00000048534 | 2.03070815 | 0.00284968 | junction adhesion molecule like [Source:MGI Symbol;Acc:MGI:2685484] |
| Scarb2 | ENSMUSG00000029426 | 1.2414962 | 0.00288465 | scavenger receptor class B, member 2 [Source:MGI Symbol;Acc:MGI:1196458] |
| Stat4 | ENSMUSG00000062939 | 1.44773739 | 0.00334542 | signal transducer and activator of transcription 4 [Source:MGI Symbol;Acc:MGI:103062] |
| N4bp3 | ENSMUSG00000001053 | 1.06694151 | 0.00353951 | NEDD4 binding protein 3 [Source:MGI Symbol;Acc:MGI:2442218] |
| I830077J02Rik | ENSMUSG00000074342 | 4.27768059 | 0.00391896 | RIKEN cDNA I830077J02 gene [Source:MGI Symbol;Acc:MGI:3588284] |
| Traf6 | ENSMUSG00000027164 | 1.08956234 | 0.00419903 | TNF receptor-associated factor 6 [Source:MGI Symbol;Acc:MGI:108072] |
| Siglech | ENSMUSG00000051504 | 3.47703852 | 0.00444096 | sialic acid binding Ig-like lectin H [Source:MGI Symbol;Acc:MGI:2443256] |
| P2ry13 | ENSMUSG00000036362 | 2.6879031 | 0.00467396 | purinergic receptor P2Y, G-protein coupled 13 [Source:MGI Symbol;Acc:MGI:1921441] |
| Cbl | ENSMUSG00000034342 | 1.5341775 | 0.00495917 | Casitas B-lineage lymphoma [Source:MGI Symbol;Acc:MGI:88279] |
| Gng2 | ENSMUSG00000043004 | 1.0412398 | 0.00498498 | guanine nucleotide binding protein (G protein), gamma 2 [Source:MGI Symbol;Acc:MGI:102705] |
| Oas1b | ENSMUSG00000029605 | 1.59701582 | 0.00511219 | 2'-5' oligoadenylate synthetase 1B [Source:MGI Symbol;Acc:MGI:97430] |
| Tgtp2 | ENSMUSG00000078921 | 2.31360739 | 0.0056649 | T cell specific GTPase 2 [Source:MGI Symbol;Acc:MGI:3710083] |
| Mycbp2 | ENSMUSG00000033004 | 1.15645072 | 0.00584373 | MYC binding protein 2 [Source:MGI Symbol;Acc:MGI:2179432] |
| Mx2 | ENSMUSG00000023341 | 3.59769882 | 0.00624358 | MX dynamin-like GTPase 2 [Source:MGI Symbol;Acc:MGI:97244] |
| Pdcd1lg2 | ENSMUSG00000016498 | 4.75771217 | 0.00782567 | programmed cell death 1 ligand 2 [Source:MGI Symbol;Acc:MGI:1930125] |
| 1700048O20Rik | ENSMUSG00000043773 | 1.53012184 | 0.00816291 | RIKEN cDNA 1700048O20 gene [Source:MGI Symbol;Acc:MGI:1920637] |
| Lpar6 | ENSMUSG00000033446 | 2.00690434 | 0.00836613 | lysophosphatidic acid receptor 6 [Source:MGI Symbol;Acc:MGI:1914418] |
| Slfn5 | ENSMUSG00000054404 | 3.26583654 | 0.00858333 | schlafen 5 [Source:MGI Symbol;Acc:MGI:1329004] |
| Lgmn | ENSMUSG00000021190 | 1.18108565 | 0.00904245 | legumain [Source:MGI Symbol;Acc:MGI:1330838] |
| Nmral1 | ENSMUSG00000063445 | 1.18047799 | 0.00911857 | NmrA-like family domain containing 1 [Source:MGI Symbol;Acc:MGI:1915074] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-6. Genes significantly up-regulated in immature B cell subsets in IgBM without stimuli compare to IgNL without stimuli.

| Symbol | Ensembl gene id | logFC (BM-R10/NL-R10) | adj.P.val | Annotation |
|---|---|---|---|---|
| H2-Q7 | ENSMUSG00000060550 | 6.03313552 | 1.72E-89 | histocompatibility 2, Q region locus 7 [Source:MGI Symbol;Acc:MGI:95936] |
| H2-Q6 | ENSMUSG00000073409 | 6.68708917 | 4.75E-89 | histocompatibility 2, Q region locus 6 [Source:MGI Symbol;Acc:MGI:95935] |
| Igll1 | ENSMUSG00000075370 | 3.5546253 | 4.85E-43 | immunoglobulin lambda-like polypeptide 1 [Source:MGI Symbol;Acc:MGI:96529] |
| Hvcn1 | ENSMUSG00000064267 | 2.25188065 | 1.54E-39 | hydrogen voltage-gated channel 1 [Source:MGI Symbol;Acc:MGI:1921346] |
| Rpgrip1 | ENSMUSG00000057132 | 3.69780117 | 1.42E-34 | retinitis pigmentosa GTPase regulator interacting protein 1 [Source:MGI Symbol;Acc:MGI:1932134] |
| Ramp1 | ENSMUSG00000034353 | 2.73761329 | 1.29E-33 | receptor (calcitonin) activity modifying protein 1 [Source:MGI Symbol;Acc:MGI:1858418] |
| Foxd2os | ENSMUSG00000085399 | 8.25432954 | 3.86E-28 | forkhead box D2, opposite strand [Source:MGI Symbol;Acc:MGI:2444065] |
| Vpreb1 | ENSMUSG00000059305 | 3.4986603 | 1.17E-23 | pre-B lymphocyte gene 1 [Source:MGI Symbol;Acc:MGI:98936] |
| Sept11 | ENSMUSG00000058013 | 1.59776047 | 2.17E-22 | septin 11 [Source:MGI Symbol;Acc:MGI:1277214] |
| Snn | ENSMUSG00000037972 | 1.70550868 | 5.33E-22 | stannin [Source:MGI Symbol;Acc:MGI:1276549] |
| Fcmr | ENSMUSG00000042474 | 2.22365561 | 2.53E-20 | Fc fragment of IgM receptor [Source:MGI Symbol;Acc:MGI:1916419] |
| Slco5a1 | ENSMUSG00000025938 | 4.67544413 | 2.60E-18 | solute carrier organic anion transporter family, member 5A1 [Source:MGI Symbol;Acc:MGI:2443431] |
| Serpinb1a | ENSMUSG00000044734 | 1.78117757 | 1.93E-15 | serine (or cysteine) peptidase inhibitor, clade B, member 1a [Source:MGI Symbol;Acc:MGI:1913472] |
| Pfkp | ENSMUSG00000021196 | 1.71161311 | 1.93E-15 | phosphofructokinase, platelet [Source:MGI Symbol;Acc:MGI:1891833] |
| Igkv9-123 | ENSMUSG00000076512 | 7.9776574 | 2.47E-15 | immunoglobulin kappa variable 9-123 [Source:MGI Symbol;Acc:MGI:3643848] |
| Lrmp | ENSMUSG00000030263 | 1.62897433 | 3.03E-15 | lymphoid-restricted membrane protein [Source:MGI Symbol;Acc:MGI:108424] |
| Ppp1r36 | ENSMUSG00000052221 | 7.36224074 | 4.05E-15 | protein phosphatase 1, regulatory subunit 36 [Source:MGI Symbol;Acc:MGI:2684916] |
| Dusp10 | ENSMUSG00000039384 | 1.92574115 | 3.38E-14 | dual specificity phosphatase 10 [Source:MGI Symbol;Acc:MGI:1927070] |
| Pla2g12a | ENSMUSG00000027999 | 1.89295557 | 1.14E-13 | phospholipase A2, group XIIA [Source:MGI Symbol;Acc:MGI:1913600] |
| Cd72 | ENSMUSG00000028459 | 2.6694028 | 2.95E-13 | CD72 antigen [Source:MGI Symbol;Acc:MGI:88345] |
| Osbpl9 | ENSMUSG00000028559 | 1.08130418 | 4.18E-13 | oxysterol binding protein-like 9 [Source:MGI Symbol;Acc:MGI:1923784] |
| Parp8 | ENSMUSG00000021725 | 2.84462297 | 4.48E-13 | poly (ADP-ribose) polymerase family, member 8 [Source:MGI Symbol;Acc:MGI:1098713] |
| Arpc5l | ENSMUSG00000026755 | 1.02891572 | 2.15E-12 | actin related protein 2/3 complex, subunit 5-like [Source:MGI Symbol;Acc:MGI:1921442] |
| Plcl2 | ENSMUSG00000038910 | 1.72583703 | 9.62E-12 | phospholipase C-like 2 [Source:MGI Symbol;Acc:MGI:1352756] |
| Adssl1 | ENSMUSG00000011148 | 1.62278742 | 1.42E-11 | adenylosuccinate synthetase like 1 [Source:MGI Symbol;Acc:MGI:87947] |
| Bach2 | ENSMUSG00000040270 | 1.04814689 | 1.75E-10 | BTB and CNC homology, basic leucine zipper transcription factor 2 [Source:MGI Symbol;Acc:MGI:894679] |
| Gpr155 | ENSMUSG00000041762 | 2.16193877 | 3.06E-10 | G protein-coupled receptor 155 [Source:MGI Symbol;Acc:MGI:1915776] |
| Arhgap24 | ENSMUSG00000057315 | 1.51560065 | 3.76E-10 | Rho GTPase activating protein 24 [Source:MGI Symbol;Acc:MGI:1922647] |
| Wdr6 | ENSMUSG00000066357 | 1.62496999 | 3.91E-10 | WD repeat domain 6 [Source:MGI Symbol;Acc:MGI:1930140] |
| Gid4 | ENSMUSG00000018415 | 1.467925 | 4.01E-10 | GID complex subunit 4, VID24 homolog [Source:MGI Symbol;Acc:MGI:1914021] |
| Ddx54 | ENSMUSG00000029599 | 1.12695491 | 4.48E-10 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 54 [Source:MGI Symbol;Acc:MGI:1919240] |
| Otud1 | ENSMUSG00000043415 | 2.64986868 | 4.90E-10 | OTU domain containing 1 [Source:MGI Symbol;Acc:MGI:1918448] |
| Endou | ENSMUSG00000022468 | 1.7382345 | 8.50E-10 | endonuclease, polyU-specific [Source:MGI Symbol;Acc:MGI:97746] |
| Fam3c | ENSMUSG00000029672 | 1.27190076 | 9.82E-10 | family with sequence similarity 3, member C [Source:MGI Symbol;Acc:MGI:107892] |
| Zbtb20 | ENSMUSG00000022708 | 1.45256616 | 4.35E-09 | zinc finger and BTB domain containing 20 [Source:MGI Symbol;Acc:MGI:1929213] |
| Tsga10 | ENSMUSG00000060771 | 1.39924446 | 7.10E-09 | testis specific 10 [Source:MGI Symbol;Acc:MGI:2685063] |
| Il7r | ENSMUSG00000003882 | 3.60057082 | 1.12E-08 | interleukin 7 receptor [Source:MGI Symbol;Acc:MGI:96562] |
| Map4k1 | ENSMUSG00000037337 | 1.1198598 | 1.14E-08 | mitogen-activated protein kinase kinase kinase kinase 1 [Source:MGI Symbol;Acc:MGI:1346882] |
| Ephx1 | ENSMUSG00000038776 | 2.11944046 | 1.86E-08 | epoxide hydrolase 1, microsomal [Source:MGI Symbol;Acc:MGI:95405] |
| Samsn1 | ENSMUSG00000022876 | 1.76809864 | 1.86E-08 | SAM domain, SH3 domain and nuclear localization signals, 1 [Source:MGI Symbol;Acc:MGI:1914992] |
| Fcer2a | ENSMUSG00000005540 | 3.77205894 | 1.86E-08 | Fc receptor, IgE, low affinity II, alpha polypeptide [Source:MGI Symbol;Acc:MGI:95497] |
| Kcnq5 | ENSMUSG00000028033 | 2.60567308 | 2.25E-08 | potassium voltage-gated channel, subfamily Q, member 5 [Source:MGI Symbol;Acc:MGI:1924937] |
| Ets2 | ENSMUSG00000022895 | 2.75668148 | 2.54E-08 | E26 avian leukemia oncogene 2, 3' domain [Source:MGI Symbol;Acc:MGI:95456] |
| Dennd5b | ENSMUSG00000030313 | 2.57531232 | 3.39E-08 | DENN/MADD domain containing 5B [Source:MGI Symbol;Acc:MGI:2444273] |
| Gapt | ENSMUSG00000046006 | 2.86755515 | 3.49E-08 | Grb2-binding adaptor, transmembrane [Source:MGI Symbol;Acc:MGI:3608341] |
| Ddc | ENSMUSG00000020182 | 2.35938258 | 4.07E-08 | dopa decarboxylase [Source:MGI Symbol;Acc:MGI:94876] |
| Ctdp1 | ENSMUSG00000033323 | 1.51543733 | 8.53E-08 | CTD (carboxy-terminal domain, RNA polymerase II, polypeptide A) phosphatase, subunit 1 [Source:MGI Symbol;Acc:MGI:1926953] |
| Pex5 | ENSMUSG00000005069 | 1.54289292 | 8.86E-08 | peroxisomal biogenesis factor 5 [Source:MGI Symbol;Acc:MGI:1098808] |
| H2-DMb1 | ENSMUSG00000079547 | 1.01266782 | 1.11E-07 | histocompatibility 2, class II, locus Mb1 [Source:MGI Symbol;Acc:MGI:95922] |
| Zfp78 | ENSMUSG00000055150 | 7.15169163 | 1.18E-07 | zinc finger protein 78 [Source:MGI Symbol;Acc:MGI:107783] |
| Tram1 | ENSMUSG00000025935 | 1.42718458 | 1.40E-07 | translocating chain-associating membrane protein 1 [Source:MGI Symbol;Acc:MGI:1919515] |
| Adgre5 | ENSMUSG00000002885 | 1.28147277 | 1.73E-07 | adhesion G protein-coupled receptor E5 [Source:MGI Symbol;Acc:MGI:1347095] |
| Dnah7a | ENSMUSG00000096141 | 7.70442237 | 2.36E-07 | dynein, axonemal, heavy chain 7A [Source:MGI Symbol;Acc:MGI:2685838] |
| Dtnb | ENSMUSG00000071454 | 1.4248677 | 4.43E-07 | dystrobrevin, beta [Source:MGI Symbol;Acc:MGI:1203728] |
| Ptpdc1 | ENSMUSG00000038042 | 8.29330262 | 4.62E-07 | protein tyrosine phosphatase domain containing 1 [Source:MGI Symbol;Acc:MGI:2145430] |
| Hdac9 | ENSMUSG00000004698 | 4.88481542 | 4.76E-07 | histone deacetylase 9 [Source:MGI Symbol;Acc:MGI:1931221] |
| Mthfd1l | ENSMUSG00000040675 | 1.77099736 | 6.72E-07 | methylenetetrahydrofolate dehydrogenase (NADP+ dependent) 1-like [Source:MGI Symbol;Acc:MGI:1924836] |
| Igkv4-92 | ENSMUSG00000076531 | 3.17399883 | 7.18E-07 | immunoglobulin kappa variable 4-92 [Source:MGI Symbol;Acc:MGI:2686254] |
| Lmo2 | ENSMUSG00000032698 | 1.74574158 | 8.96E-07 | LIM domain only 2 [Source:MGI Symbol;Acc:MGI:102811] |
| Clic4 | ENSMUSG00000037242 | 1.11495191 | 1.28E-06 | chloride intracellular channel 4 (mitochondrial) [Source:MGI Symbol;Acc:MGI:1352754] |
| Slco4a1 | ENSMUSG00000038963 | 1.96792445 | 1.65E-06 | solute carrier organic anion transporter family, member 4a1 [Source:MGI Symbol;Acc:MGI:1351866] |
| Mapk3 | ENSMUSG00000063065 | 1.26826877 | 1.65E-06 | mitogen-activated protein kinase 3 [Source:MGI Symbol;Acc:MGI:1346859] |
| Socs2 | ENSMUSG00000020027 | 2.18157834 | 2.04E-06 | suppressor of cytokine signaling 2 [Source:MGI Symbol;Acc:MGI:1201787] |
| Slpi | ENSMUSG00000017002 | 4.23929013 | 2.66E-06 | secretory leukocyte peptidase inhibitor [Source:MGI Symbol;Acc:MGI:109297] |
| Vav3 | ENSMUSG00000033721 | 2.33993376 | 5.34E-06 | vav 3 oncogene [Source:MGI Symbol;Acc:MGI:1888518] |
| Stap1 | ENSMUSG00000029254 | 1.10352372 | 5.99E-06 | signal transducing adaptor family member 1 [Source:MGI Symbol;Acc:MGI:1926193] |
| H2-Q5 | ENSMUSG00000055413 | 3.60568624 | 6.33E-06 | histocompatibility 2, Q region locus 5 [Source:MGI Symbol;Acc:MGI:95934] |
| Psat1 | ENSMUSG00000024640 | 1.64912367 | 6.40E-06 | phosphoserine aminotransferase 1 [Source:MGI Symbol;Acc:MGI:2183441] |
| Cd1d1 | ENSMUSG00000028076 | 1.20146155 | 1.20E-05 | CD1d1 antigen [Source:MGI Symbol;Acc:MGI:107674] |
| Yars | ENSMUSG00000028811 | 1.37139153 | 1.60E-05 | tyrosyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2147627] |
| Galnt6 | ENSMUSG00000037280 | 3.8772856 | 1.92E-05 | polypeptide N-acetylgalactosaminyltransferase 6 [Source:MGI Symbol;Acc:MGI:1891640] |
| Phgdh | ENSMUSG00000053398 | 1.63000282 | 2.11E-05 | 3-phosphoglycerate dehydrogenase [Source:MGI Symbol;Acc:MGI:1355330] |
| Osbpl8 | ENSMUSG00000020189 | 1.13637396 | 2.20E-05 | oxysterol binding protein-like 8 [Source:MGI Symbol;Acc:MGI:2443807] |

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| | | | | |
|---|---|---|---|---|
| Shmt2 | ENSMUSG00000025403 | 1.29369897 | 2.82E-05 | serine hydroxymethyltransferase 2 (mitochondrial) [Source:MGI Symbol;Acc:MGI:1277989] |
| Gm12057 | ENSMUSG00000101716 | 1.88830505 | 3.08E-05 | predicted gene 12057 [Source:MGI Symbol;Acc:MGI:3650030] |
| Arhgap18 | ENSMUSG00000039031 | 1.34627081 | 3.33E-05 | Rho GTPase activating protein 18 [Source:MGI Symbol;Acc:MGI:1921160] |
| Ttc17 | ENSMUSG00000027194 | 1.23991806 | 3.63E-05 | tetratricopeptide repeat domain 17 [Source:MGI Symbol;Acc:MGI:1921819] |
| Lpp | ENSMUSG00000033306 | 2.06693769 | 3.78E-05 | LIM domain containing preferred translocation partner in lipoma [Source:MGI Symbol;Acc:MGI:2441849] |
| Aicda | ENSMUSG00000040627 | 1.863141 | 4.96E-05 | activation-induced cytidine deaminase [Source:MGI Symbol;Acc:MGI:1342279] |
| Lmo4 | ENSMUSG00000028266 | 2.62705439 | 5.42E-05 | LIM domain only 4 [Source:MGI Symbol;Acc:MGI:109360] |
| Lef1 | ENSMUSG00000027985 | 1.98894794 | 7.54E-05 | lymphoid enhancer binding factor 1 [Source:MGI Symbol;Acc:MGI:96770] |
| Slamf7 | ENSMUSG00000038179 | 1.70710449 | 7.55E-05 | SLAM family member 7 [Source:MGI Symbol;Acc:MGI:1922595] |
| St6gal1 | ENSMUSG00000022885 | 1.11005315 | 7.88E-05 | beta galactoside alpha 2,6 sialyltransferase 1 [Source:MGI Symbol;Acc:MGI:108470] |
| Pknox1 | ENSMUSG00000006705 | 1.20770985 | 7.91E-05 | Pbx/knotted 1 homeobox [Source:MGI Symbol;Acc:MGI:1201409] |
| Zfpm1 | ENSMUSG00000049577 | 1.6280278 | 8.37E-05 | zinc finger protein, multitype 1 [Source:MGI Symbol;Acc:MGI:1095400] |
| Egfl6 | ENSMUSG00000000402 | 1.58155494 | 8.76E-05 | EGF-like-domain, multiple 6 [Source:MGI Symbol;Acc:MGI:1858599] |
| Fam134b | ENSMUSG00000022270 | 1.50510532 | 8.76E-05 | reticulophagy regulator 1 [Source:MGI Symbol;Acc:MGI:1913520] |
| Phf10 | ENSMUSG00000023883 | 1.06563818 | 0.00011409 | PHD finger protein 10 [Source:MGI Symbol;Acc:MGI:1919307] |
| Plek | ENSMUSG00000020120 | 1.85032084 | 0.00011448 | pleckstrin [Source:MGI Symbol;Acc:MGI:1860485] |
| Gfra1 | ENSMUSG00000025089 | 2.81671784 | 0.00011738 | glial cell line derived neurotrophic factor family receptor alpha 1 [Source:MGI Symbol;Acc:MGI:1100842] |
| B4galt4 | ENSMUSG00000022793 | 7.90270763 | 0.0001396 | UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 4 [Source:MGI Symbol;Acc:MGI:1928387] |
| 1110051M20Rik | ENSMUSG00000040591 | 1.87489698 | 0.00015312 | RIKEN cDNA 1110051M20 gene [Source:MGI Symbol;Acc:MGI:1915079] |
| Csrp2 | ENSMUSG00000020186 | 1.54050891 | 0.00015699 | cysteine and glycine-rich protein 2 [Source:MGI Symbol;Acc:MGI:1202907] |
| AW112010 | ENSMUSG00000075010 | 4.00201631 | 0.00016451 | expressed sequence AW112010 [Source:MGI Symbol;Acc:MGI:2147706] |
| Arl5a | ENSMUSG00000036093 | 1.33644524 | 0.00018103 | ADP-ribosylation factor-like 5A [Source:MGI Symbol;Acc:MGI:1922673] |
| Coq7 | ENSMUSG00000030652 | 1.06750114 | 0.00018227 | demethyl-Q 7 [Source:MGI Symbol;Acc:MGI:107207] |
| Cr2 | ENSMUSG00000026616 | 4.292953 | 0.00018632 | complement receptor 2 [Source:MGI Symbol;Acc:MGI:88489] |
| Cd276 | ENSMUSG00000035914 | 5.4551168 | 0.00018668 | CD276 antigen [Source:MGI Symbol;Acc:MGI:2183926] |
| Irf4 | ENSMUSG00000021356 | 1.26320578 | 0.00019224 | interferon regulatory factor 4 [Source:MGI Symbol;Acc:MGI:1096873] |
| Rsph1 | ENSMUSG00000024033 | 3.17893325 | 0.00019453 | radial spoke head 1 homolog (Chlamydomonas) [Source:MGI Symbol;Acc:MGI:1194909] |
| Il2ra | ENSMUSG00000026770 | 1.99612961 | 0.00020559 | interleukin 2 receptor, alpha chain [Source:MGI Symbol;Acc:MGI:96549] |
| Gsn | ENSMUSG00000026879 | 1.39844329 | 0.00020559 | gelsolin [Source:MGI Symbol;Acc:MGI:95851] |
| Cox6a2 | ENSMUSG00000030785 | 3.313887 | 0.00023346 | cytochrome c oxidase subunit VIa polypeptide 2 [Source:MGI Symbol;Acc:MGI:104649] |
| Casp7 | ENSMUSG00000025076 | 1.6272143 | 0.00023623 | caspase 7 [Source:MGI Symbol;Acc:MGI:109383] |
| Gpr12 | ENSMUSG00000041468 | 4.79583116 | 0.00028632 | G-protein coupled receptor 12 [Source:MGI Symbol;Acc:MGI:101909] |
| Pycr1 | ENSMUSG00000025140 | 3.4304694 | 0.0002997 | pyrroline-5-carboxylate reductase 1 [Source:MGI Symbol;Acc:MGI:2384795] |
| Rtn4ip1 | ENSMUSG00000019864 | 1.30923803 | 0.00030854 | reticulon 4 interacting protein 1 [Source:MGI Symbol;Acc:MGI:2178759] |
| Efcab7 | ENSMUSG00000073791 | 1.51635611 | 0.0003261 | EF-hand calcium binding domain 7 [Source:MGI Symbol;Acc:MGI:2385199] |
| Spns3 | ENSMUSG00000020798 | 1.2792767 | 0.00035551 | spinster homolog 3 [Source:MGI Symbol;Acc:MGI:1924827] |
| Rsph9 | ENSMUSG00000023966 | 1.98256959 | 0.00036346 | radial spoke head 9 homolog (Chlamydomonas) [Source:MGI Symbol;Acc:MGI:1922814] |
| Decr1 | ENSMUSG00000028223 | 1.61934891 | 0.0003687 | 2,4-dienoyl CoA reductase 1, mitochondrial [Source:MGI Symbol;Acc:MGI:1914710] |
| Lrrc61 | ENSMUSG00000073096 | 2.58882188 | 0.00042199 | leucine rich repeat containing 61 [Source:MGI Symbol;Acc:MGI:2652848] |
| Lactb2 | ENSMUSG00000025937 | 1.25695408 | 0.00043515 | lactamase, beta 2 [Source:MGI Symbol;Acc:MGI:2442551] |
| Pcbd2 | ENSMUSG00000021496 | 1.29255239 | 0.00044762 | pterin 4 alpha carbinolamine dehydratase/dimerization cofactor of hepatocyte nuclear factor 1 alpha (TCF1) 2 [Source:MGI Symbol;Acc:MGI:1919812] |
| Slc7a1 | ENSMUSG00000041313 | 1.14081165 | 0.00044964 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 1 [Source:MGI Symbol;Acc:MGI:88117] |
| Il18 | ENSMUSG00000039217 | 2.61964768 | 0.00046695 | interleukin 18 [Source:MGI Symbol;Acc:MGI:107936] |
| Clec2i | ENSMUSG00000030365 | 2.13008877 | 0.00047246 | C-type lectin domain family 2, member i [Source:MGI Symbol;Acc:MGI:2136650] |
| Fxn | ENSMUSG00000059363 | 1.31876818 | 0.00050124 | frataxin [Source:MGI Symbol;Acc:MGI:1096879] |
| Rasal1 | ENSMUSG00000029602 | 2.60529028 | 0.00052367 | RAS protein activator like 1 (GAP1 like) [Source:MGI Symbol;Acc:MGI:1330842] |
| Wdfy1 | ENSMUSG00000073643 | 1.58634759 | 0.00053082 | WD repeat and FYVE domain containing 1 [Source:MGI Symbol;Acc:MGI:1916618] |
| Slamf9 | ENSMUSG00000026548 | 3.12394371 | 0.00054206 | SLAM family member 9 [Source:MGI Symbol;Acc:MGI:1923692] |
| Hmces | ENSMUSG00000030060 | 1.25678674 | 0.00055117 | 5-hydroxymethylcytosine (hmC) binding, ES cell specific [Source:MGI Symbol;Acc:MGI:1914053] |
| Socs5 | ENSMUSG00000037104 | 3.13162497 | 0.00062219 | suppressor of cytokine signaling 5 [Source:MGI Symbol;Acc:MGI:2385459] |
| Sergef | ENSMUSG00000030839 | 1.35365981 | 0.00067988 | secretion regulating guanine nucleotide exchange factor [Source:MGI Symbol;Acc:MGI:1351630] |
| Grn | ENSMUSG00000034708 | 1.1017855 | 0.00069987 | granulin [Source:MGI Symbol;Acc:MGI:95832] |
| Emid1 | ENSMUSG00000034164 | 1.55831454 | 0.00083409 | EMI domain containing 1 [Source:MGI Symbol;Acc:MGI:2155091] |
| Trio | ENSMUSG00000022263 | 2.25160116 | 0.00084575 | triple functional domain (PTPRF interacting) [Source:MGI Symbol;Acc:MGI:1927230] |
| Aars | ENSMUSG00000031960 | 1.09799295 | 0.00085014 | alanyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2384560] |
| Zscan20 | ENSMUSG00000061894 | 4.68792558 | 0.00095745 | zinc finger and SCAN domains 20 [Source:MGI Symbol;Acc:MGI:2679268] |
| Tctn1 | ENSMUSG00000038593 | 2.00815916 | 0.00095745 | tectonic family member 1 [Source:MGI Symbol;Acc:MGI:3603820] |
| Litaf | ENSMUSG00000022500 | 1.31031077 | 0.00095745 | LPS-induced TN factor [Source:MGI Symbol;Acc:MGI:1929512] |
| Slc3a2 | ENSMUSG00000010095 | 1.06790335 | 0.00095908 | solute carrier family 3 (activators of dibasic and neutral amino acid transport), member 2 [Source:MGI Symbol;Acc:MGI:96955] |
| Slain1 | ENSMUSG00000055717 | 1.25449916 | 0.00097592 | SLAIN motif family, member 1 [Source:MGI Symbol;Acc:MGI:2145578] |
| Med15 | ENSMUSG00000012114 | 1.14095998 | 0.00114704 | mediator complex subunit 15 [Source:MGI Symbol;Acc:MGI:2137379] |
| Trove2 | ENSMUSG00000018199 | 4.14691258 | 0.00115166 | TROVE domain family, member 2 [Source:MGI Symbol;Acc:MGI:106652] |
| Vpreb2 | ENSMUSG00000059280 | 6.25441422 | 0.0011746 | pre-B lymphocyte gene 2 [Source:MGI Symbol;Acc:MGI:98937] |
| Rtn1 | ENSMUSG00000021087 | 6.2388796 | 0.00123911 | reticulon 1 [Source:MGI Symbol;Acc:MGI:1933947] |
| Gas7 | ENSMUSG00000033066 | 3.62185067 | 0.00127495 | growth arrest specific 7 [Source:MGI Symbol;Acc:MGI:1202388] |
| Pex3 | ENSMUSG00000019809 | 1.33205198 | 0.00129895 | peroxisomal biogenesis factor 3 [Source:MGI Symbol;Acc:MGI:1929646] |
| Sbk1 | ENSMUSG00000042978 | 1.16930966 | 0.0013483 | SH3-binding kinase 1 [Source:MGI Symbol;Acc:MGI:2135937] |
| D930028M14Rik | ENSMUSG00000074274 | 6.56523577 | 0.00138459 | RIKEN cDNA D930028M14 gene [Source:MGI Symbol;Acc:MGI:3687343] |
| Bcat1 | ENSMUSG00000030268 | 1.66275374 | 0.00139691 | branched chain aminotransferase 1, cytosolic [Source:MGI Symbol;Acc:MGI:104861] |
| Myo1e | ENSMUSG00000032220 | 3.05100334 | 0.00143265 | myosin IE [Source:MGI Symbol;Acc:MGI:106621] |
| Ssfa2 | ENSMUSG00000027007 | 2.31421486 | 0.00156206 | sperm specific antigen 2 [Source:MGI Symbol;Acc:MGI:1917849] |
| Oxct1 | ENSMUSG00000022186 | 1.06406307 | 0.00165808 | 3-oxoacid CoA transferase 1 [Source:MGI Symbol;Acc:MGI:1914291] |
| Myl4 | ENSMUSG00000061086 | 1.83979566 | 0.00171195 | myosin, light polypeptide 4 [Source:MGI Symbol;Acc:MGI:97267] |
| Swap70 | ENSMUSG00000031015 | 1.18058194 | 0.00178417 | SWA-70 protein [Source:MGI Symbol;Acc:MGI:1298390] |
| Ttll1 | ENSMUSG00000022442 | 1.25354421 | 0.00181416 | tubulin tyrosine ligase-like 1 [Source:MGI Symbol;Acc:MGI:2443047] |
| Sord | ENSMUSG00000027227 | 1.29971963 | 0.00218693 | sorbitol dehydrogenase [Source:MGI Symbol;Acc:MGI:98266] |
| Igkv9-124 | ENSMUSG00000096632 | 4.27373402 | 0.0023091 | immunoglobulin kappa chain variable 9-124 [Source:MGI Symbol;Acc:MGI:3646892] |
| Tubgcp2 | ENSMUSG00000025474 | 1.2645221 | 0.0023091 | tubulin, gamma complex associated protein 2 [Source:MGI Symbol;Acc:MGI:1921487] |
| Pag1 | ENSMUSG00000027508 | 1.50500848 | 0.00235689 | phosphoprotein associated with glycosphingolipid microdomains 1 [Source:MGI Symbol;Acc:MGI:2443160] |
| Nrgn | ENSMUSG00000053310 | 2.91018461 | 0.00261005 | neurogranin [Source:MGI Symbol;Acc:MGI:1927184] |
| Ncln | ENSMUSG00000020238 | 1.24280549 | 0.00280566 | nicalin [Source:MGI Symbol;Acc:MGI:1926081] |
| Mms22l | ENSMUSG00000045751 | 1.28304785 | 0.00309583 | MMS22-like, DNA repair protein [Source:MGI Symbol;Acc:MGI:2684980] |
| Neil3 | ENSMUSG00000039396 | 1.61159516 | 0.0034783 | nei like 3 (E. coli) [Source:MGI Symbol;Acc:MGI:2384588] |
| E130307A14Rik | ENSMUSG00000087177 | 1.59751032 | 0.00349715 | RIKEN cDNA E130307A14 gene [Source:MGI Symbol;Acc:MGI:3036287] |
| Ergic1 | ENSMUSG00000001576 | 1.30957859 | 0.00351967 | endoplasmic reticulum-golgi intermediate compartment (ERGIC) 1 [Source:MGI Symbol;Acc:MGI:1914708] |

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|---|---|---|---|---|
| Klhl25 | ENSMUSG00000055652 | 1.50443993 | 0.00357529 | kelch-like 25 [Source:MGI Symbol;Acc:MGI:2668031] |
| Dusp6 | ENSMUSG00000019960 | 1.60783284 | 0.00363385 | dual specificity phosphatase 6 [Source:MGI Symbol;Acc:MGI:1914853] |
| Trib2 | ENSMUSG00000020601 | 1.06026802 | 0.00367119 | tribbles pseudokinase 2 [Source:MGI Symbol;Acc:MGI:2145021] |
| Arntl | ENSMUSG00000055116 | 2.11888718 | 0.00371472 | aryl hydrocarbon receptor nuclear translocator-like [Source:MGI Symbol;Acc:MGI:1096381] |
| Zdhhc13 | ENSMUSG00000030471 | 1.09008515 | 0.00411696 | zinc finger, DHHC domain containing 13 [Source:MGI Symbol;Acc:MGI:1919227] |
| Kcna3 | ENSMUSG00000047959 | 1.89297933 | 0.00414637 | potassium voltage-gated channel, shaker-related subfamily, member 3 [Source:MGI Symbol;Acc:MGI:96660] |
| Lgr5 | ENSMUSG00000020140 | 1.99035063 | 0.0041723 | leucine rich repeat containing G protein coupled receptor 5 [Source:MGI Symbol;Acc:MGI:1341817] |
| Rgs7bp | ENSMUSG00000021719 | 3.12404105 | 0.00455638 | regulator of G-protein signalling 7 binding protein [Source:MGI Symbol;Acc:MGI:106334] |
| Ppm1e | ENSMUSG00000046442 | 1.83129695 | 0.00464327 | protein phosphatase 1E (PP2C domain containing) [Source:MGI Symbol;Acc:MGI:2444096] |
| Med23 | ENSMUSG00000019984 | 1.2806767 | 0.00466594 | mediator complex subunit 23 [Source:MGI Symbol;Acc:MGI:1917458] |
| Siae | ENSMUSG00000001942 | 2.43044502 | 0.00468532 | sialic acid acetylesterase [Source:MGI Symbol;Acc:MGI:104803] |
| A530040E14Rik | ENSMUSG00000072109 | 1.2571761 | 0.0050571 | RIKEN cDNA A530040E14 gene [Source:MGI Symbol;Acc:MGI:3612703] |
| H2-T10 | ENSMUSG00000079491 | 1.62509742 | 0.00507845 | histocompatibility 2, T region locus 10 [Source:MGI Symbol;Acc:MGI:95942] |
| Msh5 | ENSMUSG00000007035 | 1.82867795 | 0.0058395 | mutS homolog 5 [Source:MGI Symbol;Acc:MGI:1329021] |
| Rgs18 | ENSMUSG00000026357 | 2.35924663 | 0.00606996 | regulator of G-protein signaling 18 [Source:MGI Symbol;Acc:MGI:1927498] |
| Lig4 | ENSMUSG00000049717 | 2.12090082 | 0.00614126 | ligase IV, DNA, ATP-dependent [Source:MGI Symbol;Acc:MGI:1335098] |
| Casp1 | ENSMUSG00000025888 | 1.64745871 | 0.00671294 | caspase 1 [Source:MGI Symbol;Acc:MGI:96544] |
| Slc7a5 | ENSMUSG00000040010 | 1.33897678 | 0.0069475 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 5 [Source:MGI Symbol;Acc:MGI:1298205] |
| Scarb1 | ENSMUSG00000037936 | 1.10885779 | 0.00710017 | scavenger receptor class B, member 1 [Source:MGI Symbol;Acc:MGI:893578] |
| Mst1r | ENSMUSG00000032584 | 7.17965737 | 0.00712589 | macrophage stimulating 1 receptor (c-met-related tyrosine kinase) [Source:MGI Symbol;Acc:MGI:99614] |
| Nbn | ENSMUSG00000028224 | 1.30361364 | 0.00749447 | nibrin [Source:MGI Symbol;Acc:MGI:1351625] |
| Cdk6 | ENSMUSG00000040274 | 1.92336078 | 0.00793141 | cyclin-dependent kinase 6 [Source:MGI Symbol;Acc:MGI:1277162] |
| Cep72 | ENSMUSG00000021572 | 1.50125086 | 0.00851157 | centrosomal protein 72 [Source:MGI Symbol;Acc:MGI:1921720] |
| Pold2 | ENSMUSG00000020471 | 1.09979098 | 0.00852529 | polymerase (DNA directed), delta 2, regulatory subunit [Source:MGI Symbol;Acc:MGI:1097163] |
| Mybl2 | ENSMUSG00000017861 | 1.37994691 | 0.00868598 | myeloblastosis oncogene-like 2 [Source:MGI Symbol;Acc:MGI:101785] |
| Dtx1 | ENSMUSG00000029603 | 2.38135366 | 0.00914508 | deltex 1, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:1352744] |
| B9d1 | ENSMUSG00000001039 | 3.64023266 | 0.009922 | B9 protein domain 1 [Source:MGI Symbol;Acc:MGI:1351471] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-7. Genes significantly activated in immature B cell subsets in Ig NL upon stimulation.

| Symbol | Ensembl gene id | logFC (NL-sHEL/NL-R10) | adj.P.val | Annotation |
|---|---|---|---|---|
| Irs2 | ENSMUSG00000038894 | 4.92248843 | 8.79E-40 | insulin receptor substrate 2 [Source:MGI Symbol;Acc:MGI:109334] |
| Grn | ENSMUSG00000034708 | 1.879738572 | 4.85E-36 | granulin [Source:MGI Symbol;Acc:MGI:95832] |
| Mreg | ENSMUSG00000039395 | 4.768683839 | 5.94E-36 | melanoregulin [Source:MGI Symbol;Acc:MGI:2151839] |
| Lilrb4a | ENSMUSG00000062593 | 11.62055565 | 6.44E-35 | leukocyte immunoglobulin-like receptor, subfamily B, member 4A [Source:MGI |
| Cd69 | ENSMUSG00000030156 | 2.720618995 | 5.62E-34 | CD69 antigen [Source:MGI Symbol;Acc:MGI:88343] |
| Alcam | ENSMUSG00000022636 | 2.648660412 | 1.22E-31 | activated leukocyte cell adhesion molecule [Source:MGI Symbol;Acc:MGI:1313266] |
| Zc3h12c | ENSMUSG00000035164 | 11.09968947 | 1.98E-31 | zinc finger CCCH type containing 12C [Source:MGI Symbol;Acc:MGI:3026959] |
| Batf | ENSMUSG00000034266 | 2.285763219 | 1.79E-30 | basic leucine zipper transcription factor, ATF-like [Source:MGI Symbol;Acc:MGI:1859147] |
| D1Ertd622e | ENSMUSG00000044768 | 1.703319085 | 3.53E-28 | DNA segment, Chr 1, ERATO Doi 622, expressed [Source:MGI Symbol;Acc:MGI:1277184] |
| Shmt1 | ENSMUSG00000020534 | 3.708743205 | 9.54E-27 | serine hydroxymethyltransferase 1 (soluble) [Source:MGI Symbol;Acc:MGI:98299] |
| Samsn1 | ENSMUSG00000022876 | 3.779001142 | 2.93E-25 | SAM domain, SH3 domain and nuclear localization signals, 1 [Source:MGI |
| Egr2 | ENSMUSG00000037868 | 8.256817612 | 7.68E-25 | early growth response 2 [Source:MGI Symbol;Acc:MGI:95296] |
| Fcmr | ENSMUSG00000042474 | 1.867337218 | 4.19E-24 | Fc fragment of IgM receptor [Source:MGI Symbol;Acc:MGI:1916419] |
| Adi1 | ENSMUSG00000020629 | 1.621684987 | 5.70E-22 | acireductone dioxygenase 1 [Source:MGI Symbol;Acc:MGI:2144929] |
| Bcar3 | ENSMUSG00000028121 | 1.547128548 | 1.80E-21 | breast cancer anti-estrogen resistance 3 [Source:MGI Symbol;Acc:MGI:1352501] |
| Cystm1 | ENSMUSG00000046727 | 9.876485836 | 9.33E-21 | cysteine-rich transmembrane module containing 1 [Source:MGI Symbol;Acc:MGI:1913310] |
| Lrrc32 | ENSMUSG00000090958 | 6.533099653 | 4.84E-20 | leucine rich repeat containing 32 [Source:MGI Symbol;Acc:MGI:93882] |
| Hexa | ENSMUSG00000025232 | 1.716466931 | 2.20E-19 | hexosaminidase A [Source:MGI Symbol;Acc:MGI:96073] |
| Satb1 | ENSMUSG00000023927 | 2.229449961 | 7.52E-19 | special AT-rich sequence binding protein 1 [Source:MGI Symbol;Acc:MGI:105084] |
| Lamp1 | ENSMUSG00000031447 | 1.231079864 | 1.33E-18 | lysosomal-associated membrane protein 1 [Source:MGI Symbol;Acc:MGI:96745] |
| Egr1 | ENSMUSG00000038418 | 7.053930295 | 7.13E-18 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Uap1l1 | ENSMUSG00000026956 | 2.403716434 | 9.77E-18 | UDP-N-acteylglucosamine pyrophosphorylase 1-like 1 [Source:MGI Symbol;Acc:MGI:2443318] |
| Trmt6 | ENSMUSG00000037376 | 1.851177276 | 1.39E-16 | tRNA methyltransferase 6 [Source:MGI Symbol;Acc:MGI:1914176] |
| Cd83 | ENSMUSG00000015396 | 4.337514544 | 1.52E-16 | CD83 antigen [Source:MGI Symbol;Acc:MGI:1328316] |
| Ddx54 | ENSMUSG00000029599 | 1.183996304 | 2.73E-16 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 54 [Source:MGI Symbol;Acc:MGI:1919240] |
| Ccr7 | ENSMUSG00000037944 | 1.686094145 | 3.39E-16 | chemokine (C-C motif) receptor 7 [Source:MGI Symbol;Acc:MGI:103011] |
| Irf4 | ENSMUSG00000021356 | 2.790788676 | 8.62E-16 | interferon regulatory factor 4 [Source:MGI Symbol;Acc:MGI:1096873] |
| Ccl4 | ENSMUSG00000018930 | 6.761040982 | 5.16E-15 | chemokine (C-C motif) ligand 4 [Source:MGI Symbol;Acc:MGI:98261] |
| Ilf3 | ENSMUSG00000032178 | 1.491941169 | 6.18E-15 | interleukin enhancer binding factor 3 [Source:MGI Symbol;Acc:MGI:1339973] |
| Il1r1 | ENSMUSG00000026072 | 6.903067164 | 6.72E-15 | interleukin 1 receptor, type I [Source:MGI Symbol;Acc:MGI:96545] |
| Fam46c | ENSMUSG00000044468 | 6.823951773 | 9.37E-15 | family with sequence similarity 46, member C [Source:MGI Symbol;Acc:MGI:1921895] |
| Akap1 | ENSMUSG00000018428 | 9.190816358 | 1.19E-14 | A kinase (PRKA) anchor protein 1 [Source:MGI Symbol;Acc:MGI:104729] |
| Plek | ENSMUSG00000020120 | 3.338276427 | 1.29E-14 | pleckstrin [Source:MGI Symbol;Acc:MGI:1860485] |
| Ephx1 | ENSMUSG00000038776 | 2.438265172 | 4.63E-14 | epoxide hydrolase 1, microsomal [Source:MGI Symbol;Acc:MGI:95405] |
| Tpp1 | ENSMUSG00000030894 | 1.256890352 | 8.96E-14 | tripeptidyl peptidase I [Source:MGI Symbol;Acc:MGI:1336194] |
| Dnase2a | ENSMUSG00000003812 | 2.013620559 | 3.30E-13 | deoxyribonuclease II alpha [Source:MGI Symbol;Acc:MGI:1329019] |
| Taf4b | ENSMUSG00000054321 | 2.814370237 | 3.52E-13 | TATA-box binding protein associated factor 4b [Source:MGI Symbol;Acc:MGI:2152345] |
| Mfsd1 | ENSMUSG00000027775 | 1.292079634 | 4.63E-13 | major facilitator superfamily domain containing 1 [Source:MGI Symbol;Acc:MGI:1914118] |
| Tars | ENSMUSG00000022241 | 1.569395943 | 5.22E-13 | threonyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:106314] |
| Irf2bp2 | ENSMUSG00000051495 | 1.817142172 | 6.00E-13 | interferon regulatory factor 2 binding protein 2 [Source:MGI Symbol;Acc:MGI:2443921] |
| Asph | ENSMUSG00000028207 | 3.031489163 | 6.86E-13 | aspartate-beta-hydroxylase [Source:MGI Symbol;Acc:MGI:1914186] |
| Ccl3 | ENSMUSG00000000982 | 5.545174048 | 8.51E-13 | chemokine (C-C motif) ligand 3 [Source:MGI Symbol;Acc:MGI:98260] |
| Fyn | ENSMUSG00000019843 | 2.040200557 | 1.17E-12 | Fyn proto-oncogene [Source:MGI Symbol;Acc:MGI:95602] |
| Nfatc1 | ENSMUSG00000033016 | 2.090325281 | 1.18E-12 | nuclear factor of activated T cells, cytoplasmic, calcineurin dependent 1 [Source:MGI |
| Slco4a1 | ENSMUSG00000038963 | 2.572482369 | 3.30E-12 | solute carrier organic anion transporter family, member 4a1 [Source:MGI |
| Chst10 | ENSMUSG00000026080 | 4.957172382 | 4.58E-12 | carbohydrate sulfotransferase 10 [Source:MGI Symbol;Acc:MGI:2138283] |
| Nab2 | ENSMUSG00000025402 | 6.919899633 | 6.18E-12 | Ngfi-A binding protein 2 [Source:MGI Symbol;Acc:MGI:107563] |
| Mir155hg | ENSMUSG00000097418 | 4.717425603 | 6.84E-12 | Mir155 host gene (non-protein coding) [Source:MGI Symbol;Acc:MGI:5477161] |
| Dgkh | ENSMUSG00000034731 | 6.614895025 | 1.04E-11 | diacylglycerol kinase, eta [Source:MGI Symbol;Acc:MGI:2444188] |
| Rilpl2 | ENSMUSG00000029401 | 2.209913466 | 1.51E-11 | Rab interacting lysosomal protein-like 2 [Source:MGI Symbol;Acc:MGI:1933112] |
| Gstt2 | ENSMUSG00000033318 | 1.798557748 | 1.61E-11 | glutathione S-transferase, theta 2 [Source:MGI Symbol;Acc:MGI:106188] |
| 5033430I15Rik | ENSMUSG00000038152 | 7.371925658 | 2.13E-11 | RIKEN cDNA 5033430I15 gene [Source:MGI Symbol;Acc:MGI:1923250] |
| Gcsh | ENSMUSG00000034424 | 2.499870628 | 2.71E-11 | glycine cleavage system protein H (aminomethyl carrier) [Source:MGI |
| Cish | ENSMUSG00000032578 | 7.283131826 | 3.77E-11 | cytokine inducible SH2-containing protein [Source:MGI Symbol;Acc:MGI:103159] |
| Tgif1 | ENSMUSG00000047407 | 1.666863795 | 4.25E-11 | TGFB-induced factor homeobox 1 [Source:MGI Symbol;Acc:MGI:1194497] |
| Ets2 | ENSMUSG00000022895 | 3.69887782 | 5.37E-11 | E26 avian leukemia oncogene 2, 3' domain [Source:MGI Symbol;Acc:MGI:95456] |
| Ppid | ENSMUSG00000027804 | 1.232341407 | 7.32E-11 | peptidylprolyl isomerase D (cyclophilin D) [Source:MGI Symbol;Acc:MGI:1914988] |
| Twsg1 | ENSMUSG00000024098 | 1.802347357 | 9.07E-11 | twisted gastrulation BMP signaling modulator 1 [Source:MGI Symbol;Acc:MGI:2137520] |
| Metrnl | ENSMUSG00000039208 | 7.434882821 | 1.09E-10 | meteorin, glial cell differentiation regulator-like [Source:MGI Symbol;Acc:MGI:2384806] |
| Mif | ENSMUSG00000033307 | 1.967013709 | 2.23E-10 | macrophage migration inhibitory factor (glycosylation-inhibiting factor) [Source:MGI |
| Bcl2a1d | ENSMUSG00000099974 | 6.606061054 | 2.30E-10 | B cell leukemia/lymphoma 2 related protein A1d [Source:MGI Symbol;Acc:MGI:1278325] |
| Ahcyl2 | ENSMUSG00000029772 | 3.238319981 | 2.38E-10 | S-adenosylhomocysteine hydrolase-like 2 [Source:MGI Symbol;Acc:MGI:1921590] |
| Gtf2h1 | ENSMUSG00000006599 | 1.43204808 | 2.61E-10 | general transcription factor II H, polypeptide 1 [Source:MGI Symbol;Acc:MGI:1277216] |
| Xpot | ENSMUSG00000034667 | 1.833410342 | 2.66E-10 | exportin, tRNA (nuclear export receptor for tRNAs) [Source:MGI Symbol;Acc:MGI:1920442] |
| Slc25a19 | ENSMUSG00000020744 | 1.709876218 | 2.70E-10 | solute carrier family 25 (mitochondrial thiamine pyrophosphate carrier), member 19 [Source:MGI |
| Mrps6 | ENSMUSG00000039680 | 1.407476933 | 2.84E-10 | mitochondrial ribosomal protein S6 [Source:MGI Symbol;Acc:MGI:2153111] |
| Pfkp | ENSMUSG00000021196 | 3.34460961 | 3.42E-10 | phosphofructokinase, platelet [Source:MGI Symbol;Acc:MGI:1891833] |
| Zdhhc13 | ENSMUSG00000030471 | 1.369565653 | 4.92E-10 | zinc finger, DHHC domain containing 13 [Source:MGI Symbol;Acc:MGI:1919227] |
| Gm37560 | ENSMUSG00000103165 | 7.893858057 | 5.55E-10 | predicted gene, 37560 [Source:MGI Symbol;Acc:MGI:5610788] |
| Acoxl | ENSMUSG00000027380 | 7.521907021 | 5.59E-10 | acyl-Coenzyme A oxidase-like [Source:MGI Symbol;Acc:MGI:1921371] |
| Rps6kb1 | ENSMUSG00000020516 | 1.398563044 | 5.70E-10 | ribosomal protein S6 kinase, polypeptide 1 [Source:MGI Symbol;Acc:MGI:1270849] |
| Clic4 | ENSMUSG00000037242 | 1.265253904 | 6.95E-10 | chloride intracellular channel 4 (mitochondrial) [Source:MGI Symbol;Acc:MGI:1352754] |
| Degs1 | ENSMUSG00000038633 | 1.209520109 | 7.11E-10 | delta(4)-desaturase, sphingolipid 1 [Source:MGI Symbol;Acc:MGI:1097711] |
| Pmaip1 | ENSMUSG00000024521 | 1.832651049 | 1.19E-09 | phorbol-12-myristate-13-acetate-induced protein 1 [Source:MGI Symbol;Acc:MGI:1930146] |
| Slc7a1 | ENSMUSG00000041313 | 2.056353242 | 1.21E-09 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 1 [Source:MGI |
| Fnip1 | ENSMUSG00000035992 | 1.168680686 | 1.33E-09 | folliculin interacting protein 1 [Source:MGI Symbol;Acc:MGI:2444668] |
| Slc19a1 | ENSMUSG00000001436 | 2.834090945 | 1.96E-09 | solute carrier family 19 (folate transporter), member 1 [Source:MGI Symbol;Acc:MGI:103182] |
| Nolc1 | ENSMUSG00000015176 | 2.170041511 | 2.03E-09 | nucleolar and coiled-body phosphoprotein 1 [Source:MGI Symbol;Acc:MGI:1918019] |
| Sep-11 | ENSMUSG00000058013 | 1.505085275 | 2.05E-09 | septin 11 [Source:MGI Symbol;Acc:MGI:1277214] |

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|---|---|---|---|---|
| Rftn1 | ENSMUSG00000039316 | 1.345070643 | 2.23E-09 | raftlin lipid raft linker 1 [Source:MGI Symbol;Acc:MGI:1923688] |
| Bend3 | ENSMUSG00000038214 | 5.580826419 | 2.26E-09 | BEN domain containing 3 [Source:MGI Symbol;Acc:MGI:2677212] |
| Nop58 | ENSMUSG00000026020 | 1.702815279 | 2.32E-09 | NOP58 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1933184] |
| Mif4gd | ENSMUSG00000020743 | 1.441810259 | 3.27E-09 | MIF4G domain containing [Source:MGI Symbol;Acc:MGI:1916924] |
| Fam3c | ENSMUSG00000029672 | 1.097739706 | 3.52E-09 | family with sequence similarity 3, member C [Source:MGI Symbol;Acc:MGI:107892] |
| Slc3a2 | ENSMUSG00000010095 | 1.887212984 | 4.74E-09 | solute carrier family 3 (activators of dibasic and neutral amino acid transport), member 2 |
| Swap70 | ENSMUSG00000031015 | 1.962254779 | 4.82E-09 | SWA-70 protein [Source:MGI Symbol;Acc:MGI:1298390] |
| Ehd1 | ENSMUSG00000024772 | 1.915943738 | 5.85E-09 | EH-domain containing 1 [Source:MGI Symbol;Acc:MGI:1341878] |
| Tma16 | ENSMUSG00000025591 | 1.639088979 | 6.35E-09 | translation machinery associated 16 [Source:MGI Symbol;Acc:MGI:1913532] |
| Nars | ENSMUSG00000024587 | 1.69802081 | 6.50E-09 | asparaginyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:1917473] |
| Ybx3 | ENSMUSG00000030189 | 2.266047362 | 6.69E-09 | Y box protein 3 [Source:MGI Symbol;Acc:MGI:2137670] |
| Ndufaf4 | ENSMUSG00000028261 | 1.588946862 | 8.76E-09 | NADH dehydrogenase (ubiquinone) 1 alpha subcomplex, assembly factor 4 [Source:MGI |
| Gm16062 | ENSMUSG00000087249 | 3.172020062 | 8.97E-09 | predicted gene 16062 [Source:MGI Symbol;Acc:MGI:3802162] |
| Erbin | ENSMUSG00000021709 | 1.056429017 | 8.97E-09 | Erbb2 interacting protein [Source:MGI Symbol;Acc:MGI:1890169] |
| Ssfa2 | ENSMUSG00000027007 | 3.000397014 | 9.36E-09 | sperm specific antigen 2 [Source:MGI Symbol;Acc:MGI:1917849] |
| Plscr1 | ENSMUSG00000032369 | 2.60366572 | 9.60E-09 | phospholipid scramblase 1 [Source:MGI Symbol;Acc:MGI:893575] |
| Cdk4 | ENSMUSG00000006728 | 1.33719069 | 9.62E-09 | cyclin-dependent kinase 4 [Source:MGI Symbol;Acc:MGI:88357] |
| Arhgap24 | ENSMUSG00000057315 | 1.389125419 | 1.01E-08 | Rho GTPase activating protein 24 [Source:MGI Symbol;Acc:MGI:1922647] |
| Agfg1 | ENSMUSG00000026159 | 1.042015351 | 1.11E-08 | ArfGAP with FG repeats 1 [Source:MGI Symbol;Acc:MGI:1333754] |
| Phgdh | ENSMUSG00000053398 | 2.602562534 | 1.33E-08 | 3-phosphoglycerate dehydrogenase [Source:MGI Symbol;Acc:MGI:1355330] |
| Renbp | ENSMUSG00000031387 | 2.907278399 | 1.39E-08 | renin binding protein [Source:MGI Symbol;Acc:MGI:105940] |
| B4galt4 | ENSMUSG00000022793 | 7.441116014 | 1.46E-08 | UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 4 [Source:MGI |
| Ergic1 | ENSMUSG00000001576 | 2.344237679 | 1.61E-08 | endoplasmic reticulum-golgi intermediate compartment (ERGIC) 1 [Source:MGI |
| Plk2 | ENSMUSG00000021701 | 2.530123213 | 1.87E-08 | polo like kinase 2 [Source:MGI Symbol;Acc:MGI:1099790] |
| Hpgds | ENSMUSG00000029919 | 3.884247687 | 2.05E-08 | hematopoietic prostaglandin D synthase [Source:MGI Symbol;Acc:MGI:1859384] |
| Snhg15 | ENSMUSG00000085156 | 2.154022123 | 2.09E-08 | small nucleolar RNA host gene 15 [Source:MGI Symbol;Acc:MGI:3650059] |
| Aatf | ENSMUSG00000018697 | 1.795443011 | 2.49E-08 | apoptosis antagonizing transcription factor [Source:MGI Symbol;Acc:MGI:1929608] |
| Ifrd1 | ENSMUSG00000001627 | 1.848100196 | 3.11E-08 | interferon-related developmental regulator 1 [Source:MGI Symbol;Acc:MGI:1316717] |
| Mapk6 | ENSMUSG00000042688 | 1.98526409 | 3.86E-08 | mitogen-activated protein kinase 6 [Source:MGI Symbol;Acc:MGI:1354946] |
| Nfkbie | ENSMUSG00000023947 | 1.83114449 | 3.95E-08 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, epsilon [Source:MGI |
| Fam136a | ENSMUSG00000057497 | 1.448769475 | 3.96E-08 | family with sequence similarity 136, member A [Source:MGI Symbol;Acc:MGI:1913738] |
| Snhg4 | ENSMUSG00000097769 | 2.351914602 | 4.63E-08 | small nucleolar RNA host gene 4 [Source:MGI Symbol;Acc:MGI:4937091] |
| Nme1 | ENSMUSG00000037601 | 1.422008948 | 4.63E-08 | NME/NM23 nucleoside diphosphate kinase 1 [Source:MGI Symbol;Acc:MGI:97355] |
| Polr1b | ENSMUSG00000027395 | 2.340255269 | 4.76E-08 | polymerase (RNA) I polypeptide B [Source:MGI Symbol;Acc:MGI:108014] |
| Ctdp1 | ENSMUSG00000033323 | 1.357100356 | 5.64E-08 | CTD (carboxy-terminal domain, RNA polymerase II, polypeptide A) phosphatase, subunit 1 |
| Rcl1 | ENSMUSG00000024785 | 2.025001906 | 5.97E-08 | RNA terminal phosphate cyclase-like 1 [Source:MGI Symbol;Acc:MGI:1913275] |
| Ppp4r2 | ENSMUSG00000052144 | 2.430973779 | 7.34E-08 | protein phosphatase 4, regulatory subunit 2 [Source:MGI Symbol;Acc:MGI:3027896] |
| Gng4 | ENSMUSG00000021303 | 7.599989494 | 8.71E-08 | guanine nucleotide binding protein (G protein), gamma 4 [Source:MGI Symbol;Acc:MGI:102703] |
| Zfp52 | ENSMUSG00000051341 | 1.624599191 | 8.71E-08 | zinc finger protein 52 [Source:MGI Symbol;Acc:MGI:99199] |
| Stx11 | ENSMUSG00000039232 | 2.593910276 | 1.01E-07 | syntaxin 11 [Source:MGI Symbol;Acc:MGI:1921982] |
| Uck2 | ENSMUSG00000026558 | 1.860108498 | 1.12E-07 | uridine-cytidine kinase 2 [Source:MGI Symbol;Acc:MGI:1931744] |
| Yars2 | ENSMUSG00000022792 | 1.629385415 | 1.12E-07 | tyrosyl-tRNA synthetase 2 (mitochondrial) [Source:MGI Symbol;Acc:MGI:1917370] |
| Sdhaf1 | ENSMUSG00000074211 | 1.559663481 | 1.14E-07 | succinate dehydrogenase complex assembly factor 1 [Source:MGI Symbol;Acc:MGI:1915582] |
| Actn1 | ENSMUSG00000015143 | 5.734743393 | 1.14E-07 | actinin, alpha 1 [Source:MGI Symbol;Acc:MGI:2137706] |
| Ccdc50 | ENSMUSG00000038127 | 1.405248176 | 1.35E-07 | coiled-coil domain containing 50 [Source:MGI Symbol;Acc:MGI:1914751] |
| Larp1 | ENSMUSG00000037331 | 1.541622129 | 1.36E-07 | La ribonucleoprotein domain family, member 1 [Source:MGI Symbol;Acc:MGI:1890165] |
| Dgcr6 | ENSMUSG00000003531 | 1.499591197 | 1.36E-07 | DiGeorge syndrome critical region gene 6 [Source:MGI Symbol;Acc:MGI:1202877] |
| Cd180 | ENSMUSG00000021624 | 1.013092775 | 1.37E-07 | CD180 antigen [Source:MGI Symbol;Acc:MGI:1194924] |
| Shisa8 | ENSMUSG00000096883 | 4.838849708 | 1.44E-07 | shisa family member 8 [Source:MGI Symbol;Acc:MGI:2146080] |
| Rem2 | ENSMUSG00000022176 | 3.771412399 | 1.51E-07 | rad and gem related GTP binding protein 2 [Source:MGI Symbol;Acc:MGI:2155260] |
| Fam213a | ENSMUSG00000021792 | 2.779139399 | 1.54E-07 | family with sequence similarity 213, member A [Source:MGI Symbol;Acc:MGI:1917814] |
| Polr1c | ENSMUSG00000067148 | 1.423921355 | 1.55E-07 | polymerase (RNA) I polypeptide C [Source:MGI Symbol;Acc:MGI:103288] |
| Hspa9 | ENSMUSG00000024359 | 1.559708498 | 1.59E-07 | heat shock protein 9 [Source:MGI Symbol;Acc:MGI:96245] |
| Stt3b | ENSMUSG00000032437 | 1.499931144 | 1.71E-07 | STT3, subunit of the oligosaccharyltransferase complex, homolog B (S. cerevisiae) [Source:MGI |
| Bysl | ENSMUSG00000023988 | 1.328375263 | 2.06E-07 | bystin-like [Source:MGI Symbol;Acc:MGI:1858419] |
| Qtrt1 | ENSMUSG00000002825 | 1.710580035 | 2.08E-07 | queuine tRNA-ribosyltransferase catalytic subunit 1 [Source:MGI Symbol;Acc:MGI:1931441] |
| Herpud1 | ENSMUSG00000031770 | 1.079976197 | 2.09E-07 | homocysteine-inducible, endoplasmic reticulum stress-inducible, ubiquitin-like domain member 1 |
| Tsen2 | ENSMUSG00000042389 | 1.918337022 | 2.22E-07 | tRNA splicing endonuclease subunit 2 [Source:MGI Symbol;Acc:MGI:2141599] |
| Gnl3 | ENSMUSG00000042354 | 2.365333585 | 2.28E-07 | guanine nucleotide binding protein-like 3 (nucleolar) [Source:MGI Symbol;Acc:MGI:1353651] |
| Myo1e | ENSMUSG00000032220 | 4.096879681 | 2.40E-07 | myosin IE [Source:MGI Symbol;Acc:MGI:106621] |
| Ppan | ENSMUSG00000004100 | 1.832034128 | 2.60E-07 | peter pan homolog (Drosophila) [Source:MGI Symbol;Acc:MGI:2178445] |
| Napa | ENSMUSG00000006024 | 1.183460881 | 2.60E-07 | N-ethylmaleimide sensitive fusion protein attachment protein alpha [Source:MGI |
| Mettl13 | ENSMUSG00000026694 | 2.354072897 | 2.94E-07 | methyltransferase like 13 [Source:MGI Symbol;Acc:MGI:1918699] |
| Sars | ENSMUSG00000068739 | 1.590713764 | 3.11E-07 | seryl-aminoacyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:102809] |
| Ghitm | ENSMUSG00000041028 | 1.1424746 | 3.13E-07 | growth hormone inducible transmembrane protein [Source:MGI Symbol;Acc:MGI:1913342] |
| Polr3h | ENSMUSG00000022476 | 1.415385761 | 3.55E-07 | polymerase (RNA) III (DNA directed) polypeptide H [Source:MGI Symbol;Acc:MGI:1926179] |
| Tcn2 | ENSMUSG00000020432 | 1.630374938 | 3.90E-07 | transcobalamin 2 [Source:MGI Symbol;Acc:MGI:98534] |
| Cd3eap | ENSMUSG00000047649 | 2.202399868 | 4.05E-07 | CD3E antigen, epsilon polypeptide associated protein [Source:MGI Symbol;Acc:MGI:1917583] |
| Urb1 | ENSMUSG00000039929 | 1.77159327 | 4.06E-07 | URB1 ribosome biogenesis 1 homolog (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:2146468] |
| Slc7a5 | ENSMUSG00000040010 | 2.174770175 | 5.06E-07 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 5 [Source:MGI |
| Nfkbiz | ENSMUSG00000035356 | 2.467431413 | 5.85E-07 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, zeta [Source:MGI |
| Timm8a1 | ENSMUSG00000048007 | 1.781275235 | 6.09E-07 | translocase of inner mitochondrial membrane 8A1 [Source:MGI Symbol;Acc:MGI:1353433] |
| 3110082I17Rik | ENSMUSG00000053553 | 2.369347086 | 6.54E-07 | RIKEN cDNA 3110082I17 gene [Source:MGI Symbol;Acc:MGI:1920462] |
| Nip7 | ENSMUSG00000031917 | 1.247724453 | 6.54E-07 | NIP7, nucleolar pre-rRNA processing protein [Source:MGI Symbol;Acc:MGI:1913414] |
| Noc2l | ENSMUSG00000095567 | 1.507414888 | 8.64E-07 | NOC2 like nucleolar associated transcriptional repressor [Source:MGI |
| Lztfl1 | ENSMUSG00000025245 | 1.322284915 | 8.71E-07 | leucine zipper transcription factor-like 1 [Source:MGI Symbol;Acc:MGI:1934860] |
| Acer3 | ENSMUSG00000030760 | 1.822246432 | 8.92E-07 | alkaline ceramidase 3 [Source:MGI Symbol;Acc:MGI:1913440] |
| Exoc2 | ENSMUSG00000021357 | 1.875037475 | 9.21E-07 | exocyst complex component 2 [Source:MGI Symbol;Acc:MGI:1913732] |
| Gpr65 | ENSMUSG00000021886 | 1.496102797 | 9.21E-07 | G-protein coupled receptor 65 [Source:MGI Symbol;Acc:MGI:108031] |
| Nhp2 | ENSMUSG00000001056 | 1.550665453 | 9.69E-07 | NHP2 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1098547] |

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|---|---|---|---|---|
| Gfer | ENSMUSG00000040888 | 1.036993613 | 9.76E-07 | growth factor, augmenter of liver regeneration [Source:MGI Symbol;Acc:MGI:107757] |
| Znhit6 | ENSMUSG00000074182 | 1.637455691 | 9.78E-07 | zinc finger, HIT type 6 [Source:MGI Symbol;Acc:MGI:1916996] |
| Flcn | ENSMUSG00000032633 | 1.243441851 | 1.06E-06 | folliculin [Source:MGI Symbol;Acc:MGI:2442184] |
| Ddx21 | ENSMUSG00000020075 | 1.601285238 | 1.12E-06 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 21 [Source:MGI Symbol;Acc:MGI:1860494] |
| Apex1 | ENSMUSG00000035960 | 1.608833074 | 1.13E-06 | apurinic/apyrimidinic endonuclease 1 [Source:MGI Symbol;Acc:MGI:88042] |
| Psat1 | ENSMUSG00000024640 | 2.044921668 | 1.21E-06 | phosphoserine aminotransferase 1 [Source:MGI Symbol;Acc:MGI:2183441] |
| Lrpprc | ENSMUSG00000024120 | 1.435343167 | 1.28E-06 | leucine-rich PPR-motif containing [Source:MGI Symbol;Acc:MGI:1919666] |
| Ppa1 | ENSMUSG00000020089 | 1.882040307 | 1.34E-06 | pyrophosphatase (inorganic) 1 [Source:MGI Symbol;Acc:MGI:97831] |
| Eprs | ENSMUSG00000026615 | 1.585118708 | 1.34E-06 | glutamyl-prolyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:97838] |
| Trim37 | ENSMUSG00000018548 | 1.366096251 | 1.50E-06 | tripartite motif-containing 37 [Source:MGI Symbol;Acc:MGI:2153072] |
| Nrgn | ENSMUSG00000053310 | 4.113342178 | 1.55E-06 | neurogranin [Source:MGI Symbol;Acc:MGI:1927184] |
| Smyd5 | ENSMUSG00000033706 | 2.516425571 | 1.62E-06 | SET and MYND domain containing 5 [Source:MGI Symbol;Acc:MGI:108048] |
| Eftud2 | ENSMUSG00000020929 | 1.089627971 | 1.67E-06 | elongation factor Tu GTP binding domain containing 2 [Source:MGI Symbol;Acc:MGI:1336880] |
| Grwd1 | ENSMUSG00000053801 | 1.9447405 | 1.91E-06 | glutamate-rich WD repeat containing 1 [Source:MGI Symbol;Acc:MGI:2141989] |
| Abcc1 | ENSMUSG00000023088 | 3.094663532 | 1.92E-06 | ATP-binding cassette, sub-family C (CFTR/MRP), member 1 [Source:MGI |
| Gns | ENSMUSG00000034707 | 1.457957442 | 1.95E-06 | glucosamine (N-acetyl)-6-sulfatase [Source:MGI Symbol;Acc:MGI:1922862] |
| Gng12 | ENSMUSG00000036402 | 1.31296531 | 2.12E-06 | guanine nucleotide binding protein (G protein), gamma 12 [Source:MGI |
| Gla | ENSMUSG00000031266 | 1.878131632 | 2.20E-06 | galactosidase, alpha [Source:MGI Symbol;Acc:MGI:1347344] |
| Lars | ENSMUSG00000024493 | 1.515881131 | 2.21E-06 | leucyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:1913808] |
| 2700038G22Rik | ENSMUSG00000097180 | 1.489989125 | 2.26E-06 | RIKEN cDNA 2700038G22 gene [Source:MGI Symbol;Acc:MGI:1914444] |
| Nfkb1 | ENSMUSG00000028163 | 1.21696941 | 2.29E-06 | nuclear factor of kappa light polypeptide gene enhancer in B cells 1, p105 [Source:MGI |
| Cnot8 | ENSMUSG00000020515 | 1.077613292 | 2.44E-06 | CCR4-NOT transcription complex, subunit 8 [Source:MGI Symbol;Acc:MGI:1916375] |
| Stap1 | ENSMUSG00000029254 | 1.424627543 | 2.45E-06 | signal transducing adaptor family member 1 [Source:MGI Symbol;Acc:MGI:1926193] |
| Gfi1 | ENSMUSG00000029275 | 4.341623695 | 2.51E-06 | growth factor independent 1 [Source:MGI Symbol;Acc:MGI:103170] |
| Gspt1 | ENSMUSG00000062203 | 1.30190189 | 2.60E-06 | G1 to S phase transition 1 [Source:MGI Symbol;Acc:MGI:1316728] |
| Alkbh6 | ENSMUSG00000042831 | 1.318688269 | 2.62E-06 | alkB homolog 6 [Source:MGI Symbol;Acc:MGI:2142037] |
| Fabp5 | ENSMUSG00000027533 | 4.426911358 | 2.87E-06 | fatty acid binding protein 5, epidermal [Source:MGI Symbol;Acc:MGI:101790] |
| Srm | ENSMUSG00000006442 | 2.419922343 | 2.91E-06 | spermidine synthase [Source:MGI Symbol;Acc:MGI:102690] |
| Mettl1 | ENSMUSG00000006732 | 2.366258646 | 2.91E-06 | methyltransferase like 1 [Source:MGI Symbol;Acc:MGI:1339986] |
| Jmjd4 | ENSMUSG00000036819 | 1.427260074 | 2.91E-06 | jumonji domain containing 4 [Source:MGI Symbol;Acc:MGI:2144404] |
| Rsl1d1 | ENSMUSG00000005846 | 1.246328877 | 2.94E-06 | ribosomal L1 domain containing 1 [Source:MGI Symbol;Acc:MGI:1913659] |
| Cirh1a | ENSMUSG00000041438 | 1.650198766 | 2.95E-06 | UTP4 small subunit processome component [Source:MGI Symbol;Acc:MGI:1096573] |
| Zfp593 | ENSMUSG00000028840 | 2.135247899 | 2.99E-06 | zinc finger protein 593 [Source:MGI Symbol;Acc:MGI:1915290] |
| Cd63 | ENSMUSG00000025351 | 9.566821865 | 3.25E-06 | CD63 antigen [Source:MGI Symbol;Acc:MGI:99529] |
| Pla2g12a | ENSMUSG00000027999 | 1.164671495 | 3.39E-06 | phospholipase A2, group XIIA [Source:MGI Symbol;Acc:MGI:1913600] |
| Pes1 | ENSMUSG00000020430 | 1.32077544 | 3.69E-06 | pescadillo ribosomal biogenesis factor 1 [Source:MGI Symbol;Acc:MGI:1890613] |
| Nol10 | ENSMUSG00000061458 | 1.49081026 | 3.69E-06 | nucleolar protein 10 [Source:MGI Symbol;Acc:MGI:2684913] |
| Rcn1 | ENSMUSG00000005973 | 1.743216852 | 3.72E-06 | reticulocalbin 1 [Source:MGI Symbol;Acc:MGI:104559] |
| Gart | ENSMUSG00000022962 | 1.684324882 | 3.76E-06 | phosphoribosylglycinamide formyltransferase [Source:MGI Symbol;Acc:MGI:95654] |
| Litaf | ENSMUSG00000022500 | 1.797968565 | 3.77E-06 | LPS-induced TN factor [Source:MGI Symbol;Acc:MGI:1929512] |
| C230085N15Rik | ENSMUSG00000102212 | 1.644955106 | 4.27E-06 | RIKEN cDNA C230085N15 gene [Source:MGI Symbol;Acc:MGI:2444267] |
| Cdk5r1 | ENSMUSG00000048895 | 2.464010062 | 4.49E-06 | cyclin-dependent kinase 5, regulatory subunit 1 (p35) [Source:MGI Symbol;Acc:MGI:101764] |
| Mpp6 | ENSMUSG00000038388 | 1.411513702 | 4.63E-06 | membrane protein, palmitoylated 6 (MAGUK p55 subfamily member 6) [Source:MGI |
| Mogs | ENSMUSG00000030036 | 1.972078832 | 4.91E-06 | mannosyl-oligosaccharide glucosidase [Source:MGI Symbol;Acc:MGI:1929872] |
| Rrp1b | ENSMUSG00000058392 | 2.138436723 | 4.91E-06 | ribosomal RNA processing 1 homolog B (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1919712] |
| Ipo5 | ENSMUSG00000030662 | 1.582620337 | 5.07E-06 | importin 5 [Source:MGI Symbol;Acc:MGI:1917822] |
| Rrad | ENSMUSG00000031880 | 1.858988581 | 5.21E-06 | Ras-related associated with diabetes [Source:MGI Symbol;Acc:MGI:1930943] |
| Siah2 | ENSMUSG00000036432 | 1.669379196 | 5.21E-06 | seven in absentia 2 [Source:MGI Symbol;Acc:MGI:108062] |
| Utp18 | ENSMUSG00000054079 | 1.321418699 | 5.36E-06 | UTP18 small subunit processome component [Source:MGI Symbol;Acc:MGI:1923402] |
| Timm10 | ENSMUSG00000027076 | 1.529697273 | 5.76E-06 | translocase of inner mitochondrial membrane 10 [Source:MGI Symbol;Acc:MGI:1353429] |
| Bzw2 | ENSMUSG00000020547 | 1.808939633 | 6.01E-06 | basic leucine zipper and W2 domains 2 [Source:MGI Symbol;Acc:MGI:1914162] |
| Prdx6 | ENSMUSG00000026701 | 1.331113775 | 6.18E-06 | peroxiredoxin 6 [Source:MGI Symbol;Acc:MGI:894320] |
| St6galnac4 | ENSMUSG00000079442 | 1.750810813 | 6.19E-06 | ST6 (alpha-N-acetyl-neuraminyl-2,3-beta-galactosyl-1,3)-N-acetylgalactosaminide alpha-2,6- |
| Atp1a1 | ENSMUSG00000033161 | 1.449847765 | 6.19E-06 | ATPase, Na+/K+ transporting, alpha 1 polypeptide [Source:MGI Symbol;Acc:MGI:88105] |
| Ahr | ENSMUSG00000019256 | 5.233927346 | 6.29E-06 | aryl-hydrocarbon receptor [Source:MGI Symbol;Acc:MGI:105043] |
| Socs2 | ENSMUSG00000020027 | 2.052289731 | 7.05E-06 | suppressor of cytokine signaling 2 [Source:MGI Symbol;Acc:MGI:1201787] |
| Tmem199 | ENSMUSG00000051232 | 1.009599845 | 7.64E-06 | transmembrane protein 199 [Source:MGI Symbol;Acc:MGI:2144113] |
| Ccnd2 | ENSMUSG00000000184 | 2.647801373 | 8.03E-06 | cyclin D2 [Source:MGI Symbol;Acc:MGI:88314] |
| Gaa | ENSMUSG00000025579 | 2.259520488 | 8.03E-06 | glucosidase, alpha, acid [Source:MGI Symbol;Acc:MGI:95609] |
| Ctdnep1 | ENSMUSG00000018559 | 1.469411641 | 8.03E-06 | CTD nuclear envelope phosphatase 1 [Source:MGI Symbol;Acc:MGI:1914431] |
| Gnpda1 | ENSMUSG00000052102 | 1.173227806 | 8.44E-06 | glucosamine-6-phosphate deaminase 1 [Source:MGI Symbol;Acc:MGI:1347054] |
| 5830444F18Rik | ENSMUSG00000102744 | 1.926352761 | 8.51E-06 | RIKEN cDNA 5830444F18 gene [Source:MGI Symbol;Acc:MGI:2444780] |
| Eif4ebp1 | ENSMUSG00000031490 | 1.56456517 | 9.04E-06 | eukaryotic translation initiation factor 4E binding protein 1 [Source:MGI Symbol;Acc:MGI:103267] |
| Yars | ENSMUSG00000028811 | 1.577189595 | 9.11E-06 | tyrosyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2147627] |
| Nat10 | ENSMUSG00000027185 | 1.67662922 | 9.38E-06 | N-acetyltransferase 10 [Source:MGI Symbol;Acc:MGI:2138939] |
| Zfp622 | ENSMUSG00000052253 | 1.219955521 | 9.38E-06 | zinc finger protein 622 [Source:MGI Symbol;Acc:MGI:1289282] |
| Atad3a | ENSMUSG00000029036 | 2.039146057 | 9.71E-06 | ATPase family, AAA domain containing 3A [Source:MGI Symbol;Acc:MGI:1919214] |
| Nbn | ENSMUSG00000028224 | 2.063496843 | 1.11E-05 | nibrin [Source:MGI Symbol;Acc:MGI:1351625] |
| Nsun5 | ENSMUSG00000000916 | 1.048128435 | 1.11E-05 | NOL1/NOP2/Sun domain family, member 5 [Source:MGI Symbol;Acc:MGI:2140844] |
| Mat2a | ENSMUSG00000053907 | 1.256911973 | 1.16E-05 | methionine adenosyltransferase II, alpha [Source:MGI Symbol;Acc:MGI:2443731] |
| Ldha | ENSMUSG00000063229 | 1.526475155 | 1.21E-05 | lactate dehydrogenase A [Source:MGI Symbol;Acc:MGI:96759] |
| Fam134b | ENSMUSG00000022270 | 1.540163172 | 1.29E-05 | reticulophagy regulator 1 [Source:MGI Symbol;Acc:MGI:1913520] |
| Hmgn3 | ENSMUSG00000066456 | 1.159313938 | 1.29E-05 | high mobility group nucleosomal binding domain 3 [Source:MGI Symbol;Acc:MGI:2138069] |
| Ncl | ENSMUSG00000026234 | 1.68357004 | 1.29E-05 | nucleolin [Source:MGI Symbol;Acc:MGI:97286] |
| Hk2 | ENSMUSG00000000628 | 2.24569018 | 1.34E-05 | hexokinase 2 [Source:MGI Symbol;Acc:MGI:1315197] |
| Nop16 | ENSMUSG00000025869 | 1.593455693 | 1.48E-05 | NOP16 nucleolar protein [Source:MGI Symbol;Acc:MGI:107862] |
| Ms4a4a | ENSMUSG00000101389 | 1.933833885 | 1.50E-05 | membrane-spanning 4-domains, subfamily A, member 4A [Source:MGI |
| Ifitm2 | ENSMUSG00000060591 | 2.070089067 | 1.50E-05 | interferon induced transmembrane protein 2 [Source:MGI Symbol;Acc:MGI:1933382] |
| Lap3 | ENSMUSG00000039682 | 2.027336317 | 1.53E-05 | leucine aminopeptidase 3 [Source:MGI Symbol;Acc:MGI:1914238] |
| D030028A08Rik | ENSMUSG00000078700 | 2.758061553 | 1.56E-05 | RIKEN cDNA D030028A08 gene [Source:MGI Symbol;Acc:MGI:2441931] |
| Slc15a3 | ENSMUSG00000024737 | 2.004867931 | 1.56E-05 | solute carrier family 15, member 3 [Source:MGI Symbol;Acc:MGI:1929691] |
| E430025E21Rik | ENSMUSG00000022350 | 1.09814796 | 1.56E-05 | WASH complex subunit 5 [Source:MGI Symbol;Acc:MGI:2146110] |
| Pno1 | ENSMUSG00000020116 | 1.395192261 | 1.61E-05 | partner of NOB1 homolog [Source:MGI Symbol;Acc:MGI:1913499] |
| Taf5l | ENSMUSG00000038697 | 1.086674276 | 1.70E-05 | TATA-box binding protein associated factor 5 like [Source:MGI Symbol;Acc:MGI:1919039] |

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|---|---|---|---|---|
| Ipo4 | ENSMUSG00000002319 | 2.766970313 | 1.80E-05 | importin 4 [Source:MGI Symbol;Acc:MGI:1923001] |
| Dusp4 | ENSMUSG00000031530 | 8.885341788 | 1.87E-05 | dual specificity phosphatase 4 [Source:MGI Symbol;Acc:MGI:2442191] |
| Pprc1 | ENSMUSG00000055491 | 1.860966978 | 1.88E-05 | peroxisome proliferative activated receptor, gamma, coactivator-related 1 [Source:MGI |
| Odc1 | ENSMUSG00000011179 | 2.022207695 | 1.93E-05 | ornithine decarboxylase, structural 1 [Source:MGI Symbol;Acc:MGI:97402] |
| Fosl2 | ENSMUSG00000029135 | 4.45379241 | 1.98E-05 | fos-like antigen 2 [Source:MGI Symbol;Acc:MGI:102858] |
| Prodh | ENSMUSG00000003526 | 2.9654286 | 2.09E-05 | proline dehydrogenase [Source:MGI Symbol;Acc:MGI:97770] |
| Wdr36 | ENSMUSG00000038299 | 1.189539285 | 2.11E-05 | WD repeat domain 36 [Source:MGI Symbol;Acc:MGI:1917819] |
| Heatr1 | ENSMUSG00000050244 | 1.536647096 | 2.18E-05 | HEAT repeat containing 1 [Source:MGI Symbol;Acc:MGI:2442524] |
| Tsr1 | ENSMUSG00000038335 | 1.521433546 | 2.18E-05 | TSR1 20S rRNA accumulation [Source:MGI Symbol;Acc:MGI:2144566] |
| Thap4 | ENSMUSG00000026279 | 1.34699496 | 2.26E-05 | THAP domain containing 4 [Source:MGI Symbol;Acc:MGI:1914276] |
| Mrto4 | ENSMUSG00000028741 | 1.452642238 | 2.27E-05 | mRNA turnover 4, ribosome maturation factor [Source:MGI Symbol;Acc:MGI:1917152] |
| Chchd4 | ENSMUSG00000034203 | 2.081565394 | 2.35E-05 | coiled-coil-helix-coiled-coil-helix domain containing 4 [Source:MGI Symbol;Acc:MGI:1919420] |
| Polr3e | ENSMUSG00000030880 | 1.723442671 | 2.45E-05 | polymerase (RNA) III (DNA directed) polypeptide E [Source:MGI Symbol;Acc:MGI:1349452] |
| AI506816 | ENSMUSG00000105987 | 1.647185221 | 2.53E-05 | expressed sequence AI506816 [Source:MGI Symbol;Acc:MGI:2140929] |
| Mapkapk3 | ENSMUSG00000032577 | 1.483927229 | 2.63E-05 | mitogen-activated protein kinase-activated protein kinase 3 [Source:MGI |
| Gm8369 | ENSMUSG00000058470 | 1.231632191 | 2.67E-05 | predicted gene 8369 [Source:MGI Symbol;Acc:MGI:3645380] |
| Mdn1 | ENSMUSG00000058006 | 1.891381629 | 2.81E-05 | midasin AAA ATPase 1 [Source:MGI Symbol;Acc:MGI:1926159] |
| Spata5 | ENSMUSG00000027722 | 1.535711379 | 2.86E-05 | spermatogenesis associated 5 [Source:MGI Symbol;Acc:MGI:1927170] |
| Tagap | ENSMUSG00000033450 | 3.741384832 | 2.89E-05 | T cell activation Rho GTPase activating protein [Source:MGI Symbol;Acc:MGI:3615484] |
| Il1r2 | ENSMUSG00000026073 | 3.728781746 | 2.95E-05 | interleukin 1 receptor, type II [Source:MGI Symbol;Acc:MGI:96546] |
| Ankrd13b | ENSMUSG00000037907 | 6.944096815 | 3.09E-05 | ankyrin repeat domain 13b [Source:MGI Symbol;Acc:MGI:2144501] |
| Npm1 | ENSMUSG00000057113 | 1.291622389 | 3.15E-05 | nucleophosmin 1 [Source:MGI Symbol;Acc:MGI:106184] |
| Ncln | ENSMUSG00000020238 | 1.539116479 | 3.18E-05 | nicalin [Source:MGI Symbol;Acc:MGI:1926081] |
| Shmt2 | ENSMUSG00000025403 | 1.645817063 | 3.29E-05 | serine hydroxymethyltransferase 2 (mitochondrial) [Source:MGI Symbol;Acc:MGI:1277989] |
| Wdr77 | ENSMUSG00000000561 | 1.766832338 | 3.39E-05 | WD repeat domain 77 [Source:MGI Symbol;Acc:MGI:1917715] |
| Ddx51 | ENSMUSG00000029504 | 1.530452952 | 3.39E-05 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 51 [Source:MGI Symbol;Acc:MGI:1916913] |
| Gars | ENSMUSG00000029777 | 1.216021954 | 3.51E-05 | glycyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2449057] |
| 9130401M01Rik | ENSMUSG00000101892 | 1.675361352 | 3.64E-05 | RIKEN cDNA 9130401M01 gene [Source:MGI Symbol;Acc:MGI:1923008] |
| St13 | ENSMUSG00000022403 | 1.371055567 | 3.69E-05 | suppression of tumorigenicity 13 [Source:MGI Symbol;Acc:MGI:1917606] |
| Trmt61a | ENSMUSG00000060950 | 2.467027284 | 3.75E-05 | tRNA methyltransferase 61A [Source:MGI Symbol;Acc:MGI:2443487] |
| Zhx2 | ENSMUSG00000071757 | 1.397887204 | 3.75E-05 | zinc fingers and homeoboxes 2 [Source:MGI Symbol;Acc:MGI:2683087] |
| Mthfd1 | ENSMUSG00000021048 | 1.877070048 | 4.13E-05 | methylenetetrahydrofolate dehydrogenase (NADP+ dependent), methenyltetrahydrofolate cyclohydrolase, formyltetrahydrofolate synthase [Source:MGI Symbol;Acc:MGI:1342005] |
| Kifc3 | ENSMUSG00000031788 | 5.521942981 | 4.28E-05 | kinesin family member C3 [Source:MGI Symbol;Acc:MGI:109202] |
| Hps4 | ENSMUSG00000042328 | 1.796682721 | 4.38E-05 | HPS4, biogenesis of lysosomal organelles complex 3 subunit 2 [Source:MGI |
| Slc7a6 | ENSMUSG00000031904 | 1.495844352 | 4.84E-05 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 6 [Source:MGI |
| Rpp14 | ENSMUSG00000023156 | 1.082019522 | 5.03E-05 | ribonuclease P 14 subunit [Source:MGI Symbol;Acc:MGI:1914303] |
| Hspa5 | ENSMUSG00000026864 | 1.046205284 | 5.27E-05 | heat shock protein 5 [Source:MGI Symbol;Acc:MGI:95835] |
| Pa2g4 | ENSMUSG00000025364 | 1.323549385 | 5.36E-05 | proliferation-associated 2G4 [Source:MGI Symbol;Acc:MGI:894684] |
| Bcl2l1 | ENSMUSG00000007659 | 1.765958296 | 5.36E-05 | BCL2-like 1 [Source:MGI Symbol;Acc:MGI:88139] |
| Pdxk | ENSMUSG00000032788 | 2.13088969 | 5.46E-05 | pyridoxal (pyridoxine, vitamin B6) kinase [Source:MGI Symbol;Acc:MGI:1351869] |
| Hspd1 | ENSMUSG00000025980 | 1.581353693 | 5.77E-05 | heat shock protein 1 (chaperonin) [Source:MGI Symbol;Acc:MGI:96242] |
| Zgpat | ENSMUSG00000027582 | 1.234698468 | 5.91E-05 | zinc finger, CCCH-type with G patch domain [Source:MGI Symbol;Acc:MGI:2449939] |
| Wdfy1 | ENSMUSG00000073643 | 1.485039866 | 6.66E-05 | WD repeat and FYVE domain containing 1 [Source:MGI Symbol;Acc:MGI:1916618] |
| 2310061I04Rik | ENSMUSG00000050705 | 1.145832811 | 6.73E-05 | RIKEN cDNA 2310061I04 gene [Source:MGI Symbol;Acc:MGI:1916912] |
| Gar1 | ENSMUSG00000028010 | 1.29771633 | 6.77E-05 | GAR1 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1930948] |
| Chac1 | ENSMUSG00000027313 | 2.539843478 | 6.86E-05 | ChaC, cation transport regulator 1 [Source:MGI Symbol;Acc:MGI:1916315] |
| Bop1 | ENSMUSG00000022557 | 1.267005784 | 6.86E-05 | block of proliferation 1 [Source:MGI Symbol;Acc:MGI:1334460] |
| Wbp5 | ENSMUSG00000042712 | 1.262403355 | 7.04E-05 | transcription elongation factor A like 9 [Source:MGI Symbol;Acc:MGI:109567] |
| Rgs1 | ENSMUSG00000026358 | 9.04049368 | 8.00E-05 | regulator of G-protein signaling 1 [Source:MGI Symbol;Acc:MGI:1354694] |
| Cct3 | ENSMUSG00000001416 | 1.199315046 | 8.08E-05 | chaperonin containing Tcp1, subunit 3 (gamma) [Source:MGI Symbol;Acc:MGI:104708] |
| Rrp15 | ENSMUSG00000001305 | 1.473109016 | 8.70E-05 | ribosomal RNA processing 15 homolog (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1914473] |
| C1qbp | ENSMUSG00000018446 | 1.502016545 | 9.40E-05 | complement component 1, q subcomponent binding protein [Source:MGI |
| Tomm5 | ENSMUSG00000078713 | 1.067425938 | 0.00010323 | translocase of outer mitochondrial membrane 5 homolog (yeast) [Source:MGI |
| Eif3b | ENSMUSG00000056076 | 1.280711536 | 0.00010524 | eukaryotic translation initiation factor 3, subunit B [Source:MGI Symbol;Acc:MGI:106478] |
| Gsto1 | ENSMUSG00000025068 | 2.406004132 | 0.0001072 | glutathione S-transferase omega 1 [Source:MGI Symbol;Acc:MGI:1342273] |
| Fam162a | ENSMUSG00000003955 | 1.543698418 | 0.00010935 | family with sequence similarity 162, member A [Source:MGI Symbol;Acc:MGI:1917436] |
| Tnfrsf26 | ENSMUSG00000045362 | 1.219367642 | 0.00010994 | tumor necrosis factor receptor superfamily, member 26 [Source:MGI Symbol;Acc:MGI:2651928] |
| Tamm41 | ENSMUSG00000030316 | 1.26166504 | 0.00011718 | TAM41 mitochondrial translocator assembly and maintenance homolog [Source:MGI |
| Bex4 | ENSMUSG00000047844 | 3.484748482 | 0.00011742 | brain expressed X-linked 4 [Source:MGI Symbol;Acc:MGI:3606746] |
| Fpgs | ENSMUSG00000009566 | 1.605653698 | 0.00011854 | folylpolyglutamyl synthetase [Source:MGI Symbol;Acc:MGI:95576] |
| Zc3h12d | ENSMUSG00000039981 | 1.651789258 | 0.0001215 | zinc finger CCCH type containing 12D [Source:MGI Symbol;Acc:MGI:3045313] |
| Shcbp1l | ENSMUSG00000042708 | 5.87251387 | 0.0001356 | Shc SH2-domain binding protein 1-like [Source:MGI Symbol;Acc:MGI:1919086] |
| Cluh | ENSMUSG00000020741 | 3.198170696 | 0.0001356 | clustered mitochondria (cluA/CLU1) homolog [Source:MGI Symbol;Acc:MGI:1921398] |
| Nop56 | ENSMUSG00000027405 | 1.150728817 | 0.0001356 | NOP56 ribonucleoprotein [Source:MGI Symbol;Acc:MGI:1914384] |
| Egr3 | ENSMUSG00000033730 | 6.166451058 | 0.00013852 | early growth response 3 [Source:MGI Symbol;Acc:MGI:1306780] |
| Sgpl1 | ENSMUSG00000020097 | 1.540629312 | 0.00013852 | sphingosine phosphate lyase 1 [Source:MGI Symbol;Acc:MGI:1261415] |
| Slc17a5 | ENSMUSG00000049624 | 1.340174193 | 0.00014091 | solute carrier family 17 (anion/sugar transporter), member 5 [Source:MGI |
| Smyd2 | ENSMUSG00000026603 | 5.929789781 | 0.00014277 | SET and MYND domain containing 2 [Source:MGI Symbol;Acc:MGI:1915889] |
| Mrpl12 | ENSMUSG00000039640 | 1.065002094 | 0.00015309 | mitochondrial ribosomal protein L12 [Source:MGI Symbol;Acc:MGI:1926273] |
| Marcksl1 | ENSMUSG00000047945 | 1.689625592 | 0.00015416 | MARCKS-like 1 [Source:MGI Symbol;Acc:MGI:97143] |
| Elp5 | ENSMUSG00000018565 | 1.519937426 | 0.00015608 | elongator acetyltransferase complex subunit 5 [Source:MGI Symbol;Acc:MGI:1859017] |
| Prmt5 | ENSMUSG00000023110 | 1.01274671 | 0.00015755 | protein arginine N-methyltransferase 5 [Source:MGI Symbol;Acc:MGI:1351645] |
| Mir17hg | ENSMUSG00000089726 | 1.895877931 | 0.00016396 | Mir17 host gene (non-protein coding) [Source:MGI Symbol;Acc:MGI:1923207] |
| Eif4a1 | ENSMUSG00000059796 | 1.356377075 | 0.00016433 | eukaryotic translation initiation factor 4A1 [Source:MGI Symbol;Acc:MGI:95303] |
| Nifk | ENSMUSG00000026377 | 1.327412954 | 0.0001652 | nucleolar protein interacting with the FHA domain of MKI67 [Source:MGI |
| Hmox1 | ENSMUSG00000005413 | 2.504221751 | 0.00016972 | heme oxygenase 1 [Source:MGI Symbol;Acc:MGI:96163] |
| 4930519P11Rik | ENSMUSG00000097602 | 5.849537056 | 0.00017007 | RIKEN cDNA 4930519P11 gene [Source:MGI Symbol;Acc:MGI:1921971] |
| Crem | ENSMUSG00000063889 | 1.277341826 | 0.00017623 | cAMP responsive element modulator [Source:MGI Symbol;Acc:MGI:88495] |
| Usp10 | ENSMUSG00000031826 | 1.125778162 | 0.00017623 | ubiquitin specific peptidase 10 [Source:MGI Symbol;Acc:MGI:894652] |
| Ttc27 | ENSMUSG00000024078 | 1.866763608 | 0.00017762 | tetratricopeptide repeat domain 27 [Source:MGI Symbol;Acc:MGI:1921446] |
| Tnfaip3 | ENSMUSG00000019850 | 2.464670286 | 0.00018377 | tumor necrosis factor, alpha-induced protein 3 [Source:MGI Symbol;Acc:MGI:1196377] |
| Ubqln4 | ENSMUSG00000008604 | 1.74645824 | 0.00018783 | ubiquilin 4 [Source:MGI Symbol;Acc:MGI:2150152] |
| Traf1 | ENSMUSG00000026875 | 3.593204606 | 0.00019258 | TNF receptor-associated factor 1 [Source:MGI Symbol;Acc:MGI:101836] |
| Nop14 | ENSMUSG00000036693 | 1.540662721 | 0.00019622 | NOP14 nucleolar protein [Source:MGI Symbol;Acc:MGI:1922666] |
| Znrf3 | ENSMUSG00000041961 | 2.622460194 | 0.00020059 | zinc and ring finger 3 [Source:MGI Symbol;Acc:MGI:3039616] |
| Ddx27 | ENSMUSG00000017999 | 1.402127625 | 0.00020231 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 27 [Source:MGI Symbol;Acc:MGI:2385884] |

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| Myc | ENSMUSG00000022346 | 3.031004406 | 0.00020302 | myelocytomatosis oncogene [Source:MGI Symbol;Acc:MGI:97250] |
| Abcf2 | ENSMUSG00000028953 | 1.067415577 | 0.00020823 | ATP-binding cassette, sub-family F (GCN20), member 2 [Source:MGI Symbol;Acc:MGI:1351657] |
| Gm17477 | ENSMUSG00000084917 | 4.373404389 | 0.00021057 | predicted gene, 17477 [Source:MGI Symbol;Acc:MGI:4937111] |
| Iars | ENSMUSG00000037851 | 1.503348281 | 0.00021358 | isoleucine-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2145219] |
| Il4i1 | ENSMUSG00000074141 | 2.485922162 | 0.00022497 | interleukin 4 induced 1 [Source:MGI Symbol;Acc:MGI:109552] |
| Rasal1 | ENSMUSG00000029602 | 2.389404338 | 0.00022589 | RAS protein activator like 1 (GAP1 like) [Source:MGI Symbol;Acc:MGI:1330842] |
| Tsr2 | ENSMUSG00000025264 | 1.849017483 | 0.00023287 | TSR2 20S rRNA accumulation [Source:MGI Symbol;Acc:MGI:1916749] |
| Slc25a39 | ENSMUSG00000018677 | 1.550945289 | 0.00023433 | solute carrier family 25, member 39 [Source:MGI Symbol;Acc:MGI:1196386] |
| Hivep3 | ENSMUSG00000028634 | 2.403952617 | 0.00024349 | human immunodeficiency virus type I enhancer binding protein 3 [Source:MGI |
| Nr4a1 | ENSMUSG00000023034 | 6.964980425 | 0.0002444 | nuclear receptor subfamily 4, group A, member 1 [Source:MGI Symbol;Acc:MGI:1352454] |
| Eif2b3 | ENSMUSG00000028683 | 1.488233769 | 0.00025098 | eukaryotic translation initiation factor 2B, subunit 3 [Source:MGI Symbol;Acc:MGI:1313286] |
| Dnajc11 | ENSMUSG00000039768 | 1.044480733 | 0.00025169 | DnaJ heat shock protein family (Hsp40) member C11 [Source:MGI Symbol;Acc:MGI:2443386] |
| Cars | ENSMUSG00000010755 | 1.252472679 | 0.00026048 | cysteinyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:1351477] |
| Adm | ENSMUSG00000030790 | 3.636452439 | 0.00027747 | adrenomedullin [Source:MGI Symbol;Acc:MGI:108058] |
| Set | ENSMUSG00000054766 | 1.081797184 | 0.00027935 | SET nuclear oncogene [Source:MGI Symbol;Acc:MGI:1860267] |
| Vav3 | ENSMUSG00000033721 | 1.963635392 | 0.00028034 | vav 3 oncogene [Source:MGI Symbol;Acc:MGI:1888518] |
| Bex1 | ENSMUSG00000050071 | 4.716843748 | 0.00028271 | brain expressed X-linked 1 [Source:MGI Symbol;Acc:MGI:1328321] |
| Eef1e1 | ENSMUSG00000001707 | 1.05575199 | 0.00028722 | eukaryotic translation elongation factor 1 epsilon 1 [Source:MGI Symbol;Acc:MGI:1913393] |
| Gm37248 | ENSMUSG00000103216 | 2.33434547 | 0.00029784 | predicted gene, 37248 [Source:MGI Symbol;Acc:MGI:5610476] |
| Klf10 | ENSMUSG00000037465 | 1.832574394 | 0.00030536 | Kruppel-like factor 10 [Source:MGI Symbol;Acc:MGI:1101353] |
| Aars | ENSMUSG00000031960 | 1.279973815 | 0.0003137 | alanyl-tRNA synthetase [Source:MGI Symbol;Acc:MGI:2384560] |
| Wdr12 | ENSMUSG00000026019 | 1.183512207 | 0.0003137 | WD repeat domain 12 [Source:MGI Symbol;Acc:MGI:1927241] |
| Phb2 | ENSMUSG00000004264 | 1.174454587 | 0.00032591 | prohibitin 2 [Source:MGI Symbol;Acc:MGI:102520] |
| Wdr4 | ENSMUSG00000024037 | 1.169037433 | 0.00034148 | WD repeat domain 4 [Source:MGI Symbol;Acc:MGI:1889002] |
| Bcl2l11 | ENSMUSG00000027381 | 1.455195287 | 0.00035029 | BCL2-like 11 (apoptosis facilitator) [Source:MGI Symbol;Acc:MGI:1197519] |
| Utp15 | ENSMUSG00000041747 | 1.221073507 | 0.00035471 | UTP15 small subunit processome component [Source:MGI Symbol;Acc:MGI:2145443] |
| Psmg1 | ENSMUSG00000022913 | 1.210928953 | 0.00038791 | proteasome (prosome, macropain) assembly chaperone 1 [Source:MGI |
| Bcap29 | ENSMUSG00000020650 | 1.290480284 | 0.00043397 | B cell receptor associated protein 29 [Source:MGI Symbol;Acc:MGI:101917] |
| Dclre1a | ENSMUSG00000025077 | 4.506120367 | 0.00043715 | DNA cross-link repair 1A [Source:MGI Symbol;Acc:MGI:1930042] |
| Noa1 | ENSMUSG00000036285 | 1.003805747 | 0.00043715 | nitric oxide associated 1 [Source:MGI Symbol;Acc:MGI:1914306] |
| Hsp90ab1 | ENSMUSG00000023944 | 1.111149688 | 0.00045015 | heat shock protein 90 alpha (cytosolic), class B member 1 [Source:MGI Symbol;Acc:MGI:96247] |
| Dis3 | ENSMUSG00000033166 | 1.375963709 | 0.00045811 | DIS3 homolog, exosome endoribonuclease and 3'-5' exoribonuclease [Source:MGI |
| Hilpda | ENSMUSG00000043421 | 2.006197376 | 0.00046202 | hypoxia inducible lipid droplet associated [Source:MGI Symbol;Acc:MGI:1916823] |
| Agpat5 | ENSMUSG00000031467 | 1.207601041 | 0.00046202 | 1-acylglycerol-3-phosphate O-acyltransferase 5 (lysophosphatidic acid acyltransferase, epsilon) |
| Aen | ENSMUSG00000030609 | 1.238288214 | 0.00046319 | apoptosis enhancing nuclease [Source:MGI Symbol;Acc:MGI:1915298] |
| Phb | ENSMUSG00000038845 | 1.144006888 | 0.00046621 | prohibitin [Source:MGI Symbol;Acc:MGI:97572] |
| Eif3g | ENSMUSG00000070319 | 1.055260034 | 0.00048855 | eukaryotic translation initiation factor 3, subunit G [Source:MGI Symbol;Acc:MGI:1858258] |
| Dtx1 | ENSMUSG00000029603 | 2.699489499 | 0.00049552 | deltex 1, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:1352744] |
| Nop2 | ENSMUSG00000038279 | 1.543955465 | 0.00050531 | NOP2 nucleolar protein [Source:MGI Symbol;Acc:MGI:107891] |
| Wdr5 | ENSMUSG00000026917 | 1.055292015 | 0.00051594 | WD repeat domain 5 [Source:MGI Symbol;Acc:MGI:2155884] |
| Rpp40 | ENSMUSG00000021418 | 1.787049971 | 0.00051906 | ribonuclease P 40 subunit [Source:MGI Symbol;Acc:MGI:1346084] |
| Ruvbl2 | ENSMUSG00000003868 | 1.226902293 | 0.00053428 | RuvB-like protein 2 [Source:MGI Symbol;Acc:MGI:1342299] |
| Phf10 | ENSMUSG00000023883 | 1.126354684 | 0.00053744 | PHD finger protein 10 [Source:MGI Symbol;Acc:MGI:1919307] |
| Ctps | ENSMUSG00000028633 | 1.617511656 | 0.00054303 | cytidine 5'-triphosphate synthase [Source:MGI Symbol;Acc:MGI:1858304] |
| Ddx1 | ENSMUSG00000037149 | 1.101694949 | 0.00054625 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 1 [Source:MGI Symbol;Acc:MGI:2144727] |
| Nek6 | ENSMUSG00000026749 | 3.549242969 | 0.00054827 | NIMA (never in mitosis gene a)-related expressed kinase 6 [Source:MGI |
| Ddx10 | ENSMUSG00000053289 | 1.033694739 | 0.00055402 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 10 [Source:MGI Symbol;Acc:MGI:1924841] |
| Nsun2 | ENSMUSG00000021595 | 1.546459427 | 0.00055419 | NOL1/NOP2/Sun domain family member 2 [Source:MGI Symbol;Acc:MGI:107252] |
| Mfsd12 | ENSMUSG00000034854 | 2.410849457 | 0.0005559 | major facilitator superfamily domain containing 12 [Source:MGI Symbol;Acc:MGI:3604804] |
| Ciart | ENSMUSG00000038550 | 2.909676213 | 0.00055908 | circadian associated repressor of transcription [Source:MGI Symbol;Acc:MGI:2684975] |
| Rel | ENSMUSG00000020275 | 1.235111139 | 0.00056319 | reticuloendotheliosis oncogene [Source:MGI Symbol;Acc:MGI:97897] |
| Orai1 | ENSMUSG00000049686 | 1.564945333 | 0.00056563 | ORAI calcium release-activated calcium modulator 1 [Source:MGI Symbol;Acc:MGI:1925542] |
| Ide | ENSMUSG00000056999 | 1.410813546 | 0.00057693 | insulin degrading enzyme [Source:MGI Symbol;Acc:MGI:96412] |
| 1110038B12Rik | ENSMUSG00000092203 | 1.478251711 | 0.00058068 | RIKEN cDNA 1110038B12 gene [Source:MGI Symbol;Acc:MGI:1916013] |
| Wdr46 | ENSMUSG00000024312 | 1.582355515 | 0.00062213 | WD repeat domain 46 [Source:MGI Symbol;Acc:MGI:1931871] |
| Rpf2 | ENSMUSG00000038510 | 1.041990791 | 0.00063047 | ribosome production factor 2 homolog [Source:MGI Symbol;Acc:MGI:1914489] |
| Wsb2 | ENSMUSG00000029364 | 1.191951436 | 0.00065646 | WD repeat and SOCS box-containing 2 [Source:MGI Symbol;Acc:MGI:2144041] |
| Phf23 | ENSMUSG00000018572 | 1.117718046 | 0.00065958 | PHD finger protein 23 [Source:MGI Symbol;Acc:MGI:1925496] |
| Mybbp1a | ENSMUSG00000040463 | 1.348617286 | 0.00068309 | MYB binding protein (P160) 1a [Source:MGI Symbol;Acc:MGI:106181] |
| Naa25 | ENSMUSG00000042719 | 1.127796613 | 0.00069056 | N(alpha)-acetyltransferase 25, NatB auxiliary subunit [Source:MGI Symbol;Acc:MGI:2442563] |
| Pycrl | ENSMUSG00000022571 | 1.112248353 | 0.00069421 | pyrroline-5-carboxylate reductase-like [Source:MGI Symbol;Acc:MGI:1913444] |
| E430014B02Rik | ENSMUSG00000102973 | 1.631007999 | 0.00070494 | RIKEN cDNA E430014B02 gene [Source:MGI Symbol;Acc:MGI:2445017] |
| Cd320 | ENSMUSG00000002308 | 1.673205314 | 0.00072801 | CD320 antigen [Source:MGI Symbol;Acc:MGI:1860083] |
| Ddit3 | ENSMUSG00000025408 | 1.527127698 | 0.00073175 | DNA-damage inducible transcript 3 [Source:MGI Symbol;Acc:MGI:109247] |
| Prmt3 | ENSMUSG00000030505 | 1.227447746 | 0.0007708 | protein arginine N-methyltransferase 3 [Source:MGI Symbol;Acc:MGI:1919224] |
| Lncpint | ENSMUSG00000044471 | 3.013800515 | 0.00079748 | long non-protein coding RNA, Trp53 induced transcript [Source:MGI Symbol;Acc:MGI:2673128] |
| Alg3 | ENSMUSG00000033809 | 1.268833322 | 0.00079969 | asparagine-linked glycosylation 3 (alpha-1,3-mannosyltransferase) [Source:MGI |
| Polr2h | ENSMUSG00000021018 | 1.339776913 | 0.00080534 | polymerase (RNA) II (DNA directed) polypeptide H [Source:MGI Symbol;Acc:MGI:2384309] |
| Tmem97 | ENSMUSG00000037278 | 1.603632377 | 0.00080715 | transmembrane protein 97 [Source:MGI Symbol;Acc:MGI:1916321] |
| Casp4 | ENSMUSG00000033538 | 2.672163673 | 0.00083076 | caspase 4, apoptosis-related cysteine peptidase [Source:MGI Symbol;Acc:MGI:107700] |
| Dpp7 | ENSMUSG00000026958 | 2.166907618 | 0.00083076 | dipeptidylpeptidase 7 [Source:MGI Symbol;Acc:MGI:1933213] |
| Ksr1 | ENSMUSG00000018334 | 3.647678791 | 0.00087074 | kinase suppressor of ras 1 [Source:MGI Symbol;Acc:MGI:105051] |
| Pus7 | ENSMUSG00000057541 | 2.559414732 | 0.00088227 | pseudouridylate synthase 7 [Source:MGI Symbol;Acc:MGI:1925947] |
| Timm9 | ENSMUSG00000021079 | 1.244794901 | 0.00089806 | translocase of inner mitochondrial membrane 9 [Source:MGI Symbol;Acc:MGI:1353436] |
| Kat2a | ENSMUSG00000020918 | 1.041921209 | 0.00090345 | K(lysine) acetyltransferase 2A [Source:MGI Symbol;Acc:MGI:1343101] |
| Prpf19 | ENSMUSG00000024735 | 1.312538915 | 0.0009058 | pre-mRNA processing factor 19 [Source:MGI Symbol;Acc:MGI:106247] |
| Tmem238 | ENSMUSG00000030431 | 2.499524644 | 0.00098632 | transmembrane protein 238 [Source:MGI Symbol;Acc:MGI:1922935] |
| Nfkb2 | ENSMUSG00000025225 | 1.174282268 | 0.00099747 | nuclear factor of kappa light polypeptide gene enhancer in B cells 2, p49/p100 [Source:MGI |
| Gm2065 | ENSMUSG00000102882 | 5.408211688 | 0.00100004 | predicted gene 2065 [Source:MGI Symbol;Acc:MGI:3780232] |
| Rrs1 | ENSMUSG00000061024 | 1.259423558 | 0.00100939 | ribosome biogenesis regulator 1 [Source:MGI Symbol;Acc:MGI:1929721] |

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|---|---|---|---|---|
| Klhl8 | ENSMUSG00000029312 | 4.38027424 | 0.00101484 | kelch-like 8 [Source:MGI Symbol;Acc:MGI:2179430] |
| Cad | ENSMUSG00000013629 | 1.999821293 | 0.00104328 | carbamoyl-phosphate synthetase 2, aspartate transcarbamylase, and dihydroorotase |
| Otud1 | ENSMUSG00000043415 | 1.652531989 | 0.00105166 | OTU domain containing 1 [Source:MGI Symbol;Acc:MGI:1918448] |
| Srfbp1 | ENSMUSG00000024528 | 1.134961666 | 0.00106643 | serum response factor binding protein 1 [Source:MGI Symbol;Acc:MGI:1914472] |
| Vegfb | ENSMUSG00000024962 | 1.984823063 | 0.0010763 | vascular endothelial growth factor B [Source:MGI Symbol;Acc:MGI:106199] |
| Bcl2a1b | ENSMUSG00000089929 | 4.803300281 | 0.00110837 | B cell leukemia/lymphoma 2 related protein A1b [Source:MGI Symbol;Acc:MGI:1278326] |
| Tbl2 | ENSMUSG00000005374 | 1.708527625 | 0.00111374 | transducin (beta)-like 2 [Source:MGI Symbol;Acc:MGI:1351652] |
| Snapc4 | ENSMUSG00000036281 | 1.833922575 | 0.00113798 | small nuclear RNA activating complex, polypeptide 4 [Source:MGI Symbol;Acc:MGI:2443935] |
| Ptges3 | ENSMUSG00000071072 | 1.047795866 | 0.00114355 | prostaglandin E synthase 3 [Source:MGI Symbol;Acc:MGI:1929282] |
| Utp20 | ENSMUSG00000004356 | 1.806785197 | 0.00116593 | UTP20 small subunit processome component [Source:MGI Symbol;Acc:MGI:1917933] |
| Itgb1 | ENSMUSG00000025809 | 1.160833982 | 0.00116619 | integrin beta 1 (fibronectin receptor beta) [Source:MGI Symbol;Acc:MGI:96610] |
| Ftsj3 | ENSMUSG00000020706 | 1.224062993 | 0.00119404 | FtsJ RNA methyltransferase homolog 3 (E. coli) [Source:MGI Symbol;Acc:MGI:1860295] |
| Pdcd11 | ENSMUSG00000025047 | 1.402291534 | 0.00119815 | programmed cell death 11 [Source:MGI Symbol;Acc:MGI:1341788] |
| Cth | ENSMUSG00000028179 | 8.973975258 | 0.00127385 | cystathionase (cystathionine gamma-lyase) [Source:MGI Symbol;Acc:MGI:1339968] |
| Gm17586 | ENSMUSG00000097062 | 5.809909781 | 0.00128338 | predicted gene, 17586 [Source:MGI Symbol;Acc:MGI:4937220] |
| Ccdc137 | ENSMUSG00000049957 | 1.33393795 | 0.00133846 | coiled-coil domain containing 137 [Source:MGI Symbol;Acc:MGI:1914541] |
| Stx6 | ENSMUSG00000026470 | 1.108490819 | 0.00133846 | syntaxin 6 [Source:MGI Symbol;Acc:MGI:1926235] |
| Slc38a7 | ENSMUSG00000036534 | 2.065805411 | 0.00137426 | solute carrier family 38, member 7 [Source:MGI Symbol;Acc:MGI:2679005] |
| Sh2d2a | ENSMUSG00000028071 | 2.573656964 | 0.00137535 | SH2 domain containing 2A [Source:MGI Symbol;Acc:MGI:1351596] |
| Kcnh4 | ENSMUSG00000035355 | 7.317608809 | 0.00139015 | potassium voltage-gated channel, subfamily H (eag-related), member 4 [Source:MGI |
| Slc7a3 | ENSMUSG00000031297 | 5.018947034 | 0.00140824 | solute carrier family 7 (cationic amino acid transporter, y+ system), member 3 [Source:MGI |
| Supv3l1 | ENSMUSG00000020079 | 1.505415078 | 0.00141209 | suppressor of var1, 3-like 1 (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:2441711] |
| Tomm40 | ENSMUSG00000002984 | 1.303231475 | 0.00142362 | translocase of outer mitochondrial membrane 40 homolog (yeast) [Source:MGI |
| Taf1a | ENSMUSG00000072258 | 1.164234337 | 0.0014316 | TATA-box binding protein associated factor, RNA polymerase I, A [Source:MGI |
| Dusp12 | ENSMUSG00000026659 | 1.407568111 | 0.00146311 | dual specificity phosphatase 12 [Source:MGI Symbol;Acc:MGI:1890614] |
| 2410002F23Rik | ENSMUSG00000045411 | 1.683520501 | 0.00147515 | RIKEN cDNA 2410002F23 gene [Source:MGI Symbol;Acc:MGI:1914226] |
| Spag4 | ENSMUSG00000038180 | 4.232805912 | 0.00147918 | sperm associated antigen 4 [Source:MGI Symbol;Acc:MGI:2444120] |
| Sla2 | ENSMUSG00000027636 | 2.206887372 | 0.00153842 | Src-like-adaptor 2 [Source:MGI Symbol;Acc:MGI:1925049] |
| Ubxn2a | ENSMUSG00000020634 | 1.654149616 | 0.00155464 | UBX domain protein 2A [Source:MGI Symbol;Acc:MGI:2442310] |
| Fam83g | ENSMUSG00000042377 | 8.570868098 | 0.00156467 | family with sequence similarity 83, member G [Source:MGI Symbol;Acc:MGI:1916890] |
| Rrp9 | ENSMUSG00000041506 | 1.583065441 | 0.00156909 | RRP9, small subunit (SSU) processome component, homolog (yeast) [Source:MGI |
| Dctpp1 | ENSMUSG00000042462 | 1.400828358 | 0.00159215 | dCTP pyrophosphatase 1 [Source:MGI Symbol;Acc:MGI:1913672] |
| Ctu2 | ENSMUSG00000049482 | 1.111123605 | 0.00159215 | cytosolic thiouridylase subunit 2 [Source:MGI Symbol;Acc:MGI:1914215] |
| Srrd | ENSMUSG00000029346 | 1.124194387 | 0.00164647 | SRR1 domain containing [Source:MGI Symbol;Acc:MGI:1917368] |
| Eif1a | ENSMUSG00000057561 | 1.281949572 | 0.0016904 | eukaryotic translation initiation factor 1A [Source:MGI Symbol;Acc:MGI:95298] |
| Dvl2 | ENSMUSG00000020888 | 1.239405195 | 0.00172057 | dishevelled segment polarity protein 2 [Source:MGI Symbol;Acc:MGI:106613] |
| Amdhd2 | ENSMUSG00000036820 | 1.360829578 | 0.00172186 | amidohydrolase domain containing 2 [Source:MGI Symbol;Acc:MGI:2443978] |
| Nup188 | ENSMUSG00000052533 | 1.466611092 | 0.00177101 | nucleoporin 188 [Source:MGI Symbol;Acc:MGI:2446190] |
| Sigmar1 | ENSMUSG00000036078 | 1.471929292 | 0.00178713 | sigma non-opioid intracellular receptor 1 [Source:MGI Symbol;Acc:MGI:1195268] |
| Gem | ENSMUSG00000028214 | 1.252779999 | 0.00182238 | GTP binding protein (gene overexpressed in skeletal muscle) [Source:MGI |
| Uba6 | ENSMUSG00000035898 | 1.150137556 | 0.00183182 | ubiquitin-like modifier activating enzyme 6 [Source:MGI Symbol;Acc:MGI:1913894] |
| Ranbp1 | ENSMUSG00000005732 | 1.069814333 | 0.00183459 | RAN binding protein 1 [Source:MGI Symbol;Acc:MGI:96269] |
| Mthfd1l | ENSMUSG00000040675 | 1.58794482 | 0.00183716 | methylenetetrahydrofolate dehydrogenase (NADP+ dependent) 1-like [Source:MGI Symbol;Acc:MGI:1924836] |
| Mtap | ENSMUSG00000062937 | 2.243227806 | 0.00191279 | methylthioadenosine phosphorylase [Source:MGI Symbol;Acc:MGI:1914152] |
| Ece2 | ENSMUSG00000022842 | 1.537536007 | 0.00195542 | endothelin converting enzyme 2 [Source:MGI Symbol;Acc:MGI:1101356] |
| Dkc1 | ENSMUSG00000031403 | 1.219936128 | 0.00198481 | dyskeratosis congenita 1, dyskerin [Source:MGI Symbol;Acc:MGI:1861727] |
| Lyar | ENSMUSG00000067367 | 1.168376782 | 0.00198585 | Ly1 antibody reactive clone [Source:MGI Symbol;Acc:MGI:107470] |
| G6pc3 | ENSMUSG00000034793 | 1.341438435 | 0.00202877 | glucose 6 phosphatase, catalytic, 3 [Source:MGI Symbol;Acc:MGI:1915651] |
| Pwp1 | ENSMUSG00000001785 | 1.089073959 | 0.00209625 | PWP1 homolog, endonuclein [Source:MGI Symbol;Acc:MGI:1914735] |
| Etfbkmt | ENSMUSG00000039958 | 1.067105477 | 0.00211549 | electron transfer flavoprotein beta subunit lysine methyltransferase [Source:MGI |
| Reep3 | ENSMUSG00000019873 | 1.029934526 | 0.00211549 | receptor accessory protein 3 [Source:MGI Symbol;Acc:MGI:88930] |
| Slc25a33 | ENSMUSG00000028982 | 3.199037976 | 0.00225204 | solute carrier family 25, member 33 [Source:MGI Symbol;Acc:MGI:1917806] |
| Ifrd2 | ENSMUSG00000010048 | 1.842991401 | 0.00229568 | interferon-related developmental regulator 2 [Source:MGI Symbol;Acc:MGI:1316708] |
| Bid | ENSMUSG00000004446 | 1.187406747 | 0.00231982 | BH3 interacting domain death agonist [Source:MGI Symbol;Acc:MGI:108093] |
| Slc35f2 | ENSMUSG00000042195 | 2.770402316 | 0.00233711 | solute carrier family 35, member F2 [Source:MGI Symbol;Acc:MGI:1919272] |
| D16Ertd472e | ENSMUSG00000022864 | 1.440267406 | 0.00237553 | DNA segment, Chr 16, ERATO Doi 472, expressed [Source:MGI Symbol;Acc:MGI:1196400] |
| Tiparp | ENSMUSG00000034640 | 1.060785566 | 0.00239274 | TCDD-inducible poly(ADP-ribose) polymerase [Source:MGI Symbol;Acc:MGI:2159210] |
| Bmi1 | ENSMUSG00000026739 | 2.355668253 | 0.00250005 | Bmi1 polycomb ring finger oncogene [Source:MGI Symbol;Acc:MGI:88174] |
| Dph2 | ENSMUSG00000028540 | 1.142941999 | 0.00251813 | DPH2 homolog [Source:MGI Symbol;Acc:MGI:1914978] |
| Mafg | ENSMUSG00000051510 | 1.833270628 | 0.00252872 | v-maf musculoaponeurotic fibrosarcoma oncogene family, protein G (avian) [Source:MGI Symbol;Acc:MGI:96911] |
| Twnk | ENSMUSG00000025209 | 1.760722448 | 0.00252872 | twinkle mtDNA helicase [Source:MGI Symbol;Acc:MGI:2137410] |
| Sdad1 | ENSMUSG00000029415 | 1.154307974 | 0.00256677 | SDA1 domain containing 1 [Source:MGI Symbol;Acc:MGI:2140779] |
| Tmem51 | ENSMUSG00000040616 | 3.93882484 | 0.00262501 | transmembrane protein 51 [Source:MGI Symbol;Acc:MGI:2384874] |
| Ppat | ENSMUSG00000029246 | 1.558962287 | 0.00270582 | phosphoribosyl pyrophosphate amidotransferase [Source:MGI Symbol;Acc:MGI:2387203] |
| Dusp2 | ENSMUSG00000027368 | 1.16887908 | 0.00273356 | dual specificity phosphatase 2 [Source:MGI Symbol;Acc:MGI:101911] |
| Eif5a | ENSMUSG00000078812 | 1.068778524 | 0.00275775 | eukaryotic translation initiation factor 5A [Source:MGI Symbol;Acc:MGI:106248] |
| Pea15a | ENSMUSG00000013698 | 2.188503892 | 0.00276725 | phosphoprotein enriched in astrocytes 15A [Source:MGI Symbol;Acc:MGI:104799] |
| Jdp2 | ENSMUSG00000034271 | 2.106229932 | 0.00289422 | Jun dimerization protein 2 [Source:MGI Symbol;Acc:MGI:1932093] |
| Pebp1 | ENSMUSG00000032959 | 1.105756601 | 0.00289422 | phosphatidylethanolamine binding protein 1 [Source:MGI Symbol;Acc:MGI:1344408] |
| Cct6a | ENSMUSG00000029447 | 1.068368363 | 0.00290508 | chaperonin containing Tcp1, subunit 6a (zeta) [Source:MGI Symbol;Acc:MGI:107943] |
| Ier2 | ENSMUSG00000053560 | 1.659588534 | 0.00293389 | immediate early response 2 [Source:MGI Symbol;Acc:MGI:104815] |
| Surf2 | ENSMUSG00000014873 | 1.204766306 | 0.00294746 | surfeit gene 2 [Source:MGI Symbol;Acc:MGI:98444] |
| Gtpbp4 | ENSMUSG00000021149 | 1.182998314 | 0.00300005 | GTP binding protein 4 [Source:MGI Symbol;Acc:MGI:1916487] |
| Aebp2 | ENSMUSG00000030232 | 1.136055418 | 0.00310137 | AE binding protein 2 [Source:MGI Symbol;Acc:MGI:1338038] |
| Hspe1 | ENSMUSG00000073676 | 1.18798983 | 0.00314301 | heat shock protein 1 (chaperonin 10) [Source:MGI Symbol;Acc:MGI:104680] |
| Isyna1 | ENSMUSG00000019139 | 1.426907942 | 0.00319826 | myo-inositol 1-phosphate synthase A1 [Source:MGI Symbol;Acc:MGI:1919030] |
| Wdr18 | ENSMUSG00000035754 | 1.064570991 | 0.00327852 | WD repeat domain 18 [Source:MGI Symbol;Acc:MGI:2158400] |
| Fdx1l | ENSMUSG00000079677 | 1.181699607 | 0.00328431 | ferredoxin 1-like [Source:MGI Symbol;Acc:MGI:1915415] |
| Gpatch4 | ENSMUSG00000028069 | 1.346783857 | 0.00330351 | G patch domain containing 4 [Source:MGI Symbol;Acc:MGI:1913864] |
| Polr3d | ENSMUSG00000000776 | 1.995964721 | 0.0033233 | polymerase (RNA) III (DNA directed) polypeptide D [Source:MGI Symbol;Acc:MGI:1914315] |

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|---|---|---|---|---|
| Ero1l | ENSMUSG00000021831 | 1.834073424 | 0.00347271 | ERO1-like (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1354385] |
| Slpi | ENSMUSG00000017002 | 3.097325265 | 0.00355564 | secretory leukocyte peptidase inhibitor [Source:MGI Symbol;Acc:MGI:109297] |
| Aldh18a1 | ENSMUSG00000025007 | 2.00771623 | 0.00361934 | aldehyde dehydrogenase 18 family, member A1 [Source:MGI Symbol;Acc:MGI:1888908] |
| Wdr43 | ENSMUSG00000041057 | 1.253540676 | 0.00366161 | WD repeat domain 43 [Source:MGI Symbol;Acc:MGI:1919765] |
| Fbl | ENSMUSG00000046865 | 1.27085205 | 0.00370123 | fibrillarin [Source:MGI Symbol;Acc:MGI:95486] |
| Slc39a6 | ENSMUSG00000024270 | 1.235055437 | 0.00375882 | solute carrier family 39 (metal ion transporter), member 6 [Source:MGI |
| Pip4k2c | ENSMUSG00000025417 | 1.415274299 | 0.00383959 | phosphatidylinositol-5-phosphate 4-kinase, type II, gamma [Source:MGI |
| Ikbkap | ENSMUSG00000028431 | 1.058015837 | 0.00386909 | inhibitor of kappa light polypeptide enhancer in B cells, kinase complex-associated protein |
| Ints3 | ENSMUSG00000027933 | 1.417578805 | 0.00400603 | integrator complex subunit 3 [Source:MGI Symbol;Acc:MGI:2140050] |
| Wbscr16 | ENSMUSG00000061979 | 1.179005064 | 0.00403183 | reculator of chromosome condensation 1 like [Source:MGI Symbol;Acc:MGI:2137600] |
| Pitrm1 | ENSMUSG00000021193 | 1.170312234 | 0.00405718 | pitrilysin metallepetidase 1 [Source:MGI Symbol;Acc:MGI:1916867] |
| Esf1 | ENSMUSG00000045624 | 1.110970915 | 0.00414487 | ESF1 nucleolar pre-rRNA processing protein homolog [Source:MGI Symbol;Acc:MGI:1913830] |
| Wdr75 | ENSMUSG00000025995 | 1.35303037 | 0.00432006 | WD repeat domain 75 [Source:MGI Symbol;Acc:MGI:1920924] |
| Tnfrsf23 | ENSMUSG00000037613 | 3.809486567 | 0.00439839 | tumor necrosis factor receptor superfamily, member 23 [Source:MGI Symbol;Acc:MGI:1930269] |
| Slc5a3 | ENSMUSG00000089774 | 2.189426209 | 0.00441891 | solute carrier family 5 (inositol transporters), member 3 [Source:MGI Symbol;Acc:MGI:1858226] |
| C130013H08Rik | ENSMUSG00000105509 | 2.698171141 | 0.00441986 | RIKEN cDNA C130013H08 gene [Source:MGI Symbol;Acc:MGI:3697343] |
| Chka | ENSMUSG00000024843 | 1.508962711 | 0.00448624 | choline kinase alpha [Source:MGI Symbol;Acc:MGI:107760] |
| Nfkbid | ENSMUSG00000036931 | 1.640193231 | 0.00460097 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, delta [Source:MGI Symbol;Acc:MGI:3041243] |
| Trnau1ap | ENSMUSG00000028898 | 1.3393892 | 0.00460981 | tRNA selenocysteine 1 associated protein 1 [Source:MGI Symbol;Acc:MGI:1919037] |
| Clec2i | ENSMUSG00000030365 | 1.813429845 | 0.00477866 | C-type lectin domain family 2, member i [Source:MGI Symbol;Acc:MGI:2136650] |
| Guk1 | ENSMUSG00000020444 | 1.210847281 | 0.00492494 | guanylate kinase 1 [Source:MGI Symbol;Acc:MGI:95871] |
| Stat5a | ENSMUSG00000004043 | 1.340341827 | 0.00497135 | signal transducer and activator of transcription 5A [Source:MGI Symbol;Acc:MGI:103036] |
| Aprt | ENSMUSG00000006589 | 1.409746668 | 0.00499992 | adenine phosphoribosyl transferase [Source:MGI Symbol;Acc:MGI:88061] |
| Bhlhe40 | ENSMUSG00000030103 | 6.741789979 | 0.00506933 | basic helix-loop-helix family, member e40 [Source:MGI Symbol;Acc:MGI:1097714] |
| B3gnt7 | ENSMUSG00000079445 | 3.219986894 | 0.00506933 | UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 7 [Source:MGI |
| B230377A18Rik | ENSMUSG00000104195 | 3.578474209 | 0.00509122 | RIKEN cDNA B230377A18 gene [Source:MGI Symbol;Acc:MGI:3704260] |
| A930024E05Rik | ENSMUSG00000056735 | 3.313311251 | 0.00539333 | RIKEN cDNA A930024E05 gene [Source:MGI Symbol;Acc:MGI:1924414] |
| Pvt1 | ENSMUSG00000097039 | 2.477562451 | 0.00544677 | plasmacytoma variant translocation 1 [Source:MGI Symbol;Acc:MGI:97824] |
| Tbl3 | ENSMUSG00000040688 | 1.449034412 | 0.00553137 | transducin (beta)-like 3 [Source:MGI Symbol;Acc:MGI:2384863] |
| Rexo2 | ENSMUSG00000032026 | 1.073971705 | 0.00580263 | RNA exonuclease 2 [Source:MGI Symbol;Acc:MGI:1888981] |
| Rpp25 | ENSMUSG00000062309 | 7.756076205 | 0.00604965 | ribonuclease P/MRP 25 subunit [Source:MGI Symbol;Acc:MGI:2143151] |
| Nudt9 | ENSMUSG00000029310 | 1.028136811 | 0.00622608 | nudix (nucleoside diphosphate linked moiety X)-type motif 9 [Source:MGI |
| Ppp1r14b | ENSMUSG00000056612 | 1.110378713 | 0.00633039 | protein phosphatase 1, regulatory (inhibitor) subunit 14B [Source:MGI Symbol;Acc:MGI:107682] |
| Slc1a4 | ENSMUSG00000020142 | 3.786312674 | 0.00652971 | solute carrier family 1 (glutamate/neutral amino acid transporter), member 4 [Source:MGI |
| Rasd1 | ENSMUSG00000049892 | 3.590844316 | 0.00652971 | RAS, dexamethasone-induced 1 [Source:MGI Symbol;Acc:MGI:1270848] |
| Heatr3 | ENSMUSG00000031657 | 1.936516126 | 0.00658138 | HEAT repeat containing 3 [Source:MGI Symbol;Acc:MGI:2444491] |
| Slc16a3 | ENSMUSG00000025161 | 5.83128068 | 0.00663926 | solute carrier family 16 (monocarboxylic acid transporters), member 3 [Source:MGI Symbol;Acc:MGI:1933438] |
| Ntmt1 | ENSMUSG00000026857 | 1.476336329 | 0.0068436 | N-terminal Xaa-Pro-Lys N-methyltransferase 1 [Source:MGI Symbol;Acc:MGI:1913867] |
| Map9 | ENSMUSG00000033900 | 7.255651653 | 0.00695253 | microtubule-associated protein 9 [Source:MGI Symbol;Acc:MGI:2442208] |
| Pi4k2a | ENSMUSG00000025178 | 1.210199972 | 0.00722868 | phosphatidylinositol 4-kinase type 2 alpha [Source:MGI Symbol;Acc:MGI:1934031] |
| St7 | ENSMUSG00000029534 | 1.144708613 | 0.00726232 | suppression of tumorigenicity 7 [Source:MGI Symbol;Acc:MGI:1927450] |
| Vegfa | ENSMUSG00000023951 | 1.449631579 | 0.00740176 | vascular endothelial growth factor A [Source:MGI Symbol;Acc:MGI:103178] |
| Pabpc4 | ENSMUSG00000011257 | 1.649952451 | 0.00753725 | poly(A) binding protein, cytoplasmic 4 [Source:MGI Symbol;Acc:MGI:2385206] |
| Sec24a | ENSMUSG00000036391 | 1.647863216 | 0.0078627 | Sec24 related gene family, member A (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1924621] |
| Cyp20a1 | ENSMUSG00000049439 | 1.087313974 | 0.00800263 | cytochrome P450, family 20, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:1925201] |
| Kdm6b | ENSMUSG00000018476 | 2.163054523 | 0.00808393 | KDM1 lysine (K)-specific demethylase 6B [Source:MGI Symbol;Acc:MGI:2448492] |
| Cd9 | ENSMUSG00000030342 | 2.841156781 | 0.00813742 | CD9 antigen [Source:MGI Symbol;Acc:MGI:88348] |
| Tarsl2 | ENSMUSG00000030515 | 7.363299991 | 0.00815818 | threonyl-tRNA synthetase-like 2 [Source:MGI Symbol;Acc:MGI:2444486] |
| Trmt11 | ENSMUSG00000019792 | 1.028528952 | 0.00867004 | tRNA methyltransferase 11 [Source:MGI Symbol;Acc:MGI:1920931] |
| Nfkbia | ENSMUSG00000021025 | 1.06455253 | 0.00906679 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, alpha [Source:MGI |
| Noc4l | ENSMUSG00000033294 | 1.116296197 | 0.00910281 | NOC4 like [Source:MGI Symbol;Acc:MGI:2140843] |
| Ak7 | ENSMUSG00000041323 | 7.400236118 | 0.0094038 | adenylate kinase 7 [Source:MGI Symbol;Acc:MGI:1926051] |
| Pisd | ENSMUSG00000023452 | 1.314444883 | 0.00946965 | phosphatidylserine decarboxylase [Source:MGI Symbol;Acc:MGI:2445114] |
| Slc52a2 | ENSMUSG00000022560 | 1.127290497 | 0.00950796 | solute carrier protein 52, member 2 [Source:MGI Symbol;Acc:MGI:1289288] |
| 0610010F05Rik | ENSMUSG00000042208 | 1.390614373 | 0.00959733 | RIKEN cDNA 0610010F05 gene [Source:MGI Symbol;Acc:MGI:1918925] |
| Elac2 | ENSMUSG00000020549 | 1.576097545 | 0.00962657 | elaC ribonuclease Z 2 [Source:MGI Symbol;Acc:MGI:1890496] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-8. Genes significantly repressed in in immature B cell subsets in Ig NL upon stimulation.

| Symbol | Ensembl gene id | logFC (NL-sHEL/NL-R10) | adj.P.val | Annotation |
|---|---|---|---|---|
| Fgd2 | ENSMUSG00000024013 | 3.148124386 | 1.71E-45 | FYVE, RhoGEF and PH domain containing 2 [Source:MGI Symbol;Acc:MGI:1347084] |
| Cd55 | ENSMUSG00000026399 | 2.805701169 | 5.45E-42 | CD55 molecule, decay accelerating factor for complement [Source:MGI |
| Napsa | ENSMUSG00000002204 | 1.418734447 | 8.83E-37 | napsin A aspartic peptidase [Source:MGI Symbol;Acc:MGI:109365] |
| S100a10 | ENSMUSG00000041959 | 1.886937089 | 8.91E-35 | S100 calcium binding protein A10 (calpactin) [Source:MGI Symbol;Acc:MGI:1339468] |
| Col27a1 | ENSMUSG00000045672 | 3.705366661 | 1.30E-30 | collagen, type XXVII, alpha 1 [Source:MGI Symbol;Acc:MGI:2672118] |
| Pld4 | ENSMUSG00000052160 | 2.765773656 | 5.57E-29 | phospholipase D family, member 4 [Source:MGI Symbol;Acc:MGI:2144765] |
| Spi1 | ENSMUSG00000002111 | 1.844046085 | 2.66E-27 | spleen focus forming virus (SFFV) proviral integration oncogene [Source:MGI |
| Rflnb | ENSMUSG00000020846 | 5.937772981 | 1.56E-24 | refilin B [Source:MGI Symbol;Acc:MGI:1923816] |
| Ptp4a3 | ENSMUSG00000059895 | 1.558171476 | 2.50E-24 | protein tyrosine phosphatase 4a3 [Source:MGI Symbol;Acc:MGI:1277098] |
| Id3 | ENSMUSG00000007872 | 3.053331753 | 3.08E-23 | inhibitor of DNA binding 3 [Source:MGI Symbol;Acc:MGI:96398] |
| Abi3 | ENSMUSG00000018381 | 2.442497374 | 3.90E-23 | ABI gene family, member 3 [Source:MGI Symbol;Acc:MGI:1913860] |
| Tsc22d3 | ENSMUSG00000031431 | 1.876178904 | 8.29E-23 | TSC22 domain family, member 3 [Source:MGI Symbol;Acc:MGI:1196284] |
| Cotl1 | ENSMUSG00000031827 | 1.721212522 | 4.29E-22 | coactosin-like 1 (Dictyostelium) [Source:MGI Symbol;Acc:MGI:1919292] |
| Pik3c2b | ENSMUSG00000026447 | 2.192893988 | 1.10E-21 | phosphatidylinositol-4-phosphate 3-kinase catalytic subunit type 2 beta [Source:MGI |
| Cep89 | ENSMUSG00000023072 | 2.805850421 | 2.41E-21 | centrosomal protein 89 [Source:MGI Symbol;Acc:MGI:1919390] |
| Mgst2 | ENSMUSG00000074604 | 2.765449326 | 4.44E-21 | microsomal glutathione S-transferase 2 [Source:MGI Symbol;Acc:MGI:2448481] |
| Cd79a | ENSMUSG00000003379 | 1.424066929 | 7.93E-21 | CD79A antigen (immunoglobulin-associated alpha) [Source:MGI Symbol;Acc:MGI:101774] |
| S100a11 | ENSMUSG00000027907 | 1.350567907 | 7.53E-20 | S100 calcium binding protein A11 [Source:MGI Symbol;Acc:MGI:1338798] |
| Fermt3 | ENSMUSG00000024965 | 1.547828064 | 7.70E-20 | fermitin family member 3 [Source:MGI Symbol;Acc:MGI:2147790] |
| Coro1a | ENSMUSG00000030707 | 1.422818303 | 8.20E-20 | coronin, actin binding protein 1A [Source:MGI Symbol;Acc:MGI:1345961] |
| Cst3 | ENSMUSG00000027447 | 1.394855302 | 9.71E-20 | cystatin C [Source:MGI Symbol;Acc:MGI:102519] |
| Mzb1 | ENSMUSG00000024353 | 1.956382103 | 3.93E-19 | marginal zone B and B1 cell-specific protein 1 [Source:MGI Symbol;Acc:MGI:1917066] |
| Gpr18 | ENSMUSG00000050350 | 1.485659186 | 8.79E-19 | G protein-coupled receptor 18 [Source:MGI Symbol;Acc:MGI:107859] |
| Bin2 | ENSMUSG00000098112 | 1.584452994 | 4.39E-18 | bridging integrator 2 [Source:MGI Symbol;Acc:MGI:3611448] |
| Rasgrp2 | ENSMUSG00000032946 | 2.776679537 | 5.23E-18 | RAS, guanyl releasing protein 2 [Source:MGI Symbol;Acc:MGI:1333849] |
| Rasa3 | ENSMUSG00000031453 | 2.638891519 | 7.34E-18 | RAS p21 protein activator 3 [Source:MGI Symbol;Acc:MGI:1197013] |
| Pafah1b3 | ENSMUSG00000005447 | 1.42514113 | 2.46E-17 | platelet-activating factor acetylhydrolase, isoform 1b, subunit 3 [Source:MGI |
| Mtch1 | ENSMUSG00000024012 | 1.261988409 | 3.13E-17 | mitochondrial carrier 1 [Source:MGI Symbol;Acc:MGI:1929261] |
| 2010309G21Rik | ENSMUSG00000106567 | 2.443498043 | 3.23E-17 | RIKEN cDNA 2010309G21 gene [Source:MGI Symbol;Acc:MGI:1917268] |
| Gm43603 | ENSMUSG00000104710 | 4.832928566 | 1.37E-16 | predicted gene, 31243 [Source:MGI Symbol;Acc:MGI:5590402] |
| Arl5c | ENSMUSG00000038352 | 1.528786357 | 1.51E-16 | ADP-ribosylation factor-like 5C [Source:MGI Symbol;Acc:MGI:3028577] |
| Ifi30 | ENSMUSG00000031838 | 2.390213727 | 1.96E-16 | interferon gamma inducible protein 30 [Source:MGI Symbol;Acc:MGI:2137648] |
| Gng2 | ENSMUSG00000043004 | 2.216446469 | 3.27E-16 | guanine nucleotide binding protein (G protein), gamma 2 [Source:MGI Symbol;Acc:MGI:102705] |
| Klf13 | ENSMUSG00000052040 | 1.854119534 | 4.19E-16 | Kruppel-like factor 13 [Source:MGI Symbol;Acc:MGI:1354948] |
| Pecam1 | ENSMUSG00000020717 | 1.896519389 | 8.04E-16 | platelet/endothelial cell adhesion molecule 1 [Source:MGI Symbol;Acc:MGI:97537] |
| Dedd2 | ENSMUSG00000054499 | 1.176083571 | 1.84E-15 | death effector domain-containing DNA binding protein 2 [Source:MGI Symbol;Acc:MGI:1914629] |
| Inpp5k | ENSMUSG00000006127 | 1.757516433 | 2.41E-15 | inositol polyphosphate 5-phosphatase K [Source:MGI Symbol;Acc:MGI:1194899] |
| Ncf4 | ENSMUSG00000071715 | 1.742445872 | 4.14E-15 | neutrophil cytosolic factor 4 [Source:MGI Symbol;Acc:MGI:109186] |
| Igkv2-109 | ENSMUSG00000105606 | 5.714118034 | 5.31E-15 | immunoglobulin kappa variable 2-109 [Source:MGI Symbol;Acc:MGI:3642626] |
| Ceacam1 | ENSMUSG00000074272 | 3.244221658 | 1.93E-14 | carcinoembryonic antigen-related cell adhesion molecule 1 [Source:MGI |
| Tmem173 | ENSMUSG00000024349 | 2.17290083 | 2.45E-14 | transmembrane protein 173 [Source:MGI Symbol;Acc:MGI:1919762] |
| Spib | ENSMUSG00000008193 | 1.403726115 | 3.11E-14 | Spi-B transcription factor (Spi-1/PU.1 related) [Source:MGI Symbol;Acc:MGI:892986] |
| Ucp2 | ENSMUSG00000033685 | 1.040917016 | 3.11E-14 | uncoupling protein 2 (mitochondrial, proton carrier) [Source:MGI Symbol;Acc:MGI:109354] |
| Traf5 | ENSMUSG00000026637 | 2.124045772 | 4.63E-14 | TNF receptor-associated factor 5 [Source:MGI Symbol;Acc:MGI:107548] |
| Stx7 | ENSMUSG00000019998 | 1.267968484 | 4.63E-14 | syntaxin 7 [Source:MGI Symbol;Acc:MGI:1858210] |
| Tuba1a | ENSMUSG00000072235 | 1.478867379 | 7.93E-14 | tubulin, alpha 1A [Source:MGI Symbol;Acc:MGI:98869] |
| S1pr4 | ENSMUSG00000044199 | 2.076663296 | 1.62E-13 | sphingosine-1-phosphate receptor 4 [Source:MGI Symbol;Acc:MGI:1333809] |
| Rnase6 | ENSMUSG00000021880 | 1.668068784 | 1.92E-13 | ribonuclease, RNase A family, 6 [Source:MGI Symbol;Acc:MGI:1925666] |
| Selplg | ENSMUSG00000048163 | 1.556256458 | 3.63E-13 | selectin, platelet (p-selectin) ligand [Source:MGI Symbol;Acc:MGI:106689] |
| Cd36 | ENSMUSG00000002944 | 1.30039591 | 6.97E-13 | CD36 molecule [Source:MGI Symbol;Acc:MGI:107899] |
| Syk | ENSMUSG00000021457 | 2.010028642 | 8.05E-13 | spleen tyrosine kinase [Source:MGI Symbol;Acc:MGI:99515] |
| Myl12b | ENSMUSG00000034868 | 1.577750673 | 1.44E-12 | myosin, light chain 12B, regulatory [Source:MGI Symbol;Acc:MGI:107494] |
| N4bp3 | ENSMUSG00000001053 | 2.050766804 | 1.84E-12 | NEDD4 binding protein 3 [Source:MGI Symbol;Acc:MGI:2442218] |
| Add1 | ENSMUSG00000029106 | 1.347471141 | 2.02E-12 | adducin 1 (alpha) [Source:MGI Symbol;Acc:MGI:87918] |
| Gpsm3 | ENSMUSG00000034786 | 1.258031429 | 2.07E-12 | G-protein signalling modulator 3 (AGS3-like, C. elegans) [Source:MGI |
| Snx20 | ENSMUSG00000031662 | 1.960971514 | 2.44E-12 | sorting nexin 20 [Source:MGI Symbol;Acc:MGI:1918857] |
| Plxdc1 | ENSMUSG00000017417 | 4.889793453 | 2.83E-12 | plexin domain containing 1 [Source:MGI Symbol;Acc:MGI:1919574] |
| Gucd1 | ENSMUSG00000033416 | 1.631392649 | 4.96E-12 | guanylyl cyclase domain containing 1 [Source:MGI Symbol;Acc:MGI:1916028] |
| Cnn2 | ENSMUSG00000004665 | 1.476050333 | 5.44E-12 | calponin 2 [Source:MGI Symbol;Acc:MGI:105093] |
| Hes1 | ENSMUSG00000022528 | 3.254166613 | 5.44E-12 | hairy and enhancer of split 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:104853] |
| Lsp1 | ENSMUSG00000018819 | 1.538631563 | 5.97E-12 | lymphocyte specific 1 [Source:MGI Symbol;Acc:MGI:96832] |
| Atf7ip | ENSMUSG00000030213 | 1.046932773 | 6.05E-12 | activating transcription factor 7 interacting protein [Source:MGI Symbol;Acc:MGI:1858965] |
| Tspan32 | ENSMUSG00000000244 | 1.555930045 | 7.38E-12 | tetraspanin 32 [Source:MGI Symbol;Acc:MGI:1350360] |
| Foxo1 | ENSMUSG00000044167 | 1.446895251 | 2.88E-11 | forkhead box O1 [Source:MGI Symbol;Acc:MGI:1890077] |
| Rhbdf2 | ENSMUSG00000020806 | 3.187555956 | 3.05E-11 | rhomboid 5 homolog 2 [Source:MGI Symbol;Acc:MGI:2442473] |
| Slc43a2 | ENSMUSG00000038178 | 2.532355814 | 3.86E-11 | solute carrier family 43, member 2 [Source:MGI Symbol;Acc:MGI:2442746] |
| Acp5 | ENSMUSG00000001348 | 2.736354657 | 4.29E-11 | acid phosphatase 5, tartrate resistant [Source:MGI Symbol;Acc:MGI:87883] |
| Scimp | ENSMUSG00000057135 | 3.99949808 | 5.36E-11 | SLP adaptor and CSK interacting membrane protein [Source:MGI Symbol;Acc:MGI:3610314] |
| Gpd1l | ENSMUSG00000050627 | 1.445410151 | 5.76E-11 | glycerol-3-phosphate dehydrogenase 1-like [Source:MGI Symbol;Acc:MGI:1289257] |
| Gm37065 | ENSMUSG00000104413 | 1.992688608 | 6.39E-11 | predicted gene, 37065 [Source:MGI Symbol;Acc:MGI:5610293] |
| Mterf2 | ENSMUSG00000049038 | 1.545014198 | 1.33E-10 | mitochondrial transcription termination factor 2 [Source:MGI Symbol;Acc:MGI:1921488] |

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|---|---|---|---|---|
| Slamf6 | ENSMUSG00000015314 | 2.252235128 | 1.60E-10 | SLAM family member 6 [Source:MGI Symbol;Acc:MGI:1353620] |
| Rnf13 | ENSMUSG00000036503 | 1.008813641 | 1.75E-10 | ring finger protein 13 [Source:MGI Symbol;Acc:MGI:1346341] |
| Snord35b | ENSMUSG00000064767 | 3.629444554 | 1.81E-10 | small nucleolar RNA, C/D box 35B [Source:MGI Symbol;Acc:MGI:1351321] |
| Emp3 | ENSMUSG00000040212 | 2.159348339 | 1.85E-10 | epithelial membrane protein 3 [Source:MGI Symbol;Acc:MGI:1098729] |
| Cyth4 | ENSMUSG00000018008 | 2.037853092 | 2.01E-10 | cytohesin 4 [Source:MGI Symbol;Acc:MGI:2441702] |
| Dgka | ENSMUSG00000025357 | 2.432015825 | 2.23E-10 | diacylglycerol kinase, alpha [Source:MGI Symbol;Acc:MGI:102952] |
| Rac2 | ENSMUSG00000033220 | 1.24863989 | 2.38E-10 | RAS-related C3 botulinum substrate 2 [Source:MGI Symbol;Acc:MGI:97846] |
| Tctn2 | ENSMUSG00000029386 | 2.848995501 | 3.01E-10 | tectonic family member 2 [Source:MGI Symbol;Acc:MGI:1915228] |
| Twf2 | ENSMUSG00000023277 | 1.07151904 | 4.15E-10 | twinfilin actin binding protein 2 [Source:MGI Symbol;Acc:MGI:1346078] |
| Cd19 | ENSMUSG00000030724 | 1.135043875 | 5.20E-10 | CD19 antigen [Source:MGI Symbol;Acc:MGI:88319] |
| Tbc1d10c | ENSMUSG00000040247 | 1.547214742 | 5.50E-10 | TBC1 domain family, member 10c [Source:MGI Symbol;Acc:MGI:1922072] |
| Slc9a3r1 | ENSMUSG00000020733 | 1.179650414 | 5.62E-10 | solute carrier family 9 (sodium/hydrogen exchanger), member 3 regulator 1 [Source:MGI |
| Tnfaip8l2 | ENSMUSG00000013707 | 2.091276828 | 6.02E-10 | tumor necrosis factor, alpha-induced protein 8-like 2 [Source:MGI Symbol;Acc:MGI:1917019] |
| Btg2 | ENSMUSG00000020423 | 1.362992494 | 6.06E-10 | B cell translocation gene 2, anti-proliferative [Source:MGI Symbol;Acc:MGI:108384] |
| Anxa6 | ENSMUSG00000018340 | 1.867539506 | 6.82E-10 | annexin A6 [Source:MGI Symbol;Acc:MGI:88255] |
| Arhgdib | ENSMUSG00000030220 | 1.544284631 | 7.11E-10 | Rho, GDP dissociation inhibitor (GDI) beta [Source:MGI Symbol;Acc:MGI:101940] |
| Pym1 | ENSMUSG00000064030 | 1.285245512 | 8.61E-10 | PYM homolog 1, exon junction complex associated factor [Source:MGI |
| Ypel3 | ENSMUSG00000042675 | 1.158675736 | 9.75E-10 | yippee-like 3 (Drosophila) [Source:MGI Symbol;Acc:MGI:1913340] |
| Cd37 | ENSMUSG00000030798 | 1.086655413 | 9.75E-10 | CD37 antigen [Source:MGI Symbol;Acc:MGI:88330] |
| Grk6 | ENSMUSG00000074886 | 1.691193268 | 1.11E-09 | G protein-coupled receptor kinase 6 [Source:MGI Symbol;Acc:MGI:1347078] |
| Gm12159 | ENSMUSG00000084773 | 7.103644327 | 1.44E-09 | predicted gene 12159 [Source:MGI Symbol;Acc:MGI:3649482] |
| Gm43291 | ENSMUSG00000105646 | 1.217391193 | 1.46E-09 | predicted gene, 30211 [Source:MGI Symbol;Acc:MGI:5589370] |
| Pstpip1 | ENSMUSG00000032322 | 2.038031358 | 1.56E-09 | proline-serine-threonine phosphatase-interacting protein 1 [Source:MGI |
| B3gnt8 | ENSMUSG00000059479 | 2.884673217 | 1.98E-09 | UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 8 [Source:MGI |
| Bank1 | ENSMUSG00000037922 | 3.68280051 | 2.01E-09 | B cell scaffold protein with ankyrin repeats 1 [Source:MGI Symbol;Acc:MGI:2442120] |
| Gmfg | ENSMUSG00000060791 | 1.705256701 | 2.53E-09 | glia maturation factor, gamma [Source:MGI Symbol;Acc:MGI:1927135] |
| Gnai2 | ENSMUSG00000032562 | 1.178738623 | 2.53E-09 | guanine nucleotide binding protein (G protein), alpha inhibiting 2 [Source:MGI |
| Ptpn18 | ENSMUSG00000026126 | 1.089568592 | 2.73E-09 | protein tyrosine phosphatase, non-receptor type 18 [Source:MGI Symbol;Acc:MGI:108410] |
| Ing1 | ENSMUSG00000045969 | 1.062566219 | 3.28E-09 | inhibitor of growth family, member 1 [Source:MGI Symbol;Acc:MGI:1349481] |
| Ppp1r18 | ENSMUSG00000034595 | 1.305027852 | 4.15E-09 | protein phosphatase 1, regulatory subunit 18 [Source:MGI Symbol;Acc:MGI:1923698] |
| Bin1 | ENSMUSG00000024381 | 1.562716339 | 4.79E-09 | bridging integrator 1 [Source:MGI Symbol;Acc:MGI:108092] |
| Hhex | ENSMUSG00000024986 | 1.708680035 | 4.82E-09 | hematopoietically expressed homeobox [Source:MGI Symbol;Acc:MGI:96086] |
| Fmnl1 | ENSMUSG00000055805 | 1.815084693 | 4.88E-09 | formin-like 1 [Source:MGI Symbol;Acc:MGI:1888994] |
| Myadm | ENSMUSG00000068566 | 3.157859764 | 5.27E-09 | myeloid-associated differentiation marker [Source:MGI Symbol;Acc:MGI:1355332] |
| Sipa1l1 | ENSMUSG00000042700 | 2.378091845 | 5.41E-09 | signal-induced proliferation-associated 1 like 1 [Source:MGI Symbol;Acc:MGI:2443679] |
| Cnp | ENSMUSG00000006782 | 1.492749306 | 6.26E-09 | 2',3'-cyclic nucleotide 3' phosphodiesterase [Source:MGI Symbol;Acc:MGI:88437] |
| Klf2 | ENSMUSG00000055148 | 2.119942661 | 6.43E-09 | Kruppel-like factor 2 (lung) [Source:MGI Symbol;Acc:MGI:1342772] |
| Sh3bgrl3 | ENSMUSG00000028843 | 1.282898768 | 6.50E-09 | SH3 domain binding glutamic acid-rich protein-like 3 [Source:MGI Symbol;Acc:MGI:1920973] |
| Nuak1 | ENSMUSG00000020032 | 3.153918339 | 7.08E-09 | NUAK family, SNF1-like kinase, 1 [Source:MGI Symbol;Acc:MGI:1925226] |
| Rnpep | ENSMUSG00000041926 | 1.124757595 | 8.04E-09 | arginyl aminopeptidase (aminopeptidase B) [Source:MGI Symbol;Acc:MGI:2384902] |
| Bcl11a | ENSMUSG00000000861 | 1.555876713 | 1.02E-08 | B cell CLL/lymphoma 11A (zinc finger protein) [Source:MGI Symbol;Acc:MGI:106190] |
| Ly6d | ENSMUSG00000034634 | 1.19428964 | 1.05E-08 | lymphocyte antigen 6 complex, locus D [Source:MGI Symbol;Acc:MGI:96881] |
| Arhgef18 | ENSMUSG00000004568 | 1.645993944 | 1.12E-08 | rho/rac guanine nucleotide exchange factor (GEF) 18 [Source:MGI Symbol;Acc:MGI:2142567] |
| S100a6 | ENSMUSG00000001025 | 2.196764593 | 1.39E-08 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Myo1c | ENSMUSG00000017774 | 1.180015269 | 1.45E-08 | myosin IC [Source:MGI Symbol;Acc:MGI:106612] |
| Gm2a | ENSMUSG00000000594 | 1.9329019 | 1.52E-08 | GM2 ganglioside activator protein [Source:MGI Symbol;Acc:MGI:95762] |
| Gm13919 | ENSMUSG00000085417 | 1.940792622 | 1.53E-08 | predicted gene 13919 [Source:MGI Symbol;Acc:MGI:3651616] |
| H2-DMa | ENSMUSG00000037649 | 1.170392509 | 1.99E-08 | histocompatibility 2, class II, locus DMa [Source:MGI Symbol;Acc:MGI:95921] |
| Fam65b | ENSMUSG00000036006 | 1.302985773 | 2.07E-08 | RHO family interacting cell polarization regulator 2 [Source:MGI Symbol;Acc:MGI:2444879] |
| Klf3 | ENSMUSG00000029178 | 2.045586973 | 2.10E-08 | Kruppel-like factor 3 (basic) [Source:MGI Symbol;Acc:MGI:1342773] |
| Cd2 | ENSMUSG00000027863 | 2.749963178 | 2.54E-08 | CD2 antigen [Source:MGI Symbol;Acc:MGI:88320] |
| Cbfa2t3 | ENSMUSG00000006362 | 2.274339014 | 3.94E-08 | core-binding factor, runt domain, alpha subunit 2, translocated to, 3 (human) [Source:MGI |
| Ptgr1 | ENSMUSG00000028378 | 2.484635769 | 4.00E-08 | prostaglandin reductase 1 [Source:MGI Symbol;Acc:MGI:1914353] |
| Add3 | ENSMUSG00000025026 | 1.482423297 | 4.23E-08 | adducin 3 (gamma) [Source:MGI Symbol;Acc:MGI:1351615] |
| Rnase12 | ENSMUSG00000068407 | 6.665552076 | 4.28E-08 | ribonuclease, RNase A family, 12 (non-active) [Source:MGI Symbol;Acc:MGI:3528588] |
| Pdlim1 | ENSMUSG00000055044 | 1.281354118 | 6.35E-08 | PDZ and LIM domain 1 (elfin) [Source:MGI Symbol;Acc:MGI:1860611] |
| Serinc5 | ENSMUSG00000021703 | 2.501141432 | 6.60E-08 | serine incorporator 5 [Source:MGI Symbol;Acc:MGI:2444223] |
| Slc25a53 | ENSMUSG00000044348 | 2.161338361 | 6.81E-08 | solute carrier family 25, member 53 [Source:MGI Symbol;Acc:MGI:1914312] |
| Ccdc28b | ENSMUSG00000028795 | 1.396234513 | 8.06E-08 | coiled coil domain containing 28B [Source:MGI Symbol;Acc:MGI:1913514] |
| 1700048O20Rik | ENSMUSG00000043773 | 2.950341594 | 8.97E-08 | RIKEN cDNA 1700048O20 gene [Source:MGI Symbol;Acc:MGI:1920637] |
| Ech1 | ENSMUSG00000053898 | 1.052047548 | 1.14E-07 | enoyl coenzyme A hydratase 1, peroxisomal [Source:MGI Symbol;Acc:MGI:1858208] |
| 1700016K19Rik | ENSMUSG00000053783 | 8.061488453 | 1.32E-07 | RIKEN cDNA 1700016K19 gene [Source:MGI Symbol;Acc:MGI:1921480] |
| Tsen34 | ENSMUSG00000035585 | 1.280025662 | 1.34E-07 | tRNA splicing endonuclease subunit 34 [Source:MGI Symbol;Acc:MGI:1913328] |
| Ifngr1 | ENSMUSG00000020009 | 1.717078952 | 1.48E-07 | interferon gamma receptor 1 [Source:MGI Symbol;Acc:MGI:107655] |
| F730311O21Rik | ENSMUSG00000100658 | 3.006401367 | 1.50E-07 | RIKEN cDNA F730311O21 gene [Source:MGI Symbol;Acc:MGI:3643355] |
| Susd3 | ENSMUSG00000021384 | 2.116352844 | 1.71E-07 | sushi domain containing 3 [Source:MGI Symbol;Acc:MGI:1913579] |
| Arid3a | ENSMUSG00000019564 | 1.892297368 | 1.80E-07 | AT rich interactive domain 3A (BRIGHT-like) [Source:MGI Symbol;Acc:MGI:1328360] |
| Gngt2 | ENSMUSG00000038811 | 1.697311546 | 1.85E-07 | guanine nucleotide binding protein (G protein), gamma transducing activity polypeptide 2 |
| Pold4 | ENSMUSG00000024854 | 1.128685485 | 1.88E-07 | polymerase (DNA-directed), delta 4 [Source:MGI Symbol;Acc:MGI:1916995] |
| Arhgap9 | ENSMUSG00000040345 | 1.104804746 | 1.94E-07 | Rho GTPase activating protein 9 [Source:MGI Symbol;Acc:MGI:2143764] |
| Ccdc180 | ENSMUSG00000035539 | 2.377279565 | 2.08E-07 | coiled-coil domain containing 180 [Source:MGI Symbol;Acc:MGI:2685871] |
| Mmgt2 | ENSMUSG00000048497 | 1.169589357 | 2.16E-07 | membrane magnesium transporter 2 [Source:MGI Symbol;Acc:MGI:2448491] |
| Def6 | ENSMUSG00000002257 | 1.744397624 | 2.27E-07 | differentially expressed in FDCP 6 [Source:MGI Symbol;Acc:MGI:1346328] |
| Hexb | ENSMUSG00000021665 | 1.691132504 | 2.27E-07 | hexosaminidase B [Source:MGI Symbol;Acc:MGI:96074] |
| Tmsb4x | ENSMUSG00000049775 | 1.325151155 | 2.78E-07 | thymosin, beta 4, X chromosome [Source:MGI Symbol;Acc:MGI:99510] |
| AI467606 | ENSMUSG00000045165 | 2.093689392 | 3.00E-07 | expressed sequence AI467606 [Source:MGI Symbol;Acc:MGI:2141979] |
| Ccdc88b | ENSMUSG00000047810 | 3.481390625 | 3.06E-07 | coiled-coil domain containing 88B [Source:MGI Symbol;Acc:MGI:1925567] |
| Cplx2 | ENSMUSG00000025867 | 3.912155498 | 3.10E-07 | complexin 2 [Source:MGI Symbol;Acc:MGI:104726] |
| Ostf1 | ENSMUSG00000024725 | 1.149310869 | 3.65E-07 | osteoclast stimulating factor 1 [Source:MGI Symbol;Acc:MGI:700012] |
| Rab3a | ENSMUSG00000031840 | 4.427324809 | 3.91E-07 | RAB3A, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:97843] |

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|---|---|---|---|---|
| Eng | ENSMUSG00000026814 | 2.054284621 | 4.17E-07 | endoglin [Source:MGI Symbol;Acc:MGI:95392] |
| Rabgap1l | ENSMUSG00000026721 | 1.349000863 | 4.17E-07 | RAB GTPase activating protein 1-like [Source:MGI Symbol;Acc:MGI:1352507] |
| Cecr2 | ENSMUSG00000071226 | 1.130498902 | 4.51E-07 | CECR2, histone acetyl-lysine reader [Source:MGI Symbol;Acc:MGI:1923799] |
| Lilra6 | ENSMUSG00000030427 | 6.529847629 | 4.75E-07 | leukocyte immunoglobulin-like receptor, subfamily A (with TM domain), member 6 [Source:MGI |
| Haao | ENSMUSG00000000673 | 1.766816966 | 5.34E-07 | 3-hydroxyanthranilate 3,4-dioxygenase [Source:MGI Symbol;Acc:MGI:1349444] |
| Rdh12 | ENSMUSG00000021123 | 2.192200061 | 5.67E-07 | retinol dehydrogenase 12 [Source:MGI Symbol;Acc:MGI:1925224] |
| Cat | ENSMUSG00000027187 | 1.299228247 | 6.77E-07 | catalase [Source:MGI Symbol;Acc:MGI:88271] |
| Cnn3 | ENSMUSG00000053931 | 1.333178504 | 7.20E-07 | calponin 3, acidic [Source:MGI Symbol;Acc:MGI:1919244] |
| Stk38 | ENSMUSG00000024006 | 1.131649036 | 8.29E-07 | serine/threonine kinase 38 [Source:MGI Symbol;Acc:MGI:2442572] |
| Gpx4 | ENSMUSG00000075706 | 1.026798363 | 8.46E-07 | glutathione peroxidase 4 [Source:MGI Symbol;Acc:MGI:104767] |
| Dirc2 | ENSMUSG00000022848 | 1.963108479 | 8.68E-07 | disrupted in renal carcinoma 2 (human) [Source:MGI Symbol;Acc:MGI:2387188] |
| 1600014C10Rik | ENSMUSG00000054676 | 1.385753068 | 1.08E-06 | RIKEN cDNA 1600014C10 gene [Source:MGI Symbol;Acc:MGI:1919494] |
| Gimap7 | ENSMUSG00000043931 | 3.28452345 | 1.19E-06 | GTPase, IMAP family member 7 [Source:MGI Symbol;Acc:MGI:1349657] |
| Klhl6 | ENSMUSG00000043008 | 1.317576576 | 1.39E-06 | kelch-like 6 [Source:MGI Symbol;Acc:MGI:2686922] |
| Tcp11l2 | ENSMUSG00000020034 | 1.065233205 | 1.53E-06 | t-complex 11 (mouse) like 2 [Source:MGI Symbol;Acc:MGI:2444679] |
| Gm15987 | ENSMUSG00000085786 | 1.665163601 | 1.56E-06 | predicted gene 15987 [Source:MGI Symbol;Acc:MGI:3801849] |
| Dpp4 | ENSMUSG00000035000 | 1.151436605 | 1.58E-06 | dipeptidylpeptidase 4 [Source:MGI Symbol;Acc:MGI:94919] |
| Fam212a | ENSMUSG00000042106 | 2.415709682 | 1.78E-06 | family with sequence similarity 212, member A [Source:MGI Symbol;Acc:MGI:1915426] |
| Filip1l | ENSMUSG00000043336 | 1.10654084 | 1.90E-06 | filamin A interacting protein 1-like [Source:MGI Symbol;Acc:MGI:1925999] |
| Rcn3 | ENSMUSG00000019539 | 3.099818004 | 2.19E-06 | reticulocalbin 3, EF-hand calcium binding domain [Source:MGI Symbol;Acc:MGI:1277122] |
| Fry | ENSMUSG00000056602 | 1.557874323 | 2.30E-06 | FRY microtubule binding protein [Source:MGI Symbol;Acc:MGI:2443895] |
| A630033H20Rik | ENSMUSG00000054293 | 1.434556507 | 2.44E-06 | RIKEN cDNA A630033H20 gene [Source:MGI Symbol;Acc:MGI:2441814] |
| Gna15 | ENSMUSG00000034792 | 2.274687868 | 2.66E-06 | guanine nucleotide binding protein, alpha 15 [Source:MGI Symbol;Acc:MGI:95770] |
| Ets1 | ENSMUSG00000032035 | 1.607927624 | 2.73E-06 | E26 avian leukemia oncogene 1, 5' domain [Source:MGI Symbol;Acc:MGI:95455] |
| Tpcn1 | ENSMUSG00000032741 | 1.985138479 | 3.11E-06 | two pore channel 1 [Source:MGI Symbol;Acc:MGI:2182472] |
| Slc29a3 | ENSMUSG00000020100 | 1.63578491 | 3.38E-06 | solute carrier family 29 (nucleoside transporters), member 3 [Source:MGI |
| Kbtbd11 | ENSMUSG00000055675 | 5.692511001 | 3.54E-06 | kelch repeat and BTB (POZ) domain containing 11 [Source:MGI Symbol;Acc:MGI:1922151] |
| Bcl7a | ENSMUSG00000029438 | 1.365815695 | 3.74E-06 | B cell CLL/lymphoma 7A [Source:MGI Symbol;Acc:MGI:1924295] |
| Ell3 | ENSMUSG00000027246 | 2.322510513 | 3.86E-06 | elongation factor RNA polymerase II-like 3 [Source:MGI Symbol;Acc:MGI:2673679] |
| Prkcb | ENSMUSG00000052889 | 1.581518181 | 3.91E-06 | protein kinase C, beta [Source:MGI Symbol;Acc:MGI:97596] |
| Siglecg | ENSMUSG00000030468 | 1.879776608 | 3.91E-06 | sialic acid binding Ig-like lectin G [Source:MGI Symbol;Acc:MGI:2443630] |
| E2f2 | ENSMUSG00000018983 | 2.084455278 | 4.04E-06 | E2F transcription factor 2 [Source:MGI Symbol;Acc:MGI:1096341] |
| 1110059E24Rik | ENSMUSG00000035171 | 1.440286095 | 4.09E-06 | RIKEN cDNA 1110059E24 gene [Source:MGI Symbol;Acc:MGI:1913456] |
| Gmpr | ENSMUSG00000000253 | 2.507484411 | 4.33E-06 | guanosine monophosphate reductase [Source:MGI Symbol;Acc:MGI:1913605] |
| Adam19 | ENSMUSG00000011256 | 1.255511191 | 4.34E-06 | a disintegrin and metallopeptidase domain 19 (meltrin beta) [Source:MGI |
| Clic1 | ENSMUSG00000007041 | 1.08277277 | 5.75E-06 | chloride intracellular channel 1 [Source:MGI Symbol;Acc:MGI:2148924] |
| Phactr2 | ENSMUSG00000062866 | 1.542622948 | 5.84E-06 | phosphatase and actin regulator 2 [Source:MGI Symbol;Acc:MGI:2446138] |
| Cacna1i | ENSMUSG00000022416 | 5.230404022 | 6.01E-06 | calcium channel, voltage-dependent, alpha 1I subunit [Source:MGI Symbol;Acc:MGI:2178051] |
| Mctp2 | ENSMUSG00000032776 | 2.140526314 | 6.26E-06 | multiple C2 domains, transmembrane 2 [Source:MGI Symbol;Acc:MGI:2685335] |
| Lrrc8c | ENSMUSG00000054720 | 1.552817187 | 6.33E-06 | leucine rich repeat containing 8 family, member C [Source:MGI Symbol;Acc:MGI:2140839] |
| Tspo | ENSMUSG00000041736 | 1.022968871 | 6.90E-06 | translocator protein [Source:MGI Symbol;Acc:MGI:88222] |
| Kctd12 | ENSMUSG00000098557 | 1.988740864 | 7.00E-06 | potassium channel tetramerisation domain containing 12 [Source:MGI |
| Evl | ENSMUSG00000021262 | 1.151477878 | 8.12E-06 | Ena-vasodilator stimulated phosphoprotein [Source:MGI Symbol;Acc:MGI:1194884] |
| Cpm | ENSMUSG00000020183 | 2.374583601 | 8.32E-06 | carboxypeptidase M [Source:MGI Symbol;Acc:MGI:1917824] |
| Hist2h2be | ENSMUSG00000068854 | 1.487923297 | 8.38E-06 | histone cluster 2, H2be [Source:MGI Symbol;Acc:MGI:2448415] |
| Mta3 | ENSMUSG00000055817 | 1.435150928 | 8.42E-06 | metastasis associated 3 [Source:MGI Symbol;Acc:MGI:2151172] |
| Adrb2 | ENSMUSG00000045730 | 1.560408518 | 8.51E-06 | adrenergic receptor, beta 2 [Source:MGI Symbol;Acc:MGI:87938] |
| Sell | ENSMUSG00000026581 | 2.233069593 | 9.89E-06 | selectin, lymphocyte [Source:MGI Symbol;Acc:MGI:98279] |
| Zfp961 | ENSMUSG00000052446 | 1.239878714 | 1.00E-05 | zinc finger protein 961 [Source:MGI Symbol;Acc:MGI:3583954] |
| Tsc22d4 | ENSMUSG00000029723 | 1.164957852 | 1.20E-05 | TSC22 domain family, member 4 [Source:MGI Symbol;Acc:MGI:1926079] |
| Phf14 | ENSMUSG00000029629 | 1.41683037 | 1.25E-05 | PHD finger protein 14 [Source:MGI Symbol;Acc:MGI:1923539] |
| Iglc3 | ENSMUSG00000105547 | 2.870487246 | 1.31E-05 | immunoglobulin lambda constant 3 [Source:MGI Symbol;Acc:MGI:99886] |
| Aes | ENSMUSG00000054452 | 1.089378532 | 1.32E-05 | amino-terminal enhancer of split [Source:MGI Symbol;Acc:MGI:95806] |
| Erg | ENSMUSG00000040732 | 2.98360645 | 1.38E-05 | ETS transcription factor [Source:MGI Symbol;Acc:MGI:95415] |
| Sfn | ENSMUSG00000047281 | 2.493223872 | 1.41E-05 | stratifin [Source:MGI Symbol;Acc:MGI:1891831] |
| Gm37802 | ENSMUSG00000103303 | 1.958204397 | 1.56E-05 | predicted gene, 37802 [Source:MGI Symbol;Acc:MGI:5611030] |
| Prkd2 | ENSMUSG00000041187 | 1.658535946 | 1.60E-05 | protein kinase D2 [Source:MGI Symbol;Acc:MGI:2141917] |
| Txnip | ENSMUSG00000038393 | 1.678989123 | 1.63E-05 | thioredoxin interacting protein [Source:MGI Symbol;Acc:MGI:1889549] |
| Mgat1 | ENSMUSG00000020346 | 1.247004139 | 1.84E-05 | mannoside acetylglucosaminyltransferase 1 [Source:MGI Symbol;Acc:MGI:96973] |
| Lpar6 | ENSMUSG00000033446 | 2.334512436 | 1.97E-05 | lysophosphatidic acid receptor 6 [Source:MGI Symbol;Acc:MGI:1914418] |
| Trp53cor1 | ENSMUSG00000085912 | 4.232982297 | 2.14E-05 | tumor protein p53 pathway corepressor 1 [Source:MGI Symbol;Acc:MGI:3801771] |
| Vim | ENSMUSG00000026728 | 2.117698193 | 2.24E-05 | vimentin [Source:MGI Symbol;Acc:MGI:98932] |
| Fkbp11 | ENSMUSG00000003355 | 2.714872829 | 2.27E-05 | FK506 binding protein 11 [Source:MGI Symbol;Acc:MGI:1913370] |
| Stk10 | ENSMUSG00000020272 | 1.609295973 | 2.32E-05 | serine/threonine kinase 10 [Source:MGI Symbol;Acc:MGI:1099439] |
| Arhgap27 | ENSMUSG00000034255 | 1.098228706 | 2.33E-05 | Rho GTPase activating protein 27 [Source:MGI Symbol;Acc:MGI:1916903] |
| Abcd1 | ENSMUSG00000031378 | 2.056804789 | 2.36E-05 | ATP-binding cassette, sub-family D (ALD), member 1 [Source:MGI Symbol;Acc:MGI:1349215] |
| Fes | ENSMUSG00000053158 | 2.829155995 | 2.37E-05 | feline sarcoma oncogene [Source:MGI Symbol;Acc:MGI:95514] |
| Ap1s2 | ENSMUSG00000031367 | 1.249321374 | 2.45E-05 | adaptor-related protein complex 1, sigma 2 subunit [Source:MGI Symbol;Acc:MGI:1889383] |
| Macf1 | ENSMUSG00000028649 | 1.365498712 | 2.51E-05 | microtubule-actin crosslinking factor 1 [Source:MGI Symbol;Acc:MGI:108559] |
| Smchd1 | ENSMUSG00000024054 | 1.252904174 | 2.63E-05 | SMC hinge domain containing 1 [Source:MGI Symbol;Acc:MGI:1921605] |
| Gimap3 | ENSMUSG00000039264 | 2.047082781 | 2.84E-05 | GTPase, IMAP family member 3 [Source:MGI Symbol;Acc:MGI:1932723] |
| Gm42722 | ENSMUSG00000106093 | 4.451664692 | 3.22E-05 | predicted gene 42722 [Source:MGI Symbol;Acc:MGI:5662859] |
| Pigyl | ENSMUSG00000010607 | 1.256120312 | 3.26E-05 | phosphatidylinositol glycan anchor biosynthesis, class Y-like [Source:MGI |
| Mad2l1bp | ENSMUSG00000034509 | 1.108751647 | 3.32E-05 | MAD2L1 binding protein [Source:MGI Symbol;Acc:MGI:1913841] |
| Atp1b1 | ENSMUSG00000026576 | 1.04398947 | 3.35E-05 | ATPase, Na+/K+ transporting, beta 1 polypeptide [Source:MGI Symbol;Acc:MGI:88108] |
| Lrrk1 | ENSMUSG00000015133 | 1.325026957 | 3.61E-05 | leucine-rich repeat kinase 1 [Source:MGI Symbol;Acc:MGI:2142227] |
| Gga2 | ENSMUSG00000030872 | 1.215594925 | 3.72E-05 | golgi associated, gamma adaptin ear containing, ARF binding protein 2 [Source:MGI |
| BC017643 | ENSMUSG00000039294 | 1.132826325 | 3.75E-05 | cDNA sequence BC017643 [Source:MGI Symbol;Acc:MGI:2384959] |
| Akna | ENSMUSG00000039158 | 1.331459522 | 4.12E-05 | AT-hook transcription factor [Source:MGI Symbol;Acc:MGI:2140340] |
| Iglc1 | ENSMUSG00000105906 | 3.550097068 | 4.34E-05 | immunoglobulin lambda constant 1 [Source:MGI Symbol;Acc:MGI:99546] |

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|---|---|---|---|---|
| Fam78a | ENSMUSG00000050592 | 2.247509923 | 4.77E-05 | family with sequence similarity 78, member A [Source:MGI Symbol;Acc:MGI:2443569] |
| Emb | ENSMUSG00000021728 | 1.748981243 | 4.96E-05 | embigin [Source:MGI Symbol;Acc:MGI:95321] |
| Cdk2ap2 | ENSMUSG00000024856 | 1.079464375 | 5.80E-05 | CDK2-associated protein 2 [Source:MGI Symbol;Acc:MGI:1098779] |
| Osgin1 | ENSMUSG00000074063 | 8.719538322 | 5.91E-05 | oxidative stress induced growth inhibitor 1 [Source:MGI Symbol;Acc:MGI:1919089] |
| Smpdl3a | ENSMUSG00000019872 | 1.88445535 | 5.91E-05 | sphingomyelin phosphodiesterase, acid-like 3A [Source:MGI Symbol;Acc:MGI:1931437] |
| Rubcnl | ENSMUSG00000034959 | 1.279204592 | 5.91E-05 | RUN and cysteine rich domain containing beclin 1 interacting protein like [Source:MGI |
| Ctso | ENSMUSG00000028015 | 1.052988534 | 5.91E-05 | cathepsin O [Source:MGI Symbol;Acc:MGI:2139628] |
| Flna | ENSMUSG00000031328 | 1.644447885 | 6.19E-05 | filamin, alpha [Source:MGI Symbol;Acc:MGI:95556] |
| Cyld | ENSMUSG00000036712 | 1.128308133 | 6.45E-05 | CYLD lysine 63 deubiquitinase [Source:MGI Symbol;Acc:MGI:1921506] |
| Cdkn2d | ENSMUSG00000096472 | 2.135494652 | 6.64E-05 | cyclin-dependent kinase inhibitor 2D (p19, inhibits CDK4) [Source:MGI Symbol;Acc:MGI:105387] |
| Tbxa2r | ENSMUSG00000034881 | 2.796005917 | 7.37E-05 | thromboxane A2 receptor [Source:MGI Symbol;Acc:MGI:98496] |
| Ass1 | ENSMUSG00000076441 | 1.558179943 | 7.37E-05 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Gm26637 | ENSMUSG00000097567 | 1.267369729 | 8.39E-05 | predicted gene, 26637 [Source:MGI Symbol;Acc:MGI:5477131] |
| Zmiz1 | ENSMUSG00000007817 | 1.665694804 | 8.82E-05 | zinc finger, MIZ-type containing 1 [Source:MGI Symbol;Acc:MGI:3040693] |
| Kdm3b | ENSMUSG00000038773 | 1.048656175 | 9.76E-05 | KDM3B lysine (K)-specific demethylase 3B [Source:MGI Symbol;Acc:MGI:1923356] |
| Cdh23 | ENSMUSG00000012819 | 3.97844761 | 0.00010833 | cadherin 23 (otocadherin) [Source:MGI Symbol;Acc:MGI:1890219] |
| Spata13 | ENSMUSG00000021990 | 1.200601943 | 0.00011169 | spermatogenesis associated 13 [Source:MGI Symbol;Acc:MGI:104838] |
| Prr5 | ENSMUSG00000036106 | 1.556142438 | 0.00011303 | proline rich 5 (renal) [Source:MGI Symbol;Acc:MGI:1924714] |
| Phyh | ENSMUSG00000026664 | 1.208322872 | 0.00011533 | phytanoyl-CoA hydroxylase [Source:MGI Symbol;Acc:MGI:891978] |
| N4bp2 | ENSMUSG00000037795 | 1.147520946 | 0.00011738 | NEDD4 binding protein 2 [Source:MGI Symbol;Acc:MGI:2684414] |
| Faap20 | ENSMUSG00000073684 | 1.089949361 | 0.00012457 | Fanconi anemia core complex associated protein 20 [Source:MGI Symbol;Acc:MGI:1914763] |
| Mgst1 | ENSMUSG00000008540 | 1.892728976 | 0.00013684 | microsomal glutathione S-transferase 1 [Source:MGI Symbol;Acc:MGI:1913850] |
| Gpr137b | ENSMUSG00000021306 | 1.341148116 | 0.00013967 | G protein-coupled receptor 137B [Source:MGI Symbol;Acc:MGI:1891463] |
| Fam65a | ENSMUSG00000038604 | 1.25410128 | 0.0001621 | RHO family interacting cell polarization regulator 1 [Source:MGI Symbol;Acc:MGI:1922937] |
| Cisd3 | ENSMUSG00000078695 | 1.891286534 | 0.00018066 | CDGSH iron sulfur domain 3 [Source:MGI Symbol;Acc:MGI:101788] |
| Fcgrt | ENSMUSG00000003420 | 7.334690048 | 0.00018801 | Fc receptor, IgG, alpha chain transporter [Source:MGI Symbol;Acc:MGI:103017] |
| Entpd1 | ENSMUSG00000048120 | 2.270887112 | 0.00019912 | ectonucleoside triphosphate diphosphohydrolase 1 [Source:MGI Symbol;Acc:MGI:102805] |
| Tpm4 | ENSMUSG00000031799 | 1.328385311 | 0.00020016 | tropomyosin 4 [Source:MGI Symbol;Acc:MGI:2449202] |
| Trmt12 | ENSMUSG00000037085 | 1.069855866 | 0.00021108 | tRNA methyltranferase 12 [Source:MGI Symbol;Acc:MGI:1915510] |
| Gimap4 | ENSMUSG00000054435 | 2.211574265 | 0.00021157 | GTPase, IMAP family member 4 [Source:MGI Symbol;Acc:MGI:1349656] |
| Tfeb | ENSMUSG00000023990 | 1.274367485 | 0.00021349 | transcription factor EB [Source:MGI Symbol;Acc:MGI:103270] |
| Bend5 | ENSMUSG00000028545 | 1.161860183 | 0.00022286 | BEN domain containing 5 [Source:MGI Symbol;Acc:MGI:1914871] |
| Ltb | ENSMUSG00000024399 | 2.240808838 | 0.00023592 | lymphotoxin B [Source:MGI Symbol;Acc:MGI:104796] |
| Gm11690 | ENSMUSG00000085844 | 4.65663916 | 0.00024325 | predicted gene 11690 [Source:MGI Symbol;Acc:MGI:3652329] |
| Capg | ENSMUSG00000056737 | 1.129551813 | 0.00024377 | capping protein (actin filament), gelsolin-like [Source:MGI Symbol;Acc:MGI:1098259] |
| Mob3a | ENSMUSG00000003348 | 1.086053109 | 0.00026399 | MOB kinase activator 3A [Source:MGI Symbol;Acc:MGI:3050117] |
| Olfml2b | ENSMUSG00000038463 | 5.788074689 | 0.00026425 | olfactomedin-like 2B [Source:MGI Symbol;Acc:MGI:2443310] |
| Iglv3 | ENSMUSG00000076939 | 1.060950874 | 0.0002712 | immunoglobulin lambda variable 3 [Source:MGI Symbol;Acc:MGI:3645509] |
| Tspan14 | ENSMUSG00000037824 | 1.243280883 | 0.00027436 | tetraspanin 14 [Source:MGI Symbol;Acc:MGI:1196325] |
| Plec | ENSMUSG00000022565 | 1.359472425 | 0.00027476 | plectin [Source:MGI Symbol;Acc:MGI:1277961] |
| Il10ra | ENSMUSG00000032089 | 1.869286955 | 0.00028262 | interleukin 10 receptor, alpha [Source:MGI Symbol;Acc:MGI:96538] |
| Pde2a | ENSMUSG00000030653 | 2.092638854 | 0.0002827 | predicted gene 45837 [Source:MGI Symbol;Acc:MGI:5804952] |
| Pla2g16 | ENSMUSG00000060675 | 1.818832696 | 0.00029033 | phospholipase A2, group XVI [Source:MGI Symbol;Acc:MGI:2179715] |
| Mgea5 | ENSMUSG00000025220 | 1.213319167 | 0.0003071 | meningioma expressed antigen 5 (hyaluronidase) [Source:MGI Symbol;Acc:MGI:1932139] |
| Gimap1 | ENSMUSG00000090019 | 1.027476091 | 0.00032789 | GTPase, IMAP family member 1 [Source:MGI Symbol;Acc:MGI:109368] |
| Tmem163 | ENSMUSG00000026347 | 1.065854018 | 0.0003477 | transmembrane protein 163 [Source:MGI Symbol;Acc:MGI:1919410] |
| Hdac7 | ENSMUSG00000022475 | 1.556915202 | 0.0003609 | histone deacetylase 7 [Source:MGI Symbol;Acc:MGI:1891835] |
| Ppfia4 | ENSMUSG00000026458 | 3.142215172 | 0.00039127 | protein tyrosine phosphatase, receptor type, f polypeptide (PTPRF), interacting protein (liprin), |
| Stac2 | ENSMUSG00000017400 | 2.449741974 | 0.00041806 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Idh2 | ENSMUSG00000030541 | 1.256688538 | 0.00043397 | isocitrate dehydrogenase 2 (NADP+), mitochondrial [Source:MGI Symbol;Acc:MGI:96414] |
| Itgb7 | ENSMUSG00000001281 | 2.787735984 | 0.00044102 | integrin beta 7 [Source:MGI Symbol;Acc:MGI:96616] |
| Ddah2 | ENSMUSG00000007039 | 2.519051709 | 0.00045498 | dimethylarginine dimethylaminohydrolase 2 [Source:MGI Symbol;Acc:MGI:1859016] |
| Spn | ENSMUSG00000051457 | 1.729498717 | 0.00046202 | sialophorin [Source:MGI Symbol;Acc:MGI:98384] |
| Crip1 | ENSMUSG00000006360 | 1.539215814 | 0.00048476 | cysteine-rich protein 1 (intestinal) [Source:MGI Symbol;Acc:MGI:88501] |
| Dhrs1 | ENSMUSG00000002332 | 1.02964327 | 0.00048704 | dehydrogenase/reductase (SDR family) member 1 [Source:MGI Symbol;Acc:MGI:1196314] |
| Unc119 | ENSMUSG00000002058 | 1.221469779 | 0.00051223 | unc-119 lipid binding chaperone [Source:MGI Symbol;Acc:MGI:1328357] |
| P2ry13 | ENSMUSG00000036362 | 2.041192813 | 0.00051342 | purinergic receptor P2Y, G-protein coupled 13 [Source:MGI Symbol;Acc:MGI:1921441] |
| Traf6 | ENSMUSG00000027164 | 1.15496764 | 0.00052637 | TNF receptor-associated factor 6 [Source:MGI Symbol;Acc:MGI:108072] |
| Lax1 | ENSMUSG00000051998 | 1.115136095 | 0.00052789 | lymphocyte transmembrane adaptor 1 [Source:MGI Symbol;Acc:MGI:2443362] |
| Nrm | ENSMUSG00000059791 | 1.977827717 | 0.00056881 | nurim (nuclear envelope membrane protein) [Source:MGI Symbol;Acc:MGI:2146855] |
| Gm43819 | ENSMUSG00000105826 | 2.879609855 | 0.00057996 | predicted gene, 42141 [Source:MGI Symbol;Acc:MGI:5625026] |
| Naaa | ENSMUSG00000029413 | 2.268169855 | 0.00058993 | N-acylethanolamine acid amidase [Source:MGI Symbol;Acc:MGI:1914361] |
| Rassf4 | ENSMUSG00000042129 | 2.676497475 | 0.00061227 | Ras association (RalGDS/AF-6) domain family member 4 [Source:MGI |
| Aldoc | ENSMUSG00000017390 | 7.554006358 | 0.00070365 | aldolase C, fructose-bisphosphate [Source:MGI Symbol;Acc:MGI:101863] |
| Mar-01 | ENSMUSG00000036469 | 2.003134446 | 0.00073167 | membrane-associated ring finger (C3HC4) 1 [Source:MGI Symbol;Acc:MGI:1920175] |
| Pde4b | ENSMUSG00000028525 | 1.374452166 | 0.00075607 | phosphodiesterase 4B, cAMP specific [Source:MGI Symbol;Acc:MGI:99557] |
| Map4k2 | ENSMUSG00000024948 | 1.502506322 | 0.00079435 | mitogen-activated protein kinase kinase kinase kinase 2 [Source:MGI Symbol;Acc:MGI:1346883] |
| Cyp4f18 | ENSMUSG00000003484 | 1.801033754 | 0.00083252 | cytochrome P450, family 4, subfamily f, polypeptide 18 [Source:MGI Symbol;Acc:MGI:1919304] |
| Jund | ENSMUSG00000071076 | 1.004806108 | 0.00083649 | jun D proto-oncogene [Source:MGI Symbol;Acc:MGI:96648] |
| Ccdc69 | ENSMUSG00000049588 | 1.727623852 | 0.00085538 | coiled-coil domain containing 69 [Source:MGI Symbol;Acc:MGI:1196234] |
| Hck | ENSMUSG00000003283 | 2.584341167 | 0.00086498 | hemopoietic cell kinase [Source:MGI Symbol;Acc:MGI:96052] |
| Gfra2 | ENSMUSG00000022103 | 2.438165934 | 0.00087243 | glial cell line derived neurotrophic factor family receptor alpha 2 [Source:MGI |
| Kif21b | ENSMUSG00000041642 | 2.464913513 | 0.0009136 | kinesin family member 21B [Source:MGI Symbol;Acc:MGI:109234] |
| Ctps2 | ENSMUSG00000031360 | 1.039177171 | 0.00096448 | cytidine 5'-triphosphate synthase 2 [Source:MGI Symbol;Acc:MGI:1933185] |
| Apobec2 | ENSMUSG00000040694 | 3.082015877 | 0.00096692 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide 2 [Source:MGI |
| Arhgap4 | ENSMUSG00000031389 | 1.549342446 | 0.00098686 | Rho GTPase activating protein 4 [Source:MGI Symbol;Acc:MGI:2159577] |
| Vangl2 | ENSMUSG00000026556 | 1.38909498 | 0.00099133 | vang-like 2 (van gogh, Drosophila) [Source:MGI Symbol;Acc:MGI:2135272] |
| Kmo | ENSMUSG00000039783 | 1.056528076 | 0.00099156 | kynurenine 3-monooxygenase (kynurenine 3-hydroxylase) [Source:MGI |
| Gimap1os | ENSMUSG00000044867 | 1.543048772 | 0.00100946 | GTPase, IMAP family member 1, opposite strand [Source:MGI Symbol;Acc:MGI:3781523] |
| Ski | ENSMUSG00000029050 | 2.060792893 | 0.00101073 | ski sarcoma viral oncogene homolog (avian) [Source:MGI Symbol;Acc:MGI:98310] |

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|---|---|---|---|---|
| Stoml1 | ENSMUSG00000032333 | 1.721758683 | 0.00101466 | stomatin-like 1 [Source:MGI Symbol;Acc:MGI:1916356] |
| Nuak2 | ENSMUSG00000009772 | 2.026076492 | 0.00105603 | NUAK family, SNF1-like kinase, 2 [Source:MGI Symbol;Acc:MGI:1921387] |
| Arhgef6 | ENSMUSG00000031133 | 1.225764606 | 0.0010897 | Rac/Cdc42 guanine nucleotide exchange factor (GEF) 6 [Source:MGI |
| Mylip | ENSMUSG00000038175 | 1.825312486 | 0.00110565 | myosin regulatory light chain interacting protein [Source:MGI Symbol;Acc:MGI:2388271] |
| Smpd1 | ENSMUSG00000037049 | 1.340336792 | 0.00116937 | sphingomyelin phosphodiesterase 1, acid lysosomal [Source:MGI Symbol;Acc:MGI:98325] |
| Map3k15 | ENSMUSG00000031303 | 6.042554127 | 0.00119404 | mitogen-activated protein kinase kinase kinase 15 [Source:MGI Symbol;Acc:MGI:2448588] |
| Traf3ip3 | ENSMUSG00000037318 | 1.323742801 | 0.00122567 | TRAF3 interacting protein 3 [Source:MGI Symbol;Acc:MGI:2441706] |
| Rhoh | ENSMUSG00000029204 | 1.09600398 | 0.00124114 | ras homolog family member H [Source:MGI Symbol;Acc:MGI:1921984] |
| AB124611 | ENSMUSG00000057191 | 1.293243501 | 0.00125341 | cDNA sequence AB124611 [Source:MGI Symbol;Acc:MGI:3043001] |
| Ctdsp2 | ENSMUSG00000078429 | 1.354331837 | 0.00127296 | CTD (carboxy-terminal domain, RNA polymerase II, polypeptide A) small phosphatase 2 |
| Fam111a | ENSMUSG00000024691 | 1.358640202 | 0.00133846 | family with sequence similarity 111, member A [Source:MGI Symbol;Acc:MGI:1915508] |
| Ablim1 | ENSMUSG00000025085 | 1.503282742 | 0.001397 | actin-binding LIM protein 1 [Source:MGI Symbol;Acc:MGI:1194500] |
| Trp53i13 | ENSMUSG00000044328 | 1.405551348 | 0.00150825 | transformation related protein 53 inducible protein 13 [Source:MGI Symbol;Acc:MGI:1915125] |
| Ero1lb | ENSMUSG00000057069 | 1.378111709 | 0.00160759 | ERO1-like beta (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1914725] |
| Rbm43 | ENSMUSG00000036249 | 1.163246599 | 0.00161878 | RNA binding motif protein 43 [Source:MGI Symbol;Acc:MGI:1918934] |
| Lbr | ENSMUSG00000004880 | 1.448577651 | 0.00162485 | lamin B receptor [Source:MGI Symbol;Acc:MGI:2138281] |
| Sla | ENSMUSG00000022372 | 1.172336915 | 0.00170577 | src-like adaptor [Source:MGI Symbol;Acc:MGI:104295] |
| Hmha1 | ENSMUSG00000035697 | 1.192995764 | 0.00173217 | Rho GTPase activating protein 45 [Source:MGI Symbol;Acc:MGI:1917969] |
| Fam46a | ENSMUSG00000032265 | 1.682461497 | 0.00174787 | family with sequence similarity 46, member A [Source:MGI Symbol;Acc:MGI:2670964] |
| Adcy7 | ENSMUSG00000031659 | 1.484211594 | 0.00187455 | adenylate cyclase 7 [Source:MGI Symbol;Acc:MGI:102891] |
| St3gal1 | ENSMUSG00000013846 | 1.710949985 | 0.0018932 | ST3 beta-galactoside alpha-2,3-sialyltransferase 1 [Source:MGI Symbol;Acc:MGI:98304] |
| Zfp710 | ENSMUSG00000048897 | 1.402099365 | 0.00209579 | zinc finger protein 710 [Source:MGI Symbol;Acc:MGI:1921747] |
| Stx2 | ENSMUSG00000029428 | 1.700369415 | 0.00212403 | syntaxin 2 [Source:MGI Symbol;Acc:MGI:108059] |
| Elk3 | ENSMUSG00000008398 | 1.0780225 | 0.00229793 | ELK3, member of ETS oncogene family [Source:MGI Symbol;Acc:MGI:101762] |
| Stambpl1 | ENSMUSG00000024776 | 1.277485564 | 0.00233601 | STAM binding protein like 1 [Source:MGI Symbol;Acc:MGI:1923880] |
| Pdk2 | ENSMUSG00000038967 | 1.707374933 | 0.00237436 | pyruvate dehydrogenase kinase, isoenzyme 2 [Source:MGI Symbol;Acc:MGI:1343087] |
| Stxbp1 | ENSMUSG00000026797 | 1.77630659 | 0.00239245 | syntaxin binding protein 1 [Source:MGI Symbol;Acc:MGI:107363] |
| Fcgr2b | ENSMUSG00000026656 | 1.250007746 | 0.00239878 | Fc receptor, IgG, low affinity IIb [Source:MGI Symbol;Acc:MGI:95499] |
| Pirb | ENSMUSG00000058818 | 2.59249445 | 0.00252872 | paired Ig-like receptor B [Source:MGI Symbol;Acc:MGI:894311] |
| Uchl1 | ENSMUSG00000029223 | 1.147146121 | 0.00256122 | ubiquitin carboxy-terminal hydrolase L1 [Source:MGI Symbol;Acc:MGI:103149] |
| Hes6 | ENSMUSG00000067071 | 1.054014396 | 0.00262501 | hairy and enhancer of split 6 [Source:MGI Symbol;Acc:MGI:1859852] |
| Sh2d3c | ENSMUSG00000059013 | 1.574196687 | 0.00276745 | SH2 domain containing 3C [Source:MGI Symbol;Acc:MGI:1351631] |
| 4930426D05Rik | ENSMUSG00000043168 | 1.443124988 | 0.00281255 | RIKEN cDNA 4930426D05 gene [Source:MGI Symbol;Acc:MGI:1921894] |
| Slc14a1 | ENSMUSG00000059336 | 1.627809319 | 0.00281732 | solute carrier family 14 (urea transporter), member 1 [Source:MGI Symbol;Acc:MGI:1351654] |
| Hsdl2 | ENSMUSG00000028383 | 1.041631027 | 0.00286521 | hydroxysteroid dehydrogenase like 2 [Source:MGI Symbol;Acc:MGI:1919729] |
| Padi2 | ENSMUSG00000028927 | 2.016991886 | 0.00294146 | peptidyl arginine deiminase, type II [Source:MGI Symbol;Acc:MGI:1338892] |
| Ppl | ENSMUSG00000039457 | 8.914489373 | 0.00302147 | periplakin [Source:MGI Symbol;Acc:MGI:1194898] |
| Gm5533 | ENSMUSG00000056699 | 7.891233483 | 0.0031493 | predicted gene 5533 [Source:MGI Symbol;Acc:MGI:3647595] |
| Gm37893 | ENSMUSG00000103928 | 3.431321647 | 0.00320721 | predicted gene, 37893 [Source:MGI Symbol;Acc:MGI:5611121] |
| Prex1 | ENSMUSG00000039621 | 1.281698996 | 0.00323268 | phosphatidylinositol-3,4,5-trisphosphate-dependent Rac exchange factor 1 [Source:MGI |
| Gm26740 | ENSMUSG00000097705 | 1.624045424 | 0.00335874 | predicted gene, 26740 [Source:MGI Symbol;Acc:MGI:5477234] |
| Glrx | ENSMUSG00000021591 | 1.263257752 | 0.00353587 | glutaredoxin [Source:MGI Symbol;Acc:MGI:2135625] |
| Pdlim2 | ENSMUSG00000022090 | 1.127979164 | 0.00361537 | PDZ and LIM domain 2 [Source:MGI Symbol;Acc:MGI:2384850] |
| Dapp1 | ENSMUSG00000028159 | 1.17834307 | 0.00382996 | dual adaptor for phosphotyrosine and 3-phosphoinositides 1 [Source:MGI |
| Itpr3 | ENSMUSG00000042644 | 1.716629996 | 0.00383154 | inositol 1,4,5-triphosphate receptor 3 [Source:MGI Symbol;Acc:MGI:96624] |
| Abhd18 | ENSMUSG00000037818 | 2.321507123 | 0.00392942 | abhydrolase domain containing 18 [Source:MGI Symbol;Acc:MGI:1915468] |
| Vamp1 | ENSMUSG00000030337 | 1.769538484 | 0.00397681 | vesicle-associated membrane protein 1 [Source:MGI Symbol;Acc:MGI:1313276] |
| Ifit3b | ENSMUSG00000062488 | 1.70149297 | 0.00400603 | interferon-induced protein with tetratricopeptide repeats 3B [Source:MGI |
| Cux1 | ENSMUSG00000029705 | 1.047192894 | 0.00401235 | cut-like homeobox 1 [Source:MGI Symbol;Acc:MGI:88568] |
| Ralgps2 | ENSMUSG00000026594 | 1.517948829 | 0.00409331 | Ral GEF with PH domain and SH3 binding motif 2 [Source:MGI Symbol;Acc:MGI:1925505] |
| Milr1 | ENSMUSG00000040528 | 1.29535511 | 0.00410546 | mast cell immunoglobulin like receptor 1 [Source:MGI Symbol;Acc:MGI:2685731] |
| Arhgap27os3 | ENSMUSG00000085887 | 1.871648959 | 0.00417424 | Rho GTPase activating protein 27, opposite strand 3 [Source:MGI Symbol;Acc:MGI:3650159] |
| Chst15 | ENSMUSG00000030930 | 1.688228303 | 0.00427404 | carbohydrate (N-acetylgalactosamine 4-sulfate 6-O) sulfotransferase 15 [Source:MGI |
| Flot1 | ENSMUSG00000059714 | 1.171152469 | 0.00435682 | flotillin 1 [Source:MGI Symbol;Acc:MGI:1100500] |
| Rhof | ENSMUSG00000029449 | 1.105621044 | 0.00458421 | ras homolog family member F (in filopodia) [Source:MGI Symbol;Acc:MGI:1345629] |
| Sertad3 | ENSMUSG00000055200 | 1.168553644 | 0.00461746 | SERTA domain containing 3 [Source:MGI Symbol;Acc:MGI:2180697] |
| Mast3 | ENSMUSG00000031833 | 1.502899794 | 0.00473028 | microtubule associated serine/threonine kinase 3 [Source:MGI Symbol;Acc:MGI:2683541] |
| Cobll1 | ENSMUSG00000034903 | 1.85046438 | 0.00491993 | Cobl-like 1 [Source:MGI Symbol;Acc:MGI:2442894] |
| Ldlrap1 | ENSMUSG00000037295 | 1.149700004 | 0.00495032 | low density lipoprotein receptor adaptor protein 1 [Source:MGI Symbol;Acc:MGI:2140175] |
| Zfp53 | ENSMUSG00000057409 | 1.221991859 | 0.00505446 | zinc finger protein 53 [Source:MGI Symbol;Acc:MGI:99200] |
| Ethe1 | ENSMUSG00000064254 | 1.297209625 | 0.00506698 | ethylmalonic encephalopathy 1 [Source:MGI Symbol;Acc:MGI:1913321] |
| Pax5 | ENSMUSG00000014030 | 1.16399543 | 0.00528178 | paired box 5 [Source:MGI Symbol;Acc:MGI:97489] |
| 1810034E14Rik | ENSMUSG00000097101 | 3.502344119 | 0.00566122 | RIKEN cDNA 1810034E14 gene [Source:MGI Symbol;Acc:MGI:1913753] |
| Slc46a3 | ENSMUSG00000029650 | 3.426524238 | 0.00572499 | solute carrier family 46, member 3 [Source:MGI Symbol;Acc:MGI:1918956] |
| Ctse | ENSMUSG00000004552 | 1.434838277 | 0.00600518 | cathepsin E [Source:MGI Symbol;Acc:MGI:107361] |
| Tmx4 | ENSMUSG00000034723 | 1.587487075 | 0.00636339 | thioredoxin-related transmembrane protein 4 [Source:MGI Symbol;Acc:MGI:106558] |
| Map3k5 | ENSMUSG00000071369 | 1.189874883 | 0.00706075 | mitogen-activated protein kinase kinase kinase 5 [Source:MGI Symbol;Acc:MGI:1346876] |
| Adgrl2 | ENSMUSG00000028184 | 2.099992957 | 0.00727242 | adhesion G protein-coupled receptor L2 [Source:MGI Symbol;Acc:MGI:2139714] |
| Gm43625 | ENSMUSG00000105636 | 3.314016291 | 0.0074308 | predicted gene 43625 [Source:MGI Symbol;Acc:MGI:5663762] |
| Atp8a1 | ENSMUSG00000037685 | 1.187212847 | 0.00779337 | ATPase, aminophospholipid transporter (APLT), class I, type 8A, member 1 [Source:MGI |
| Iglc2 | ENSMUSG00000076937 | 2.950778557 | 0.00781978 | immunoglobulin lambda constant 2 [Source:MGI Symbol;Acc:MGI:99547] |
| Tle3 | ENSMUSG00000032280 | 1.666774645 | 0.00789617 | transducin-like enhancer of split 3 [Source:MGI Symbol;Acc:MGI:104634] |
| Rassf5 | ENSMUSG00000026430 | 1.287881929 | 0.00797766 | Ras association (RalGDS/AF-6) domain family member 5 [Source:MGI |
| Pinlyp | ENSMUSG00000011632 | 3.681201674 | 0.00867682 | phospholipase A2 inhibitor and LY6/PLAUR domain containing [Source:MGI |
| Acss1 | ENSMUSG00000027452 | 1.164548697 | 0.00892365 | acyl-CoA synthetase short-chain family member 1 [Source:MGI Symbol;Acc:MGI:1915988] |
| Cd52 | ENSMUSG00000000682 | 1.289566206 | 0.00950796 | CD52 antigen [Source:MGI Symbol;Acc:MGI:1346088] |
| Card19 | ENSMUSG00000037960 | 1.839869721 | 0.0098623 | caspase recruitment domain family, member 19 [Source:MGI Symbol;Acc:MGI:1915730] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-9. Genes significantly activated in in immature B cell subsets in Ig adult BM upon stimulation.

| Symbol | Ensembl gene id | logFC (BM-sHEL/BM-R10) | adj.P.val | Annotation |
|---|---|---|---|---|
| Nek6 | ENSMUSG00000026749 | 7.75482264 | 3.96E-37 | NIMA (never in mitosis gene a)-related expressed kinase 6 [Source:MGI Symbol;Acc:MGI:1891638] |
| Egr2 | ENSMUSG00000037868 | 9.13085321 | 2.41E-36 | early growth response 2 [Source:MGI Symbol;Acc:MGI:95296] |
| Nrgn | ENSMUSG00000053310 | 2.27705955 | 1.36E-33 | neurogranin [Source:MGI Symbol;Acc:MGI:1927184] |
| Ttc3 | ENSMUSG00000040785 | 1.60046591 | 4.91E-21 | tetratricopeptide repeat domain 3 [Source:MGI Symbol;Acc:MGI:1276539] |
| Cd69 | ENSMUSG00000030156 | 2.24204393 | 4.84E-20 | CD69 antigen [Source:MGI Symbol;Acc:MGI:88343] |
| Mir155hg | ENSMUSG00000097418 | 2.87094461 | 4.93E-20 | Mir155 host gene (non-protein coding) [Source:MGI Symbol;Acc:MGI:5477161] |
| Myo1d | ENSMUSG00000035441 | 9.18329533 | 2.29E-19 | myosin ID [Source:MGI Symbol;Acc:MGI:107728] |
| Gbp6 | ENSMUSG00000104713 | 5.21148962 | 1.38E-18 | guanylate binding protein 6 [Source:MGI Symbol;Acc:MGI:2140937] |
| Fam213a | ENSMUSG00000021792 | 2.39397916 | 6.64E-18 | family with sequence similarity 213, member A [Source:MGI Symbol;Acc:MGI:1917814] |
| Cd63 | ENSMUSG00000025351 | 9.78238023 | 4.84E-17 | CD63 antigen [Source:MGI Symbol;Acc:MGI:99529] |
| Ppp4r2 | ENSMUSG00000052144 | 1.26063408 | 8.38E-17 | protein phosphatase 4, regulatory subunit 2 [Source:MGI Symbol;Acc:MGI:3027896] |
| Mfsd1 | ENSMUSG00000027775 | 1.85799803 | 7.76E-14 | major facilitator superfamily domain containing 1 [Source:MGI Symbol;Acc:MGI:1914118] |
| Dusp14 | ENSMUSG00000018648 | 5.49530658 | 8.25E-14 | dual specificity phosphatase 14 [Source:MGI Symbol;Acc:MGI:1927168] |
| Slc25a19 | ENSMUSG00000020744 | 1.19014076 | 9.92E-14 | solute carrier family 25 (mitochondrial thiamine pyrophosphate carrier), member 19 [Source:MGI Symbol;Acc:MGI:1914533] |
| Junb | ENSMUSG00000052837 | 1.80113181 | 1.22E-13 | jun B proto-oncogene [Source:MGI Symbol;Acc:MGI:96647] |
| P2rx4 | ENSMUSG00000029470 | 1.38753186 | 5.09E-12 | purinergic receptor P2X, ligand-gated ion channel 4 [Source:MGI Symbol;Acc:MGI:1338859] |
| Atf3 | ENSMUSG00000026628 | 6.54384662 | 5.59E-12 | activating transcription factor 3 [Source:MGI Symbol;Acc:MGI:109384] |
| Mcam | ENSMUSG00000032135 | 8.67981378 | 7.11E-12 | melanoma cell adhesion molecule [Source:MGI Symbol;Acc:MGI:1933966] |
| Fabp5 | ENSMUSG00000027533 | 3.83799024 | 4.11E-11 | fatty acid binding protein 5, epidermal [Source:MGI Symbol;Acc:MGI:101790] |
| Mreg | ENSMUSG00000039395 | 3.07387423 | 4.30E-11 | melanoregulin [Source:MGI Symbol;Acc:MGI:2151839] |
| Gnpda1 | ENSMUSG00000052102 | 1.80039408 | 7.19E-10 | glucosamine-6-phosphate deaminase 1 [Source:MGI Symbol;Acc:MGI:1347054] |
| Fyn | ENSMUSG00000019843 | 1.68382446 | 1.24E-09 | Fyn proto-oncogene [Source:MGI Symbol;Acc:MGI:95602] |
| Nab2 | ENSMUSG00000025402 | 3.26565792 | 1.95E-09 | Ngfi-A binding protein 2 [Source:MGI Symbol;Acc:MGI:107563] |
| Nfkbiz | ENSMUSG00000035356 | 3.03384508 | 5.03E-09 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, zeta [Source:MGI Symbol;Acc:MGI:1931595] |
| Egr1 | ENSMUSG00000038418 | 4.04815398 | 6.08E-09 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Exoc2 | ENSMUSG00000021357 | 1.20469343 | 6.97E-09 | exocyst complex component 2 [Source:MGI Symbol;Acc:MGI:1913732] |
| Fxyd5 | ENSMUSG00000009687 | 1.71236145 | 9.40E-09 | FXYD domain-containing ion transport regulator 5 [Source:MGI Symbol;Acc:MGI:1201785] |
| Acer3 | ENSMUSG00000030760 | 2.01801578 | 9.53E-09 | alkaline ceramidase 3 [Source:MGI Symbol;Acc:MGI:1913440] |
| Tpp1 | ENSMUSG00000030894 | 1.21185065 | 1.03E-08 | tripeptidyl peptidase I [Source:MGI Symbol;Acc:MGI:1336194] |
| Ctdnep1 | ENSMUSG00000018559 | 1.11272237 | 1.20E-08 | CTD nuclear envelope phosphatase 1 [Source:MGI Symbol;Acc:MGI:1914431] |
| Pdcd1lg2 | ENSMUSG00000016498 | 6.51680014 | 8.27E-08 | programmed cell death 1 ligand 2 [Source:MGI Symbol;Acc:MGI:1930125] |
| Nfkbie | ENSMUSG00000023947 | 1.67765481 | 8.48E-08 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, epsilon [Source:MGI Symbol;Acc:MGI:1194908] |
| Hexa | ENSMUSG00000025232 | 1.51650261 | 8.66E-08 | hexosaminidase A [Source:MGI Symbol;Acc:MGI:96073] |
| Trmt61a | ENSMUSG00000060950 | 1.81372146 | 1.09E-07 | tRNA methyltransferase 61A [Source:MGI Symbol;Acc:MGI:2443487] |
| Nr4a3 | ENSMUSG00000028341 | 5.40967921 | 1.43E-07 | nuclear receptor subfamily 4, group A, member 3 [Source:MGI Symbol;Acc:MGI:1352457] |
| Prodh | ENSMUSG00000003526 | 4.03527905 | 1.78E-07 | proline dehydrogenase [Source:MGI Symbol;Acc:MGI:97770] |
| Mturn | ENSMUSG00000038065 | 1.87307313 | 2.67E-07 | maturin, neural progenitor differentiation regulator homolog (Xenopus) [Source:MGI Symbol;Acc:MGI:1915485] |
| Rasgef1a | ENSMUSG00000030134 | 8.58426947 | 4.77E-07 | RasGEF domain family, member 1A [Source:MGI Symbol;Acc:MGI:1917977] |
| Sgms1 | ENSMUSG00000040451 | 1.22572638 | 4.83E-07 | sphingomyelin synthase 1 [Source:MGI Symbol;Acc:MGI:2444110] |
| Vegfb | ENSMUSG00000024962 | 1.55127473 | 8.25E-07 | vascular endothelial growth factor B [Source:MGI Symbol;Acc:MGI:106199] |
| Gstt2 | ENSMUSG00000033318 | 1.85330252 | 2.10E-06 | glutathione S-transferase, theta 2 [Source:MGI Symbol;Acc:MGI:106188] |
| Hpgds | ENSMUSG00000029919 | 3.79966074 | 2.29E-06 | hematopoietic prostaglandin D synthase [Source:MGI Symbol;Acc:MGI:1859384] |
| Fbxo30 | ENSMUSG00000047648 | 2.88108565 | 2.41E-06 | F-box protein 30 [Source:MGI Symbol;Acc:MGI:1919115] |
| Arhgap24 | ENSMUSG00000057315 | 1.14932169 | 2.41E-06 | Rho GTPase activating protein 24 [Source:MGI Symbol;Acc:MGI:1922647] |
| Ier2 | ENSMUSG00000053560 | 1.44643103 | 2.53E-06 | immediate early response 2 [Source:MGI Symbol;Acc:MGI:104815] |
| Mdn1 | ENSMUSG00000058006 | 1.6478212 | 2.92E-06 | midasin AAA ATPase 1 [Source:MGI Symbol;Acc:MGI:1926159] |
| Mif | ENSMUSG00000033307 | 1.04197757 | 3.00E-06 | macrophage migration inhibitory factor (glycosylation-inhibiting factor) [Source:MGI Symbol;Acc:MGI:96982] |
| Bcl2a1b | ENSMUSG00000089929 | 3.26880718 | 3.08E-06 | B cell leukemia/lymphoma 2 related protein A1b [Source:MGI Symbol;Acc:MGI:1278326] |
| Myof | ENSMUSG00000048612 | 2.16219033 | 4.70E-06 | myoferlin [Source:MGI Symbol;Acc:MGI:1919192] |
| Irf1 | ENSMUSG00000018899 | 1.01850819 | 5.37E-06 | interferon regulatory factor 1 [Source:MGI Symbol;Acc:MGI:96590] |
| Ccl3 | ENSMUSG00000000982 | 8.87386267 | 6.18E-06 | chemokine (C-C motif) ligand 3 [Source:MGI Symbol;Acc:MGI:98260] |
| Ppp1r15a | ENSMUSG00000040435 | 1.99639378 | 8.28E-06 | protein phosphatase 1, regulatory (inhibitor) subunit 15A [Source:MGI Symbol;Acc:MGI:1927072] |
| Klf10 | ENSMUSG00000037465 | 2.23415999 | 1.18E-05 | Kruppel-like factor 10 [Source:MGI Symbol;Acc:MGI:1101353] |
| Dvl2 | ENSMUSG00000020888 | 1.1782532 | 1.29E-05 | dishevelled segment polarity protein 2 [Source:MGI Symbol;Acc:MGI:106613] |
| Il1r1 | ENSMUSG00000026072 | 7.01811914 | 2.06E-05 | interleukin 1 receptor, type I [Source:MGI Symbol;Acc:MGI:96545] |
| Dpp7 | ENSMUSG00000026958 | 1.81655974 | 2.18E-05 | dipeptidylpeptidase 7 [Source:MGI Symbol;Acc:MGI:1933213] |
| Sos2 | ENSMUSG00000034801 | 1.57344401 | 2.26E-05 | son of sevenless homolog 2 (Drosophila) [Source:MGI Symbol;Acc:MGI:98355] |
| Uap1l1 | ENSMUSG00000026956 | 1.7010702 | 2.67E-05 | UDP-N-acteylglucosamine pyrophosphorylase 1-like 1 [Source:MGI Symbol;Acc:MGI:2443318] |
| Slc38a7 | ENSMUSG00000036534 | 1.52409595 | 2.68E-05 | solute carrier family 38, member 7 [Source:MGI Symbol;Acc:MGI:2679005] |
| Cd83 | ENSMUSG00000015396 | 1.42240563 | 7.75E-05 | CD83 antigen [Source:MGI Symbol;Acc:MGI:1328316] |
| Alcam | ENSMUSG00000022636 | 1.75283091 | 8.24E-05 | activated leukocyte cell adhesion molecule [Source:MGI Symbol;Acc:MGI:1313266] |
| Sgpl1 | ENSMUSG00000020097 | 1.70011551 | 0.00010735 | sphingosine phosphate lyase 1 [Source:MGI Symbol;Acc:MGI:1261415] |
| Irs2 | ENSMUSG00000038894 | 2.63332578 | 0.00012432 | insulin receptor substrate 2 [Source:MGI Symbol;Acc:MGI:109334] |
| Gadd45b | ENSMUSG00000015312 | 1.14437809 | 0.00012673 | growth arrest and DNA-damage-inducible 45 beta [Source:MGI Symbol;Acc:MGI:107776] |
| Tagap | ENSMUSG00000033450 | 3.98087899 | 0.00013278 | T cell activation Rho GTPase activating protein [Source:MGI Symbol;Acc:MGI:3615484] |
| Ccr7 | ENSMUSG00000037944 | 1.5212512 | 0.00013622 | chemokine (C-C motif) receptor 7 [Source:MGI Symbol;Acc:MGI:103011] |
| Cnot8 | ENSMUSG00000020515 | 1.18528524 | 0.00016453 | CCR4-NOT transcription complex, subunit 8 [Source:MGI Symbol;Acc:MGI:1916375] |
| Tpst2 | ENSMUSG00000029344 | 1.71098719 | 0.00020937 | protein-tyrosine sulfotransferase 2 [Source:MGI Symbol;Acc:MGI:1309516] |
| Zc3h12a | ENSMUSG00000042677 | 1.40015151 | 0.000223 | zinc finger CCCH type containing 12A [Source:MGI Symbol;Acc:MGI:2385891] |
| Lamp1 | ENSMUSG00000031447 | 1.04246411 | 0.00022509 | lysosomal-associated membrane protein 1 [Source:MGI Symbol;Acc:MGI:96745] |
| Adgrg1 | ENSMUSG00000031785 | 1.59782075 | 0.00022704 | adhesion G protein-coupled receptor G1 [Source:MGI Symbol;Acc:MGI:1340051] |
| Gfi1 | ENSMUSG00000029275 | 3.37535003 | 0.00023777 | growth factor independent 1 [Source:MGI Symbol;Acc:MGI:103170] |
| Fuca2 | ENSMUSG00000019810 | 1.14766972 | 0.00024473 | fucosidase, alpha-L- 2, plasma [Source:MGI Symbol;Acc:MGI:1914098] |
| Satb1 | ENSMUSG00000023927 | 1.33602114 | 0.00027059 | special AT-rich sequence binding protein 1 [Source:MGI Symbol;Acc:MGI:105084] |
| Nab1 | ENSMUSG00000002881 | 1.16904906 | 0.00027059 | Ngfi-A binding protein 1 [Source:MGI Symbol;Acc:MGI:107564] |
| Etfbkmt | ENSMUSG00000039958 | 1.26483275 | 0.00029403 | electron transfer flavoprotein beta subunit lysine methyltransferase [Source:MGI Symbol;Acc:MGI:2443575] |
| BE692007 | ENSMUSG00000099757 | 1.08115956 | 0.00029403 | expressed sequence BE692007 [Source:MGI Symbol;Acc:MGI:3035348] |
| Gcsh | ENSMUSG00000034424 | 1.18542173 | 0.00029529 | glycine cleavage system protein H (aminomethyl carrier) [Source:MGI Symbol;Acc:MGI:1915383] |
| Hps4 | ENSMUSG00000042328 | 1.0151272 | 0.00033244 | HPS4, biogenesis of lysosomal organelles complex 3 subunit 2 [Source:MGI Symbol;Acc:MGI:2177742] |

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| | | | | |
|---|---|---|---|---|
| Flcn | ENSMUSG00000032633 | 1.46857382 | 0.00033822 | folliculin [Source:MGI Symbol;Acc:MGI:2442184] |
| Batf | ENSMUSG00000034266 | 1.6802239 | 0.00034676 | basic leucine zipper transcription factor, ATF-like [Source:MGI Symbol;Acc:MGI:1859147] |
| Git1 | ENSMUSG00000011877 | 1.60286372 | 0.00044985 | G protein-coupled receptor kinase-interactor 1 [Source:MGI Symbol;Acc:MGI:1927140] |
| Pfkp | ENSMUSG00000021196 | 1.15537202 | 0.00045195 | phosphofructokinase, platelet [Source:MGI Symbol;Acc:MGI:1891833] |
| Ms4a4b | ENSMUSG00000056290 | 2.19556569 | 0.00046393 | membrane-spanning 4-domains, subfamily A, member 4B [Source:MGI Symbol;Acc:MGI:1913083] |
| Gbp3 | ENSMUSG00000028268 | 1.01181987 | 0.0005133 | guanylate binding protein 3 [Source:MGI Symbol;Acc:MGI:1926263] |
| Nbn | ENSMUSG00000028224 | 1.08710682 | 0.00063309 | nibrin [Source:MGI Symbol;Acc:MGI:1351625] |
| Abcb1b | ENSMUSG00000028970 | 2.4080322 | 0.00066793 | ATP-binding cassette, sub-family B (MDR/TAP), member 1B [Source:MGI Symbol;Acc:MGI:97568] |
| Igf2r | ENSMUSG00000023830 | 2.82313127 | 0.00075732 | insulin-like growth factor 2 receptor [Source:MGI Symbol;Acc:MGI:96435] |
| Nr4a1 | ENSMUSG00000023034 | 2.33916652 | 0.00078448 | nuclear receptor subfamily 4, group A, member 1 [Source:MGI Symbol;Acc:MGI:1352454] |
| Chka | ENSMUSG00000024843 | 1.01612409 | 0.00089967 | choline kinase alpha [Source:MGI Symbol;Acc:MGI:107760] |
| Lxn | ENSMUSG00000047557 | 1.00051461 | 0.00089967 | latexin [Source:MGI Symbol;Acc:MGI:107633] |
| E330020D12Rik | ENSMUSG00000073538 | 1.53779117 | 0.0009057 | Riken cDNA E330020D12 gene [Source:MGI Symbol;Acc:MGI:3761270] |
| Gsto1 | ENSMUSG00000025068 | 2.10569915 | 0.00093455 | glutathione S-transferase omega 1 [Source:MGI Symbol;Acc:MGI:1342273] |
| Rilpl2 | ENSMUSG00000029401 | 1.03950149 | 0.00096869 | Rab interacting lysosomal protein-like 2 [Source:MGI Symbol;Acc:MGI:1933112] |
| Ccdc86 | ENSMUSG00000024732 | 1.04493189 | 0.00105596 | coiled-coil domain containing 86 [Source:MGI Symbol;Acc:MGI:1277220] |
| Gm9728 | ENSMUSG00000106248 | 7.27550544 | 0.00119109 | predicted gene 9728 [Source:MGI Symbol;Acc:MGI:3780132] |
| Usb1 | ENSMUSG00000031792 | 1.04997999 | 0.00124878 | U6 snRNA biogenesis 1 [Source:MGI Symbol;Acc:MGI:2142454] |
| H2-K2 | ENSMUSG00000067203 | 1.039109 | 0.00138239 | histocompatibility 2, K region locus 2 [Source:MGI Symbol;Acc:MGI:95906] |
| Znhit6 | ENSMUSG00000074182 | 1.05618417 | 0.00138374 | zinc finger, HIT type 6 [Source:MGI Symbol;Acc:MGI:1916996] |
| Shmt1 | ENSMUSG00000020534 | 1.46547534 | 0.00140351 | serine hydroxymethyltransferase 1 (soluble) [Source:MGI Symbol;Acc:MGI:98299] |
| Mapk6 | ENSMUSG00000042688 | 1.29706979 | 0.00172786 | mitogen-activated protein kinase 6 [Source:MGI Symbol;Acc:MGI:1354946] |
| Dnase2a | ENSMUSG00000003812 | 1.71459448 | 0.00179832 | deoxyribonuclease II alpha [Source:MGI Symbol;Acc:MGI:1329019] |
| Tnfrsf26 | ENSMUSG00000045362 | 1.65546611 | 0.00179832 | tumor necrosis factor receptor superfamily, member 26 [Source:MGI Symbol;Acc:MGI:2651928] |
| Gstm1 | ENSMUSG00000058135 | 1.36427709 | 0.00179832 | glutathione S-transferase, mu 1 [Source:MGI Symbol;Acc:MGI:95860] |
| Shisa8 | ENSMUSG00000096883 | 4.23860014 | 0.00198322 | shisa family member 8 [Source:MGI Symbol;Acc:MGI:2146080] |
| Sec24a | ENSMUSG00000036391 | 1.49583055 | 0.00210372 | Sec24 related gene family, member A (S. cerevisiae) [Source:MGI Symbol;Acc:MGI:1924621] |
| Pik3ip1 | ENSMUSG00000034614 | 1.68373262 | 0.00227766 | phosphoinositide-3-kinase interacting protein 1 [Source:MGI Symbol;Acc:MGI:1917016] |
| Pus7 | ENSMUSG00000057541 | 1.68545324 | 0.00239898 | pseudouridylate synthase 7 [Source:MGI Symbol;Acc:MGI:1925947] |
| Nfatc1 | ENSMUSG00000033016 | 1.45999742 | 0.0027338 | nuclear factor of activated T cells, cytoplasmic, calcineurin dependent 1 [Source:MGI Symbol;Acc:MGI:102469] |
| Rcl1 | ENSMUSG00000024785 | 1.1335487 | 0.0029129 | RNA terminal phosphate cyclase-like 1 [Source:MGI Symbol;Acc:MGI:1913275] |
| Grn | ENSMUSG00000034708 | 1.13421689 | 0.00317964 | granulin [Source:MGI Symbol;Acc:MGI:95832] |
| Gns | ENSMUSG00000034707 | 1.02114225 | 0.00329278 | glucosamine (N-acetyl)-6-sulfatase [Source:MGI Symbol;Acc:MGI:1922862] |
| Zc3h12c | ENSMUSG00000035164 | 6.96065985 | 0.00333028 | zinc finger CCCH type containing 12C [Source:MGI Symbol;Acc:MGI:3026959] |
| Tgif1 | ENSMUSG00000047407 | 1.23455534 | 0.003379 | TGFB-induced factor homeobox 1 [Source:MGI Symbol;Acc:MGI:1194497] |
| Nfkbid | ENSMUSG00000036931 | 1.31272634 | 0.00340228 | nuclear factor of kappa light polypeptide gene enhancer in B cells inhibitor, delta [Source:MGI Symbol;Acc:MGI:3041243] |
| Dusp6 | ENSMUSG00000019960 | 1.09400417 | 0.00340228 | dual specificity phosphatase 6 [Source:MGI Symbol;Acc:MGI:1914853] |
| Lztfl1 | ENSMUSG00000025245 | 1.60599808 | 0.00369882 | leucine zipper transcription factor-like 1 [Source:MGI Symbol;Acc:MGI:1934860] |
| Myc | ENSMUSG00000022346 | 2.76191542 | 0.00381937 | myelocytomatosis oncogene [Source:MGI Symbol;Acc:MGI:97250] |
| Tnfaip3 | ENSMUSG00000019850 | 1.37013142 | 0.00395126 | tumor necrosis factor, alpha-induced protein 3 [Source:MGI Symbol;Acc:MGI:1196377] |
| Sgk1 | ENSMUSG00000019970 | 1.03139602 | 0.00405868 | serum/glucocorticoid regulated kinase 1 [Source:MGI Symbol;Acc:MGI:1340062] |
| Papss1 | ENSMUSG00000028032 | 1.16042111 | 0.00438288 | 3'-phosphoadenosine 5'-phosphosulfate synthase 1 [Source:MGI Symbol;Acc:MGI:1330587] |
| Nln | ENSMUSG00000021710 | 1.63293011 | 0.00442457 | neurolysin (metallopeptidase M3 family) [Source:MGI Symbol;Acc:MGI:1923055] |
| Bhlhe40 | ENSMUSG00000030103 | 2.21386229 | 0.00467359 | basic helix-loop-helix family, member e40 [Source:MGI Symbol;Acc:MGI:1097714] |
| Plk2 | ENSMUSG00000021701 | 1.65732726 | 0.00484218 | polo like kinase 2 [Source:MGI Symbol;Acc:MGI:1099790] |
| Mphosph9 | ENSMUSG00000038126 | 1.5677445 | 0.00736479 | M-phase phosphoprotein 9 [Source:MGI Symbol;Acc:MGI:2443138] |
| Adi1 | ENSMUSG00000020629 | 1.38629161 | 0.00781752 | acireductone dioxygenase 1 [Source:MGI Symbol;Acc:MGI:2144929] |
| Degs1 | ENSMUSG00000038633 | 1.4487632 | 0.00926902 | delta(4)-desaturase, sphingolipid 1 [Source:MGI Symbol;Acc:MGI:1097711] |
| Renbp | ENSMUSG00000031387 | 2.14920977 | 0.00955038 | renin binding protein [Source:MGI Symbol;Acc:MGI:105940] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-10. Genes significantly repressed in in immature B cell subsets in Ig adult BM upon stimulation.

| Symbol | Ensembl gene id | logFC (BM-R10/BM-sHEL) | adj.P.val | Annotation |
|---|---|---|---|---|
| Bank1 | ENSMUSG00000037922 | 2.02283392 | 1.73E-30 | B cell scaffold protein with ankyrin repeats 1 [Source:MGI Symbol;Acc:MGI:2442120] |
| Ptpn6 | ENSMUSG00000004266 | 1.3623271 | 4.93E-20 | protein tyrosine phosphatase, non-receptor type 6 [Source:MGI Symbol;Acc:MGI:96055] |
| Wfdc21 | ENSMUSG00000051748 | 3.0332095 | 3.89E-18 | WAP four-disulfide core domain 21 [Source:MGI Symbol;Acc:MGI:1913357] |
| Cd24a | ENSMUSG00000047139 | 1.01266832 | 1.00E-17 | CD24a antigen [Source:MGI Symbol;Acc:MGI:88323] |
| Pld4 | ENSMUSG00000052160 | 2.22709834 | 2.41E-17 | phospholipase D family, member 4 [Source:MGI Symbol;Acc:MGI:2144765] |
| Hdac9 | ENSMUSG00000004698 | 1.32819674 | 1.05E-12 | histone deacetylase 9 [Source:MGI Symbol;Acc:MGI:1931221] |
| Slamf6 | ENSMUSG00000015314 | 1.21495418 | 1.14E-12 | SLAM family member 6 [Source:MGI Symbol;Acc:MGI:1353620] |
| Cd22 | ENSMUSG00000030577 | 1.06793974 | 1.18E-11 | CD22 antigen [Source:MGI Symbol;Acc:MGI:88322] |
| Abi3 | ENSMUSG00000018381 | 1.16157609 | 2.18E-10 | ABI gene family, member 3 [Source:MGI Symbol;Acc:MGI:1913860] |
| Gm11335 | ENSMUSG00000085016 | 7.92097613 | 5.58E-10 | predicted gene 11335 [Source:MGI Symbol;Acc:MGI:3705194] |
| Rasgrp2 | ENSMUSG00000032946 | 1.37101428 | 2.43E-09 | RAS, guanyl releasing protein 2 [Source:MGI Symbol;Acc:MGI:1333849] |
| Ccr6 | ENSMUSG00000040899 | 9.84497638 | 6.91E-09 | chemokine (C-C motif) receptor 6 [Source:MGI Symbol;Acc:MGI:1333797] |
| Cnn3 | ENSMUSG00000053931 | 1.32985719 | 2.40E-08 | calponin 3, acidic [Source:MGI Symbol;Acc:MGI:1919244] |
| Rnase6 | ENSMUSG00000021880 | 1.21982311 | 3.51E-08 | ribonuclease, RNase A family, 6 [Source:MGI Symbol;Acc:MGI:1925666] |
| Mzb1 | ENSMUSG00000024353 | 1.21417732 | 3.51E-08 | marginal zone B and B1 cell-specific protein 1 [Source:MGI Symbol;Acc:MGI:1917066] |
| Cd1d1 | ENSMUSG00000028076 | 1.5372464 | 5.32E-08 | CD1d1 antigen [Source:MGI Symbol;Acc:MGI:107674] |
| Hes6 | ENSMUSG00000067071 | 1.22272859 | 1.55E-07 | hairy and enhancer of split 6 [Source:MGI Symbol;Acc:MGI:1859852] |
| Rtn4ip1 | ENSMUSG00000019864 | 1.98122427 | 3.43E-07 | reticulon 4 interacting protein 1 [Source:MGI Symbol;Acc:MGI:2178759] |
| Ehd4 | ENSMUSG00000027293 | 1.15627126 | 4.78E-07 | EH-domain containing 4 [Source:MGI Symbol;Acc:MGI:1919619] |
| Prkcb | ENSMUSG00000052889 | 1.14535847 | 6.47E-07 | protein kinase C, beta [Source:MGI Symbol;Acc:MGI:97596] |
| Ceacam1 | ENSMUSG00000074272 | 2.01123154 | 6.91E-07 | carcinoembryonic antigen-related cell adhesion molecule 1 [Source:MGI Symbol;Acc:MGI:1347245] |
| Rasgrp1 | ENSMUSG00000027347 | 1.22797865 | 7.31E-07 | RAS guanyl releasing protein 1 [Source:MGI Symbol;Acc:MGI:1314635] |
| Emid1 | ENSMUSG00000034164 | 1.09353244 | 1.40E-06 | EMI domain containing 1 [Source:MGI Symbol;Acc:MGI:2155091] |
| B3gnt8 | ENSMUSG00000059479 | 1.05078959 | 1.66E-06 | UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 8 [Source:MGI Symbol;Acc:MGI:2385269] |
| Nrm | ENSMUSG00000059791 | 1.24367831 | 2.92E-06 | nurim (nuclear envelope membrane protein) [Source:MGI Symbol;Acc:MGI:2146855] |
| AI467606 | ENSMUSG00000045165 | 1.12630298 | 3.69E-06 | expressed sequence AI467606 [Source:MGI Symbol;Acc:MGI:2141979] |
| Ifi30 | ENSMUSG00000031838 | 1.24858588 | 5.09E-06 | interferon gamma inducible protein 30 [Source:MGI Symbol;Acc:MGI:2137648] |
| Tmprss3 | ENSMUSG00000024034 | 2.03773687 | 5.36E-06 | transmembrane protease, serine 3 [Source:MGI Symbol;Acc:MGI:2155445] |
| Napsa | ENSMUSG00000002204 | 1.18242198 | 6.78E-06 | napsin A aspartic peptidase [Source:MGI Symbol;Acc:MGI:109365] |
| Rsph1 | ENSMUSG00000024033 | 1.83642057 | 9.67E-06 | radial spoke head 1 homolog (Chlamydomonas) [Source:MGI Symbol;Acc:MGI:1194909] |
| Prkcg | ENSMUSG00000078816 | 1.33672095 | 1.18E-05 | protein kinase C, gamma [Source:MGI Symbol;Acc:MGI:97597] |
| E2f2 | ENSMUSG00000018983 | 1.45148692 | 1.19E-05 | E2F transcription factor 2 [Source:MGI Symbol;Acc:MGI:1096341] |
| Ap1s2 | ENSMUSG00000031367 | 1.07199542 | 1.27E-05 | adaptor-related protein complex 1, sigma 2 subunit [Source:MGI Symbol;Acc:MGI:1889383] |
| Idh2 | ENSMUSG00000030541 | 1.24203222 | 3.60E-05 | isocitrate dehydrogenase 2 (NADP+), mitochondrial [Source:MGI Symbol;Acc:MGI:96414] |
| Anxa6 | ENSMUSG00000018340 | 1.22828359 | 3.87E-05 | annexin A6 [Source:MGI Symbol;Acc:MGI:88255] |
| Myl4 | ENSMUSG00000061086 | 1.04703321 | 4.20E-05 | myosin, light polypeptide 4 [Source:MGI Symbol;Acc:MGI:97267] |
| St6gal1 | ENSMUSG00000022885 | 1.16343186 | 4.61E-05 | beta galactoside alpha 2,6 sialyltransferase 1 [Source:MGI Symbol;Acc:MGI:108470] |
| Adap1 | ENSMUSG00000056413 | 1.53229607 | 5.55E-05 | ArfGAP with dual PH domains 1 [Source:MGI Symbol;Acc:MGI:2442201] |
| Vpreb1 | ENSMUSG00000059305 | 2.1492507 | 7.98E-05 | pre-B lymphocyte gene 1 [Source:MGI Symbol;Acc:MGI:98936] |
| Ipp | ENSMUSG00000028696 | 2.00063172 | 0.00010004 | IAP promoted placental gene [Source:MGI Symbol;Acc:MGI:96581] |
| Cyth4 | ENSMUSG00000018008 | 1.2273491 | 0.00010551 | cytohesin 4 [Source:MGI Symbol;Acc:MGI:2441702] |
| Galns | ENSMUSG00000015027 | 1.21565261 | 0.00011226 | galactosamine (N-acetyl)-6-sulfate sulfatase [Source:MGI Symbol;Acc:MGI:1355303] |
| Phyh | ENSMUSG00000026664 | 1.43037187 | 0.00011302 | phytanoyl-CoA hydroxylase [Source:MGI Symbol;Acc:MGI:891978] |
| Rcbtb2 | ENSMUSG00000022106 | 1.42109155 | 0.00013212 | regulator of chromosome condensation (RCC1) and BTB (POZ) domain containing protein 2 [Source:MGI Symbol;Acc:MGI:1917200] |
| Gngt2 | ENSMUSG00000038811 | 1.15812008 | 0.00014405 | guanine nucleotide binding protein (G protein), gamma transducing activity polypeptide 2 [Source:MGI Symbol;Acc:MGI:893584] |
| Aicda | ENSMUSG00000040627 | 1.83629212 | 0.00015118 | activation-induced cytidine deaminase [Source:MGI Symbol;Acc:MGI:1342279] |
| 5031439G07Rik | ENSMUSG00000036046 | 1.60158807 | 0.0001652 | RIKEN cDNA 5031439G07 gene [Source:MGI Symbol;Acc:MGI:2444899] |
| Rgs14 | ENSMUSG00000052087 | 1.64655242 | 0.00016588 | regulator of G-protein signaling 14 [Source:MGI Symbol;Acc:MGI:1859709] |
| Rgs18 | ENSMUSG00000026357 | 1.26042096 | 0.000171 | regulator of G-protein signaling 18 [Source:MGI Symbol;Acc:MGI:1927498] |
| Dusp10 | ENSMUSG00000039384 | 1.18922282 | 0.0001726 | dual specificity phosphatase 10 [Source:MGI Symbol;Acc:MGI:1927070] |
| Hes1 | ENSMUSG00000022528 | 1.47314287 | 0.00021503 | hairy and enhancer of split 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:104853] |
| Igll1 | ENSMUSG00000075370 | 2.08059613 | 0.00022778 | immunoglobulin lambda-like polypeptide 1 [Source:MGI Symbol;Acc:MGI:96529] |
| Fry | ENSMUSG00000056602 | 1.68940948 | 0.00024473 | FRY microtubule binding protein [Source:MGI Symbol;Acc:MGI:2443895] |
| Gfra2 | ENSMUSG00000022103 | 1.53037011 | 0.00027462 | glial cell line derived neurotrophic factor family receptor alpha 2 [Source:MGI Symbol;Acc:MGI:1195462] |
| Neil3 | ENSMUSG00000039396 | 1.25545577 | 0.00029722 | nei like 3 (E. coli) [Source:MGI Symbol;Acc:MGI:2384588] |
| Gm37065 | ENSMUSG00000104413 | 1.0994157 | 0.00030214 | predicted gene, 37065 [Source:MGI Symbol;Acc:MGI:5610293] |
| Asf1b | ENSMUSG00000005470 | 1.05696919 | 0.00033778 | anti-silencing function 1B histone chaperone [Source:MGI Symbol;Acc:MGI:1914179] |
| Rpgrip1 | ENSMUSG00000057132 | 1.6334234 | 0.00034461 | retinitis pigmentosa GTPase regulator interacting protein 1 [Source:MGI Symbol;Acc:MGI:1932134] |
| Zfp160 | ENSMUSG00000067942 | 1.13049999 | 0.00036547 | zinc finger protein 160 [Source:MGI Symbol;Acc:MGI:108187] |
| Fgd2 | ENSMUSG00000024013 | 1.81124196 | 0.00038534 | FYVE, RhoGEF and PH domain containing 2 [Source:MGI Symbol;Acc:MGI:1347084] |
| Hhex | ENSMUSG00000024986 | 1.15303905 | 0.00043094 | hematopoietically expressed homeobox [Source:MGI Symbol;Acc:MGI:96086] |
| Lynx1 | ENSMUSG00000022594 | 1.1575329 | 0.00043369 | Ly6/neurotoxin 1 [Source:MGI Symbol;Acc:MGI:1345180] |
| Gpr155 | ENSMUSG00000041762 | 1.47603229 | 0.00044664 | G protein-coupled receptor 155 [Source:MGI Symbol;Acc:MGI:1915776] |
| Coro2a | ENSMUSG00000028337 | 1.35782438 | 0.00053214 | coronin, actin binding protein 2A [Source:MGI Symbol;Acc:MGI:1345966] |
| Traip | ENSMUSG00000032586 | 1.34737955 | 0.00064936 | TRAF-interacting protein [Source:MGI Symbol;Acc:MGI:1096377] |
| Bcat1 | ENSMUSG00000030268 | 1.27120604 | 0.00069812 | branched chain aminotransferase 1, cytosolic [Source:MGI Symbol;Acc:MGI:104861] |
| Gas7 | ENSMUSG00000033066 | 3.64443704 | 0.00082218 | growth arrest specific 7 [Source:MGI Symbol;Acc:MGI:1202388] |
| Cd55 | ENSMUSG00000026399 | 1.37139253 | 0.00092427 | CD55 molecule, decay accelerating factor for complement [Source:MGI Symbol;Acc:MGI:104850] |
| Iglc1 | ENSMUSG00000105906 | 1.06398484 | 0.00105589 | immunoglobulin lambda constant 1 [Source:MGI Symbol;Acc:MGI:99546] |
| Atp2a3 | ENSMUSG00000020788 | 1.24316202 | 0.00106906 | ATPase, Ca++ transporting, ubiquitous [Source:MGI Symbol;Acc:MGI:1194503] |
| Prr5 | ENSMUSG00000036106 | 1.65057849 | 0.00165763 | proline rich 5 (renal) [Source:MGI Symbol;Acc:MGI:1924714] |
| Rsph9 | ENSMUSG00000023966 | 1.37896771 | 0.00182966 | radial spoke head 9 homolog (Chlamydomonas) [Source:MGI Symbol;Acc:MGI:1922814] |
| Mns1 | ENSMUSG00000032221 | 1.1827395 | 0.00202814 | meiosis-specific nuclear structural protein 1 [Source:MGI Symbol;Acc:MGI:107933] |
| Gsn | ENSMUSG00000026879 | 1.22471528 | 0.00241105 | gelsolin [Source:MGI Symbol;Acc:MGI:95851] |
| Gucd1 | ENSMUSG00000033416 | 1.17493775 | 0.00300825 | guanylyl cyclase domain containing 1 [Source:MGI Symbol;Acc:MGI:1916028] |
| Fyco1 | ENSMUSG00000025241 | 1.03134722 | 0.00326867 | FYVE and coiled-coil domain containing 1 [Source:MGI Symbol;Acc:MGI:107277] |
| Ehbp1l1 | ENSMUSG00000024937 | 1.33444167 | 0.00413362 | EH domain binding protein 1-like 1 [Source:MGI Symbol;Acc:MGI:3612340] |
| Stil | ENSMUSG00000028718 | 1.52461096 | 0.00530311 | Scl/Tal1 interrupting locus [Source:MGI Symbol;Acc:MGI:107477] |
| Ccdc134 | ENSMUSG00000068114 | 1.10018394 | 0.00539657 | coiled-coil domain containing 134 [Source:MGI Symbol;Acc:MGI:1923707] |

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| | | | | |
|---|---|---|---|---|
| Car2 | ENSMUSG00000027562 | 1.44930607 | 0.00584605 | carbonic anhydrase 2 [Source:MGI Symbol;Acc:MGI:88269] |
| Nuak2 | ENSMUSG00000009772 | 1.30891033 | 0.00630201 | NUAK family, SNF1-like kinase, 2 [Source:MGI Symbol;Acc:MGI:1921387] |
| Fmnl3 | ENSMUSG00000023008 | 1.41675266 | 0.0068722 | formin-like 3 [Source:MGI Symbol;Acc:MGI:109569] |
| 9530077C05Rik | ENSMUSG00000036411 | 1.97959675 | 0.00696636 | RIKEN cDNA 9530077C05 gene [Source:MGI Symbol;Acc:MGI:1915533] |
| St3gal5 | ENSMUSG00000056091 | 1.34062537 | 0.00788121 | ST3 beta-galactoside alpha-2,3-sialyltransferase 5 [Source:MGI Symbol;Acc:MGI:1339963] |
| Zfp775 | ENSMUSG00000007216 | 1.95552701 | 0.00955038 | zinc finger protein 775 [Source:MGI Symbol;Acc:MGI:2683557] |
| Maged1 | ENSMUSG00000025151 | 6.21921233 | 0.00982602 | melanoma antigen, family D, 1 [Source:MGI Symbol;Acc:MGI:1930187] |
| Chaf1a | ENSMUSG00000002835 | 1.20181347 | 0.01029251 | chromatin assembly factor 1, subunit A (p150) [Source:MGI Symbol;Acc:MGI:1351331] |
| Top3b | ENSMUSG00000022779 | 1.12674341 | 0.01125633 | topoisomerase (DNA) III beta [Source:MGI Symbol;Acc:MGI:1333803] |
| Spns3 | ENSMUSG00000020798 | 1.10689564 | 0.01155763 | spinster homolog 3 [Source:MGI Symbol;Acc:MGI:1924827] |
| Wnt10a | ENSMUSG00000026167 | 2.33480246 | 0.01166562 | wingless-type MMTV integration site family, member 10A [Source:MGI Symbol;Acc:MGI:108071] |
| Sell | ENSMUSG00000026581 | 1.18826988 | 0.01326535 | selectin, lymphocyte [Source:MGI Symbol;Acc:MGI:98279] |
| Gm12057 | ENSMUSG00000084081 | 1.56109497 | 0.01442747 | predicted gene 12057 [Source:MGI Symbol;Acc:MGI:3650030] |
| Slpi | ENSMUSG00000017002 | 1.85026968 | 0.01446883 | secretory leukocyte peptidase inhibitor [Source:MGI Symbol;Acc:MGI:109297] |
| Kif4 | ENSMUSG00000034311 | 1.11519181 | 0.01578228 | kinesin family member 4 [Source:MGI Symbol;Acc:MGI:108389] |
| Il18 | ENSMUSG00000039217 | 2.55815847 | 0.01683499 | interleukin 18 [Source:MGI Symbol;Acc:MGI:107936] |
| Pag1 | ENSMUSG00000027508 | 1.46513909 | 0.01749452 | phosphoprotein associated with glycosphingolipid microdomains 1 [Source:MGI Symbol;Acc:MGI:2443160] |
| Abcd1 | ENSMUSG00000031378 | 1.23463202 | 0.01846994 | ATP-binding cassette, sub-family D (ALD), member 1 [Source:MGI Symbol;Acc:MGI:1349215] |
| Gapt | ENSMUSG00000046006 | 1.51917972 | 0.02287507 | Grb2-binding adaptor, transmembrane [Source:MGI Symbol;Acc:MGI:3608341] |
| Cyfip1 | ENSMUSG00000030447 | 2.16540252 | 0.02622477 | cytoplasmic FMR1 interacting protein 1 [Source:MGI Symbol;Acc:MGI:1338801] |
| Slc37a2 | ENSMUSG00000032122 | 1.35477238 | 0.02689693 | solute carrier family 37 (glycerol-3-phosphate transporter), member 2 [Source:MGI Symbol;Acc:MGI:1929693] |
| Klhl14 | ENSMUSG00000042514 | 1.54307424 | 0.03582783 | kelch-like 14 [Source:MGI Symbol;Acc:MGI:1921249] |
| Ptgr1 | ENSMUSG00000028378 | 1.3346333 | 0.03925312 | prostaglandin reductase 1 [Source:MGI Symbol;Acc:MGI:1914353] |
| Mrvi1 | ENSMUSG00000005611 | 5.52209986 | 0.04985507 | MRV integration site 1 [Source:MGI Symbol;Acc:MGI:1338023] |

adjusted P value <=0.01

Fold change >= 2

## Table 6-11. Genes significantly up-regulated in anergic B cells compare to FO B cells.

| Symbol | Ensembl gene id | logFC (Anergic/FO) | adj.P.val | Annotation |
|---|---|---|---|---|
| Sv2b | ENSMUSG00000053025 | 7.808619521 | 6.63E-14 | synaptic vesicle glycoprotein 2 b [Source:MGI Symbol;Acc:MGI:1927338] |
| Rasgef1a | ENSMUSG00000030134 | 7.654068191 | 3.03E-13 | RasGEF domain family, member 1A [Source:MGI Symbol;Acc:MGI:1917977] |
| Rgs13 | ENSMUSG00000051079 | 7.622838577 | 2.11E-51 | regulator of G-protein signaling 13 [Source:MGI Symbol;Acc:MGI:2180585] |
| Gfi1 | ENSMUSG00000029275 | 6.567950447 | 1.62E-44 | growth factor independent 1 [Source:MGI Symbol;Acc:MGI:103170] |
| Col4a5 | ENSMUSG00000031274 | 6.435782323 | 6.25E-10 | collagen, type IV, alpha 5 [Source:MGI Symbol;Acc:MGI:88456] |
| Gm8183 | ENSMUSG00000098174 | 6.356565538 | 0.000456562 | predicted gene 8183 [Source:MGI Symbol;Acc:MGI:3643325] |
| Lonrf3 | ENSMUSG00000016239 | 6.182446742 | 0.000547411 | LON peptidase N-terminal domain and ring finger 3 [Source:MGI Symbol;Acc:MGI:1921615] |
| Ankrd13b | ENSMUSG00000037907 | 6.129462782 | 8.34E-08 | ankyrin repeat domain 13b [Source:MGI Symbol;Acc:MGI:2144501] |
| Wnt10a | ENSMUSG00000026167 | 6.031174139 | 1.65E-17 | wingless-type MMTV integration site family, member 10A [Source:MGI Symbol;Acc:MGI:108071] |
| Gm2895 | ENSMUSG00000091412 | 5.958179466 | 0.002361942 | predicted gene 2895 [Source:MGI Symbol;Acc:MGI:3781073] |
| Havcr1 | ENSMUSG00000040405 | 5.908418575 | 9.99E-24 | hepatitis A virus cellular receptor 1 [Source:MGI Symbol;Acc:MGI:2159680] |
| Ccl4 | ENSMUSG00000018930 | 5.694416644 | 1.13E-05 | chemokine (C-C motif) ligand 4 [Source:MGI Symbol;Acc:MGI:98261] |
| Nrgn | ENSMUSG00000053310 | 5.51248469 | 8.25E-57 | neurogranin [Source:MGI Symbol;Acc:MGI:1927184] |
| Ndrg1 | ENSMUSG00000005125 | 5.484390822 | 5.17E-135 | N-myc downstream regulated gene 1 [Source:MGI Symbol;Acc:MGI:1341799] |
| Platr29 | ENSMUSG00000084816 | 5.344698978 | 0.000557723 | pluripotency associated transcript 29 [Source:MGI Symbol;Acc:MGI:3650001] |
| Myb | ENSMUSG00000019982 | 5.263717242 | 1.05E-39 | myeloblastosis oncogene [Source:MGI Symbol;Acc:MGI:97249] |
| Tnfsf4 | ENSMUSG00000026700 | 5.168616083 | 0.001333845 | tumor necrosis factor (ligand) superfamily, member 4 [Source:MGI Symbol;Acc:MGI:104511] |
| Tbx21 | ENSMUSG00000001444 | 4.780993929 | 5.24E-26 | T-box 21 [Source:MGI Symbol;Acc:MGI:1888984] |
| Hcrtr2 | ENSMUSG00000032360 | 4.756056466 | 0.000281422 | hypocretin (orexin) receptor 2 [Source:MGI Symbol;Acc:MGI:2680765] |
| Echdc3 | ENSMUSG00000039063 | 4.753504397 | 3.27E-07 | enoyl Coenzyme A hydratase domain containing 3 [Source:MGI Symbol;Acc:MGI:1915106] |
| Stum | ENSMUSG00000053963 | 4.698761033 | 4.98E-23 | mechanosensory transduction mediator [Source:MGI Symbol;Acc:MGI:2138735] |
| Mreg | ENSMUSG00000039395 | 4.516735821 | 1.22E-75 | melanoregulin [Source:MGI Symbol;Acc:MGI:2151839] |
| Egr2 | ENSMUSG00000037868 | 4.491544364 | 7.29E-15 | early growth response 2 [Source:MGI Symbol;Acc:MGI:95296] |
| Sdc1 | ENSMUSG00000020592 | 4.487959617 | 1.63E-45 | syndecan 1 [Source:MGI Symbol;Acc:MGI:1349162] |
| Nr4a1 | ENSMUSG00000023034 | 4.468100742 | 3.37E-129 | nuclear receptor subfamily 4, group A, member 1 [Source:MGI Symbol;Acc:MGI:1352454] |
| Tacc2 | ENSMUSG00000030852 | 4.400367386 | 3.92E-11 | transforming, acidic coiled-coil containing protein 2 [Source:MGI Symbol;Acc:MGI:1928899] |
| A430072P03Rik | ENSMUSG00000090030 | 4.379322042 | 0.000219565 | RIKEN cDNA A430072P03 gene [Source:MGI Symbol;Acc:MGI:3041214] |
| Endou | ENSMUSG00000022468 | 4.368405603 | 1.62E-38 | endonuclease, polyU-specific [Source:MGI Symbol;Acc:MGI:97746] |
| Egr3 | ENSMUSG00000033730 | 4.348531768 | 2.26E-160 | early growth response 3 [Source:MGI Symbol;Acc:MGI:1306780] |
| Adgrg1 | ENSMUSG00000031785 | 4.33510508 | 5.76E-14 | adhesion G protein-coupled receptor G1 [Source:MGI Symbol;Acc:MGI:1340051] |
| Loxhd1 | ENSMUSG00000032818 | 4.206522983 | 2.91E-19 | lipoxygenase homology domains 1 [Source:MGI Symbol;Acc:MGI:1914609] |
| Fibcd1 | ENSMUSG00000026841 | 4.123016008 | 0.000763404 | fibrinogen C domain containing 1 [Source:MGI Symbol;Acc:MGI:2138953] |
| Cenpv | ENSMUSG00000018509 | 4.031577215 | 5.99E-07 | centromere protein V [Source:MGI Symbol;Acc:MGI:1920389] |
| Lck | ENSMUSG00000000409 | 3.842913208 | 1.27E-109 | lymphocyte protein tyrosine kinase [Source:MGI Symbol;Acc:MGI:96756] |
| Axl | ENSMUSG00000002602 | 3.807857855 | 1.01E-22 | AXL receptor tyrosine kinase [Source:MGI Symbol;Acc:MGI:1347244] |
| Gad1 | ENSMUSG00000070880 | 3.762160808 | 2.66E-64 | glutamate decarboxylase 1 [Source:MGI Symbol;Acc:MGI:95632] |
| Rgs1 | ENSMUSG00000026358 | 3.70964947 | 6.29E-09 | regulator of G-protein signaling 1 [Source:MGI Symbol;Acc:MGI:1354694] |
| Pgpep1l | ENSMUSG00000030553 | 3.547456856 | 7.16E-05 | pyroglutamyl-peptidase I-like [Source:MGI Symbol;Acc:MGI:1925694] |
| Pcp4 | ENSMUSG00000090223 | 3.529002598 | 3.28E-11 | Purkinje cell protein 4 [Source:MGI Symbol;Acc:MGI:97509] |
| Fam20c | ENSMUSG00000025854 | 3.525860845 | 4.35E-24 | family with sequence similarity 20, member C [Source:MGI Symbol;Acc:MGI:2136853] |
| Ahr | ENSMUSG00000019256 | 3.501617204 | 1.92E-47 | aryl-hydrocarbon receptor [Source:MGI Symbol;Acc:MGI:105043] |
| Ets2 | ENSMUSG00000022895 | 3.44468156 | 3.85E-75 | E26 avian leukemia oncogene 2, 3' domain [Source:MGI Symbol;Acc:MGI:95456] |
| Akap1 | ENSMUSG00000018428 | 3.363606655 | 4.52E-05 | A kinase (PRKA) anchor protein 1 [Source:MGI Symbol;Acc:MGI:104729] |
| Lzts2 | ENSMUSG00000035342 | 3.355543863 | 1.64E-10 | leucine zipper, putative tumor suppressor 2 [Source:MGI Symbol;Acc:MGI:2385095] |
| Spry2 | ENSMUSG00000022114 | 3.298902201 | 0.000414542 | sprouty homolog 2 (Drosophila) [Source:MGI Symbol;Acc:MGI:1345138] |
| Kifc3 | ENSMUSG00000031788 | 3.281156314 | 7.56E-37 | kinesin family member C3 [Source:MGI Symbol;Acc:MGI:109202] |
| Izumo1r | ENSMUSG00000031933 | 3.274694456 | 3.58E-06 | IZUMO1 receptor, JUNO [Source:MGI Symbol;Acc:MGI:1929185] |
| Crisp3 | ENSMUSG00000025433 | 3.268202884 | 2.57E-64 | cysteine-rich secretory protein 3 [Source:MGI Symbol;Acc:MGI:102552] |
| Ephx1 | ENSMUSG00000038776 | 3.240701158 | 1.63E-172 | epoxide hydrolase 1, microsomal [Source:MGI Symbol;Acc:MGI:95405] |
| Rgs2 | ENSMUSG00000026360 | 3.237887886 | 6.21E-136 | regulator of G-protein signaling 2 [Source:MGI Symbol;Acc:MGI:1098271] |
| Rgl1 | ENSMUSG00000026482 | 3.215108424 | 3.06E-179 | ral guanine nucleotide dissociation stimulator,-like 1 [Source:MGI Symbol;Acc:MGI:107484] |
| Dll1 | ENSMUSG00000014773 | 3.129728481 | 1.81E-13 | delta-like 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:104659] |
| Nr4a3 | ENSMUSG00000028341 | 3.11670417 | 1.22E-21 | nuclear receptor subfamily 4, group A, member 3 [Source:MGI Symbol;Acc:MGI:1352457] |
| Fosb | ENSMUSG00000003545 | 3.081039869 | 4.18E-27 | FBJ osteosarcoma oncogene B [Source:MGI Symbol;Acc:MGI:95575] |
| Nab2 | ENSMUSG00000025402 | 3.059920453 | 1.16E-112 | Ngfi-A binding protein 2 [Source:MGI Symbol;Acc:MGI:107563] |
| Gm37205 | ENSMUSG00000103656 | 3.004404274 | 8.24E-05 | predicted gene, 37205 [Source:MGI Symbol;Acc:MGI:5610433] |
| Ms4a4a | ENSMUSG00000101389 | 2.985017396 | 1.25E-07 | membrane-spanning 4-domains, subfamily A, member 4A [Source:MGI |
| Igf1r | ENSMUSG00000005533 | 2.977856125 | 3.59E-06 | insulin-like growth factor I receptor [Source:MGI Symbol;Acc:MGI:96433] |
| Litaf | ENSMUSG00000022500 | 2.916065059 | 2.49E-50 | LPS-induced TN factor [Source:MGI Symbol;Acc:MGI:1929512] |
| Cdh24 | ENSMUSG00000059674 | 2.89084194 | 5.62E-17 | cadherin-like 24 [Source:MGI Symbol;Acc:MGI:1928330] |
| Zfpm1 | ENSMUSG00000049577 | 2.888558178 | 2.27E-45 | zinc finger protein, multitype 1 [Source:MGI Symbol;Acc:MGI:1095400] |
| Car2 | ENSMUSG00000027562 | 2.871642825 | 3.82E-06 | carbonic anhydrase 2 [Source:MGI Symbol;Acc:MGI:88269] |
| Ighg1 | ENSMUSG00000076614 | 2.849137111 | 8.67E-11 | immunoglobulin heavy constant gamma 1 (G1m marker) [Source:MGI Symbol;Acc:MGI:96446] |
| Prdm1 | ENSMUSG00000038151 | 2.822598473 | 1.13E-11 | PR domain containing 1, with ZNF domain [Source:MGI Symbol;Acc:MGI:99655] |
| Gm42835 | ENSMUSG00000104554 | 2.807553819 | 7.19E-29 | predicted gene 4610 [Source:MGI Symbol;Acc:MGI:3782793] |
| Bhlhe40 | ENSMUSG00000030103 | 2.794143962 | 3.19E-48 | basic helix-loop-helix family, member e40 [Source:MGI Symbol;Acc:MGI:1097714] |
| Sox4 | ENSMUSG00000076431 | 2.794004321 | 1.62E-51 | SRY (sex determining region Y)-box 4 [Source:MGI Symbol;Acc:MGI:98366] |
| Crip3 | ENSMUSG00000023968 | 2.772348334 | 6.31E-21 | cysteine-rich protein 3 [Source:MGI Symbol;Acc:MGI:2152434] |
| Cers6 | ENSMUSG00000027035 | 2.766427208 | 4.15E-55 | ceramide synthase 6 [Source:MGI Symbol;Acc:MGI:2442564] |
| Klf10 | ENSMUSG00000037465 | 2.754059048 | 8.50E-36 | Kruppel-like factor 10 [Source:MGI Symbol;Acc:MGI:1101353] |
| Cacna1h | ENSMUSG00000024112 | 2.70111899 | 5.15E-53 | calcium channel, voltage-dependent, T type, alpha 1H subunit [Source:MGI |
| Plk2 | ENSMUSG00000021701 | 2.649910437 | 1.91E-33 | polo like kinase 2 [Source:MGI Symbol;Acc:MGI:1099790] |
| Egr1 | ENSMUSG00000038418 | 2.646894856 | 8.30E-47 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Gm38377 | ENSMUSG00000102662 | 2.646262594 | 3.59E-08 | predicted gene, 38377 [Source:MGI Symbol;Acc:MGI:5611605] |
| Kcnh4 | ENSMUSG00000035355 | 2.627237663 | 3.72E-15 | potassium voltage-gated channel, subfamily H (eag-related), member 4 [Source:MGI |
| Gm37747 | ENSMUSG00000104262 | 2.585513275 | 6.21E-05 | predicted gene, 37747 [Source:MGI Symbol;Acc:MGI:5610975] |
| Fam167a | ENSMUSG00000035095 | 2.576061866 | 7.02E-80 | family with sequence similarity 167, member A [Source:MGI Symbol;Acc:MGI:3606565] |
| Rgs3 | ENSMUSG00000059810 | 2.549894479 | 2.65E-44 | regulator of G-protein signaling 3 [Source:MGI Symbol;Acc:MGI:1354734] |
| Gm19585 | ENSMUSG00000100150 | 2.538117819 | 1.21E-11 | predicted gene, 19585 [Source:MGI Symbol;Acc:MGI:5011770] |
| Dhrs3 | ENSMUSG00000066026 | 2.526478546 | 0.005940359 | dehydrogenase/reductase (SDR family) member 3 [Source:MGI Symbol;Acc:MGI:1315215] |
| Hbb-bt | ENSMUSG00000073940 | 2.487393513 | 2.14E-09 | hemoglobin, beta adult t chain [Source:MGI Symbol;Acc:MGI:5474850] |
| S1pr3 | ENSMUSG00000067586 | 2.472377725 | 1.57E-19 | sphingosine-1-phosphate receptor 3 [Source:MGI Symbol;Acc:MGI:1339365] |
| Hpgds | ENSMUSG00000029919 | 2.465301019 | 1.25E-40 | hematopoietic prostaglandin D synthase [Source:MGI Symbol;Acc:MGI:1859384] |
| Rapgef3 | ENSMUSG00000022469 | 2.386448825 | 2.40E-19 | Rap guanine nucleotide exchange factor (GEF) 3 [Source:MGI Symbol;Acc:MGI:2441741] |

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|---|---|---|---|---|
| Bcl2a1d | ENSMUSG00000099974 | 2.379547739 | 1.75E-09 | B cell leukemia/lymphoma 2 related protein A1d [Source:MGI Symbol;Acc:MGI:1278325] |
| Hmgn3 | ENSMUSG00000066456 | 2.365912932 | 1.17E-13 | high mobility group nucleosomal binding domain 3 [Source:MGI Symbol;Acc:MGI:2138069] |
| Zfp948 | ENSMUSG00000067931 | 2.360503762 | 1.82E-25 | zinc finger protein 948 [Source:MGI Symbol;Acc:MGI:3040683] |
| Bcl6b | ENSMUSG00000000317 | 2.348163472 | 2.13E-08 | B cell CLL/lymphoma 6, member B [Source:MGI Symbol;Acc:MGI:1278332] |
| Ispd | ENSMUSG00000043153 | 2.33628706 | 2.39E-07 | isoprenoid synthase domain containing [Source:MGI Symbol;Acc:MGI:1923097] |
| Zfp52 | ENSMUSG00000051341 | 2.330207925 | 7.81E-67 | zinc finger protein 52 [Source:MGI Symbol;Acc:MGI:99199] |
| Adgre1 | ENSMUSG00000004730 | 2.321734049 | 4.95E-10 | adhesion G protein-coupled receptor E1 [Source:MGI Symbol;Acc:MGI:106912] |
| Shank1 | ENSMUSG00000038738 | 2.307083243 | 1.82E-53 | SH3 and multiple ankyrin repeat domains 1 [Source:MGI Symbol;Acc:MGI:3613677] |
| St8sia6 | ENSMUSG00000003418 | 2.280566461 | 1.91E-36 | ST8 alpha-N-acetyl-neuraminide alpha-2,8-sialyltransferase 6 [Source:MGI |
| Dusp4 | ENSMUSG00000031530 | 2.245478815 | 8.38E-48 | dual specificity phosphatase 4 [Source:MGI Symbol;Acc:MGI:2442191] |
| Pacsin1 | ENSMUSG00000040276 | 2.235351009 | 3.72E-37 | protein kinase C and casein kinase substrate in neurons 1 [Source:MGI |
| Cecr6 | ENSMUSG00000094626 | 2.230014092 | 0.006704034 | transmembrane protein 121B [Source:MGI Symbol;Acc:MGI:2136977] |
| Alcam | ENSMUSG00000022636 | 2.217171314 | 3.70E-91 | activated leukocyte cell adhesion molecule [Source:MGI Symbol;Acc:MGI:1313266] |
| Rgs7bp | ENSMUSG00000021719 | 2.19509771 | 2.55E-05 | regulator of G-protein signalling 7 binding protein [Source:MGI Symbol;Acc:MGI:106334] |
| Cpd | ENSMUSG00000020841 | 2.192069998 | 3.11E-09 | carboxypeptidase D [Source:MGI Symbol;Acc:MGI:107265] |
| Igkv1-135 | ENSMUSG00000096336 | 2.169660609 | 0.000735267 | immunoglobulin kappa variable 1-135 [Source:MGI Symbol;Acc:MGI:3819952] |
| Ccnd2 | ENSMUSG00000000184 | 2.150452494 | 9.71E-111 | cyclin D2 [Source:MGI Symbol;Acc:MGI:88314] |
| Fcmr | ENSMUSG00000042474 | 2.089363799 | 1.19E-119 | Fc fragment of IgM receptor [Source:MGI Symbol;Acc:MGI:1916419] |
| Bcl2a1b | ENSMUSG00000089929 | 2.08881327 | 6.12E-17 | B cell leukemia/lymphoma 2 related protein A1b [Source:MGI Symbol;Acc:MGI:1278326] |
| Npr2 | ENSMUSG00000028469 | 2.078557681 | 1.29E-11 | natriuretic peptide receptor 2 [Source:MGI Symbol;Acc:MGI:97372] |
| Bcat1 | ENSMUSG00000030268 | 2.072566195 | 0.003172549 | branched chain aminotransferase 1, cytosolic [Source:MGI Symbol;Acc:MGI:104861] |
| Cldn10 | ENSMUSG00000022132 | 2.059241125 | 2.85E-05 | claudin 10 [Source:MGI Symbol;Acc:MGI:1913101] |
| Slc25a13 | ENSMUSG00000015112 | 2.053879608 | 0.000103783 | solute carrier family 25 (mitochondrial carrier, adenine nucleotide translocator), member 13 |

adjusted P value <=0.01

Fold change >=4

**Table 6-12. Genes significantly up-regulated in FO B cells compare to anergic B cells.**

| Symbol | Ensembl gene id | logFC (FO/Anergic) | adj.P.val | Annotation |
|---|---|---|---|---|
| Platr7 | ENSMUSG00000097076 | 3.652705392 | 3.31E-05 | pluripotency associated transcript 7 [Source:MGI Symbol;Acc:MGI:3045387] |
| Lair1 | ENSMUSG00000055541 | 3.481086098 | 5.81E-18 | leukocyte-associated Ig-like receptor 1 [Source:MGI Symbol;Acc:MGI:105492] |
| Gm42780 | ENSMUSG00000105890 | 3.442119921 | 0.002639768 | predicted gene 42780 [Source:MGI Symbol;Acc:MGI:5662917] |
| Srms | ENSMUSG00000027579 | 3.246853466 | 1.75E-20 | src-related kinase lacking C-terminal regulatory tyrosine and N-terminal myristylation sites [Source:MGI Symbol;Acc:MGI:101865] |
| Trem1 | ENSMUSG00000042265 | 3.213790217 | 1.03E-10 | triggering receptor expressed on myeloid cells 1 [Source:MGI Symbol;Acc:MGI:1930005] |
| F630028O10Rik | ENSMUSG00000078122 | 3.208269913 | 1.78E-40 | RIKEN cDNA F630028O10 gene [Source:MGI Symbol;Acc:MGI:3641813] |
| S100a8 | ENSMUSG00000056054 | 3.189487711 | 0.005904645 | S100 calcium binding protein A8 (calgranulin A) [Source:MGI Symbol;Acc:MGI:88244] |
| Tbc1d9 | ENSMUSG00000031709 | 3.160178754 | 4.85E-15 | TBC1 domain family, member 9 [Source:MGI Symbol;Acc:MGI:1918560] |
| Lrrc25 | ENSMUSG00000049988 | 3.158245854 | 1.23E-25 | leucine rich repeat containing 25 [Source:MGI Symbol;Acc:MGI:2445284] |
| Clec4a3 | ENSMUSG00000043832 | 3.15605298 | 0.032986795 | C-type lectin domain family 4, member a3 [Source:MGI Symbol;Acc:MGI:1920399] |
| S100a9 | ENSMUSG00000056071 | 3.153262509 | 0.000185305 | S100 calcium binding protein A9 (calgranulin B) [Source:MGI Symbol;Acc:MGI:1338947] |
| Gm37004 | ENSMUSG00000102286 | 3.149295223 | 1.57E-06 | predicted gene, 37004 [Source:MGI Symbol;Acc:MGI:5610232] |
| Trbc1 | ENSMUSG00000076490 | 3.13816412 | 0.022523243 | T cell receptor beta, constant region 1 [Source:MGI Symbol;Acc:MGI:4439726] |
| Osgin1 | ENSMUSG00000074063 | 3.12987004 | 0.045512802 | oxidative stress induced growth inhibitor 1 [Source:MGI Symbol;Acc:MGI:1919089] |
| Lifr | ENSMUSG00000054263 | 3.060324261 | 6.07E-133 | leukemia inhibitory factor receptor [Source:MGI Symbol;Acc:MGI:96788] |
| Cyp27a1 | ENSMUSG00000026170 | 2.941260511 | 8.50E-88 | cytochrome P450, family 27, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:88594] |
| Gpr34 | ENSMUSG00000040229 | 2.799600389 | 1.96E-21 | G protein-coupled receptor 34 [Source:MGI Symbol;Acc:MGI:1346334] |
| Pltp | ENSMUSG00000017754 | 2.784375357 | 3.77E-72 | phospholipid transfer protein [Source:MGI Symbol;Acc:MGI:103151] |
| Rap1gap2 | ENSMUSG00000038807 | 2.784230089 | 2.46E-66 | RAP1 GTPase activating protein 2 [Source:MGI Symbol;Acc:MGI:3028623] |
| 1700028I16Rik | ENSMUSG00000056821 | 2.767849434 | 0.000537239 | RIKEN cDNA 1700028I16 gene [Source:MGI Symbol;Acc:MGI:1917253] |
| Mical3 | ENSMUSG00000051586 | 2.631276404 | 1.34E-32 | microtubule associated monooxygenase, calponin and LIM domain containing 3 [Source:MGI Symbol;Acc:MGI:2442733] |
| Sh2d6 | ENSMUSG00000052631 | 2.619632884 | 0.000722083 | SH2 domain containing 6 [Source:MGI Symbol;Acc:MGI:1918380] |
| S100a6 | ENSMUSG00000001025 | 2.608863174 | 5.52E-11 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Lrrc23 | ENSMUSG00000030125 | 2.486542139 | 0.000633623 | leucine rich repeat containing 23 [Source:MGI Symbol;Acc:MGI:1315192] |
| Alox5ap | ENSMUSG00000060063 | 2.468777133 | 2.20E-06 | arachidonate 5-lipoxygenase activating protein [Source:MGI Symbol;Acc:MGI:107505] |
| Tmem176b | ENSMUSG00000029810 | 2.428410516 | 3.14E-11 | transmembrane protein 176B [Source:MGI Symbol;Acc:MGI:1916348] |
| 2310047D07Rik | ENSMUSG00000100783 | 2.419767116 | 0.045498344 | RIKEN cDNA 2310047D07 gene [Source:MGI Symbol;Acc:MGI:1916907] |
| Cdc42bpb | ENSMUSG00000021279 | 2.382452668 | 1.59E-15 | CDC42 binding protein kinase beta [Source:MGI Symbol;Acc:MGI:2136459] |
| Grk3 | ENSMUSG00000042249 | 2.356789838 | 6.64E-17 | G protein-coupled receptor kinase 3 [Source:MGI Symbol;Acc:MGI:87941] |
| Pik3r6 | ENSMUSG00000046207 | 2.345342505 | 0.005226655 | phosphoinositide-3-kinase regulatory subunit 5 [Source:MGI Symbol;Acc:MGI:2144613] |
| Socs3 | ENSMUSG00000053113 | 2.322860068 | 2.47E-23 | suppressor of cytokine signaling 3 [Source:MGI Symbol;Acc:MGI:1201791] |
| Dock4 | ENSMUSG00000035954 | 2.280380188 | 0.012248063 | dedicator of cytokinesis 4 [Source:MGI Symbol;Acc:MGI:1918006] |
| Dmpk | ENSMUSG00000030409 | 2.183938057 | 1.49E-06 | dystrophia myotonica-protein kinase [Source:MGI Symbol;Acc:MGI:94906] |
| 2010310C07Rik | ENSMUSG00000101268 | 2.172851278 | 0.042640896 | RIKEN cDNA 2010310C07 gene [Source:MGI Symbol;Acc:MGI:1919381] |
| Trabd2b | ENSMUSG00000070867 | 2.157344072 | 0.00895228 | TraB domain containing 2B [Source:MGI Symbol;Acc:MGI:3650152] |
| Tgfbi | ENSMUSG00000035493 | 2.152171214 | 0.000176312 | transforming growth factor, beta induced [Source:MGI Symbol;Acc:MGI:99959] |
| Gm42778 | ENSMUSG00000105112 | 2.146740253 | 4.93E-06 | predicted gene 42778 [Source:MGI Symbol;Acc:MGI:5662915] |
| Ankrd33b | ENSMUSG00000022237 | 2.137290186 | 0.007707763 | ankyrin repeat domain 33B [Source:MGI Symbol;Acc:MGI:1917904] |
| Ass1 | ENSMUSG00000076441 | 2.097858036 | 3.44E-30 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Ahnak | ENSMUSG00000069833 | 2.037197348 | 1.35E-85 | AHNAK nucleoprotein (desmoyokin) [Source:MGI Symbol;Acc:MGI:1316648] |
| Stac2 | ENSMUSG00000017400 | 2.032790758 | 6.60E-17 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Tha1 | ENSMUSG00000017713 | 2.024251904 | 2.75E-14 | threonine aldolase 1 [Source:MGI Symbol;Acc:MGI:1919026] |
| Dyrk3 | ENSMUSG00000016526 | 2.017513729 | 8.83E-08 | dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3 [Source:MGI Symbol;Acc:MGI:1330300] |

adjusted P value <=0.01

Fold change >=4

## Table 6-13. Genes significantly up-regulated in MZ B cells compare to FO B cells.

| Symbol | Ensembl gene id | logFC (MZ/FO) | adj.P.val | Annotation |
|---|---|---|---|---|
| Slit3 | ENSMUSG000000564 | 7.813393 | 1.74E-16 | slit homolog 3 (Drosophila) [Source:MGI Symbol;Acc:MGI:1315202] |
| Gm42684 | ENSMUSG000001053 | 7.734084 | 1.38E-26 | predicted gene 42684 [Source:MGI Symbol;Acc:MGI:5662821] |
| Gm37643 | ENSMUSG000001031 | 7.66394 | 8.89E-15 | predicted gene, 37643 [Source:MGI Symbol;Acc:MGI:5610871] |
| Gm15523 | ENSMUSG000000901 | 7.487261 | 1.96E-23 | predicted gene 15523 [Source:MGI Symbol;Acc:MGI:3782970] |
| AF067061 | ENSMUSG000000950 | 7.444367 | 6.69E-13 | cDNA sequence AF067061 [Source:MGI Symbol;Acc:MGI:2681166] |
| Fam149a | ENSMUSG000000700 | 6.712991 | 1.14E-29 | family with sequence similarity 149, member A [Source:MGI Symbol;Acc:MGI:2387177] |
| Asb2 | ENSMUSG000000212 | 6.712172 | 0 | ankyrin repeat and SOCS box-containing 2 [Source:MGI Symbol;Acc:MGI:1929743] |
| S1pr3 | ENSMUSG000000675 | 6.680058 | 1.42E-121 | sphingosine-1-phosphate receptor 3 [Source:MGI Symbol;Acc:MGI:1339365] |
| Abcb1a | ENSMUSG000000405 | 6.538157 | 2.10E-174 | ATP-binding cassette, sub-family B (MDR/TAP), member 1A [Source:MGI Symbol;Acc:MGI:97570] |
| Alpl | ENSMUSG000000287 | 6.506623 | 1.48E-06 | alkaline phosphatase, liver/bone/kidney [Source:MGI Symbol;Acc:MGI:87983] |
| 6030419C1 | ENSMUSG000000666 | 6.461714 | 2.29E-06 | RIKEN cDNA 6030419C18 gene [Source:MGI Symbol;Acc:MGI:2442108] |
| Ackr3 | ENSMUSG000000443 | 6.217221 | 5.31E-99 | atypical chemokine receptor 3 [Source:MGI Symbol;Acc:MGI:109562] |
| Drd5 | ENSMUSG000000393 | 6.155127 | 3.16E-05 | dopamine receptor D5 [Source:MGI Symbol;Acc:MGI:94927] |
| Ms4a14 | ENSMUSG000000993 | 6.119655 | 2.06E-23 | membrane-spanning 4-domains, subfamily A, member 14 [Source:MGI Symbol;Acc:MGI:2686122] |
| Pla2g7 | ENSMUSG000000239 | 5.974266 | 6.66E-102 | phospholipase A2, group VII (platelet-activating factor acetylhydrolase, plasma) [Source:MGI Symbol;Acc:MGI:1351327] |
| 5033430I15 | ENSMUSG000000381 | 5.968458 | 8.45E-14 | RIKEN cDNA 5033430I15 gene [Source:MGI Symbol;Acc:MGI:1923250] |
| I830077J02 | ENSMUSG000000743 | 5.960723 | 0 | RIKEN cDNA I830077J02 gene [Source:MGI Symbol;Acc:MGI:3588284] |
| Gm26560 | ENSMUSG000000970 | 5.939112 | 0.000339 | predicted gene, 26560 [Source:MGI Symbol;Acc:MGI:5477054] |
| Gm29083 | ENSMUSG000001008 | 5.880654 | 2.54E-07 | predicted gene 29083 [Source:MGI Symbol;Acc:MGI:5579789] |
| Fat4 | ENSMUSG000000467 | 5.693458 | 0.001312 | FAT atypical cadherin 4 [Source:MGI Symbol;Acc:MGI:3045256] |
| Mir7662 | ENSMUSG000000991 | 5.647382 | 0.00141 | microRNA 7662 [Source:MGI Symbol;Acc:MGI:5531258] |
| Lipc | ENSMUSG000000322 | 5.575088 | 5.66E-15 | lipase, hepatic [Source:MGI Symbol;Acc:MGI:96216] |
| Tbx19 | ENSMUSG000000265 | 5.572559 | 1.97E-15 | T-box 19 [Source:MGI Symbol;Acc:MGI:1891158] |
| Slc6a13 | ENSMUSG000000301 | 5.533709 | 3.91E-06 | solute carrier family 6 (neurotransmitter transporter, GABA), member 13 [Source:MGI Symbol;Acc:MGI:95629] |
| Gm28183 | ENSMUSG000001013 | 5.47714 | 0.003641 | predicted gene 28183 [Source:MGI Symbol;Acc:MGI:5578889] |
| Nlrp1a | ENSMUSG000000698 | 5.474661 | 0.003497 | NLR family, pyrin domain containing 1A [Source:MGI Symbol;Acc:MGI:2684861] |
| Myo18b | ENSMUSG000000727 | 5.417399 | 1.61E-28 | myosin XVIIIb [Source:MGI Symbol;Acc:MGI:1921626] |
| Gm37422 | ENSMUSG000001044 | 5.398757 | 4.78E-28 | predicted gene, 37422 [Source:MGI Symbol;Acc:MGI:5610650] |
| Aldh5a1 | ENSMUSG000000359 | 5.387584 | 1.13E-08 | aldhehyde dehydrogenase family 5, subfamily A1 [Source:MGI Symbol;Acc:MGI:2441982] |
| Galm | ENSMUSG000000354 | 5.314062 | 7.01E-05 | galactose mutarotase [Source:MGI Symbol;Acc:MGI:2442420] |
| Gm15503 | ENSMUSG000000849 | 5.291714 | 4.17E-05 | predicted gene 15503 [Source:MGI Symbol;Acc:MGI:3782950] |
| Rgs10 | ENSMUSG000000308 | 5.274654 | 5.33E-67 | regulator of G-protein signalling 10 [Source:MGI Symbol;Acc:MGI:1915115] |
| Hbegf | ENSMUSG000000244 | 5.249547 | 3.15E-19 | heparin-binding EGF-like growth factor [Source:MGI Symbol;Acc:MGI:96070] |
| Rundc3b | ENSMUSG000000405 | 5.186363 | 4.10E-83 | RUN domain containing 3B [Source:MGI Symbol;Acc:MGI:2685286] |
| Oosp1 | ENSMUSG000000418 | 5.140926 | 1.25E-07 | oocyte secreted protein 1 [Source:MGI Symbol;Acc:MGI:2149290] |
| 2700046G0 | ENSMUSG000000977 | 5.134952 | 0.000509 | RIKEN cDNA 2700046G09 gene [Source:MGI Symbol;Acc:MGI:1914438] |
| Nbl1 | ENSMUSG000000411 | 5.079263 | 3.30E-07 | neuroblastoma, suppression of tumorigenicity 1 [Source:MGI Symbol;Acc:MGI:104591] |
| Slc39a4 | ENSMUSG000000633 | 5.027601 | 2.65E-16 | solute carrier family 39 (zinc transporter), member 4 [Source:MGI Symbol;Acc:MGI:1919277] |
| Echdc3 | ENSMUSG000000390 | 5.020119 | 6.74E-10 | enoyl Coenzyme A hydratase domain containing 3 [Source:MGI Symbol;Acc:MGI:1915106] |
| Fcrl5 | ENSMUSG000000480 | 5.009825 | 8.90E-253 | Fc receptor-like 5 [Source:MGI Symbol;Acc:MGI:3053558] |
| Tmem121 | ENSMUSG000000490 | 4.917779 | 7.29E-12 | transmembrane protein 121 [Source:MGI Symbol;Acc:MGI:1916445] |
| Gm15202 | ENSMUSG000000875 | 4.849793 | 1.38E-11 | predicted gene 15202 [Source:MGI Symbol;Acc:MGI:3705278] |
| 2010300C0 | ENSMUSG000000260 | 4.591507 | 0.007202 | RIKEN cDNA 2010300C02 gene [Source:MGI Symbol;Acc:MGI:1919347] |
| Chil6 | ENSMUSG000000279 | 4.586419 | 0.005314 | chitinase-like 6 [Source:MGI Symbol;Acc:MGI:2682303] |
| Nebl | ENSMUSG000000537 | 4.5391 | 1.23E-257 | nebulette [Source:MGI Symbol;Acc:MGI:1921353] |
| Sh2d1b1 | ENSMUSG000001024 | 4.521001 | 2.84E-23 | SH2 domain containing 1B1 [Source:MGI Symbol;Acc:MGI:1349420] |
| Lilrb4a | ENSMUSG000000625 | 4.501306 | 7.14E-146 | leukocyte immunoglobulin-like receptor, subfamily B, member 4A [Source:MGI Symbol;Acc:MGI:102701] |
| Gml2 | ENSMUSG000000686 | 4.481074 | 0.000277 | glycosylphosphatidylinositol anchored molecule like 2 [Source:MGI Symbol;Acc:MGI:1341831] |
| Myof | ENSMUSG000000486 | 4.47445 | 0 | myoferlin [Source:MGI Symbol;Acc:MGI:1919192] |
| Klk4 | ENSMUSG000000069 | 4.439948 | 0.000226 | kallikrein related-peptidase 4 (prostase, enamel matrix, prostate) [Source:MGI Symbol;Acc:MGI:1861379] |
| Tsga13 | ENSMUSG000000390 | 4.407667 | 6.87E-72 | testis specific gene A13 [Source:MGI Symbol;Acc:MGI:1891413] |
| Srgap3 | ENSMUSG000000302 | 4.373643 | 5.50E-187 | SLIT-ROBO Rho GTPase activating protein 3 [Source:MGI Symbol;Acc:MGI:2152938] |
| Tlr3 | ENSMUSG000000316 | 4.364496 | 8.39E-164 | toll-like receptor 3 [Source:MGI Symbol;Acc:MGI:2156367] |
| Col15a1 | ENSMUSG000000283 | 4.35761 | 1.16E-05 | collagen, type XV, alpha 1 [Source:MGI Symbol;Acc:MGI:88449] |
| Ffar2 | ENSMUSG000000513 | 4.35587 | 9.22E-247 | free fatty acid receptor 2 [Source:MGI Symbol;Acc:MGI:2441731] |
| Rgs3 | ENSMUSG000000598 | 4.303159 | 1.88E-182 | regulator of G-protein signaling 3 [Source:MGI Symbol;Acc:MGI:1354734] |
| Tspan15 | ENSMUSG000000370 | 4.287508 | 6.72E-171 | tetraspanin 15 [Source:MGI Symbol;Acc:MGI:1917673] |
| Plxnd1 | ENSMUSG000000301 | 4.255135 | 8.81E-215 | plexin D1 [Source:MGI Symbol;Acc:MGI:2154244] |
| Zc3h12c | ENSMUSG000000351 | 4.223911 | 4.85E-255 | zinc finger CCCH type containing 12C [Source:MGI Symbol;Acc:MGI:3026959] |
| AW011738 | ENSMUSG000000783 | 4.215522 | 2.04E-153 | expressed sequence AW011738 [Source:MGI Symbol;Acc:MGI:2140540] |
| Ptpn14 | ENSMUSG000000266 | 4.214528 | 0 | protein tyrosine phosphatase, non-receptor type 14 [Source:MGI Symbol;Acc:MGI:102467] |
| Ackr2 | ENSMUSG000000445 | 4.177708 | 1.35E-265 | atypical chemokine receptor 2 [Source:MGI Symbol;Acc:MGI:1891697] |
| Gm42835 | ENSMUSG000001045 | 4.176636 | 5.66E-93 | predicted gene 4610 [Source:MGI Symbol;Acc:MGI:3782793] |
| Gpr55 | ENSMUSG000000496 | 4.12451 | 1.44E-44 | G protein-coupled receptor 55 [Source:MGI Symbol;Acc:MGI:2685064] |

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|---|---|---|---|---|
| Rap1gap | ENSMUSG000000413 | 4.095228 | 1.31E-73 | Rap1 GTPase-activating protein [Source:MGI Symbol;Acc:MGI:109338] |
| Rec8 | ENSMUSG000000023 | 4.079786 | 2.16E-43 | REC8 meiotic recombination protein [Source:MGI Symbol;Acc:MGI:1929645] |
| 1110028F11 | ENSMUSG000000859 | 4.075609 | 2.93E-07 | RIKEN cDNA 1110028F11 gene [Source:MGI Symbol;Acc:MGI:1915940] |
| Atxn1 | ENSMUSG000000468 | 4.060241 | 0 | ataxin 1 [Source:MGI Symbol;Acc:MGI:104783] |
| Gm26535 | ENSMUSG000000977 | 4.034817 | 0.000151 | predicted gene, 26535 [Source:MGI Symbol;Acc:MGI:5477029] |
| Cacna1s | ENSMUSG000000264 | 4.03449 | 1.74E-11 | calcium channel, voltage-dependent, L type, alpha 1S subunit [Source:MGI Symbol;Acc:MGI:88294] |
| Gm43253 | ENSMUSG000001047 | 3.95456 | 1.26E-05 | predicted gene, 35172 [Source:MGI Symbol;Acc:MGI:5594331] |
| Guca2b | ENSMUSG000000329 | 3.94707 | 5.96E-07 | guanylate cyclase activator 2b (retina) [Source:MGI Symbol;Acc:MGI:1270851] |
| Dyrk4 | ENSMUSG000000303 | 3.927692 | 6.91E-14 | dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 4 [Source:MGI Symbol;Acc:MGI:1330292] |
| Adamts13 | ENSMUSG000000148 | 3.917564 | 1.66E-18 | a disintegrin-like and metallopeptidase (reprolysin type) with thrombospondin type 1 motif, 13 [Source:MGI Symbol;Acc:MGI:2685556] |
| Cd1d2 | ENSMUSG000000417 | 3.915956 | 1.00E-13 | CD1d2 antigen [Source:MGI Symbol;Acc:MGI:107675] |
| Gm15472 | ENSMUSG000000847 | 3.911117 | 1.39E-24 | predicted gene 15472 [Source:MGI Symbol;Acc:MGI:3707328] |
| Slc6a12 | ENSMUSG000000301 | 3.895489 | 0.006428 | solute carrier family 6 (neurotransmitter transporter, betaine/GABA), member 12 [Source:MGI Symbol;Acc:MGI:95628] |
| Ppl | ENSMUSG000000394 | 3.888104 | 4.37E-135 | periplakin [Source:MGI Symbol;Acc:MGI:1194898] |
| Kcnk13 | ENSMUSG000000454 | 3.832098 | 9.42E-41 | potassium channel, subfamily K, member 13 [Source:MGI Symbol;Acc:MGI:2384976] |
| Ptafr | ENSMUSG000000565 | 3.819263 | 2.42E-57 | platelet-activating factor receptor [Source:MGI Symbol;Acc:MGI:106066] |
| Ceacam2 | ENSMUSG000000543 | 3.770666 | 1.27E-108 | carcinoembryonic antigen-related cell adhesion molecule 2 [Source:MGI Symbol;Acc:MGI:1347246] |
| Kif5a | ENSMUSG000000746 | 3.766114 | 0.0013 | kinesin family member 5A [Source:MGI Symbol;Acc:MGI:109564] |
| Hgfac | ENSMUSG000000291 | 3.748388 | 6.06E-06 | hepatocyte growth factor activator [Source:MGI Symbol;Acc:MGI:1859281] |
| Robo1 | ENSMUSG000000228 | 3.744739 | 4.12E-14 | roundabout guidance receptor 1 [Source:MGI Symbol;Acc:MGI:1274781] |
| Gm37121 | ENSMUSG000001030 | 3.738897 | 7.87E-10 | predicted gene, 37121 [Source:MGI Symbol;Acc:MGI:5610349] |
| Trpm2 | ENSMUSG000000092 | 3.713706 | 1.50E-151 | transient receptor potential cation channel, subfamily M, member 2 [Source:MGI Symbol;Acc:MGI:1351901] |
| Nlrp1b | ENSMUSG000000703 | 3.712117 | 3.70E-31 | NLR family, pyrin domain containing 1B [Source:MGI Symbol;Acc:MGI:3582959] |
| Tbc1d9 | ENSMUSG000000317 | 3.654933 | 2.19E-28 | TBC1 domain family, member 9 [Source:MGI Symbol;Acc:MGI:1918560] |
| Gm6377 | ENSMUSG000000486 | 3.625439 | 3.30E-155 | predicted gene 6377 [Source:MGI Symbol;Acc:MGI:3647255] |
| Gm10645 | ENSMUSG000000742 | 3.612785 | 6.02E-13 | predicted gene 10645 [Source:MGI Symbol;Acc:MGI:3704313] |
| Jph1 | ENSMUSG000000426 | 3.607681 | 1.35E-32 | junctophilin 1 [Source:MGI Symbol;Acc:MGI:1891495] |
| Bfsp1 | ENSMUSG000000274 | 3.568499 | 0.00011 | beaded filament structural protein 1, in lens-CP94 [Source:MGI Symbol;Acc:MGI:101770] |
| Gpr156 | ENSMUSG000000469 | 3.545577 | 1.97E-60 | G protein-coupled receptor 156 [Source:MGI Symbol;Acc:MGI:2653880] |
| Gm12493 | ENSMUSG000000860 | 3.506091 | 6.28E-41 | predicted gene 12493 [Source:MGI Symbol;Acc:MGI:3651194] |
| Gm2065 | ENSMUSG000001028 | 3.488799 | 3.56E-68 | predicted gene 2065 [Source:MGI Symbol;Acc:MGI:3780232] |
| Gml | ENSMUSG000000683 | 3.455305 | 4.64E-13 | glycosylphosphatidylinositol anchored molecule like [Source:MGI Symbol;Acc:MGI:3644767] |
| Gm20421 | ENSMUSG000000924 | 3.452255 | 1.91E-05 | predicted gene 20421 [Source:MGI Symbol;Acc:MGI:5141886] |
| Marcks | ENSMUSG000000696 | 3.437487 | 2.91E-239 | myristoylated alanine rich protein kinase C substrate [Source:MGI Symbol;Acc:MGI:96907] |
| Gm16213 | ENSMUSG000000900 | 3.414571 | 0.000213 | predicted gene 16213 [Source:MGI Symbol;Acc:MGI:3801725] |
| Igkv1-135 | ENSMUSG000000963 | 3.411985 | 4.76E-21 | immunoglobulin kappa variable 1-135 [Source:MGI Symbol;Acc:MGI:3819952] |
| Pmepa1 | ENSMUSG000000384 | 3.40992 | 6.65E-12 | prostate transmembrane protein, androgen induced 1 [Source:MGI Symbol;Acc:MGI:1929600] |
| Pde4d | ENSMUSG000000216 | 3.409093 | 4.97E-197 | phosphodiesterase 4D, cAMP specific [Source:MGI Symbol;Acc:MGI:99555] |
| Ccr1 | ENSMUSG000000258 | 3.408767 | 2.10E-43 | chemokine (C-C motif) receptor 1 [Source:MGI Symbol;Acc:MGI:104618] |
| Stom | ENSMUSG000000268 | 3.406056 | 1.83E-60 | stomatin [Source:MGI Symbol;Acc:MGI:95403] |
| Mir1904 | ENSMUSG000000846 | 3.383522 | 3.48E-05 | microRNA 1904 [Source:MGI Symbol;Acc:MGI:3811419] |
| Adam3 | ENSMUSG000000315 | 3.382359 | 1.62E-05 | a disintegrin and metallopeptidase domain 3 (cyritestin) [Source:MGI Symbol;Acc:MGI:102518] |
| Nrp2 | ENSMUSG000000259 | 3.365612 | 4.97E-132 | neuropilin 2 [Source:MGI Symbol;Acc:MGI:1100492] |
| Gm30280 | ENSMUSG000001022 | 3.358179 | 1.25E-06 | predicted gene, 30280 [Source:MGI Symbol;Acc:MGI:5589439] |
| Nhs | ENSMUSG000000594 | 3.351608 | 6.61E-43 | NHS actin remodeling regulator [Source:MGI Symbol;Acc:MGI:2684894] |
| Sema7a | ENSMUSG000000382 | 3.335711 | 8.18E-228 | sema domain, immunoglobulin domain (Ig), and GPI membrane anchor, (semaphorin) 7A [Source:MGI Symbol;Acc:MGI:1306826] |
| Ighg3 | ENSMUSG000000766 | 3.310096 | 1.52E-44 | Immunoglobulin heavy constant gamma 3 [Source:MGI Symbol;Acc:MGI:2144790] |
| Sema6b | ENSMUSG000000012 | 3.304122 | 1.43E-08 | sema domain, transmembrane domain (TM), and cytoplasmic domain, (semaphorin) 6B [Source:MGI Symbol;Acc:MGI:1202889] |
| Prdm1 | ENSMUSG000000381 | 3.303873 | 1.33E-20 | PR domain containing 1, with ZNF domain [Source:MGI Symbol;Acc:MGI:99655] |
| Gm15513 | ENSMUSG000000862 | 3.293197 | 3.81E-43 | predicted gene 15513 [Source:MGI Symbol;Acc:MGI:3782961] |
| Lair1 | ENSMUSG000000555 | 3.260662 | 3.93E-104 | leukocyte-associated Ig-like receptor 1 [Source:MGI Symbol;Acc:MGI:105492] |
| 9530052E0 | ENSMUSG000000969 | 3.243917 | 0.003593 | RIKEN cDNA 9530052E02 gene [Source:MGI Symbol;Acc:MGI:3588277] |
| Cxx1c | ENSMUSG000000518 | 3.243778 | 0.003746 | retrotransposon Gag like 8C [Source:MGI Symbol;Acc:MGI:1920115] |
| Gm16793 | ENSMUSG000000973 | 3.228347 | 1.67E-07 | predicted gene, 16793 [Source:MGI Symbol;Acc:MGI:4439717] |
| Klk8 | ENSMUSG000000640 | 3.183402 | 8.01E-05 | kallikrein related-peptidase 8 [Source:MGI Symbol;Acc:MGI:1343327] |
| Hmgn3 | ENSMUSG000000664 | 3.16007 | 1.45E-31 | high mobility group nucleosomal binding domain 3 [Source:MGI Symbol;Acc:MGI:2138069] |
| Dtx1 | ENSMUSG000000296 | 3.108324 | 0 | deltex 1, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:1352744] |
| Nr3c2 | ENSMUSG000000316 | 3.063686 | 5.48E-09 | nuclear receptor subfamily 3, group C, member 2 [Source:MGI Symbol;Acc:MGI:99459] |
| Hes5 | ENSMUSG000000480 | 3.061007 | 3.91E-23 | hairy and enhancer of split 5 (Drosophila) [Source:MGI Symbol;Acc:MGI:104876] |
| Ephx2 | ENSMUSG000000220 | 3.046849 | 2.05E-09 | epoxide hydrolase 2, cytoplasmic [Source:MGI Symbol;Acc:MGI:99500] |
| Trem1 | ENSMUSG000000422 | 3.041654 | 5.97E-59 | triggering receptor expressed on myeloid cells 1 [Source:MGI Symbol;Acc:MGI:1930005] |
| Nod1 | ENSMUSG000000380 | 2.990966 | 5.23E-86 | nucleotide-binding oligomerization domain containing 1 [Source:MGI Symbol;Acc:MGI:1341839] |
| Cdon | ENSMUSG000000381 | 2.965712 | 9.50E-131 | cell adhesion molecule-related/down-regulated by oncogenes [Source:MGI Symbol;Acc:MGI:1926387] |
| Cdc42bpb | ENSMUSG000000212 | 2.958547 | 1.11E-106 | CDC42 binding protein kinase beta [Source:MGI Symbol;Acc:MGI:2136459] |
| Snhg18 | ENSMUSG000000969 | 2.948418 | 2.17E-21 | small nucleolar RNA host gene 18 [Source:MGI Symbol;Acc:MGI:1914085] |

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|---|---|---|---|---|
| Mpeg1 | ENSMUSG000000468 | 2.944851 | 3.70E-123 | macrophage expressed gene 1 [Source:MGI Symbol;Acc:MGI:1333743] |
| Gm24186 | ENSMUSG000000886 | 2.89844 | 8.10E-08 | predicted gene, 24186 [Source:MGI Symbol;Acc:MGI:5453963] |
| C430002N1 | ENSMUSG000001015 | 2.891351 | 1.88E-08 | RIKEN cDNA C430002N11 gene [Source:MGI Symbol;Acc:MGI:2442576] |
| Bcl2a1d | ENSMUSG000000999 | 2.873125 | 2.05E-17 | B cell leukemia/lymphoma 2 related protein A1d [Source:MGI Symbol;Acc:MGI:1278325] |
| Bhlhe40 | ENSMUSG000000301 | 2.866403 | 1.53E-48 | basic helix-loop-helix family, member e40 [Source:MGI Symbol;Acc:MGI:1097714] |
| Ahr | ENSMUSG000000192 | 2.854114 | 7.22E-30 | aryl-hydrocarbon receptor [Source:MGI Symbol;Acc:MGI:105043] |
| Mocos | ENSMUSG000000396 | 2.848126 | 2.17E-05 | molybdenum cofactor sulfurase [Source:MGI Symbol;Acc:MGI:1915841] |
| Dusp16 | ENSMUSG000000302 | 2.817417 | 6.92E-209 | dual specificity phosphatase 16 [Source:MGI Symbol;Acc:MGI:1917936] |
| Mkln1os | ENSMUSG000000862 | 2.817412 | 7.15E-09 | muskelin 1, intracellular mediator containing kelch motifs, opposite strand [Source:MGI Symbol;Acc:MGI:3651306] |
| Epm2a | ENSMUSG000000554 | 2.786359 | 1.58E-09 | epilepsy, progressive myoclonic epilepsy, type 2 gene alpha [Source:MGI Symbol;Acc:MGI:1341085] |
| Fgl2 | ENSMUSG000000398 | 2.774299 | 4.69E-21 | fibrinogen-like protein 2 [Source:MGI Symbol;Acc:MGI:103266] |
| Igkv1-108 | ENSMUSG000001050 | 2.747834 | 1.13E-33 | immunoglobulin kappa variable 1-108 [Source:MGI Symbol;Acc:MGI:3644576] |
| Sorbs2 | ENSMUSG000000316 | 2.74169 | 3.20E-91 | sorbin and SH3 domain containing 2 [Source:MGI Symbol;Acc:MGI:1924574] |
| Gm4956 | ENSMUSG000000259 | 2.734489 | 0.000922 | predicted gene 4956 [Source:MGI Symbol;Acc:MGI:3647976] |
| Ltk | ENSMUSG000000272 | 2.727782 | 4.61E-53 | leukocyte tyrosine kinase [Source:MGI Symbol;Acc:MGI:96840] |
| Zmat4 | ENSMUSG000000374 | 2.717045 | 6.55E-05 | zinc finger, matrin type 4 [Source:MGI Symbol;Acc:MGI:2443497] |
| Agrn | ENSMUSG000000419 | 2.706648 | 2.65E-44 | agrin [Source:MGI Symbol;Acc:MGI:87961] |
| Gm5547 | ENSMUSG000001048 | 2.683201 | 7.39E-09 | predicted gene 5547 [Source:MGI Symbol;Acc:MGI:3648206] |
| Gbp8 | ENSMUSG000000344 | 2.681778 | 1.56E-35 | guanylate-binding protein 8 [Source:MGI Symbol;Acc:MGI:1923324] |
| Terb1 | ENSMUSG000000526 | 2.663469 | 9.81E-67 | telomere repeat binding bouquet formation protein 1 [Source:MGI Symbol;Acc:MGI:2443187] |
| Nr4a1 | ENSMUSG000000230 | 2.654688 | 2.81E-28 | nuclear receptor subfamily 4, group A, member 1 [Source:MGI Symbol;Acc:MGI:1352454] |
| Gm43065 | ENSMUSG000001059 | 2.65457 | 1.51E-31 | predicted gene 43065 [Source:MGI Symbol;Acc:MGI:5663202] |
| Zfp532 | ENSMUSG000000424 | 2.654146 | 9.62E-76 | zinc finger protein 532 [Source:MGI Symbol;Acc:MGI:3036282] |
| Gm17173 | ENSMUSG000000907 | 2.644186 | 1.46E-06 | predicted gene 17173 [Source:MGI Symbol;Acc:MGI:4938000] |
| Sirpa | ENSMUSG000000379 | 2.640167 | 5.93E-108 | signal-regulatory protein alpha [Source:MGI Symbol;Acc:MGI:108563] |
| Tmed6 | ENSMUSG000000319 | 2.633368 | 0.006342 | transmembrane p24 trafficking protein 6 [Source:MGI Symbol;Acc:MGI:1913519] |
| Ptpn22 | ENSMUSG000000278 | 2.618501 | 9.54E-130 | protein tyrosine phosphatase, non-receptor type 22 (lymphoid) [Source:MGI Symbol;Acc:MGI:107170] |
| Grhl1 | ENSMUSG000000206 | 2.594669 | 7.34E-07 | grainyhead-like 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:2182540] |
| Dzip1 | ENSMUSG000000421 | 2.586545 | 5.84E-10 | DAZ interacting protein 1 [Source:MGI Symbol;Acc:MGI:1914311] |
| Camkmt | ENSMUSG000000710 | 2.585579 | 4.50E-43 | calmodulin-lysine N-methyltransferase [Source:MGI Symbol;Acc:MGI:1920832] |
| Cfp | ENSMUSG000000011 | 2.580184 | 6.90E-95 | complement factor properdin [Source:MGI Symbol;Acc:MGI:97545] |
| Cyp39a1 | ENSMUSG000000239 | 2.580007 | 8.14E-67 | cytochrome P450, family 39, subfamily a, polypeptide 1 [Source:MGI Symbol;Acc:MGI:1927096] |
| Fam83h | ENSMUSG000000467 | 2.576281 | 6.64E-08 | family with sequence similarity 83, member H [Source:MGI Symbol;Acc:MGI:2145900] |
| Emb | ENSMUSG000000217 | 2.572433 | 6.74E-35 | embigin [Source:MGI Symbol;Acc:MGI:95321] |
| Cdh17 | ENSMUSG000000282 | 2.572164 | 2.96E-103 | cadherin 17 [Source:MGI Symbol;Acc:MGI:1095414] |
| Tjp2 | ENSMUSG000000248 | 2.563882 | 4.64E-13 | tight junction protein 2 [Source:MGI Symbol;Acc:MGI:1341872] |
| Gm37780 | ENSMUSG000001026 | 2.545238 | 8.20E-34 | predicted gene, 37780 [Source:MGI Symbol;Acc:MGI:5611008] |
| Igkv2-107 | ENSMUSG000001064 | 2.52644 | 3.03E-24 | immunoglobulin kappa variable 2-107 [Source:MGI Symbol;Acc:MGI:3645630] |
| Ube2e2 | ENSMUSG000000583 | 2.519139 | 2.95E-50 | ubiquitin-conjugating enzyme E2E 2 [Source:MGI Symbol;Acc:MGI:2384997] |
| Cacna1e | ENSMUSG000000041 | 2.513771 | 1.19E-130 | calcium channel, voltage-dependent, R type, alpha 1E subunit [Source:MGI Symbol;Acc:MGI:106217] |
| Gm17322 | ENSMUSG000000976 | 2.513053 | 0.002287 | predicted gene, 17322 [Source:MGI Symbol;Acc:MGI:4936956] |
| Slc9a9 | ENSMUSG000000311 | 2.504843 | 9.66E-33 | solute carrier family 9 (sodium/hydrogen exchanger), member 9 [Source:MGI Symbol;Acc:MGI:2679732] |
| Gm37205 | ENSMUSG000001036 | 2.501039 | 0.005126 | predicted gene, 37205 [Source:MGI Symbol;Acc:MGI:5610433] |
| Dph5 | ENSMUSG000000335 | 2.500812 | 3.12E-145 | diphthamide biosynthesis 5 [Source:MGI Symbol;Acc:MGI:1916990] |
| Cacnb4 | ENSMUSG000000174 | 2.500555 | 1.37E-16 | calcium channel, voltage-dependent, beta 4 subunit [Source:MGI Symbol;Acc:MGI:103301] |
| Pcdhga8 | ENSMUSG000001038 | 2.500252 | 0.001496 | protocadherin gamma subfamily A, 8 [Source:MGI Symbol;Acc:MGI:1935221] |
| Cd1d1 | ENSMUSG000000280 | 2.493847 | 2.30E-153 | CD1d1 antigen [Source:MGI Symbol;Acc:MGI:107674] |
| Tubg2 | ENSMUSG000000450 | 2.488853 | 1.08E-16 | tubulin, gamma 2 [Source:MGI Symbol;Acc:MGI:2144208] |
| Rxfp1 | ENSMUSG000000340 | 2.485941 | 6.70E-40 | relaxin/insulin-like family peptide receptor 1 [Source:MGI Symbol;Acc:MGI:2682211] |
| Cln8 | ENSMUSG000000263 | 2.475241 | 6.13E-41 | ceroid-lipofuscinosis, neuronal 8 [Source:MGI Symbol;Acc:MGI:1349447] |
| Tgm2 | ENSMUSG000000378 | 2.472402 | 6.04E-17 | transglutaminase 2, C polypeptide [Source:MGI Symbol;Acc:MGI:98731] |
| Tmeff1 | ENSMUSG000000283 | 2.471675 | 1.14E-08 | transmembrane protein with EGF-like and two follistatin-like domains 1 [Source:MGI Symbol;Acc:MGI:1926810] |
| 2210414B0 | ENSMUSG000000853 | 2.462864 | 7.55E-08 | RIKEN cDNA 2210414B05 gene [Source:MGI Symbol;Acc:MGI:1917393] |
| Flt3 | ENSMUSG000000428 | 2.455167 | 1.01E-72 | FMS-like tyrosine kinase 3 [Source:MGI Symbol;Acc:MGI:95559] |
| Gm1045 | ENSMUSG000000960 | 2.452428 | 2.28E-10 | odontogenesis associated phosphoprotein [Source:MGI Symbol;Acc:MGI:2685891] |
| Cd300lf | ENSMUSG000000477 | 2.43778 | 7.48E-56 | CD300 molecule like family member F [Source:MGI Symbol;Acc:MGI:2442359] |
| Il9r | ENSMUSG000000202 | 2.436701 | 1.09E-115 | interleukin 9 receptor [Source:MGI Symbol;Acc:MGI:96564] |
| Gm38156 | ENSMUSG000001033 | 2.433099 | 2.05E-15 | predicted gene, 38156 [Source:MGI Symbol;Acc:MGI:5611384] |
| Kcnn1 | ENSMUSG000000029 | 2.430361 | 0.00677 | potassium intermediate/small conductance calcium-activated channel, subfamily N, member 1 [Source:MGI Symbol;Acc:MGI:1933993] |
| Tnfrsf21 | ENSMUSG000000239 | 2.421002 | 4.02E-41 | tumor necrosis factor receptor superfamily, member 21 [Source:MGI Symbol;Acc:MGI:2151075] |
| Smyd2 | ENSMUSG000000266 | 2.408791 | 1.19E-13 | SET and MYND domain containing 2 [Source:MGI Symbol;Acc:MGI:1915889] |
| Dse | ENSMUSG000000394 | 2.407473 | 5.12E-41 | dermatan sulfate epimerase [Source:MGI Symbol;Acc:MGI:2443455] |
| Pde4a | ENSMUSG000000321 | 2.406459 | 8.31E-53 | phosphodiesterase 4A, cAMP specific [Source:MGI Symbol;Acc:MGI:99558] |
| Prf1 | ENSMUSG000000372 | 2.381871 | 7.21E-49 | perforin 1 (pore forming protein) [Source:MGI Symbol;Acc:MGI:97551] |
| Igkv2-109 | ENSMUSG000001056 | 2.37805 | 5.42E-44 | immunoglobulin kappa variable 2-109 [Source:MGI Symbol;Acc:MGI:3642626] |
| Bcl2a1b | ENSMUSG000000899 | 2.364256 | 1.92E-25 | B cell leukemia/lymphoma 2 related protein A1b [Source:MGI Symbol;Acc:MGI:1278326] |
| Gm37068 | ENSMUSG000001044 | 2.355347 | 0.000259 | predicted gene, 37068 [Source:MGI Symbol;Acc:MGI:5610296] |
| Hs3st3b1 | ENSMUSG000000704 | 2.351773 | 2.00E-27 | heparan sulfate (glucosamine) 3-O-sulfotransferase 3B1 [Source:MGI Symbol;Acc:MGI:1333853] |
| Osgin1 | ENSMUSG000000740 | 2.351416 | 8.84E-07 | oxidative stress induced growth inhibitor 1 [Source:MGI Symbol;Acc:MGI:1919089] |
| Gm7265 | ENSMUSG000001025 | 2.343389 | 1.34E-52 | predicted gene 7265 [Source:MGI Symbol;Acc:MGI:3648991] |

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| | | | | |
|---|---|---|---|---|
| Lysmd2 | ENSMUSG000000321 | 2.329241 | 0.001416 | LysM, putative peptidoglycan-binding, domain containing 2 [Source:MGI Symbol;Acc:MGI:1917332] |
| Angptl3 | ENSMUSG000000285 | 2.328571 | 0.004165 | angiopoietin-like 3 [Source:MGI Symbol;Acc:MGI:1353627] |
| Cr2 | ENSMUSG000000266 | 2.326897 | 1.32E-185 | complement receptor 2 [Source:MGI Symbol;Acc:MGI:88489] |
| Perm1 | ENSMUSG000000784 | 2.326141 | 1.94E-39 | PPARGC1 and ESRR induced regulator, muscle 1 [Source:MGI Symbol;Acc:MGI:1921433] |
| Afdn | ENSMUSG000000680 | 2.317823 | 7.84E-27 | afadin, adherens junction formation factor [Source:MGI Symbol;Acc:MGI:1314653] |
| Pik3r4 | ENSMUSG000000325 | 2.309404 | 5.06E-196 | phosphoinositide-3-kinase regulatory subunit 4 [Source:MGI Symbol;Acc:MGI:1922919] |
| Slc2a13 | ENSMUSG000000362 | 2.29527 | 0.000282 | solute carrier family 2 (facilitated glucose transporter), member 13 [Source:MGI Symbol;Acc:MGI:2146030] |
| Mfhas1 | ENSMUSG000000700 | 2.293083 | 5.39E-136 | malignant fibrous histiocytoma amplified sequence 1 [Source:MGI Symbol;Acc:MGI:1098644] |
| A930005H1 | ENSMUSG000000544 | 2.286848 | 1.88E-57 | RIKEN cDNA A930005H10 gene [Source:MGI Symbol;Acc:MGI:1915411] |
| 4930594M2 | ENSMUSG000000754 | 2.286199 | 3.32E-09 | RIKEN cDNA 4930594M22 gene [Source:MGI Symbol;Acc:MGI:1925478] |
| 6330562C2 | ENSMUSG000000934 | 2.269895 | 1.66E-05 | RIKEN cDNA 6330562C20 gene [Source:MGI Symbol;Acc:MGI:1923443] |
| Rgs12 | ENSMUSG000000291 | 2.26943 | 9.60E-23 | regulator of G-protein signaling 12 [Source:MGI Symbol;Acc:MGI:1918979] |
| Apobr | ENSMUSG000000427 | 2.255057 | 3.09E-08 | apolipoprotein B receptor [Source:MGI Symbol;Acc:MGI:2176230] |
| Zfyve28 | ENSMUSG000000372 | 2.253869 | 2.90E-45 | zinc finger, FYVE domain containing 28 [Source:MGI Symbol;Acc:MGI:2684992] |
| Lsmem1 | ENSMUSG000000713 | 2.250793 | 0.000576 | leucine-rich single-pass membrane protein 1 [Source:MGI Symbol;Acc:MGI:2685735] |
| Crebl2 | ENSMUSG000000326 | 2.244007 | 4.56E-126 | cAMP responsive element binding protein-like 2 [Source:MGI Symbol;Acc:MGI:1889385] |
| Mybl2 | ENSMUSG000000178 | 2.231949 | 1.52E-16 | myeloblastosis oncogene-like 2 [Source:MGI Symbol;Acc:MGI:101785] |
| Espn | ENSMUSG000000289 | 2.208656 | 0.002722 | espin [Source:MGI Symbol;Acc:MGI:1861630] |
| Ldlrad3 | ENSMUSG000000480 | 2.18546 | 6.90E-49 | low density lipoprotein receptor class A domain containing 3 [Source:MGI Symbol;Acc:MGI:2138856] |
| D8Ertd82e | ENSMUSG000000502 | 2.174022 | 6.29E-102 | PEAK1 related kinase activating pseudokinase 1 [Source:MGI Symbol;Acc:MGI:1196223] |
| Arhgef12 | ENSMUSG000000594 | 2.139424 | 4.74E-65 | Rho guanine nucleotide exchange factor (GEF) 12 [Source:MGI Symbol;Acc:MGI:1916882] |
| Ly96 | ENSMUSG000000257 | 2.125688 | 6.31E-16 | lymphocyte antigen 96 [Source:MGI Symbol;Acc:MGI:1341909] |
| Fam167a | ENSMUSG000000350 | 2.117465 | 1.01E-53 | family with sequence similarity 167, member A [Source:MGI Symbol;Acc:MGI:3606565] |
| Rhbdf1 | ENSMUSG000000202 | 2.114847 | 4.31E-93 | rhomboid 5 homolog 1 [Source:MGI Symbol;Acc:MGI:104328] |
| Ttc8 | ENSMUSG000000210 | 2.095638 | 6.74E-06 | tetratricopeptide repeat domain 8 [Source:MGI Symbol;Acc:MGI:1923510] |
| Mdfic | ENSMUSG000000413 | 2.084348 | 1.08E-65 | MyoD family inhibitor domain containing [Source:MGI Symbol;Acc:MGI:104611] |
| Nod2 | ENSMUSG000000559 | 2.084067 | 2.86E-41 | nucleotide-binding oligomerization domain containing 2 [Source:MGI Symbol;Acc:MGI:2429397] |
| Col6a6 | ENSMUSG000000437 | 2.082018 | 2.20E-08 | collagen, type VI, alpha 6 [Source:MGI Symbol;Acc:MGI:2444259] |
| Tmtc4 | ENSMUSG000000415 | 2.07745 | 1.02E-27 | transmembrane and tetratricopeptide repeat containing 4 [Source:MGI Symbol;Acc:MGI:1921050] |
| Dtx4 | ENSMUSG000000399 | 2.075368 | 1.76E-29 | deltex 4, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:2672905] |
| Ak7 | ENSMUSG000000413 | 2.066064 | 0.003574 | adenylate kinase 7 [Source:MGI Symbol;Acc:MGI:1926051] |
| Pdia4 | ENSMUSG000000258 | 2.065516 | 3.56E-128 | protein disulfide isomerase associated 4 [Source:MGI Symbol;Acc:MGI:104864] |
| Nedd4 | ENSMUSG000000322 | 2.060686 | 5.02E-145 | neural precursor cell expressed, developmentally down-regulated 4 [Source:MGI Symbol;Acc:MGI:97297] |
| Rab39b | ENSMUSG000000312 | 2.059141 | 0.003996 | RAB39B, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:1915040] |
| C130060C0 | ENSMUSG000000975 | 2.055624 | 2.83E-05 | RIKEN cDNA C130060C02 gene [Source:MGI Symbol;Acc:MGI:3041192] |
| Gm12403 | ENSMUSG000000821 | 2.052079 | 2.41E-06 | predicted gene 12403 [Source:MGI Symbol;Acc:MGI:3650109] |
| Tfpi | ENSMUSG000000270 | 2.046839 | 1.09E-10 | tissue factor pathway inhibitor [Source:MGI Symbol;Acc:MGI:1095418] |
| Plxnc1 | ENSMUSG000000747 | 2.043205 | 2.65E-135 | plexin C1 [Source:MGI Symbol;Acc:MGI:1890127] |
| Cyb5r2 | ENSMUSG000000480 | 2.041923 | 0.007992 | cytochrome b5 reductase 2 [Source:MGI Symbol;Acc:MGI:2444415] |
| Mcoln3 | ENSMUSG000000368 | 2.04033 | 6.97E-24 | mucolipin 3 [Source:MGI Symbol;Acc:MGI:1890500] |
| Tyrobp | ENSMUSG000000305 | 2.029237 | 3.77E-42 | TYRO protein tyrosine kinase binding protein [Source:MGI Symbol;Acc:MGI:1277211] |
| Npr2 | ENSMUSG000000284 | 2.027456 | 2.59E-11 | natriuretic peptide receptor 2 [Source:MGI Symbol;Acc:MGI:97372] |
| Gm11707 | ENSMUSG000000864 | 2.0256 | 4.20E-08 | predicted gene 11707 [Source:MGI Symbol;Acc:MGI:3651836] |
| 4930568A1 | ENSMUSG000001012 | 2.021923 | 3.96E-13 | RIKEN cDNA 4930568A12 gene [Source:MGI Symbol;Acc:MGI:1923133] |
| Hpgds | ENSMUSG000000299 | 2.014445 | 3.62E-23 | hematopoietic prostaglandin D synthase [Source:MGI Symbol;Acc:MGI:1859384] |
| Tmem26 | ENSMUSG000000600 | 2.008978 | 9.75E-31 | transmembrane protein 26 [Source:MGI Symbol;Acc:MGI:2143537] |
| Cd80 | ENSMUSG000000751 | 2.007221 | 3.73E-09 | CD80 antigen [Source:MGI Symbol;Acc:MGI:101775] |

adjusted P value <=0.01

Fold change >= 4

## Table 6-14. Genes significantly up-regulated in MZ B cells compare to FO B cells.

| Symbol | Ensembl gene id | logFC (FO/MZ) | adj.P.val | Annotation |
|---|---|---|---|---|
| Lrrc23 | ENSMUSG00000030125 | 7.49177227 | 8.25E-11 | leucine rich repeat containing 23 [Source:MGI Symbol;Acc:MGI:1315192] |
| Gm37004 | ENSMUSG00000102286 | 6.94995976 | 2.86E-13 | predicted gene, 37004 [Source:MGI Symbol;Acc:MGI:5610232] |
| Enkur | ENSMUSG00000026679 | 5.7660736 | 1.93E-05 | enkurin, TRPC channel interacting protein [Source:MGI Symbol;Acc:MGI:1918483] |
| Gm11690 | ENSMUSG00000085844 | 5.6371294 | 2.59E-92 | predicted gene 11690 [Source:MGI Symbol;Acc:MGI:3652329] |
| Sh2d6 | ENSMUSG00000052631 | 5.41074961 | 2.08E-08 | SH2 domain containing 6 [Source:MGI Symbol;Acc:MGI:1918380] |
| Sorcs2 | ENSMUSG00000029093 | 5.32873234 | 1.23E-27 | sortilin-related VPS10 domain containing receptor 2 [Source:MGI Symbol;Acc:MGI:1932289] |
| Ahnak | ENSMUSG00000069833 | 5.30098099 | 0 | AHNAK nucleoprotein (desmoyokin) [Source:MGI Symbol;Acc:MGI:1316648] |
| Wfdc18 | ENSMUSG00000000983 | 5.18705351 | 0.00108488 | WAP four-disulfide core domain 18 [Source:MGI Symbol;Acc:MGI:107506] |
| Vim | ENSMUSG00000026728 | 5.16151854 | 1.38E-82 | vimentin [Source:MGI Symbol;Acc:MGI:98932] |
| Wfdc17 | ENSMUSG00000069792 | 5.15694485 | 2.60E-24 | WAP four-disulfide core domain 17 [Source:MGI Symbol;Acc:MGI:3649773] |
| Lifr | ENSMUSG00000054263 | 5.07390747 | 2.92E-204 | leukemia inhibitory factor receptor [Source:MGI Symbol;Acc:MGI:96788] |
| Cacna1i | ENSMUSG00000022416 | 4.90638294 | 4.12E-44 | calcium channel, voltage-dependent, alpha 1I subunit [Source:MGI Symbol;Acc:MGI:2178051] |
| Scn4b | ENSMUSG00000046480 | 4.86938651 | 1.62E-05 | sodium channel, type IV, beta [Source:MGI Symbol;Acc:MGI:2687406] |
| Rasl10a | ENSMUSG00000034209 | 4.84521349 | 0.00620814 | RAS-like, family 10, member A [Source:MGI Symbol;Acc:MGI:1922918] |
| Trim16 | ENSMUSG00000047821 | 4.56761578 | 3.47E-08 | tripartite motif-containing 16 [Source:MGI Symbol;Acc:MGI:2137356] |
| Platr7 | ENSMUSG00000097076 | 4.46246399 | 2.04E-07 | pluripotency associated transcript 7 [Source:MGI Symbol;Acc:MGI:3045387] |
| Trim46 | ENSMUSG00000042766 | 4.43669243 | 4.12E-19 | tripartite motif-containing 46 [Source:MGI Symbol;Acc:MGI:2673000] |
| Klf2 | ENSMUSG00000055148 | 4.41233899 | 4.01E-174 | Kruppel-like factor 2 (lung) [Source:MGI Symbol;Acc:MGI:1342772] |
| Pde2a | ENSMUSG00000030653 | 4.29133243 | 8.34E-241 | predicted gene 45837 [Source:MGI Symbol;Acc:MGI:5804952] |
| 1700097N02 | ENSMUSG00000099474 | 4.27139184 | 2.03E-06 | RIKEN cDNA 1700097N02 gene [Source:MGI Symbol;Acc:MGI:1914772] |
| Trib2 | ENSMUSG00000020601 | 4.18631408 | 3.67E-19 | tribbles pseudokinase 2 [Source:MGI Symbol;Acc:MGI:2145021] |
| Dnah8 | ENSMUSG00000033826 | 4.09088696 | 6.02E-151 | dynein, axonemal, heavy chain 8 [Source:MGI Symbol;Acc:MGI:107714] |
| Gfod1 | ENSMUSG00000051335 | 4.02568423 | 1.24E-25 | glucose-fructose oxidoreductase domain containing 1 [Source:MGI Symbol;Acc:MGI:2145304] |
| Myadm | ENSMUSG00000068566 | 3.99631145 | 7.27E-171 | myeloid-associated differentiation marker [Source:MGI Symbol;Acc:MGI:1355332] |
| Tmprss13 | ENSMUSG00000037129 | 3.96310468 | 1.46E-21 | transmembrane protease, serine 13 [Source:MGI Symbol;Acc:MGI:2682935] |
| Atp1b1 | ENSMUSG00000026576 | 3.91738195 | 7.05E-26 | ATPase, Na+/K+ transporting, beta 1 polypeptide [Source:MGI Symbol;Acc:MGI:88108] |
| Thbd | ENSMUSG00000074743 | 3.87024542 | 0.00176081 | thrombomodulin [Source:MGI Symbol;Acc:MGI:98736] |
| Serinc5 | ENSMUSG00000021703 | 3.85569854 | 9.25E-100 | serine incorporator 5 [Source:MGI Symbol;Acc:MGI:2444223] |
| Plk2 | ENSMUSG00000021701 | 3.79201402 | 1.19E-09 | polo like kinase 2 [Source:MGI Symbol;Acc:MGI:1099790] |
| Gm12159 | ENSMUSG00000084773 | 3.69159506 | 1.04E-05 | predicted gene 12159 [Source:MGI Symbol;Acc:MGI:3649482] |
| Stac2 | ENSMUSG00000017400 | 3.64219893 | 5.06E-50 | SH3 and cysteine rich domain 2 [Source:MGI Symbol;Acc:MGI:2144518] |
| Prss16 | ENSMUSG00000006179 | 3.61425019 | 9.69E-11 | protease, serine 16 (thymus) [Source:MGI Symbol;Acc:MGI:1859181] |
| Ngfr | ENSMUSG00000000120 | 3.57018481 | 3.48E-34 | nerve growth factor receptor (TNFR superfamily, member 16) [Source:MGI Symbol;Acc:MGI:97323] |
| Cxcr4 | ENSMUSG00000045382 | 3.56086852 | 4.33E-09 | chemokine (C-X-C motif) receptor 4 [Source:MGI Symbol;Acc:MGI:109563] |
| Ighv8-6 | ENSMUSG00000094505 | 3.55923477 | 0.00170284 | immunoglobulin heavy variable V8-6 [Source:MGI Symbol;Acc:MGI:3645823] |
| Rgag4 | ENSMUSG00000049191 | 3.52286504 | 5.06E-22 | retrotransposon Gag like 5 [Source:MGI Symbol;Acc:MGI:3045324] |
| Galc | ENSMUSG00000021003 | 3.47325063 | 2.56E-07 | galactosylceramidase [Source:MGI Symbol;Acc:MGI:95636] |
| Rfx2 | ENSMUSG00000024206 | 3.45184844 | 4.76E-21 | regulatory factor X, 2 (influences HLA class II expression) [Source:MGI Symbol;Acc:MGI:106583] |
| Cdkn1a | ENSMUSG00000023067 | 3.33536696 | 0.00625164 | cyclin-dependent kinase inhibitor 1A (P21) [Source:MGI Symbol;Acc:MGI:104556] |
| Dmwd | ENSMUSG00000030410 | 3.3079208 | 5.70E-17 | dystrophia myotonica-containing WD repeat motif [Source:MGI Symbol;Acc:MGI:94907] |
| Tmem51 | ENSMUSG00000040616 | 3.30683835 | 3.69E-07 | transmembrane protein 51 [Source:MGI Symbol;Acc:MGI:2384874] |
| Fam221a | ENSMUSG00000047115 | 3.28684205 | 0.00172062 | family with sequence similarity 221, member A [Source:MGI Symbol;Acc:MGI:2442161] |
| Fsip1 | ENSMUSG00000027344 | 3.25688489 | 4.15E-09 | fibrous sheath-interacting protein 1 [Source:MGI Symbol;Acc:MGI:1918563] |
| Adora2a | ENSMUSG00000020178 | 3.22690012 | 6.82E-31 | adenosine A2a receptor [Source:MGI Symbol;Acc:MGI:99402] |
| Arl11 | ENSMUSG00000043157 | 3.19448777 | 0.0032467 | ADP-ribosylation factor-like 11 [Source:MGI Symbol;Acc:MGI:2444054] |
| Prkar2b | ENSMUSG00000002997 | 3.14026988 | 4.89E-10 | protein kinase, cAMP dependent regulatory, type II beta [Source:MGI Symbol;Acc:MGI:97760] |
| Dyrk3 | ENSMUSG00000016526 | 3.13207246 | 1.70E-13 | dual-specificity tyrosine-(Y)-phosphorylation regulated kinase 3 [Source:MGI Symbol;Acc:MGI:1330300] |
| Gm37352 | ENSMUSG00000103593 | 3.1123256 | 2.33E-48 | predicted gene, 37352 [Source:MGI Symbol;Acc:MGI:5610580] |
| Alcam | ENSMUSG00000022636 | 3.08409593 | 8.27E-52 | activated leukocyte cell adhesion molecule [Source:MGI Symbol;Acc:MGI:1313266] |
| 1700029H14 | ENSMUSG00000031452 | 3.07375567 | 3.20E-05 | RIKEN cDNA 1700029H14 gene [Source:MGI Symbol;Acc:MGI:1913751] |
| Fkbp11 | ENSMUSG00000003355 | 3.05151272 | 3.58E-10 | FK506 binding protein 11 [Source:MGI Symbol;Acc:MGI:1913370] |
| S100a6 | ENSMUSG00000001025 | 3.05104793 | 3.24E-16 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Mex3b | ENSMUSG00000057706 | 2.98743834 | 3.02E-20 | mex3 RNA binding family member B [Source:MGI Symbol;Acc:MGI:1918252] |
| Gm4540 | ENSMUSG00000092072 | 2.98054815 | 2.07E-06 | predicted gene 4540 [Source:MGI Symbol;Acc:MGI:3782724] |
| Crybg3 | ENSMUSG00000091562 | 2.9639761 | 6.29E-35 | beta-gamma crystallin domain containing 3 [Source:MGI Symbol;Acc:MGI:2676311] |
| Cdkl1 | ENSMUSG00000020990 | 2.93433432 | 1.83E-30 | cyclin-dependent kinase-like 1 (CDC2-related kinase) [Source:MGI Symbol;Acc:MGI:1918341] |
| Tgfbr3 | ENSMUSG00000029287 | 2.88420826 | 6.06E-06 | transforming growth factor, beta receptor III [Source:MGI Symbol;Acc:MGI:104637] |
| Tsc22d3 | ENSMUSG00000031431 | 2.88042445 | 2.74E-155 | TSC22 domain family, member 3 [Source:MGI Symbol;Acc:MGI:1196284] |
| Epb41l4b | ENSMUSG00000028434 | 2.87122095 | 0.00699825 | erythrocyte membrane protein band 4.1 like 4b [Source:MGI Symbol;Acc:MGI:1859149] |
| Vsir | ENSMUSG00000020101 | 2.86245567 | 6.51E-59 | V-set immunoregulatory receptor [Source:MGI Symbol;Acc:MGI:1921298] |
| Pcdhgc4 | ENSMUSG00000023036 | 2.79469928 | 1.12E-06 | protocadherin gamma subfamily C, 4 [Source:MGI Symbol;Acc:MGI:1935203] |
| Igsf9 | ENSMUSG00000037995 | 2.78546945 | 4.81E-38 | immunoglobulin superfamily, member 9 [Source:MGI Symbol;Acc:MGI:2135283] |
| Sytl2 | ENSMUSG00000030616 | 2.78201686 | 0.00135884 | synaptotagmin-like 2 [Source:MGI Symbol;Acc:MGI:1933366] |
| Crisp3 | ENSMUSG00000025433 | 2.77879532 | 1.73E-11 | cysteine-rich secretory protein 3 [Source:MGI Symbol;Acc:MGI:102552] |
| Tmem176a | ENSMUSG00000023367 | 2.76904251 | 4.99E-06 | transmembrane protein 176A [Source:MGI Symbol;Acc:MGI:1913308] |
| Lamp3 | ENSMUSG00000041247 | 2.75372209 | 2.17E-06 | lysosomal-associated membrane protein 3 [Source:MGI Symbol;Acc:MGI:2441659] |
| Mapk12 | ENSMUSG00000022610 | 2.74451858 | 1.85E-17 | mitogen-activated protein kinase 12 [Source:MGI Symbol;Acc:MGI:1353438] |
| Fos | ENSMUSG00000021250 | 2.7324952 | 3.51E-07 | FBJ osteosarcoma oncogene [Source:MGI Symbol;Acc:MGI:95574] |
| Emp3 | ENSMUSG00000040212 | 2.73074472 | 4.35E-90 | epithelial membrane protein 3 [Source:MGI Symbol;Acc:MGI:1098729] |
| Iqgap2 | ENSMUSG00000021676 | 2.70395989 | 2.61E-06 | IQ motif containing GTPase activating protein 2 [Source:MGI Symbol;Acc:MGI:2449975] |

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|---|---|---|---|---|
| Gng12 | ENSMUSG00000036402 | 2.70016247 | 1.27E-09 | guanine nucleotide binding protein (G protein), gamma 12 [Source:MGI Symbol;Acc:MGI:1336171] |
| Fcgrt | ENSMUSG00000003420 | 2.69434116 | 7.63E-96 | Fc receptor, IgG, alpha chain transporter [Source:MGI Symbol;Acc:MGI:103017] |
| Cd200 | ENSMUSG00000022661 | 2.68743759 | 5.51E-59 | CD200 antigen [Source:MGI Symbol;Acc:MGI:1196990] |
| Gm26532 | ENSMUSG00000097296 | 2.68008263 | 4.20E-10 | predicted gene, 26532 [Source:MGI Symbol;Acc:MGI:5477026] |
| Cplx2 | ENSMUSG00000025867 | 2.67069024 | 1.14E-10 | complexin 2 [Source:MGI Symbol;Acc:MGI:104726] |
| Tagln2 | ENSMUSG00000026547 | 2.65505275 | 9.73E-94 | transgelin 2 [Source:MGI Symbol;Acc:MGI:1312985] |
| Eps8 | ENSMUSG00000015766 | 2.63420952 | 1.01E-13 | epidermal growth factor receptor pathway substrate 8 [Source:MGI Symbol;Acc:MGI:104684] |
| Spn | ENSMUSG00000051457 | 2.6319153 | 1.81E-24 | sialophorin [Source:MGI Symbol;Acc:MGI:98384] |
| Bach2 | ENSMUSG00000040270 | 2.6109631 | 4.93E-32 | BTB and CNC homology, basic leucine zipper transcription factor 2 [Source:MGI Symbol;Acc:MGI:894679] |
| Cd93 | ENSMUSG00000027435 | 2.59666955 | 3.85E-54 | CD93 antigen [Source:MGI Symbol;Acc:MGI:106664] |
| Diras2 | ENSMUSG00000047842 | 2.59128374 | 4.30E-29 | DIRAS family, GTP-binding RAS-like 2 [Source:MGI Symbol;Acc:MGI:1915453] |
| Cacna1h | ENSMUSG00000024112 | 2.57113681 | 1.07E-11 | calcium channel, voltage-dependent, T type, alpha 1H subunit [Source:MGI Symbol;Acc:MGI:1928842] |
| Cdkn2d | ENSMUSG00000096472 | 2.56230299 | 1.61E-41 | cyclin-dependent kinase inhibitor 2D (p19, inhibits CDK4) [Source:MGI Symbol;Acc:MGI:105387] |
| Gm24371 | ENSMUSG00000084611 | 2.55887432 | 9.88E-20 | predicted gene, 24371 [Source:MGI Symbol;Acc:MGI:5454148] |
| Gm5533 | ENSMUSG00000056699 | 2.5508747 | 2.16E-05 | predicted gene 5533 [Source:MGI Symbol;Acc:MGI:3647595] |
| Thbs3 | ENSMUSG00000028047 | 2.52595716 | 3.80E-07 | thrombospondin 3 [Source:MGI Symbol;Acc:MGI:98739] |
| Dmpk | ENSMUSG00000030409 | 2.51180841 | 2.56E-08 | dystrophia myotonica-protein kinase [Source:MGI Symbol;Acc:MGI:94906] |
| Gm42722 | ENSMUSG00000106093 | 2.51007719 | 9.03E-20 | predicted gene 42722 [Source:MGI Symbol;Acc:MGI:5662859] |
| Gm38055 | ENSMUSG00000102147 | 2.50320587 | 4.84E-06 | predicted gene, 38055 [Source:MGI Symbol;Acc:MGI:5611283] |
| 3110080O07 | ENSMUSG00000103284 | 2.49374094 | 3.69E-08 | RIKEN cDNA 3110080O07 gene [Source:MGI Symbol;Acc:MGI:1920491] |
| Itgb7 | ENSMUSG00000001281 | 2.47433578 | 1.79E-221 | integrin beta 7 [Source:MGI Symbol;Acc:MGI:96616] |
| Tgfbi | ENSMUSG00000035493 | 2.46345931 | 6.74E-06 | transforming growth factor, beta induced [Source:MGI Symbol;Acc:MGI:99959] |
| Mapk11 | ENSMUSG00000053137 | 2.46319063 | 8.92E-99 | mitogen-activated protein kinase 11 [Source:MGI Symbol;Acc:MGI:1338024] |
| Gmfg | ENSMUSG00000060791 | 2.4597058 | 7.23E-90 | glia maturation factor, gamma [Source:MGI Symbol;Acc:MGI:1927135] |
| Lgals1 | ENSMUSG00000068220 | 2.45295887 | 8.64E-16 | lectin, galactose binding, soluble 1 [Source:MGI Symbol;Acc:MGI:96777] |
| Gm26583 | ENSMUSG00000097476 | 2.43896993 | 0.0011733 | predicted gene, 26583 [Source:MGI Symbol;Acc:MGI:5477077] |
| 5430420F09I | ENSMUSG00000102808 | 2.425637 | 5.53E-12 | RIKEN cDNA 5430420F09 gene [Source:MGI Symbol;Acc:MGI:1921741] |
| Dab2ip | ENSMUSG00000026883 | 2.41723533 | 3.65E-09 | disabled 2 interacting protein [Source:MGI Symbol;Acc:MGI:1916851] |
| 4632428C04 | ENSMUSG00000097184 | 2.41066747 | 1.87E-39 | RIKEN cDNA 4632428C04 gene [Source:MGI Symbol;Acc:MGI:1921600] |
| Atp10a | ENSMUSG00000025324 | 2.40762876 | 0.00053127 | ATPase, class V, type 10A [Source:MGI Symbol;Acc:MGI:1330809] |
| Sgk1 | ENSMUSG00000019970 | 2.38876854 | 4.13E-29 | serum/glucocorticoid regulated kinase 1 [Source:MGI Symbol;Acc:MGI:1340062] |
| Ass1 | ENSMUSG00000076441 | 2.38334577 | 5.86E-44 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Pifo | ENSMUSG00000010136 | 2.36820491 | 8.13E-10 | primary cilia formation [Source:MGI Symbol;Acc:MGI:1923670] |
| Fcer2a | ENSMUSG00000005540 | 2.36138313 | 7.57E-95 | Fc receptor, IgE, low affinity II, alpha polypeptide [Source:MGI Symbol;Acc:MGI:95497] |
| Kcnj1 | ENSMUSG00000041248 | 2.35487882 | 2.96E-10 | potassium inwardly-rectifying channel, subfamily J, member 1 [Source:MGI Symbol;Acc:MGI:1927248] |
| Fam46a | ENSMUSG00000032265 | 2.35069918 | 3.00E-71 | family with sequence similarity 46, member A [Source:MGI Symbol;Acc:MGI:2670964] |
| Dusp4 | ENSMUSG00000031530 | 2.34918437 | 5.69E-15 | dual specificity phosphatase 4 [Source:MGI Symbol;Acc:MGI:2442191] |
| Slc52a3 | ENSMUSG00000027463 | 2.34528935 | 1.62E-08 | solute carrier protein family 52, member 3 [Source:MGI Symbol;Acc:MGI:1916948] |
| Tuba1a | ENSMUSG00000072235 | 2.34492315 | 1.02E-72 | tubulin, alpha 1A [Source:MGI Symbol;Acc:MGI:98869] |
| Tmem176b | ENSMUSG00000029810 | 2.33953193 | 6.46E-11 | transmembrane protein 176B [Source:MGI Symbol;Acc:MGI:1916348] |
| Gm15674 | ENSMUSG00000087691 | 2.31656658 | 1.16E-88 | predicted gene 15674 [Source:MGI Symbol;Acc:MGI:3783116] |
| Kctd14 | ENSMUSG00000051727 | 2.30914785 | 1.55E-23 | potassium channel tetramerisation domain containing 14 [Source:MGI Symbol;Acc:MGI:1289222] |
| Fam102b | ENSMUSG00000040339 | 2.30360796 | 2.37E-38 | family with sequence similarity 102, member B [Source:MGI Symbol;Acc:MGI:3036259] |
| Wscd2 | ENSMUSG00000063430 | 2.27385248 | 9.06E-08 | WSC domain containing 2 [Source:MGI Symbol;Acc:MGI:2445030] |
| 1190002N15 | ENSMUSG00000045414 | 2.26521267 | 1.77E-08 | RIKEN cDNA 1190002N15 gene [Source:MGI Symbol;Acc:MGI:1916111] |
| Rap1gap2 | ENSMUSG00000038807 | 2.26153433 | 5.74E-70 | RAP1 GTPase activating protein 2 [Source:MGI Symbol;Acc:MGI:3028623] |
| S1pr4 | ENSMUSG00000044199 | 2.25861039 | 6.33E-65 | sphingosine-1-phosphate receptor 4 [Source:MGI Symbol;Acc:MGI:1333809] |
| Iglj1 | ENSMUSG00000106668 | 2.25388689 | 0.00047322 | immunoglobulin lambda joining 1 [Source:MGI Symbol;Acc:MGI:5009822] |
| S100a10 | ENSMUSG00000041959 | 2.24170219 | 9.03E-62 | S100 calcium binding protein A10 (calpactin) [Source:MGI Symbol;Acc:MGI:1339468] |
| Cd55 | ENSMUSG00000026399 | 2.22276539 | 3.83E-23 | CD55 molecule, decay accelerating factor for complement [Source:MGI Symbol;Acc:MGI:104850] |
| Lilra6 | ENSMUSG00000030427 | 2.19535848 | 1.03E-30 | leukocyte immunoglobulin-like receptor, subfamily A (with TM domain), member 6 [Source:MGI Symbol;Acc:MGI:1195969] |
| Kcnb1 | ENSMUSG00000050556 | 2.15655881 | 1.60E-11 | potassium voltage gated channel, Shab-related subfamily, member 1 [Source:MGI Symbol;Acc:MGI:96666] |
| Palm | ENSMUSG00000035863 | 2.15136332 | 0.00801982 | paralemmin [Source:MGI Symbol;Acc:MGI:1261814] |
| Igkv4-51 | ENSMUSG00000094993 | 2.15012419 | 0.00217258 | immunoglobulin kappa chain variable 4-51 [Source:MGI Symbol;Acc:MGI:5009829] |
| Fgd6 | ENSMUSG00000020021 | 2.12811019 | 9.52E-11 | FYVE, RhoGEF and PH domain containing 6 [Source:MGI Symbol;Acc:MGI:1261419] |
| Cdc25b | ENSMUSG00000027330 | 2.10622306 | 7.07E-47 | cell division cycle 25B [Source:MGI Symbol;Acc:MGI:99701] |
| Jund | ENSMUSG00000071076 | 2.09940199 | 2.35E-42 | jun D proto-oncogene [Source:MGI Symbol;Acc:MGI:96648] |
| Slco5a1 | ENSMUSG00000025938 | 2.08415654 | 7.01E-15 | solute carrier organic anion transporter family, member 5A1 [Source:MGI Symbol;Acc:MGI:2443431] |
| Camkk1 | ENSMUSG00000020785 | 2.08091925 | 2.04E-07 | calcium/calmodulin-dependent protein kinase kinase 1, alpha [Source:MGI Symbol;Acc:MGI:1891766] |
| Egr1 | ENSMUSG00000038418 | 2.06943722 | 6.95E-11 | early growth response 1 [Source:MGI Symbol;Acc:MGI:95295] |
| Mybpc2 | ENSMUSG00000038670 | 2.06592306 | 4.78E-17 | myosin binding protein C, fast-type [Source:MGI Symbol;Acc:MGI:1336170] |
| Gm5511 | ENSMUSG00000100615 | 2.06479719 | 4.04E-09 | predicted gene 5511 [Source:MGI Symbol;Acc:MGI:3779492] |
| Gm10728 | ENSMUSG00000103701 | 2.06073639 | 0.00875126 | predicted gene 10728 [Source:MGI Symbol;Acc:MGI:3708672] |
| Smtn | ENSMUSG00000020439 | 2.05987216 | 1.79E-05 | smoothelin [Source:MGI Symbol;Acc:MGI:1354727] |
| Bmf | ENSMUSG00000040093 | 2.03556699 | 6.58E-48 | BCL2 modifying factor [Source:MGI Symbol;Acc:MGI:2176433] |
| Ccr7 | ENSMUSG00000037944 | 2.03162387 | 1.16E-14 | chemokine (C-C motif) receptor 7 [Source:MGI Symbol;Acc:MGI:103011] |
| Cecr2 | ENSMUSG00000071226 | 2.02370195 | 6.75E-66 | CECR2, histone acetyl-lysine reader [Source:MGI Symbol;Acc:MGI:1923799] |
| Iglc1 | ENSMUSG00000105906 | 2.01984339 | 9.86E-12 | immunoglobulin lambda constant 1 [Source:MGI Symbol;Acc:MGI:99546] |
| Ldlr | ENSMUSG00000032193 | 2.01652985 | 5.76E-45 | low density lipoprotein receptor [Source:MGI Symbol;Acc:MGI:96765] |
| Abca1 | ENSMUSG00000015243 | 2.00661746 | 7.56E-20 | ATP-binding cassette, sub-family A (ABC1), member 1 [Source:MGI Symbol;Acc:MGI:99607] |
| Arhgef18 | ENSMUSG00000004568 | 2.00230137 | 1.43E-108 | rho/rac guanine nucleotide exchange factor (GEF) 18 [Source:MGI Symbol;Acc:MGI:2142567] |

adjusted P value <=0.01

Fold change >= 4

## Table 6-15. Genes significantly up-regulated in B1 B cells compare to FO B cells.

| Symbol | Ensembl gene id | logFC (B1/FO) | adj.P.val | Annotation |
|---|---|---|---|---|
| Ahnak2 | ENSMUSG00000072812 | 9.54487978 | 3.60E-139 | AHNAK nucleoprotein 2 [Source:MGI Symbol;Acc:MGI:2144831] |
| Il23r | ENSMUSG00000049093 | 9.53705777 | 1.53E-117 | interleukin 23 receptor [Source:MGI Symbol;Acc:MGI:2181693] |
| Tnfrsf8 | ENSMUSG00000028602 | 9.45552261 | 1.99E-26 | tumor necrosis factor receptor superfamily, member 8 [Source:MGI Symbol;Acc:MGI:99908] |
| Gramd2 | ENSMUSG00000074259 | 8.73548006 | 2.45E-45 | GRAM domain containing 2 [Source:MGI Symbol;Acc:MGI:3528937] |
| Gnb3 | ENSMUSG00000023439 | 8.6464149 | 1.33E-31 | guanine nucleotide binding protein (G protein), beta 3 [Source:MGI Symbol;Acc:MGI:95785] |
| Ctla4 | ENSMUSG00000026011 | 8.58341643 | 4.39E-70 | cytotoxic T-lymphocyte-associated protein 4 [Source:MGI Symbol;Acc:MGI:88556] |
| Ankrd55 | ENSMUSG00000049985 | 8.46836226 | 1.08E-09 | ankyrin repeat domain 55 [Source:MGI Symbol;Acc:MGI:1924568] |
| Mall | ENSMUSG00000027377 | 8.36452615 | 4.83E-09 | mal, T cell differentiation protein-like [Source:MGI Symbol;Acc:MGI:2385152] |
| Gm30382 | ENSMUSG00000106515 | 8.27571661 | 1.60E-08 | predicted gene, 30382 [Source:MGI Symbol;Acc:MGI:5589541] |
| Pcdh9 | ENSMUSG00000055421 | 8.20532705 | 4.02E-08 | protocadherin 9 [Source:MGI Symbol;Acc:MGI:1306801] |
| Gm8848 | ENSMUSG00000106031 | 8.20532705 | 4.02E-08 | predicted gene 8848 [Source:MGI Symbol;Acc:MGI:3647327] |
| Igkv1-117 | ENSMUSG00000094335 | 8.1526042 | 3.16E-23 | immunoglobulin kappa variable 1-117 [Source:MGI Symbol;Acc:MGI:4439721] |
| Oosp1 | ENSMUSG00000041857 | 8.01419342 | 2.88E-21 | oocyte secreted protein 1 [Source:MGI Symbol;Acc:MGI:2149290] |
| Ighv5-9-1 | ENSMUSG00000095210 | 7.98442517 | 1.34E-20 | immunoglobulin heavy variable 5-9-1 [Source:MGI Symbol;Acc:MGI:4439810] |
| Atf3 | ENSMUSG00000026628 | 7.88921363 | 3.22E-27 | activating transcription factor 3 [Source:MGI Symbol;Acc:MGI:109384] |
| Lmo7 | ENSMUSG00000033060 | 7.85527034 | 3.32E-114 | LIM domain only 7 [Source:MGI Symbol;Acc:MGI:1353586] |
| Igkv8-27 | ENSMUSG00000076580 | 7.79607645 | 3.37E-11 | immunoglobulin kappa chain variable 8-27 [Source:MGI Symbol;Acc:MGI:4439868] |
| Krt8 | ENSMUSG00000049382 | 7.75786623 | 5.42E-06 | keratin 8 [Source:MGI Symbol;Acc:MGI:96705] |
| Alox15 | ENSMUSG00000018924 | 7.73198799 | 1.29E-24 | arachidonate 15-lipoxygenase [Source:MGI Symbol;Acc:MGI:87997] |
| S100a4 | ENSMUSG00000001020 | 7.63678417 | 1.58E-147 | S100 calcium binding protein A4 [Source:MGI Symbol;Acc:MGI:1330282] |
| Cacna1s | ENSMUSG00000026407 | 7.55000297 | 3.45E-50 | calcium channel, voltage-dependent, L type, alpha 1S subunit [Source:MGI Symbol;Acc:MGI:88294] |
| B430305J03Rik | ENSMUSG00000053706 | 7.50788664 | 4.70E-05 | RIKEN cDNA B430305J03 gene [Source:MGI Symbol;Acc:MGI:3697707] |
| B020031M17Ril | ENSMUSG00000078537 | 7.4277158 | 8.62E-05 | RIKEN cDNA B020031M17 gene [Source:MGI Symbol;Acc:MGI:3588226] |
| Serpinb2 | ENSMUSG00000062345 | 7.38589537 | 0.000118 | serine (or cysteine) peptidase inhibitor, clade B, member 2 [Source:MGI Symbol;Acc:MGI:97609] |
| Tnfrsf19 | ENSMUSG00000060548 | 7.37850005 | 2.08E-25 | tumor necrosis factor receptor superfamily, member 19 [Source:MGI Symbol;Acc:MGI:1352474] |
| Ryk | ENSMUSG00000032547 | 7.3022993 | 0.002882 | receptor-like tyrosine kinase [Source:MGI Symbol;Acc:MGI:101766] |
| Stk39 | ENSMUSG00000027030 | 7.29084026 | 6.62E-08 | serine/threonine kinase 39 [Source:MGI Symbol;Acc:MGI:1858416] |
| Ephb4 | ENSMUSG00000029710 | 7.25262794 | 0.000296 | Eph receptor B4 [Source:MGI Symbol;Acc:MGI:104757] |
| Smarca5-ps | ENSMUSG00000052912 | 7.25262794 | 0.000296 | SWI/SNF related, matrix associated, actin depenent ragulator of chromatin, subfamily a, member 5, pseudogene [Source:MGI Symbol;Acc:MGI:2443330] |
| Ighg2c | ENSMUSG00000076612 | 7.18059131 | 3.29E-12 | immunoglobulin heavy constant gamma 2C [Source:MGI Symbol;Acc:MGI:2686979] |
| Fbxw13 | ENSMUSG00000049314 | 7.16270004 | 0.003309 | F-box and WD-40 domain protein 13 [Source:MGI Symbol;Acc:MGI:3505590] |
| Igkv8-30 | ENSMUSG00000076577 | 7.10578547 | 0.000745 | immunoglobulin kappa chain variable 8-30 [Source:MGI Symbol;Acc:MGI:3642250] |
| Prox1 | ENSMUSG00000010175 | 7.07173551 | 2.48E-11 | prospero homeobox 1 [Source:MGI Symbol;Acc:MGI:97772] |
| Gas7 | ENSMUSG00000033066 | 7.02158498 | 1.48E-50 | growth arrest specific 7 [Source:MGI Symbol;Acc:MGI:1202388] |
| Cxcl13 | ENSMUSG00000023078 | 6.88339119 | 0.002467 | chemokine (C-X-C motif) ligand 13 [Source:MGI Symbol;Acc:MGI:1888499] |
| Sox5 | ENSMUSG00000041540 | 6.88079455 | 1.13E-234 | SRY (sex determining region Y)-box 5 [Source:MGI Symbol;Acc:MGI:98367] |
| Tppp3 | ENSMUSG00000014846 | 6.77639564 | 5.31E-150 | tubulin polymerization-promoting protein family member 3 [Source:MGI Symbol;Acc:MGI:1915221] |
| Saa3 | ENSMUSG00000040026 | 6.77481322 | 3.92E-09 | serum amyloid A 3 [Source:MGI Symbol;Acc:MGI:98223] |
| Nid1 | ENSMUSG00000005397 | 6.75517247 | 0 | nidogen 1 [Source:MGI Symbol;Acc:MGI:97342] |
| Alb | ENSMUSG00000029368 | 6.69074428 | 0.006086 | albumin [Source:MGI Symbol;Acc:MGI:87991] |
| Gm15228 | ENSMUSG00000087340 | 6.66292559 | 4.85E-39 | predicted gene 15228 [Source:MGI Symbol;Acc:MGI:3705118] |
| Gm4204 | ENSMUSG00000079139 | 6.62035422 | 0.008103 | predicted gene 4204 [Source:MGI Symbol;Acc:MGI:3782381] |
| AF067061 | ENSMUSG00000095071 | 6.62035422 | 0.008103 | cDNA sequence AF067061 [Source:MGI Symbol;Acc:MGI:2681166] |
| Neurod4 | ENSMUSG00000048015 | 6.52435507 | 1.10E-10 | neurogenic differentiation 4 [Source:MGI Symbol;Acc:MGI:108055] |
| Anxa2 | ENSMUSG00000032231 | 6.52167497 | 2.60E-120 | annexin A2 [Source:MGI Symbol;Acc:MGI:88246] |
| Nbl1 | ENSMUSG00000041120 | 6.51270234 | 1.21E-07 | neuroblastoma, suppression of tumorigenicity 1 [Source:MGI Symbol;Acc:MGI:104591] |
| S100a6 | ENSMUSG00000001025 | 6.48832093 | 6.17E-86 | S100 calcium binding protein A6 (calcyclin) [Source:MGI Symbol;Acc:MGI:1339467] |
| Fgl2 | ENSMUSG00000039899 | 6.47231213 | 5.51E-133 | fibrinogen-like protein 2 [Source:MGI Symbol;Acc:MGI:103266] |
| Gpr55 | ENSMUSG00000049608 | 6.46648106 | 8.89E-87 | G protein-coupled receptor 55 [Source:MGI Symbol;Acc:MGI:2685064] |
| Tnfsf8 | ENSMUSG00000028362 | 6.4618476 | 2.39E-19 | tumor necrosis factor (ligand) superfamily, member 8 [Source:MGI Symbol;Acc:MGI:88328] |
| Gbp2b | ENSMUSG00000040264 | 6.3895126 | 1.67E-12 | guanylate binding protein 2b [Source:MGI Symbol;Acc:MGI:95666] |
| Tppp | ENSMUSG00000021573 | 6.38515847 | 1.52E-252 | tubulin polymerization promoting protein [Source:MGI Symbol;Acc:MGI:1920198] |
| Oosp2 | ENSMUSG00000055895 | 6.29083742 | 0.000904 | oocyte secreted protein 2 [Source:MGI Symbol;Acc:MGI:2684945] |
| Ckb | ENSMUSG00000001270 | 6.19493123 | 1.27E-05 | creatine kinase, brain [Source:MGI Symbol;Acc:MGI:88407] |
| Rgs13 | ENSMUSG00000051079 | 6.06105522 | 5.77E-08 | regulator of G-protein signaling 13 [Source:MGI Symbol;Acc:MGI:2180585] |
| Sh2d1b1 | ENSMUSG00000102418 | 6.00117917 | 4.96E-25 | SH2 domain containing 1B1 [Source:MGI Symbol;Acc:MGI:1349420] |
| Bcl2a1a | ENSMUSG00000102037 | 5.98049543 | 0.003154 | B cell leukemia/lymphoma 2 related protein A1a [Source:MGI Symbol;Acc:MGI:102687] |
| Slc39a4 | ENSMUSG00000063354 | 5.93808453 | 2.52E-11 | solute carrier family 39 (zinc transporter), member 4 [Source:MGI Symbol;Acc:MGI:1919277] |
| Zbtb32 | ENSMUSG00000006310 | 5.90470238 | 8.32E-256 | zinc finger and BTB domain containing 32 [Source:MGI Symbol;Acc:MGI:1891838] |
| Gm4761 | ENSMUSG00000096086 | 5.79606987 | 0.007525 | predicted gene 4761 [Source:MGI Symbol;Acc:MGI:3648855] |
| Gstt1 | ENSMUSG00000001663 | 5.79606984 | 0.007364 | glutathione S-transferase, theta 1 [Source:MGI Symbol;Acc:MGI:107379] |
| Asns | ENSMUSG00000029752 | 5.76248705 | 1.02E-16 | asparagine synthetase [Source:MGI Symbol;Acc:MGI:1350929] |
| Cd80 | ENSMUSG00000075122 | 5.7388582 | 1.24E-85 | CD80 antigen [Source:MGI Symbol;Acc:MGI:101775] |
| Ighv5-16 | ENSMUSG00000094194 | 5.72895528 | 0.009876 | immunoglobulin heavy variable 5-16 [Source:MGI Symbol;Acc:MGI:4439556] |
| Igkv4-70 | ENSMUSG00000076547 | 5.71043992 | 5.48E-06 | immunoglobulin kappa chain variable 4-70 [Source:MGI Symbol;Acc:MGI:2686348] |
| Nr3c2 | ENSMUSG00000031618 | 5.70887188 | 7.80E-26 | nuclear receptor subfamily 3, group C, member 2 [Source:MGI Symbol;Acc:MGI:99459] |
| Apol10b | ENSMUSG00000050014 | 5.68645578 | 0.000322 | apolipoprotein L 10B [Source:MGI Symbol;Acc:MGI:3043522] |
| Tubb3 | ENSMUSG00000062380 | 5.68407008 | 3.63E-17 | tubulin, beta 3 class III [Source:MGI Symbol;Acc:MGI:107813] |
| Phldb1 | ENSMUSG00000048537 | 5.66418409 | 1.16E-05 | pleckstrin homology like domain, family B, member 1 [Source:MGI Symbol;Acc:MGI:2143230] |

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| | | | | |
|---|---|---|---|---|
| Tacstd2 | ENSMUSG00000051397 | 5.57158231 | 1.63E-05 | tumor-associated calcium signal transducer 2 [Source:MGI Symbol;Acc:MGI:1861606] |
| Prdm1 | ENSMUSG00000038151 | 5.53416195 | 3.26E-41 | PR domain containing 1, with ZNF domain [Source:MGI Symbol;Acc:MGI:99655] |
| Ddx3y | ENSMUSG00000069045 | 5.53096742 | 1.30E-71 | DEAD (Asp-Glu-Ala-Asp) box polypeptide 3, Y-linked [Source:MGI Symbol;Acc:MGI:1349406] |
| 2210408F21Rik | ENSMUSG00000087380 | 5.5135502 | 0.000976 | RIKEN cDNA 2210408F21 gene [Source:MGI Symbol;Acc:MGI:1920902] |
| Igkv14-111 | ENSMUSG00000095771 | 5.49713529 | 3.84E-49 | immunoglobulin kappa variable 14-111 [Source:MGI Symbol;Acc:MGI:4439863] |
| Bag3 | ENSMUSG00000030847 | 5.47761838 | 6.11E-05 | BCL2-associated athanogene 3 [Source:MGI Symbol;Acc:MGI:1352493] |
| Mocos | ENSMUSG00000039616 | 5.46175673 | 5.90E-16 | molybdenum cofactor sulfurase [Source:MGI Symbol;Acc:MGI:1915841] |
| Havcr1 | ENSMUSG00000040405 | 5.44645211 | 3.47E-07 | hepatitis A virus cellular receptor 1 [Source:MGI Symbol;Acc:MGI:2159680] |
| Itga5 | ENSMUSG00000000555 | 5.43337849 | 4.55E-09 | integrin alpha 5 (fibronectin receptor alpha) [Source:MGI Symbol;Acc:MGI:96604] |
| Murc | ENSMUSG00000028348 | 5.4309653 | 0.002386 | caveolae associated 4 [Source:MGI Symbol;Acc:MGI:1915266] |
| Robo1 | ENSMUSG00000022883 | 5.29183881 | 5.99E-16 | roundabout guidance receptor 1 [Source:MGI Symbol;Acc:MGI:1274781] |
| Igkv4-91 | ENSMUSG00000076532 | 5.27914332 | 0.000296 | immunoglobulin kappa chain variable 4-91 [Source:MGI Symbol;Acc:MGI:3642277] |
| Msr1 | ENSMUSG00000025044 | 5.26064758 | 0.000251 | macrophage scavenger receptor 1 [Source:MGI Symbol;Acc:MGI:98257] |
| Adgre1 | ENSMUSG00000004730 | 5.18831597 | 2.58E-43 | adhesion G protein-coupled receptor E1 [Source:MGI Symbol;Acc:MGI:106912] |
| F5 | ENSMUSG00000026579 | 5.15017105 | 2.28E-09 | coagulation factor V [Source:MGI Symbol;Acc:MGI:88382] |
| Fras1 | ENSMUSG00000034687 | 5.14757181 | 0.00055 | Fraser extracellular matrix complex subunit 1 [Source:MGI Symbol;Acc:MGI:2385368] |
| Jchain | ENSMUSG00000067149 | 5.14416554 | 1.90E-45 | immunoglobulin joining chain [Source:MGI Symbol;Acc:MGI:96493] |
| Igkv4-59 | ENSMUSG00000094006 | 5.12736282 | 1.30E-08 | immunoglobulin kappa variable 4-59 [Source:MGI Symbol;Acc:MGI:3646808] |
| C1qc | ENSMUSG00000036896 | 5.0773607 | 8.22E-07 | complement component 1, q subcomponent, C chain [Source:MGI Symbol;Acc:MGI:88225] |
| Ighg3 | ENSMUSG00000076615 | 5.04705959 | 1.43E-82 | Immunoglobulin heavy constant gamma 3 [Source:MGI Symbol;Acc:MGI:2144790] |
| Igkv1-135 | ENSMUSG00000096336 | 5.01437081 | 9.33E-31 | immunoglobulin kappa variable 1-135 [Source:MGI Symbol;Acc:MGI:3819952] |
| Slpi | ENSMUSG00000017002 | 5.01157137 | 1.58E-06 | secretory leukocyte peptidase inhibitor [Source:MGI Symbol;Acc:MGI:109297] |
| Prkar2b | ENSMUSG00000002997 | 4.95775592 | 3.97E-109 | protein kinase, cAMP dependent regulatory, type II beta [Source:MGI Symbol;Acc:MGI:97760] |
| Gm15472 | ENSMUSG00000084760 | 4.94786031 | 1.90E-18 | predicted gene 15472 [Source:MGI Symbol;Acc:MGI:3707328] |
| Mgst1 | ENSMUSG00000008540 | 4.90403984 | 3.99E-13 | microsomal glutathione S-transferase 1 [Source:MGI Symbol;Acc:MGI:1913850] |
| Tbc1d4 | ENSMUSG00000033083 | 4.88858887 | 3.70E-13 | TBC1 domain family, member 4 [Source:MGI Symbol;Acc:MGI:2429660] |
| Lyz2 | ENSMUSG00000069516 | 4.88686584 | 7.94E-74 | lysozyme 2 [Source:MGI Symbol;Acc:MGI:96897] |
| Mrc1 | ENSMUSG00000026712 | 4.8391219 | 1.43E-16 | mannose receptor, C type 1 [Source:MGI Symbol;Acc:MGI:97142] |
| Acacb | ENSMUSG00000042010 | 4.82713556 | 6.20E-10 | acetyl-Coenzyme A carboxylase beta [Source:MGI Symbol;Acc:MGI:2140940] |
| Ighg2b | ENSMUSG00000076613 | 4.71372594 | 5.63E-132 | immunoglobulin heavy constant gamma 2B [Source:MGI Symbol;Acc:MGI:96445] |
| Bhlhe41 | ENSMUSG00000030256 | 4.70715259 | 8.31E-162 | basic helix-loop-helix family, member e41 [Source:MGI Symbol;Acc:MGI:1930704] |
| Ighv2-5 | ENSMUSG00000096498 | 4.68439609 | 0.008924 | immunoglobulin heavy variable 2-5 [Source:MGI Symbol;Acc:MGI:4439517] |
| Mpeg1 | ENSMUSG00000046805 | 4.67419436 | 8.17E-218 | macrophage expressed gene 1 [Source:MGI Symbol;Acc:MGI:1333743] |
| Igkv5-48 | ENSMUSG00000076563 | 4.65477534 | 2.56E-21 | immunoglobulin kappa variable 5-48 [Source:MGI Symbol;Acc:MGI:3642817] |
| Mafa | ENSMUSG00000047591 | 4.63336851 | 1.78E-05 | v-maf musculoaponeurotic fibrosarcoma oncogene family, protein A (avian) [Source:MGI Symbol;Acc:MGI:2673307] |
| Shtn1 | ENSMUSG00000041362 | 4.63206899 | 0.000169 | shootin 1 [Source:MGI Symbol;Acc:MGI:1918903] |
| Gpx7 | ENSMUSG00000028597 | 4.62885757 | 1.90E-05 | glutathione peroxidase 7 [Source:MGI Symbol;Acc:MGI:1914555] |
| Plcd3 | ENSMUSG00000020937 | 4.62732701 | 3.39E-22 | phospholipase C, delta 3 [Source:MGI Symbol;Acc:MGI:107451] |
| Eif2s3y | ENSMUSG00000069049 | 4.62376199 | 7.38E-36 | eukaryotic translation initiation factor 2, subunit 3, structural gene Y-linked [Source:MGI Symbol;Acc:MGI:1349430] |
| Aicda | ENSMUSG00000040627 | 4.59141019 | 1.77E-28 | activation-induced cytidine deaminase [Source:MGI Symbol;Acc:MGI:1342279] |
| Nrp2 | ENSMUSG00000025969 | 4.5802867 | 3.21E-130 | neuropilin 2 [Source:MGI Symbol;Acc:MGI:1100492] |
| Tmeff1 | ENSMUSG00000028347 | 4.5607213 | 1.41E-21 | transmembrane protein with EGF-like and two follistatin-like domains 1 [Source:MGI Symbol;Acc:MGI:1926810] |
| Hmgn3 | ENSMUSG00000066456 | 4.54846813 | 2.98E-33 | high mobility group nucleosomal binding domain 3 [Source:MGI Symbol;Acc:MGI:2138069] |
| Chia1 | ENSMUSG00000062778 | 4.53012036 | 0.001232 | chitinase, acidic 1 [Source:MGI Symbol;Acc:MGI:1932052] |
| Gm37121 | ENSMUSG00000103032 | 4.50631329 | 2.95E-06 | predicted gene, 37121 [Source:MGI Symbol;Acc:MGI:5610349] |
| Abca9 | ENSMUSG00000041797 | 4.49183639 | 0.006148 | ATP-binding cassette, sub-family A (ABC1), member 9 [Source:MGI Symbol;Acc:MGI:2386796] |
| Bmpr1a | ENSMUSG00000021796 | 4.48271582 | 1.36E-12 | bone morphogenetic protein receptor, type 1A [Source:MGI Symbol;Acc:MGI:1338938] |
| Atxn1 | ENSMUSG00000046876 | 4.44636383 | 9.88E-163 | ataxin 1 [Source:MGI Symbol;Acc:MGI:104783] |
| Gm5547 | ENSMUSG00000104835 | 4.41766513 | 0.000589 | predicted gene 5547 [Source:MGI Symbol;Acc:MGI:3648206] |
| Tbc1d9 | ENSMUSG00000031709 | 4.40293956 | 1.50E-10 | TBC1 domain family, member 9 [Source:MGI Symbol;Acc:MGI:1918560] |
| Igkv16-104 | ENSMUSG00000076522 | 4.3908707 | 1.25E-08 | immunoglobulin kappa variable 16-104 [Source:MGI Symbol;Acc:MGI:2685913] |
| Tubb6 | ENSMUSG00000001473 | 4.36905201 | 9.84E-57 | tubulin, beta 6 class V [Source:MGI Symbol;Acc:MGI:1915201] |
| Gm2399 | ENSMUSG00000078141 | 4.34532571 | 0.002025 | predicted gene 2399 [Source:MGI Symbol;Acc:MGI:3780567] |
| Ptpn22 | ENSMUSG00000027843 | 4.34475531 | 2.40E-232 | protein tyrosine phosphatase, non-receptor type 22 (lymphoid) [Source:MGI Symbol;Acc:MGI:107170] |
| Diras2 | ENSMUSG00000047842 | 4.32732232 | 7.54E-190 | DIRAS family, GTP-binding RAS-like 2 [Source:MGI Symbol;Acc:MGI:1915453] |
| Il6st | ENSMUSG00000021756 | 4.25612135 | 0 | interleukin 6 signal transducer [Source:MGI Symbol;Acc:MGI:96560] |
| Specc1 | ENSMUSG00000042331 | 4.24398416 | 1.11E-81 | sperm antigen with calponin homology and coiled-coil domains 1 [Source:MGI Symbol;Acc:MGI:2442356] |
| Myo18b | ENSMUSG00000072720 | 4.23759736 | 0.000382 | myosin XVIIIb [Source:MGI Symbol;Acc:MGI:1921626] |
| Fcgr4 | ENSMUSG00000059089 | 4.22222951 | 1.50E-05 | Fc receptor, IgG, low affinity IV [Source:MGI Symbol;Acc:MGI:2179523] |
| Gm37205 | ENSMUSG00000103656 | 4.22193828 | 1.99E-05 | predicted gene, 37205 [Source:MGI Symbol;Acc:MGI:5610433] |
| Chst7 | ENSMUSG00000037347 | 4.21587762 | 1.55E-20 | carbohydrate (N-acetylglucosamino) sulfotransferase 7 [Source:MGI Symbol;Acc:MGI:1891767] |
| Hepacam2 | ENSMUSG00000044156 | 4.20695924 | 6.86E-100 | HEPACAM family member 2 [Source:MGI Symbol;Acc:MGI:2141520] |
| Cacna1e | ENSMUSG00000004110 | 4.2053529 | 1.01E-52 | calcium channel, voltage-dependent, R type, alpha 1E subunit [Source:MGI Symbol;Acc:MGI:106217] |
| Emb | ENSMUSG00000021728 | 4.19874442 | 1.20E-50 | embigin [Source:MGI Symbol;Acc:MGI:95321] |
| Rtn4rl1 | ENSMUSG00000045287 | 4.18259253 | 4.45E-10 | reticulon 4 receptor-like 1 [Source:MGI Symbol;Acc:MGI:2661375] |
| Gm2619 | ENSMUSG00000091199 | 4.17721411 | 4.64E-19 | predicted gene 2619 [Source:MGI Symbol;Acc:MGI:3780787] |
| Asph | ENSMUSG00000028207 | 4.17345341 | 8.09E-65 | aspartate-beta-hydroxylase [Source:MGI Symbol;Acc:MGI:1914186] |
| Lysmd2 | ENSMUSG00000032184 | 4.16401778 | 2.62E-06 | LysM, putative peptidoglycan-binding, domain containing 2 [Source:MGI Symbol;Acc:MGI:1917332] |
| Lmna | ENSMUSG00000028063 | 4.14803575 | 2.57E-101 | lamin A [Source:MGI Symbol;Acc:MGI:96794] |
| Plxdc2 | ENSMUSG00000026748 | 4.12419423 | 0.000328 | plexin domain containing 2 [Source:MGI Symbol;Acc:MGI:1914698] |
| Ppl | ENSMUSG00000039457 | 4.11105784 | 7.95E-60 | periplakin [Source:MGI Symbol;Acc:MGI:1194898] |
| Cldn10 | ENSMUSG00000022132 | 4.1083815 | 1.17E-13 | claudin 10 [Source:MGI Symbol;Acc:MGI:1913101] |
| Tjp2 | ENSMUSG00000024812 | 4.10029983 | 1.46E-17 | tight junction protein 2 [Source:MGI Symbol;Acc:MGI:1341872] |
| Il5ra | ENSMUSG00000005364 | 4.08544201 | 6.71E-52 | interleukin 5 receptor, alpha [Source:MGI Symbol;Acc:MGI:96558] |
| C1qb | ENSMUSG00000036905 | 4.08209457 | 4.43E-05 | complement component 1, q subcomponent, beta polypeptide [Source:MGI Symbol;Acc:MGI:88224] |

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|---|---|---|---|---|
| Ak8 | ENSMUSG00000026807 | 4.0818583 | 9.00E-07 | adenylate kinase 8 [Source:MGI Symbol;Acc:MGI:1916120] |
| Tub | ENSMUSG00000031028 | 4.07613245 | 1.14E-45 | tubby bipartite transcription factor [Source:MGI Symbol;Acc:MGI:2651573] |
| Dkkl1 | ENSMUSG00000030792 | 4.07172075 | 3.46E-18 | dickkopf-like 1 [Source:MGI Symbol;Acc:MGI:1354963] |
| Sspn | ENSMUSG00000030255 | 4.06421375 | 4.11E-25 | sarcospan [Source:MGI Symbol;Acc:MGI:1353511] |
| Mageh1 | ENSMUSG00000047238 | 4.06251046 | 0.007911 | melanoma antigen, family H, 1 [Source:MGI Symbol;Acc:MGI:1922875] |
| Bco2 | ENSMUSG00000032066 | 4.03365302 | 2.10E-13 | beta-carotene oxygenase 2 [Source:MGI Symbol;Acc:MGI:2177469] |
| Crip2 | ENSMUSG00000006356 | 4.02025336 | 5.04E-10 | cysteine rich protein 2 [Source:MGI Symbol;Acc:MGI:1915587] |
| Rassf4 | ENSMUSG00000042129 | 4.01447208 | 6.60E-276 | Ras association (RalGDS/AF-6) domain family member 4 [Source:MGI Symbol;Acc:MGI:2386853] |
| Cxcr3 | ENSMUSG00000050232 | 3.9931073 | 0.000352 | chemokine (C-X-C motif) receptor 3 [Source:MGI Symbol;Acc:MGI:1277207] |
| Rhobtb1 | ENSMUSG00000019944 | 3.97776028 | 4.08E-22 | Rho-related BTB domain containing 1 [Source:MGI Symbol;Acc:MGI:1916538] |
| Tubb2b | ENSMUSG00000045136 | 3.95852997 | 6.30E-59 | tubulin, beta 2B class IIB [Source:MGI Symbol;Acc:MGI:1920960] |
| Itgb1 | ENSMUSG00000025809 | 3.93737032 | 5.48E-237 | integrin beta 1 (fibronectin receptor beta) [Source:MGI Symbol;Acc:MGI:96610] |
| Fam46c | ENSMUSG00000044468 | 3.91874239 | 8.61E-26 | family with sequence similarity 46, member C [Source:MGI Symbol;Acc:MGI:1921895] |
| Ahnak | ENSMUSG00000069833 | 3.89701857 | 0 | AHNAK nucleoprotein (desmoyokin) [Source:MGI Symbol;Acc:MGI:1316648] |
| Fcrl5 | ENSMUSG00000048031 | 3.89676514 | 9.04E-42 | Fc receptor-like 5 [Source:MGI Symbol;Acc:MGI:3053558] |
| Dnase1l3 | ENSMUSG00000025279 | 3.8959151 | 1.04E-60 | deoxyribonuclease 1-like 3 [Source:MGI Symbol;Acc:MGI:1314633] |
| Ifi211 | ENSMUSG00000026536 | 3.8820569 | 7.61E-12 | interferon activated gene 211 [Source:MGI Symbol;Acc:MGI:3041120] |
| Gas2l1 | ENSMUSG00000034201 | 3.87009968 | 2.70E-06 | growth arrest-specific 2 like 1 [Source:MGI Symbol;Acc:MGI:1926176] |
| Cdc42bpb | ENSMUSG00000021279 | 3.86887214 | 4.86E-83 | CDC42 binding protein kinase beta [Source:MGI Symbol;Acc:MGI:2136459] |
| Lgals1 | ENSMUSG00000068220 | 3.83775077 | 8.08E-81 | lectin, galactose binding, soluble 1 [Source:MGI Symbol;Acc:MGI:96777] |
| Slc34a1 | ENSMUSG00000021490 | 3.82901032 | 6.39E-05 | solute carrier family 34 (sodium phosphate), member 1 [Source:MGI Symbol;Acc:MGI:1345284] |
| Igkv1-110 | ENSMUSG00000093861 | 3.82745583 | 3.70E-11 | immunoglobulin kappa variable 1-110 [Source:MGI Symbol;Acc:MGI:4439558] |
| Thbs1 | ENSMUSG00000040152 | 3.82064989 | 8.13E-12 | thrombospondin 1 [Source:MGI Symbol;Acc:MGI:98737] |
| A630023P12Rik | ENSMUSG00000048215 | 3.79444548 | 0.007447 | RIKEN cDNA A630023P12 gene [Source:MGI Symbol;Acc:MGI:2445162] |
| Ccdc109b | ENSMUSG00000027994 | 3.79420289 | 0.009095 | mitochondrial calcium uniporter dominant negative beta subunit [Source:MGI Symbol;Acc:MGI:1914065] |
| Akap1 | ENSMUSG00000018428 | 3.76623665 | 0.007756 | A kinase (PRKA) anchor protein 1 [Source:MGI Symbol;Acc:MGI:104729] |
| Gm43065 | ENSMUSG00000105986 | 3.7613787 | 7.55E-27 | predicted gene 43065 [Source:MGI Symbol;Acc:MGI:5663202] |
| St8sia6 | ENSMUSG00000003418 | 3.75474214 | 1.12E-57 | ST8 alpha-N-acetyl-neuraminide alpha-2,8-sialyltransferase 6 [Source:MGI Symbol;Acc:MGI:2386797] |
| Afdn | ENSMUSG00000068036 | 3.74567983 | 1.42E-38 | afadin, adherens junction formation factor [Source:MGI Symbol;Acc:MGI:1314653] |
| Emilin2 | ENSMUSG00000024053 | 3.73902326 | 2.52E-05 | elastin microfibril interfacer 2 [Source:MGI Symbol;Acc:MGI:2389136] |
| Krt222 | ENSMUSG00000035849 | 3.72400469 | 5.00E-83 | keratin 222 [Source:MGI Symbol;Acc:MGI:2442728] |
| Il2rb | ENSMUSG00000068227 | 3.70041675 | 9.87E-09 | interleukin 2 receptor, beta chain [Source:MGI Symbol;Acc:MGI:96550] |
| Itgam | ENSMUSG00000030786 | 3.69573596 | 1.98E-112 | integrin alpha M [Source:MGI Symbol;Acc:MGI:96607] |
| Ighg1 | ENSMUSG00000076614 | 3.69203749 | 4.45E-07 | immunoglobulin heavy constant gamma 1 (G1m marker) [Source:MGI Symbol;Acc:MGI:96446] |
| Nod1 | ENSMUSG00000038058 | 3.65176378 | 3.43E-51 | nucleotide-binding oligomerization domain containing 1 [Source:MGI Symbol;Acc:MGI:1341839] |
| Gm2427 | ENSMUSG00000101751 | 3.62253073 | 1.38E-05 | predicted gene 2427 [Source:MGI Symbol;Acc:MGI:3780593] |
| Dgat2 | ENSMUSG00000030747 | 3.6040277 | 0.002025 | diacylglycerol O-acyltransferase 2 [Source:MGI Symbol;Acc:MGI:1915050] |
| Cfh | ENSMUSG00000026365 | 3.59422761 | 0.000454 | complement component factor h [Source:MGI Symbol;Acc:MGI:88385] |
| Krt18 | ENSMUSG00000023043 | 3.5920272 | 0.001113 | keratin 18 [Source:MGI Symbol;Acc:MGI:96692] |
| Srgap3 | ENSMUSG00000030257 | 3.58542561 | 2.05E-38 | SLIT-ROBO Rho GTPase activating protein 3 [Source:MGI Symbol;Acc:MGI:2152938] |
| Kntc1 | ENSMUSG00000029414 | 3.58046427 | 0.000221 | kinetochore associated 1 [Source:MGI Symbol;Acc:MGI:2673709] |
| Arhgef12 | ENSMUSG00000059495 | 3.56910305 | 1.03E-91 | Rho guanine nucleotide exchange factor (GEF) 12 [Source:MGI Symbol;Acc:MGI:1916882] |
| Mcoln2 | ENSMUSG00000011008 | 3.560291 | 3.56E-109 | mucolipin 2 [Source:MGI Symbol;Acc:MGI:1915529] |
| Cyb5r2 | ENSMUSG00000048065 | 3.55319226 | 0.000609 | cytochrome b5 reductase 2 [Source:MGI Symbol;Acc:MGI:2444415] |
| Sirpa | ENSMUSG00000037902 | 3.54740698 | 5.41E-84 | signal-regulatory protein alpha [Source:MGI Symbol;Acc:MGI:108563] |
| Ypel2 | ENSMUSG00000018427 | 3.53329098 | 8.72E-72 | yippee-like 2 (Drosophila) [Source:MGI Symbol;Acc:MGI:1925114] |
| Gm7582 | ENSMUSG00000061852 | 3.5315037 | 2.75E-10 | predicted gene 7582 [Source:MGI Symbol;Acc:MGI:3643856] |
| Nfil3 | ENSMUSG00000056749 | 3.51919885 | 0.002915 | nuclear factor, interleukin 3, regulated [Source:MGI Symbol;Acc:MGI:109495] |
| Ptafr | ENSMUSG00000056529 | 3.50432468 | 2.96E-13 | platelet-activating factor receptor [Source:MGI Symbol;Acc:MGI:106066] |
| Csf2rb | ENSMUSG00000071713 | 3.50039398 | 9.80E-97 | colony stimulating factor 2 receptor, beta, low-affinity (granulocyte-macrophage) [Source:MGI Symbol;Acc:MGI:1339759] |
| P2ry12 | ENSMUSG00000036353 | 3.50005165 | 0.00483 | purinergic receptor P2Y, G-protein coupled 12 [Source:MGI Symbol;Acc:MGI:1918089] |
| Ednrb | ENSMUSG00000022122 | 3.49937416 | 0.00028 | endothelin receptor type B [Source:MGI Symbol;Acc:MGI:102720] |
| Crim1 | ENSMUSG00000024074 | 3.47938651 | 5.73E-32 | cysteine rich transmembrane BMP regulator 1 (chordin like) [Source:MGI Symbol;Acc:MGI:1354756] |
| Igkv9-120 | ENSMUSG00000094872 | 3.47206039 | 0.002568 | immunoglobulin kappa chain variable 9-120 [Source:MGI Symbol;Acc:MGI:3647784] |
| Slc1a4 | ENSMUSG00000020142 | 3.45768497 | 3.03E-07 | solute carrier family 1 (glutamate/neutral amino acid transporter), member 4 [Source:MGI Symbol;Acc:MGI:2135601] |
| Pdlim3 | ENSMUSG00000031636 | 3.42573727 | 0.00032 | PDZ and LIM domain 3 [Source:MGI Symbol;Acc:MGI:1859274] |
| Akap17b | ENSMUSG00000059708 | 3.42102949 | 5.99E-41 | A kinase (PRKA) anchor protein 17B [Source:MGI Symbol;Acc:MGI:2443758] |
| Lgals3 | ENSMUSG00000050335 | 3.38499401 | 2.22E-22 | lectin, galactose binding, soluble 3 [Source:MGI Symbol;Acc:MGI:96778] |
| Pon3 | ENSMUSG00000029759 | 3.38242922 | 2.06E-18 | paraoxonase 3 [Source:MGI Symbol;Acc:MGI:106686] |
| Igha | ENSMUSG00000095079 | 3.36254134 | 1.94E-35 | immunoglobulin heavy constant alpha [Source:MGI Symbol;Acc:MGI:96444] |
| Gm15433 | ENSMUSG00000096802 | 3.34994725 | 5.61E-22 | predicted pseudogene 15433 [Source:MGI Symbol;Acc:MGI:3705860] |
| Fam129a | ENSMUSG00000026483 | 3.34208698 | 2.34E-20 | family with sequence similarity 129, member A [Source:MGI Symbol;Acc:MGI:2137237] |
| Tubb2a | ENSMUSG00000058672 | 3.32881319 | 1.57E-31 | tubulin, beta 2A class IIA [Source:MGI Symbol;Acc:MGI:107861] |
| Cish | ENSMUSG00000032578 | 3.32151678 | 5.26E-07 | cytokine inducible SH2-containing protein [Source:MGI Symbol;Acc:MGI:103159] |
| Stom | ENSMUSG00000026880 | 3.30171075 | 4.12E-17 | stomatin [Source:MGI Symbol;Acc:MGI:95403] |
| Cubn | ENSMUSG00000026726 | 3.28923969 | 3.58E-14 | cubilin (intrinsic factor-cobalamin receptor) [Source:MGI Symbol;Acc:MGI:1931256] |
| Inppl1 | ENSMUSG00000032737 | 3.28391885 | 5.36E-33 | inositol polyphosphate phosphatase-like 1 [Source:MGI Symbol;Acc:MGI:1333787] |
| Ltbp4 | ENSMUSG00000040488 | 3.27590728 | 0.002091 | latent transforming growth factor beta binding protein 4 [Source:MGI Symbol;Acc:MGI:1321395] |
| C1qa | ENSMUSG00000036887 | 3.27468289 | 0.000481 | complement component 1, q subcomponent, alpha polypeptide [Source:MGI Symbol;Acc:MGI:88223] |
| Syn3 | ENSMUSG00000059602 | 3.26757727 | 1.52E-15 | synapsin III [Source:MGI Symbol;Acc:MGI:1351334] |
| Pmepa1 | ENSMUSG00000038400 | 3.2361293 | 0.003124 | prostate transmembrane protein, androgen induced 1 [Source:MGI Symbol;Acc:MGI:1929600] |
| Amigo2 | ENSMUSG00000048218 | 3.23514988 | 1.83E-14 | adhesion molecule with Ig like domain 2 [Source:MGI Symbol;Acc:MGI:2145995] |
| Rcn3 | ENSMUSG00000019539 | 3.22876355 | 3.45E-31 | reticulocalbin 3, EF-hand calcium binding domain [Source:MGI Symbol;Acc:MGI:1277122] |
| Trib1 | ENSMUSG00000032501 | 3.22027239 | 2.87E-16 | tribbles pseudokinase 1 [Source:MGI Symbol;Acc:MGI:2443397] |
| Fah | ENSMUSG00000030630 | 3.21896208 | 4.90E-11 | fumarylacetoacetate hydrolase [Source:MGI Symbol;Acc:MGI:95482] |
| Igkv12-44 | ENSMUSG00000096422 | 3.21840056 | 0.006835 | immunoglobulin kappa variable 12-44 [Source:MGI Symbol;Acc:MGI:4439775] |
| Nlrp1b | ENSMUSG00000070390 | 3.2159353 | 5.59E-06 | NLR family, pyrin domain containing 1B [Source:MGI Symbol;Acc:MGI:3582959] |

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|---|---|---|---|---|
| Gm16028 | ENSMUSG00000090252 | 3.21368368 | 2.12E-34 | predicted gene 16028 [Source:MGI Symbol;Acc:MGI:3801982] |
| Gbp2 | ENSMUSG00000028270 | 3.19480009 | 1.61E-68 | guanylate binding protein 2 [Source:MGI Symbol;Acc:MGI:102772] |
| Ets2 | ENSMUSG00000022895 | 3.17686058 | 4.47E-18 | E26 avian leukemia oncogene 2, 3' domain [Source:MGI Symbol;Acc:MGI:95456] |
| App | ENSMUSG00000022892 | 3.13273637 | 2.00E-13 | amyloid beta (A4) precursor protein [Source:MGI Symbol;Acc:MGI:88059] |
| Hist1h3c | ENSMUSG00000069310 | 3.12775222 | 0.008859 | histone cluster 1, H3c [Source:MGI Symbol;Acc:MGI:2448320] |
| Slamf9 | ENSMUSG00000026548 | 3.12325625 | 1.42E-14 | SLAM family member 9 [Source:MGI Symbol;Acc:MGI:1923692] |
| Abcb1b | ENSMUSG00000028970 | 3.10203924 | 7.58E-20 | ATP-binding cassette, sub-family B (MDR/TAP), member 1B [Source:MGI Symbol;Acc:MGI:97568] |
| Cd8b1 | ENSMUSG00000053044 | 3.10032414 | 5.57E-05 | CD8 antigen, beta chain 1 [Source:MGI Symbol;Acc:MGI:88347] |
| Vim | ENSMUSG00000026728 | 3.0997554 | 3.46E-35 | vimentin [Source:MGI Symbol;Acc:MGI:98932] |
| Il18 | ENSMUSG00000039217 | 3.09766344 | 6.89E-18 | interleukin 18 [Source:MGI Symbol;Acc:MGI:107936] |
| Sytl1 | ENSMUSG00000028860 | 3.08919181 | 1.56E-09 | synaptotagmin-like 1 [Source:MGI Symbol;Acc:MGI:1933365] |
| Ccr1 | ENSMUSG00000025804 | 3.07187242 | 1.63E-10 | chemokine (C-C motif) receptor 1 [Source:MGI Symbol;Acc:MGI:104618] |
| Nyap1 | ENSMUSG00000045348 | 3.06618591 | 0.000921 | neuronal tyrosine-phosphorylated phosphoinositide 3-kinase adaptor 1 [Source:MGI Symbol;Acc:MGI:2443880] |
| Rap1gap | ENSMUSG00000041351 | 3.06610689 | 6.29E-10 | Rap1 GTPase-activating protein [Source:MGI Symbol;Acc:MGI:109338] |
| Ntng2 | ENSMUSG00000035513 | 3.0568308 | 2.06E-17 | netrin G2 [Source:MGI Symbol;Acc:MGI:2159341] |
| Thbs3 | ENSMUSG00000028047 | 3.05633189 | 3.27E-16 | thrombospondin 3 [Source:MGI Symbol;Acc:MGI:98739] |
| Rab31 | ENSMUSG00000056515 | 3.04771291 | 2.79E-51 | RAB31, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:1914603] |
| Rab39b | ENSMUSG00000031202 | 3.01930613 | 0.008476 | RAB39B, member RAS oncogene family [Source:MGI Symbol;Acc:MGI:1915040] |
| Prkar2a | ENSMUSG00000032601 | 3.01463276 | 5.88E-36 | protein kinase, cAMP dependent regulatory, type II alpha [Source:MGI Symbol;Acc:MGI:108025] |
| Fam160a1 | ENSMUSG00000051000 | 3.01353022 | 0.000359 | family with sequence similarity 160, member A1 [Source:MGI Symbol;Acc:MGI:2444746] |
| Tmtc2 | ENSMUSG00000036019 | 3.01042269 | 4.11E-19 | transmembrane and tetratricopeptide repeat containing 2 [Source:MGI Symbol;Acc:MGI:1914057] |
| Mki67 | ENSMUSG00000031004 | 2.99868572 | 4.22E-25 | antigen identified by monoclonal antibody Ki 67 [Source:MGI Symbol;Acc:MGI:106035] |
| A530032D15Rik | ENSMUSG00000089844 | 2.99862599 | 6.34E-09 | RIKEN cDNA A530032D15Rik gene [Source:MGI Symbol;Acc:MGI:3037746] |
| Nacc2 | ENSMUSG00000026932 | 2.99657034 | 8.11E-12 | nucleus accumbens associated 2, BEN and BTB (POZ) domain containing [Source:MGI Symbol;Acc:MGI:1915241] |
| Lhpp | ENSMUSG00000030946 | 2.98736883 | 1.70E-07 | phospholysine phosphohistidine inorganic pyrophosphate phosphatase [Source:MGI Symbol;Acc:MGI:1923679] |
| Gm10552 | ENSMUSG00000073628 | 2.98085453 | 1.35E-25 | predicted gene 10552 [Source:MGI Symbol;Acc:MGI:3642083] |
| Sh2d6 | ENSMUSG00000052631 | 2.97417571 | 9.56E-09 | SH2 domain containing 6 [Source:MGI Symbol;Acc:MGI:1918380] |
| Bbc3 | ENSMUSG00000002083 | 2.96372387 | 1.31E-09 | BCL2 binding component 3 [Source:MGI Symbol;Acc:MGI:2181667] |
| Maged2 | ENSMUSG00000025268 | 2.95607526 | 0.000578 | melanoma antigen, family D, 2 [Source:MGI Symbol;Acc:MGI:1933391] |
| Plac8 | ENSMUSG00000029322 | 2.95200101 | 8.19E-154 | placenta-specific 8 [Source:MGI Symbol;Acc:MGI:2445289] |
| Igkv1-108 | ENSMUSG00000105043 | 2.94487406 | 8.39E-12 | immunoglobulin kappa variable 1-108 [Source:MGI Symbol;Acc:MGI:3644576] |
| Capn2 | ENSMUSG00000026509 | 2.93501956 | 9.49E-81 | calpain 2 [Source:MGI Symbol;Acc:MGI:88264] |
| Smyd2 | ENSMUSG00000026603 | 2.92973384 | 1.08E-06 | SET and MYND domain containing 2 [Source:MGI Symbol;Acc:MGI:1915889] |
| Enkur | ENSMUSG00000026679 | 2.89897049 | 3.09E-05 | enkurin, TRPC channel interacting protein [Source:MGI Symbol;Acc:MGI:1918483] |
| Rbm47 | ENSMUSG00000070780 | 2.89834651 | 2.63E-20 | RNA binding motif protein 47 [Source:MGI Symbol;Acc:MGI:2384294] |
| Gm16026 | ENSMUSG00000079455 | 2.890769 | 1.93E-31 | predicted pseudogene 16026 [Source:MGI Symbol;Acc:MGI:3783243] |
| Gm18342 | ENSMUSG00000101279 | 2.88956992 | 3.63E-07 | predicted gene, 18342 [Source:MGI Symbol;Acc:MGI:5010527] |
| Rnase4 | ENSMUSG00000021876 | 2.87448249 | 0.002915 | ribonuclease, RNase A family 4 [Source:MGI Symbol;Acc:MGI:1926217] |
| Gm3636 | ENSMUSG00000091754 | 2.87417824 | 0.000177 | predicted gene 3636 [Source:MGI Symbol;Acc:MGI:3781812] |
| Pde8a | ENSMUSG00000025584 | 2.86989914 | 3.13E-43 | phosphodiesterase 8A [Source:MGI Symbol;Acc:MGI:1277116] |
| Ccnd2 | ENSMUSG00000000184 | 2.8508498 | 1.94E-106 | cyclin D2 [Source:MGI Symbol;Acc:MGI:88314] |
| Epn2 | ENSMUSG00000001036 | 2.846011 | 1.66E-13 | epsin 2 [Source:MGI Symbol;Acc:MGI:1333766] |
| 6530402F18Rik | ENSMUSG00000079499 | 2.84285538 | 2.17E-39 | RIKEN cDNA 6530402F18 gene [Source:MGI Symbol;Acc:MGI:1923470] |
| Dgkh | ENSMUSG00000034731 | 2.82400399 | 8.22E-14 | diacylglycerol kinase, eta [Source:MGI Symbol;Acc:MGI:2444188] |
| Trabd2b | ENSMUSG00000070867 | 2.82197059 | 1.62E-06 | TraB domain containing 2B [Source:MGI Symbol;Acc:MGI:3650152] |
| Dse | ENSMUSG00000039497 | 2.82182276 | 2.68E-19 | dermatan sulfate epimerase [Source:MGI Symbol;Acc:MGI:2443455] |
| Vsir | ENSMUSG00000020101 | 2.79643588 | 7.84E-78 | V-set immunoregulatory receptor [Source:MGI Symbol;Acc:MGI:1921298] |
| Dmd | ENSMUSG00000045103 | 2.79410838 | 9.30E-15 | dystrophin, muscular dystrophy [Source:MGI Symbol;Acc:MGI:94909] |
| Igkv2-109 | ENSMUSG00000105606 | 2.78625665 | 3.00E-23 | immunoglobulin kappa variable 2-109 [Source:MGI Symbol;Acc:MGI:3642626] |
| Creb3l2 | ENSMUSG00000038648 | 2.78408605 | 1.13E-35 | cAMP responsive element binding protein 3-like 2 [Source:MGI Symbol;Acc:MGI:2442695] |
| Gm2065 | ENSMUSG00000102882 | 2.77800113 | 4.24E-10 | predicted gene 2065 [Source:MGI Symbol;Acc:MGI:3780232] |
| Bcl2a1d | ENSMUSG00000099974 | 2.76969565 | 5.87E-05 | B cell leukemia/lymphoma 2 related protein A1d [Source:MGI Symbol;Acc:MGI:1278325] |
| Pard3b | ENSMUSG00000052062 | 2.76821908 | 6.66E-28 | par-3 family cell polarity regulator beta [Source:MGI Symbol;Acc:MGI:1919301] |
| Rxra | ENSMUSG00000015846 | 2.75339584 | 8.97E-05 | retinoid X receptor alpha [Source:MGI Symbol;Acc:MGI:98214] |
| Cd44 | ENSMUSG00000005087 | 2.74543212 | 2.36E-140 | CD44 antigen [Source:MGI Symbol;Acc:MGI:88338] |
| Aldh1l2 | ENSMUSG00000020256 | 2.73774122 | 1.34E-21 | aldehyde dehydrogenase 1 family, member L2 [Source:MGI Symbol;Acc:MGI:2444680] |
| Spaca9 | ENSMUSG00000026809 | 2.72160172 | 0.003574 | sperm acrosome associated 9 [Source:MGI Symbol;Acc:MGI:1917237] |
| Dnaja4 | ENSMUSG00000032285 | 2.72099725 | 2.82E-07 | DnaJ heat shock protein family (Hsp40) member A4 [Source:MGI Symbol;Acc:MGI:1927638] |
| Ptprs | ENSMUSG00000013236 | 2.71346525 | 2.66E-44 | protein tyrosine phosphatase, receptor type, S [Source:MGI Symbol;Acc:MGI:97815] |
| Pdlim1 | ENSMUSG00000055044 | 2.71253311 | 3.46E-37 | PDZ and LIM domain 1 (elfin) [Source:MGI Symbol;Acc:MGI:1860611] |
| C130026I21Rik | ENSMUSG00000052477 | 2.71178723 | 6.43E-59 | RIKEN cDNA C130026I21 gene [Source:MGI Symbol;Acc:MGI:3612702] |
| Ahr | ENSMUSG00000019256 | 2.70633472 | 1.81E-07 | aryl-hydrocarbon receptor [Source:MGI Symbol;Acc:MGI:105043] |
| 2510009E07Rik | ENSMUSG00000043391 | 2.70201905 | 2.99E-06 | RIKEN cDNA 2510009E07 gene [Source:MGI Symbol;Acc:MGI:1919440] |
| Timd2 | ENSMUSG00000040413 | 2.6709165 | 0.001977 | T cell immunoglobulin and mucin domain containing 2 [Source:MGI Symbol;Acc:MGI:2159681] |
| Fads1 | ENSMUSG00000010663 | 2.66343531 | 0.005099 | fatty acid desaturase 1 [Source:MGI Symbol;Acc:MGI:1923517] |
| Nectin4 | ENSMUSG00000006411 | 2.65950877 | 0.000642 | nectin cell adhesion molecule 4 [Source:MGI Symbol;Acc:MGI:1918990] |
| Apobr | ENSMUSG00000042759 | 2.64497476 | 0.000732 | apolipoprotein B receptor [Source:MGI Symbol;Acc:MGI:2176230] |
| D430019H16Rik | ENSMUSG00000094910 | 2.63789779 | 1.12E-10 | RIKEN cDNA D430019H16 gene [Source:MGI Symbol;Acc:MGI:2443127] |
| Uck2 | ENSMUSG00000026558 | 2.62503803 | 1.24E-23 | uridine-cytidine kinase 2 [Source:MGI Symbol;Acc:MGI:1931744] |
| Slc25a13 | ENSMUSG00000015112 | 2.62340422 | 0.00603 | solute carrier family 25 (mitochondrial carrier, adenine nucleotide translocator), member 13 [Source:MGI Symbol;Acc:MGI:1354721] |
| Naprt | ENSMUSG00000022574 | 2.61035576 | 6.22E-06 | nicotinate phosphoribosyltransferase [Source:MGI Symbol;Acc:MGI:2442664] |
| Fut8 | ENSMUSG00000021065 | 2.60667594 | 2.11E-42 | fucosyltransferase 8 [Source:MGI Symbol;Acc:MGI:1858901] |
| Cntln | ENSMUSG00000038070 | 2.60640748 | 0.000611 | centlein, centrosomal protein [Source:MGI Symbol;Acc:MGI:2443104] |
| Klf10 | ENSMUSG00000037465 | 2.60569429 | 1.10E-08 | Kruppel-like factor 10 [Source:MGI Symbol;Acc:MGI:1101353] |
| Rnd3 | ENSMUSG00000017144 | 2.60552779 | 6.15E-21 | Rho family GTPase 3 [Source:MGI Symbol;Acc:MGI:1921444] |
| Tmem151b | ENSMUSG00000096847 | 2.6007186 | 1.42E-06 | transmembrane protein 151B [Source:MGI Symbol;Acc:MGI:2685169] |
| Lgr4 | ENSMUSG00000050199 | 2.59665979 | 0.000128 | leucine-rich repeat-containing G protein-coupled receptor 4 [Source:MGI Symbol;Acc:MGI:1891468] |
| Megf8 | ENSMUSG00000045039 | 2.59392594 | 2.89E-05 | multiple EGF-like-domains 8 [Source:MGI Symbol;Acc:MGI:2446294] |
| Gbp8 | ENSMUSG00000034438 | 2.58200934 | 6.18E-09 | guanylate-binding protein 8 [Source:MGI Symbol;Acc:MGI:1923324] |
| Itm2c | ENSMUSG00000026223 | 2.58047669 | 1.13E-22 | integral membrane protein 2C [Source:MGI Symbol;Acc:MGI:1927594] |
| Naip6 | ENSMUSG00000078942 | 2.57182381 | 1.00E-26 | NLR family, apoptosis inhibitory protein 6 [Source:MGI Symbol;Acc:MGI:1298222] |

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|---|---|---|---|---|
| Vwa5a | ENSMUSG00000023186 | 2.56942358 | 7.56E-37 | von Willebrand factor A domain containing 5A [Source:MGI Symbol;Acc:MGI:1915026] |
| Laptm4b | ENSMUSG00000022257 | 2.56504363 | 0.003971 | lysosomal-associated protein transmembrane 4B [Source:MGI Symbol;Acc:MGI:1890494] |
| Tspan17 | ENSMUSG00000025875 | 2.56384148 | 3.23E-09 | tetraspanin 17 [Source:MGI Symbol;Acc:MGI:1921507] |
| Ackr2 | ENSMUSG00000044534 | 2.55806738 | 3.08E-21 | atypical chemokine receptor 2 [Source:MGI Symbol;Acc:MGI:1891697] |
| Igkv2-107 | ENSMUSG00000106494 | 2.55723982 | 4.91E-07 | immunoglobulin kappa variable 2-107 [Source:MGI Symbol;Acc:MGI:3645630] |
| Hspg2 | ENSMUSG00000028763 | 2.55223814 | 6.42E-22 | perlecan (heparan sulfate proteoglycan 2) [Source:MGI Symbol;Acc:MGI:96257] |
| Slc20a2 | ENSMUSG00000037656 | 2.54915528 | 1.22E-37 | solute carrier family 20, member 2 [Source:MGI Symbol;Acc:MGI:97851] |
| Twsg1 | ENSMUSG00000024098 | 2.54020603 | 4.58E-39 | twisted gastrulation BMP signaling modulator 1 [Source:MGI Symbol;Acc:MGI:2137520] |
| Tmem154 | ENSMUSG00000056498 | 2.5314378 | 1.83E-66 | transmembrane protein 154 [Source:MGI Symbol;Acc:MGI:2444725] |
| Tcp11 | ENSMUSG00000062859 | 2.52390867 | 0.000164 | t-complex protein 11 [Source:MGI Symbol;Acc:MGI:98544] |
| Plekha5 | ENSMUSG00000030231 | 2.52120568 | 1.48E-12 | pleckstrin homology domain containing, family A member 5 [Source:MGI Symbol;Acc:MGI:1923802] |
| Gm16025 | ENSMUSG00000089652 | 2.48826007 | 4.03E-11 | predicted gene 16025 [Source:MGI Symbol;Acc:MGI:3802144] |
| Fosl2 | ENSMUSG00000029135 | 2.48087958 | 1.48E-09 | fos-like antigen 2 [Source:MGI Symbol;Acc:MGI:102858] |
| Fosb | ENSMUSG00000003545 | 2.48000114 | 0.00052 | FBJ osteosarcoma oncogene B [Source:MGI Symbol;Acc:MGI:95575] |
| St3gal4 | ENSMUSG00000032038 | 2.47948722 | 2.99E-10 | ST3 beta-galactoside alpha-2,3-sialyltransferase 4 [Source:MGI Symbol;Acc:MGI:1316743] |
| Grk5 | ENSMUSG00000003228 | 2.47350887 | 1.85E-27 | G protein-coupled receptor kinase 5 [Source:MGI Symbol;Acc:MGI:109161] |
| Nod2 | ENSMUSG00000055994 | 2.47102762 | 2.09E-19 | nucleotide-binding oligomerization domain containing 2 [Source:MGI Symbol;Acc:MGI:2429397] |
| Slc36a4 | ENSMUSG00000043885 | 2.46401851 | 2.30E-19 | solute carrier family 36 (proton/amino acid symporter), member 4 [Source:MGI Symbol;Acc:MGI:2442595] |
| Dmxl2 | ENSMUSG00000041268 | 2.45237925 | 1.35E-08 | Dmx-like 2 [Source:MGI Symbol;Acc:MGI:2444630] |
| Tmem106a | ENSMUSG00000034947 | 2.43172002 | 3.58E-09 | transmembrane protein 106A [Source:MGI Symbol;Acc:MGI:1922056] |
| Rfx2 | ENSMUSG00000024206 | 2.42680268 | 5.89E-17 | regulatory factor X, 2 (influences HLA class II expression) [Source:MGI Symbol;Acc:MGI:106583] |
| Iffo2 | ENSMUSG00000041025 | 2.41726943 | 1.55E-12 | intermediate filament family orphan 2 [Source:MGI Symbol;Acc:MGI:2140675] |
| Jun | ENSMUSG00000052684 | 2.41362959 | 2.04E-23 | jun proto-oncogene [Source:MGI Symbol;Acc:MGI:96646] |
| Faah | ENSMUSG00000034171 | 2.40338631 | 2.52E-20 | fatty acid amide hydrolase [Source:MGI Symbol;Acc:MGI:109609] |
| Gm23455 | ENSMUSG00000065265 | 2.38980126 | 7.55E-20 | predicted gene, 23455 [Source:MGI Symbol;Acc:MGI:5453232] |
| Myadm | ENSMUSG00000068566 | 2.38654247 | 1.82E-68 | myeloid-associated differentiation marker [Source:MGI Symbol;Acc:MGI:1355332] |
| Gm24357 | ENSMUSG00000064797 | 2.38439443 | 1.56E-16 | predicted gene, 24357 [Source:MGI Symbol;Acc:MGI:5454134] |
| Aspm | ENSMUSG00000033952 | 2.38321336 | 2.09E-08 | asp (abnormal spindle)-like, microcephaly associated (Drosophila) [Source:MGI Symbol;Acc:MGI:1334448] |
| Hist1h4f | ENSMUSG00000069274 | 2.36959053 | 6.14E-05 | histone cluster 1, H4f [Source:MGI Symbol;Acc:MGI:2448425] |
| Gcm2 | ENSMUSG00000021362 | 2.36933447 | 0.000947 | glial cells missing homolog 2 (Drosophila) [Source:MGI Symbol;Acc:MGI:1861438] |
| Gm6264 | ENSMUSG00000089716 | 2.36667904 | 8.63E-16 | predicted gene 6264 [Source:MGI Symbol;Acc:MGI:3779580] |
| Galnt7 | ENSMUSG00000031608 | 2.35502838 | 6.23E-32 | polypeptide N-acetylgalactosaminyltransferase 7 [Source:MGI Symbol;Acc:MGI:1349449] |
| S100a10 | ENSMUSG00000041959 | 2.33900491 | 1.59E-64 | S100 calcium binding protein A10 (calpactin) [Source:MGI Symbol;Acc:MGI:1339468] |
| Cd244 | ENSMUSG00000004709 | 2.3328218 | 1.31E-09 | CD244 natural killer cell receptor 2B4 [Source:MGI Symbol;Acc:MGI:109294] |
| Lrrc23 | ENSMUSG00000030125 | 2.33030179 | 0.000151 | leucine rich repeat containing 23 [Source:MGI Symbol;Acc:MGI:1315192] |
| Adora2a | ENSMUSG00000020178 | 2.32503575 | 3.26E-27 | adenosine A2a receptor [Source:MGI Symbol;Acc:MGI:99402] |
| Rgmb | ENSMUSG00000048027 | 2.31976004 | 3.05E-10 | repulsive guidance molecule family member B [Source:MGI Symbol;Acc:MGI:1916049] |
| Phgdh | ENSMUSG00000053398 | 2.31172183 | 3.41E-45 | 3-phosphoglycerate dehydrogenase [Source:MGI Symbol;Acc:MGI:1355330] |
| Cdh17 | ENSMUSG00000028217 | 2.29586657 | 3.02E-25 | cadherin 17 [Source:MGI Symbol;Acc:MGI:1095414] |
| Pim1 | ENSMUSG00000024014 | 2.28848936 | 1.42E-64 | proviral integration site 1 [Source:MGI Symbol;Acc:MGI:97584] |
| Kcnn4 | ENSMUSG00000054342 | 2.28233671 | 2.31E-30 | potassium intermediate/small conductance calcium-activated channel, subfamily N, member 4 [Source:MGI Symbol;Acc:MGI:1277957] |
| Plekha8 | ENSMUSG00000005225 | 2.2803636 | 2.78E-11 | pleckstrin homology domain containing, family A (phosphoinositide binding specific) member 8 [Source:MGI Symbol;Acc:MGI:2681164] |
| Gbp7 | ENSMUSG00000040253 | 2.28010304 | 7.02E-46 | guanylate binding protein 7 [Source:MGI Symbol;Acc:MGI:2444421] |
| Slc6a9 | ENSMUSG00000028542 | 2.27594707 | 0.001139 | solute carrier family 6 (neurotransmitter transporter, glycine), member 9 [Source:MGI Symbol;Acc:MGI:95760] |
| Tmem107 | ENSMUSG00000020895 | 2.26419933 | 0.004229 | transmembrane protein 107 [Source:MGI Symbol;Acc:MGI:1914160] |
| Kif11 | ENSMUSG00000012443 | 2.26087617 | 0.000138 | kinesin family member 11 [Source:MGI Symbol;Acc:MGI:1098231] |
| Gbp3 | ENSMUSG00000028268 | 2.2600127 | 2.11E-52 | guanylate binding protein 3 [Source:MGI Symbol;Acc:MGI:1926263] |
| Apoe | ENSMUSG00000002985 | 2.25068977 | 5.54E-13 | apolipoprotein E [Source:MGI Symbol;Acc:MGI:88057] |
| Anxa1 | ENSMUSG00000024659 | 2.24744331 | 1.20E-21 | annexin A1 [Source:MGI Symbol;Acc:MGI:96819] |
| Ass1 | ENSMUSG00000076441 | 2.24284094 | 3.11E-44 | argininosuccinate synthetase 1 [Source:MGI Symbol;Acc:MGI:88090] |
| Dclre1a | ENSMUSG00000025077 | 2.23543009 | 7.51E-06 | DNA cross-link repair 1A [Source:MGI Symbol;Acc:MGI:1930042] |
| Tagln2 | ENSMUSG00000026547 | 2.22218054 | 6.03E-76 | transgelin 2 [Source:MGI Symbol;Acc:MGI:1312985] |
| Rgs3 | ENSMUSG00000059810 | 2.2199967 | 1.58E-08 | regulator of G-protein signaling 3 [Source:MGI Symbol;Acc:MGI:1354734] |
| Unc13b | ENSMUSG00000028456 | 2.21760091 | 0.000193 | unc-13 homolog B (C. elegans) [Source:MGI Symbol;Acc:MGI:1342278] |
| Ppfibp2 | ENSMUSG00000036528 | 2.21715438 | 1.99E-26 | PTPRF interacting protein, binding protein 2 (liprin beta 2) [Source:MGI Symbol;Acc:MGI:894649] |
| Myc | ENSMUSG00000022346 | 2.21075301 | 1.31E-25 | myelocytomatosis oncogene [Source:MGI Symbol;Acc:MGI:97250] |
| Slc25a15 | ENSMUSG00000031482 | 2.20357259 | 1.21E-17 | solute carrier family 25 (mitochondrial carrier ornithine transporter), member 15 [Source:MGI Symbol;Acc:MGI:1342274] |
| Plxnd1 | ENSMUSG00000030123 | 2.18560352 | 1.81E-11 | plexin D1 [Source:MGI Symbol;Acc:MGI:2154244] |
| Gpr34 | ENSMUSG00000040229 | 2.18376378 | 4.89E-17 | G protein-coupled receptor 34 [Source:MGI Symbol;Acc:MGI:1346334] |
| Gm7609 | ENSMUSG00000079457 | 2.18370469 | 2.36E-30 | predicted pseudogene 7609 [Source:MGI Symbol;Acc:MGI:3644536] |
| Gm37261 | ENSMUSG00000103527 | 2.18320968 | 4.32E-06 | predicted gene, 37261 [Source:MGI Symbol;Acc:MGI:5610489] |
| Cpd | ENSMUSG00000020841 | 2.18123089 | 0.002964 | carboxypeptidase D [Source:MGI Symbol;Acc:MGI:107265] |
| Bicd1 | ENSMUSG00000003452 | 2.16625317 | 2.69E-05 | bicaudal D homolog 1 (Drosophila) [Source:MGI Symbol;Acc:MGI:1101760] |
| Mctp1 | ENSMUSG00000021596 | 2.14419382 | 6.46E-07 | multiple C2 domains, transmembrane 1 [Source:MGI Symbol;Acc:MGI:1926021] |
| Zfp811 | ENSMUSG00000055202 | 2.14100474 | 6.69E-06 | zinc finger protein 811 [Source:MGI Symbol;Acc:MGI:2682944] |
| Racgap1 | ENSMUSG00000023015 | 2.13760802 | 8.93E-16 | Rac GTPase-activating protein 1 [Source:MGI Symbol;Acc:MGI:1349423] |
| Epcam | ENSMUSG00000045394 | 2.1371268 | 0.008327 | epithelial cell adhesion molecule [Source:MGI Symbol;Acc:MGI:106653] |
| Naip2 | ENSMUSG00000078945 | 2.13366204 | 2.15E-28 | NLR family, apoptosis inhibitory protein 2 [Source:MGI Symbol;Acc:MGI:1298226] |
| Esr1 | ENSMUSG00000019768 | 2.13228943 | 3.51E-07 | estrogen receptor 1 (alpha) [Source:MGI Symbol;Acc:MGI:1352467] |
| Uty | ENSMUSG00000068457 | 2.13194556 | 8.88E-14 | ubiquitously transcribed tetratricopeptide repeat gene, Y chromosome [Source:MGI Symbol;Acc:MGI:894810] |
| Apobec1 | ENSMUSG00000040613 | 2.12869501 | 4.57E-33 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide 1 [Source:MGI Symbol;Acc:MGI:103298] |
| Slc12a2 | ENSMUSG00000024597 | 2.12115201 | 4.89E-13 | solute carrier family 12, member 2 [Source:MGI Symbol;Acc:MGI:101924] |
| Ap1m2 | ENSMUSG00000003309 | 2.11295533 | 0.000446 | adaptor protein complex AP-1, mu 2 subunit [Source:MGI Symbol;Acc:MGI:1336974] |
| Terc | ENSMUSG00000064796 | 2.11125342 | 6.10E-08 | telomerase RNA component [Source:MGI Symbol;Acc:MGI:109558] |
| Pepd | ENSMUSG00000063931 | 2.10007149 | 1.03E-38 | peptidase D [Source:MGI Symbol;Acc:MGI:97542] |
| Phlpp1 | ENSMUSG00000044340 | 2.09617617 | 3.75E-42 | PH domain and leucine rich repeat protein phosphatase 1 [Source:MGI Symbol;Acc:MGI:2138327] |
| Ctnnd1 | ENSMUSG00000034101 | 2.09477487 | 1.13E-09 | catenin (cadherin associated protein), delta 1 [Source:MGI Symbol;Acc:MGI:105100] |
| Mzb1 | ENSMUSG00000024353 | 2.09178978 | 3.00E-63 | marginal zone B and B1 cell-specific protein 1 [Source:MGI Symbol;Acc:MGI:1917066] |

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| | | | | |
|---|---|---|---|---|
| Eml6 | ENSMUSG00000044072 | 2.09065497 | 4.66E-08 | echinoderm microtubule associated protein like 6 [Source:MGI Symbol;Acc:MGI:2442895] |
| Inpp4a | ENSMUSG00000026113 | 2.09061382 | 2.62E-35 | inositol polyphosphate-4-phosphatase, type I [Source:MGI Symbol;Acc:MGI:1931123] |
| Ahcyl2 | ENSMUSG00000029772 | 2.0876334 | 1.89E-54 | S-adenosylhomocysteine hydrolase-like 2 [Source:MGI Symbol;Acc:MGI:1921590] |
| Gpr137b | ENSMUSG00000021306 | 2.08722537 | 2.14E-62 | G protein-coupled receptor 137B [Source:MGI Symbol;Acc:MGI:1891463] |
| Slc35e4 | ENSMUSG00000048807 | 2.08285829 | 0.008327 | solute carrier family 35, member E4 [Source:MGI Symbol;Acc:MGI:2144150] |
| Thyn1 | ENSMUSG00000035443 | 2.07877732 | 0.001158 | thymocyte nuclear protein 1 [Source:MGI Symbol;Acc:MGI:1925112] |
| Lacc1 | ENSMUSG00000044350 | 2.05504673 | 5.28E-24 | laccase (multicopper oxidoreductase) domain containing 1 [Source:MGI Symbol;Acc:MGI:2445077] |
| Dag1 | ENSMUSG00000039952 | 2.04689886 | 1.88E-36 | dystroglycan 1 [Source:MGI Symbol;Acc:MGI:101864] |
| Hist1h2bk | ENSMUSG00000062727 | 2.04094689 | 0.000258 | histone cluster 1, H2bk [Source:MGI Symbol;Acc:MGI:2448399] |
| Ptpn14 | ENSMUSG00000026604 | 2.03798558 | 6.45E-19 | protein tyrosine phosphatase, non-receptor type 14 [Source:MGI Symbol;Acc:MGI:102467] |
| Serpina3f | ENSMUSG00000066363 | 2.03149355 | 8.11E-08 | serine (or cysteine) peptidase inhibitor, clade A, member 3F [Source:MGI Symbol;Acc:MGI:2182838] |
| Ipcef1 | ENSMUSG00000064065 | 2.02854122 | 7.89E-24 | interaction protein for cytohesin exchange factors 1 [Source:MGI Symbol;Acc:MGI:2444159] |
| Dusp18 | ENSMUSG00000047205 | 2.02439361 | 0.002349 | dual specificity phosphatase 18 [Source:MGI Symbol;Acc:MGI:1922469] |
| A530040E14Rik | ENSMUSG00000072109 | 2.01633829 | 2.01E-39 | RIKEN cDNA A530040E14 gene [Source:MGI Symbol;Acc:MGI:3612703] |
| Tmcc3 | ENSMUSG00000020023 | 2.01591272 | 1.92E-20 | transmembrane and coiled coil domains 3 [Source:MGI Symbol;Acc:MGI:2442900] |
| Trf | ENSMUSG00000032554 | 2.00728769 | 0.000141 | transferrin [Source:MGI Symbol;Acc:MGI:98821] |
| Pde4a | ENSMUSG00000032177 | 2.00490543 | 3.29E-11 | phosphodiesterase 4A, cAMP specific [Source:MGI Symbol;Acc:MGI:99558] |

adjusted P value <=0.01

Fold change >= 4

## Table 6-16. Genes significantly up-regulated in FO B cells compare to B1 B cells.

| Symbol | Ensembl gene id | logFC (FO/B1) | adj.P.val | Annotation |
|---|---|---|---|---|
| Nrarp | ENSMUSG00000078202 | 8.85923064 | 2.38E-11 | Notch-regulated ankyrin repeat protein [Source:MGI Symbol;Acc:MGI:1914372] |
| Tmem108 | ENSMUSG00000042757 | 7.77656932 | 3.85E-24 | transmembrane protein 108 [Source:MGI Symbol;Acc:MGI:1932411] |
| S100a9 | ENSMUSG00000056071 | 7.05797678 | 0.003958 | S100 calcium binding protein A9 (calgranulin B) [Source:MGI Symbol;Acc:MGI:1338947] |
| Gm10392 | ENSMUSG00000072673 | 6.83633425 | 0.009918 | predicted gene 10392 [Source:MGI Symbol;Acc:MGI:3704377] |
| Emid1 | ENSMUSG00000034164 | 6.73867127 | 5.43E-44 | EMI domain containing 1 [Source:MGI Symbol;Acc:MGI:2155091] |
| Gm16341 | ENSMUSG00000087538 | 5.73368589 | 2.69E-12 | predicted gene 16341 [Source:MGI Symbol;Acc:MGI:3840137] |
| Vpreb3 | ENSMUSG00000000903 | 5.49318687 | 4.90E-47 | pre-B lymphocyte gene 3 [Source:MGI Symbol;Acc:MGI:98938] |
| Fcer2a | ENSMUSG00000005540 | 5.42470886 | 0 | Fc receptor, IgE, low affinity II, alpha polypeptide [Source:MGI Symbol;Acc:MGI:95497] |
| Treml2 | ENSMUSG00000071068 | 5.38380801 | 6.54E-175 | triggering receptor expressed on myeloid cells-like 2 [Source:MGI Symbol;Acc:MGI:2147038] |
| Pxdc1 | ENSMUSG00000021411 | 5.10898054 | 8.57E-100 | PX domain containing 1 [Source:MGI Symbol;Acc:MGI:1914145] |
| Dmwd | ENSMUSG00000030410 | 4.84687127 | 1.13E-09 | dystrophia myotonica-containing WD repeat motif [Source:MGI Symbol;Acc:MGI:94907] |
| Sox4 | ENSMUSG00000076431 | 4.79206043 | 2.22E-06 | SRY (sex determining region Y)-box 4 [Source:MGI Symbol;Acc:MGI:98366] |
| B4galt4 | ENSMUSG00000022793 | 4.7577507 | 2.96E-06 | UDP-Gal:betaGlcNAc beta 1,4-galactosyltransferase, polypeptide 4 [Source:MGI Symbol;Acc:MGI:1928387] |
| Fam83f | ENSMUSG00000022408 | 4.42942455 | 0.000104 | family with sequence similarity 83, member F [Source:MGI Symbol;Acc:MGI:2146227] |
| Dusp6 | ENSMUSG00000019960 | 4.42909319 | 4.58E-53 | dual specificity phosphatase 6 [Source:MGI Symbol;Acc:MGI:1914853] |
| Myl4 | ENSMUSG00000061086 | 4.42821017 | 1.15E-16 | myosin, light polypeptide 4 [Source:MGI Symbol;Acc:MGI:97267] |
| Gpc2 | ENSMUSG00000029510 | 4.34379486 | 2.46E-10 | glypican 2 (cerebroglycan) [Source:MGI Symbol;Acc:MGI:1919201] |
| Itgb3 | ENSMUSG00000020689 | 4.3307914 | 1.30E-66 | integrin beta 3 [Source:MGI Symbol;Acc:MGI:96612] |
| Gm43259 | ENSMUSG00000106432 | 4.30792985 | 0.000298 | predicted gene 43259 [Source:MGI Symbol;Acc:MGI:5663396] |
| Pde2a | ENSMUSG00000030653 | 4.21360273 | 2.24E-111 | predicted gene 45837 [Source:MGI Symbol;Acc:MGI:5804952] |
| 6030468B19Rik | ENSMUSG00000025573 | 4.20958827 | 3.06E-09 | RIKEN cDNA 6030468B19 gene [Source:MGI Symbol;Acc:MGI:1924977] |
| E430014B02Rik | ENSMUSG00000102973 | 4.18431665 | 1.30E-26 | RIKEN cDNA E430014B02 gene [Source:MGI Symbol;Acc:MGI:2445017] |
| Dusp2 | ENSMUSG00000027368 | 4.12252399 | 3.87E-71 | dual specificity phosphatase 2 [Source:MGI Symbol;Acc:MGI:101911] |
| Chchd10 | ENSMUSG00000049422 | 4.12081797 | 2.07E-35 | coiled-coil-helix-coiled-coil-helix domain containing 10 [Source:MGI Symbol;Acc:MGI:2143558] |
| Tnf | ENSMUSG00000024401 | 4.08494305 | 1.66E-26 | tumor necrosis factor [Source:MGI Symbol;Acc:MGI:104798] |
| Gm37593 | ENSMUSG00000103358 | 4.00524612 | 1.48E-35 | predicted gene, 37593 [Source:MGI Symbol;Acc:MGI:5610821] |
| Lta | ENSMUSG00000024402 | 3.98690342 | 3.44E-20 | lymphotoxin A [Source:MGI Symbol;Acc:MGI:104797] |
| Cd72 | ENSMUSG00000028459 | 3.9812673 | 5.36E-131 | CD72 antigen [Source:MGI Symbol;Acc:MGI:88345] |
| B3gnt7 | ENSMUSG00000079445 | 3.97462087 | 0.003681 | UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 7 [Source:MGI Symbol;Acc:MGI:2384394] |
| Zap70 | ENSMUSG00000026117 | 3.94655105 | 0.000105 | zeta-chain (TCR) associated protein kinase [Source:MGI Symbol;Acc:MGI:99613] |
| Gm36931 | ENSMUSG00000103779 | 3.92833107 | 1.22E-41 | predicted gene, 36931 [Source:MGI Symbol;Acc:MGI:5610159] |
| Gm6934 | ENSMUSG00000103753 | 3.90500891 | 8.30E-17 | predicted gene 6934 [Source:MGI Symbol;Acc:MGI:3648115] |
| Prss16 | ENSMUSG00000006179 | 3.85573837 | 0.000299 | protease, serine 16 (thymus) [Source:MGI Symbol;Acc:MGI:1859181] |
| Slamf1 | ENSMUSG00000015316 | 3.84654259 | 6.54E-60 | signaling lymphocytic activation molecule family member 1 [Source:MGI Symbol;Acc:MGI:1351314] |
| Satb1 | ENSMUSG00000023927 | 3.80706706 | 2.18E-212 | special AT-rich sequence binding protein 1 [Source:MGI Symbol;Acc:MGI:105084] |
| Adap1 | ENSMUSG00000056413 | 3.7604965 | 6.75E-23 | ArfGAP with dual PH domains 1 [Source:MGI Symbol;Acc:MGI:2442201] |
| Gm24786 | ENSMUSG00000088004 | 3.67640424 | 9.93E-05 | predicted gene, 24786 [Source:MGI Symbol;Acc:MGI:5454563] |
| 3110080O07Rik | ENSMUSG00000103284 | 3.66971931 | 0.000107 | RIKEN cDNA 3110080O07 gene [Source:MGI Symbol;Acc:MGI:1920491] |
| 9930012K11Rik | ENSMUSG00000044551 | 3.60536911 | 1.91E-09 | RIKEN cDNA 9930012K11 gene [Source:MGI Symbol;Acc:MGI:2145726] |
| C230085N15Ril | ENSMUSG00000102212 | 3.59539113 | 1.06E-38 | RIKEN cDNA C230085N15 gene [Source:MGI Symbol;Acc:MGI:2444267] |
| Slco4a1 | ENSMUSG00000038963 | 3.46706473 | 0.000488 | solute carrier organic anion transporter family, member 4a1 [Source:MGI Symbol;Acc:MGI:1351866] |

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|---|---|---|---|---|
| Gm10505 | ENSMUSG00000073430 | 3.34294162 | 2.16E-07 | predicted gene 10505 [Source:MGI Symbol;Acc:MGI:3642687] |
| Gm16214 | ENSMUSG00000086360 | 3.33374991 | 1.72E-19 | predicted gene 16214 [Source:MGI Symbol;Acc:MGI:3801724] |
| 5830444F18Rik | ENSMUSG00000102744 | 3.33095724 | 5.40E-15 | RIKEN cDNA 5830444F18 gene [Source:MGI Symbol;Acc:MGI:2444780] |
| Rflnb | ENSMUSG00000020846 | 3.30893241 | 3.54E-27 | refilin B [Source:MGI Symbol;Acc:MGI:1923816] |
| Icosl | ENSMUSG00000000732 | 3.2459893 | 2.16E-145 | icos ligand [Source:MGI Symbol;Acc:MGI:1354701] |
| Smim3 | ENSMUSG00000038059 | 3.24276244 | 8.37E-06 | small integral membrane protein 3 [Source:MGI Symbol;Acc:MGI:1917088] |
| Zfp608 | ENSMUSG00000052713 | 3.22841717 | 1.22E-101 | zinc finger protein 608 [Source:MGI Symbol;Acc:MGI:2442338] |
| Gdf11 | ENSMUSG00000025352 | 3.22156295 | 1.02E-24 | growth differentiation factor 11 [Source:MGI Symbol;Acc:MGI:1338027] |
| Pag1 | ENSMUSG00000027508 | 3.21181147 | 3.10E-195 | phosphoprotein associated with glycosphingolipid microdomains 1 [Source:MGI Symbol;Acc:MGI:2443160] |
| Gm26742 | ENSMUSG00000097707 | 3.15420886 | 3.79E-42 | predicted gene, 26742 [Source:MGI Symbol;Acc:MGI:5477236] |
| Lmo2 | ENSMUSG00000032698 | 3.14745321 | 3.48E-131 | LIM domain only 2 [Source:MGI Symbol;Acc:MGI:102811] |
| Gm38228 | ENSMUSG00000103945 | 3.14243417 | 8.84E-05 | predicted gene, 38228 [Source:MGI Symbol;Acc:MGI:5611456] |
| Ggt5 | ENSMUSG00000006344 | 3.04549285 | 9.90E-07 | gamma-glutamyltransferase 5 [Source:MGI Symbol;Acc:MGI:1346063] |
| Gm37863 | ENSMUSG00000102405 | 3.02612761 | 0.001542 | predicted gene, 37863 [Source:MGI Symbol;Acc:MGI:5611091] |
| Akap12 | ENSMUSG00000038587 | 3.00778782 | 9.67E-20 | A kinase (PRKA) anchor protein (gravin) 12 [Source:MGI Symbol;Acc:MGI:1932576] |
| Ighd | ENSMUSG00000104213 | 2.99334806 | 5.16E-175 | immunoglobulin heavy constant delta [Source:MGI Symbol;Acc:MGI:96447] |
| Gm27833 | ENSMUSG00000098733 | 2.9918679 | 0.005246 | predicted gene, 27833 [Source:MGI Symbol;Acc:MGI:5531215] |
| Hvcn1 | ENSMUSG00000064267 | 2.95850168 | 2.58E-195 | hydrogen voltage-gated channel 1 [Source:MGI Symbol;Acc:MGI:1921346] |
| Gm43260 | ENSMUSG00000105933 | 2.95679699 | 0.006935 | predicted gene 43260 [Source:MGI Symbol;Acc:MGI:5663397] |
| Adcy6 | ENSMUSG00000022994 | 2.94722159 | 0.001495 | adenylate cyclase 6 [Source:MGI Symbol;Acc:MGI:87917] |
| Cdkl1 | ENSMUSG00000020990 | 2.94416733 | 2.78E-11 | cyclin-dependent kinase-like 1 (CDC2-related kinase) [Source:MGI Symbol;Acc:MGI:1918341] |
| Cr2 | ENSMUSG00000026616 | 2.93797843 | 6.97E-184 | complement receptor 2 [Source:MGI Symbol;Acc:MGI:88489] |
| Tle2 | ENSMUSG00000034771 | 2.93646718 | 0.00174 | transducin-like enhancer of split 2 [Source:MGI Symbol;Acc:MGI:104635] |
| Dnah8 | ENSMUSG00000033826 | 2.93550776 | 2.34E-46 | dynein, axonemal, heavy chain 8 [Source:MGI Symbol;Acc:MGI:107714] |
| Gm37248 | ENSMUSG00000103216 | 2.92125836 | 6.60E-24 | predicted gene, 37248 [Source:MGI Symbol;Acc:MGI:5610476] |
| Trem1 | ENSMUSG00000042265 | 2.90989411 | 0.000987 | triggering receptor expressed on myeloid cells 1 [Source:MGI Symbol;Acc:MGI:1930005] |
| Fcmr | ENSMUSG00000042474 | 2.89399508 | 7.08E-67 | Fc fragment of IgM receptor [Source:MGI Symbol;Acc:MGI:1916419] |
| Fmnl3 | ENSMUSG00000023008 | 2.87093928 | 5.77E-55 | formin-like 3 [Source:MGI Symbol;Acc:MGI:109569] |
| Ms4a4c | ENSMUSG00000024675 | 2.86178705 | 1.22E-113 | membrane-spanning 4-domains, subfamily A, member 4C [Source:MGI Symbol;Acc:MGI:1927656] |
| Nckap5l | ENSMUSG00000023009 | 2.83527827 | 7.56E-06 | NCK-associated protein 5-like [Source:MGI Symbol;Acc:MGI:3609653] |
| Mmp11 | ENSMUSG00000000901 | 2.80908406 | 2.07E-05 | matrix metallopeptidase 11 [Source:MGI Symbol;Acc:MGI:97008] |
| Lamp3 | ENSMUSG00000041247 | 2.79638969 | 0.007401 | lysosomal-associated membrane protein 3 [Source:MGI Symbol;Acc:MGI:2441659] |
| Cd93 | ENSMUSG00000027435 | 2.77748345 | 5.01E-22 | CD93 antigen [Source:MGI Symbol;Acc:MGI:106664] |
| Dab2ip | ENSMUSG00000026883 | 2.73749741 | 0.00047 | disabled 2 interacting protein [Source:MGI Symbol;Acc:MGI:1916851] |
| Smad7 | ENSMUSG00000025880 | 2.71797895 | 4.82E-21 | SMAD family member 7 [Source:MGI Symbol;Acc:MGI:1100518] |
| Ffar2 | ENSMUSG00000051314 | 2.7166362 | 1.11E-06 | free fatty acid receptor 2 [Source:MGI Symbol;Acc:MGI:2441731] |
| C130089K02Rik | ENSMUSG00000104339 | 2.70978431 | 7.39E-05 | RIKEN cDNA C130089K02 gene [Source:MGI Symbol;Acc:MGI:2444420] |
| Sorl1 | ENSMUSG00000049313 | 2.6630616 | 3.46E-200 | sortilin-related receptor, LDLR class A repeats-containing [Source:MGI Symbol;Acc:MGI:1202296] |
| Etv5 | ENSMUSG00000013089 | 2.66152056 | 1.46E-06 | ets variant 5 [Source:MGI Symbol;Acc:MGI:1096867] |
| Slco5a1 | ENSMUSG00000025938 | 2.65834846 | 1.89E-08 | solute carrier organic anion transporter family, member 5A1 [Source:MGI Symbol;Acc:MGI:2443431] |
| Slc14a1 | ENSMUSG00000059336 | 2.6497416 | 1.14E-33 | solute carrier family 14 (urea transporter), member 1 [Source:MGI Symbol;Acc:MGI:1351654] |
| 5430420F09Rik | ENSMUSG00000102808 | 2.64166113 | 1.40E-05 | RIKEN cDNA 5430420F09 gene [Source:MGI Symbol;Acc:MGI:1921741] |
| Klrb1f | ENSMUSG00000030154 | 2.59950079 | 0.007501 | killer cell lectin-like receptor subfamily B member 1F [Source:MGI Symbol;Acc:MGI:2442965] |
| Il4i1 | ENSMUSG00000074141 | 2.59814842 | 7.23E-59 | interleukin 4 induced 1 [Source:MGI Symbol;Acc:MGI:109552] |
| Sh2d2a | ENSMUSG00000028071 | 2.59159564 | 1.64E-16 | SH2 domain containing 2A [Source:MGI Symbol;Acc:MGI:1351596] |
| Snx29 | ENSMUSG00000071669 | 2.57133316 | 1.19E-78 | sorting nexin 29 [Source:MGI Symbol;Acc:MGI:1921728] |
| 0610009L18Rik | ENSMUSG00000043644 | 2.52675301 | 0.000399 | RIKEN cDNA 0610009L18 gene [Source:MGI Symbol;Acc:MGI:1914088] |
| Prf1 | ENSMUSG00000037202 | 2.51787154 | 6.63E-05 | perforin 1 (pore forming protein) [Source:MGI Symbol;Acc:MGI:97551] |
| Tctn1 | ENSMUSG00000038593 | 2.50956005 | 1.87E-82 | tectonic family member 1 [Source:MGI Symbol;Acc:MGI:3603820] |
| Gsn | ENSMUSG00000026879 | 2.50444472 | 2.66E-52 | gelsolin [Source:MGI Symbol;Acc:MGI:95851] |
| Tuft1 | ENSMUSG00000005968 | 2.50332433 | 8.21E-05 | tuftelin 1 [Source:MGI Symbol;Acc:MGI:109572] |
| Gm5511 | ENSMUSG00000100615 | 2.48886894 | 8.13E-06 | predicted gene 5511 [Source:MGI Symbol;Acc:MGI:3779492] |
| Cnr2 | ENSMUSG00000062585 | 2.48674633 | 1.01E-72 | cannabinoid receptor 2 (macrophage) [Source:MGI Symbol;Acc:MGI:104650] |
| Bzrap1 | ENSMUSG00000034156 | 2.47599148 | 1.04E-15 | TSPO associated protein 1 [Source:MGI Symbol;Acc:MGI:2450877] |
| Serpinb1a | ENSMUSG00000044734 | 2.46730018 | 7.98E-91 | serine (or cysteine) peptidase inhibitor, clade B, member 1a [Source:MGI Symbol;Acc:MGI:1913472] |
| Bach2it1 | ENSMUSG00000087049 | 2.45886101 | 3.60E-09 | BTB and CNC homology 2, intronic transcript 1 [Source:MGI Symbol;Acc:MGI:3651084] |
| Wwc2 | ENSMUSG00000031563 | 2.44565827 | 2.98E-12 | WW, C2 and coiled-coil domain containing 2 [Source:MGI Symbol;Acc:MGI:1261872] |
| Ppp1r3b | ENSMUSG00000046794 | 2.44052959 | 1.83E-05 | protein phosphatase 1, regulatory (inhibitor) subunit 3B [Source:MGI Symbol;Acc:MGI:2177268] |
| Ltk | ENSMUSG00000027297 | 2.43066496 | 0.00083 | leukocyte tyrosine kinase [Source:MGI Symbol;Acc:MGI:96840] |
| Gm38345 | ENSMUSG00000102353 | 2.40845758 | 8.01E-08 | predicted gene, 38345 [Source:MGI Symbol;Acc:MGI:5611573] |
| Cacna1h | ENSMUSG00000024112 | 2.38031795 | 0.000466 | calcium channel, voltage-dependent, T type, alpha 1H subunit [Source:MGI Symbol;Acc:MGI:1928842] |
| Lgmn | ENSMUSG00000021190 | 2.37842308 | 5.00E-35 | legumain [Source:MGI Symbol;Acc:MGI:1330838] |
| Terb1 | ENSMUSG00000052616 | 2.37674126 | 3.83E-05 | telomere repeat binding bouquet formation protein 1 [Source:MGI Symbol;Acc:MGI:2443187] |
| Pglyrp2 | ENSMUSG00000079563 | 2.37401345 | 1.42E-20 | peptidoglycan recognition protein 2 [Source:MGI Symbol;Acc:MGI:1928099] |
| Kcnb1 | ENSMUSG00000050556 | 2.34954578 | 2.45E-05 | potassium voltage gated channel, Shab-related subfamily, member 1 [Source:MGI Symbol;Acc:MGI:96666] |
| Plekha6 | ENSMUSG00000041757 | 2.34865126 | 3.95E-06 | pleckstrin homology domain containing, family A member 6 [Source:MGI Symbol;Acc:MGI:2388662] |
| Trib2 | ENSMUSG00000020601 | 2.34423948 | 2.22E-28 | tribbles pseudokinase 2 [Source:MGI Symbol;Acc:MGI:2145021] |
| Tmem26 | ENSMUSG00000060044 | 2.33200127 | 0.000237 | transmembrane protein 26 [Source:MGI Symbol;Acc:MGI:2143537] |
| Spred2 | ENSMUSG00000045671 | 2.31788002 | 0.000238 | sprouty-related, EVH1 domain containing 2 [Source:MGI Symbol;Acc:MGI:2150019] |
| Zfp318 | ENSMUSG00000015597 | 2.31261452 | 6.33E-76 | zinc finger protein 318 [Source:MGI Symbol;Acc:MGI:1889348] |
| Smtn | ENSMUSG00000020439 | 2.31096751 | 0.009465 | smoothelin [Source:MGI Symbol;Acc:MGI:1354727] |
| Gm42928 | ENSMUSG00000105813 | 2.30518456 | 0.000213 | predicted gene 42928 [Source:MGI Symbol;Acc:MGI:5663065] |
| Gm37176 | ENSMUSG00000103378 | 2.30108631 | 1.80E-12 | predicted gene, 37176 [Source:MGI Symbol;Acc:MGI:5610404] |
| Brwd1 | ENSMUSG00000022914 | 2.29414024 | 6.37E-153 | bromodomain and WD repeat domain containing 1 [Source:MGI Symbol;Acc:MGI:1890651] |

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|---|---|---|---|---|
| Flt3 | ENSMUSG00000042817 | 2.29013207 | 6.01E-08 | FMS-like tyrosine kinase 3 [Source:MGI Symbol;Acc:MGI:95559] |
| Hivep3 | ENSMUSG00000028634 | 2.28185774 | 2.50E-17 | human immunodeficiency virus type I enhancer binding protein 3 [Source:MGI Symbol;Acc:MGI:106589] |
| Spred1 | ENSMUSG00000027351 | 2.26438264 | 5.37E-08 | sprouty protein with EVH-1 domain 1, related sequence [Source:MGI Symbol;Acc:MGI:2150016] |
| Baiap2 | ENSMUSG00000025372 | 2.26236603 | 1.52E-06 | brain-specific angiogenesis inhibitor 1-associated protein 2 [Source:MGI Symbol;Acc:MGI:2137336] |
| Ifi213 | ENSMUSG00000073491 | 2.24235077 | 7.41E-64 | interferon activated gene 213 [Source:MGI Symbol;Acc:MGI:3695276] |
| Bcl6 | ENSMUSG00000022508 | 2.24203328 | 2.74E-34 | B cell leukemia/lymphoma 6 [Source:MGI Symbol;Acc:MGI:107187] |
| Ppfia4 | ENSMUSG00000026458 | 2.22388919 | 9.75E-06 | protein tyrosine phosphatase, receptor type, f polypeptide (PTPRF), interacting protein (liprin), alpha 4 [Source:MGI Symbol;Acc:MGI:1915757] |
| Ryr2 | ENSMUSG00000021313 | 2.22158921 | 4.31E-08 | ryanodine receptor 2, cardiac [Source:MGI Symbol;Acc:MGI:99685] |
| Parp8 | ENSMUSG00000021725 | 2.21965259 | 4.37E-32 | poly (ADP-ribose) polymerase family, member 8 [Source:MGI Symbol;Acc:MGI:1098713] |
| Gcnt1 | ENSMUSG00000038843 | 2.2118519 | 4.22E-41 | glucosaminyl (N-acetyl) transferase 1, core 2 [Source:MGI Symbol;Acc:MGI:95676] |
| Map3k19 | ENSMUSG00000051590 | 2.20720963 | 2.39E-17 | mitogen-activated protein kinase kinase kinase 19 [Source:MGI Symbol;Acc:MGI:1203481] |
| Itih5 | ENSMUSG00000025780 | 2.20701369 | 3.76E-17 | inter-alpha (globulin) inhibitor H5 [Source:MGI Symbol;Acc:MGI:1925751] |
| Gm11344 | ENSMUSG00000083165 | 2.20359687 | 2.29E-07 | predicted gene 11344 [Source:MGI Symbol;Acc:MGI:3652103] |
| Cpm | ENSMUSG00000020183 | 2.19876329 | 3.05E-57 | carboxypeptidase M [Source:MGI Symbol;Acc:MGI:1917824] |
| Tlr12 | ENSMUSG00000062545 | 2.19340295 | 0.000153 | toll-like receptor 12 [Source:MGI Symbol;Acc:MGI:3045221] |
| Egr3 | ENSMUSG00000033730 | 2.19150315 | 0.002655 | early growth response 3 [Source:MGI Symbol;Acc:MGI:1306780] |
| Gm18852 | ENSMUSG00000099241 | 2.16579601 | 1.96E-16 | predicted gene, 18852 [Source:MGI Symbol;Acc:MGI:5011037] |
| Neurl3 | ENSMUSG00000047180 | 2.16339573 | 1.69E-75 | neuralized E3 ubiquitin protein ligase 3 [Source:MGI Symbol;Acc:MGI:2429944] |
| Dennd3 | ENSMUSG00000036661 | 2.15832477 | 3.15E-62 | DENN/MADD domain containing 3 [Source:MGI Symbol;Acc:MGI:2146009] |
| Cd200 | ENSMUSG00000022661 | 2.15183059 | 5.19E-33 | CD200 antigen [Source:MGI Symbol;Acc:MGI:1196990] |
| Erp27 | ENSMUSG00000030219 | 2.12874825 | 9.45E-10 | endoplasmic reticulum protein 27 [Source:MGI Symbol;Acc:MGI:1916437] |
| Ifnlr1 | ENSMUSG00000062157 | 2.12593833 | 0.002938 | interferon lambda receptor 1 [Source:MGI Symbol;Acc:MGI:2429859] |
| Slc15a3 | ENSMUSG00000024737 | 2.12293258 | 2.96E-09 | solute carrier family 15, member 3 [Source:MGI Symbol;Acc:MGI:1929691] |
| Gm37598 | ENSMUSG00000102749 | 2.12178481 | 0.001111 | predicted gene, 37598 [Source:MGI Symbol;Acc:MGI:5610826] |
| Slc16a10 | ENSMUSG00000019838 | 2.10760328 | 6.88E-10 | solute carrier family 16 (monocarboxylic acid transporters), member 10 [Source:MGI Symbol;Acc:MGI:1919722] |
| Dusp4 | ENSMUSG00000031530 | 2.10517307 | 7.15E-05 | dual specificity phosphatase 4 [Source:MGI Symbol;Acc:MGI:2442191] |
| Fcrl1 | ENSMUSG00000059994 | 2.07672828 | 1.60E-85 | Fc receptor-like 1 [Source:MGI Symbol;Acc:MGI:2442862] |
| Gm24371 | ENSMUSG00000084611 | 2.06836125 | 3.89E-06 | predicted gene, 24371 [Source:MGI Symbol;Acc:MGI:5454148] |
| Gm15440 | ENSMUSG00000051107 | 2.06657996 | 1.09E-08 | predicted gene 15440 [Source:MGI Symbol;Acc:MGI:3642353] |
| Oasl1 | ENSMUSG00000041827 | 2.06646245 | 1.96E-06 | 2'-5' oligoadenylate synthetase-like 1 [Source:MGI Symbol;Acc:MGI:2180849] |
| Gpr137c | ENSMUSG00000049092 | 2.0268104 | 8.30E-05 | G protein-coupled receptor 137C [Source:MGI Symbol;Acc:MGI:1917963] |
| Rasa4 | ENSMUSG00000004952 | 2.01865793 | 1.23E-15 | RAS p21 protein activator 4 [Source:MGI Symbol;Acc:MGI:1858600] |
| Myof | ENSMUSG00000048612 | 2.00426121 | 7.38E-11 | myoferlin [Source:MGI Symbol;Acc:MGI:1919192] |

adjusted P value <=0.01

Fold change >= 4