# Impaired polyamine metabolism causes behavioral and neuroanatomical defects in a mouse model of SnyderRobinson Syndrome 

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## Summary statement

Characterization of a mouse model of Snyder-Robinson Syndrome reveals impaired neurological functions and mitochondrial respirations and provides a set of outcome measures to evaluate future therapeutic interventions.


#### Abstract

Snyder-Robinson Syndrome (SRS) is a rare X-linked recessive disorder caused by a mutation in the SMS gene encoding spermine synthase and aberrant polyamine metabolism. SRS is


characterized by intellectual disability, thin habitus, seizure, low muscle tone/hypotonia, and osteoporosis. Progress towards understanding and treating SRS requires a model that recapitulates human mutations and disease presentations.

Here, we evaluated molecular and neurological presentations in the G56S mouse model carrying a missense mutation in the Sms gene. The lack of SMS protein in the G56S mice resulted in increased spermidine/spermine ratio, failure to thrive, short stature, and reduced bone density. They showed impaired learning capacity, increased anxiety, reduced mobility, and heightened fear responses, accompanied by reduced total and regional brain volumes. Furthermore, impaired mitochondrial oxidative phosphorylation was evident in G56S cerebral cortex, G56S fibroblasts, and Sms-null hippocampal cells, and may serve as a future therapeutic target.

Collectively, our study establishes the suitability of the G56S mice as a preclinical model for SRS and provides a set of molecular and functional outcome measures that can be used to evaluate therapeutic interventions for SRS.

## Introduction

The polyamines putrescine, spermidine, and spermine are positively charged metabolites involved in various cellular functions, such as maintaining chromatin structure, regulating gene expression, and fine-tuning metabolic pathways. They are also critical for immune cell activation, wound healing, tissue growth, and development (1-7). The levels of intracellular polyamines are tightly regulated via de novo synthesis, interconversion, and transport.

Putrescine is the main precursor in the de novo synthesis pathway, leading to the formation of higher-order polyamines spermidine and spermine (Fig. 1A). These reactions are controlled by a set of enzymes, namely spermidine synthase (SRM) and spermine synthase (SMS). Dysregulation or lack of enzymes involved in this process can cause aberrancies in polyamine metabolism, thereby contributing or underlying disease conditions such as cancers, Alzheimer's disease, and Snyder-Robinson Syndrome (SRS) (8-11).

SRS (OMIM: 309583) is a rare X-linked intellectual disability syndrome associated with pathogenic mutations in the SMS gene that lead to the loss or reduction of SMS enzymatic activity (10) (Fig. 1A). Consequently, the level of spermidine is elevated, whereas spermine is reduced. Individuals with SRS have altered spermidine/spermine ratio and exhibit thin body habitus, low muscle tone, developmental delays, and seizures (11-13), which worsen over time $(11,14)$. Some SRS individuals also have difficulty with walking, while some never achieve
ambulation (12). While mutation in the SMS gene was identified as the cause of SRS as early as 2003 (15), no suitable mammalian model exists to study disease pathophysiology and to develop effective therapeutic interventions. Previously, a mouse model called Gy (Gyro; because of its circling behavior) (16) harboring a complete deletion of the Sms gene was used to study SRS pathophysiology $(17,18)$. However, the presence of an additional mutation in the Phex gene encoding phosphate-regulating endopeptidase homolog, which is involved in phosphate transport and causes bone-related diseases $(17,18)$, complicated the interpretation of many of the abnormalities observed in this mouse model.

Here, we describe the disease presentation in a recently generated mouse model of SRS (19) that carries a mutation variant analogous to that reported in individuals diagnosed with severe SRS (12). Our findings revealed that the mutant mice recapitulated many phenotypic defects characteristics of SRS, including failure to thrive, short stature, decreased bone density, cognitive impairments, and reduced brain volumes. Furthermore, transcriptomic analysis and functional assay in various SMS-deficient models identified impaired mitochondrial oxidative phosphorylation as one of the molecular mechanisms underlying SRS pathogenesis.

## RESULTS

## Loss of SMS expression alters polyamine contents in mice.

A mouse model carrying a missense mutation in the Sms gene was generated in a collaborative effort between the Snyder-Robinson Syndrome Foundation and the Jackson Laboratory Rare Disease Translational Center (19). Specifically, the mice harbor two nucleotide changes (GGC to TCC) in exon two of the Sms gene, resulting in a Glycine to Serine substitution at position 56 of the SMS protein, hereafter called the G56S mice.

We first determined whether the G56S mutation altered the SMS expression profile and tissue polyamine levels. We found that the level of Sms mRNA remains unchanged (Fig. 1B). However, there was a near-complete loss of SMS protein in both the brain and skeletal muscles of G56S mice (Fig. 1C).

To further understand the impact of the mutation on SMS structure and functions, we performed in silico two-dimensional (2D) modeling to visualize the C-terminal and the N -terminal domains, which are important for catalytic activity and dimerization, respectively (Fig. 1D). Compared to the wildtype SMS (Fig. 1E), the presence of Serine at position 56 in the G56S SMS mutant creates an extended side chain which interferes with monomer dimerization (Fig. 1F), as
previously described by Zhang et. al., (20), and may account for the loss of SMS protein expression despite the normal transcript level.

Consequently, the spermidine level was elevated while the spermine level was reduced, resulting in a significantly higher spermidine/spermine ratio in the G56S brain (Fig. 1G) and skeletal muscles (Fig. 1H). Putrescine level was also increased in the G56S brain; however, it fell below the detection limit in the skeletal muscles. Overall, the loss of SMS expression in G56S mice resulted in elevated spermidine and the ratio of spermidine/spermine, similar to that described in cells from SRS patients (21).

## Biometric parameters are significantly altered in G56S mice

SRS-affected individuals typically exhibit an asthenic physique with a thin body build, short stature, low muscle tone, and failure to thrive (11). Therefore, we interrogated whether some of these features are present in the G56S mice. We observed that the G56S mice have significantly lower body weight (Fig. 2A) and reduced length (Fig. 2B) compared to the agematched wildtype counterparts. We found no significant differences in the amount of food consumed by both the wildtype and the G56S mice, as measured using a comprehensive laboratory animal monitoring system (CLAMS) $(22,23)$ (Supplementary Fig. 1A), suggesting that the failure to thrive is attributed to the disease and not food intake.

Subsequently, we analyzed the body composition of the mice using Echo MRI. We found that the mice had a higher percentage of lean muscle mass. Further examination of the muscle phenotypes revealed no difference in muscle fiber size (Supplementary Fig. 1B, 1C) and grip strength (Supplementary Fig. 2A) between the wildtype and G56S mutant mice. Interestingly, despite the lack of apparent muscle phenotypes, there was a significant reduction in the fat weight in the G56S mice compared to the wildtype counterparts (Fig. 2C), reflecting the asthenic feature of SRS individuals.

Next, we assessed whether bone deformities were present in the G56S mice. We subjected the mice to whole-body three-dimensional micro-CT imaging and found that the G56S mice had significantly lower bone mineral density (Fig. 2D and Supplementary Fig. 2B). Collectively, altered biometric readouts, such as shortened stature, failure to thrive, reduced body fat, and bone mineral density indicate that polyamine perturbation impacts the growth and development in the G56S mice.

## The G56S mice have less activity and exploratory behaviors than the wildtype animals.

 To assess their neurological presentations, the mice were subjected to a longitudinal open field test, which gauges the general locomotion and anxiety-like behavior over time. We observed a significant reduction in the total activity of the G56S mice starting at the age of 18 weeks old (Fig. 3A, Fig. 3B). The G56S mice also demonstrated a lack of exploratory behavior, as shown by their reluctance to enter the inner zone (Fig. 3C) and tendency to stay in the outer zone (Fig. 3D) of the open field arena. Such behavior is indicative of an anxiety-related response, which is one of the prominent features of neurological disorders such as SRS. Interestingly, there was no difference in the activity and exploratory behavior between the G56S and the wildtype animals younger than 18 weeks old, suggesting a progressive nature of the disease.
## Cognitive impairment is evident in the G56S mice.

One of the major neurological presentations in SRS is mild to severe cognitive impairments (12). Therefore, we performed a Morris water maze (MWM) assay to assess the spatial memory and learning in the G56S mice (Fig. 4A). First, the animals were trained daily to navigate and locate an escape platform that was submerged or hidden under the water. The time required for the animals to reach the escape quadrant was recorded. On day six, the platform was either removed (probe test) or placed above the water level (visible test).

We observed that, in general, the G56S mice took longer to find the escape quadrant compared to their wildtype counterparts. The trends were not significant during the training period (Fig. 4B) and in the probe test (Fig. 4C). However, there was a significant difference in the visible test (Fig. 4D). These data indicate that the G56S mice were less effective in retaining the information necessary to complete the task compared to the wildtype counterparts, suggesting some degree of learning impairments. It is important to emphasize that the mice were only tested at 16 weeks. Thus, we were unable to verify any age-related decline in the learning impairments.

## The G56S mice demonstrate heightened fear responses.

To complement the assessment of spatial learning through MWM, we measured stress-induced freezing via fear conditioning test, which centered on complete tonic immobilization behavior due to innate, anti-predator, fear-related responses in rodents. The assay comprises three parts, namely fear acquisition training (Fig. 5A), contextual (Fig. 5D), and cued (Fig. 5F) tests.

First, the mice were trained to associate sound (conditioned stimulus, CS) with a foot shock, with dedicated soundless intervals (intertrial interval, ITI) between each stimulus. The stressinduced freezing time was recorded during the CS and the ITI (Fig. 5A). We observed a consistent increase in the freezing responses following the sound stimulation in both the wildtype and G56S mice, which eventually plateaued (Fig. 5B), indicating similar rates of fear acquisition in both groups. However, during the ITIs, significantly longer and more frequent freezing responses were observed in the G56S mice (Fig. 5C), indicating more profound fear responses following stimulations than their wildtype counterparts.

On the second day, the mice were placed in the same experimental chamber, i.e., contextually similar, without any sound or electrical stimulation (Fig. 5D). We observed an increase in freezing response in the G56S mice, although it did not reach any statistical significance (Fig. 5E). On the final day, the mice were placed in a different test chamber for an initial 60 seconds habituation period, and subsequently provided with the sound stimulation, i.e., cued (Fig. 5F). The mutant mice showed clear elevated freezing percentages throughout the cued test compared to their wildtype counterparts (Fig. 5G). Taken together, these data suggest that the G56S mice exhibit heightened anxiety-related fear responses, which are typically present in neurological disorders.

## Reduced total and regional brain volumes in G56S mice.

Next, we determined whether the neuroanatomical structures were impaired in the G56S mice.
We assessed the brain volumes of 18 -week-old G56S and wildtype mice using T2-weighted MRI (Fig. 6A) and found that the G56S mice had smaller total brain volumes (Fig. 6B). Furthermore, several regions such as the amygdala, corpus callosum, and hippocampus were also smaller in volumes in the G56S mice than their wildtype counterparts (Fig. 6C). Subsequently, diffusion tensor imaging protocol was applied to interrogate any microstructural integrity of the brain. We observed a significant reduction in fractional anisotropy in the G56S amygdala and corpus callosum (Fig. 6D), which indicates disrupted fiber tracts in these regions. The amygdala is responsible for fear learning and emotional responses, whereas the hippocampus is involved in various cognitive functions. Collectively, the reduction in brain volumes and disruption in microstructural integrity, particularly in the amygdala and hippocampus regions, largely support the behavioral findings seen in the G56S mice.

## SMS deficiency alters transcriptomic profiles in the G56S brain cortical region.

To unbiasedly interrogate the molecular mechanisms underlying some of the observed phenotypic abnormalities, we performed transcriptomic analysis on RNA isolated from G56S and wildtype brain cortex. The G56S cortex exhibited a significant decrease in spermine content (Supplementary Fig. 3), similar to the total brain finding (Fig. 1G). We focused on the cortex because of its role in directing higher complex tasks, including learning, memory, and consciousness. Furthermore, previous studies suggest that spermine may have a protective role within the cerebral cortex $(24,25)$.
Our data revealed more than 1,000 differentially expressed genes (DEGs) between 18 weeks old wildtype and G56S mice (Fig. 7A and Supplementary Table 2), for which after statistical filtering, the top 40 DEGs were presented as a heatmap (Fig. 7B). Gene enrichment pathway analysis revealed inhibition of pathways involved in mitochondrial oxidative phosphorylation (OXPHOS) and eukaryotic initiation factor 2 (elF2) signaling crucial for ribosome protein synthesis, as well as activation of Huntington's disease, sirtuin, and synaptogenesis signaling pathways (Fig. 7C). Some of these genes were further visualized on Volcano plot (Fig. 7D) and confirmed by qRT-PCR (Fig. 7E). Specifically, we observed decreased expression of several genes involved in OXPHOS, such as Atp5e, Uqcr10, Cox6B1. Of note, the expression of other OXPHOS-related genes such as Cox4i1, Cox7b, Ndufa4, and Ndufa7 were also reduced, although they did not reach statistical significance. Furthermore, there were decreases in the expression of Rpl17 and Rsp14 (both implicated in ribosome protein synthesis via elF2 signaling), as well as increases in the expression of Hap1 (Huntington-associated protein 1) and Grin2b (ionotropic NMDA receptor subunit 2b). Collectively, the transcriptomic data presented here outline several cellular processes, including but not limited to mitochondrial OXPHOS, that transpire from SMS deficiency and altered polyamine contents in the brain.

## SMS deficiency impairs mitochondrial respiration in murine hippocampal cells.

Finally, we sought to perform functional validation on the impact of SMS deficiency on mitochondrial OXPHOS. We deleted the Sms gene in mouse embryonic hippocampal cells (mHippoE-14) using CRISPR-mediated knockout (Fig. 8A), resulting in altered polyamine content (Fig. 8B). We subsequently assessed the mitochondrial respiration using Seahorse Bioanalyzer (Fig. 8C) and found a significant reduction in basal respiration, maximal respiration, the rates of ATP production, and spare respiratory capacity (Figs. 8D-8G) in the SMS-KO cells, compared to control cells. In parallel, we isolated primary fibroblasts from the G56S and wildtype mice (Supplementary Fig. 4) and measured their mitochondrial respiration. Similar to the SMS-KO hippocampal cells, the G56S fibroblasts also exhibited a significant reduction in
basal and maximal respiration, ATP production, and spare respiratory capacity. Taken together, these data strongly suggest that SMS deficiency and impaired polyamine metabolism alter mitochondrial bioenergetics and functions, which may contribute to the disease pathogenesis.

## Discussion

In this study, we present a detailed characterization of the G56S mouse model carrying a missense Sms mutation, which recapitulates variants in patients with severe forms of SRS. We first demonstrated that the G56S mice lack SMS protein, resulting in high tissue spermidine levels and spermidine/spermine ratio. Furthermore, we showed that the G56S mice have small stature, with evident failure to thrive and reduced fat content, yet slightly increased lean muscle mass. Increased spermidine has been implicated in promoting lipolysis (26), which may largely explain the reduction in body fat in the G56S mice. It is also possible that the absence of SMS or alteration in the spermidine/spermine ratio impairs mitochondrial functions $(27,28)$. In this case, the mice will depend more on glycolysis as a means of energy generation, thereby resulting in increased energy expenditure and less body fat. The decreased body weight and short stature seen in the G56S mice are consistent with the notion that disturbances in polyamine homeostasis impair cell growth and tissue development (4), which may lead to general growth failure.

We also observed low bone mineral density in the G56S mice. While most SRS-affected individuals, including those with the G56S mutation (12), are eventually diagnosed with kyphoscoliosis, no scoliosis was detected in micro-CT scans of these mice. However, we cannot rule out the possibility that abnormal spines may develop in older mice.

The G56S mice display signs of cognitive impairment, reduction in exploratory behavior, and heightened fear responses, which strongly indicate the existence of neurological abnormalities similar to what has been reported in many SRS-affected individuals. Since polyamines are involved in the development of the nervous system (29), specific brain regions might be contributing to these behavioral defects. Indeed, the volumes of the amygdala and hippocampus, which are involved in fear-associated memory and learning, are decreased in the G56S mice, similar to those reported in humans (24). The MRI finding also suggests brain atrophy, as indicated by the decrease in the fractional anisotropy value. Thus, these results indicate that impaired polyamine metabolism and excess spermidine accumulation might cause atrophy and neuronal loss in these regions (24), which could manifest as impaired behavioral and learning outcomes.

The disruption of the polyamine pathway in the central nervous system has previously been associated with abnormal behavioral defects in the Dach-SMOX mouse model with overexpression of spermine oxidase and overactive spermine catabolism $(30,31)$. Consequently, the Dach-SMOX mice have decreased spermine and elevated spermidine and by-products of spermine catabolism in the cerebral cortex $(30,31)$. Importantly, these mice show greater susceptibility to epileptic seizures and are thus used as a tool to evaluate treatment for epilepsy $(31,32)$. Given that epileptic seizure is one of the significant clinical presentations in patients with SRS (11-13), it would be crucial to interrogate whether SMS deficiency manifests as epileptic seizure in the G56S mice. Overall, the disruption of the polyamine pathway in both the Dach-SMOX and the G56S mice has significant consequences on the central nervous system pathophysiology.

One potential mechanism that explains the behavioral defects observed in the G56S mice is the spermidine-mediated disruption of receptor signaling. In an earlier study, Rubin et al. (33) reported that intra-amygdala administration of spermidine in an experimental rat model resulted in a dose-dependent increase in freezing responses. These results suggested that the excess accumulation of spermidine in the brains of G56S mice might contribute to the observed increase in anxiety-related behaviors. However, the precise mechanisms underlying spermidinemediated increases in fear responses remain unknown.

Spermidine may regulate the function of the amygdala via interactions with and modulation of the ion channel receptor for N-methyl-D-aspartate (NMDA). An earlier report detailed polyamine-mediated negative regulation of this receptor (34). Administration of arcaine, a putative competitive antagonist at the polyamine binding site of the NMDA receptor, decreased spermidine-induced fear responses in rats (33). Collectively, these results suggest that spermidine levels may impact amygdala function and that excess accumulation of spermidine may induce a fear response and other behavioral abnormalities seen in the G56S mice.

In addition to the neuroanatomic defects, the transcriptomic analysis revealed other potential mechanisms contributing to the phenotypic abnormalities observed in the G56S mice. These include impaired mitochondrial function, alterations in ribosomal protein synthesis signaling pathways, and upregulation of genes implicated in the pathogenesis of Huntington's disease. Although not elucidated further in our study, mitochondrial dysfunction has been implicated in various neurological or neurodegenerative diseases (35), including in SRS (27,28). Schwartz et al., (11) also found decreased mitochondria respiration in isolated fibroblasts from SRS patients (unpublished personal communication). Increased spermidine levels that accumulate in cells that lack SMS may promote the synthesis and release of reactive oxygen species (ROS), which
induce mitochondrial oxidative stress and impaired mitochondrial function (28). Furthermore, earlier reports suggest that spermine modulates mammalian mitochondrial translation initiation processes $(36,37)$. Thus, the lack of SMS and spermine in the G56S mice may inhibit the synthesis of mitochondrial proteins and potentially result in impaired mitochondrial functions. In addition, normal mitochondrial metabolism can result in the accumulation of potentially damaging levels of by-products, including ROS and $\mathrm{Ca}^{2+}(38)$. As a polycationic molecule, spermine is known to have the potential to scavenge mitochondrial ROS $(39,40)$ and reduce the levels of mitochondrial permeability transition pore (mPTP) generated in response to $\mathrm{Ca}^{2+}$ accumulation (41). Thus, the lack of SMS or an observed decrease in cellular spermine content may result in mitochondrial damage. Finally, it is also possible that mitochondrial impairment in SRS may relate to the decreased expression of nuclear genes encoding mitochondrial proteins reported in this study. Although we do not yet understand how Sms mutations and/or decrease in spermine content result in the changes in gene expression pattern observed in this study, either factor may be involved in direct or indirect interactions with critical transcription factors. Identifying these relevant transcription factors will be important to improve our understanding of how spermine and/or SMS modulate mitochondrial functions.

Finally, we acknowledge that natural history studies in mice are a valuable way to understand disease progression. Indeed, longitudinal assessments of mobility and anxiety in the open field assay show developmental changes over time (Figure 3), indicating phenotypic deterioration of the G56S mice. However, the remainder of the behavioral assays and neuroanatomical assessments were performed at a single time point, which prevented us from capturing the agerelated decline in a comprehensive manner. Such limitation was largely attributed to the difficulty in obtaining a sufficient number of hemizygous G56S mice. As shown in Supplementary Figure 5, the rate of obtaining male hemizygous G56S mice was below the typical Mendelian ratio. It is likely due to embryonic lethality; however, interrogating such a mechanism is out of the scope of this study. These observations were not unique to our facility and reported by other laboratories (personal communication, Snyder-Robinson Foundation Conference). During our disease characterization study, an effort has been made to swap the genetic backgrounds from C57BL/6J (described in this paper) to B 6 C 3 H , which is a mix of C57BL/6J and $\mathrm{C} 3 \mathrm{H} / \mathrm{HeJ}$ backgrounds, to improve the breeding quality. This new strain $\mathrm{B} 6 \mathrm{C} 3 \mathrm{H}-$ Sms ${ }^{\text {em2Lutzy } / J \text {, (Jackson Laboratory stock \# 033707), is commercially available and can be }}$ incorporated for future pre-clinical assessment of therapeutic interventions for SRS.

In conclusion, efforts to develop effective therapies for SRS will require a better understanding of the disease pathophysiology as well as suitable mutation/variant-specific animal models that
recapitulate many of the critical clinical manifestations in the affected individuals. The findings presented in this study suggest that the G56S mouse is a good model that can be used to study SRS pathogenesis and serve as an important tool for therapeutic development. Several therapeutic interventions that are currently in development focus on rebalancing the spermidine/spermine ratio using polyamine analogs $(21,42)$ or difluoromethylornithine to slow down putrescine production (21), or alleviating the effect of spermidine-induced ROS using antioxidant $(28,43)$. Gene therapy and genome editing are gaining momentum in the rare disease space (44) for which mutation in SMS in SRS would be a suitable target. Our study lays the critical foundation and provides useful parameters that may be adopted in efforts to assess the efficacy of any therapeutic agents and/or improve current clinical management of SRS.

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## Declaration of interests

The authors declare no competing interest.

## Author contributions

Conceptualization: O.A. and D.U.K; Investigation: O.A., A.M., M.J., M.S.P., Y.G., Y.W., J.F., T.M.S, R.A.C.; Formal analysis and visualization: O.A., A.M., M.E.P., Y.G., Y.W., H.B., D.U.K; Writing: O.A. and D.U.K.; Supervision, D.U.K. All authors read and commented on the manuscript.

## Data availability

All data relevant to this study are included in the article or uploaded as supplementary information. The sequencing files for the transcriptomic analysis presented in this study are available in the public open repository, https://www.ncbi.nlm.nih.gov/geo/ with the accession number GSE226413.

## Materials and methods

Mice: All animals used in this study were housed at the University of Pittsburgh Division of Laboratory Animal Resources, Rangos Research Building, following the IACUC protocol number 2206137, which was approved by the University of Pittsburgh's Institutional Animal Care and Use Committee. The colony of mutant mice was established by breeding female heterozygous Sms mutation carriers (C57BL/6J-Sms ${ }^{\text {em2Lutzy } / J ; ~ J a c k s o n ~ L a b o r a t o r y ~ s t o c k ~ \# ~}$ 031170) and male WT C57BL/6J mice (Jackson Laboratory stock \# 000664). The male offspring of this cross that harbored the X-linked G56S Sms mutation and WT littermate controls were used in the experiments described in this study. To ensure that only male mice harboring the desired mutation were used, pups were genotyped at Transnetyx.com using the following probes: forward primer ACCTGGCAGGACCATGGATATTTA, reverse primer GTGTTCACATCTAAAGCCCATGAGA, reporter 1 AACAAGAATGGCAGGTAAG and reporter 2 ACGAACAAGAATTCCAGG.

Open field activity assay: The open field chamber is a hollow square field box equipped with tracking software (ACTITRACK, Panlab/Harvard Apparatus, USA) connected to an infrared tracking system that monitors animal movement. The walls of the box were opacified (covered with aluminum foil) to prevent the environment from influencing the behavior of the mouse
undergoing testing. The chamber was divided into two imaginary zones: an outer zone (45 x 45 cm ) and an inner or center zone ( $18.5 \mathrm{~cm} \times 18.5 \mathrm{~cm}$, centered at 22.5 cm from the wall on each side). Experiments were undertaken under constant room temperature ( $22-25^{\circ} \mathrm{C}$ ) and light levels. The mice were habituated in the procedure room for 15 minutes each time before the assay was initiated. This was done to reduce any stress on the mice before the tests were conducted. Each mouse was released at the same location near the wall of the box and movement was evaluated for 15 minutes using the infrared tracking system. The positions recorded for each mouse were used to generate tracking plots and to determine the distance traveled, speed, and time spent in each zone (i.e., within the entire apparatus and specifically in the center zone). The total amount of time spent and the type of body motion (i.e., rearing, leaning, and vertical activity) detected in the center zone were used as relative measurements of explorative behavior and anxiety-related responses, respectively.

Auditory-cued fear conditioning: The conditioning procedure was carried out using a specifically designed chamber (model H10-11M-TC-SF Coulbourn Instruments, Whitehall, PA, USA). The conditioning chamber ( $25 \times 25 \times 25 \mathrm{~cm}$ ) had three grey methacrylate walls, a grid floor connected to a shock scrambler to deliver foot shock as the unconditioned stimulus (US), and a speaker mounted on the chamber ceiling to deliver audible tones as the conditioned stimulus (CS). The conditioning chamber was fitted with a high-sensitivity camera system that monitored animal movement. The chamber was confined in a ventilated, soundproof enclosure ( $78 \times 53 \times 50 \mathrm{~cm}$ ) on an anti-vibration table in a quiet room. The door to the room remained closed throughout the conditioning and testing periods.

On the first day (fear acquisition), the animals were habituated for 120 sec in the chamber before the delivery of CS-US pairs (i.e., a 75 dB tone [CS] for 20 sec followed by a $15-\mathrm{sec}$ trace and then foot shocks [US] of 0.6 mA for 2 sec ) with variable and pseudo-randomly distributed intervals between pairs of stimuli ( $90-203 \mathrm{sec}$ ). On the second day (fear retention), the session started with the mice placed in the same environment. During this phase, the mice were provided with no stimulation that might elicit contextual fear responses. Freezing responses in this otherwise familiar environment were monitored.

For the third session, the mice were placed in a different environmental setting (i.e., a chamber with a covered floor and white walls) to assess the retention of cued fear in a novel context. Baseline fear responses were monitored for 90 sec followed by the delivery of three CS ( 75 dB and 20 s) separated by variable inter-trial intervals (ITIs). The movement of the animal was sampled at a frequency of 50 Hz for quantitative analysis (Freezeframe, Coulbourn Instruments,

USA). Freezing was analyzed during the delivery of the CS ( 20 sec periods) as well as during the 15 sec trace period that would ordinarily precede the US (not delivered) to monitor the associative fear response. The animals were gently handled before, during, and after the test to avoid introducing any additional potential stress before or during each test that could influence the measured responses.

Morris Water Maze (MWM) Task: The MWM task was performed in a circular pool containing water using the procedure described by Tsien et al. (45) with slight modifications. The animals were trained to find an escape platform that was submerged in the water. The training protocol (hidden platform, used to evaluate spatial learning) included five sessions with 4 trials per session per day. Navigation was tracked by a video camera and the escape latency (i.e., the time required to locate the platform) was recorded. An animal that failed to locate the platform within 90 sec was guided to the platform. We then performed visible (to measure spatial memory) and probe (to measure non-spatial memory) tests on day six. In the visible test, colored tape was placed at the top of the platform. For the probe test, the platform was removed; the mice were allowed to swim in the pool for 60 s , and the time spent in each quadrant of the pool was recorded. The visual acuity of the mice in the pool was confirmed by the changes in the swimming direction when approached by the technician carrying out the test. The acquired data was analyzed using the ANY-maze software.

In vivo Magnetic Resonance Imaging (MRI) scans: All mice were subjected to in vivo brain imaging while under isoflurane anesthesia. The mice were placed in a clear plexiglass anesthesia induction box that permitted unimpeded visual monitoring. Induction was achieved by the administration of $3 \%$ isoflurane in oxygen for several minutes. The depth of anesthesia was monitored by the toe reflex (extension of limbs, spine positioning) and respiration rate. Once established, the appropriate level of anesthesia was maintained by continuous administration of $1-2 \%$ isoflurane in oxygen via a nose cone. The mice were then transferred to the designated animal bed for imaging. Respiration was monitored using a pneumatic sensor placed between the animal bed and the mouse's abdomen. Rectal temperature was measured with a fiber optic sensor and maintained with a feedback-controlled source of warm air (SA Instruments, Stony Brook, NY, USA).
In vivo brain MRI was carried out on a Bruker BioSpec 70/30 USR spectrometer (Bruker BioSpin MRI, Billerica, MA, USA) operating at 7-Tesla field strength and equipped with an actively shielded gradient system and a quadrature radio-frequency volume coil with an inner
diameter of 35 mm . Multi-planar $\mathrm{T}_{2}$-weighted anatomical images were acquired with a Rapid Imaging with Refocused Echoes (RARE) pulse sequence with the following parameters: field of view $(F O V)=2 \mathrm{~cm}$, matrix $=256 \times 256$, slice thickness $=1 \mathrm{~mm}$, in-plane resolution $=78 \mu \mathrm{mX}$ $78 \mu \mathrm{~m}$, echo time $(T E)=12 \mathrm{msec}$, RARE factor $=8$, effective echo time $(E T E)=48 \mathrm{msec}$, repetition time $(T R)=1800 \mathrm{msec}$, and flip angle $=180^{\circ}$. Multi-planar diffusion MRI was performed using the following parameters: field of view $(F O V)=2.0 \mathrm{~cm}$, matrix $=128 \times 128$, slice thickness $=1.5 \mathrm{~mm}$, in-plane resolution $=156 \mu \mathrm{~m} \times 156 \mu \mathrm{~m}, \mathrm{TE}=16.31 \mathrm{msec}, \mathrm{TR}=1500$ msec, diffusion preparation with the spin echo sequence, diffusion gradient duration $=4 \mathrm{msec}$, diffusion gradient separation $=8 \mathrm{msec}$, diffusion direction $=30$, number of $A_{0}$ images $=1$, and $b$ value $=1500 \mathrm{~s} / \mathrm{mm}^{2}$.

The MRI data were exported to a DICOM format and analyzed using the open-source ITKSNAP (http://www.itksnap.org) brain segmentation software by 2 independent observers who were blinded to the experimental conditions. The volumes of each region of interest (ROI), including the amygdala, corpus callosum, thalamus, ventricles, hippocampus, and cortex were manually drawn by blinded observers based on the information obtained from the Allen mouse brain atlas (https://mouse.brain-map.org/static/atlas). To account for potential differences in the sizes of brains in G56S and WT mice, volumes from each brain region were normalized to the total brain volume of each mouse.

Diffusion MRI was analyzed by the open-source DSI studio (http://dsi-studio.labsolver.org/) to obtain fractional anisotropy (FA). ROIs contributing to quantitative and statistical analyses, including the cortex, hippocampus, thalamus, corpus callosum, and ventricles with cerebrospinal fluid (CSF) were manually segmented and defined by blinded independent observers.

In vivo micro-Computed Tomography (micro-CT) scans: All mice undergoing in vivo microCT imaging were maintained under general inhalation anesthesia with isoflurane as described for MRI scans above. Once established, anesthesia was maintained with $1.5 \%$ isoflurane in oxygen administered using a nose cone, and the mouse was transferred to the designated animal bed for imaging. Respiration was monitored as described above. Respiration gating was performed using a BioVet system that was triggered by maximal inhalation with a 500 ms trigger delay.

Respiration-gated in vivo micro-CT imaging was performed with Siemens Inveon Multimodality micro-CT-SPECT-PET system with the following parameters: full rotation, $360^{\circ}$ projections; settle time 1000 msec ; 4X4 binning; effective pixel size of $76.75 \mu \mathrm{~m}$; trans axial field of view
(FOV) 78.6 mm with 4096 pixels; axial FOV 76.1 mm with 3968 pixels 80 kV of voltage; current of $500 \mu \mathrm{~A}$; exposure time of 410 ms . The three-dimensional (3D) micro-CT images were reconstructed using the Feldkamp algorithm and were calibrated in Hounsfield Units (HU). Double distilled water was set at a readout of 0 and air at -1000 HU .

The 3D micro-CT image stacks were analyzed using the Inveon Research Workplace (IRW). The ROI analysis function was used with a thresholding tool that created several ROIs with different Hounsfield Units (HU). A cylindrical 3D ROI was drawn around the body that encompassed the entire body. All external air around the mouse was excluded from the ROI and a custom threshold was set between $400-5700 \mathrm{HU}$ to capture the bones. The mean HU values obtained from each ROI were used to quantify bone density.

Body composition measurements: The body composition (percentage lean and fat weight) of the mice was measured by quantitative MRI (EchoMRI, Echo Medical Systems, Houston, TX). Animals were placed in thin-walled plastic cylinders with plastic restraining inserts. Each animal was briefly subjected to a low-intensity electromagnetic field that measured total body composition. Percentages of fat and lean weights were determined based on total body weight.

Cell lines: Primary fibroblast cells from the ears of the G56S and WT mice were isolated using the protocol described by Khan and Gasser (46). The identity of the fibroblasts was confirmed by Vimentin immunofluorescence staining against non-fibroblasts sources. Mouse embryonic hippocampal cells (mHippoE-14) were purchased from Cedarlane, Canada. Cedarlane Canada performed authentication of the mHippoE-14 prior to shipping. Antibiotic-free supernatant was collected from all cell lines and tested for mycoplasma annually. Cell lines used in this study are confirmed to be mycoplasma-negative.

RNA isolation and quantitative polymerase chain reaction (qPCR): Total RNA was isolated from mouse tissues using the Nucleospin RNA Plus kit (Macherey-Nagel, cat\# 740984.50), following the manufacturer's instructions. cDNA synthesis was performed using the iScript Reverse Transcriptase Supermix kit (BioRad, Cat\# 1708841) according to the manufacturer's instructions. qPCR was performed using a 2 X SYBR Green Fast qPCR Mix kit (ABclonal, cat\# RM21203) in a C1000 Touch Thermal Cycler (BioRad, USA). The primer sequences used to amplify target genes of interest are listed in Supplementary Table 1. The expression of endogenous Gapdh was used as an internal control to measure the relative expression of genes
of interest. The $2^{\Delta \Delta C t}$ was used to assess relative fold change in gene expression in tissue samples from WT and G56S mice. Values are presented as the percentage change in fold expression.

RNA-sequencing (RNA-seq) and pathway enrichment analysis: After completing the RNA extraction procedure described above, samples were submitted to the Health Sciences Genomic Core at the UPMC Children's Hospital of Pittsburgh. RNA quality was determined using the Agilent Bioanalyzer 5300 Fragment Analyzer (Agilent Technologies, USA). cDNA libraries were prepared using the Illumina Stranded mRNA library preparation kit (Illumina). Sequencing was performed using the NextSeq 2000 platform with pair-end 58 bp reads. Analysis of sequence reads, including quality control, mapping, and generation of tables of differentially expressed genes (DEGs), heatmaps, and volcano plots) were performed using the Qiagen licensed CLC Genomic Workbench software vs 22.0.1. Pathway enrichment analysis of the DEGs was performed using the Qiagen-licensed Ingenuity Pathway Analysis (IPA) software. The gene expression profile identified by RNA-seq was validated by qPCR as described above.

In vitro analysis of mitochondria respiration (Seahorse assay): Oxygen consumption rates (OCRs) were determined using a Seahorse XFe96 Extracellular Flux Bioanalyzer (Agilent Technologies, Santa Clara, California, USA). Cells were plated in a 96 -well assay plate at a density of 10,000 (for mHippoE-14 cell line) or 40,000 cells/well (for primary fibroblasts) and cultured overnight. The following day, cells were equilibrated with Seahorse XF base medium (Agilent Technologies) supplemented with glucose, sodium pyruvate, and L-glutamine at $37^{\circ} \mathrm{C}$ in a non $-\mathrm{CO}_{2}$ incubator for 1 hour before assay measurement. Mitochondrial function was assessed by sequential addition of $1.5 \mu \mathrm{M}$ oligomycin, $1 \mu \mathrm{M}$ FCCP (carbonyl cyanide-4[trifluoromethoxy] phenylhydrazone), and $0.5 \mu \mathrm{M}$ rotenone/antimycin A by the Seahorse Bioanalyzer. Data was normalized by the total protein content of the cells.

Protein isolation, quantification, and western blotting. Total proteins were extracted from tissues isolated from G56S and WT mice tissues using RIPA homogenizing buffer ( $150 \mu \mathrm{~L}$ of 50 mM Tris $\mathrm{HCl} \mathrm{pH} 7.4,150 \mathrm{nM} \mathrm{NaCl}, 1 \mathrm{mM}$ EDTA) followed by homogenization using a bullet blender. After homogenization, $150 \mu \mathrm{~L}$ of RIPA double-detergent buffer ( $2 \%$ deoxycholate, $2 \%$ NP-40, 2\% Triton X-100 in RIPA homogenizing buffer) supplemented with protease inhibitor cocktail (Roche, cat\# A32953) was added to the tissue homogenate followed by incubation on a
shaker for 1 h at $4^{\circ} \mathrm{C}$. The tissue homogenate was then centrifuged at $11,000 \mathrm{~g}$ for 10 min at $4^{\circ} \mathrm{C}$. The resulting supernatant was used to quantify total protein using the Pierce BCA protein assay kit (Thermo Scientific, cat\# 23225) according to the manufacturer's protocol. Twenty micrograms of total protein were fractionated on $4-12 \%$ gradient gel (Thermo Scientific, cat\# NP0336BOX). After proteins had separated on the gel, they were transferred by electroblotting onto a polyvinylidene fluoride (PVDF) membrane and blocked with $5 \%$ non-fat milk in TBS-Tween-20. The membrane was then incubated overnight with rabbit anti-spermine synthase (Abcam, cat\# ab156879 [EPR9252B]) or rabbit anti-vinculin (Abcam, cat\# ab129002 [EPR8185]). After incubation with the primary antibody, the membranes were washed and then incubated with the secondary antibody (Goat Anti-Rabbit IgG - HRP conjugate, Bio-Rad cat\# 1706515) for one hour at room temperature. Specific protein bands were detected using SuperSignal ${ }^{\text {TM }}$ West Femto Maximum Sensitivity Substrate (Thermo Scientific, cat\# 34095). Bands corresponding to immunoreactive SMS and Vinculin were identified and quantified using the ChemiDoc Imaging System (BioRad).

Polyamine measurement: The polyamine content in isolated tissues was measured by the precolumn dansylation, a high-performance liquid chromatography method described by Kabra et al. using 1,7-diaminoheptane as the internal standard (47).

Statistical analysis: Statistical analysis was performed using GraphPad Prism software vs 9.0. Each variable was statistically compared between the WT and G56S mice using an unpaired ttest unless otherwise stated. A p-value less than 0.05 was considered statistically significant.

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Figures


Fig. 1. Lack of spermine synthase and perturbation of polyamine metabolism in SRS. A. Polyamine metabolism pathway in healthy and SRS. Abbreviations: ODC, ornithine decarboxylase; SRM, spermidine synthase; SMS, spermine synthase; SMOX, spermine oxidase; SAM, s-adenosylmethionine; AMD-1, adenosylmethionine decarboxylase; dcSAM, decarboxylated s-adenosylmethionine; PAO, acetylpolyamine oxidase; SAT1, spermidine/spermine acetyltransferase. B. Sms mRNA expression in the brain of 7 -week-old wildtype and G56S mutant. C. SMS protein expression in brain and skeletal muscles (triceps and gastrocnemius) of 7 -week-old wildtype and G56S mice. D. 2D-crystal crystal structure of the SMS protein with glycine at position 56 in the N-terminal region (circled). The 2D-crystal structure of SMS was modeled from protein data bank ID: 3C6M. E. The atomic structure of glycine at position 56 in the $N$-terminal region of SMS protein. F. Serine in place of glycine at position 56 of SMS protein; the extended serine sidechain is highlighted in yellow. G-H. Brain (G) and skeletal muscle (H) polyamine content and SPD/SPM ratios in 24-week-old wildtype and G56S mice quantified by HPLC. Note: putrescine levels were below the limit of detection in the G56S skeletal muscle. Data represent mean $\pm$ S.E.M from $\mathrm{n}=3-5$ mice per group; ns $=$ not significant, ${ }^{*} p<0.05,{ }^{* *} p<0.01$.


Fig. 2. Biometric analyses of G56S and WT mice. A. Body weight was measured at the indicated ages. B. Body length of 24 -week-old mice. C. Body composition of 15-week-old mice (\% lean and \% fat weight) determined by Echo-MRI scan. D. Bone mineral density of 20 -week-old mice measured by micro-CT scan. Data represent mean $\pm$ S.E.M., $\mathrm{n}=7$ mice per group, ${ }^{* *} p<0.01,{ }^{* * *} p<0.001,{ }^{* * * *} p<0.0001$.


Fig. 3. Anxiety-related response monitoring in an open field test. A.
Representative movement pattern of 24 weeks old WT and G56S mice. B. Total activity of the animals at the indicated ages. C. Number of entries to the inner zone of the open field chamber. D. Number of resting time in the outer zone of the open field chamber. Data represent mean $\pm$ S.E.M., $n=7,{ }^{*} p<0.05 ;{ }^{* *} p<0.01$; ns, not significant.


Fig. 4. Performance of 16 -week-old G56S and WT mice in a Morris Water Maze (MWM) test. A. Illustration of the three components of the MWM test. The escape platform is submerged/hidden during the training period (daily for 5 days), removed during the probe test (day 6), or placed above the water level during the visible test (day 6). The top view of the area illustrates the location of the quadrants in which the animals are placed and the placement of the escape platform. B. Time required to locate a hidden/submerged escape platform on each day of the five-day training period. C. Time spent in the escape quadrant during the probe test, in which the platform was absent. D. Time required to locate a visible escape platform on day 6. Data represent mean $\pm$ S.E.M., $\mathrm{n}=7$ mice per group; two-way ANOVA for repeated measures (A) and unpaired $t$-tests for (B) and (C). ns, not significant; ${ }^{*} p<0.05$.


Fig. 5. Auditory-cued fear responses of 5 months old G56S and WT mice. A. Illustration of fear acquisition training on day 1 , in which the animals were subjected to sound stimulation for 20 seconds at 75 decibels, i.e., conditioned stimulation (CS) followed by foot shock and staggered inter-trial interval (ITI). B-C. The fear response was expressed as the percentage of time spent in a stereotypical freezing state during CS (B) and ITI (C) periods. D. Illustration of contextual test on day 2, in which the animal was placed in the same environment (indicated by a square cage), yet without sound and shock stimulation. $\mathbf{E}$. The freezing state of the animals was recorded at the indicated times. F. Illustration of cued-fear response on day 3, in which the animals were placed in a new environment (indicated by a circle cage) and provided with CS, i.e., sound stimulation for 20 seconds at 75 decibels, three times with no foot shock and variable ITIs. G. The freezing state of the animals were recorded at baseline (during habituation), during CS and ITIs. Data represent mean $\pm$ S.E.M. from $n=7$ animals per group and two-way ANOVA analysis for repeated measures (B-C, and E) and unpaired $t$-tests for (G). ns, not significant; ${ }^{*} p<0.05 ;{ }^{* *} p<0.01 ;{ }^{* * *} p<0.001$; **** $p<0.0001$.


Fig. 6. Brain MRI of 18 -week-old WT and G56S mice. A. Representative MRI images of coronal sections of WT and G56S brains. Annotations of different brain regions were based on the Allen Mouse Brain Atlas. B-C. Volumetric analyses of the total brain volume (B) and volumes of annotated regions (C) are highlighted on panel (A). Regional brain volumes were normalized to the total brain volumes. D. Fractional anisotropy (fa) was quantified using DSI studio software. Comparisons of single variables between WT and G56S mice were performed using unpaired $t$-tests. Data represent mean $\pm$ S.E.M., $n=5-7$ mice per group, ${ }^{*} p<0.05$; ${ }^{* *} p<0.01$; ${ }^{* * *} p<0.001$; ns, not significant.


Fig. 7. Transcriptomic analysis of brain cortex from 18 -week-old WT and G56S mice. A. Comparison of brain cortical region between WT and G56S mice revealed 1137 differentially expressed genes (DEGs), comprising 589 upregulated and 548 downregulated transcripts. B. Heatmap of selected genes that exhibit statistically significant differences in expression ( $p<0.05$ ) and absolute values of $\log _{2}$-fold change (LFC) greater than or equal to 1. C. Different biological pathways upon gene enrichment analysis of the upregulated and downregulated transcripts with $p<0.05$ and absolute LFC $\geq 0.5$. D. A volcano plot showing the relative expression of selected genes involved in oxidative phosphorylation. E. qPCR validation of selected genes implicated in oxidative phosphorylation, eukaryotic initiation factor 2 (eIF2) signaling, and Huntington's disease. Data represent mean $\pm$ S.E.M from $n=3$ animals per group. * $p<$ 0.05 ; ** $p<0.01$, ns, not significant.


Fig. 8. Mitochondrial respiration in SMS knockout murine hippocampal cells. A. SMS-deficient in vitro model (SMS-KO) was generated using CRISPR-mediated deletion in murine embryonic hippocampal (mHippoE) cells. SMS protein expression in the SMS-KO and CTRL mHippoE cells was assessed using Western blot and B. Polyamine content measured by HPLC. C. Mitochondrial respiration profiles of CTRL (red line) and SMS-KO (blue) cells. Oligomycin (ATP synthase inhibitor), FCCP ( $\mathrm{H}^{+}$ ionophore), and rotenone/antimycin (mitochondria complex I/III inhibitors) were added at the indicated times. D-G. Comparison of basal respiration (D), maximal respiration (E), ATP production (F), and spare respiratory capacity (G) between mHippoE SMS-KO and CTRL assessed using a Seahorse XFe96 analyzer. Data represent mean $\pm$ S.E.M. from $\mathrm{n}=16$ technical replicates of three independent experiments. ** $p<0.05$; ** $p<0.01$; *** $p<$ 0.001 .



WT


G56S


Supplementary Fig. 1

Fig. S1. A. 5-day food consumption monitoring of G56S and age-matched WT mice using a comprehensive laboratory animal monitoring system (CLAMS). B. Immunofluorescence images of WT and G56S mice muscle fibers stained with anti-laminin antibody to detect laminin (red) and DAPI to detect the nuclei (blue). C. Quantification of muscle fibers crosssectional area (CSA) using ImageJ software. Data represent mean $\pm$ S.E.M, $n=3$ mice per group. ns, not significant.


Supplementary Fig. 2

Fig. S2. A. Forelimb grip strength of the G56S and WT mice, normalized to the body weight of the animals. Data is presented as mean $\pm$ S.E.M, $\mathrm{n}=3$ mice per group. ${ }^{*} p<0.05$; ** $p<$ 0.01. B. Representative 3D micro-CT scan images of a mouse under anesthesia. Images were analyzed using the Inveon Research Workplace (IRW) and a threshold was applied to exclude soft tissues. The remaining dense tissue (bone, colored white) was subsequently quantified (green line lines around the dense bone images). Note: The scan captured about $90 \%$ of the animal's body without the tail.


Supplementary Fig. 3
Fig. S3. The polyamine content of the brain cortex of 18 -week-old wildtype and G56S mice as quantified by HPLC. The putrescine level was below the limit of detection. Data represent mean $\pm$ S.E.M from $\mathrm{n}=3$ mice per group; $\mathrm{ns}=$ not significant, ${ }^{*} p<0.05$.


Supplementary Fig. 4
Fig. S4. A. SMS protein expression in primary fibroblasts isolated from ear clips of WT and G56S mice. Immortalized lines generated in parallel were also analyzed for SMS protein. B. Respiratory profiles of WT and G56S primary fibroblasts. Oligomycin (ATP synthase inhibitor), FCCP ( $\mathrm{H}^{+}$ionophore), and rotenone/antimycin (mitochondria complex I/III inhibitors) were added at the times indicated. C-E. Basal respiration (C), maximal respiration (D), and ATP production (E) in WT and G56S primary fibroblasts were assessed using a Seahorse XFe96 analyzer. Data represent mean $\pm$ S.E.M. of $n=8$ technical replicates of two independent experiments. ${ }^{* *} p<0.01$; ${ }^{* * *} p<0.001$.


Total Mice $=376$

## Supplementary Fig. 5

Fig. S5. Total number of WT, heterozygous, and hemizygous mice on the C57BL/6J background generated within one year. Breeding was set up by pairing female heterozygous mice with WT male mice.

Table S1. qPCR primer sequences

|  | Name | qPCR Primer Sequence (5' $\rightarrow$ 3') | Note |
| :---: | :---: | :---: | :---: |
| 1 | Mouse SMS | CCACACTATGGCAGCAGCAAG | Forward |
|  |  | TGCACTGACTCTGTCATCCCC | Reverse |
| 2 | Mouse GAPDH | CTCCCACTCTTCCACCTTCG | Forward |
|  |  | GCCTCTCTTGCTCAGTGTCC | Reverse |
| 3 | Mouse ATP5e | TACTCTGAAGCGACCCAGCG | Forward |
|  |  | GCGTTCGCTTTGAACTCGGT | Reverse |
| 4 | Mouse Cox7B | TAGTCGCCGCAGTTCCATCT | Forward |
|  |  | GCCACCACTTGCTGAATGCT | Reverse |
| 5 | Mouse Uqcr10 | ACGCGATCTACGAGCACATCA | Forward |
|  |  | GTCGGTGAACGGCAACTTGAAA | Reverse |
| 6 | Mouse RPS14 | ATCAAACTCCGGGCCACAGG | Forward |
|  |  | TGACATCCTCAATCCGCCCA | Reverse |
| 7 | Mouse RPL17 | TTCCTGTAAGCGGCCAGAGG | Forward |
|  |  | GCATTCCCTTGATGGCCTGG | Reverse |
| 8 | Mouse Hap1 | GGCTGAGGAGCTCCGAACAT | Forward |
|  |  | TCCCTGCAGTGAGTGTCACG | Reverse |
| 9 | Mouse GRIN2B | CGGAGCTGGCATCCGAATACA | Forward |
|  |  | TGGAGCGTGGTCATTCCCAA | Reverse |
| 10 | Mouse Cox4i1 | GTCTTGGTCTTCCGGTTGCG | Forward |
|  |  | CATGTGCTCGAAGGCACACC | Reverse |
| 11 | Mouse Cox6B1 | GAGTGGTACCGGCGTGTGTA | Forward |
|  |  | TGCCTTCAGCTATGCGGTCA | Reverse |
| 12 | Mouse Ndufa4 | GCAAGCCAAGAAGCATCCCA | Forward |
|  |  | GTGCCAAGCGCATCACATACA | Reverse |
| 13 | mNdufa7 | TCCTCGGGACAGAGTCGTCA | Forward |
|  |  | CGCTTGGCGATCTCCTGGTA | Reverse |

able S2. List of differentially regulated genes between WT and G56S cortex

| Downregulated genes |  |  |  |  |  |  | Upregulated genes |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GENE ID | Chr. | Max group mean | $\begin{aligned} & \log _{2} \text { fold } \\ & \Delta \end{aligned}$ | Fold $\Delta$ | P-value | FDR p-value | GENE ID | Chr. | Max group mean | $\begin{aligned} & \log _{2} \\ & \text { fold } \Delta \end{aligned}$ | Fold $\Delta$ | P-value | FDR p-value |
| Icam4 | 9 | 1.232 | -1.081 | -2.116 | 0.015256 | 0.049965978 | Sall4 | 2 | 0.061 | 2.240 | 4.725 | 0.014972619 | 0.049296734 |
| Itgae | 11 | 0.086 | -1.746 | -3.355 | 0.0149964 | 0.04934519 | Mki67 | 7 | 0.132 | 1.188 | 2.278 | 0.014911876 | 0.049128658 |
| Gm29427 | 1 | 0.082 | -6.163 | -71.637 | 0.0147132 | 0.048544108 | Hif3a | 7 | 0.575 | 1.006 | 2.009 | 0.014636548 | 0.048336364 |
| Gm15155 | X | 0.155 | -2.533 | -5.788 | 0.0142146 | 0.047145333 | Serpine1 | 5 | 0.495 | 1.111 | 2.161 | 0.014609617 | 0.048263114 |
| Zfp708 | 13 | 0.889 | -1.018 | -2.025 | 0.01367 | 0.045811738 | Rtl9 | X | 0.414 | 1.036 | 2.051 | 0.014601504 | 0.048245012 |
| Gm36028 | 16 | 0.129 | -2.512 | -5.704 | 0.0131286 | 0.044305362 | Lbhd2 | 12 | 4.575 | 1.321 | 2.498 | 0.014141085 | 0.046952399 |
| Cabp5 | 7 | 0.052 | -2.680 | -6.407 | 0.012376 | 0.042279546 | Ccdc146 | 5 | 0.175 | 1.498 | 2.825 | 0.014018309 | 0.046671642 |
| S100a8 | 3 | 1.455 | -1.472 | -2.774 | 0.0120425 | 0.041255871 | C3 | 17 | 0.130 | 1.356 | 2.560 | 0.013858007 | 0.046255643 |
| Cxcr2 | 1 | 0.045 | -2.728 | -6.626 | 0.0119643 | 0.041043567 | Ptch2 | 4 | 0.255 | 1.221 | 2.331 | 0.013849803 | 0.046245114 |
| Rps18-ps6 | 13 | 0.354 | -2.608 | -6.097 | 0.0117889 | 0.040594792 | Dusp27 | 1 | 0.193 | 1.296 | 2.456 | 0.013096298 | 0.044225726 |
| Nox1 | X | 0.035 | -3.037 | -8.208 | 0.0115929 | 0.040037389 | Olfr550 | 7 | 0.065 | 2.041 | 4.115 | 0.01287429 | 0.043615912 |
| Btn2a2 | 13 | 0.556 | -1.247 | -2.373 | 0.0115272 | 0.039870833 | Zar1 | 5 | 0.464 | 1.727 | 3.310 | 0.012750287 | 0.043251807 |
| 2410137M14Rik | 17 | 0.119 | -3.658 | -12.627 | 0.0114156 | 0.039559307 | Tlr9 | 9 | 0.410 | 1.147 | 2.215 | 0.012681643 | 0.043082778 |
| Prickle4 | 17 | 0.136 | -6.374 | -82.941 | 0.0112358 | 0.03912124 | Padi1 | 4 | 0.032 | 3.656 | 12.603 | 0.012406248 | 0.042343515 |
| Gm12166 | 11 | 0.423 | -1.943 | -3.845 | 0.011084 | 0.038666368 | Insrr | 3 | 0.107 | 1.485 | 2.800 | 0.01142127 | 0.039571557 |
| Crybg2 | 4 | 0.202 | -1.233 | -2.351 | 0.0109537 | 0.038303114 | Piezo2 | 18 | 0.119 | 1.224 | 2.337 | 0.011255273 | 0.039181698 |
| Crybb3 | 5 | 0.948 | -1.234 | -2.353 | 0.0105557 | 0.037170073 | Gas2l2 | 11 | 0.127 | 2.074 | 4.210 | 0.010224392 | 0.036219378 |
| Gm49354 | 13 | 0.436 | -2.504 | -5.671 | 0.0103565 | 0.036595261 | Lhcgr | 17 | 0.105 | 1.439 | 2.712 | 0.010196621 | 0.03614197 |
| Carlr | 2 | 0.591 | -1.057 | -2.081 | 0.010068 | 0.035803999 | Upb1 | 10 | 0.229 | 1.351 | 2.552 | 0.010155438 | 0.036031032 |
| Aox2 | 1 | 0.036 | -2.731 | -6.641 | 0.0100032 | 0.035623463 | Kcnj13 | 1 | 3.008 | 1.085 | 2.121 | $9.84 \mathrm{E}-03$ | 0.035157132 |
| Ugt2a2 | 5 | 0.112 | -2.911 | -7.523 | $9.21 \mathrm{E}-03$ | 0.033177085 | Prdm1 | 10 | 0.324 | 1.222 | 2.333 | $9.44 \mathrm{E}-03$ | 0.033878918 |
| Meltf | 16 | 0.211 | -1.289 | -2.444 | $9.21 \mathrm{E}-03$ | 0.033177085 | Xkrx | X | 0.481 | 1.209 | 2.311 | $9.14 \mathrm{E}-03$ | 0.032988803 |
| Gm49325 | 10 | 1.561 | -1.891 | -3.709 | 8.64E-03 | 0.031548506 | Atp10b | 11 | 0.248 | 1.016 | 2.023 | 9.10E-03 | 0.032871908 |
| Mcmdc2 | 1 | 0.224 | -1.164 | -2.241 | 8.30E-03 | 0.030467473 | Irs4 | X | 0.302 | 1.393 | 2.626 | 8.90E-03 | 0.032289358 |
| Pla2g4b | 2 | 0.080 | -6.666 | $101.533$ | 8.16E-03 | 0.030048676 | SIc16a8 | 15 | 0.198 | 3.201 | 9.197 | $8.85 \mathrm{E}-03$ | 0.032171631 |
| Gm27021 | 8 | 0.846 | -1.480 | -2.789 | 8.12E-03 | 0.029923006 | Foxd2 | 4 | 0.246 | 1.542 | 2.912 | 8.80E-03 | 0.032000665 |
| Ninj2 | 6 | 1.599 | -1.122 | -2.176 | 7.61E-03 | 0.028373499 | Uncx | 5 | 0.119 | 1.997 | 3.990 | 8.70E-03 | 0.031712493 |
| Tmem37 | 1 | 1.299 | -1.032 | -2.044 | 7.52E-03 | 0.028081285 | Ppl | 16 | 0.263 | 1.253 | 2.383 | $8.58 \mathrm{E}-03$ | 0.031363116 |
| Cldn22 | 8 | 1.898 | -1.375 | -2.593 | 7.45E-03 | 0.027907129 | Tjp3 | 10 | 0.216 | 1.448 | 2.729 | 8.56E-03 | 0.031292662 |
| Theg | 10 | 0.203 | -1.941 | -3.840 | 6.92E-03 | 0.026231111 | Gm49387 | 14 | 0.170 | 6.812 | 112.398 | 8.45E-03 | 0.030950136 |
| 4930451111Rik | 7 | 0.450 | -2.470 | -5.542 | 6.83E-03 | 0.025906738 | Pi16 | 17 | 0.233 | 1.403 | 2.645 | $8.35 \mathrm{E}-03$ | 0.030596331 |
| Gm14443 | 2 | 0.272 | -1.367 | -2.580 | $6.78 \mathrm{E}-03$ | 0.025770946 | Lyve1 | 7 | 0.404 | 1.348 | 2.546 | $8.21 \mathrm{E}-03$ | 0.030205314 |
| I11b | 2 | 0.385 | -1.718 | -3.291 | $6.33 \mathrm{E}-03$ | 0.024308452 | Sgcd | 11 | 0.499 | 1.083 | 2.119 | $8.01 \mathrm{E}-03$ | 0.029587199 |
| Msinl | 17 | 0.110 | -2.381 | -5.209 | 6.29E-03 | 0.024218452 | Rspo4 | 2 | 0.106 | 2.110 | 4.316 | 7.86E-03 | 0.029158838 |
| Nxf7 | X | 0.530 | -1.381 | -2.604 | 6.26E-03 | 0.024107165 | Art4 | 6 | 0.086 | 2.781 | 6.875 | $7.63 \mathrm{E}-03$ | 0.028440374 |
| Ms4a6b | 19 | 0.697 | -1.043 | -2.061 | 5.96E-03 | 0.023145939 | Casr | 16 | 0.323 | 1.542 | 2.911 | $7.58 \mathrm{E}-03$ | 0.028311324 |
| Tsacc | 3 | 2.120 | -1.354 | -2.557 | $5.94 \mathrm{E}-03$ | 0.023082795 | Drd2 | 9 | 6.856 | 1.004 | 2.006 | $7.26 \mathrm{E}-03$ | 0.027284202 |
| Cldn14 | 16 | 0.313 | -1.664 | -3.169 | $5.90 \mathrm{E}-03$ | 0.022928132 | Gabrr1 | 4 | 0.104 | 2.216 | 4.647 | $7.15 \mathrm{E}-03$ | 0.026982211 |
| Cpa2 | 6 | 1.275 | -1.085 | -2.121 | $5.74 \mathrm{E}-03$ | 0.022418642 | Col6a6 | 9 | 0.114 | 1.424 | 2.683 | 7.15E-03 | 0.026962991 |
| Aldh3a1 | 11 | 0.754 | -1.308 | -2.476 | $5.65 \mathrm{E}-03$ | 0.02212661 | Cd109 | 9 | 0.306 | 1.124 | 2.180 | $7.08 \mathrm{E}-03$ | 0.026729975 |
| 4930447C04Rik | 12 | 0.224 | -1.368 | -2.581 | 5.39E-03 | 0.021313052 | Prl | 13 | 0.174 | 4.013 | 16.144 | 6.64E-03 | 0.025301073 |
| Cklf | 8 | 0.471 | -1.061 | -2.087 | $5.31 \mathrm{E}-03$ | 0.021078633 | Lbp | 2 | 1.281 | 1.079 | 2.112 | 6.63E-03 | 0.025277187 |
| Tph2 | 10 | 0.567 | -1.231 | -2.347 | 5.20E-03 | 0.020688469 | Tspan10 | 11 | 0.113 | 4.278 | 19.396 | $6.30 \mathrm{E}-03$ | 0.024224603 |
| Riiad1 | 3 | 3.277 | -1.010 | -2.014 | 4.83E-03 | 0.019466421 | Lpar3 | 3 | 0.241 | 1.573 | 2.976 | $6.25 \mathrm{E}-03$ | 0.024107165 |
| Dapk2 | 9 | 0.646 | -1.162 | -2.238 | $4.75 \mathrm{E}-03$ | 0.019186352 | Baiap2l1 | 5 | 0.398 | 1.407 | 2.651 | $6.12 \mathrm{E}-03$ | 0.02369708 |
| Espnl | 1 | 0.140 | -1.457 | -2.746 | $4.67 \mathrm{E}-03$ | 0.018906298 | Omp | 7 | 7.290 | 2.073 | 4.207 | 6.06E-03 | 0.023446773 |
| Gm28040_1 | 1 | 0.507 | -2.062 | -4.176 | $4.58 \mathrm{E}-03$ | 0.018628452 | Hs3st3a1 | 11 | 0.700 | 1.159 | 2.233 | $5.97 \mathrm{E}-03$ | 0.023167195 |
| Hsbp111 | 18 | 0.996 | -1.390 | -2.621 | $4.36 \mathrm{E}-03$ | 0.017855181 | Xirp1 | 9 | 0.045 | 2.275 | 4.841 | $5.73 \mathrm{E}-03$ | 0.022412724 |
| Adam8 | 7 | 0.447 | -1.294 | -2.451 | 4.33E-03 | 0.017784998 | Ripk4 | 16 | 0.204 | 1.490 | 2.810 | $5.69 \mathrm{E}-03$ | 0.022278549 |
| Tsks | 7 | 0.356 | -1.484 | -2.797 | 4.33E-03 | 0.017761659 | Otogl | 10 | 0.134 | 1.386 | 2.614 | $5.60 \mathrm{E}-03$ | 0.021988938 |
| Cyp2a5 | 7 | 1.058 | -1.812 | -3.510 | $4.18 \mathrm{E}-03$ | 0.017277402 | Vmn1r206 | 13 | 0.090 | 2.165 | 4.483 | $5.37 \mathrm{E}-03$ | 0.02126614 |
| 5430401F13Rik | 6 | 0.442 | -7.275 | $154.900$ | $4.12 \mathrm{E}-03$ | 0.017088884 | Trim58 | 11 | 0.070 | 4.007 | 16.082 | $5.33 \mathrm{E}-03$ | 0.021139014 |
| Gzma | 13 | 0.254 | -2.500 | -5.656 | 4.11E-03 | 0.017036255 | Ebf2 | 14 | 0.279 | 1.207 | 2.308 | 5.28E-03 | 0.020994739 |
| Pde6g | 11 | 0.302 | -2.260 | -4.789 | 4.10E-03 | 0.017031615 | Krt73 | 15 | 1.003 | 1.051 | 2.073 | $5.27 \mathrm{E}-03$ | 0.020926536 |
| Arc | 15 | 108.220 | -1.098 | -2.141 | 4.07E-03 | 0.016912551 | Derpc | 8 | 0.620 | 2.145 | 4.423 | 5.13E-03 | 0.020458671 |
| Cyp11a1 | 9 | 0.969 | -1.024 | -2.034 | 3.87E-03 | 0.016198655 | Ndor1_1 | 2 | 0.443 | 1.784 | 3.443 | $4.91 \mathrm{E}-03$ | 0.019735353 |
| Padi6 | 4 | 0.187 | -1.888 | -3.701 | 3.75E-03 | 0.01576052 | Galr1 | 18 | 0.181 | 1.687 | 3.220 | $4.59 \mathrm{E}-03$ | 0.018650884 |
| Ankrd31 | 13 | 0.080 | -1.721 | -3.296 | 3.62E-03 | 0.01535137 | Wdr72 | 9 | 0.039 | 4.383 | 20.864 | $4.53 \mathrm{E}-03$ | 0.018444103 |
| Cwh43 | 5 | 0.673 | -1.186 | -2.276 | 3.35E-03 | 0.014418289 | Gm20517 | 17 | 0.078 | 7.181 | 145.156 | $4.45 \mathrm{E}-03$ | 0.018153393 |
| Shld3 | 13 | 1.470 | -1.023 | -2.033 | 3.26E-03 | 0.014111735 | Ttc21a | 9 | 0.353 | 1.378 | 2.600 | $4.43 \mathrm{E}-03$ | 0.018104735 |
| Ccdc18 | 5 | 0.335 | -1.172 | -2.253 | 3.21E-03 | 0.013926538 | Rd3l | 12 | 0.316 | 1.798 | 3.478 | $4.34 \mathrm{E}-03$ | 0.017810698 |
| Gm2004 | 2 | 0.255 | -7.667 | $203.241$ | $3.19 \mathrm{E}-03$ | 0.013868882 | Gm21149 | 5 | 0.149 | 4.230 | 18.767 | $4.31 \mathrm{E}-03$ | 0.017706449 |
| Gm42420 | 6 | 1.160 | -1.582 | -2.993 | 3.15E-03 | 0.013731805 | Sim1 | 10 | 0.044 | 2.159 | 4.467 | $4.30 \mathrm{E}-03$ | 0.017684148 |
| Gm49345 | 13 | 0.266 | -2.785 | -6.891 | 2.97E-03 | 0.013026242 | Gsx2 | 5 | 0.318 | 1.828 | 3.549 | $4.20 \mathrm{E}-03$ | 0.017351742 |
| Myl2 | 5 | 0.332 | -1.739 | -3.338 | $2.75 \mathrm{E}-03$ | 0.012189479 | Krt5 | 15 | 0.119 | 2.788 | 6.908 | $4.17 \mathrm{E}-03$ | 0.017243666 |


| Fap | 2 | 0.679 | -1.083 | -2.118 | $2.73 \mathrm{E}-03$ | 0.01213112 | Tram2 | 1 | 0.318 | 1.045 | 2.063 | $3.96 \mathrm{E}-03$ | 0.016522911 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Sftpc | 14 | 2.187 | -1.140 | -2.203 | $2.70 \mathrm{E}-03$ | 0.012039046 | Cenpe | 3 | 0.203 | 1.282 | 2.431 | 3.96E-03 | 0.016516251 |
| Gm28040_2 | 1 | 0.717 | -1.605 | -3.042 | $2.68 \mathrm{E}-03$ | 0.011959293 | Nkx6-1 | 5 | 0.113 | 2.309 | 4.955 | 3.94E-03 | 0.016448186 |
| Ptpn18 | 1 | 1.990 | -1.033 | -2.047 | $2.63 \mathrm{E}-03$ | 0.011737559 | Postn | 3 | 0.766 | 1.055 | 2.078 | $3.91 \mathrm{E}-03$ | 0.016328544 |
| Il12a | 3 | 1.087 | -1.356 | -2.559 | $2.27 \mathrm{E}-03$ | 0.010443603 | Fbxl7 | 15 | 0.404 | 1.222 | 2.332 | $3.79 \mathrm{E}-03$ | 0.015926839 |
| Sult1c1 | 17 | 0.235 | -3.086 | -8.493 | $2.26 \mathrm{E}-03$ | 0.010394065 | 1700012B09Rik | 9 | 0.942 | 1.633 | 3.101 | $3.57 \mathrm{E}-03$ | 0.015181755 |
| BC035044 | 6 | 1.279 | -1.088 | -2.126 | $2.20 \mathrm{E}-03$ | 0.010186514 | Krt2 | 15 | 1.196 | 1.102 | 2.146 | $3.57 \mathrm{E}-03$ | 0.015181755 |
| Ly6m | 15 | 0.100 | -3.208 | -9.238 | $2.09 \mathrm{E}-03$ | $9.76 \mathrm{E}-03$ | Mmp19 | 10 | 0.361 | 1.464 | 2.759 | 3.53E-03 | 0.015052811 |
| Lypd2 | 15 | 1.000 | -1.913 | -3.766 | $2.09 \mathrm{E}-03$ | $9.75 \mathrm{E}-03$ | Gm4767 | 10 | 0.147 | 1.797 | 3.475 | 3.33E-03 | 0.014341057 |
| Hjv | 3 | 0.584 | -1.526 | -2.880 | $2.04 \mathrm{E}-03$ | 9.54E-03 | Gxylt2 | 6 | 0.374 | 1.010 | 2.014 | 3.25E-03 | 0.014080706 |
| Ccl6 | 11 | 1.782 | -1.063 | -2.089 | $1.91 \mathrm{E}-03$ | 9.02E-03 | Chrna10 | 7 | 0.469 | 2.280 | 4.856 | 3.24E-03 | 0.014038216 |
| Zar11 | 5 | 0.871 | -1.622 | -3.079 | $1.89 \mathrm{E}-03$ | 8.96E-03 | A730046J19Rik | X | 0.157 | 1.845 | 3.593 | $3.23 \mathrm{E}-03$ | 0.014009994 |
| Fam174c | 10 | 4.596 | -1.072 | -2.102 | $1.88 \mathrm{E}-03$ | $8.91 \mathrm{E}-03$ | Avp | 2 | 5.003 | 2.153 | 4.447 | 3.22E-03 | 0.0139575 |
| Cd40 | 2 | 0.308 | -1.644 | -3.126 | $1.84 \mathrm{E}-03$ | 8.79E-03 | Ly75 | 2 | 0.243 | 1.202 | 2.301 | 3.14E-03 | 0.013680301 |
| Rnf39 | 17 | 1.835 | -1.004 | -2.005 | $1.81 \mathrm{E}-03$ | 8.66E-03 | Zic3 | X | 0.757 | 1.010 | 2.014 | 3.10E-03 | 0.013517732 |
| Gm28778 | 1 | 1.092 | -2.205 | -4.609 | $1.76 \mathrm{E}-03$ | 8.47E-03 | Nkx2-1 | 12 | 0.427 | 1.723 | 3.301 | $3.02 \mathrm{E}-03$ | 0.01322799 |
| Olfr464 | 11 | 0.400 | -1.636 | -3.107 | $1.76 \mathrm{E}-03$ | 8.46E-03 | Adamts5 | 16 | 0.348 | 1.005 | 2.006 | $2.78 \mathrm{E}-03$ | 0.012312269 |
| Gm3696 | 14 | 1.386 | -1.048 | -2.067 | 1.70E-03 | 8.20E-03 | Fgf16 | X | 0.978 | 1.689 | 3.224 | $2.74 \mathrm{E}-03$ | 0.012163341 |
| Arr3 | X | 0.403 | -1.726 | -3.308 | $1.69 \mathrm{E}-03$ | 8.18E-03 | BC035947 | 1 | 0.488 | 1.388 | 2.618 | $2.64 \mathrm{E}-03$ | 0.011780173 |
| Hpx | 7 | 0.561 | -1.599 | -3.028 | $1.47 \mathrm{E}-03$ | 7.30E-03 | Ak7 | 12 | 0.570 | 1.504 | 2.836 | $2.64 \mathrm{E}-03$ | 0.011780173 |
| Ocm | 5 | 0.719 | -1.896 | -3.723 | $1.45 \mathrm{E}-03$ | 7.22E-03 | Gucy2f | X | 0.203 | 1.291 | 2.447 | $2.37 \mathrm{E}-03$ | 0.010785066 |
| Gm6619 | 6 | 0.969 | -3.401 | -10.566 | $1.35 \mathrm{E}-03$ | $6.76 \mathrm{E}-03$ | Nmb | 7 | 10.408 | 1.474 | 2.778 | 2.29E-03 | 0.010488119 |
| Golt1a | 1 | 0.167 | -2.676 | -6.390 | $1.33 \mathrm{E}-03$ | $6.72 \mathrm{E}-03$ | SIc38a8 | 8 | 0.200 | 2.283 | 4.867 | $2.24 \mathrm{E}-03$ | 0.010346868 |
| Ugt2a1 | 5 | 0.283 | -3.508 | -11.377 | $1.23 \mathrm{E}-03$ | $6.26 \mathrm{E}-03$ | Cldn19 | 4 | 0.284 | 1.900 | 3.733 | $2.22 \mathrm{E}-03$ | 0.010252521 |
| Hes3 | 4 | 0.142 | -2.864 | -7.280 | $1.21 \mathrm{E}-03$ | 6.20E-03 | Flnc | 6 | 0.348 | 1.107 | 2.153 | $2.21 \mathrm{E}-03$ | 0.010215889 |
| Ccnb1ip1 | 14 | 0.232 | -2.225 | -4.675 | $1.21 \mathrm{E}-03$ | $6.20 \mathrm{E}-03$ | Fam167a | 14 | 0.567 | 1.052 | 2.074 | 2.17E-03 | 0.010092077 |
| Gm2296 | 9 | 0.432 | -2.838 | -7.149 | $1.21 \mathrm{E}-03$ | $6.19 \mathrm{E}-03$ | Gm49368 | 7 | 0.052 | 3.419 | 10.695 | $2.09 \mathrm{E}-03$ | $9.76 \mathrm{E}-03$ |
| Urah | 7 | 0.750 | -1.617 | -3.068 | $1.21 \mathrm{E}-03$ | $6.19 \mathrm{E}-03$ | Cdca7l | 12 | 0.412 | 1.558 | 2.944 | $2.09 \mathrm{E}-03$ | $9.76 \mathrm{E}-03$ |
| Spag6 | 2 | 1.015 | -1.191 | -2.284 | $1.20 \mathrm{E}-03$ | 6.16E-03 | Dsg2 | 18 | 0.366 | 1.094 | 2.134 | 2.02E-03 | $9.46 \mathrm{E}-03$ |
| Il11ra2 | 4 | 0.295 | -2.116 | -4.336 | $1.18 \mathrm{E}-03$ | $6.05 \mathrm{E}-03$ | Hephl1 | 9 | 0.113 | 7.828 | 227.296 | $2.00 \mathrm{E}-03$ | 9.39E-03 |
| Spdya | 17 | 0.655 | -1.462 | -2.754 | $1.17 \mathrm{E}-03$ | 6.03E-03 | Arhgef16 | 4 | 0.396 | 1.689 | 3.225 | $1.96 \mathrm{E}-03$ | $9.21 \mathrm{E}-03$ |
| Olfr77 | 9 | 0.216 | -1.259 | -2.393 | 1.15E-03 | 5.95E-03 | Lhx1 | 11 | 0.063 | 2.750 | 6.725 | $1.95 \mathrm{E}-03$ | 9.19E-03 |
| Vsig2 | 9 | 0.722 | -1.609 | -3.050 | $1.07 \mathrm{E}-03$ | 5.60E-03 | 6430571L13Rik | 9 | 3.415 | 1.111 | 2.160 | $1.94 \mathrm{E}-03$ | 9.16E-03 |
| Dazl | 17 | 1.136 | -1.000 | -2.001 | 1.00E-03 | $5.31 \mathrm{E}-03$ | SIc43a3 | 2 | 0.504 | 1.811 | 3.508 | $1.90 \mathrm{E}-03$ | 8.98E-03 |
| Ccl9 | 11 | 0.985 | -1.106 | -2.153 | 8.05E-04 | 4.42E-03 | Sfmbt2 | 2 | 0.315 | 1.098 | 2.140 | $1.86 \mathrm{E}-03$ | 8.87E-03 |
| Traf5 | 1 | 1.699 | -1.023 | -2.032 | $7.79 \mathrm{E}-04$ | $4.31 \mathrm{E}-03$ | S100a5 | 3 | 18.688 | 2.913 | 7.531 | $1.75 \mathrm{E}-03$ | 8.39E-03 |
| Cenpa | 5 | 1.425 | -1.177 | -2.260 | $7.55 \mathrm{E}-04$ | 4.20E-03 | Vash2 | 1 | 0.822 | 1.057 | 2.081 | $1.68 \mathrm{E}-03$ | 8.12E-03 |
| 9430038101Rik | 7 | 0.611 | -1.014 | -2.020 | $6.76 \mathrm{E}-04$ | $3.81 \mathrm{E}-03$ | Prss56 | 1 | 0.490 | 2.383 | 5.217 | $1.67 \mathrm{E}-03$ | 8.07E-03 |
| Slfn2 | 11 | 1.826 | -1.122 | -2.176 | $5.85 \mathrm{E}-04$ | 3.40E-03 | Col6a3 | 1 | 0.252 | 1.053 | 2.074 | $1.66 \mathrm{E}-03$ | 8.04E-03 |
| S100a4 | 3 | 4.855 | -1.267 | -2.406 | $5.65 \mathrm{E}-04$ | 3.30E-03 | Serpina9 | 12 | 1.264 | 1.427 | 2.688 | $1.58 \mathrm{E}-03$ | $7.76 \mathrm{E}-03$ |
| Ptges3l | 11 | 1.126 | -1.231 | -2.348 | $5.59 \mathrm{E}-04$ | 3.27E-03 | Prdm12 | 2 | 0.091 | 3.268 | 9.636 | $1.52 \mathrm{E}-03$ | 7.51E-03 |
| Tcap | 11 | 4.094 | -1.099 | -2.142 | $5.31 \mathrm{E}-04$ | 3.14E-03 | Cubn | 2 | 0.090 | 1.672 | 3.187 | 1.49E-03 | 7.37E-03 |
| Gngt2 | 11 | 2.871 | -1.058 | -2.082 | $5.04 \mathrm{E}-04$ | 3.00E-03 | Emilin2 | 17 | 0.726 | 1.025 | 2.034 | $1.44 \mathrm{E}-03$ | 7.14E-03 |
| Fcor | 8 | 11.272 | -1.009 | -2.012 | $4.38 \mathrm{E}-04$ | $2.66 \mathrm{E}-03$ | Pcdhb21 | 18 | 0.659 | 1.039 | 2.055 | $1.43 \mathrm{E}-03$ | 7.13E-03 |
| Mpl | 4 | 0.282 | -2.027 | -4.076 | $4.37 \mathrm{E}-04$ | $2.66 \mathrm{E}-03$ | Pcdhb2 | 18 | 1.050 | 1.077 | 2.110 | $1.43 \mathrm{E}-03$ | 7.11E-03 |
| Gmfg | 7 | 2.348 | -1.419 | -2.675 | $4.28 \mathrm{E}-04$ | $2.61 \mathrm{E}-03$ | Fzd5 | 1 | 0.448 | 1.062 | 2.088 | $1.36 \mathrm{E}-03$ | 6.84E-03 |
| Prss22 | 17 | 1.166 | -1.609 | -3.051 | 3.97E-04 | $2.47 \mathrm{E}-03$ | Barhl2 | 5 | 0.700 | 1.676 | 3.195 | $1.32 \mathrm{E}-03$ | 6.66E-03 |
| Tmem232 | 17 | 0.918 | -1.291 | -2.447 | 3.60E-04 | $2.28 \mathrm{E}-03$ | Esyt3 | 9 | 0.689 | 1.317 | 2.491 | $1.23 \mathrm{E}-03$ | 6.28E-03 |
| Adamts13 | 2 | 0.462 | -1.366 | -2.578 | 3.40E-04 | $2.17 \mathrm{E}-03$ | Cdh23 | 10 | 0.212 | 1.201 | 2.299 | $1.12 \mathrm{E}-03$ | $5.81 \mathrm{E}-03$ |
| Lat2 | 5 | 2.131 | -1.220 | -2.330 | $3.37 \mathrm{E}-04$ | $2.16 \mathrm{E}-03$ | Spata18 | 5 | 0.308 | 2.117 | 4.338 | 1.10E-03 | 5.73E-03 |
| Ly6d | 15 | 0.643 | -2.446 | -5.447 | 3.29E-04 | 2.12E-03 | Myh4 | 11 | 0.283 | 1.937 | 3.830 | $1.06 \mathrm{E}-03$ | $5.55 \mathrm{E}-03$ |
| Kif4 | X | 0.617 | -1.252 | -2.382 | 3.27E-04 | $2.11 \mathrm{E}-03$ | Tmem26 | 10 | 0.092 | 2.539 | 5.813 | $1.05 \mathrm{E}-03$ | $5.52 \mathrm{E}-03$ |
| Gm5617 | 9 | 7.211 | -1.112 | -2.162 | 3.07E-04 | $2.00 \mathrm{E}-03$ | Rab37 | 11 | 2.208 | 1.458 | 2.747 | $1.03 \mathrm{E}-03$ | $5.42 \mathrm{E}-03$ |
| Cd164l2 | 4 | 2.925 | -1.246 | -2.371 | $2.95 \mathrm{E}-04$ | $1.94 \mathrm{E}-03$ | Duox2 | 2 | 0.042 | 3.945 | 15.403 | $9.84 \mathrm{E}-04$ | 5.23E-03 |
| Fbxo17 | 7 | 1.793 | -1.081 | -2.115 | 2.95E-04 | $1.94 \mathrm{E}-03$ | Ghsr | 3 | 0.097 | 2.449 | 5.462 | 9.05E-04 | $4.88 \mathrm{E}-03$ |
| Asb11 | X | 1.998 | -1.121 | -2.175 | $2.87 \mathrm{E}-04$ | $1.90 \mathrm{E}-03$ | Col4a6 | X | 0.294 | 1.242 | 2.366 | 8.32E-04 | $4.55 \mathrm{E}-03$ |
| Rpe65 | 3 | 1.793 | -1.313 | -2.484 | $2.51 \mathrm{E}-04$ | $1.69 \mathrm{E}-03$ | Alx3 | 3 | 0.995 | 1.385 | 2.612 | 8.14E-04 | $4.46 \mathrm{E}-03$ |
| B230307C23Rik | 16 | 1.427 | -1.102 | -2.146 | $2.51 \mathrm{E}-04$ | $1.69 \mathrm{E}-03$ | Mgam | 6 | 0.072 | 8.357 | 327.981 | 7.93E-04 | $4.38 \mathrm{E}-03$ |
| Tmprss7 | 16 | 1.018 | -1.252 | -2.381 | 2.10E-04 | $1.46 \mathrm{E}-03$ | Gh | 11 | 1.039 | 8.408 | 339.614 | 7.54E-04 | 4.20E-03 |
| Npc111 | 11 | 0.243 | -2.167 | -4.492 | $2.07 \mathrm{E}-04$ | $1.45 \mathrm{E}-03$ | Foxd3 | 4 | 0.387 | 8.417 | 341.707 | 7.45E-04 | $4.16 \mathrm{E}-03$ |
| Nanos3 | 8 | 0.763 | -2.228 | -4.684 | $2.04 \mathrm{E}-04$ | $1.43 \mathrm{E}-03$ | Foxb1 | 9 | 0.096 | 3.231 | 9.392 | 7.30E-04 | $4.09 \mathrm{E}-03$ |
| Sap25 | 5 | 0.325 | -5.508 | -45.492 | $2.01 \mathrm{E}-04$ | $1.41 \mathrm{E}-03$ | Tfap2c | 2 | 0.248 | 2.523 | 5.747 | 7.21E-04 | 4.04E-03 |
| Pagr1a | 7 | 2.112 | -2.461 | -5.506 | 1.80E-04 | $1.29 \mathrm{E}-03$ | Lmod1 | 1 | 0.696 | 1.299 | 2.460 | 6.86E-04 | 3.86E-03 |
| Gm11627 | 11 | 4.981 | -1.085 | -2.122 | $1.74 \mathrm{E}-04$ | $1.25 \mathrm{E}-03$ | Gabre | X | 0.234 | 1.701 | 3.252 | $6.71 \mathrm{E}-04$ | 3.80E-03 |
| Spata24 | 18 | 4.844 | -1.060 | -2.085 | $1.53 \mathrm{E}-04$ | $1.12 \mathrm{E}-03$ | Trim67 | 8 | 0.719 | 1.043 | 2.060 | $6.42 \mathrm{E}-04$ | 3.67E-03 |
| Nudt6 | 3 | 2.450 | -1.109 | -2.157 | $1.53 \mathrm{E}-04$ | $1.12 \mathrm{E}-03$ | Gm49496 | 13 | 0.845 | 8.535 | 370.982 | 6.26E-04 | 3.59E-03 |
| Ctsk | 3 | 2.757 | -1.007 | -2.009 | $1.44 \mathrm{E}-04$ | $1.06 \mathrm{E}-03$ | Zim1 | 7 | 0.550 | 1.058 | 2.082 | 6.22E-04 | 3.58E-03 |
| Cd7 | 11 | 1.580 | -1.796 | -3.473 | $1.25 \mathrm{E}-04$ | 9.40E-04 | Fign | 2 | 0.362 | 1.103 | 2.147 | $6.14 \mathrm{E}-04$ | 3.53E-03 |
| Higd1b | 11 | 4.627 | -1.165 | -2.243 | $1.08 \mathrm{E}-04$ | 8.34E-04 | Dlx6 | 6 | 4.211 | 1.012 | 2.017 | $5.66 \mathrm{E}-04$ | 3.30E-03 |
| Barx2 | 9 | 3.093 | -1.042 | -2.059 | 1.03E-04 | 8.04E-04 | Siglec1 | 2 | 0.068 | 2.373 | 5.180 | $5.64 \mathrm{E}-04$ | 3.30E-03 |
| Lsm5 | 6 | 10.730 | -1.100 | -2.144 | $9.54 \mathrm{E}-05$ | 7.53E-04 | Ssc5d | 7 | 0.541 | 1.315 | 2.488 | $5.61 \mathrm{E}-04$ | 3.28E-03 |
| Sptbn5 | 2 | 0.553 | -1.016 | -2.022 | 8.69E-05 | 6.99E-04 | Cpa6 | 1 | 0.670 | 2.354 | 5.114 | $5.17 \mathrm{E}-04$ | 3.07E-03 |
| Gm13305 | 4 | 0.197 | -3.527 | -11.525 | 7.05E-05 | $5.88 \mathrm{E}-04$ | Sostdc1 | 12 | 1.391 | 1.703 | 3.256 | $5.17 \mathrm{E}-04$ | 3.07E-03 |
| Rskr | 11 | 1.155 | -1.547 | -2.922 | $6.86 \mathrm{E}-05$ | $5.74 \mathrm{E}-04$ | Prrg4 | 2 | 0.238 | 1.887 | 3.698 | $5.06 \mathrm{E}-04$ | $3.01 \mathrm{E}-03$ |


| Tspan11 | 6 | 1.043 | -1.110 | -2.158 | 6.59E-05 | 5.54E-04 | Igf1 | 10 | 0.840 | 1.012 | 2.016 | 5.00E-04 | $2.98 \mathrm{E}-03$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nup37 | 10 | 3.259 | -1.048 | -2.068 | 6.46E-05 | 5.46E-04 | Clca3a1 | 3 | 0.405 | 2.144 | 4.421 | 4.97E-04 | 2.97E-03 |
| Mis18a | 16 | 4.969 | -1.002 | -2.003 | $6.21 \mathrm{E}-05$ | $5.29 \mathrm{E}-04$ | Pkp2 | 16 | 2.943 | 1.050 | 2.071 | 4.83E-04 | 2.89E-03 |
| Rdm1 | 11 | 6.523 | -1.023 | -2.032 | 6.17E-05 | 5.26E-04 | Chrna2 | 14 | 0.373 | 1.816 | 3.522 | $4.65 \mathrm{E}-04$ | $2.80 \mathrm{E}-03$ |
| Gm50253 | 17 | 0.692 | -1.299 | -2.460 | 5.15E-05 | $4.51 \mathrm{E}-04$ | Ppm1j | 3 | 1.912 | 2.123 | 4.355 | $4.55 \mathrm{E}-04$ | $2.75 \mathrm{E}-03$ |
| Ccdc84 | 9 | 1.602 | -1.076 | -2.108 | 5.02E-05 | 4.42E-04 | Kcne2 | 16 | 0.776 | 3.433 | 10.803 | 4.40E-04 | $2.68 \mathrm{E}-03$ |
| Hba-a2 | 11 | 327.603 | -1.155 | -2.227 | $4.75 \mathrm{E}-05$ | 4.20E-04 | SIc18a2 | 19 | 0.242 | 2.092 | 4.262 | 4.07E-04 | $2.51 \mathrm{E}-03$ |
| Atoh7 | 10 | 0.949 | -1.883 | -3.687 | $4.25 \mathrm{E}-05$ | 3.85E-04 | Mecom | 3 | 0.492 | 1.032 | 2.045 | $4.01 \mathrm{E}-04$ | $2.49 \mathrm{E}-03$ |
| Mobp | 9 | 149.552 | -1.197 | -2.293 | 4.18E-05 | 3.79E-04 | Gpr101 | X | 2.267 | 1.238 | 2.358 | 3.87E-04 | $2.42 \mathrm{E}-03$ |
| Gm49333 | 16 | 0.173 | -4.753 | -26.955 | 3.97E-05 | 3.63E-04 | Folr1 | 7 | 0.958 | 2.751 | 6.733 | 3.63E-04 | 2.29E-03 |
| Sag | 1 | 2.214 | -1.175 | -2.258 | 3.60E-05 | 3.34E-04 | Gm9732 | 14 | 0.184 | 4.037 | 16.420 | 3.38E-04 | 2.17E-03 |
| Gm14434 | 2 | 1.098 | -1.913 | -3.765 | 3.25E-05 | 3.07E-04 | Six 3 | 17 | 1.193 | 1.826 | 3.545 | 3.13E-04 | 2.03E-03 |
| Proca1 | 11 | 2.839 | -1.170 | -2.251 | 3.13E-05 | 2.97E-04 | Glra1 | 11 | 0.349 | 1.995 | 3.986 | 3.11E-04 | 2.02E-03 |
| Coa4 | 7 | 3.778 | -1.074 | -2.105 | $2.80 \mathrm{E}-05$ | 2.70E-04 | P2ry1 | 3 | 0.729 | 1.236 | 2.356 | 3.03E-04 | $1.98 \mathrm{E}-03$ |
| Tmsb15b2 | X | 6.679 | -1.255 | -2.387 | $2.47 \mathrm{E}-05$ | $2.41 \mathrm{E}-04$ | Gm49353 | 10 | 4.752 | 1.113 | 2.163 | 3.02E-04 | $1.98 \mathrm{E}-03$ |
| Ifit1bl1 | 19 | 2.309 | -1.172 | -2.254 | $2.32 \mathrm{E}-05$ | 2.29E-04 | Crhr2 | 6 | 0.621 | 1.482 | 2.793 | 3.00E-04 | $1.97 \mathrm{E}-03$ |
| Pdzph1 | 17 | 1.022 | -1.192 | -2.284 | 2.23E-05 | 2.22E-04 | Shox2 | 3 | 0.151 | 4.922 | 30.316 | 2.86E-04 | $1.89 \mathrm{E}-03$ |
| Cyp2g1 | 7 | 0.524 | -3.582 | -11.972 | 2.00E-05 | 2.02E-04 | Nppa | 4 | 1.215 | 2.815 | 7.036 | $2.75 \mathrm{E}-04$ | 1.83E-03 |
| Hba-a1 | 11 | 178.809 | -1.153 | -2.223 | $1.92 \mathrm{E}-05$ | $1.95 \mathrm{E}-04$ | Pcdhb6 | 18 | 1.024 | 1.068 | 2.096 | $2.71 \mathrm{E}-04$ | $1.80 \mathrm{E}-03$ |
| Bcas1 | 2 | 78.413 | -1.171 | -2.251 | $1.60 \mathrm{E}-05$ | 1.67E-04 | Stac | 9 | 1.083 | 1.276 | 2.421 | $2.68 \mathrm{E}-04$ | $1.79 \mathrm{E}-03$ |
| Mbp | 18 | 430.303 | -1.091 | -2.130 | $1.55 \mathrm{E}-05$ | 1.63E-04 | Nid2 | 14 | 1.065 | 1.030 | 2.042 | $2.54 \mathrm{E}-04$ | $1.71 \mathrm{E}-03$ |
| Amn | 12 | 4.397 | -1.032 | -2.045 | $1.55 \mathrm{E}-05$ | 1.63E-04 | Glra4 | X | 0.183 | 3.855 | 14.466 | $2.52 \mathrm{E}-04$ | $1.70 \mathrm{E}-03$ |
| Tmsb15b1 | X | 6.223 | -1.456 | -2.743 | $1.54 \mathrm{E}-05$ | 1.62E-04 | Cdh3 | 8 | 0.218 | 2.379 | 5.201 | $2.52 \mathrm{E}-04$ | $1.70 \mathrm{E}-03$ |
| Cenps | 4 | 2.517 | -1.228 | -2.343 | $1.45 \mathrm{E}-05$ | $1.54 \mathrm{E}-04$ | Insyn2a | 7 | 2.619 | 1.035 | 2.049 | $2.44 \mathrm{E}-04$ | $1.66 \mathrm{E}-03$ |
| Olfr78 | 7 | 0.111 | -2.673 | -6.378 | $1.34 \mathrm{E}-05$ | $1.44 \mathrm{E}-04$ | Slc17a8 | 10 | 0.591 | 1.274 | 2.418 | $2.43 \mathrm{E}-04$ | $1.65 \mathrm{E}-03$ |
| Gm10334 | 6 | 0.888 | -2.599 | -6.058 | 1.19E-05 | $1.30 \mathrm{E}-04$ | Rin3 | 12 | 0.771 | 1.039 | 2.054 | 2.30E-04 | $1.57 \mathrm{E}-03$ |
| Tefm | 11 | 4.573 | -1.065 | -2.092 | 1.17E-05 | $1.28 \mathrm{E}-04$ | Epn3 | 11 | 0.525 | 1.916 | 3.773 | $2.14 \mathrm{E}-04$ | $1.49 \mathrm{E}-03$ |
| Clec18a | 8 | 1.026 | -1.432 | -2.699 | $1.14 \mathrm{E}-05$ | 1.26E-04 | Tubb6 | 18 | 1.831 | 1.661 | 3.162 | $2.09 \mathrm{E}-04$ | $1.46 \mathrm{E}-03$ |
| G0s2 | 1 | 7.935 | -1.055 | -2.078 | $1.05 \mathrm{E}-05$ | 1.17E-04 | Cckar | 5 | 0.091 | 4.360 | 20.538 | $2.08 \mathrm{E}-04$ | $1.45 \mathrm{E}-03$ |
| Cd300c2 | 11 | 4.834 | -1.222 | -2.333 | $1.00 \mathrm{E}-05$ | 1.13E-04 | A2m | 6 | 0.835 | 1.177 | 2.262 | $2.04 \mathrm{E}-04$ | $1.43 \mathrm{E}-03$ |
| Pigbos1 | 9 | 13.772 | -1.161 | -2.237 | 8.31E-06 | 9.66E-05 | Rbm20 | 19 | 1.051 | 1.044 | 2.062 | 2.02E-04 | $1.42 \mathrm{E}-03$ |
| Prcd | 11 | 3.885 | -1.293 | -2.450 | 7.62E-06 | 8.94E-05 | Mfrp | 9 | 0.906 | 2.759 | 6.769 | 2.00E-04 | $1.41 \mathrm{E}-03$ |
| Gm6710 | 2 | 2.225 | -1.253 | -2.383 | 7.26E-06 | 8.60E-05 | Crybg1 | 10 | 0.332 | 1.464 | 2.758 | 1.99E-04 | 1.40E-03 |
| Ccl27b | 4 | 2.163 | -2.434 | -5.405 | 5.45E-06 | 6.76E-05 | Enpp3 | 10 | 0.147 | 2.078 | 4.223 | $1.90 \mathrm{E}-04$ | $1.34 \mathrm{E}-03$ |
| Ccdc58 | 16 | 6.495 | -1.085 | -2.121 | 5.03E-06 | 6.35E-05 | Epha2 | 4 | 0.735 | 1.270 | 2.412 | $1.86 \mathrm{E}-04$ | $1.32 \mathrm{E}-03$ |
| Scx | 15 | 2.199 | -1.613 | -3.058 | 3.60E-06 | $4.70 \mathrm{E}-05$ | Lama1 | 17 | 0.446 | 1.171 | 2.252 | 1.85E-04 | $1.31 \mathrm{E}-03$ |
| Gm5148 | 3 | 5.861 | -1.011 | -2.015 | 3.28E-06 | $4.36 \mathrm{E}-05$ | Tex15 | 8 | 0.210 | 1.636 | 3.109 | $1.82 \mathrm{E}-04$ | $1.30 \mathrm{E}-03$ |
| Plb1 | 5 | 0.396 | -1.753 | -3.370 | 3.15E-06 | 4.22E-05 | Ecel1 | 1 | 7.965 | 1.397 | 2.634 | $1.62 \mathrm{E}-04$ | 1.18E-03 |
| Kazald1 | 19 | 3.972 | -1.335 | -2.522 | 2.27E-06 | 3.18E-05 | Frem2 | 3 | 0.361 | 1.144 | 2.210 | $1.62 \mathrm{E}-04$ | 1.17E-03 |
| Hilpda | 6 | 6.604 | -1.153 | -2.223 | $2.21 \mathrm{E}-06$ | 3.12E-05 | Neb | 2 | 0.132 | 1.449 | 2.729 | $1.51 \mathrm{E}-04$ | $1.11 \mathrm{E}-03$ |
| Mdfic2 | 6 | 1.049 | -2.025 | -4.070 | 2.16E-06 | 3.07E-05 | Gdnf | 15 | 0.210 | 2.124 | 4.358 | $1.48 \mathrm{E}-04$ | $1.09 \mathrm{E}-03$ |
| Cela1 | 15 | 2.345 | -1.341 | -2.533 | $1.61 \mathrm{E}-06$ | $2.40 \mathrm{E}-05$ | Vdr | 15 | 0.190 | 2.252 | 4.765 | $1.41 \mathrm{E}-04$ | $1.04 \mathrm{E}-03$ |
| Evi2a | 11 | 12.960 | -1.040 | -2.056 | $1.54 \mathrm{E}-06$ | $2.31 \mathrm{E}-05$ | Tspan18 | 2 | 2.376 | 1.195 | 2.289 | $1.40 \mathrm{E}-04$ | $1.04 \mathrm{E}-03$ |
| Efcab10 | 12 | 4.963 | -1.564 | -2.957 | $1.34 \mathrm{E}-06$ | 2.06E-05 | Filip11 | 16 | 1.485 | 1.057 | 2.081 | 1.40E-04 | 1.04E-03 |
| Dtl | 1 | 1.322 | -1.061 | -2.086 | $1.29 \mathrm{E}-06$ | 2.02E-05 | Cyp26b1 | 6 | 3.077 | 1.030 | 2.042 | $1.23 \mathrm{E}-04$ | 9.29E-04 |
| Echdc2 | 4 | 5.909 | -1.003 | -2.004 | 1.05E-06 | 1.69E-05 | Minar1 | 9 | 0.802 | 1.149 | 2.218 | $1.22 \mathrm{E}-04$ | $9.28 \mathrm{E}-04$ |
| Ctla2a | 13 | 6.182 | -1.067 | -2.094 | 7.90E-07 | $1.34 \mathrm{E}-05$ | Loxl1 | 9 | 1.440 | 1.105 | 2.151 | 1.20E-04 | 9.13E-04 |
| Smim4 | 14 | 5.361 | -1.196 | -2.291 | 7.38E-07 | $1.28 \mathrm{E}-05$ | Pcdhb13 | 18 | 1.611 | 1.108 | 2.155 | 1.12E-04 | 8.62E-04 |
| 2310009B15Rik | 1 | 10.617 | -1.042 | -2.059 | 7.15E-07 | $1.24 \mathrm{E}-05$ | Ntsr1 | 2 | 3.033 | 1.064 | 2.091 | 1.12E-04 | 8.58E-04 |
| Hbb-bt | 7 | 76.496 | -1.614 | -3.061 | 6.67E-07 | 1.17E-05 | Dnah11 | 12 | 0.140 | 2.042 | 4.117 | $1.12 \mathrm{E}-04$ | 8.57E-04 |
| Mthfs | 9 | 3.406 | -1.466 | -2.763 | 6.20E-07 | 1.10E-05 | Drc7 | 8 | 1.009 | 1.908 | 3.754 | 1.07E-04 | 8.27E-04 |
| Mthfsl | 9 | 8.638 | -1.093 | -2.133 | 5.95E-07 | 1.07E-05 | Lrrc55 | 2 | 5.433 | 1.112 | 2.162 | $1.05 \mathrm{E}-04$ | 8.14E-04 |
| Ormdl1 | 1 | 5.907 | -1.081 | -2.115 | 5.79E-07 | 1.04E-05 | Npffr2 | 5 | 0.282 | 3.979 | 15.766 | $9.61 \mathrm{E}-05$ | 7.57E-04 |
| Plekhb1 | 7 | 128.788 | -1.112 | -2.162 | 5.58E-07 | $1.01 \mathrm{E}-05$ | Cspg4b | 13 | 0.380 | 1.257 | 2.391 | $9.49 \mathrm{E}-05$ | 7.51E-04 |
| Psmg4 | 13 | 17.153 | -1.091 | -2.130 | $5.31 \mathrm{E}-07$ | 9.68E-06 | Pappa | 4 | 0.108 | 2.309 | 4.954 | $9.43 \mathrm{E}-05$ | 7.47E-04 |
| Pcbd2 | 13 | 21.521 | -1.039 | -2.055 | 5.15E-07 | 9.46E-06 | Mpz | 1 | 0.219 | 4.216 | 18.585 | 9.19E-05 | 7.32E-04 |
| Tyw5 | 1 | 5.236 | -1.043 | -2.061 | 4.27E-07 | 8.05E-06 | Scube2 | 7 | 0.466 | 2.053 | 4.149 | 9.18E-05 | $7.31 \mathrm{E}-04$ |
| Gm14418 | 2 | 3.165 | -1.320 | -2.497 | 3.52E-07 | 6.89E-06 | Fam184b | 5 | 1.597 | 1.007 | 2.010 | $9.14 \mathrm{E}-05$ | 7.28E-04 |
| Sebox | 11 | 2.533 | -1.855 | -3.616 | 3.33E-07 | 6.58E-06 | Adamts9 | 6 | 0.694 | 1.190 | 2.282 | 8.39E-05 | $6.81 \mathrm{E}-04$ |
| Haus1 | 18 | 7.138 | -1.096 | -2.138 | 3.24E-07 | 6.42E-06 | Sema5a | 15 | 4.972 | 1.013 | 2.018 | 8.33E-05 | $6.77 \mathrm{E}-04$ |
| Agmat | 4 | 1.568 | -2.102 | -4.292 | 2.89E-07 | 5.83E-06 | Gdpd4 | 7 | 0.160 | 4.328 | 20.080 | 7.71E-05 | 6.35E-04 |
| Rps20 | 4 | 57.768 | -1.021 | -2.030 | $2.24 \mathrm{E}-07$ | 4.73E-06 | Htr1d | 4 | 0.901 | 1.560 | 2.949 | 7.05E-05 | 5.88E-04 |
| Saysd1 | 14 | 5.773 | -1.019 | -2.027 | 2.13E-07 | $4.52 \mathrm{E}-06$ | Htr4 | 18 | 1.052 | 1.205 | 2.305 | 6.52E-05 | 5.50E-04 |
| Shld1 | 2 | 6.828 | -1.059 | -2.083 | 1.77E-07 | 3.90E-06 | Lgr6 | 1 | 1.955 | 2.060 | 4.169 | 6.34E-05 | 5.37E-04 |
| Etnk2 | 1 | 3.174 | -1.217 | -2.324 | $1.74 \mathrm{E}-07$ | 3.84E-06 | Mab2111 | 3 | 1.138 | 1.827 | 3.547 | 5.91E-05 | 5.08E-04 |
| Oxld1 | 11 | 11.001 | -1.201 | -2.298 | 1.62E-07 | 3.61E-06 | Emilin1 | 5 | 1.160 | 1.133 | 2.194 | $5.88 \mathrm{E}-05$ | 5.06E-04 |
| Gng11 | 6 | 15.850 | -1.098 | -2.140 | 1.10E-07 | 2.59E-06 | Ccdc187 | 2 | 0.477 | 1.158 | 2.231 | 5.86E-05 | 5.05E-04 |
| Thrsp | 7 | 27.069 | -1.144 | -2.209 | $8.59 \mathrm{E}-08$ | 2.09E-06 | Il12rb2 | 6 | 0.150 | 4.186 | 18.205 | 5.52E-05 | 4.80E-04 |
| Eef1b2 | 1 | 101.516 | -1.050 | -2.071 | 8.19E-08 | $2.01 \mathrm{E}-06$ | Svep1 | 4 | 0.195 | 1.702 | 3.254 | 5.35E-05 | 4.66E-04 |
| Zfp931 | 2 | 5.877 | -1.137 | -2.199 | 7.50E-08 | 1.85E-06 | Fbln2 | 6 | 1.527 | 1.049 | 2.069 | 5.03E-05 | $4.42 \mathrm{E}-04$ |
| S100a16 | 3 | 70.710 | -1.025 | -2.035 | 7.19E-08 | 1.79E-06 | Slc6a3 | 13 | 0.439 | 2.823 | 7.075 | $4.77 \mathrm{E}-05$ | 4.23E-04 |
| Cox8a | 19 | 952.702 | -1.000 | -2.001 | 7.02E-08 | 1.75E-06 | Gng4 | 13 | 45.349 | 1.206 | 2.308 | $4.75 \mathrm{E}-05$ | 4.20E-04 |
| Cldn10 | 14 | 20.726 | -1.016 | -2.022 | 6.97E-08 | $1.74 \mathrm{E}-06$ | Lhx8 | 3 | 1.108 | 2.869 | 7.304 | $4.48 \mathrm{E}-05$ | 4.01E-04 |
| Ddit4l | 3 | 8.382 | -1.019 | -2.026 | $5.97 \mathrm{E}-08$ | 1.52E-06 | Zfhx3 | 8 | 0.293 | 1.138 | 2.200 | $4.26 \mathrm{E}-05$ | 3.85E-04 |


| Mt3 | 8 | 426.586 | -1.026 | -2.037 | 5.02E-08 | 1.32E-06 | Oprm1 | 10 | 0.276 | 1.526 | 2.880 | 4.19E-05 | 3.80E-04 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Opalin | 19 | 14.975 | -1.064 | -2.091 | $5.01 \mathrm{E}-08$ | $1.32 \mathrm{E}-06$ | Lhx5 | 5 | 0.189 | 2.960 | 7.782 | $3.95 \mathrm{E}-05$ | $3.62 \mathrm{E}-04$ |
| Fis1 | 5 | 179.651 | -1.019 | -2.027 | $4.95 \mathrm{E}-08$ | $1.30 \mathrm{E}-06$ | Gcnt1 | 19 | 1.810 | 1.748 | 3.360 | 3.95E-05 | $3.62 \mathrm{E}-04$ |
| Tmed1 | 9 | 12.824 | -1.013 | -2.017 | $4.86 \mathrm{E}-08$ | $1.28 \mathrm{E}-06$ | Crb1 | 1 | 0.429 | 1.355 | 2.558 | $3.91 \mathrm{E}-05$ | 3.60E-04 |
| Dpm3 | 3 | 19.997 | -1.048 | -2.068 | $4.80 \mathrm{E}-08$ | $1.27 \mathrm{E}-06$ | Htr2c | X | 12.536 | 1.051 | 2.072 | $3.85 \mathrm{E}-05$ | $3.55 \mathrm{E}-04$ |
| Tyrobp | 7 | 49.279 | -1.101 | -2.145 | $4.71 \mathrm{E}-08$ | $1.25 \mathrm{E}-06$ | Rtl1 | 12 | 0.113 | 2.411 | 5.318 | $3.73 \mathrm{E}-05$ | $3.45 \mathrm{E}-04$ |
| Lage3 | X | 8.604 | -1.058 | -2.082 | $4.55 \mathrm{E}-08$ | $1.22 \mathrm{E}-06$ | Tafa3 | 3 | 0.220 | 3.446 | 10.896 | $3.71 \mathrm{E}-05$ | 3.44E-04 |
| Zswim7 | 11 | 13.747 | -1.159 | -2.233 | $4.16 \mathrm{E}-08$ | $1.13 \mathrm{E}-06$ | Pcdha10 | 18 | 1.419 | 1.109 | 2.156 | $3.56 \mathrm{E}-05$ | $3.32 \mathrm{E}-04$ |
| Nudcd2 | 11 | 10.596 | -1.029 | -2.041 | 3.99E-08 | $1.09 \mathrm{E}-06$ | Tpbgl | 7 | 2.721 | 1.113 | 2.163 | $3.29 \mathrm{E}-05$ | 3.10E-04 |
| Hscb | 5 | 9.706 | -1.341 | -2.534 | $3.81 \mathrm{E}-08$ | $1.05 \mathrm{E}-06$ | Klhl1 | 14 | 0.693 | 1.364 | 2.574 | 3.27E-05 | 3.08E-04 |
| Pdlim2 | 14 | 7.670 | -1.129 | -2.188 | $3.55 \mathrm{E}-08$ | 9.99E-07 | Grem1 | 2 | 0.812 | 1.679 | 3.202 | $2.69 \mathrm{E}-05$ | $2.61 \mathrm{E}-04$ |
| Cox16 | 12 | 6.338 | -1.011 | -2.016 | 3.27E-08 | $9.31 \mathrm{E}-07$ | Adra2b | 2 | 0.253 | 2.366 | 5.154 | $2.67 \mathrm{E}-05$ | $2.58 \mathrm{E}-04$ |
| Vti1b | 12 | 137.282 | -1.062 | -2.087 | 3.14E-08 | 8.98E-07 | Shisa6 | 11 | 5.377 | 1.502 | 2.833 | $2.53 \mathrm{E}-05$ | $2.46 \mathrm{E}-04$ |
| Nkain4 | 2 | 45.135 | -1.001 | -2.002 | 2.98E-08 | 8.62E-07 | SIc35d3 | 10 | 2.602 | 1.809 | 3.505 | $2.48 \mathrm{E}-05$ | $2.42 \mathrm{E}-04$ |
| Sec61b | 4 | 37.398 | -1.012 | -2.017 | $2.73 \mathrm{E}-08$ | 7.97E-07 | Hspa1b | 17 | 13.471 | 1.628 | 3.091 | $2.18 \mathrm{E}-05$ | $2.17 \mathrm{E}-04$ |
| Selenow | 7 | 1605.333 | -1.053 | -2.074 | $2.70 \mathrm{E}-08$ | 7.93E-07 | Igfbpl1 | 4 | 0.904 | 2.116 | 4.334 | $2.00 \mathrm{E}-05$ | $2.02 \mathrm{E}-04$ |
| Ciao2a | 9 | 25.636 | -1.063 | -2.089 | $2.64 \mathrm{E}-08$ | $7.77 \mathrm{E}-07$ | Notch2 | 3 | 2.879 | 1.053 | 2.074 | $1.76 \mathrm{E}-05$ | $1.81 \mathrm{E}-04$ |
| BC028528 | 3 | 6.361 | -1.564 | -2.956 | $2.61 \mathrm{E}-08$ | 7.69E-07 | Rassf4 | 6 | 1.813 | 1.171 | 2.251 | $1.63 \mathrm{E}-05$ | $1.69 \mathrm{E}-04$ |
| Gm11808 | 4 | 868.926 | -1.023 | -2.033 | $2.48 \mathrm{E}-08$ | 7.30E-07 | Dsc3 | 18 | 0.583 | 1.455 | 2.742 | $1.49 \mathrm{E}-05$ | $1.58 \mathrm{E}-04$ |
| Cox6b1 | 7 | 530.444 | -1.009 | -2.012 | $2.44 \mathrm{E}-08$ | 7.23E-07 | Nlrp10 | 7 | 0.190 | 3.398 | 10.543 | $1.43 \mathrm{E}-05$ | $1.53 \mathrm{E}-04$ |
| Tnnc1 | 14 | 13.631 | -1.578 | -2.985 | $2.26 \mathrm{E}-08$ | $6.77 \mathrm{E}-07$ | Pcdha6 | 18 | 1.454 | 1.089 | 2.127 | $1.43 \mathrm{E}-05$ | $1.53 \mathrm{E}-04$ |
| Rpl27 | 11 | 201.738 | -1.072 | -2.103 | 2.23E-08 | 6.68E-07 | Col5a2 | 1 | 0.720 | 1.220 | 2.329 | $1.42 \mathrm{E}-05$ | $1.52 \mathrm{E}-04$ |
| Rpl7 | 1 | 319.809 | -1.038 | -2.054 | $2.17 \mathrm{E}-08$ | $6.56 \mathrm{E}-07$ | Tenm2 | 11 | 8.758 | 1.125 | 2.181 | $1.34 \mathrm{E}-05$ | $1.44 \mathrm{E}-04$ |
| Drap1 | 19 | 233.925 | -1.017 | -2.023 | $2.15 \mathrm{E}-08$ | 6.52E-07 | Chrm2 | 6 | 2.611 | 1.153 | 2.224 | $1.33 \mathrm{E}-05$ | $1.43 \mathrm{E}-04$ |
| Mrpl54 | 10 | 58.985 | -1.061 | -2.087 | 1.93E-08 | 5.96E-07 | Nkain3 | 4 | 0.969 | 1.332 | 2.517 | $1.30 \mathrm{E}-05$ | $1.41 \mathrm{E}-04$ |
| Izumo4 | 10 | 13.011 | -1.005 | -2.006 | $1.77 \mathrm{E}-08$ | 5.50E-07 | Sh3rf2 | 18 | 1.059 | 1.704 | 3.257 | $1.27 \mathrm{E}-05$ | $1.38 \mathrm{E}-04$ |
| Idnk | 13 | 6.060 | -1.021 | -2.029 | $1.75 \mathrm{E}-08$ | 5.44E-07 | Myof | 19 | 0.886 | 1.154 | 2.226 | $1.14 \mathrm{E}-05$ | $1.26 \mathrm{E}-04$ |
| Rplp1 | 9 | 1415.181 | -1.052 | -2.073 | $1.58 \mathrm{E}-08$ | 4.97E-07 | Pcdha9 | 18 | 2.223 | 1.006 | 2.008 | $1.03 \mathrm{E}-05$ | 1.16E-04 |
| Uqcr11 | 10 | 456.561 | -1.119 | -2.173 | $1.51 \mathrm{E}-08$ | $4.79 \mathrm{E}-07$ | Prok2 | 6 | 0.417 | 2.727 | 6.620 | $9.96 \mathrm{E}-06$ | $1.13 \mathrm{E}-04$ |
| Hint1 | 11 | 275.140 | -1.089 | -2.128 | 1.43E-08 | $4.58 \mathrm{E}-07$ | Slit1 | 19 | 15.540 | 1.107 | 2.153 | 9.98E-06 | 1.13E-04 |
| H2-T23 | 17 | 15.976 | -1.069 | -2.098 | $1.35 \mathrm{E}-08$ | $4.42 \mathrm{E}-07$ | Cldn2 | X | 0.530 | 3.568 | 11.859 | 9.39E-06 | $1.07 \mathrm{E}-04$ |
| Rps28 | 17 | 249.919 | -1.006 | -2.008 | 1.33E-08 | $4.37 \mathrm{E}-07$ | Tchh | 3 | 1.277 | 1.218 | 2.326 | $9.18 \mathrm{E}-06$ | $1.05 \mathrm{E}-04$ |
| Bola3 | 6 | 13.695 | -1.109 | -2.156 | $1.33 \mathrm{E}-08$ | 4.36E-07 | Ttr | 18 | 261.301 | 4.896 | 29.769 | 9.06E-06 | $1.04 \mathrm{E}-04$ |
| Zfp945 | 17 | 2.219 | -1.100 | -2.143 | $1.32 \mathrm{E}-08$ | 4.36E-07 | Gpr50 | X | 0.432 | 2.742 | 6.692 | 8.85E-06 | $1.02 \mathrm{E}-04$ |
| Ccdc107 | 4 | 39.563 | -1.048 | -2.068 | $1.20 \mathrm{E}-08$ | 4.01E-07 | Arhgap36 | X | 1.525 | 1.880 | 3.681 | 8.77E-06 | $1.01 \mathrm{E}-04$ |
| Rps17 | 7 | 510.139 | -1.172 | -2.253 | $1.19 \mathrm{E}-08$ | 3.99E-07 | Vangl1 | 3 | 0.688 | 1.178 | 2.262 | $8.75 \mathrm{E}-06$ | $1.01 \mathrm{E}-04$ |
| Stac2 | 11 | 54.584 | -1.089 | -2.128 | $1.19 \mathrm{E}-08$ | 3.99E-07 | Itih2 | 2 | 2.214 | 1.190 | 2.281 | 7.62E-06 | $8.94 \mathrm{E}-05$ |
| Mrps16 | 14 | 12.617 | -1.055 | -2.078 | 9.54E-09 | 3.26E-07 | Trp73 | 4 | 0.358 | 1.957 | 3.882 | 6.95E-06 | 8.27E-05 |
| Nme3 | 17 | 35.438 | -1.030 | -2.042 | 8.60E-09 | 2.97E-07 | Hspa1a | 17 | 9.667 | 1.549 | 2.926 | $6.34 \mathrm{E}-06$ | $7.69 \mathrm{E}-05$ |
| Rplp0 | 5 | 286.580 | -1.068 | -2.096 | 8.42E-09 | 2.92E-07 | Abca4 | 3 | 0.524 | 1.494 | 2.816 | $6.21 \mathrm{E}-06$ | $7.55 \mathrm{E}-05$ |
| Slirp | 12 | 10.203 | -1.053 | -2.075 | $8.01 \mathrm{E}-09$ | 2.79E-07 | Dlx1 | 2 | 8.850 | 1.389 | 2.619 | $5.92 \mathrm{E}-06$ | $7.25 \mathrm{E}-05$ |
| Hsd11b1 | 1 | 11.995 | -1.496 | -2.820 | 7.35E-09 | 2.59E-07 | Scube3 | 17 | 0.505 | 1.639 | 3.115 | 5.59E-06 | 6.90E-05 |
| Cstb | 10 | 47.035 | -1.018 | -2.025 | $7.21 \mathrm{E}-09$ | 2.55E-07 | Rgs9 | 11 | 7.286 | 1.233 | 2.351 | 5.50E-06 | $6.81 \mathrm{E}-05$ |
| Mgst3 | 1 | 113.215 | -1.001 | -2.001 | $6.91 \mathrm{E}-09$ | 2.47E-07 | Oxtr | 6 | 2.979 | 1.041 | 2.058 | $5.28 \mathrm{E}-06$ | $6.59 \mathrm{E}-05$ |
| Rps6 | 4 | 559.255 | -1.074 | -2.106 | $6.71 \mathrm{E}-09$ | $2.41 \mathrm{E}-07$ | Slc4a5 | 6 | 0.274 | 4.472 | 22.192 | $5.24 \mathrm{E}-06$ | $6.55 \mathrm{E}-05$ |
| Med21 | 6 | 17.341 | -1.076 | -2.107 | $6.68 \mathrm{E}-09$ | 2.40E-07 | Zfhx4 | 3 | 0.700 | 1.043 | 2.060 | $4.74 \mathrm{E}-06$ | $6.03 \mathrm{E}-05$ |
| Med31 | 11 | 11.717 | -1.124 | -2.179 | $6.22 \mathrm{E}-09$ | $2.24 \mathrm{E}-07$ | Pde1c | 6 | 0.784 | 1.011 | 2.016 | $4.53 \mathrm{E}-06$ | $5.78 \mathrm{E}-05$ |
| Cox6a1 | 5 | 926.523 | -1.086 | -2.124 | 5.59E-09 | 2.04E-07 | Acan | 7 | 0.798 | 1.462 | 2.755 | 4.46E-06 | $5.70 \mathrm{E}-05$ |
| Cox7c | 13 | 216.254 | -1.165 | -2.242 | 5.60E-09 | $2.04 \mathrm{E}-07$ | Meis1 | 11 | 1.040 | 1.699 | 3.247 | $4.27 \mathrm{E}-06$ | $5.49 \mathrm{E}-05$ |
| Atp5o_2 | 16 | 281.631 | -1.053 | -2.074 | 5.30E-09 | $1.96 \mathrm{E}-07$ | Bend4 | 5 | 1.049 | 1.098 | 2.141 | $4.00 \mathrm{E}-06$ | $5.18 \mathrm{E}-05$ |
| Mrps18c | 5 | 29.719 | -1.004 | -2.005 | 5.29E-09 | $1.95 \mathrm{E}-07$ | Alx4 | 2 | 0.612 | 1.430 | 2.695 | 3.39E-06 | $4.48 \mathrm{E}-05$ |
| Rps9 | 7 | 228.943 | -1.084 | -2.120 | 5.26E-09 | $1.95 \mathrm{E}-07$ | Eln | 5 | 2.472 | 1.145 | 2.212 | $3.03 \mathrm{E}-06$ | $4.08 \mathrm{E}-05$ |
| Selenof | 3 | 123.152 | -1.138 | -2.200 | 5.22E-09 | 1.93E-07 | Thsd4 | 9 | 1.907 | 1.457 | 2.745 | 3.00E-06 | $4.05 \mathrm{E}-05$ |
| Nat8f1 | 6 | 12.161 | -1.241 | -2.363 | $4.96 \mathrm{E}-09$ | 1.87E-07 | Tnrc6b | 15 | 4.076 | 1.017 | 2.024 | $2.63 \mathrm{E}-06$ | $3.61 \mathrm{E}-05$ |
| Rpsa | 9 | 327.177 | -1.103 | -2.148 | 4.89E-09 | $1.84 \mathrm{E}-07$ | Cntnap5c | 17 | 1.534 | 1.337 | 2.526 | $2.62 \mathrm{E}-06$ | $3.60 \mathrm{E}-05$ |
| Psmd10 | X | 17.127 | -1.050 | -2.071 | $4.48 \mathrm{E}-09$ | $1.71 \mathrm{E}-07$ | Chrna3 | 9 | 0.268 | 2.978 | 7.877 | $2.25 \mathrm{E}-06$ | $3.17 \mathrm{E}-05$ |
| Atp5h | 11 | 426.107 | -1.061 | -2.087 | 4.43E-09 | $1.70 \mathrm{E}-07$ | Epha3 | 16 | 1.773 | 1.056 | 2.080 | $2.16 \mathrm{E}-06$ | $3.07 \mathrm{E}-05$ |
| Dmac1 | 4 | 49.544 | -1.002 | -2.003 | $4.42 \mathrm{E}-09$ | $1.69 \mathrm{E}-07$ | Sema3g | 14 | 2.449 | 1.196 | 2.291 | $2.12 \mathrm{E}-06$ | $3.02 \mathrm{E}-05$ |
| Tmem160 | 7 | 52.295 | -1.023 | -2.032 | $4.42 \mathrm{E}-09$ | $1.69 \mathrm{E}-07$ | Fhdc1 | 3 | 0.928 | 1.305 | 2.470 | $1.99 \mathrm{E}-06$ | $2.86 \mathrm{E}-05$ |
| Arl1 | 10 | 93.628 | -1.097 | -2.138 | $4.25 \mathrm{E}-09$ | 1.65E-07 | KI | 5 | 2.819 | 1.985 | 3.959 | $1.94 \mathrm{E}-06$ | 2.80E-05 |
| Hbb-bs | 7 | 547.675 | -1.903 | -3.740 | $4.11 \mathrm{E}-09$ | $1.60 \mathrm{E}-07$ | Tshz1 | 18 | 12.905 | 1.233 | 2.350 | $1.92 \mathrm{E}-06$ | $2.77 \mathrm{E}-05$ |
| Tmem218 | 9 | 7.642 | -1.062 | -2.087 | 3.80E-09 | $1.49 \mathrm{E}-07$ | Sall3 | 18 | 2.012 | 1.397 | 2.633 | $1.79 \mathrm{E}-06$ | $2.62 \mathrm{E}-05$ |
| Zfyve21 | 12 | 15.993 | -1.109 | -2.157 | $3.74 \mathrm{E}-09$ | $1.48 \mathrm{E}-07$ | Hcn3 | 3 | 4.086 | 1.008 | 2.011 | $1.70 \mathrm{E}-06$ | $2.51 \mathrm{E}-05$ |
| Rpl24 | 16 | 489.211 | -1.088 | -2.126 | $3.74 \mathrm{E}-09$ | $1.47 \mathrm{E}-07$ | Tmem72 | 6 | 0.113 | 4.226 | 18.710 | $1.70 \mathrm{E}-06$ | $2.51 \mathrm{E}-05$ |
| Nenf | 1 | 113.198 | -1.049 | -2.069 | 3.54E-09 | $1.41 \mathrm{E}-07$ | Gabrq | X | 0.626 | 2.025 | 4.071 | $1.69 \mathrm{E}-06$ | $2.50 \mathrm{E}-05$ |
| Blvra | 2 | 15.794 | -1.022 | -2.030 | 3.52E-09 | $1.41 \mathrm{E}-07$ | Prokr2 | 2 | 0.760 | 1.598 | 3.028 | $1.58 \mathrm{E}-06$ | $2.37 \mathrm{E}-05$ |
| Romo1 | 2 | 75.128 | -1.029 | -2.041 | 3.33E-09 | $1.34 \mathrm{E}-07$ | DIl1 | 17 | 1.965 | 1.164 | 2.241 | $1.23 \mathrm{E}-06$ | $1.93 \mathrm{E}-05$ |
| Oaz1 | 10 | 406.737 | -1.054 | -2.077 | $3.21 \mathrm{E}-09$ | $1.31 \mathrm{E}-07$ | Igsf10 | 3 | 0.393 | 1.479 | 2.788 | $1.21 \mathrm{E}-06$ | $1.91 \mathrm{E}-05$ |
| Rapgef4 | 2 | 252.576 | -1.313 | -2.484 | 3.08E-09 | $1.26 \mathrm{E}-07$ | Dcx | X | 3.458 | 1.514 | 2.856 | $1.15 \mathrm{E}-06$ | $1.82 \mathrm{E}-05$ |
| Atox1 | 11 | 90.711 | -1.058 | -2.081 | 3.05E-09 | $1.25 \mathrm{E}-07$ | Col3a1 | 1 | 1.318 | 1.415 | 2.667 | $1.05 \mathrm{E}-06$ | $1.69 \mathrm{E}-05$ |
| Sertad1 | 7 | 14.140 | -1.139 | -2.203 | 3.02E-09 | $1.24 \mathrm{E}-07$ | Adamts19 | 18 | 0.221 | 4.327 | 20.068 | 1.03E-06 | $1.66 \mathrm{E}-05$ |
| Ndufs6 | 13 | 87.805 | -1.073 | -2.104 | $2.88 \mathrm{E}-09$ | 1.19E-07 | Thbs1 | 2 | 0.920 | 1.525 | 2.877 | $1.01 \mathrm{E}-06$ | $1.63 \mathrm{E}-05$ |
| Rpl37 | 15 | 353.115 | -1.167 | -2.245 | $2.75 \mathrm{E}-09$ | $1.14 \mathrm{E}-07$ | Thsd7b | 1 | 1.374 | 1.098 | 2.141 | 1.00E-06 | $1.62 \mathrm{E}-05$ |
| Cd6 | 19 | 1.106 | -2.057 | -4.163 | 2.65E-09 | $1.11 \mathrm{E}-07$ | Cacna1e | 1 | 14.741 | 1.072 | 2.102 | $9.77 \mathrm{E}-07$ | 1.60E-05 |


| Pts |
| :---: |
| 1810009A15Rik |
| Rpl13 |
| Cox14 |
| Tmsb4x |
| Rpa3 |
| Ramp3 |
| Eif3h |
| Rps3a1 |
| Rpl14 |
| Timm10 |
| Pigyl |
| C1d |
| Sar1b |
| Ndufs5 |
| B9d1 |
| Atp6v1g1 |
| Uqcrq |
| Ndufb7 |
| Tsen15 |
| Ndufa2 |
| Nhp2 |
| Rps13 |
| Sec11c |
| Pard6a |
| Coa8 |
| Micos13 |
| Rbp4 |
| Rbm7 |
| Atp5j2 |
| Atp6v0b |
| Avpi1 |
| Ssna1 |
| Gm14326 |
| Rbis |
| Alkbh7 |
| Mylk3 |
| Coa6 |
| Polr2i |
| Zfand2b |
| Hspe1 |
| Kcnmb4 |
| Tmem126a |
| Gtf2a2 |
| Cox6c |
| Ndufa11 |
| Rpl2211 |
| Glt8d2 |
| Ppih |
| Cox17 |
| Rpl37a |
| Prxl2b |
| Bbip1 |
| Mrpl46 |
| Trappc2l |
| Atp6v1f |
| Use1 |
| Sdhd |
| Mpc1 |
| S100a1 |
| Cryzl1 |
| Ss1812 |
| Cox7a2 |
| Scg5 |
| Ciao2b |
| Tomm7 |
| Rpl36al |
| Mrps28 |
| Rgcc |
| Commd2 |
| Dctn3 |
| Rpl27a |
| Rps5 |
| Robo3 |


| 9 | 29.160 | -1.084 |
| :---: | :---: | :---: |
| 19 | 22.685 | -1.057 |
| 8 | 740.411 | -1.118 |
| 15 | 36.994 | -1.017 |
| X | 703.242 | -1.071 |
| 6 | 12.687 | -1.405 |
| 11 | 11.320 | -1.358 |
| 15 | 200.270 | -1.073 |
| 3 | 582.464 | -1.119 |
| 9 | 333.108 | -1.115 |
| 2 | 45.085 | -1.038 |
| 9 | 43.882 | -1.064 |
| 11 | 14.888 | -1.003 |
| 11 | 58.194 | -1.010 |
| 4 | 183.378 | -1.020 |
| 11 | 20.153 | -1.112 |
| 4 | 122.462 | -1.001 |
| 11 | 113.495 | -1.180 |
| 8 | 198.793 | -1.034 |
| 1 | 25.144 | -1.032 |
| 18 | 180.058 | -1.033 |
| 11 | 46.096 | -1.025 |
| 7 | 109.339 | -1.173 |
| 18 | 92.855 | -1.047 |
| 8 | 25.608 | -1.083 |
| 12 | 11.408 | -1.028 |
| 17 | 104.646 | -1.088 |
| 19 | 14.722 | -1.063 |
| 9 | 15.390 | -1.002 |
| 5 | 175.488 | -1.173 |
| 4 | 178.901 | -1.053 |
| 19 | 29.822 | -1.142 |
| 2 | 44.439 | -1.009 |
| 2 | 9.142 | -1.038 |
| 3 | 14.385 | -1.094 |
| 17 | 25.442 | -1.087 |
| 8 | 0.991 | -1.678 |
| 8 | 26.874 | -1.056 |
| 7 | 26.405 | -1.017 |
| 1 | 16.906 | -1.046 |
| 1 | 113.915 | -1.024 |
| 10 | 44.312 | -1.001 |
| 7 | 32.397 | -1.064 |
| 9 | 13.177 | -1.124 |
| 15 | 193.352 | -1.200 |
| 17 | 107.437 | -1.031 |
| 3 | 105.688 | -1.150 |
| 10 | 7.325 | -1.087 |
| 4 | 9.200 | -1.073 |
| 16 | 17.833 | -1.075 |
| 1 | 371.977 | -1.145 |
| 4 | 123.097 | -1.062 |
| 19 | 19.872 | -1.027 |
| 7 | 35.530 | -1.048 |
| 8 | 32.411 | -1.039 |
| 6 | 151.743 | -1.008 |
| 8 | 69.645 | -1.111 |
| 9 | 107.248 | -1.031 |
| 17 | 98.007 | -1.036 |
| 3 | 146.851 | -1.185 |
| 16 | 22.485 | -1.026 |
| 9 | 14.158 | -1.137 |
| 9 | 353.063 | -1.214 |
| 2 | 219.424 | -1.090 |
| 8 | 28.616 | -1.106 |
| 5 | 74.592 | -1.105 |
| 12 | 68.249 | -1.092 |
| 3 | 20.234 | -1.150 |
| 14 | 33.555 | -1.215 |
| 3 | 7.197 | -1.114 |
| 4 | 129.191 | -1.040 |
| 7 | 359.921 | -1.186 |
| 7 | 357.372 | -1.202 |
| 9 | 1.638 | -1.884 |


| -2.120 | 2.46E-09 | 1.03E-07 |
| :---: | :---: | :---: |
| -2.081 | $2.36 \mathrm{E}-09$ | 9.99E-08 |
| -2.170 | $2.34 \mathrm{E}-09$ | 9.92E-08 |
| -2.024 | $2.19 \mathrm{E}-09$ | $9.35 \mathrm{E}-08$ |
| -2.100 | $2.17 \mathrm{E}-09$ | $9.31 \mathrm{E}-08$ |
| -2.647 | $1.99 \mathrm{E}-09$ | 8.62E-08 |
| -2.564 | $1.99 \mathrm{E}-09$ | 8.62E-08 |
| -2.103 | 1.96E-09 | 8.53E-08 |
| -2.173 | $1.91 \mathrm{E}-09$ | $8.38 \mathrm{E}-08$ |
| -2.165 | 1.89E-09 | 8.28E-08 |
| -2.054 | 1.82E-09 | $8.01 \mathrm{E}-08$ |
| -2.090 | 1.82E-09 | 8.01E-08 |
| -2.005 | 1.76E-09 | 7.82E-08 |
| -2.014 | $1.76 \mathrm{E}-09$ | 7.82E-08 |
| -2.028 | $1.75 \mathrm{E}-09$ | $7.81 \mathrm{E}-08$ |
| -2.161 | 1.69E-09 | $7.56 \mathrm{E}-08$ |
| -2.002 | $1.67 \mathrm{E}-09$ | 7.52E-08 |
| -2.266 | $1.67 \mathrm{E}-09$ | $7.52 \mathrm{E}-08$ |
| -2.047 | 1.56E-09 | 7.09E-08 |
| -2.045 | $1.54 \mathrm{E}-09$ | 7.02E-08 |
| -2.046 | $1.55 \mathrm{E}-09$ | 7.02E-08 |
| -2.035 | 1.52E-09 | 6.98E-08 |
| -2.255 | $1.48 \mathrm{E}-09$ | $6.80 \mathrm{E}-08$ |
| -2.067 | $1.43 \mathrm{E}-09$ | $6.56 \mathrm{E}-08$ |
| -2.118 | 1.28E-09 | 5.95E-08 |
| -2.039 | $1.24 \mathrm{E}-09$ | 5.84E-08 |
| -2.126 | 1.20E-09 | $5.71 \mathrm{E}-08$ |
| -2.089 | $1.14 \mathrm{E}-09$ | $5.45 \mathrm{E}-08$ |
| -2.003 | $1.13 \mathrm{E}-09$ | $5.41 \mathrm{E}-08$ |
| -2.255 | 1.12E-09 | 5.39E-08 |
| -2.075 | $1.04 \mathrm{E}-09$ | 5.03E-08 |
| -2.207 | $9.78 \mathrm{E}-10$ | $4.74 \mathrm{E}-08$ |
| -2.013 | $9.67 \mathrm{E}-10$ | $4.70 \mathrm{E}-08$ |
| -2.054 | $9.21 \mathrm{E}-10$ | $4.50 \mathrm{E}-08$ |
| -2.135 | $9.18 \mathrm{E}-10$ | 4.49E-08 |
| -2.124 | $9.13 \mathrm{E}-10$ | $4.48 \mathrm{E}-08$ |
| -3.200 | $9.04 \mathrm{E}-10$ | $4.45 \mathrm{E}-08$ |
| -2.079 | 9.04E-10 | $4.45 \mathrm{E}-08$ |
| -2.024 | 8.84E-10 | 4.39E-08 |
| -2.064 | 8.28E-10 | $4.15 \mathrm{E}-08$ |
| -2.034 | $8.00 \mathrm{E}-10$ | $4.06 \mathrm{E}-08$ |
| -2.001 | 7.70E-10 | 3.95E-08 |
| -2.090 | 7.17E-10 | 3.72E-08 |
| -2.180 | 6.87E-10 | $3.60 \mathrm{E}-08$ |
| -2.297 | $6.85 \mathrm{E}-10$ | $3.60 \mathrm{E}-08$ |
| -2.044 | 6.90E-10 | 3.60E-08 |
| -2.219 | 6.46E-10 | $3.41 \mathrm{E}-08$ |
| -2.124 | 6.43E-10 | $3.40 \mathrm{E}-08$ |
| -2.103 | $5.59 \mathrm{E}-10$ | $3.00 \mathrm{E}-08$ |
| -2.106 | 5.60E-10 | 3.00E-08 |
| -2.211 | $5.51 \mathrm{E}-10$ | $2.97 \mathrm{E}-08$ |
| -2.088 | $5.45 \mathrm{E}-10$ | $2.95 \mathrm{E}-08$ |
| -2.038 | $5.47 \mathrm{E}-10$ | $2.95 \mathrm{E}-08$ |
| -2.068 | $5.35 \mathrm{E}-10$ | 2.92E-08 |
| -2.054 | 5.03E-10 | $2.76 \mathrm{E}-08$ |
| -2.011 | $4.62 \mathrm{E}-10$ | 2.55E-08 |
| -2.160 | $4.59 \mathrm{E}-10$ | $2.54 \mathrm{E}-08$ |
| -2.043 | $4.41 \mathrm{E}-10$ | $2.45 \mathrm{E}-08$ |
| -2.050 | 4.27E-10 | $2.39 \mathrm{E}-08$ |
| -2.273 | $4.17 \mathrm{E}-10$ | $2.34 \mathrm{E}-08$ |
| -2.037 | 3.94E-10 | 2.23E-08 |
| -2.200 | $3.41 \mathrm{E}-10$ | $1.96 \mathrm{E}-08$ |
| -2.320 | 3.07E-10 | $1.78 \mathrm{E}-08$ |
| -2.129 | 2.97E-10 | $1.73 \mathrm{E}-08$ |
| -2.153 | $2.92 \mathrm{E}-10$ | $1.71 \mathrm{E}-08$ |
| -2.151 | 2.86E-10 | $1.67 \mathrm{E}-08$ |
| -2.131 | 2.82E-10 | $1.66 \mathrm{E}-08$ |
| -2.219 | 2.80E-10 | $1.65 \mathrm{E}-08$ |
| -2.321 | $2.79 \mathrm{E}-10$ | $1.65 \mathrm{E}-08$ |
| -2.165 | $2.69 \mathrm{E}-10$ | $1.60 \mathrm{E}-08$ |
| -2.057 | 2.63E-10 | $1.58 \mathrm{E}-08$ |
| -2.276 | $2.47 \mathrm{E}-10$ | $1.48 \mathrm{E}-08$ |
| -2.301 | $2.18 \mathrm{E}-10$ | $1.32 \mathrm{E}-08$ |
| -3.690 | 2.12E-10 | $1.29 \mathrm{E}-08$ |


| Gbx1 | 5 | 0.547 | 2.637 | 6.221 | 9.60E-07 | $1.57 \mathrm{E}-05$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Tcf7l2 | 19 | 1.735 | 1.285 | 2.437 | $9.43 \mathrm{E}-07$ | $1.56 \mathrm{E}-05$ |
| Il17rd | 14 | 0.734 | 1.155 | 2.226 | 9.25E-07 | 1.53E-05 |
| Epb4114a | 18 | 1.498 | 1.411 | 2.659 | 9.25E-07 | $1.53 \mathrm{E}-05$ |
| Crispld2 | 8 | 1.531 | 1.264 | 2.402 | 9.18E-07 | $1.53 \mathrm{E}-05$ |
| Celsr2 | 3 | 21.444 | 1.097 | 2.139 | 9.15E-07 | 1.52E-05 |
| Cep350 | 1 | 3.477 | 1.009 | 2.013 | 9.12E-07 | $1.52 \mathrm{E}-05$ |
| Baiap3 | 17 | 8.273 | 1.578 | 2.986 | 8.42E-07 | $1.42 \mathrm{E}-05$ |
| Vipr2 | 12 | 1.853 | 2.813 | 7.028 | 8.28E-07 | $1.40 \mathrm{E}-05$ |
| Grin2b | 6 | 13.969 | 1.327 | 2.509 | 8.08E-07 | 1.37E-05 |
| Prkca | 11 | 25.259 | 1.009 | 2.012 | 7.88E-07 | $1.34 \mathrm{E}-05$ |
| Spata13 | 14 | 2.168 | 1.028 | 2.039 | 7.65E-07 | $1.31 \mathrm{E}-05$ |
| Isl1 | 13 | 0.785 | 2.524 | 5.751 | 6.22E-07 | $1.11 \mathrm{E}-05$ |
| Dock11 | X | 1.463 | 1.123 | 2.179 | 5.87E-07 | 1.05E-05 |
| Frem3 | 8 | 0.262 | 2.441 | 5.431 | $5.78 \mathrm{E}-07$ | $1.04 \mathrm{E}-05$ |
| Adra2a | 19 | 6.285 | 1.035 | 2.049 | $5.01 \mathrm{E}-07$ | 9.24E-06 |
| Ltbp2 | 12 | 0.232 | 3.372 | 10.354 | $4.91 \mathrm{E}-07$ | 9.07E-06 |
| Gal | 19 | 1.545 | 2.975 | 7.865 | 4.86E-07 | 9.00E-06 |
| Impg1 | 9 | 0.235 | 3.080 | 8.456 | 4.21E-07 | 7.97E-06 |
| Col18a1 | 10 | 1.211 | 1.349 | 2.547 | 4.07E-07 | 7.75E-06 |
| Magel2 | 7 | 0.867 | 1.783 | 3.441 | 4.04E-07 | $7.70 \mathrm{E}-06$ |
| Slc9a4 | 1 | 1.264 | 1.726 | 3.309 | 3.96E-07 | 7.59E-06 |
| Peg3 | 7 | 27.883 | 1.056 | 2.079 | 3.80E-07 | 7.34E-06 |
| Pcdhga4 | 18 | 6.345 | 1.024 | 2.033 | 3.71E-07 | $7.21 \mathrm{E}-06$ |
| Sdk1 | 5 | 0.876 | 1.052 | 2.074 | 3.54E-07 | 6.91E-06 |
| Hap1 | 11 | 65.482 | 1.095 | 2.135 | 3.52E-07 | 6.89E-06 |
| Gdpd5 | 7 | 6.761 | 1.118 | 2.170 | 3.33E-07 | $6.58 \mathrm{E}-06$ |
| Glp1r | 17 | 0.405 | 2.197 | 4.585 | 3.13E-07 | 6.22E-06 |
| Armcx4 | X | 7.815 | 1.039 | 2.055 | 3.09E-07 | 6.15E-06 |
| Kirrel | 3 | 1.114 | 1.216 | 2.324 | 2.87E-07 | 5.79E-06 |
| Alk | 17 | 1.591 | 1.202 | 2.301 | 2.69E-07 | 5.50E-06 |
| Syt10 | 15 | 7.904 | 1.325 | 2.505 | 2.36E-07 | 4.97E-06 |
| Nhs | X | 0.825 | 1.403 | 2.645 | 2.08E-07 | $4.42 \mathrm{E}-06$ |
| Tll1 | 8 | 0.711 | 1.806 | 3.498 | 2.06E-07 | 4.40E-06 |
| Ttc28 | 5 | 2.423 | 1.046 | 2.065 | $1.91 \mathrm{E}-07$ | 4.14E-06 |
| Nav1 | 1 | 6.886 | 1.063 | 2.089 | $1.91 \mathrm{E}-07$ | 4.14E-06 |
| Arid5b | 10 | 4.654 | 1.031 | 2.043 | $1.84 \mathrm{E}-07$ | 4.03E-06 |
| Fstl5 | 3 | 7.281 | 1.391 | 2.623 | $1.78 \mathrm{E}-07$ | 3.91E-06 |
| Drd3 | 16 | 0.472 | 4.694 | 25.883 | 1.68E-07 | $3.74 \mathrm{E}-06$ |
| Nrxn3 | 12 | 19.094 | 1.018 | 2.026 | $1.67 \mathrm{E}-07$ | 3.73E-06 |
| Tbx21 | 11 | 1.726 | 4.190 | 18.252 | $1.46 \mathrm{E}-07$ | $3.31 \mathrm{E}-06$ |
| Creb312 | 6 | 2.248 | 1.012 | 2.017 | $1.31 \mathrm{E}-07$ | 3.01E-06 |
| Stk32b | 5 | 1.611 | 1.399 | 2.637 | $1.25 \mathrm{E}-07$ | 2.88E-06 |
| Lonrf2 | 1 | 29.059 | 1.001 | 2.001 | 1.18E-07 | $2.74 \mathrm{E}-06$ |
| Birc6 | 17 | 5.771 | 1.005 | 2.007 | 1.16E-07 | 2.71E-06 |
| Pcbp3 | 10 | 31.059 | 1.343 | 2.536 | $1.14 \mathrm{E}-07$ | $2.65 \mathrm{E}-06$ |
| Tacr1 | 6 | 1.880 | 2.022 | 4.062 | 1.08E-07 | 2.54E-06 |
| Kcnk15 | 2 | 0.955 | 3.949 | 15.444 | 1.07E-07 | 2.54E-06 |
| Tnc | 4 | 1.036 | 1.282 | 2.431 | 1.05E-07 | 2.48E-06 |
| Ntrk1 | 3 | 0.861 | 2.712 | 6.551 | $1.02 \mathrm{E}-07$ | $2.43 \mathrm{E}-06$ |
| Actn2 | 13 | 5.874 | 1.175 | 2.258 | 9.02E-08 | 2.19E-06 |
| Slc32a1 | 2 | 53.360 | 1.012 | 2.016 | 8.55E-08 | 2.09E-06 |
| Lancl3 | X | 1.984 | 1.651 | 3.139 | 7.61E-08 | 1.87E-06 |
| Sp7 | 15 | 1.808 | 2.927 | 7.605 | 7.27E-08 | 1.80E-06 |
| SIc10a4 | 5 | 2.180 | 2.634 | 6.206 | 7.19E-08 | 1.79E-06 |
| Trdn | 10 | 0.231 | 3.301 | 9.855 | 6.63E-08 | $1.67 \mathrm{E}-06$ |
| SIc18a3 | 14 | 1.061 | 2.412 | 5.323 | $6.60 \mathrm{E}-08$ | $1.66 \mathrm{E}-06$ |
| Sema3d | 5 | 1.189 | 1.329 | 2.512 | $6.20 \mathrm{E}-08$ | 1.57E-06 |
| Scn2a | 2 | 30.058 | 1.016 | 2.022 | $5.75 \mathrm{E}-08$ | 1.47E-06 |
| Fry | 5 | 12.431 | 1.131 | 2.190 | 5.72E-08 | 1.47E-06 |
| Hydin | 8 | 0.167 | 1.885 | 3.693 | $5.47 \mathrm{E}-08$ | $1.41 \mathrm{E}-06$ |
| Inpp4b | 8 | 1.345 | 1.148 | 2.216 | 5.27E-08 | $1.36 \mathrm{E}-06$ |
| Pakap_3 | 4 | 5.907 | 1.036 | 2.050 | 5.12E-08 | 1.33E-06 |
| Tox3 | 8 | 5.340 | 1.086 | 2.124 | 5.02E-08 | 1.32E-06 |
| Dscaml1 | 9 | 11.138 | 1.066 | 2.093 | $4.68 \mathrm{E}-08$ | 1.24E-06 |
| Cntnap3 | 13 | 2.634 | 1.303 | 2.467 | $4.66 \mathrm{E}-08$ | $1.24 \mathrm{E}-06$ |
| Chrnb4 | 9 | 0.391 | 4.210 | 18.505 | $4.61 \mathrm{E}-08$ | $1.23 \mathrm{E}-06$ |
| Nr2f2 | 7 | 7.107 | 1.149 | 2.218 | $4.58 \mathrm{E}-08$ | $1.22 \mathrm{E}-06$ |
| Zfp366 | 13 | 1.440 | 1.277 | 2.424 | $4.45 \mathrm{E}-08$ | $1.19 \mathrm{E}-06$ |
| Foxo1 | 3 | 4.407 | 1.061 | 2.086 | $4.37 \mathrm{E}-08$ | $1.18 \mathrm{E}-06$ |
| Gbx2 | 1 | 0.481 | 4.489 | 22.459 | $3.80 \mathrm{E}-08$ | 1.05E-06 |
| Dlx5 | 6 | 7.388 | 1.589 | 3.009 | 3.77E-08 | $1.04 \mathrm{E}-06$ |
| Igsf1 | X | 1.713 | 1.328 | 2.510 | $3.75 \mathrm{E}-08$ | $1.04 \mathrm{E}-06$ |
| Fndc1 | 17 | 0.949 | 1.589 | 3.008 | 3.56E-08 | 1.00E-06 |


| Tbca | 13 | 83.059 | -1.057 | -2.081 | 2.09E-10 | 1.28E-08 | Ush1g | 11 | 1.029 | 2.878 | 7.353 | 3.46E-08 | $9.75 \mathrm{E}-07$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1110065P20Rik | 4 | 40.675 | -1.034 | -2.048 | 2.05E-10 | $1.26 \mathrm{E}-08$ | Fam20c | 5 | 17.038 | 1.018 | 2.026 | $3.41 \mathrm{E}-08$ | $9.65 \mathrm{E}-07$ |
| Dgcr6 | 16 | 47.392 | -1.106 | -2.152 | 1.94E-10 | $1.20 \mathrm{E}-08$ | Sall1 | 8 | 7.930 | 1.188 | 2.279 | 3.36E-08 | 9.53E-07 |
| Lamtor5 | 3 | 64.624 | -1.049 | -2.070 | 1.90E-10 | $1.17 \mathrm{E}-08$ | Pde3a | 6 | 0.652 | 1.441 | 2.715 | $3.11 \mathrm{E}-08$ | 8.93E-07 |
| Mrpl20 | 4 | 56.533 | -1.039 | -2.055 | $1.78 \mathrm{E}-10$ | $1.11 \mathrm{E}-08$ | Nxph4 | 10 | 5.932 | 1.669 | 3.179 | $3.08 \mathrm{E}-08$ | 8.84E-07 |
| Rps27rt | 9 | 31.475 | -1.860 | -3.629 | $1.76 \mathrm{E}-10$ | 1.10E-08 | Krt9 | 11 | 4.107 | 1.151 | 2.220 | 3.06E-08 | $8.79 \mathrm{E}-07$ |
| Nop10 | 2 | 45.483 | -1.042 | -2.059 | 1.70E-10 | 1.07E-08 | Dsg1c | 18 | 0.252 | 3.704 | 13.028 | 2.89E-08 | 8.38E-07 |
| Pdcd10 | 3 | 23.684 | -1.087 | -2.125 | 1.59E-10 | 1.01E-08 | Zfp503 | 14 | 1.889 | 1.436 | 2.706 | $2.44 \mathrm{E}-08$ | 7.23E-07 |
| A430005L14Rik | 4 | 25.514 | -1.131 | -2.191 | 1.45E-10 | 9.33E-09 | AW551984 | 9 | 3.193 | 1.526 | 2.881 | $2.38 \mathrm{E}-08$ | $7.07 \mathrm{E}-07$ |
| Supt4a | 11 | 66.477 | -1.081 | -2.116 | 1.44E-10 | 9.33E-09 | Npr1 | 3 | 2.291 | 2.130 | 4.378 | $2.35 \mathrm{E}-08$ | 6.99E-07 |
| Rpl10a | 17 | 254.726 | -1.187 | -2.277 | $1.44 \mathrm{E}-10$ | 9.33E-09 | Gaa | 11 | 95.077 | 1.051 | 2.072 | $2.27 \mathrm{E}-08$ | $6.79 \mathrm{E}-07$ |
| Krt12 | 11 | 9.553 | -1.345 | -2.540 | $1.41 \mathrm{E}-10$ | 9.17E-09 | Gpr161 | 1 | 3.678 | 1.348 | 2.546 | $2.21 \mathrm{E}-08$ | $6.66 \mathrm{E}-07$ |
| Mettl23 | 11 | 12.204 | -1.126 | -2.183 | 1.40E-10 | 9.14E-09 | Atrx | X | 8.169 | 1.075 | 2.107 | $2.20 \mathrm{E}-08$ | $6.64 \mathrm{E}-07$ |
| Lin7b | 7 | 78.436 | -1.063 | -2.089 | $1.26 \mathrm{E}-10$ | 8.28E-09 | Dlx2 | 2 | 5.256 | 1.704 | 3.259 | 2.13E-08 | 6.46E-07 |
| Coa3 | 11 | 114.862 | -1.007 | -2.009 | 1.22E-10 | 8.11E-09 | Ret | 6 | 1.024 | 1.518 | 2.865 | $2.06 \mathrm{E}-08$ | $6.31 \mathrm{E}-07$ |
| Ptpmt1 | 2 | 12.638 | -1.107 | -2.154 | 1.17E-10 | 7.86E-09 | Cyp1b1 | 17 | 1.151 | 1.541 | 2.909 | $2.06 \mathrm{E}-08$ | $6.31 \mathrm{E}-07$ |
| Rpl35 | 2 | 226.640 | -1.303 | -2.467 | 1.13E-10 | 7.62E-09 | Aqp1 | 6 | 1.808 | 3.537 | 11.605 | $2.00 \mathrm{E}-08$ | 6.16E-07 |
| Rps23 | 13 | 428.004 | -1.249 | -2.376 | 1.07E-10 | $7.34 \mathrm{E}-09$ | Abca1 | 4 | 4.693 | 1.036 | 2.051 | $1.79 \mathrm{E}-08$ | 5.53E-07 |
| Serf1 | 13 | 11.032 | -1.236 | -2.356 | $1.06 \mathrm{E}-10$ | 7.24E-09 | Dgkg | 16 | 22.447 | 1.085 | 2.121 | $1.66 \mathrm{E}-08$ | 5.19E-07 |
| Sft2d1 | 17 | 22.450 | -1.149 | -2.217 | $1.01 \mathrm{E}-10$ | 6.99E-09 | Pag1 | 3 | 3.001 | 1.040 | 2.056 | $1.64 \mathrm{E}-08$ | 5.15E-07 |
| Atpif1 | 4 | 449.563 | -1.152 | -2.222 | $9.61 \mathrm{E}-11$ | 6.64E-09 | Sema6a | 18 | 4.452 | 1.018 | 2.025 | $1.64 \mathrm{E}-08$ | 5.13E-07 |
| Rpl31 | 1 | 292.055 | -1.259 | -2.393 | $9.47 \mathrm{E}-11$ | 6.60E-09 | Sv2a | 3 | 113.223 | 1.030 | 2.042 | $1.52 \mathrm{E}-08$ | 4.80E-07 |
| Pop5 | 5 | 34.957 | -1.152 | -2.222 | 8.78E-11 | 6.18E-09 | Wnt5a | 14 | 1.849 | 1.241 | 2.363 | 1.50E-08 | $4.79 \mathrm{E}-07$ |
| Rpl36a | X | 299.385 | -1.152 | -2.222 | $8.77 \mathrm{E}-11$ | $6.18 \mathrm{E}-09$ | St3gal1 | 15 | 7.302 | 1.003 | 2.004 | $1.44 \mathrm{E}-08$ | $4.61 \mathrm{E}-07$ |
| Rpl11 | 4 | 410.997 | -1.244 | -2.368 | $8.65 \mathrm{E}-11$ | 6.14E-09 | Grik3 | 4 | 10.474 | 1.016 | 2.022 | $1.42 \mathrm{E}-08$ | $4.58 \mathrm{E}-07$ |
| Vcpkmt | 12 | 16.446 | -1.167 | -2.245 | $8.40 \mathrm{E}-11$ | 5.98E-09 | Zfp608 | 18 | 4.838 | 1.186 | 2.276 | $1.42 \mathrm{E}-08$ | $4.58 \mathrm{E}-07$ |
| Gng10 | 4 | 53.701 | -1.138 | -2.201 | $6.98 \mathrm{E}-11$ | 4.99E-09 | Runx1t1 | 4 | 2.654 | 1.048 | 2.068 | $1.41 \mathrm{E}-08$ | $4.57 \mathrm{E}-07$ |
| Rpl36 | 17 | 538.114 | -1.326 | -2.506 | $6.97 \mathrm{E}-11$ | 4.99E-09 | Cemip2 | 19 | 2.214 | 1.079 | 2.113 | $1.41 \mathrm{E}-08$ | $4.57 \mathrm{E}-07$ |
| Gls2 | 10 | 8.821 | -1.052 | -2.074 | $6.77 \mathrm{E}-11$ | 4.88E-09 | Sp9 | 2 | 3.199 | 1.863 | 3.637 | $1.35 \mathrm{E}-08$ | $4.42 \mathrm{E}-07$ |
| Tma7 | 9 | 110.473 | -1.052 | -2.073 | $6.37 \mathrm{E}-11$ | $4.61 \mathrm{E}-09$ | Ylpm1 | 12 | 14.427 | 1.151 | 2.220 | $1.35 \mathrm{E}-08$ | $4.42 \mathrm{E}-07$ |
| Psmb10 | 8 | 36.444 | -1.087 | -2.124 | $6.21 \mathrm{E}-11$ | $4.51 \mathrm{E}-09$ | Kcnd2 | 6 | 17.589 | 1.100 | 2.144 | $1.32 \mathrm{E}-08$ | $4.35 \mathrm{E}-07$ |
| Rack1 | 11 | 248.145 | -1.215 | -2.321 | $5.75 \mathrm{E}-11$ | $4.19 \mathrm{E}-09$ | Foxp2 | 6 | 1.287 | 1.260 | 2.395 | $1.27 \mathrm{E}-08$ | $4.20 \mathrm{E}-07$ |
| Rpl38 | 11 | 493.499 | -1.251 | -2.380 | $5.72 \mathrm{E}-11$ | 4.19E-09 | Pde11a | 2 | 1.299 | 1.479 | 2.787 | $1.26 \mathrm{E}-08$ | $4.17 \mathrm{E}-07$ |
| Polr2e | 10 | 81.028 | -1.008 | -2.011 | $5.53 \mathrm{E}-11$ | 4.08E-09 | Slc8a1 | 17 | 10.306 | 1.215 | 2.321 | $1.21 \mathrm{E}-08$ | $4.01 \mathrm{E}-07$ |
| Arhgdig | 17 | 92.215 | -1.030 | -2.043 | $5.54 \mathrm{E}-11$ | $4.08 \mathrm{E}-09$ | Prkg1 | 19 | 1.700 | 1.228 | 2.343 | $1.16 \mathrm{E}-08$ | 3.90E-07 |
| Rnf7 | 9 | 85.667 | -1.062 | -2.088 | 5.39E-11 | 4.02E-09 | Abl2 | 1 | 8.261 | 1.045 | 2.064 | $1.06 \mathrm{E}-08$ | 3.57E-07 |
| Acyp2 | 11 | 29.454 | -1.167 | -2.245 | $5.01 \mathrm{E}-11$ | $3.81 \mathrm{E}-09$ | Abi3bp | 16 | 1.797 | 1.789 | 3.457 | $1.04 \mathrm{E}-08$ | $3.51 \mathrm{E}-07$ |
| Mrps33 | 6 | 63.453 | -1.031 | -2.044 | $4.10 \mathrm{E}-11$ | 3.14E-09 | Pcdhgb6 | 18 | 8.261 | 1.037 | 2.052 | 9.96E-09 | $3.39 \mathrm{E}-07$ |
| Mtln | 2 | 41.715 | -1.162 | -2.238 | $3.78 \mathrm{E}-11$ | 2.93E-09 | Nexmif | X | 3.948 | 1.041 | 2.058 | 9.18E-09 | 3.15E-07 |
| Rps8 | 4 | 622.285 | -1.227 | -2.341 | $3.76 \mathrm{E}-11$ | 2.93E-09 | Ace | 11 | 5.447 | 1.209 | 2.312 | 9.09E-09 | 3.13E-07 |
| Pstk | 7 | 13.656 | -1.196 | -2.291 | $3.76 \mathrm{E}-11$ | 2.93E-09 | Pcdhga1 | 18 | 2.741 | 1.067 | 2.096 | 8.10E-09 | 2.82E-07 |
| Rps27a | 11 | 434.982 | -1.313 | -2.484 | 3.79E-11 | 2.93E-09 | Pcdhga10 | 18 | 5.126 | 1.066 | 2.093 | 7.97E-09 | 2.79E-07 |
| Dpm1 | 2 | 6.420 | -1.169 | -2.249 | 3.68E-11 | 2.90E-09 | Atp8a2 | 14 | 4.454 | 1.065 | 2.092 | $7.41 \mathrm{E}-09$ | $2.61 \mathrm{E}-07$ |
| Lsm1 | 8 | 10.382 | -1.104 | -2.150 | $3.55 \mathrm{E}-11$ | 2.82E-09 | Itga4 | 2 | 2.056 | 1.104 | 2.150 | $7.21 \mathrm{E}-09$ | $2.55 \mathrm{E}-07$ |
| Naa38 | 11 | 75.298 | -1.122 | -2.176 | $3.39 \mathrm{E}-11$ | 2.70E-09 | Gad1 | 2 | 102.059 | 1.189 | 2.280 | $5.94 \mathrm{E}-09$ | $2.15 \mathrm{E}-07$ |
| Nme2 | 11 | 59.952 | -1.226 | -2.339 | 3.19E-11 | $2.56 \mathrm{E}-09$ | Kcnb2 | 1 | 1.928 | 1.276 | 2.422 | 5.73E-09 | $2.08 \mathrm{E}-07$ |
| Arpp19 | 9 | 81.280 | -1.143 | -2.209 | 3.02E-11 | 2.46E-09 | Brd4 | 17 | 12.329 | 1.028 | 2.039 | 5.46E-09 | $2.00 \mathrm{E}-07$ |
| Mpc2 | 1 | 107.807 | -1.081 | -2.116 | $2.35 \mathrm{E}-11$ | 1.92E-09 | Cracd | 5 | 6.737 | 1.066 | 2.094 | 5.22E-09 | $1.93 \mathrm{E}-07$ |
| Ndufb6 | 4 | 126.344 | -1.118 | -2.171 | $2.32 \mathrm{E}-11$ | 1.92E-09 | Cntnap5a | 1 | 4.802 | 1.047 | 2.066 | 5.19E-09 | $1.93 \mathrm{E}-07$ |
| Bok | 1 | 41.610 | -1.117 | -2.169 | $2.30 \mathrm{E}-11$ | $1.90 \mathrm{E}-09$ | Atp2b4 | 1 | 34.293 | 1.131 | 2.190 | $5.14 \mathrm{E}-09$ | $1.92 \mathrm{E}-07$ |
| Mrpl12 | 11 | 87.780 | -1.117 | -2.170 | 2.29E-11 | $1.90 \mathrm{E}-09$ | Tmem255a | X | 10.525 | 1.176 | 2.260 | $4.75 \mathrm{E}-09$ | $1.79 \mathrm{E}-07$ |
| Ndufb2 | 6 | 23.583 | -1.099 | -2.142 | $2.27 \mathrm{E}-11$ | $1.90 \mathrm{E}-09$ | Tmem131 | 1 | 10.427 | 1.050 | 2.071 | $4.68 \mathrm{E}-09$ | $1.78 \mathrm{E}-07$ |
| S100a6 | 3 | 17.280 | -1.342 | -2.536 | 2.24E-11 | 1.89E-09 | Ankfn1 | 11 | 1.145 | 1.627 | 3.089 | $4.62 \mathrm{E}-09$ | $1.76 \mathrm{E}-07$ |
| Mrpl41 | 2 | 74.708 | -1.105 | -2.151 | 2.23E-11 | 1.88E-09 | F5 | 1 | 0.554 | 3.393 | 10.505 | $4.35 \mathrm{E}-09$ | $1.68 \mathrm{E}-07$ |
| Smim26 | 2 | 39.871 | -1.199 | -2.296 | $2.17 \mathrm{E}-11$ | 1.84E-09 | Slco5a1 | 1 | 0.449 | 2.318 | 4.987 | $4.24 \mathrm{E}-09$ | $1.64 \mathrm{E}-07$ |
| Bri3 | 5 | 50.339 | -1.127 | -2.184 | 2.00E-11 | $1.71 \mathrm{E}-09$ | Slc6a9 | 4 | 12.981 | 1.066 | 2.093 | 3.90E-09 | $1.53 \mathrm{E}-07$ |
| Bnip3 | 7 | 87.361 | -1.084 | -2.120 | 1.93E-11 | $1.67 \mathrm{E}-09$ | Camk2d | 3 | 14.373 | 1.127 | 2.184 | 3.63E-09 | $1.44 \mathrm{E}-07$ |
| Serp2 | 14 | 132.735 | -1.122 | -2.177 | 1.92E-11 | $1.67 \mathrm{E}-09$ | Glg1 | 8 | 36.124 | 1.161 | 2.236 | $3.64 \mathrm{E}-09$ | $1.44 \mathrm{E}-07$ |
| Rps271 | 9 | 28.486 | -1.268 | -2.408 | 1.70E-11 | $1.53 \mathrm{E}-09$ | Slc8a3 | 12 | 6.143 | 1.195 | 2.290 | $3.58 \mathrm{E}-09$ | $1.42 \mathrm{E}-07$ |
| Rps16 | 7 | 297.442 | -1.282 | -2.432 | 1.63E-11 | 1.47E-09 | Car12 | 9 | 6.261 | 1.124 | 2.180 | 3.40E-09 | $1.36 \mathrm{E}-07$ |
| Coq2 | 5 | 46.236 | -1.110 | -2.158 | $1.57 \mathrm{E}-11$ | $1.43 \mathrm{E}-09$ | Trim62 | 4 | 6.919 | 1.099 | 2.142 | $3.38 \mathrm{E}-09$ | $1.36 \mathrm{E}-07$ |
| Chchd6 | 6 | 91.373 | -1.069 | -2.099 | 1.43E-11 | $1.33 \mathrm{E}-09$ | Diaph2 | X | 2.783 | 1.048 | 2.068 | $3.34 \mathrm{E}-09$ | $1.35 \mathrm{E}-07$ |
| Ndufaf5 | 2 | 45.218 | -1.140 | -2.204 | $1.41 \mathrm{E}-11$ | $1.32 \mathrm{E}-09$ | Epha5 | 5 | 10.794 | 1.025 | 2.035 | $3.31 \mathrm{E}-09$ | $1.34 \mathrm{E}-07$ |
| Rps10 | 17 | 203.467 | -1.302 | -2.466 | 1.39E-11 | $1.31 \mathrm{E}-09$ | Gprin3 | 6 | 1.574 | 1.206 | 2.307 | 3.26E-09 | $1.32 \mathrm{E}-07$ |
| Ramp1 | 1 | 45.692 | -1.194 | -2.288 | $1.27 \mathrm{E}-11$ | $1.21 \mathrm{E}-09$ | Cep170 | 1 | 7.698 | 1.072 | 2.103 | $3.11 \mathrm{E}-09$ | $1.27 \mathrm{E}-07$ |
| Fau | 19 | 456.742 | -1.273 | -2.417 | 1.20E-11 | 1.15E-09 | Patj | 4 | 1.161 | 1.541 | 2.911 | 3.08E-09 | 1.26E-07 |
| Ssr4 | X | 67.560 | -1.129 | -2.188 | 1.17E-11 | 1.13E-09 | Bmp6 | 13 | 5.423 | 1.029 | 2.041 | 2.90E-09 | $1.20 \mathrm{E}-07$ |
| Polr2k | 15 | 34.655 | -1.264 | -2.402 | 1.13E-11 | 1.10E-09 | Pbx3 | 2 | 9.370 | 1.951 | 3.865 | $2.54 \mathrm{E}-09$ | $1.06 \mathrm{E}-07$ |
| Rpl39 | X | 221.883 | -1.249 | -2.376 | 1.02E-11 | $9.95 \mathrm{E}-10$ | Pcdh8 | 14 | 15.444 | 1.130 | 2.188 | $2.50 \mathrm{E}-09$ | $1.05 \mathrm{E}-07$ |
| Gm13304 | 4 | 27.472 | -1.284 | -2.436 | 9.95E-12 | $9.74 \mathrm{E}-10$ | Slc5a3 | 16 | 2.627 | 1.378 | 2.599 | 2.49E-09 | $1.05 \mathrm{E}-07$ |
| Tmem42 | 9 | 15.537 | -1.188 | -2.278 | $9.87 \mathrm{E}-12$ | $9.72 \mathrm{E}-10$ | Tacr3 | 3 | 1.164 | 1.712 | 3.276 | $2.44 \mathrm{E}-09$ | $1.03 \mathrm{E}-07$ |
| Gpx1 | 9 | 135.875 | -1.226 | -2.339 | 8.59E-12 | $8.51 \mathrm{E}-10$ | Csmd3 | 15 | 1.777 | 1.188 | 2.278 | 2.20E-09 | $9.41 \mathrm{E}-08$ |
| Pradc1 | 6 | 14.909 | -1.234 | -2.353 | 8.15E-12 | $8.11 \mathrm{E}-10$ | Smoc1 | 12 | 9.338 | 1.119 | 2.172 | $2.11 \mathrm{E}-09$ | $9.09 \mathrm{E}-08$ |
| Rpl19 | 11 | 944.560 | -1.300 | -2.463 | 8.09E-12 | 8.10E-10 | Zfp462 | 4 | 4.285 | 1.147 | 2.214 | 2.02E-09 | 8.74E-08 |


| Rpl26 | 11 | 681.432 | -1.341 | -2.533 | 7.60E-12 | 7.69E-10 | Atg2b | 12 | 6.801 | 1.053 | 2.074 | 2.00E-09 | 8.64E-08 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Bud31 | 5 | 65.330 | -1.125 | -2.181 | $7.44 \mathrm{E}-12$ | $7.61 \mathrm{E}-10$ | Inpp5j | 11 | 15.085 | 1.316 | 2.489 | 1.95E-09 | $8.52 \mathrm{E}-08$ |
| Tmem208 | 8 | 20.091 | -1.234 | -2.352 | $7.37 \mathrm{E}-12$ | $7.61 \mathrm{E}-10$ | Dgkk | X | 0.486 | 2.037 | 4.103 | $1.77 \mathrm{E}-09$ | $7.82 \mathrm{E}-08$ |
| Smim36 | 11 | 10.048 | -1.164 | -2.241 | 7.43E-12 | $7.61 \mathrm{E}-10$ | Klhl30 | 1 | 0.859 | 4.112 | 17.288 | 1.69E-09 | $7.56 \mathrm{E}-08$ |
| Ndufb8 | 19 | 126.274 | -1.286 | -2.439 | 6.73E-12 | $7.05 \mathrm{E}-10$ | Hspg2 | 4 | 0.971 | 1.431 | 2.696 | $1.69 \mathrm{E}-09$ | $7.56 \mathrm{E}-08$ |
| Vps29 | 5 | 51.228 | -1.113 | -2.163 | 6.56E-12 | 6.90E-10 | Chd6 | 2 | 7.056 | 1.097 | 2.139 | $1.42 \mathrm{E}-09$ | 6.53E-08 |
| Rps7 | 12 | 430.269 | -1.310 | -2.480 | 5.76E-12 | $6.14 \mathrm{E}-10$ | Slc9a1 | 4 | 12.799 | 1.031 | 2.043 | $1.31 \mathrm{E}-09$ | $6.07 \mathrm{E}-08$ |
| Bola2 | 7 | 28.810 | -1.214 | -2.319 | $5.68 \mathrm{E}-12$ | $6.08 \mathrm{E}-10$ | Myh9 | 15 | 12.502 | 1.078 | 2.111 | $1.29 \mathrm{E}-09$ | $5.99 \mathrm{E}-08$ |
| Atp5l | 9 | 489.142 | -1.213 | -2.318 | $5.58 \mathrm{E}-12$ | $6.04 \mathrm{E}-10$ | Amigo2 | 15 | 3.777 | 1.251 | 2.380 | $1.26 \mathrm{E}-09$ | 5.89E-08 |
| Sirt3 | 7 | 51.832 | -1.144 | -2.210 | 5.46E-12 | $5.95 \mathrm{E}-10$ | Shisa3 | 5 | 2.134 | 4.181 | 18.143 | $1.25 \mathrm{E}-09$ | $5.86 \mathrm{E}-08$ |
| Rps11 | 7 | 537.293 | -1.310 | -2.479 | 5.28E-12 | 5.80E-10 | Zfp618 | 4 | 0.995 | 1.331 | 2.516 | 1.24E-09 | $5.84 \mathrm{E}-08$ |
| Cox4i1 | 8 | 1125.198 | -1.321 | -2.499 | 5.14E-12 | 5.68E-10 | Pdgfra | 5 | 8.418 | 1.023 | 2.032 | $1.24 \mathrm{E}-09$ | $5.84 \mathrm{E}-08$ |
| Ndufa4 | 6 | 589.078 | -1.254 | -2.384 | 5.08E-12 | 5.63E-10 | Parm1 | 5 | 16.911 | 1.124 | 2.179 | 1.13E-09 | $5.39 \mathrm{E}-08$ |
| Mrpl13 | 15 | 34.701 | -1.188 | -2.278 | 4.82E-12 | 5.39E-10 | Myh10 | 11 | 32.158 | 1.118 | 2.171 | 9.30E-10 | $4.53 \mathrm{E}-08$ |
| Syt12 | 7 | 7.067 | -1.149 | -2.218 | $4.54 \mathrm{E}-12$ | 5.13E-10 | Cachd1 | 4 | 3.762 | 1.115 | 2.166 | 8.65E-10 | $4.31 \mathrm{E}-08$ |
| Ndufs4 | 13 | 41.817 | -1.127 | -2.183 | $4.28 \mathrm{E}-12$ | $4.87 \mathrm{E}-10$ | Strn | 17 | 8.427 | 1.020 | 2.028 | 8.67E-10 | $4.31 \mathrm{E}-08$ |
| Rps15 | 10 | 1118.562 | -1.361 | -2.569 | $4.11 \mathrm{E}-12$ | $4.71 \mathrm{E}-10$ | Chat | 14 | 1.677 | 2.596 | 6.047 | 8.30E-10 | $4.15 \mathrm{E}-08$ |
| Nt5c | 11 | 46.877 | -1.126 | -2.182 | 4.11E-12 | $4.71 \mathrm{E}-10$ | Kirrel3 | 9 | 13.597 | 1.029 | 2.041 | 8.19E-10 | $4.14 \mathrm{E}-08$ |
| Bloc1s2 | 19 | 51.503 | -1.151 | -2.220 | 4.07E-12 | $4.71 \mathrm{E}-10$ | Pde10a | 17 | 15.985 | 1.190 | 2.281 | 8.01E-10 | $4.06 \mathrm{E}-08$ |
| Rps12 | 10 | 409.667 | -1.446 | -2.725 | 4.01E-12 | $4.70 \mathrm{E}-10$ | Cntnap4 | 8 | 6.841 | 1.157 | 2.230 | 7.89E-10 | $4.03 \mathrm{E}-08$ |
| Fmc1 | 6 | 71.237 | -1.352 | -2.553 | 3.77E-12 | $4.48 \mathrm{E}-10$ | Astn1 | 1 | 40.418 | 1.104 | 2.149 | $7.77 \mathrm{E}-10$ | 3.97E-08 |
| Mrpl28 | 17 | 76.515 | -1.226 | -2.340 | 3.75E-12 | $4.48 \mathrm{E}-10$ | Prlr | 15 | 0.353 | 2.565 | 5.917 | 7.42E-10 | 3.82E-08 |
| Rps19 | 7 | 163.352 | -1.345 | -2.540 | 3.56E-12 | $4.31 \mathrm{E}-10$ | Shisa8 | 15 | 5.827 | 2.872 | 7.322 | 7.25E-10 | $3.75 \mathrm{E}-08$ |
| Dkkl1 | 7 | 22.477 | -1.228 | -2.342 | 3.18E-12 | 3.93E-10 | Adamtsl1 | 4 | 1.104 | 1.325 | 2.505 | 7.07E-10 | 3.68E-08 |
| Gm21586 | 4 | 14.680 | -1.977 | -3.937 | 3.06E-12 | 3.82E-10 | Disp2 | 2 | 40.987 | 1.172 | 2.253 | 6.88E-10 | 3.60E-08 |
| Snrpg | 6 | 36.757 | -1.275 | -2.420 | 3.03E-12 | 3.82E-10 | Zswim5 | 4 | 3.940 | 1.121 | 2.175 | 6.35E-10 | 3.37E-08 |
| Atp5k | 5 | 409.610 | -1.260 | -2.395 | $2.71 \mathrm{E}-12$ | 3.45E-10 | Dchs2 | 3 | 0.396 | 2.191 | 4.565 | 6.04E-10 | 3.22E-08 |
| Acot13 | 13 | 140.840 | -1.227 | -2.341 | 2.70E-12 | $3.45 \mathrm{E}-10$ | Heatr5b | 17 | 8.180 | 1.090 | 2.129 | 5.77E-10 | 3.08E-08 |
| Atp5md | 19 | 83.141 | -1.373 | -2.590 | 2.57E-12 | $3.31 \mathrm{E}-10$ | Map3k1 | 13 | 2.409 | 1.741 | 3.342 | $5.31 \mathrm{E}-10$ | $2.91 \mathrm{E}-08$ |
| Psma7 | 2 | 129.006 | -1.150 | -2.219 | 2.30E-12 | 3.03E-10 | Calb2 | 8 | 52.968 | 2.099 | 4.283 | $4.41 \mathrm{E}-10$ | $2.45 \mathrm{E}-08$ |
| Rpain | 11 | 10.116 | -1.399 | -2.638 | $2.28 \mathrm{E}-12$ | 3.03E-10 | Fmod | 1 | 12.626 | 1.148 | 2.217 | $4.03 \mathrm{E}-10$ | 2.27E-08 |
| Snrnp25 | 11 | 32.574 | -1.251 | -2.380 | 2.18E-12 | $2.91 \mathrm{E}-10$ | Sp8 | 12 | 2.339 | 3.498 | 11.298 | $4.01 \mathrm{E}-10$ | 2.27E-08 |
| Cebpzos | 17 | 24.619 | -1.222 | -2.333 | 2.08E-12 | 2.82E-10 | Dnm3 | 1 | 17.933 | 1.090 | 2.128 | 3.92E-10 | $2.23 \mathrm{E}-08$ |
| Ovol2 | 2 | 4.309 | -1.921 | -3.787 | 2.05E-12 | $2.81 \mathrm{E}-10$ | Numa1 | 7 | 12.523 | 1.102 | 2.146 | 3.80E-10 | $2.17 \mathrm{E}-08$ |
| Gm14295 | 2 | 8.166 | -1.213 | -2.318 | $2.04 \mathrm{E}-12$ | $2.81 \mathrm{E}-10$ | Kit | 5 | 12.124 | 1.124 | 2.179 | 3.67E-10 | $2.10 \mathrm{E}-08$ |
| Ndufb1 | 12 | 82.045 | -1.254 | -2.385 | 2.03E-12 | 2.81E-10 | Tpr | 1 | 13.717 | 1.032 | 2.044 | 3.53E-10 | $2.03 \mathrm{E}-08$ |
| Rpl5 | 5 | 280.651 | -1.388 | -2.616 | 1.72E-12 | 2.47E-10 | Notch3 | 17 | 2.380 | 1.070 | 2.100 | 3.39E-10 | $1.96 \mathrm{E}-08$ |
| Tmem141 | 2 | 25.858 | -1.221 | -2.332 | 1.53E-12 | 2.23E-10 | Cacng5 | 11 | 11.277 | 2.262 | 4.796 | 2.79E-10 | $1.65 \mathrm{E}-08$ |
| Rpl9-ps6 | 19 | 17.573 | -1.960 | -3.889 | 1.26E-12 | 1.88E-10 | Zc3h13 | 14 | 9.941 | 1.219 | 2.328 | 2.69E-10 | $1.60 \mathrm{E}-08$ |
| 1810037I17Rik | 3 | 69.280 | -1.270 | -2.411 | 1.17E-12 | $1.77 \mathrm{E}-10$ | Kctd12 | 14 | 19.037 | 1.068 | 2.097 | 2.32E-10 | $1.40 \mathrm{E}-08$ |
| Gpx4 | 10 | 490.006 | -1.344 | -2.538 | 1.15E-12 | 1.76E-10 | Prrc2c | 1 | 13.338 | 1.276 | 2.421 | 2.23E-10 | $1.35 \mathrm{E}-08$ |
| Medag | 5 | 8.542 | -1.413 | -2.663 | 1.13E-12 | $1.74 \mathrm{E}-10$ | Rrbp1 | 2 | 9.715 | 1.036 | 2.050 | 2.07E-10 | $1.27 \mathrm{E}-08$ |
| Rps24 | 14 | 339.149 | -1.443 | -2.720 | 1.00E-12 | $1.56 \mathrm{E}-10$ | Sorcs2 | 5 | 10.146 | 1.061 | 2.086 | 1.87E-10 | $1.16 \mathrm{E}-08$ |
| Immp11 | 2 | 26.872 | -1.241 | -2.363 | $9.91 \mathrm{E}-13$ | $1.55 \mathrm{E}-10$ | Zfp516 | 18 | 2.957 | 1.182 | 2.268 | $1.75 \mathrm{E}-10$ | $1.10 \mathrm{E}-08$ |
| Gm2000 | 1 | 272.523 | -1.309 | -2.477 | 8.82E-13 | $1.41 \mathrm{E}-10$ | L1cam | X | 31.708 | 1.119 | 2.172 | 1.67E-10 | $1.06 \mathrm{E}-08$ |
| Rps3 | 7 | 333.208 | -1.408 | -2.654 | 7.84E-13 | $1.26 \mathrm{E}-10$ | Gprasp1 | X | 83.709 | 1.195 | 2.290 | $1.66 \mathrm{E}-10$ | 1.05E-08 |
| Chchd1 | 14 | 59.108 | -1.211 | -2.314 | 7.64E-13 | $1.24 \mathrm{E}-10$ | Grm4 | 17 | 7.086 | 1.574 | 2.978 | $1.53 \mathrm{E}-10$ | 9.74E-09 |
| Mrpl14 | 17 | 41.175 | -1.216 | -2.324 | 7.05E-13 | 1.16E-10 | Scgn | 13 | 2.777 | 4.115 | 17.323 | 1.50E-10 | 9.63E-09 |
| Tmem242 | 17 | 53.182 | -1.225 | -2.337 | 6.77E-13 | 1.13E-10 | Tnr | 1 | 15.720 | 1.241 | 2.364 | 1.49E-10 | 9.56E-09 |
| Ndufb9 | 15 | 531.951 | -1.379 | -2.600 | 6.62E-13 | $1.11 \mathrm{E}-10$ | Fras1 | 5 | 1.305 | 1.211 | 2.316 | 1.39E-10 | 9.10E-09 |
| Arhgap15 | 2 | 3.968 | -1.358 | -2.563 | 6.32E-13 | $1.07 \mathrm{E}-10$ | Lamb1 | 12 | 3.703 | 1.290 | 2.446 | $1.24 \mathrm{E}-10$ | 8.19E-09 |
| 1110032F04Rik | 3 | 7.229 | -1.261 | -2.397 | 6.03E-13 | $1.03 \mathrm{E}-10$ | Doc2g | 19 | 32.343 | 4.075 | 16.856 | 1.20E-10 | 8.01E-09 |
| Churc1 | 12 | 63.499 | -1.206 | -2.308 | $5.74 \mathrm{E}-13$ | $9.93 \mathrm{E}-11$ | Pnma8b | 7 | 125.206 | 1.144 | 2.210 | $1.19 \mathrm{E}-10$ | 7.96E-09 |
| Pet100 | 8 | 21.997 | -1.334 | -2.522 | $5.68 \mathrm{E}-13$ | $9.91 \mathrm{E}-11$ | Igf2r | 17 | 4.580 | 1.146 | 2.213 | 1.15E-10 | $7.72 \mathrm{E}-09$ |
| Timm10b | 7 | 11.252 | -1.171 | -2.252 | $5.51 \mathrm{E}-13$ | 9.70E-11 | Slc7a14 | 3 | 15.630 | 1.245 | 2.371 | 1.11E-10 | 7.52E-09 |
| Cd302 | 2 | 18.749 | -1.320 | -2.497 | 5.09E-13 | 9.13E-11 | Pcdhga2 | 18 | 4.896 | 1.187 | 2.277 | 1.10E-10 | 7.51E-09 |
| Atp5mpl | 12 | 162.351 | -1.242 | -2.365 | $4.88 \mathrm{E}-13$ | 8.85E-11 | Hectd1 | 12 | 14.164 | 1.183 | 2.271 | $9.57 \mathrm{E}-11$ | 6.64E-09 |
| Ndufaf2 | 13 | 8.459 | -1.301 | -2.465 | 4.59E-13 | $8.59 \mathrm{E}-11$ | Ackr1 | 1 | 19.072 | 1.066 | 2.093 | $9.46 \mathrm{E}-11$ | 6.60E-09 |
| Rpl32 | 6 | 331.435 | -1.415 | -2.667 | 3.20E-13 | 6.10E-11 | Sox1 | 8 | 5.342 | 1.141 | 2.205 | 9.10E-11 | $6.38 \mathrm{E}-09$ |
| Camk2n1 | 4 | 865.622 | -1.389 | -2.619 | 3.15E-13 | 6.06E-11 | Col25a1 | 3 | 6.523 | 1.328 | 2.510 | $5.51 \mathrm{E}-11$ | 4.08E-09 |
| gene:ENSMUSG00000115423 | 2 | 27.714 | -1.248 | -2.375 | $2.52 \mathrm{E}-13$ | $4.97 \mathrm{E}-11$ | Plce1 | 19 | 1.959 | 1.117 | 2.168 | 5.38E-11 | 4.02E-09 |
| Guk1 | 11 | 154.448 | -1.277 | -2.424 | 2.45E-13 | $4.88 \mathrm{E}-11$ | Dpysl3 | 18 | 10.024 | 1.088 | 2.126 | 5.26E-11 | 3.95E-09 |
| Car8 | 4 | 5.822 | -1.493 | -2.815 | 2.11E-13 | $4.25 \mathrm{E}-11$ | Slc5a7 | 17 | 1.223 | 2.377 | 5.194 | $5.08 \mathrm{E}-11$ | 3.83E-09 |
| Rpl13a | 7 | 798.360 | -1.481 | -2.792 | 2.10E-13 | $4.25 \mathrm{E}-11$ | Unc5c | 3 | 3.596 | 1.209 | 2.311 | $5.05 \mathrm{E}-11$ | 3.82E-09 |
| Dctpp1 | 7 | 24.670 | -1.354 | -2.557 | 1.92E-13 | 3.94E-11 | Nynrin | 14 | 2.230 | 1.202 | 2.300 | $4.15 \mathrm{E}-11$ | 3.17E-09 |
| Rpl41 | 10 | 1279.109 | -1.450 | -2.732 | 1.85E-13 | 3.85E-11 | Cpd | 11 | 13.941 | 1.084 | 2.120 | 4.07E-11 | 3.13E-09 |
| Cd34 | 1 | 34.742 | -1.162 | -2.238 | $1.71 \mathrm{E}-13$ | 3.59E-11 | Srgap1 | 10 | 2.737 | 1.207 | 2.309 | 3.78E-11 | 2.93E-09 |
| Rpl34 | 3 | 121.667 | -1.544 | -2.916 | $1.57 \mathrm{E}-13$ | $3.34 \mathrm{E}-11$ | Thsd7a | 6 | 4.024 | 1.384 | 2.610 | 3.27E-11 | 2.62E-09 |
| Rpl35a | 16 | 399.006 | -1.491 | -2.810 | 1.43E-13 | 3.11E-11 | Pcdhgb5 | 18 | 2.857 | 1.281 | 2.429 | 3.13E-11 | 2.53E-09 |
| Bbln | 2 | 70.642 | -1.338 | -2.529 | 1.20E-13 | 2.65E-11 | Scn3a | 2 | 4.356 | 1.228 | 2.343 | 3.06E-11 | 2.48E-09 |
| Rps18 | 17 | 488.375 | -1.436 | -2.705 | 1.19E-13 | $2.65 \mathrm{E}-11$ | Aebp1 | 11 | 9.651 | 1.268 | 2.409 | $2.34 \mathrm{E}-11$ | 1.92E-09 |
| Uqcrh | 4 | 646.578 | -1.430 | -2.695 | 1.08E-13 | 2.45E-11 | Ankrd63 | 2 | 11.012 | 1.294 | 2.452 | $2.06 \mathrm{E}-11$ | 1.76E-09 |
| Elof1 | 9 | 43.907 | -1.235 | -2.354 | 9.17E-14 | $2.14 \mathrm{E}-11$ | Nectin1 | 9 | 12.922 | 1.189 | 2.280 | 1.96E-11 | 1.69E-09 |
| Cep20 | 16 | 46.584 | -1.279 | -2.427 | $4.74 \mathrm{E}-14$ | 1.13E-11 | Raver1 | 9 | 7.821 | 1.349 | 2.548 | $1.89 \mathrm{E}-11$ | 1.65E-09 |


| Mien1 | 11 | 139.140 | -1.195 | -2.289 | 4.53E-14 | $1.11 \mathrm{E}-11$ | Lamc1 | 1 | 5.222 | 1.209 | 2.312 | $1.81 \mathrm{E}-11$ | 1.59E-09 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mrpl33 | 5 | 15.113 | -1.428 | -2.691 | 4.18E-14 | $1.04 \mathrm{E}-11$ | Cdh4 | 2 | 7.614 | 1.255 | 2.387 | 1.79E-11 | $1.57 \mathrm{E}-09$ |
| Cox7b | X | 298.286 | -1.385 | -2.612 | 3.50E-14 | 8.90E-12 | Th | 7 | 8.572 | 3.884 | 14.764 | $1.75 \mathrm{E}-11$ | 1.54E-09 |
| Rps21 | 2 | 901.784 | -1.534 | -2.895 | $2.90 \mathrm{E}-14$ | 7.92E-12 | Map1b | 13 | 70.502 | 1.411 | 2.660 | $1.73 \mathrm{E}-11$ | 1.54E-09 |
| Rps25 | 9 | 288.305 | -1.451 | -2.734 | $2.34 \mathrm{E}-14$ | 6.59E-12 | Syt6 | 3 | 6.522 | 2.039 | 4.109 | $1.71 \mathrm{E}-11$ | 1.53E-09 |
| Uqcr10 | 11 | 399.904 | -1.335 | -2.523 | 2.32E-14 | $6.59 \mathrm{E}-12$ | Wfs1 | 5 | 54.162 | 1.268 | 2.407 | 1.63E-11 | $1.47 \mathrm{E}-09$ |
| Rps27 | 3 | 554.984 | -1.515 | -2.857 | $1.54 \mathrm{E}-14$ | $4.77 \mathrm{E}-12$ | Cacna1c | 6 | 5.791 | 1.320 | 2.496 | $1.56 \mathrm{E}-11$ | 1.43E-09 |
| Vip | 10 | 37.569 | -1.281 | -2.429 | $1.56 \mathrm{E}-14$ | $4.77 \mathrm{E}-12$ | Slc29a4 | 5 | 8.308 | 1.176 | 2.259 | $1.46 \mathrm{E}-11$ | $1.35 \mathrm{E}-09$ |
| Pfdn5 | 15 | 228.147 | -1.487 | -2.803 | 1.29E-14 | $4.21 \mathrm{E}-12$ | Clic6 | 16 | 2.452 | 2.505 | 5.677 | 1.45E-11 | 1.34E-09 |
| Rpl9 | 5 | 304.025 | -1.553 | -2.935 | 9.22E-15 | 3.25E-12 | Pcdhga5 | 18 | 5.840 | 1.150 | 2.219 | $1.42 \mathrm{E}-11$ | 1.33E-09 |
| Ndufa7 | 17 | 294.099 | -1.359 | -2.565 | 6.87E-15 | $2.52 \mathrm{E}-12$ | Zswim6 | 13 | 5.284 | 1.208 | 2.311 | $1.31 \mathrm{E}-11$ | 1.24E-09 |
| Ift20 | 11 | 57.388 | -1.334 | -2.520 | 6.56E-15 | 2.45E-12 | Fat1 | 8 | 4.625 | 1.386 | 2.614 | 8.07E-12 | 8.10E-10 |
| Rpl12 | 2 | 382.798 | -1.534 | -2.895 | 5.33E-15 | 2.07E-12 | Frmd7 | X | 3.510 | 3.994 | 15.938 | 7.52E-12 | 7.65E-10 |
| Gm20878 | 4 | 9.870 | -1.981 | -3.949 | 4.79E-15 | $2.04 \mathrm{E}-12$ | Cacna2d2 | 9 | 8.884 | 1.139 | 2.202 | $7.00 \mathrm{E}-12$ | $7.29 \mathrm{E}-10$ |
| Cst6 | 19 | 2.805 | -1.570 | -2.970 | $4.43 \mathrm{E}-15$ | 1.93E-12 | Ntn1 | 11 | 2.991 | 1.308 | 2.476 | $5.98 \mathrm{E}-12$ | 6.33E-10 |
| Lsm7 | 10 | 37.524 | -1.291 | -2.447 | 4.19E-15 | 1.87E-12 | Lamc3 | 2 | 1.754 | 1.403 | 2.645 | $5.61 \mathrm{E}-12$ | $6.05 \mathrm{E}-10$ |
| Ccl21d | 4 | 7.138 | -3.266 | -9.618 | 3.29E-15 | $1.51 \mathrm{E}-12$ | Slit3 | 11 | 9.393 | 1.399 | 2.637 | $4.77 \mathrm{E}-12$ | 5.36E-10 |
| Rpl17 | 18 | 549.320 | -1.584 | -2.997 | $2.77 \mathrm{E}-15$ | 1.30E-12 | Otof | 5 | 4.388 | 1.430 | 2.694 | $4.10 \mathrm{E}-12$ | $4.71 \mathrm{E}-10$ |
| Al413582 | 17 | 56.494 | -1.400 | -2.639 | 1.49E-15 | 7.17E-13 | Col1a2 | 6 | 5.163 | 1.177 | 2.262 | 3.87E-12 | $4.58 \mathrm{E}-10$ |
| Rps14 | 18 | 414.518 | -1.605 | -3.043 | 7.52E-16 | 3.94E-13 | Sez6 | 11 | 64.844 | 1.267 | 2.407 | 3.60E-12 | $4.34 \mathrm{E}-10$ |
| Cops9 | 1 | 106.297 | -1.396 | -2.631 | $7.20 \mathrm{E}-16$ | 3.92E-13 | Shisa9 | 16 | 16.460 | 1.201 | 2.299 | 3.47E-12 | 4.23E-10 |
| Sec61g | 11 | 33.549 | -1.415 | -2.667 | $7.28 \mathrm{E}-16$ | 3.92E-13 | Gad2 | 2 | 42.753 | 1.415 | 2.667 | 3.42E-12 | $4.21 \mathrm{E}-10$ |
| Atp5e | 2 | 453.391 | -1.485 | -2.800 | 6.28E-16 | 3.60E-13 | Insyn2b | 11 | 1.165 | 2.632 | 6.198 | 3.06E-12 | 3.82E-10 |
| Cpne9 | 6 | 14.920 | -1.451 | -2.735 | 1.88E-16 | 1.23E-13 | Dchs1 | 7 | 2.185 | 1.274 | 2.419 | $2.54 \mathrm{E}-12$ | 3.30E-10 |
| Ndufb4 | 16 | 180.611 | -1.433 | -2.700 | $1.71 \mathrm{E}-16$ | $1.16 \mathrm{E}-13$ | Strip2 | 6 | 6.451 | 1.268 | 2.408 | 2.43E-12 | 3.18E-10 |
| Uqcc2 | 17 | 267.408 | -1.501 | -2.830 | 8.67E-17 | 6.62E-14 | Pgap1 | 1 | 3.317 | 1.388 | 2.618 | 2.12E-12 | $2.86 \mathrm{E}-10$ |
| Gng13 | 17 | 89.320 | -1.521 | -2.870 | 8.14E-17 | 6.48E-14 | Kcna5 | 6 | 3.759 | 1.802 | 3.488 | $2.00 \mathrm{E}-12$ | 2.79E-10 |
| Mrpl53 | 6 | 62.839 | -1.383 | -2.608 | 3.87E-17 | 3.38E-14 | Ndnf | 6 | 3.652 | 1.670 | 3.181 | 1.89E-12 | $2.67 \mathrm{E}-10$ |
| Tmem256 | 11 | 124.314 | -1.525 | -2.879 | 3.59E-17 | 3.38E-14 | Erich3 | 3 | 2.812 | 1.300 | 2.463 | $1.76 \mathrm{E}-12$ | $2.50 \mathrm{E}-10$ |
| Timm8b | 9 | 262.456 | -1.442 | -2.716 | 2.20E-17 | 2.28E-14 | Dhx9 | 1 | 22.554 | 1.174 | 2.256 | $1.61 \mathrm{E}-12$ | 2.32E-10 |
| Igfbp6 | 15 | 53.281 | -1.411 | -2.660 | 2.24E-17 | $2.28 \mathrm{E}-14$ | C4b | 17 | 7.788 | 1.307 | 2.475 | $1.41 \mathrm{E}-12$ | 2.06E-10 |
| Acyp1 | 12 | 19.279 | -1.507 | -2.842 | 1.05E-17 | 1.20E-14 | Bgn | X | 11.680 | 1.265 | 2.404 | $1.29 \mathrm{E}-12$ | 1.90E-10 |
| Tomm5 | 4 | 71.549 | -1.515 | -2.858 | 7.02E-18 | 8.57E-15 | Zic1 | 9 | 4.162 | 1.595 | 3.021 | $1.25 \mathrm{E}-12$ | $1.88 \mathrm{E}-10$ |
| Znhit3 | 11 | 40.763 | -1.554 | -2.937 | 2.27E-18 | 3.19E-15 | Tenm4 | 7 | 8.792 | 1.291 | 2.446 | 9.17E-13 | 1.45E-10 |
| Rspo1 | 4 | 6.578 | -2.173 | -4.509 | $1.78 \mathrm{E}-18$ | $2.72 \mathrm{E}-15$ | Grin3a | 4 | 9.822 | 1.299 | 2.460 | 7.53E-13 | $1.23 \mathrm{E}-10$ |
| Gm13306 | 4 | 12.675 | -2.616 | -6.129 | 6.50E-22 | 1.70E-18 | Cdhr1 | 14 | 20.545 | 3.488 | 11.219 | 5.26E-13 | 9.36E-11 |
| Pvalb | 15 | 74.155 | -1.995 | -3.987 | $9.23 \mathrm{E}-25$ | 5.52E-21 | Soga1 | 2 | 4.763 | 1.427 | 2.689 | $4.85 \mathrm{E}-13$ | 8.85E-11 |
| Myl4 | 11 | 16.799 | -1.928 | -3.807 | 2.23E-28 | 2.04E-24 | Dpysl5 | 5 | 7.088 | 1.239 | 2.360 | $4.79 \mathrm{E}-13$ | 8.85E-11 |
| Ccl27a | 4 | 70.635 | -1.850 | -3.604 | 5.75E-32 | 1.05E-27 | Epha6 | 16 | 8.139 | 1.452 | 2.736 | 3.72E-13 | 7.03E-11 |
|  |  |  |  |  |  |  | Crybg3 | 16 | 1.179 | 1.499 | 2.827 | $2.84 \mathrm{E}-13$ | 5.53E-11 |
|  |  |  |  |  |  |  | Nid1 | 13 | 2.403 | 1.519 | 2.866 | 1.49E-13 | $3.21 \mathrm{E}-11$ |
|  |  |  |  |  |  |  | Zfp804a | 2 | 5.302 | 1.294 | 2.453 | $9.41 \mathrm{E}-14$ | 2.16E-11 |
|  |  |  |  |  |  |  | Pcdhga9 | 18 | 5.344 | 1.422 | 2.679 | $9.22 \mathrm{E}-14$ | $2.14 \mathrm{E}-11$ |
|  |  |  |  |  |  |  | Gpr149 | 3 | 1.051 | 2.466 | 5.524 | 4.65E-14 | $1.12 \mathrm{E}-11$ |
|  |  |  |  |  |  |  | Myo16 | 8 | 10.397 | 1.933 | 3.818 | 3.80E-14 | 9.54E-12 |
|  |  |  |  |  |  |  | Kcnd3 | 3 | 12.461 | 1.416 | 2.669 | 3.48E-14 | 8.90E-12 |
|  |  |  |  |  |  |  | Pappa2 | 1 | 0.885 | 2.219 | 4.656 | 3.32E-14 | 8.80E-12 |
|  |  |  |  |  |  |  | Ms4a15 | 19 | 6.186 | 7.645 | 200.113 | 3.36E-14 | 8.80E-12 |
|  |  |  |  |  |  |  | Ntng1 | 3 | 7.106 | 1.371 | 2.587 | $3.00 \mathrm{E}-14$ | 8.07E-12 |
|  |  |  |  |  |  |  | Hen4 | 9 | 2.366 | 1.943 | 3.845 | $2.46 \mathrm{E}-14$ | 6.83E-12 |
|  |  |  |  |  |  |  | Dcc | 18 | 2.530 | 1.484 | 2.797 | $2.21 \mathrm{E}-14$ | $6.42 \mathrm{E}-12$ |
|  |  |  |  |  |  |  | Tenm1 | X | 4.118 | 1.343 | 2.537 | 1.86E-14 | $5.51 \mathrm{E}-12$ |
|  |  |  |  |  |  |  | Slc13a4 | 6 | 7.873 | 1.319 | 2.496 | $1.82 \mathrm{E}-14$ | 5.45E-12 |
|  |  |  |  |  |  |  | Akap9 | 5 | 4.898 | 1.404 | 2.647 | $1.56 \mathrm{E}-14$ | $4.77 \mathrm{E}-12$ |
|  |  |  |  |  |  |  | Fn1 | 1 | 11.058 | 1.373 | 2.589 | $1.31 \mathrm{E}-14$ | $4.22 \mathrm{E}-12$ |
|  |  |  |  |  |  |  | Tenm3 | 8 | 10.203 | 1.490 | 2.808 | $1.20 \mathrm{E}-14$ | 3.99E-12 |
|  |  |  |  |  |  |  | Myh11 | 16 | 2.926 | 1.585 | 2.999 | $1.11 \mathrm{E}-14$ | 3.75E-12 |
|  |  |  |  |  |  |  | Tiam1 | 16 | 17.904 | 1.360 | 2.568 | 9.69E-15 | 3.35E-12 |
|  |  |  |  |  |  |  | Mdga1 | 17 | 7.328 | 1.633 | 3.101 | 8.06E-15 | 2.89E-12 |
|  |  |  |  |  |  |  | Ndst4 | 3 | 3.882 | 1.432 | 2.699 | 5.37E-15 | 2.07E-12 |
|  |  |  |  |  |  |  | Lgr5 | 10 | 2.097 | 3.629 | 12.372 | $5.34 \mathrm{E}-15$ | 2.07E-12 |
|  |  |  |  |  |  |  | Col1a1 | 11 | 2.961 | 1.429 | 2.693 | $5.41 \mathrm{E}-15$ | $2.07 \mathrm{E}-12$ |
|  |  |  |  |  |  |  | Polr2a | 11 | 15.921 | 1.361 | 2.568 | $4.94 \mathrm{E}-15$ | 2.06E-12 |
|  |  |  |  |  |  |  | Igsf3 | 3 | 3.939 | 1.555 | 2.937 | $1.21 \mathrm{E}-15$ | 5.97E-13 |
|  |  |  |  |  |  |  | Cspg4 | 9 | 3.433 | 1.324 | 2.503 | 8.14E-16 | 4.14E-13 |
|  |  |  |  |  |  |  | Scn5a | 9 | 1.666 | 2.201 | 4.597 | 6.13E-16 | 3.60E-13 |
|  |  |  |  |  |  |  | Grm1 | 10 | 8.766 | 1.460 | 2.751 | 3.09E-16 | $1.88 \mathrm{E}-13$ |
|  |  |  |  |  |  |  | Robo1 | 16 | 7.520 | 1.383 | 2.608 | 2.28E-16 | $1.44 \mathrm{E}-13$ |
|  |  |  |  |  |  |  | Ngfr | 11 | 2.361 | 2.550 | 5.857 | $1.54 \mathrm{E}-16$ | 1.09E-13 |
|  |  |  |  |  |  |  | Ptpro | 6 | 19.547 | 2.258 | 4.784 | 9.89E-17 | 7.24E-14 |
|  |  |  |  |  |  |  | Ptpn14 | 1 | 2.768 | 1.535 | 2.899 | $5.61 \mathrm{E}-17$ | $4.67 \mathrm{E}-14$ |
|  |  |  |  |  |  |  | Dlk1 | 12 | 3.946 | 1.864 | 3.641 | 3.73E-17 | 3.38E-14 |
|  |  |  |  |  |  |  | Eomes | 9 | 3.592 | 7.127 | 139.807 | 3.78E-18 | 4.94E-15 |
|  |  |  |  |  |  |  | Filip1 | 9 | 6.238 | 1.633 | 3.102 | $3.00 \mathrm{E}-19$ | 4.99E-16 |


|  |  |  |  |  |  |  | Vwf |  | 6 | 3.821 | 1.816 | 3.520 | 2.24E-19 | 4.10E-16 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  | Nos1 |  | 5 | 11.660 | 1.634 | 3.104 | 2.09E-20 | 4.24E-17 |
|  |  |  |  |  |  |  | Nrp2 |  | 1 | 7.671 | 1.622 | 3.078 | 1.41E-20 | 3.23E-17 |
|  |  |  |  |  |  |  | Reln |  | 5 | 10.356 | 1.876 | 3.670 | 6.63E-23 | 2.02E-19 |
|  |  |  |  |  |  |  | Gm28635 |  | 2 | 0.991 | 5.864 | 58.258 | 1.51E-24 | 5.52E-21 |
|  |  |  |  |  |  |  | Sv2c |  | 13 | 6.719 | 2.018 | 4.051 | 1.44E-24 | 5.52E-21 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

