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Supplemental Information

A *P2rx7* Passenger Mutation Affects the Vitality and Function of T cells in Congenic Mice

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Transparent Methods

Mice

8 to 18 weeks old male and female mice on the C57BL/6 and Balb/c background were used in this study. P2rx4^{tm1Rass} on the B6 background were obtained from the lab of Francois Rassendren. Balb/c-P2X4^{ko} mice were generated by backcrossing B6-P2X4^{ko} mice with Balb/c-WT mice for 13 generations. In some experiments cells from B6-P2X7^{ko} mice (P2rx7^{tm1Gab}) were used as negative control for P2X7 cell surface staining. Hvcn1^{Gt(RRRN293)Byg} on the B6 background were obtained from the lab of David Clapham. All mouse experiments were approved by the responsible regulatory committee (Hamburger Behörde für Gesundheit und Verbraucherschutz, Veterinärwesen/Lebensmittelsicherheit, ORG722, ORG983, G12/130). All experiments were performed according to the relevant guidelines and regulations.

Antibodies and flow cytometry

For FACS analysis, the following antibodies were used: anti-CD3-Bv421-(clone 17A2, Biolegend), anti-CD4-Bv421 (clone RM 4-5, eBioscience), anti-CD8-FITC (clone 53-6.7, Biolegend), anti-CD25 PE (clone PC61, Biolegend), anti-CD27-APC (clone LG.3A10, Biolegend) and anti-P2X7-AF647 (clone Hano44, UKE) (Adriouch et al. 2005). Flow cytometric analyses were performed on a BD Fortessa (Beckton Dickinson) or a BD FACS CantoII (Beckton Dickinson).

Preparation of immune cells

The isolation of immune cells was performed strictly at 4°C on ice. Spleen and peripheral lymph nodes were mashed through a cell strainer (50 mL falcon strainer, 70 µm, GBO) using a syringe piston. Single cell suspension was kept in FACS buffer containing 1 mM EDTA (Sigma) and 0.1 % bovine serum albumin (Sigma). Erythrocytes were lysed using an ACK lysis buffer (155 mM NH₄Cl, 10 mM KHCO₃, 0.1 mM EDTA, pH 7.2). For some T cell experiments, mice were injected (i.v.) with 50 µg of the ARTC2.2-blocking nanobody s+16a 30 min prior to sacrificing the mice in order to prevent ADP-ribosylation of P2X7 on T cells during cell preparation.

Quantitative real-time PCR

RNA was extracted from FACS sorted immune cells using the RNeasy Plus Mini Kit (Qiagen) followed by cDNA synthesis using the Maxima First Strand cDNA Synthesis Kit (Thermo Fisher Scientific) as recommended by the respective supplier. RT-qPCR was performed on a Lightcycler 96 (Roche). A P2rx7-specific Taqman probe (Mm00440582_m1; Thermo Scientific) was used to determine P2rx7 mRNA expression levels.

P2rx7 SNP sequencing

Sequencing of a region flanking SNP rs48804829 in the *P2rx7* gene was performed using the primers P2x7_P451L_forw (gggaaaagtctgcaagttgtc) and P2x7_P451L_rev (gaagagcttgagggtggtg). The PCR product was purified with the PCR clean-up gel extraction kit (Macherey-Nagel) and send to Eurofins, Germany, for sequencing.

Monitoring P2X7 induced cell death on T cells

T cells were isolated by flow cytometric cell sorting. 5×10^4 cell were resuspended in 400 μ l complete RPMI medium containing propidium iodide PI (2.5 μ g/ml, ImmunoChemistry Technologies). Half of the sample was left at 4°C and the other half was incubated for 2 h at 37°C. Cell vitality was analyzed directly after incubation by flow cytometry.

Monitoring P2X7 shedding of CD27 on T cells

Purified splenocytes from WT and P2X4ko mice were stained with lineage markers and anti-CD27 for 30 min, then washed and WT or P2X4ko cells were labeled with eFluor⁶⁷⁰. The labeled and unlabeled samples were mixed in a 1:1 ratio and aliquots were subjected to ATP dose response analyses (16-500 μ M ATP). For this, cells were incubated in the presence of ATP at 37°C for 15 minutes, samples without ATP were incubated at 4°C and 37°C as controls. Loss of CD27 from the cell surface was analyzed by flow cytometry.

For the real-time CD27 shedding measurements, WT or P2X4ko cells were labeled with eFluor⁶⁷⁰. The labeled and unlabeled samples were mixed in a 1:1 ratio and aliquots and cell surface CD27 expression was monitored on a flow cytometer while continuously increasing the sample temperature to 37°C using an infrared lamp (IR) lamp. A temperature of 37°C was reached after 7-8 min and kept constant while measuring continued for another 7-8 minutes

Monitoring P2X7-induced calcium uptake

HEK cells stably transfected with expression plasmids for P2X7k 451L, P2X7k 451P, P2X7a 451L or P2X7a 451P were loaded with 2 μ M Fluo-4 (Invitrogen) for 20 min at 4°C and 10 min at 37°C, washed once with FACS buffer and resuspended in PBS supplemented with 0.9 mM CaCl₂ and 0.49 mM MgCl₂ (Invitrogen) and analyzed by flow cytometry. An IR lamp was used to maintain a constant sample temperature of 37°C. The baseline Fluo4 signal was measured for 2 minutes, then ATP was added to the sample at the indicated concentration and measuring continued for 3-4 minutes.

In vitro migration assay

Th were isolated from WT and P2X4ko mice by FACS and one WT or P2X4ko Th were stained with Fluor⁶⁷⁰. Labeled and unlabeled cells were mixed in a 1:1 ratio, washed and resuspended in RPMI complete medium. 2 x 10⁵ cells in 100 µl were transferred into the upper chamber of a trans-well plate (5µm pores, Corning). The lower chamber was prepared with either 150 µl RPMI complete medium or 150 µl RPMI complete medium containing SDF1α (100 ng/ml, Biolegend). The trans-well plate was placed in a 37°C incubator and cells were allowed to migrate for 2 h. Afterwards, vital cells (propidium iodide negative) in the upper and lower chamber were counted by flow cytometry.

Cytokine secretion assay

For *in vitro* cytokine secretion assays CTL were isolated by FACS from spleen single cell suspensions. 5 x 10⁴ cells were directly sorted in 200 µl RPMI complete medium and stimulated for 24 h in the presence of phorbol 12-myristate 13-acetate (PMA, 20 ng/ml, Invivogen) and ionomycin (1 µg/ml, Invivogen). Supernatants were analyzed for 13 cytokines (IFN-γ, TNF-α, IL-2, IL-4, IL-21, IL-22, IL-17A, IL-17F, IL-10, IL-9, IL-5 and IL-13) using the LEGENDplex mouse Th cytokine 13-plex kit (Biolegend).

In silico research and statistics

mRNA sequencing data from CD4 T cells of inbred mouse strains was obtained from the immgen database (GSE60337) (Mostafavi et al. 2014). Details of *P2rx7* neighboring genes were obtained from BioMart on ensembl.org (Yates et al. 2020). For statistical analyses, GraphPad Prism 8 was used and two groups were compared using the student's t test.

References Transparent Methods

Adriouch, S. et al., 2005. Probing the expression and function of the P2X7 purinoceptor with antibodies raised by genetic immunization. *Cellular Immunology*, 236(1-2), pp.72–77.

Mostafavi, S. et al., 2014. Variation and Genetic Control of Gene Expression in Primary Immunocytes across Inbred Mouse Strains. *Journal of Immunology*, 193(9), pp.4485–4496.

Yates, A.D. et al., 2020. Ensembl 2020. *Nucleic acids research*, 48(D1), pp.D682–D688.

Supplementary Figures

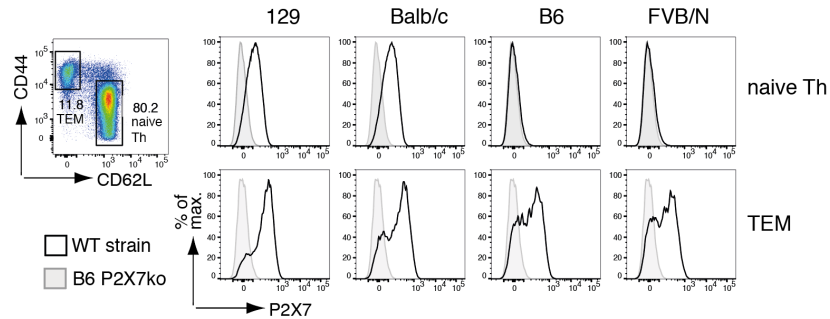


Figure S1. P2X7 expression levels in naïve and effector/memory T cells (TEM) from different mouse strains. Related to Figure 1. Flow cytometric analyses of cell surface P2X7 expression on CD4⁺ naïve (CD62L⁺CD44^{low}) and effector/memory (CD62L⁻CD44^{high}) CD4⁺ T cells (TEM) of 129, Balb/c, B6 and FVB/N mice.

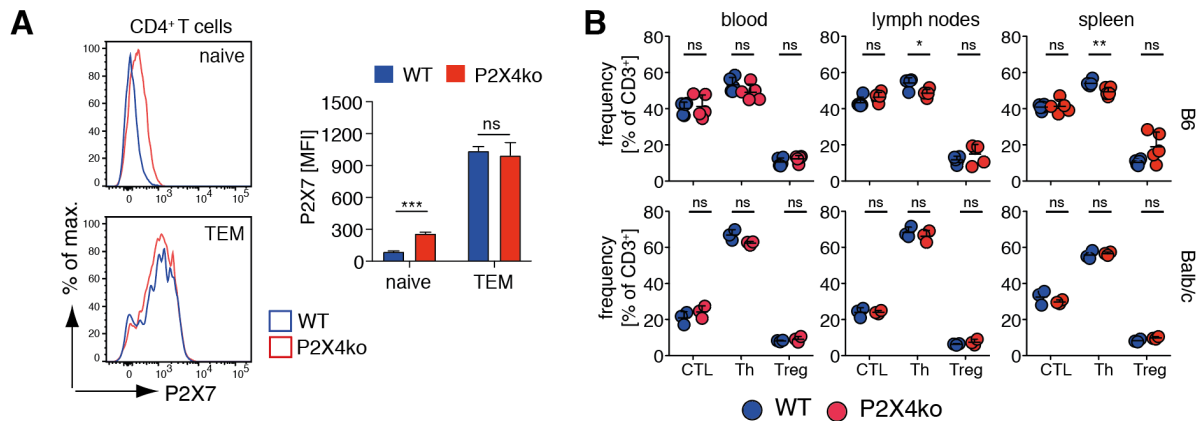


Figure S2. Naïve and effector memory T cells P2X7 expression analyses and T cell frequencies in P2X4ko and WT mice. Related to Figure 2. (A) Flow cytometric analyses of cell surface P2X7 expression on CD4⁺ naïve (CD62L⁺CD44^{low}) and effector/memory (CD62L⁻CD44^{high}) T cells of B6 WT (blue) and P2X4ko (red) mice. (B) Frequencies of CTL, Th and Treg (n = 3-5) in relation to all CD3⁺ T cells was determined in blood, peripheral lymph nodes and spleen of B6 and Balb/c P2X4ko (red) and WT mice (blue). Data are represented as mean \pm SD. Statistical comparison of two groups was performed by using the student's t test (p < 0.05 = * / p < 0.01 = ** / p < 0.001 = ***, ns = no significant).

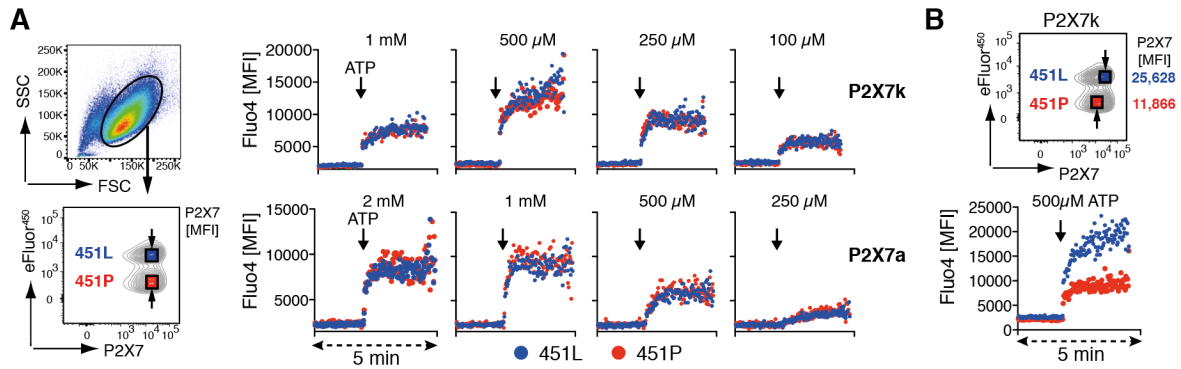


Figure S3. The intensity of the calcium influx depends on the expression level of P2X7. Related to Figure 3. (A) HEK cells stably transfected with P2X7 451L or 451P (P2X7k or P2X7a splice variant) were distinguished by eFluor⁴⁵⁰ labeling and P2X7 expression level were determined by co-staining with an anti-P2X7 antibody (clone RH23A44). Comparative P2X7 451P/L HEK cell analyses were adjusted for P2X7 expression levels by creating a gating region with a comparable P2X7 mean fluorescence intensity (MFI). For the analyses, mixed HEK cells were loaded with Fluo4 and measured in a real-time flow cytometry assay with 2 min baseline recording followed by 3 min ATP stimulation (100 μ M – 2 mM). Calcium influx was measured by increase in Fluo4 MFI. (B) Analysis of the 500 μ M ATP P2X7k sample was repeated with a skewed adjustment of P2X7 expression.

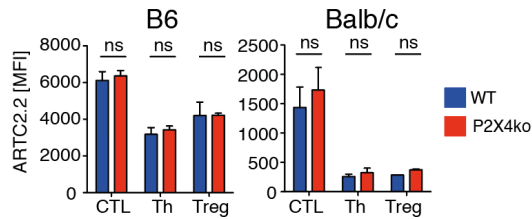


Figure S4. ARTC2.2 expression is comparable on P2X4ko and WT T cells. Related to Figure 3. Flow cytometric analyses of cell surface ARTC2.2 expression on CTL, Th and Treg of WT and P2X4ko mice on the B6 and Balb/c background. The mean fluorescence intensity (MFI) of ARTC2.2 on the different T cell populations from WT and P2X4ko mice (n = 3) was compared. Data are represented as mean \pm SD. Statistical comparison of two groups was performed by using the student's t test (p < 0.05 = * / p < 0.01 = ** / p < 0.001 = ***, ns = no significant).

Table S1: 129-based knockout mice for *P2rx7* neighboring genes. Related to Figure 6.

gene name	gene start (bp)	gene end (bp)	distance to <i>P2rx7</i> (bp)	gene description	129-based KO mice
<i>Rasa1</i>	120648812	120679597	-1964314	RAS protein activator like 1 (GAP1 like) [Source:MGI Symbol;Acc:MGI:1330842]	---
<i>Dtx1</i>	120680202	120711927	-1931984	deltex 1, E3 ubiquitin ligase [Source:MGI Symbol;Acc:MGI:1352744]	<i>Dtx1tm1.1Mzl</i> <i>Dtx1tm1Crey</i> <i>Dtx1tm1Mjb</i>
<i>Oas2</i>	120730333	120749853	-1894058	2'-5' oligoadenylate synthetase 2 [Source:MGI Symbol;Acc:MGI:2180852]	<i>Oas2Gt(OST112989)Lex</i>
<i>Oas3</i>	120753098	120777661	-1866250	2'-5' oligoadenylate synthetase 3 [Source:MGI Symbol;Acc:MGI:2180850]	---
<i>Oas1e</i>	120786226	120795530	-1848381	2'-5' oligoadenylate synthetase 1E [Source:MGI Symbol;Acc:MGI:2180856]	---
<i>Oas1c</i>	120800194	120812514	-1831397	2'-5' oligoadenylate synthetase 1C [Source:MGI Symbol;Acc:MGI:2149633]	---
<i>Oas1b</i>	120812635	120824163	-1819748	2'-5' oligoadenylate synthetase 1B [Source:MGI Symbol;Acc:MGI:97430]	<i>Oas1b1.1Brin</i>
<i>Oas1f</i>	120847367	120857986	-1785925	2'-5' oligoadenylate synthetase 1F [Source:MGI Symbol;Acc:MGI:2180855]	<i>Oas1fGt(OST425760)Lex</i>
<i>Oas1h</i>	120861421	120873506	-1770405	2'-5' oligoadenylate synthetase 1H [Source:MGI Symbol;Acc:MGI:2180853]	---
<i>Oas1g</i>	120876142	120887613	-1756298	2'-5' oligoadenylate synthetase 1G [Source:MGI Symbol;Acc:MGI:97429]	---
<i>Oas1a</i>	120896256	120907521	-1736390	2'-5' oligoadenylate synthetase 1A [Source:MGI Symbol;Acc:MGI:2180860]	---
<i>Oas1d</i>	120914536	120921652	-1722259	2'-5' oligoadenylate synthetase 1D [Source:MGI Symbol;Acc:MGI:2140770]	<i>Oas1d1tm1Zuk</i>
<i>Rph3a</i>	120940499	121010092	-1633819	rabphilin 3A [Source:MGI Symbol;Acc:MGI:102788]	<i>Rph3atm1Sud</i>
<i>Ptpn11</i>	121130533	121191397	-1452514	protein tyrosine phosphatase, non-receptor type 11 [Source:MGI Symbol;Acc:MGI:99511]	<i>Ptpn11tm1.1Rbns</i> <i>Ptpn11tm1.1Wbm</i> <i>Ptpn11tm1Bgn</i> <i>Ptpn11tm1Rbn</i> <i>Ptpn11tm1Yan</i>
<i>Rpl6</i>	121204481	121209241	-1434670	ribosomal protein L6 [Source:MGI Symbol;Acc:MGI:108057]	<i>Rpl6Gt(OST1622)Lex</i> <i>Rpl6Gt(PST17838)Mfgc</i>
<i>Hectd4</i>	121220219	121368577	-1275334	HECT domain E3 ubiquitin protein ligase 4 [Source:MGI Symbol;Acc:MGI:3647820]	<i>Hectd4Gt(255G8)Cmhd</i> <i>Hectd4Gt(BC0299)Wtsi</i> <i>Hectd4Gt(BGA536)Byg</i>
<i>Trafd1</i>	121371725	121385632	-1258279	TRAF type zinc finger domain containing 1 [Source:MGI Symbol;Acc:MGI:1923551]	<i>Trafd1tm1Ayo</i>
<i>Naa25</i>	121397936	121444378	-1199533	N(alpha)-acetyltransferase 25, NatB auxiliary subunit [Source:MGI Symbol;Acc:MGI:2442563]	<i>Naa25Gt(RRK280)Byg</i> <i>Naa25Gt(AL0004)Wtsi</i>
<i>Erp29</i>	121428590	121452506	-1191405	endoplasmic reticulum protein 29 [Source:MGI Symbol;Acc:MGI:1914647]	<i>Erp29tm1Dfer</i> <i>Erp29Gt(KST171)Byg</i> <i>Erp29Gt(G014A01)Wrst</i>
<i>Tmem116</i>	121451893	121524183	-1119728	transmembrane protein 116 [Source:MGI Symbol;Acc:MGI:1924712]	<i>Tmem116Gt(OST44984)Lex</i> <i>Tmem116Gt(PST12765)Mfgc</i>
<i>Adam1b</i>	121500098	121503435	-1140476	a disintegrin and metallopeptidase domain 1b [Source:MGI Symbol;Acc:MGI:2429506]	---
<i>Adam1a</i>	121518576	121545482	-1098429	a disintegrin and metallopeptidase domain 1a [Source:MGI Symbol;Acc:MGI:2429504]	<i>Adam1b1tm1Tba</i>
<i>Mapkapk5</i>	121525038	121545905	-1098006	MAP kinase-activated protein kinase 5 [Source:MGI Symbol;Acc:MGI:1333110]	<i>Mapkapk5tm1Mgl</i> <i>Mapkapk5tm1Pqs</i>
<i>Aldh2</i>	121566027	121593824	-1050087	aldehyde dehydrogenase 2, mitochondrial [Source:MGI Symbol;Acc:MGI:99600]	<i>Aldh2Gt(OST7285)Lex</i> <i>Aldh2Gt(D053A10)Wrst</i>
<i>Acad12</i>	121596775	121618938	-1024973	acyl-Coenzyme A dehydrogenase family, member 12 [Source:MGI Symbol;Acc:MGI:2443320]	<i>Acad12Gt(OST300106)Lex</i>
<i>Acad10</i>	121621026	121660514	-983397	acyl-Coenzyme A dehydrogenase family, member 10 [Source:MGI Symbol;Acc:MGI:1919235]	<i>Acad10Gt(OST448289)Lex</i>
<i>Brp</i>	121660563	121687256	-956655	BRCA1 associated protein [Source:MGI Symbol;Acc:MGI:1919649]	---
<i>Atxn2</i>	121711337	121816493	-827418	ataxin 2 [Source:MGI Symbol;Acc:MGI:1277223]	<i>Atxn2tm1.1Geno</i> <i>Atxn2tm1Pit</i> <i>Atxn2tm2.1Geno</i> <i>Atxn2tm1.1Aub</i> <i>Atxn2tm2.1Aub</i> <i>Atxn2tm3.1Aub</i> <i>Atxn2Gt(A014A02)Wrst</i>
<i>Sh2b3</i>	121815488	121837646	-806265	SH2B adaptor protein 3 [Source:MGI Symbol;Acc:MGI:893598]	<i>Sh2b3tm1Paw</i> <i>Sh2b3tm1Rmp</i>
<i>Pheta1</i>	121848984	121854632	-789279	PH domain containing endocytic trafficking adaptor 1 [Source:MGI Symbol;Acc:MGI:2442708]	---
<i>Cux2</i>	121856366	122050102	-593809	cut-like homeobox 2 [Source:MGI Symbol;Acc:MGI:107321]	<i>Cux2tm1.1Nieto</i>
<i>Myl2</i>	122100951	122113472	-530439	myosin, light polypeptide 2, regulatory, cardiac, slow [Source:MGI Symbol;Acc:MGI:97272]	<i>Myl2tm1(cre)Krc</i> <i>Myl2tm1(Hand1)Tana</i> <i>Myl2tm1.1Chen</i> <i>Myl2tm2.1Chen</i>
<i>Ccdc63</i>	122108040	122140823	-503088	coiled-coil domain containing 63 [Source:MGI Symbol;Acc:MGI:3607777]	---
<i>Ppp1cc</i>	122158278	122175273	-468638	protein phosphatase 1 catalytic subunit gamma [Source:MGI Symbol;Acc:MGI:104872]	<i>Ppp1cctm1Lex</i> <i>Ppp1cctm1Var</i>
<i>Hvcn1</i>	122206804	122242297	-401614	hydrogen voltage-gated channel 1 [Source:MGI Symbol;Acc:MGI:1921346]	<i>Hvcn1Gt(RRN293)Byg</i>
<i>Tctn1</i>	122237848	122264460	-379451	tectonic family member 1 [Source:MGI Symbol;Acc:MGI:3603820]	---
<i>Pptc7</i>	122284365	122324281	-319630	PTC7 protein phosphatase homolog [Source:MGI Symbol;Acc:MGI:2444593]	---
<i>Rad9b</i>	122323223	122354233	-289678	RAD9 checkpoint clamp component B [Source:MGI Symbol;Acc:MGI:2385231]	<i>Rad9b1tm1Lieb</i>
<i>Vps29</i>	122354369	122364984	-278927	VPS29 retromer complex component [Source:MGI Symbol;Acc:MGI:1928344]	<i>Vps29Gt(OST309649)Lex</i>

<i>Fam216a</i>	122364580	122372364	-271547	family with sequence similarity 216, member A [Source:MGI Symbol;Acc:MGI:1916198]	---
<i>Gpn3</i>	122371876	122382902	-261009	GNP-loop GTPase 3 [Source:MGI Symbol;Acc:MGI:1289326]	---
<i>Arpc3</i>	122391878	122414184	-229727	actin related protein 2/3 complex, subunit 3 [Source:MGI Symbol;Acc:MGI:1928375]	<i>Arpc3tm1Jtak</i>
<i>Anapc7</i>	122421693	122444912	-198999	anaphase promoting complex subunit 7 [Source:MGI Symbol;Acc:MGI:1929711]	---
<i>Atp2a2</i>	122453513	122502225	-141686	ATPase, Ca++ transporting, cardiac muscle, slow twitch 2 [Source:MGI Symbol;Acc:MGI:88110]	<i>Atp2a2tm1.1Iemr</i> <i>Atp2a2tm1Fwuy</i> <i>Atp2a2tm1Ges</i>
<i>Ift81</i>	122550204	122614518	-29393	intraflagellar transport 81 [Source:MGI Symbol;Acc:MGI:1098597]	---
<i>P2rx7</i>	122643911	122691432	0	purinergic receptor P2X, ligand-gated ion channel, 7 [Source:MGI Symbol;Acc:MGI:1339957]	<i>P2rx7tm1Lex</i> <i>P2rx7tm1Gab</i> <i>P2rx7tm1.2Jde</i> <i>P2rx7Gt(OST90373)Lex</i>
<i>P2rx4</i>	122707544	122729738	16112	purinergic receptor P2X, ligand-gated ion channel 4 [Source:MGI Symbol;Acc:MGI:1338859]	<i>P2rx4tm1Rass</i> <i>P2rx4tm1Dgen</i>
<i>Camkk2</i>	122731170	122779409	39738	calcium/calmodulin-dependent protein kinase kinase 2, beta [Source:MGI Symbol;Acc:MGI:2444812]	<i>Camkk2tm1Kpg</i> <i>Camkk2tm1Shyy</i> <i>Camkk2tm1Tch</i> <i>Camkk2tm2.1Kpg</i> <i>Camkk2tm2Kpg</i>
<i>Anapc5</i>	122787459	122821339	96027	anaphase-promoting complex subunit 5 [Source:MGI Symbol;Acc:MGI:1929722]	---
<i>Rnf34</i>	122850048	122871291	158616	ring finger protein 34 [Source:MGI Symbol;Acc:MGI:2153340]	---
<i>Kdm2b</i>	122870665	122989823	179233	lysine (K)-specific demethylase 2B [Source:MGI Symbol;Acc:MGI:1354737]	<i>Kdm2btm1.1Atz</i> <i>Kdm2btm1.1Bes</i> <i>Kdm2btm1Nobu</i>
<i>Orai1</i>	123015074	123030456	323642	ORAI calcium release-activated calcium modulator 1 [Source:MGI Symbol;Acc:MGI:1925542]	<i>Orai1tm1.1Ygwa</i>
<i>Morn3</i>	123035769	123047016	344337	MORN repeat containing 3 [Source:MGI Symbol;Acc:MGI:1922140]	---
<i>Tmem120b</i>	123068415	123117749	376983	transmembrane protein 120B [Source:MGI Symbol;Acc:MGI:3603158]	---
<i>Rhof</i>	123103044	123132692	411612	ras homolog family member F (in filopodia) [Source:MGI Symbol;Acc:MGI:1345629]	---
<i>Setd1b</i>	123142193	123168629	450761	SET domain containing 1B [Source:MGI Symbol;Acc:MGI:2652820]	<i>Setd1btm1.1Afst</i> <i>Setd1btm1Afst</i>
<i>Psmc9</i>	123169413	123250131	477981	proteasome (prosome, macropain) 26S subunit, non-ATPase, 9 [Source:MGI Symbol;Acc:MGI:1914401]	---
<i>Hpd</i>	123171807	123182727	480375	4-hydroxyphenylpyruvic acid dioxygenase [Source:MGI Symbol;Acc:MGI:96213]	---
<i>Wdr66</i>	123252102	123327484	560670	WD repeat domain 66 [Source:MGI Symbol;Acc:MGI:1918495]	---
<i>Bcl7a</i>	123343834	123374992	652402	B cell CLL/lymphoma 7A [Source:MGI Symbol;Acc:MGI:1924295]	---
<i>Mlxip</i>	123394798	123457932	703366	MLX interacting protein [Source:MGI Symbol;Acc:MGI:2141183]	<i>Mlxiptm1.1Lchan</i> <i>Mlxiptm1.2Lchan</i>
<i>Rpl31-ps6</i>	123466509	123466886	775077	ribosomal protein L31, pseudogene 6 [Source:MGI Symbol;Acc:MGI:3783190]	---
<i>Il31</i>	123480157	123489489	788725	interleukin 31 [Source:MGI Symbol;Acc:MGI:1923649]	---
<i>Lrrc43</i>	123489305	123508205	797873	leucine rich repeat containing 43 [Source:MGI Symbol;Acc:MGI:2685907]	---
<i>Diablo</i>	123509765	123524176	818333	diablo, IAP-binding mitochondrial protein [Source:MGI Symbol;Acc:MGI:1913843]	<i>Diablotm1Mak</i>
<i>B3gnt4</i>	123510460	123511882	819028	UDP-GlcNAc:betaGal beta-1,3-N-acetylglucosaminyltransferase 4 [Source:MGI Symbol;Acc:MGI:2680208]	---
<i>Vps33a</i>	123528659	123573038	837227	VPS33A CORVET/HOPS core subunit [Source:MGI Symbol;Acc:MGI:1924823]	---
<i>Clip1</i>	123577795	123684618	886363	CAP-GLY domain containing linker protein 1 [Source:MGI Symbol;Acc:MGI:1928401]	<i>Clip1tm1.1Gal</i> <i>Clip1tm1Gal</i>
<i>Zcchc8</i>	123698294	123721100	1006862	zinc finger, CCHC domain containing 8 [Source:MGI Symbol;Acc:MGI:1917900]	---
<i>Rsrc2</i>	123728426	123749414	1036994	arginine/serine-rich coiled-coil 2 [Source:MGI Symbol;Acc:MGI:1913489]	---
<i>Kntc1</i>	123749716	123821593	1058284	kinetochore associated 1 [Source:MGI Symbol;Acc:MGI:2673709]	<i>Kntc1Gt(OST40060)Lex</i>
<i>Hcar2</i>	123863570	123865499	1172138	hydroxycarboxylic acid receptor 2 [Source:MGI Symbol;Acc:MGI:1933383]	<i>Hcar2tm1Lex</i> <i>Hcar2tm1Soff</i>
<i>Hcar1</i>	123876736	123880020	1185304	hydroxycarboxylic acid receptor 1 [Source:MGI Symbol;Acc:MGI:2441671]	---
<i>Denr</i>	123907175	123928835	1215743	density-regulated protein [Source:MGI Symbol;Acc:MGI:1915434]	<i>DenrGt(CSI770)Byg</i> <i>DenrGt(OST114)Lex</i>
<i>Ccdc62</i>	123930679	123969895	1239247	coiled-coil domain containing 62 [Source:MGI Symbol;Acc:MGI:2684996]	---
<i>Hip1r</i>	123973628	124005558	1282196	huntingtin interacting protein 1 related [Source:MGI Symbol;Acc:MGI:1352504]	<i>Hip1rtm1Tsr</i>
<i>Vps37b</i>	124004641	124032270	1313209	vacuolar protein sorting 37B [Source:MGI Symbol;Acc:MGI:1916724]	---
<i>Abcb9</i>	124061530	124095798	1370098	ATP-binding cassette, sub-family B (MDR/TAP), member 9 [Source:MGI Symbol;Acc:MGI:1861729]	<i>Abcb9Gt(231G11)Cmhd</i>
<i>Ogfod2</i>	124112297	124115483	1420865	2-oxoglutarate and iron-dependent oxygenase domain containing 2 [Source:MGI Symbol;Acc:MGI:1913877]	---
<i>Arl6ip4</i>	124116089	124118196	1424657	ADP-ribosylation factor-like 6 interacting protein 4 [Source:MGI Symbol;Acc:MGI:1929500]	<i>Arl6ip4Gt(OST31151)Lex</i>
<i>Pitpnm2</i>	124118690	124249760	1427258	phosphatidylinositol transfer protein, membrane-associated 2 [Source:MGI Symbol;Acc:MGI:1336192]	<i>Pitpnm2tm1Tlii</i>
<i>Pitpnm2os2</i>	124194907	124200346	1503475	phosphatidylinositol transfer protein, membrane-associated 2, opposite strand 2 [Source:MGI Symbol;Acc:MGI:3840147]	---
<i>Pitpnm2os1</i>	124229725	124237137	1538293	phosphatidylinositol transfer protein, membrane-associated 2, opposite strand 1 [Source:MGI Symbol;Acc:MGI:1923177]	---

<i>Mphosph9</i>	124250959	124327972	1559527	M-phase phosphoprotein 9 [Source:MGI Symbol;Acc:MGI:2443138]	Mphosph9Gt(OST104880)Lex
<i>Cdk2ap1</i>	124345417	124363082	1653985	CDK2 (cyclin-dependent kinase 2)-associated protein 1 [Source:MGI Symbol;Acc:MGI:1202069]	Cdk2ap1tm1Dtw Cdk2ap1Gt(D133C05)Wrst Cdk2ap1Gt(OST35764)Lex
<i>Sbno1</i>	124368702	124426001	1677270	strawberry notch 1 [Source:MGI Symbol;Acc:MGI:2384298]	Sbno1Gt(OST114991)Lex
<i>Kmt5a</i>	124439930	124462308	1748498	lysine methyltransferase 5A [Source:MGI Symbol;Acc:MGI:1915206]	Kmt5atm1.1Dare Kmt5aGt(RRB075)Byg Kmt5aGt(305D01)Cmhd Kmt5aGt(D060E05)Wrst Kmt5aGt(OST1973)Lex
<i>Rilpl2</i>	124463265	124478366	1771833	Rab interacting lysosomal protein-like 2 [Source:MGI Symbol;Acc:MGI:1933112]	Rilpl2Gt(OST96650)Lex Rilpl2Gt(450F7)Cmhd
<i>Snrnp35</i>	124483134	124491124	1791702	small nuclear ribonucleoprotein 35 (U11/U12) [Source:MGI Symbol;Acc:MGI:1923417]	Snrnp35Gt(D178F04)Wrst Snrnp35Gt(OST56118)Lex
<i>Rilpl1</i>	124493080	124531391	1801648	Rab interacting lysosomal protein-like 1 [Source:MGI Symbol;Acc:MGI:1922945]	Rilpl1Gt(209A4)Cmhd Rilpl1Gt(OST684)Lex
<i>Tmed2</i>	124540695	124550506	1849263	transmembrane p24 trafficking protein 2 [Source:MGI Symbol;Acc:MGI:1929269]	Tmed2Gt(OST78169)Lex
<i>Ddx55</i>	124552864	124569660	1861432	DEAD (Asp-Glu-Ala-Asp) box polypeptide 55 [Source:MGI Symbol;Acc:MGI:1915098]	Ddx55Gt(CSH561)Byg Ddx55Gt(OST406009)Lex
<i>Eif2b1</i>	124570213	124579131	1878781	eukaryotic translation initiation factor 2B, subunit 1 (alpha) [Source:MGI Symbol;Acc:MGI:2384802]	Eif2b1Gt(OST132125)Lex
<i>Gtf2h3</i>	124579140	124597680	1887708	general transcription factor IIH, polypeptide 3 [Source:MGI Symbol;Acc:MGI:1277143]	Gtf2h3Gt(D144D12)Wrst Gtf2h3Gt(RRG412)Byg
<i>Tctn2</i>	124598749	124627738	1907317	tectonic family member 2 [Source:MGI Symbol;Acc:MGI:1915228]	Tctn2tm1.1Reit Tctn2Gt(OST378011)Lex
<i>Atp6v0a2</i>	124628576	124724455	1937144	ATPase, H+ transporting, lysosomal V0 subunit A2 [Source:MGI Symbol;Acc:MGI:104855]	---