Translational mechanisms of stem cell fate regulation in epidermal oncogene tolerance

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Abstract

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Morphologically and functionally normal human skin carries a surprisingly high burden of oncogenic lesions, suggesting that the skin has exceptional capacity to tolerate oncogene hyperactivity. To date, we have made significant progress in understanding how homeostatic adult epidermis suppresses the expansion of individual clones derived from somatic mutations. However, the mechanisms behind oncogene tolerance during epidermal development, a time of significant physiological tissue expansion, has not been explored. This is exemplified in RASopathies, where patients rarely develop epidermal defects or cancers despite germline mutations in the RAS/MAPK signaling pathway. Here, we find that oncogenic RAS-induced progenitor cell hyperproliferation is coordinated with differentiation to restrain aberrant growth and preserve epidermal development. We uncover a novel translation mechanism mediated by initiation factor eIF2B5 that co-regulates RAS proliferation and differentiation, resulting in hyperplastic but controlled growth. Using *in vivo* ribosome profiling, we reveal that eIF2B5

selectively regulates the translation of a substantial subset of the oncogenic RAS translatome. Furthermore, by coupling ribosome profiling with genetic screening, we provide direct functional evidence that RAS-induced differentiation is driven by eIF2B5-mediated translation of ubiquitination genes. We reveal ubiquitin ligase FBXO32 as a promoter of epidermal differentiation with no effect on proliferation, thus restraining RAS-driven pathological growth and tumorigenesis. Our study challenges the accepted view that oncogenic translation is inherently tumor promoting and unveils how it directly steers cell fate to mediate epidermal oncogene tolerance.

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Chapter 1 -- Introduction

1.1 Stem cell dynamics in epidermal growth

The skin is the primary mechanical barrier that protects animals from UV radiation, dehydration, injury, and infection. It is composed of an epithelial layer, the epidermis, and an underlying dermis, separated by a basement membrane. In addition, the epidermis contains various appendages to support skin function, such as hair follicles, sebaceous glands, and sweat glands. Throughout the life of the animal, hair follicles and interfollicular epidermis (IFE) undergo continual turnover through cycles of regeneration and repair (Fuchs and Raghavan, 2002). However, distinct stem cell systems function to replenish these epidermal compartments (Blanpain and Fuchs, 2006).

Like other commonly studied hierarchical stem cell models, such as the intestinal epithelium and hematopoietic system (Barker et al., 2008; Morrison and Spradling, 2008), hair follicles are regenerated from a small population of slow-cycling stem cells (Fig. 1.1A). During follicle growth, stem cells in the bulge generate the outer root sheath as well as the highly proliferative progenitor cells of the matrix (Fuchs, 2007). Subsequently, matrix progenitors terminally differentiate into other layers of the hair follicle and hair shaft. In contrast to this hierarchical organization, the existence of a true slow-cycling stem cell population within the IFE is controversial (Dekoninck and Blanpain, 2019). Early proliferation kinetic experiments suggested the existence of columnar epidermal proliferative units that were supported by a single stem cell and its daughter progenitors (Potten, 1974). However, recent lineage tracing studies have demonstrated that the IFE is entirely maintained by a single population of equipotent progenitors that undergo stochastic cell fate choices following cell division (Clayton

et al., 2007; Doupé et al., 2010; Lim et al., 2013; Rompolas et al., 2016). The progenitor population of the IFE comprises a single layer of basal cells in contact with the basement membrane (Fig. 1.1B) (Fuchs, 2007). These highly proliferative progenitors can self-renew or give rise to terminally differentiated suprabasal cells that move outward towards the skin's surface (Fuchs, 2007). Differentiated keratinocytes eventually cornify to form the skin's protective barrier before sloughing into the external environment. By continually replacing lost cells through the proliferation and outward differentiation of basal progenitors, the IFE is able to self-perpetuate throughout life. Overall epidermal architecture is well conserved across different mammalian species and body sites (Rittié, 2016)

The mammalian IFE is the paradigm for exploring stratified epithelial development and maintenance. Its clearly defined progenitor pool and stratification make the IFE an ideal model to probe stem cell regulation during tissue growth (Beronja et al., 2013; 2010; Williams et al., 2011). Epidermal growth potential is critically dependent on progenitor cell fate choice and proliferation rate, two behaviors that directly control the progenitor pool size of the tissue (Hanahan and Weinberg, 2011; Tomasetti and Levy, 2010). A basal progenitor may divide through: 1) symmetric renewal, where both daughter cells remain progenitor cells; 2) asymmetric division, where one daughter cell differentiates and the other renews; or 3) symmetric differentiation, where both daughter cells differentiate (Tomasetti and Levy, 2010). A high rate of renewing divisions increases the tissue's mitotic pool size, thereby accelerating tissue growth. The frequency of progenitor cell divisions (i.e. proliferation rate) further modulates the rate of progenitor pool expansion and tissue growth.

Extensive work has been dedicated to understanding the stem cell dynamics governing IFE development and tissue homeostasis. During embryogenesis, the mouse surface ectoderm undergoes substantial growth to match embryo expansion (Beronja et al., 2013). Beginning as a monolayer in the early embryo, the epidermis progressively stratifies through differentiation to establish a functional barrier by birth (Blanpain and Fuchs, 2006). This rapid developmental growth is achieved through frequent progenitor cell proliferation accompanied by a high rate of self-renewal (Ying et al., 2018). In contrast, as the epidermis matures to adulthood, tissue homeostasis is established through balanced progenitor cell renewal and differentiation that precisely compensates for cell loss via shedding (Blanpain and Fuchs, 2009). This is predominantly achieved by asymmetric cell divisions and a low proliferation rate, resulting in a static progenitor pool size (Rompolas et al., 2016; Ying et al., 2018). Furthermore, progenitors can sense the differentiation of their immediate neighbors and initiate proliferation and self-renewal in response, allowing the tissue to preserve homeostasis (Mesa et al., 2018). Therefore, precise coordination between these two axes of stem cell behaviors is necessary to maintain physiological tissue size (Blanpain and Fuchs, 2009).

Unbalanced shifts between proliferation and fate choice can lead to excess tissue expansion (Pardal et al., 2005). In the presence of external insults, such as wounding, dynamic shifts in stem cell behavior are necessary to replace lost cells. Significant plasticity exists between epidermal compartments during wound repair, allowing both IFE basal cells and hair follicle stem cells to contribute to re-epithelization (Dekoninck and Blanpain, 2019). Upon tissue damage, epidermal progenitors and suprabasal cells at the wound border initiate self-renewing hyperproliferation and migrate into the wound center to replace lost tissue (Park et al., 2017).

This is coordinated with subsequent differentiation to regenerate epidermal tissue architecture. As the wound resolves, the tissue reverts to normal homeostasis, and balanced stem cell behaviors are re-established.

1.2 Epidermal tolerance to oncogene activation

While non-homeostatic progenitor cell behaviors operate during embryonic development and wound repair to meet physiological tissue needs, oncogene activation may induce a pathological loss of progenitor cell coordination, leading to uncontrolled tissue growth and tumorigenesis (Pardal et al., 2005). In many tissues, oncogene activation induces hyperproliferation and drives excess growth (Hanahan and Weinberg, 2011; Pardal et al., 2005). However, sequencing of aged, sun-exposed skin has revealed that physiologically normal human skin carries a surprisingly high burden of mutations in known cancer-driving genes (Martincorena et al., 2015). This suggests that the skin possesses remarkable ability to tolerate genetic abnormalities. The adaptive mechanisms that restrain oncogenic overgrowth to protect against progression to cancer are not well understood.

Tissues can employ several cell-autonomous strategies to block the proliferation of oncogenic clones. Initially described in cell culture following oncogenic activation of *Hras* (Serrano et al., 1997), senescence has now been established as a potent tumor-suppressive mechanism under certain physiological scenarios (Muñoz-Espín and Serrano, 2014). Activation of $Braf^{V600E}$ in nevi (Michaloglou et al., 2005), *Nras* in lymphocytes (Braig et al., 2005), or loss of tumor suppressor *Pten* in the prostate epithelium (Chen et al., 2005) can all induce senescence *in vivo.* Similarly, apoptosis can also suppress oncogenic clonal expansion, such as during

overexpression of MYC or E1A (Lowe et al., 2004). While senescence and apoptosis can efficiently restrict growth, both strategies result in an abrupt block to proliferation, which can result in significant tissue damage in rapid turnover tissues like the epidermis. However, this is incompatible with the finding that the epidermis maintains functional and structural integrity despite substantial oncogenic burden (Martincorena et al., 2015). Accordingly, we have not observed senescence or apoptosis to be significant factors in regulating epidermal growth potential (Ying et al., 2018).

Neighboring wildtype (WT) cells can also facilitate oncogene tolerance through interactions that displace mutant clones from the tissue (Brown et al., 2017; Ying et al., 2018). An illustrative case is our recent observation through intravital imaging that hair follicles of the adult epidermis can entirely resolve abnormal growth following oncogenic activation of *Hras1* or β-catenin (Brown et al., 2017). This phenomenon is dependent on the encapsulation of mutant cells by surrounding WT cells. We have further observed that oncogenic *Pik3ca* clones are completely blocked from expansion and eventually expelled from the adult IFE (Ying et al., 2018). This process is mediated by oncogene-induced loss of pro-renewal JNK signaling, resulting in rapid differentiation of mutant clones relative to surrounding WT cells. In these studies, we have begun to uncover the growth-restrictive potential of homeostatic adult epidermis in response to somatic mutations. While this model is highly relevant to adult aging, it does not explain tissue behavior upon widespread oncogene activation during embryonic development, such as in the case of congenital RASopathies (Rauen, 2013).

RASopathies are the most common family of congenital disorders and arise from germline or mosaic mutations in the RAS/MAPK signaling pathway (Rauen, 2013). Patients have a

predisposition to cancer as well as characteristic craniofacial, neurological, and musculoskeletal malformations (Hafner and Groesser, 2014; Rauen, 2013). Despite significant morphological defects across other organ systems, skin phenotypes are relatively mild, often not presenting until adolescence or adulthood, and generally involve hair follicles or melanocytes rather than the IFE (Digilio et al., 2011; Hernández-Martín and Torrelo, 2011; Pierpont et al., 2014). Furthermore, despite the frequency of RAS mutations in cutaneous squamous cell carcinomas (Prior et al., 2012), RASopathy patients rarely develop epidermal tumors (Kratz et al., 2011). An exception is Costello syndrome, caused by activating mutations in *Hras1*, where patients develop facial papillomas that are restricted in size and do not progress to malignancy (Gripp and Lin, 2012; Kratz et al., 2011), indicative of hyperplastic but restrained growth. The absence of immediate epidermal defects suggests that protective mechanisms operate during the embryonic period to tolerate broad oncogene hyperactivity and limit excess growth. However, the precise molecular mechanisms behind this growth-restrictive phenomenon are not understood.

Known strategies of epidermal oncogene tolerance cannot be utilized when a large proportion of the tissue carries the same oncogenic lesion. Broad oncogene activation abolishes the growth-suppressive potential of WT neighbors, and complete elimination of mutant cells from the tissue would significantly disrupt tissue architecture. Furthermore, widespread proliferation block is incompatible with epidermal development, which requires continual proliferation to support substantial tissue expansion (Fuchs and Raghavan, 2002; van der Flier and Clevers, 2009). In contrast, despite broad oncogene hyperactivity, RASopathy patients have intact epidermis at birth (Digilio et al., 2011; Hafner and Groesser, 2014; Rauen, 2013), suggesting

that epidermal growth during development is non-pathological. A fundamental question is how the oncogene-activated epidermis maintains the rapid physiological growth necessary for normal development while restraining pathological overgrowth.

1.3 Regulation of epidermal progenitor cell behavior

Numerous molecular mechanisms regulate epidermal progenitor cell behavior and may play a role in governing tissue response to oncogene activation. Amongst these, several transcription factors have been implicated in activating proliferation and terminal differentiation programs. p63 is a master regulator of epidermal morphogenesis and controls the transcription of a wide range of genes involved in cell cycle, cell adhesion, and differentiation (Soares and Zhou, 2018). As a result, p63 is necessary for stratification of the embryonic epidermis and maintenance of epidermal progenitors. p63 activity is also upregulated in basal progenitors and suprabasal cells during wound repair, in contrast to low levels of p63 expression in unperturbed epidermis, ensuring continued proliferation and differentiation during wound repair (Senoo, 2013). AP-2 transcription factors have also been implicated in epidermal stratification, and deletion of AP-2 transcription factors leads to suppression of terminal differentiation *in vivo* (Wang et al., 2008). Transcription programs downstream of the Wnt/β-catenin and Notch signaling pathways also play complex roles in regulating proliferation and fate choice. Loss of Wnt-regulated LEF/TCF or Notch-regulated RBP-J transcription factors results in epidermal thinning and differentiation defects in the developing epidermis (Blanpain and Fuchs, 2006; Nguyen et al., 2009). Conversely, basal progenitors have been shown to robustly express Wnt target gene *Axin2* and self-renew in response to Wnt signaling during wound repair (Lim et al., 2013).

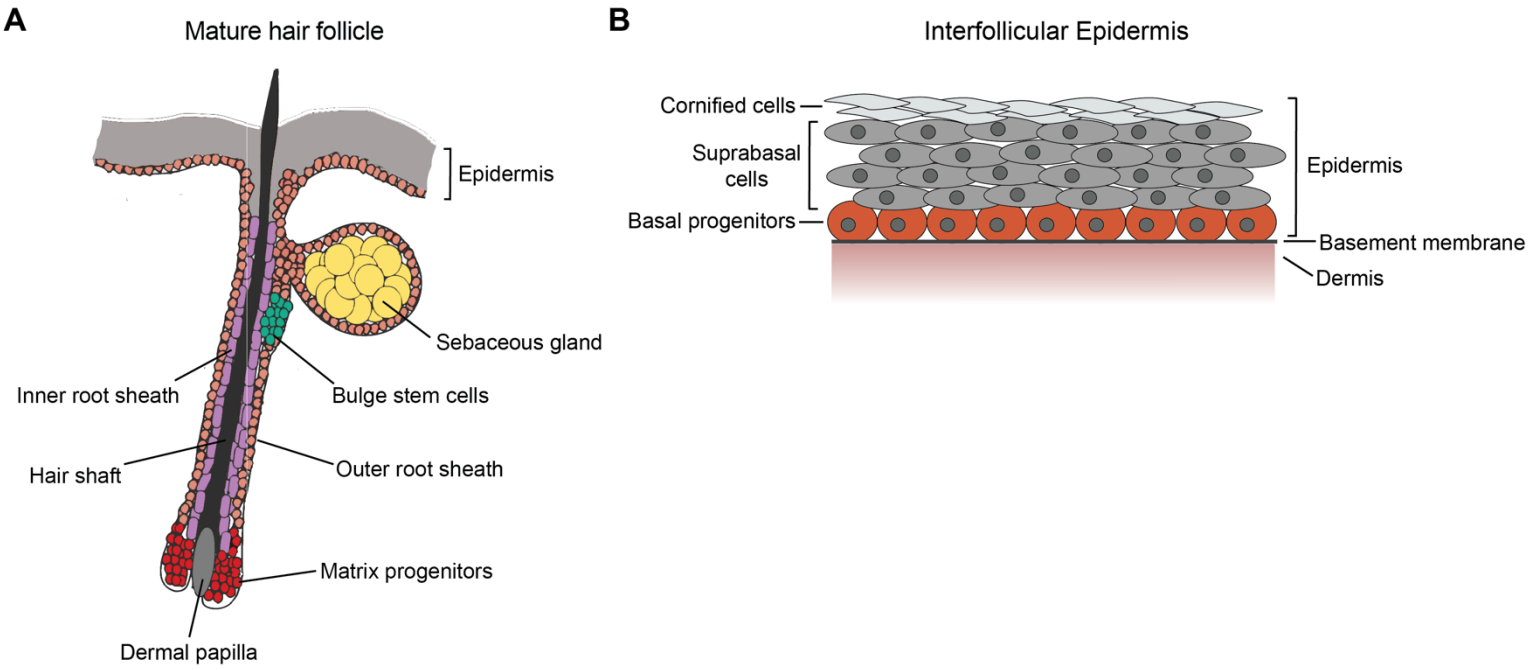
In conjunction with transcriptional regulation, epigenetic factors are also critical for epidermal progenitor cell maintenance and proliferation. Chromatin remodeling and gene repression by Polycomb group proteins is necessary for maintenance of basal cell proliferation potential, and loss of PcG member EZH2 results in premature and accelerated epidermal differentiation (Ezhkova et al., 2009). Likewise, simultaneous depletion of histone deacetylases HDAC1 and HDAC2, which induces loss of chromatin compaction, results in failure of embryonic epidermal stratification and age-dependent loss of progenitor cell proliferation potential (LeBoeuf et al., 2010). Thus, the epigenetic chromatin repression machinery operates to maintain a self-renewing state in epidermal progenitors.

While stemness has commonly been considered an epigenetically and transcriptionally regulated process, this view is not fully compatible with the dynamic nature of epidermal progenitor cells. *In vivo* lineage tracing has revealed that epidermal cell fate is not determined at the time of cell division, but instead occurs afterwards through stochastic delamination (Rompolas et al., 2016). This process is rapidly adaptable to tissue stresses, such as oncogene activation or wounding (Brown et al., 2017; Mesa et al., 2017; Park et al., 2017), suggesting that the mechanisms governing cell fate choice are also highly responsive. Protein synthesis control provides a highly dynamic mode of gene regulation (Buszczak et al., 2014). As the most energetically demanding step in gene expression, protein synthesis is tightly regulated and rapidly adaptable to cellular and environmental changes. Intriguingly, translational regulation has recently been implicated in both stem cell fate choice and proliferation (Buszczak et al., 2014), suggesting it may play a central role in epidermal tissue response to oncogene activation.

Differences in translation rate have been correlated with the establishment and maintenance of distinct cell fates (Signer et al., 2014; Zismanov et al., 2016). In the epidermis, low levels of protein synthesis are linked to increased progenitor cell renewal and induce tissue expansion (Blanco et al., 2016; Sendoel et al., 2017). In contrast, elevated translation rate can cause excessive accumulation of differentiated cells, disrupting tissue morphology and barrier function (Liakath-Ali et al., 2018). However, the specific translatome changes driving stem cell fate choice have not been functionally established. As an essential cellular process, translation is also necessary for stem cell survival and proliferation (Liu et al., 2006; Morita et al., 2015), and elevated translation rate is characteristic of rapidly proliferating oncogenic tissues (Barna et al., 2008; Gandin et al., 2008; Hsieh et al., 2015). Furthermore, major oncogenes, such as RAS, mTOR, and c-Myc, directly reprogram translation by altering the activity of eukaryotic initiation factors and ribosomal proteins (Hsieh et al., 2012; Truitt et al., 2015; Aspesi and Ellis, 2019). Oncogene-induced translation reprogramming can manifest as a change in both global translation rate as well as selective translation of specific mRNA networks that support cancer-driving behaviors (Truitt and Ruggero, 2016). Translation's putative ability to simultaneously regulate stem cell fate choice and proliferation suggests that it may act as a self-correcting mechanism to coordinate stem cell behaviors. Moreover, the interactive relationship between oncogenes and the translation machinery suggests that translational control could be a key mediator of epidermal tolerance to oncogene activation.

Here, we use an *Hras*^{G12V} model of Costello syndrome (Chen et al., 2009) to explore the cellular and molecular mechanisms behind oncogene tolerance during epidermal development. The mouse epidermis is a well-characterized model of rapidly growing tissue during early

oncogenesis (Beronja et al., 2010; 2013; Williams et al., 2011) and is an ideal system to examine the interplay between oncogenes and translation in stem cell fate regulation. We report that oncogene activation induces translationally-regulated differentiation to contain epidermal overgrowth. In Chapter 3, we describe the morphological and cellular changes produced by epidermal *Hras*^{G12V} activation. We find that *Hras*^{G12V}-induced progenitor cell hyperproliferation is counteracted by compensatory differentiation, resulting in hyperplastic but contained growth that permits functional epidermal development during embryogenesis. In Chapter 4, we uncover translation initiation factor eIF2B5 as a central regulator of *Hras*^{G12V} growth and coordinator of differentiation in response to oncogene-induced hyperproliferation. We further find that eIF2B5 specifically regulates the translation of a substantial proportion of the *Hras*^{G12V}-induced translation landscape. In Chapter 5, we reveal that eIF2B5 coordinates *Hras*^{G12V} progenitor cell behaviors through the selective translation of distinct proliferation and differentiation regulators. This allows the epidermis to adaptively modulate cell fate while maintaining the rapid proliferation needed for normal skin function. Notably, while previous studies have indirectly linked translation rate with cell fate choice (Blanco et al., 2016; Liakath-Ali et al., 2018; Signer et al., 2014), our analyses provide direct functional evidence that oncogene-induced differentiation operates through eIF2B5-mediated translation of ubiquitination genes, resulting in a striking restriction of RAS tumorigenesis. Our study therefore uncovers a novel translational mechanism by which the developing epidermis manages oncogenic stress to contain aberrant tissue growth.



1.1 Epidermal stem cell models

A) Schematic of a mature hair follicle demonstrates hierarchical organization of stem cells. Slow-cycling stem cells reside in the bulge and generate transient amplifying progenitors of the hair matrix. (Adapted from Fuchs and Horsley, 2008).

B) Schematic of the interfollicular epidermis, which is entirely maintained through proliferation and differentiation of its basal progenitor population.

Chapter 2 – Materials and Methods

Animals

Hras$^{G12V/G12V\ fl/fl}$ (Chen et al., 2009), *Rosa26*$^{YFP\ fl/fl}$, and *Rosa26*$^{mT/mG\ fl/fl}$ Cre-reporter mice (Jackson Laboratories) were on C56BL/6 or C56BL/6-Tyr$^{c\text{-}2J}$/J background. We used equal numbers of male and female animals throughout the study. *In utero* injections were performed at E9.5 with maternal mice aged 2-8 months. *In* utero injections were performed under isoflurane anesthesia. Postoperatively, maternal mice were monitored daily for 5 days. Tumorigenesis studies were performed with embryonically transduced mice and were monitored every 2-3 days until 16 weeks of age. Mice were housed and cared for in an AAALAC-accredited facility at the Fred Hutchinson Cancer Research Center, and all animal experiments were conducted in accordance with ethical regulations of the Fred Hutchinson Cancer Research Center and IACUC-approved protocols (project license number 50814).

Primary keratinocyte cell culture

Basal cells were isolated (Nowak and Fuchs, 2009) from E18.5 skin following 2mg/ml dispase (Corning 354235) digestion at 37 C° for 1 hour to isolate the epidermis, 0.25% trypsin digestion for 10 minutes to generate single cells, and FACS sorting following CD49f/α6-Integrin-PerCP (GoH3, 1:50; BioLegend) staining using BD FACSAria II (BD Biosciences). Isolated basal cells were co-cultured on mitomycin C-treated NIH/3T3 feeder cells in 0.05 mM Ca^{2+} E-media supplemented with 15% fetal bovine serum for 5 passages to generate primary keratinocyte cell culture lines.

Lentiviral constructs

RNA interference-mediated gene depletion was achieved using pLKO.1 shRNA vectors from the mouse TRC1.0 shRNA library (Sigma-Aldrich). Additional shRNA sequences targeting genes of interest (Table 2-1) were obtained from The RNAi Consortium Library and cloned into the pLKO.1 vector (Addgene plasmid 52628) using AgeI and EcoRI digestion sites. Genome-wide ORF-mediated overexpression was achieved using the human ORFeome CCSB-Broad Lentiviral Expression Library (Dharmacon). To construct the lentiviral pools and ensure equal lentivirus representation, plasmids were mixed together in equal molar ratios. Cre-shRNA expression was achieved using pLKO-Cre vectors as previously described (Beronja et al., 2010; 2013). Mouse *Fbxo32* ORF was obtained from transOMIC (BC027211). Expression of Cre-recombinase with EF1α promoter-driven ORF overexpression was achieved through Gibson cloning into a pLX Cre EF1α vector modified from pLX302 (Addgene) as previously described (Ying et al., 2018). Co-expression of shRNA in tandem with ORF overexpression in the pLX Cre EF1α vector was achieved by inserting hU6 promoter-driven shRNA downstream of the Rev-responsive element (RRE) using AleI and AscI digestion sites.

Lentivirus production

Large-scale production and concentration of lentivirus were performed as previously described (Beronja et al., 2010). 293TN cells (System Biosciences) were transfected with pLKO.1 and helper plasmids pMD2.G and psPAX2 (Addgene plasmid 12259 and 12260) by calcium phosphate transfection. Viral supernatant was collected 64 h after transfection and filtered through a Stericup-HV PVDF 0.45µm filter. Filtered supernatant was concentrated ~2,000-fold, first by

passage through a Centricon Plus-70 100KD centrifugal filter (Millipore), and then by ultracentrifugation in a MLS-50 rotor (Beckman Coulter).

Lentiviral transduction of embryos

Ultrasound-guided in utero lentiviral transduction was performed as previously described (Beronja and Fuchs, 2012; Beronja et al., 2010; 2013). Females at E9.5 of gestation were anesthetized with isofluorane (Hospira) and 30uL buprenorphine hydrochloride (Buprenex, Reckitt Benckiser Healthcare). The abdominal cavity was exposed by incisions in the abdominal skin and peritoneum, and uterine horns were exteriorized and submerged in Petri dish containing phosphate-buffered saline (PBS). A high-frequency ultrasound system with RMV707B scanhead (Vevo 700 High-resolution Imaging System, VisualSonics) was used to visualize embryos. A microinjection needle pulled from a thick-walled glass capillary (Drummond Scientific) was used with a microinjector (Nanoject II nanoliter injector, Drummond Scientific) to inject 1uL of lentivirus into the amniotic cavity of each embryo. Up to 12 embryos were injected per litter. The peritoneal incision was closed using absorbable sutures, and the abdominal skin incision was closed with staples. Surgical procedures were limited 30 minutes for high survival rates. Females were monitored for 5 days post-surgery.

Lentiviral transduction of primary keratinocytes

Primary keratocytes were plated in 6-well dishes at 150,000 cells/well and incubated with lentivirus in the presence 0.05 mM Ca^{2+} E-media supplemented with 25% chelated FBS and 100 μg/mL polybrene for 30min. Keratinocytes were then centrifuged at 1100g for 30min at 37C

before transduction media was replaced with culture media (0.05 mM Ca^{2+} E-media supplemented with 15% chelated FBS). Subsequent analyses were performed after 2 days in culture media.

Immunofluorescence

Mouse skin and tumor tissues were paraformaldehyde-fixed, OCT embedded, and cut into 8μm-thick sections. Sections were incubated in 0.1% PBST containing 2% goat serum, 2% donkey serium, 1% gelatin, and 1% BSA for 1hr at room temperature. If necessary, sections were incubated with M.O.M. mouse blocking reagent (Vector) for 1 hr at room temperature. Section were then incubated with primary antibodies overnight at 4°C, followed by incubation with Alexa-Fluor conjugated secondary antibodies (Invitrogen) for 1hr at room temperature. Slides were mounted using ProLong Gold Antifade Mountant (Thermo Fisher). For EdU-BrdU proliferation and pulse-chase differentiation assays, tissue sections were first processed for EdU Click-iT according to manufacturer's instructions (Thermo Fisher). Next, tissues were fully processed for K10 and GFP immunofluorescence detection. Lastly, tissue sections were incubated in 2N HCl at 37°C for 30 minutes to denature DNA, quenched with 0.1M sodium borate pH 8.5 twice, and processed for BrdU immunofluorescence detection. Confocal images were taken on a Zeiss LSM700 system, using Plan-Apochromat 20x/0.8 dry objective. Images were processed using Zeiss Zen and ImageJ software. The following primary antibodies were used: chicken anti-GFP (ab13970, 1:1000; Abcam); mouse anti-BrdU (MoBU-1, 1:100; Invitrogen); rabbit anti-Keratin 10 (Poly19054, 1:1000; BioLegend); mouse anti-Puromycin (12D10, 1:500; Millipore); guinea pig anti-Keratin 5 (BP5006, 1:1000; Origene).

EdU-BrdU proliferation assay

Basal cell proliferation rate was quantified based on nucleoside incorporation as previously described (Ying et al., 2018). We administered EdU intraperitoneally, followed by BrdU injection 2hr later, before assessing nucleoside incorporation by immunofluorescence 6 hours post-BrdU injection. Cells that complete S-phase during the first 2 hours incorporate EdU only, while cells subsequently going through S-phase incorporate both EdU and BrdU. Therefore, cells that divide within the initial 2 hours have EdU^+ $BrdU^-$ labelled progeny. One cell division gives rise to two nucleoside-labeled daughter cells, so the number of dividing cells in the initial 2 hours is (total EdU+BrdU- cells)/2. In the epidermis, only basal cells have the potential to divide. Therefore, the proliferation rate of basal cells that divided in the initial 2 hours is ((total EdU+BrdU- cells)/2)/(total basal cell number).

EdU-BrdU pulse-chase differentiation assay

Basal cell differentiation was quantified based on nucleoside incorporation and differentiation marker expression as previously described (Ying et al., 2018). Since we can uniquely label a population of cells (EdU^+ $BrdU^-$) that have undergone division within the initial 2 hours as described above, we can also assess the differentiation state of their daughter cells based on expression of differentiation marker keratin 10 (K10). We injected animals intraperitoneally with EdU, followed by BrdU injection 2 hours later before assessing nucleoside incorporation and K10 expression by immunofluorescence 6 hours post-BrdU injection. We can calculate the rate of progenitor cell renewal during the first 2 hours using the following equation: Renewal rate= (number of EdU^+ $BrdU^-$ $K10^-$ cells) / (total number of EdU^+ $BrdU^-$ cells).

Puromycin incorporation assay

Translation rate assay was adapted from previous protocol (Goodman and Hornberger, 2013). Animals were transduced at E9.5 by *in utero* injection of lentivirus. At E18.5, maternal mice were injected intraperitoneally with 50mg/kg body mass puromycin (Fisher Scientific) and euthanized after 30 min to collect E18.5 embryos. Headskin was fixed in 4% paraformaldehyde and paraffin-embedded. Sections were de-waxed and stained using the immunofluorescence procedure described below with the following modifications: antigen retrieval was performed using citrate-based antigen unmasking solution (Vector) at 95°C for 30 min. Sections were subjected to incubation with puromycin antibody (12D10, Millipore) followed by incubation with secondary antibody conjugated to Alexa-Fluor 594 (Invitrogen). Puromycin intensity in transduced epidermal basal cells was quantified by (Alexa-Fluor 594 total fluorescence intensity)/(surface area) in K5+GFP+ regions of tissue cross-sections using Imaris software (Bitplane). To normalize for potential differences in puromycin administration or incorporation between animals, we employed the following internal controls: 1) In clonally transduced tissues, puromycin intensity in K5+GFP+ transduced basal cells was normalized to puromycin intensity in neighboring K5+ GFP- untransduced WT basal cells in each tissue section; and 2) In fully transduced tissues, puromycin intensity in K5+ epidermal basal cells was normalized to puromycin intensity in the immediate underlying dermis in each tissue section.

***In vivo* functional screens**

To quantify construct abundance in the proliferation and renewal screens, tissue was processed as previously described (Ying et al., 2018). Briefly, head skin of mice at E18.5 was digested in

2mg/ml dispase (Corning 354235) at 37 C° for 1 hour to separate epidermis from dermis. Epidermal tissue was further digested with 0.25% trypsin for 20 minutes into single cells. Head skins from 8 animals were pooled together to make one biological replicate, thus achieving a ~40-fold coverage. For the proliferation screen, single epidermal cells were subjected to Click-iT EdU detection (Invitrogen, C10338) followed by CD49f/α6-Integrin-PerCP (GoH3, 1:50; Biolegend) staining. Cell populations of interest were isolated using BD FACSAria II machine (BD Biosciences). For the renewal screen, single epidermal progenitor cells were stained with CD326/EpCAM-APC (G8.8, 1:50; BD Biosciences) and CD49f/α6-Integrin-PerCP (GoH3, 1:50; Biolegend). gDNA from all samples was extracted using QIAamp DNA tissue mini kit (Qiagen). shRNA pre-amplification, sequencing (HiSeq 2500, Illumina), and data analysis were performed as previously described (Beronja et al., 2013). Briefly, raw Illumina reads were trimmed to 21nt hairpin sequences using the FASTX-Toolkit and aligned to a custom reference genome of all screened shRNA sequences with BWA (Li and Durbin, 2009). Mapped sequences were indexed with Samtools (Li et al., 2009) to generate read counts per shRNA. Differential enrichment or depletion of shRNAs in each condition was identified using DeSeq2 (Love et al., 2014). For each screened shRNA, a statistical cutoff of FDR<0.05 was used (minimum read count of 5). Genes identified as putative proliferation or renewal regulators must have at least 2 shRNAs significantly enriched/depleted with the same directionality across all significantly altered shRNAs.

Western blot analysis

Cells were lysed for 30 min on ice in RIPA Lysis Buffer supplemented with phosphatase and protease inhibitor cocktails (Santa Cruz Biotechnology). Lysates were cleared by centrifugation

at 17000g for 10min at 4°C. Supernatants were removed and assayed for protein concentration using the Pierce BCA Protein Assay Kit (Thermo Fisher). Western blotting was performed using Novex system (Invitrogen). Equal amounts of proteins were subjected to SDS-PAGE and transferred to PVDF membranes (Thermo Fisher). Membranes were incubated with primary antibodies at 4°C overnight. Membranes were washed in TBS-Tween and then incubated with HRP conjugated anti-mouse or anti-rabbit secondary antibodies (Jackson Immunoresearch) for 1hr at room temp and developed using SuperSignal™ West Pico PLUS Chemiluminescent Substrate (Thermo Fisher). Signal detection was captured using Odyssey Fc system (LI-COR).

The following primary antibodies were used: mouse anti-eIF2B5 (B-7, 1:50; Santa Cruz Biotechnology); mouse anti-β-Actin (2D4H5, 1:3000 for WB; Proteintech); mouse anti-Puromycin (12D10, 1:1000; Millipore); mouse anti-EIF2α (L57A5, 1:500; Cell Signaling); rabbit anti-phospho-EIF2α Ser51 (119A11, 1:500; Cell Signaling); rabbit anti-FBXO32 (EPR9148(2), 1:500; Abcam); mouse anti-V5 (V5-10, 1:3000 for WB; Sigma-Aldrich); rabbit anti-GSK3β (D5C5Z, 1:500; Cell Signaling); rabbit anti-phospho-GSK3β Ser9 (9336, 1:1000; Cell Signaling).

Clonal expansion

E9.5 animals expressing *R26*$^{mT/mG}$ Cre-reporter were transduced by in utero lentiviral injection at MOI <<1. At E18.5, whole-mount headskin was fixed in 4% paraformaldehyde and stained using the immunofluorescence procedure described above with chicken anti-GFP (ab13970, 1:500; Abcam) overnight at 4°C, followed by incubation with a secondary antibody conjugated to Alexa-Fluor 488 (Invitrogen) overnight at 4°C. Tissue was optically cleared using the seeDB method as previously described (Ke et al., 2013) for confocal imaging.

Quantitative PCR

Total RNA was isolated using the RNeasy Plus Mini Kit (Qiagen) and reverse-transcribed with iScript Reverse Transcription Supermix (Bio-Rad). cDNA was diluted 1:5 with water. Quantitative PCR was performed with 1 µl cDNA using SYBR Green PCR Master Mix (Thermo Fisher) with primer sets specific for *Eif2b5*, *Fbxo32*, and *Ppib* as a control (Table 2-1). Normalized mRNA expression levels were calculated using comparative Ct.

Proteasome activity assay

Primary keratinocytes were transduced with lentivirus and plated in triplicate per condition at 5000 cells/well/90uL in a 96 well plate. Cells were treated for 4hrs with DMSO control, 1mg/mL puromycin, or 100nM bortezomib before assaying for proteasome activity using the 20S Proteasome Activity Assay Kit (APT280, Millipore) according to the manufacturer's protocol. Cells were incubated with the Proteasome Assay Loading Solution (LLVY-R110 peptide substrate) for 2hr at 37˚C. Fluorescence was measured with a microtiter plate reader (Biotek Synergy HT).

***In vitro* proliferation assay**

To measure *in vitro* cell proliferation, the IncuCyte ZOOM™ proliferation assay was used (Essen Bioscience). Primary keratinocytes were transduced with lentivirus and seeded at 5000 cells/well in 500 µl of media each in a 24-well plate. Plates were then placed in the IncuCyte ZOOM™ and live cell time-lapse imaging without labels was performed. Cell proliferation was monitored by analyzing the occupied area (% confluence) of cell images over time. Cell confluence at each timepoint was normalized to initial confluence per condition.

Apoptosis assay

Animals transduced with lentivirus at E9.5 were processed at E18.5 to isolate epidermal cells as described above (Nowak and Fuchs, 2009) and stained for active caspase 3 expression according to manufacturer's instructions (BD Pharmingen). Flow cytometric analysis of caspase 3 staining in YFP+ transduced cells was performed on BD LSR II.

***In vivo* basal cell ribosome profiling**

The *in vivo* basal cell ribosome profiling sample preparation is adapted from previously described methodology (Sendoel et al., 2017). Headskins of E18.5 mice were collected immediately after euthanization and digested in 5mg/mL dispase (Corning 354235) supplemented with 8 mg/ml cyclohexamide (CHX in EtOH) for 20 min at 37 °C. Epidermis was separated from dermis and placed immediately in 0.25% trypsin supplemented with 4 mg/ml CHX and incubated for 8 min at 37 °C. The resulting cell suspension, enriched for basal epidermal keratinocytes, was filtered through a 40-µm cell strainer, spun down, and lysed in mammalian lysis buffer supplemented with 0.1 mg/ml CHX according to the TruSeq Ribo Profile (Mammalian) protocol (Illumina). Cells were lysed on ice for 10 min, centrifuged at 16,000*g* at 4 °C for 10 min and supernatant was flash-frozen in liquid nitrogen. 20 headskins were pooled per biological replicate. The supernatant was used to isolate both total RNA and ribosome bound fractions as previously described (Ingolia et al., 2009) using the TruSeq Ribo Profile Mammalian kit (Illumina). Lysates were treated with TruSeq RP nuclease for 45 min at room temperature to generate ribosome-protected fragments, which were isolated using sephacryl S400 columns (GE Healthcare). rRNAs were removed from ribosome-protected fragments and total RNA using Ribo-Zero Gold (Illumina, MRZH11124).

Quality of the RNA was determined using Agilent 2100 Bioanalyzer, with all samples passing the quality threshold of RNA integrity numbers (RIN) > 9. Barcodes were used to generate pooled libraries. Ribosome-protected fragments and total mRNA libraries were amplified in 7–9 PCR cycles. Libraries were analyzed on using the Agilent 2100 Bioanalyzer before sequencing. The pools were sequenced on a HiSeq 2500 platform using the SR50 protocol. Profiling analysis methodology was adapted from a previously described analysis pipeline (Ingolia et al., 2009). The raw sequences were trimmed using the FASTX-Toolkit to remove the 3' adaptor sequence (AGATCGGAAGAGCACACGTCT). Trimmed sequence reads were aligned to mouse rRNA reference using Bowtie and mapped rRNA sequences were discarded (Langmead et al., 2009). TopHat2 was used to align non-rRNA reads to the mouse genome mm10 and counted for gene associations against the UCSC genes database with HTSeq (Anders et al., 2015; Kim et al., 2013). R/Bioconductor package Xtail was used to find differentially expressed genes at the translational level using both ribosome-bound and mRNA samples (Xiao et al., 2016). Differential expression analysis of total mRNA reads was performed using R/Bioconductor package edgeR (Robinson et al., 2010). R/Bioconductor package riboseqR was used to calculate triplicate periodicity in all samples (Chung et al., 2015). For each analysis, a statistical cutoff of FDR<0.1 and $\log_2$Fold Change>0.5 was used (minimum read count of 5). Genes with significant differential translation efficiency were uploaded into Ingenuity Pathway Analysis (Qiagen), and a core analysis was run to identify canonical pathways and functional enrichment.

5'UTR analysis

5' UTRs of the 1324 *Hras*^{G12V} translationally upregulated genes and the subset of 554 eIF2B5-regulated *Hras*^{G12V} upregulated genes were obtained using the known gene ID from the UCSC Genome Browser (mm10). Target versus non-target mRNAs were compared for 5' UTR length, %G+C content and folding energy by the Wilcoxon two-sided test. Multiple E_m (expectation maximization) for Motif Elicitation (MEME) and Find Individual Motif Occurrences (FIMO) was used to derive the guanine-rich translational element and determine its enrichment in the *Hras*^{G12V} and eIF2B5-regulated gene sets compared to the full mouse genome.

Tumor-free survival, tumor growth, and tumor burden

Animals were transduced at E9.5 with low-titer lentivirus containing Cre and shRNA against scrambled control or test genes. Transductions were confirmed by fluorescence of Cre-reporter YFP in ear clippings, and the remaining animals were monitored for 12 weeks post-birth. Animals were examined every 2–3 days and scored positive when tumors were larger than 2mm in diameter. Tumor-bearing animals were tracked weekly to measure individual tumors along their length, width, and depth for up to 5 weeks post-tumor initiation. Tumor volume was calculated using formula $V=(\pi/6)x(LxWxD)$ (Tomayko and Reynolds, 1989). Tumor burden is the total number of tumors that arise per animal during the 4 weeks after first tumor initiation.

***In vitro* translation sensitivity screen**

Pooled ORF lentivirus produced from the human ORFeome CCSB-Broad Lentiviral Expression Library was titered by serial dilution and keratinocyte transduction to identify *in vitro*

transduction conditions for MOI<<1. Mouse primary keratinocytes in 6-well plates were transduced with the screening library to achieve 30-fold coverage of the screening library. After 1 day, transduced cells were transferred to 96-well plates and plated at clonal density (~5 cells/well). 3 days post-transduction, cells were selected with 1μg/mL puromycin (Fisher Scientific). Wells that successfully grew under puromycin selection was transferred to 12-well plates for further expansion. Confluent 12-well plates were harvested for gDNA using QIAamp DNA tissue mini kit (Qiagen). The ORF region was pre-amplified from gDNA using custom barcoded primers, such that gDNA from each culture well was amplified with a unique barcode on the forward primer. Barcoded amplicons were pooled in equimolar ratios and fragmented by sonication. Following adaptor ligation, libraries were size-selected for 350 bp fragments before final library amplification. The pooled library was sequenced on a HiSeq 2500 platform (Illumina). The 5' reads containing unique barcodes were demultiplexed, while all other reads were discarded. Raw sequences were trimmed using the FASTX-Toolkit to remove adaptor and barcode sequences. Trimmed sequence reads were aligned to a reference genome containing the first 31 nt of all ORFs CCSB-Broad library using BWA (Li and Durbin, 2009). Mapped sequences were indexed for gene associations with Samtools (Li et al., 2009) to generate read counts per ORF. The top 30 ORFs from each well sample was extracted and collated to identify the number of samples in which each ORF appeared.

Statistical Analysis

All quantitative data were collected from experiments performed at least in triplicate and expressed as mean ± s.d. Differences between conditions were assayed using two-tailed

Student's t-test using Prism 7 (GraphPad). Overlap between gene lists was assayed using hypergeometric test. Significant differences were considered when $p<0.05$.

Table 2.1 shRNA and primer sequences used in this study

Name	Sequence 5' → 3'
shRNA sequences	
sh*Eif2b5* A11	CCGGGCAGACTGAGAATTATTGGAACTCGAGTTCCAATAATTCTCAGTCTGCTTTTTG
sh*Eif2b5* A12	CCGGGCGAGTCAAACTGAAGCCATACTCGAGTATGGCTTCAGTTTGACTCGCTTTTTG
sh*Eif2b5* B1	CCGGGCATGTGACAACTAGGGAATACTCGAGTATTCCCTAGTTGTCACATGCTTTTTG
sh*Eif2b5* B2	CCGGGCAGAAGAAGAGTCATCCGAACTCGAGTTCGGATGACTCTTCTTCTGCTTTTTG
sh*Eif2b5* B3	CCGGGCTCTGACTTTCTCTTGATATCTCGAGATATCAAGAGAAAGTCAGAGCTTTTTG
sh*Fbxo32* #1	CCGGCGCCATGGATACTGTACTTTGCTCGAGCAAAGTACAGTATCCATGGCGTTTTTG
sh*Fbxo32* #2	CCGGATTTGCAAGCAAGACTATAAACTCGAGTTTATAGTCTTGCTTGCAAATTTTTTG
sh*Fbxo32* F6	CCGGCCTATGAAGATGCCACACAATCTCGAGATTGTGTGGCATCTTCATAGGTTTTTG
sh*Fbxo32* F7	CCGGCGTTTGATCTTGTCTGACAAACTCGAGTTTGTCAGACAAGATCAAACGTTTTTG
sh*Fbxo32* F8	CCGGGCGCCATGGATACTGTACTTTCTCGAGAAAGTACAGTATCCATGGCGCTTTTTG
sh*Fbxo32* F9	CCGGGCTGGATTGGAAGAAGATGTACTCGAGTACATCTTCTTCCAATCCAGCTTTTTG
sh*Fbxo32* F10	CCGGGTGCTTACAACTGAACATCATCTCGAGATGATGTTCAGTTGTAAGCACTTTTTG
shScrambled	CCGGTCCTAAGGTTAAGTCGCCCTCGCTCGAGCGAGGGCGACTTAACCTTAGGTTTTTG
Quantitative PCR primers	
Eif2b5 F	GGCCCTAACTGCCATATTGGTGA
Eif2b5 R	TGGCTTCAGTTTGACTCGCTC
Fbxo32_CDS (exon 3)_ F	ACAAAGGAAGTACGAAGGAGC
Fbxo32_CDS (exon 5)_R	GGGATGTGAGCTGTGACTTTG
Fbxo32_3UTR_ F	GCAAACACTGCCACATTCTC
Fbxo32_3UTR_R	GTTGTCGTGTGCTGGGATTA
Ppib F	GGGACCTAAAGTCACAGTCAAGGT
Ppib R	AGCCAAATCCTTTCTCTCCTGTAGC

Chapter 3 – Oncogenic RAS activation alters stem cell dynamics to preserve epidermal development

Oncogene activation is known to alter cellular behaviors and can lead to broad changes in tissue architecture (Hanahan and Weinberg, 2011; Pardal et al., 2005). We sought to characterize the oncogene-induced changes in gross epidermal morphology and investigate the progenitor cell behaviors mediating epidermal oncogene tolerance. Epidermis-restricted oncogene activation allowed us to examine the effects on epidermal development independent of other skin compartments.

3.1 *Hras^{G12V}* activation induces epidermal overgrowth

To model oncogene activation, we employed a Cre-Lox conditional knock-in *Hras$^{G12V/G12V\ fl/fl}$* mouse model of Costello syndrome (Fig. 3.1A) (Chen et al., 2009). Endogenous *Hras1* is flanked by LoxP sites and excised upon transduction with lentivirus containing Cre recombinase (LV-Cre), resulting in oncogenic *Hras^{G12V}* expression at physiological levels under its endogenous promoter. Homozygous *Hras^{G12V}* activation results in complete substitution of the endogenous locus for the mutant allele (Fig. 3.1B). Cre-reporters *Rosa26$^{YFP\ fl/fl}$* and *Rosa26$^{mT/mG\ fl/fl}$* were used to visualize LV-Cre tranduced cells (Muzumdar et al., 2007; Srinivas et al., 2001) (Fig. 3.1C). Throughout the study, we activated epidermal *Hras^{G12V}* expression by transducing E9.5 embryos via ultrasound-guided *in utero* microinjection of lentivirus into the amniotic cavity (Fig. 3.1D-E) (Beronja et al., 2010). At E9.5, the developing epidermis is comprised of a single layer of ectodermal cells with progenitor potential and is readily transducible. By the completion of embryonic development at

E18.5, the epidermis has undergone significant expansion, and a range of transduction levels can be achieved depending on viral titer (Fig. 3.1F).

Upon broad epidermal activation of *Hras*^{G12V}, E18.5 embryos displayed thickened and raised skin in comparison to WT embryos (Fig. 3.2A), indicative of tissue overgrowth. In tissue cross sections, *Hras*^{G12V} epidermis exhibited significant expansion of basal progenitor cells, marked by keratin 5 (K5; Fig. 3.2B), in contrast to the single basal layer found in WT epidermis. Furthermore, *Hras*^{G12V} expression also induced significant expansion of the keratin 10 (K10)-expressing suprabasal population. To investigate whether the observed *Hras*^{G12V} epidermal hyperplasia was due to increased growth from individual oncogene-activated cells, we transduced the epidermis at a single-cell density and examined the growth of individual clones (Fig. 3.2C). *Hras*^{G12V} displayed substantially greater basal cell expansion by E18.5 than what was observed in WT epidermis, suggesting that overall *Hras*^{G12V} epidermal overgrowth is mediated by oncogene-induced expansion of the basal progenitor population.

3.2 *Hras*^{G12V} activation alters stem cell dynamics to limit epidermal overgrowth

Tissue growth is dependent on the interplay between stem cell proliferation and fate choice, which together directly control a tissue's progenitor pool size and therefore its growth potential (Hanahan and Weinberg, 2011; Tomasetti and Levy, 2010). Modulation of the rate of progenitor cell proliferation or self-renewal can have profound effects on the rate of tissue growth. We define renewal rate as the rate at which daughter cells from a basal cell division event maintain progenitor potential. Under continual proliferation and a 10-day tissue turnover rate (Rompolas et al., 2016), small changes in renewal rate dictate whether the tissue maintains

homeostasis (renewal rate=0.5), or undergoes rapid expansion (renewal rate>0.5) or loss (renewal rate<0.5) (Fig. 3.3A-B). The tissue effects determined by renewal are further amplified by differences in proliferation rate.

Since oncogene activation commonly drives excess growth by inducing hyperproliferation (Hanahan and Weinberg, 2011; Pardal et al., 2005), we first assessed progenitor cell proliferation by measuring nucleoside incorporation, which allows us to mark actively dividing basal progenitors. We found a significant ~2-fold increase in proliferation rate $Hras^{G12V}$ compared to WT IFE basal cells (Fig. 3.3C). In embryonic WT epidermis, proliferation is accompanied by a high rate of progenitor cell self-renewal (renewal rate=0.7), which facilitates the rapid growth necessary for development (Beronja et al., 2013; Ying et al., 2018). We therefore expected $Hras^{G12V}$-induced hyperproliferation to have a substantial effect in accelerating epidermal growth. We modelled the theoretical tissue expansion from a single ectodermal cell at E9.5 to E18.5, using our observed proliferation rates in $Hras^{G12V}$ and WT epidermis and a renewal rate=0.7 following epidermal stratification at E15.5 (Sotiropoulou and Blanpain, 2012) (Fig. 3.3D). Our model successfully predicted the experimentally observed tissue expansion in developing WT epidermis (Beronja et al., 2013), and further predicted that $Hras^{G12V}$ epidermis would undergo 25-fold the expansion of WT epidermis within the same timeframe. However, this is not compatible with the moderate epidermal overgrowth observed at E18.5 or the neonatal phenotype in Costello syndrome (Fig. 3.2A-B) (Digilio et al., 2011; Gripp and Lin, 2012), suggesting that increased proliferation is balanced by a potent growth-suppressive mechanism.

We recently demonstrated that strong suppression of progenitor cell renewal can reduce the fitness of mutant clones relative to WT neighbors, resulting in their complete ablation from

the epidermis (Ying et al., 2018). While this clonal competition mechanism cannot be employed during tissue-wide oncogene activation, we hypothesized that a mechanism which moderates renewal rate may counteract hyperproliferation to contain the expansion of *Hras*^{G12V} epidermis. We tested tissue renewal rate following *Hras*^{G12V} activation using a quantitative EdU-BrdU pulse-chase incorporation assay (Ying et al., 2018), which allowed us to uniquely mark dividing basal cells and score the fate of their daughter cells based on expression of differentiation marker keratin 10 (K10) (Fig. 3.3E) (Fuchs, 1993). We found a striking reduction of basal cell renewal, and therefore a higher level of basal cell differentiation, in broadly activated *Hras*^{G12V} epidermis compared to WT tissue. Importantly, although reduced, *Hras*^{G12V} renewal rate remained at 0.5, which allows for maintenance of the mutant tissue and containment of growth. Oncogenic tissue containment is fundamentally different from the strong renewal block and complete clonal expulsion previously observed following oncogenic *Pik3ca* activation (Ying et al., 2018). We expect that differentiation is coordinated with oncogene-induced hyperproliferation in order to restrict the progenitor pool size of the epidermis, allowing it to tolerate oncogene hyperactivity and limit excess growth. This stem cell coordination also highlights a fundamental change in epidermal development, from high renewal and low proliferation in WT to low renewal and high proliferation in *Hras*^{G12V} epidermis, suggesting that epidermal development is a remarkably robust process as long as stem cell coordination is maintained. However, the molecular mechanisms behind the coordinated stem cell response to oncogene activation are unknown.

Summary

Here, we use a *Hras*^{G12V} mouse model of Costello syndrome to understand epidermal morphology and progenitor cell behavior in response to oncogene activation during embryonic development. We found that *Hras*^{G12V} activation induces substantial epidermal hyperplasia through expansion of both basal progenitor and suprabasal differentiated layers. However, the tissue growth predicted by *Hras*^{G12V}-induced progenitor cell hyperproliferation is greatly in excess of our observed epidermal overgrowth, suggesting that additional growth-suppressive strategies act to limit excess tissue expansion. We identified compensatory progenitor cell differentiation as an oncogene tolerance mechanism that maintains the epidermis during development while reducing aberrant growth.

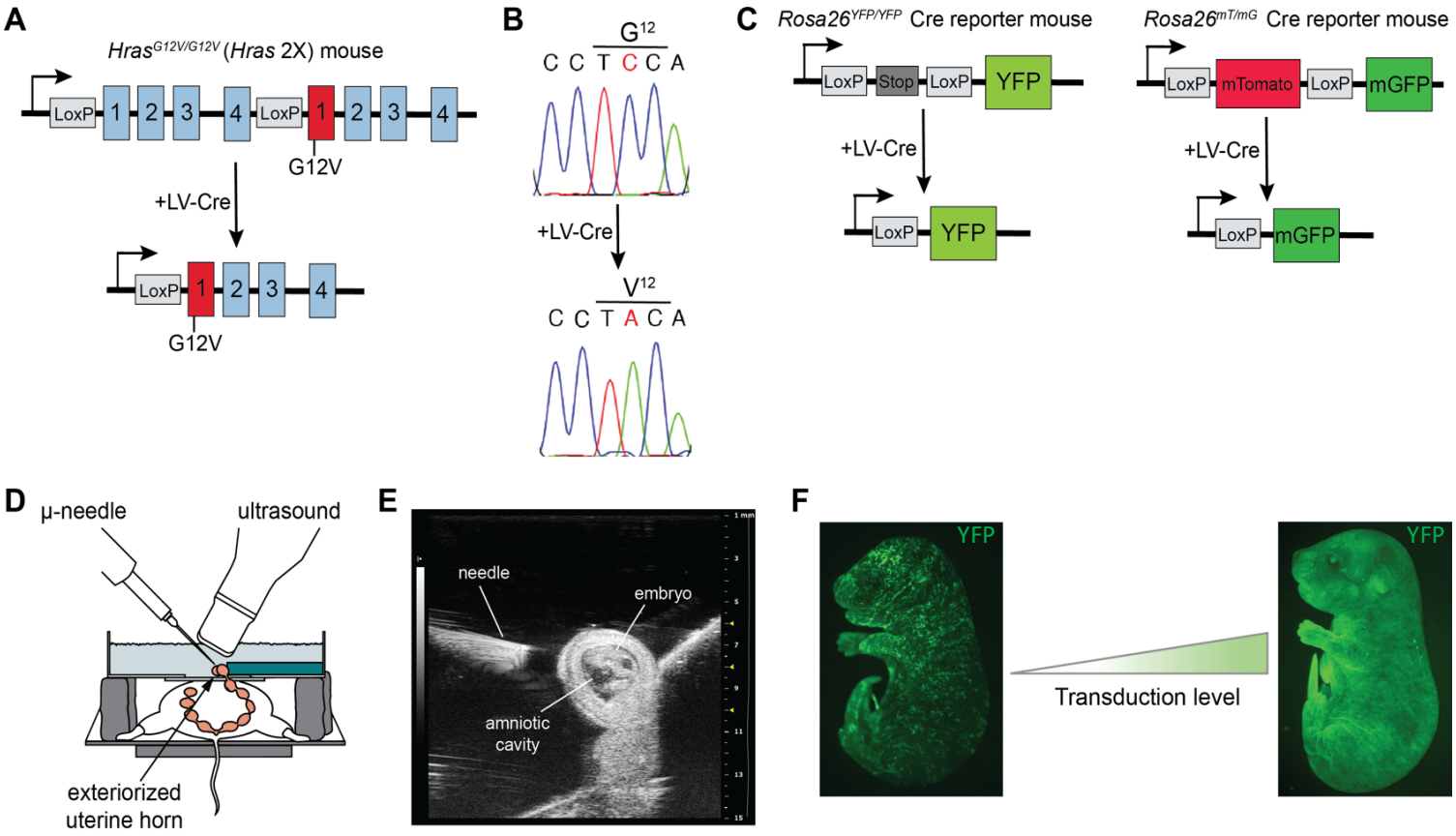


Figure 3.1 Oncogene activation can be induced in mouse epidermis

A) Physiological knock-in model for Cre-inducible expression of oncogenic *Hras*^{G12V}. Cre recombinase is expressed from a lentivirus that can co-express shRNA or ORF.

B) Sequencing traces of *Hras1* locus in epidermal basal cells following transduction with LV-Cre results in efficient activation of *Hras*^{G12V} expression.

C) *Rosa26*$^{YFP\ fl/fl}$ Cre reporter mouse exchanges stop codon for YFP following Cre expression. *Rosa26*$^{mT/mG\ fl/fl}$ Cre reporter mouse exchanges membrane-associated red (mT) fluorophore with green (mG) following Cre expression. Cre recombinase is expressed from a lentivirus that can co-express shRNA or ORF.

D-E) Schematic **(D)** and ultrasound **(E)** of ultrasound-guided *in utero* lentivirus injection technique.

F) A range of transduction levels can be achieved by adjusting titer of lentivirus injected.

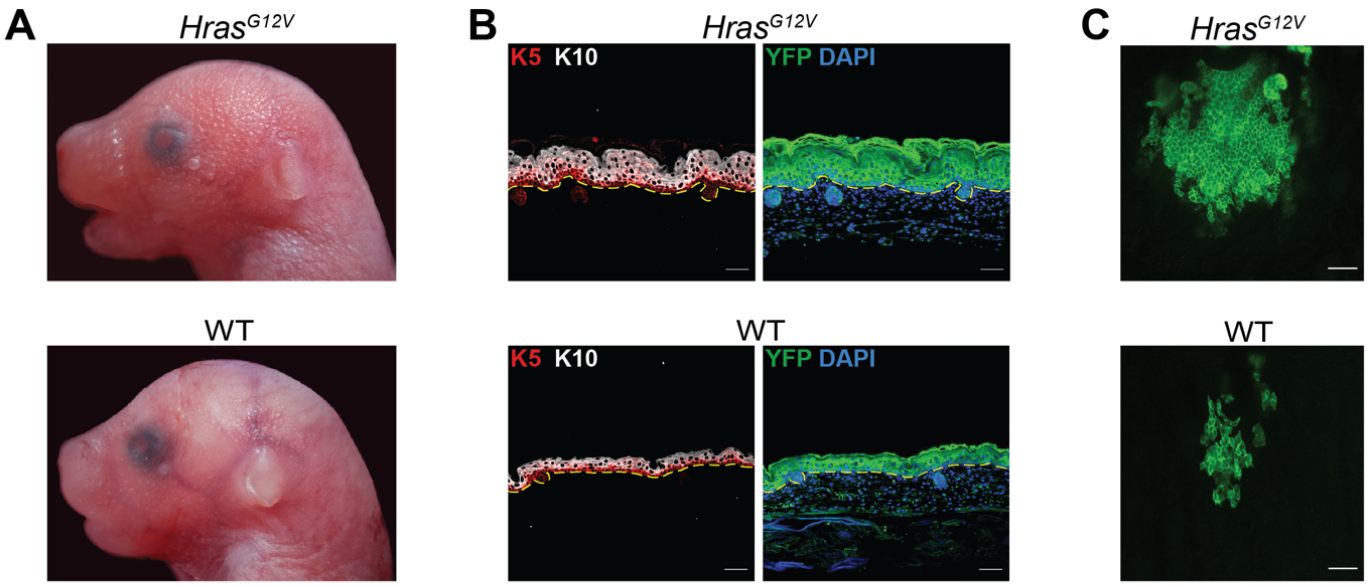


Figure 3.2 *Hras*^{G12V} induces epidermal expansion

A) Gross skin morphology of E18.5 *Hras*^{G12V} and WT mice transduced with control shRNA.

B) Representative immunofluorescence staining of keratin 5 (K5, red) and keratin 10 (K10, white) in WT and *Hras*^{G12V} E18.5 epidermis cross-sections transduced with control shRNA. Cre reporter YFP (green) marks the transduced epidermis and DAPI (blue) marks nuclei. Dashed line indicates basement membrane. Scale bars, 50 µm.

C) Representative immunofluorescence staining of clonal expansion in E18.5 epidermis from a single transduced basal cell at E9.5.

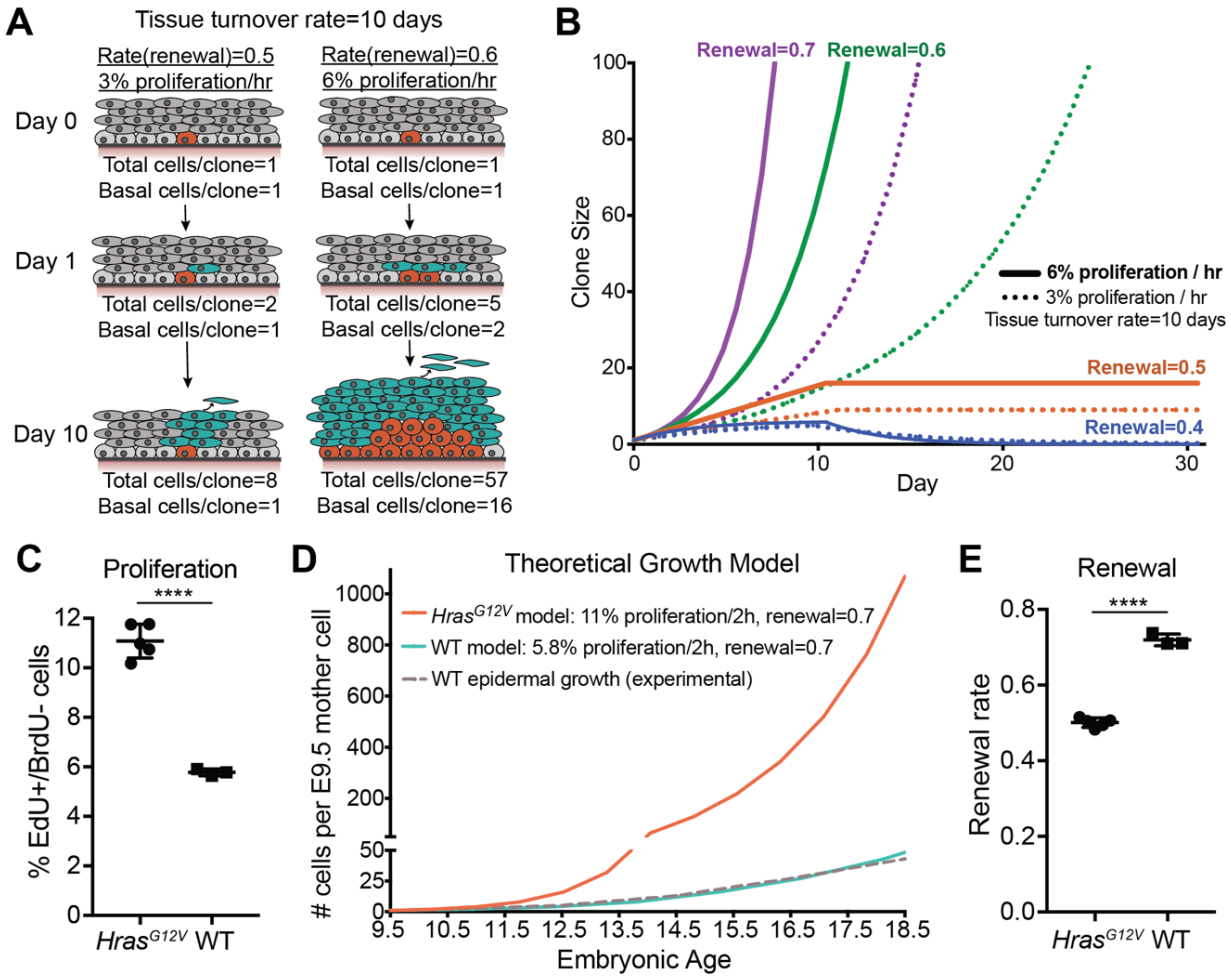


Figure 3.3 *Hras^{G12V}* induces compensatory progenitor cell differentiation

A) Schematic and **B)** model of theoretical clone growth dependent on rates of progenitor cell renewal and proliferation. Renewal rate refers to the proportion of daughter cells following cell divisions that retain progenitor potential.

C) Quantification of proliferation rate in transduced IFE basal cells nucleoside incorporation. *Hras^{G12V}* or WT epidermis is transduced with control shRNA. Each data point represents an individual animal. Approx. 100 basal cells were scored per animal per condition. (****:P-value<0.0001).

D) Model of theoretical growth derived from a single mother cell at E9.5 dependent on rates of proliferation observed in *Hras*^{G12V} and WT progenitor cells and WT renewal rate of 0.7 (Ying et al., 2018). Renewal rate refers to the proportion of daughter cells following cell divisions that retain progenitor potential. WT epidermal growth (gray dashed line) indicates average cell numbers from experimental quantification (Beronja et al., 2013).

E) Quantification of EdU/BrdU pulse-chase renewal assay in transduced epidermal basal cells. P(renewal) = (EdU+/BrdU-/K10- daughter cells) / (total EdU+/BrdU- daughter cells). *Hras*^{G12V} or WT epidermis is transduced with control shRNA. Each data point represents an individual animal. Approx. 100 cell divisions were scored per animal per condition. (****:P-value<0.0001).

Chapter 4 – eIF2B5 coordinates progenitor cell behaviors to mediate oncogene tolerance

Oncogene tolerance in the epidermis is dependent on modulation of progenitor cell fate choice to counteract oncogene-induced hyperproliferation. To uncover the molecular mechanisms regulating this behavior adjustment, we focused on translational control of gene expression. Protein synthesis has recently been linked to both stem cell fate choice and proliferation regulation (Buszcznak et al., 2014; Signer et al., 2014; Zismanov et al., 2016). This dual role suggests that translational regulation may coordinate progenitor cell behaviors to mediate oncogene tolerance during embryogenesis.

4.1 eIF2B5 mediates *Hras^{G12V}*-induced translation upregulation

To understand translation's role in tissue response to oncogene activation, we began by examining the effect of *Hras^{G12V}* activation on E18.5 epidermal progenitor cell translation rate. Animals were injected with puromycin, an amino acid analog, 30 minutes before tissue processing and immunofluorescence staining of puromycin incorporation (Fig. 4.1A) (Goodman and Hornberger, 2013). Quantification of puromycin intensity in K5+ basal progenitors revealed a significant ~50% increase in protein synthesis in *Hras^{G12V}* basal cells relative to WT (Fig. 4.1B). Many oncogenes can reprogram translation by directly altering the activity of eukaryotic initiation factors and ribosomal proteins (Hsieh et al., 2012; Truitt et al., 2015). We therefore hypothesized that the observed translation rate increase in *Hras^{G12V}* basal progenitors reflected an interactive relationship with the translation apparatus. To identify which components within the translation machinery were necessary for *Hras^{G12V}* progenitor cell behaviors, we performed

two *in vivo* functional screens that distinguished genes as regulators of proliferation or renewal (Fig. 4.1C) (Ying et al., 2018). To target translation machinery components *in vivo*, we generated a lentivirus pool of 1228 shRNAs directed at 195 translation initiation factors, elongation factors, ribosomal proteins, tRNA synthetases, and poly(A) binding proteins (Bhat et al., 2015; Moffat et al., 2006). We transduced E9.5 $Hras^{G12V}$ mouse epidermis with the shRNA pool at clonal density (MOI<1) (Beronja et al., 2013). For the proliferation screen, E18.5 mice were given an 8hr EdU pulse before FACS collecting equal numbers of oncogene-activated (YFP+) dividing (EdU+) and non-dividing (EdU-) epidermal basal cells. For the renewal screen, equal numbers of oncogene-activated basal (α6 Itg^{high}) and suprabasal (α6 Itg^{low}) cells were collected. Our analysis is based on the principle that shRNAs targeting proliferation promoters will be enriched in the non-dividing relative to dividing population, while shRNAs targeting renewal promoters will be enriched in the suprabasal relative to basal population (Ying et al., 2018). We identified significantly enriched or depleted shRNAs with DESeq2 and classified genes as putative proliferation or renewal regulators if at least two of their shRNAs were significantly changed with consistent directionality (Beronja et al., 2013).

Our screens uncovered 101 translation genes as proliferation promoters (Fig. 4.1D, F, Table 4.1), consistent with the essential role of translation in cell cycle progression (Lee et al., 2015; Stumpf et al., 2013). In contrast, only 15 translation genes were identified as differentiation promoters, and 8 genes were identified as renewal promoters (Fig. 4.1E, F, Table 4.2). Notably, a significant subset of 11 genes simultaneously promoted $Hras^{G12V}$ progenitor cell proliferation and differentiation ($p<0.05$; Fig. 4.1F). Amongst these dual regulators, translation initiation factor *Eif2b5* was the only central mediator of protein synthesis also implicated in a congenital disorder

marked by a tissue specific defect (Li et al., 2004; Scali et al., 2006). eIF2B5 is the catalytic subunit of the eIF2B complex, a guanine exchange factor that returns eIF2 to its active state (Pavitt, 2005) (Fig. 4.2A). Active eIF2 associates with initiator methionine-tRNA to form the ternary complex, which is necessary for translation initiation. Although *Eif2b5* is highly amplified across human epithelial cancers (Cancer Genome Atlas Network, 2015; The Cancer Genome Atlas Research Network, 2012; 2017b; 2017a), little is known about its early *in vivo* role following oncogene activation. Given its central role in translation initiation as well as our surprising discovery that eIF2B5 coordinates both cell proliferation and differentiation, we focused our downstream studies on *Eif2b5* to dissect the interplay between $Hras^{G12V}$ activation and protein synthesis control.

We began by assessing the role of eIF2B5 in $Hras^{G12V}$ aberrant translation. First, we tested all shRNAs against *Eif2b5* from our screening pool in keratinocyte culture and identified two independent shRNAs that significantly depleted *Eif2b5* mRNA and protein (Fig. 4.2B-C). We transduced E9.5 embryos with lentivirus depleting *Eif2b5* and assessed translation rate in transduced (mGFP+) basal cells (K5+) at E18.5, normalized to neighboring untransduced WT basal cells. Immunofluorescence staining of puromycin incorporation following 30min puromycin pulse revealed that *Eif2b5* depletion reduced $Hras^{G12V}$ translation rates to WT levels (Fig. 4.2D-E). Remarkably, *Eif2b5* depletion in WT epidermis did not significantly alter translation rate, suggesting that $Hras^{G12V}$ tissue has particular dependency on eIF2B5-mediated translation. To examine whether the observed basal cell translation rate differences were dependent on dermal interactions, we assessed puromycin incorporation by western blot in puromycin-pulsed primary keratinocytes cultured from FACS-isolated basal cells (Fig. 4.3A). We again observed eIF2B5-

dependent translation upregulation in *Hras*^{G12V} primary keratinocytes, demonstrating that translation upregulation is cell-autonomous and independent of dermal signaling. Furthermore, these translational differences were not due to induction of secondary cell stress, as indicated by analyses of eIF2α phosphorylation on serine 51 (Fig. 4.3A) (Koromilas, 2015). Rather than being increased as occurs under stress, Ser51 p-eIF2α was decreased upon *Eif2b5* depletion. This reduction may act as a compensatory mechanism to rescue translation (Harding et al., 2009; Kojima et al., 2003). In addition, the translation rate assay was not confounded by differences in proteasome activity between genetic backgrounds (Fig. 4.3B).

We next sought to identify a mechanism by which *Hras*^{G12V} may directly regulate eIF2B5 activity to produce the translational upregulation observed in *Hras*^{G12V} tissue. Surprisingly, there was no difference in *Eif2b5* transcript or protein levels between *Hras*^{G12V} and WT basal cells (Fig. 4.4A-B). We then probed additional regulatory mechanisms that may alter eIF2B5 protein activity. A candidate regulator is GSK3β, which can phosphorylate eIF2B5 on serine 535 to inhibit its activity (Welsh et al., 1998). GSK3β itself can be inhibited through phosphorylation on serine 9 by AKT or on threonine 43 by ERK, which are both downstream effectors of HRAS (McCubrey et al., 2014). Furthermore, the AKT-GSK3β-eIF2B5 signaling module has been shown to be a potent regulator of eIF2B5 activity *in vivo* (Guo et al., 2016). We assessed the protein level of these pathway components in basal cells and found that p-GSK3β Ser9 was upregulated in *Hras*^{G12V} cells, while p-eIF2B5 Ser535 was downregulated (Fig. 4.4B). This correlative finding requires further functional studies to probe the direct effects of signaling manipulation on basal cell translation rate.

4.2 *Hras^{G12V}* progenitor cell behaviors and tissue growth are dependent on eIF2B5

Given the role of eIF2B5 in *Hras^{G12V}* translation upregulation, we next investigated whether *Hras^{G12V}*-induced progenitor cell behaviors are also regulated by eIF2B5. Upon *Eif2b5* depletion, *Hras^{G12V}* basal cell proliferation rate, measured by nucleoside incorporation in dividing cells, was decreased to WT levels (Fig. 4.5A). To assess progenitor cell renewal, we utilized our EdU-BrdU pulse-chase assay and found that *Eif2b5* depletion also rescued *Hras^{G12V}* basal cell renewal up to WT levels (Fig. 4.5B). In contrast, depletion of *Eif2b5* in WT tissue did not significantly affect progenitor cell proliferation or renewal, suggesting that eIF2B5 has an oncogene-specific role in regulating stem cell behavior. We also assessed apoptosis through flow cytometry quantification of epidermal cells expressing activated Caspase 3+ and observed no significant change across any conditions (Fig. 4.5C). These findings demonstrate that eIF2B5-mediated translation is necessary to coordinate *Hras^{G12V}*-induced progenitor cell proliferation with compensatory differentiation, suggesting that it is essential for epidermal oncogene tolerance.

Since eIF2B5 is necessary for *Hras^{G12V}* progenitor cell behaviors, we hypothesized that eIF2B5 also regulates the *Hras^{G12V}* overgrowth phenotype. To assess growth, we first examined clonal expansion from single-cell *Hras^{G12V}* activation and found that depletion of *Eif2b5* reduced *Hras^{G12V}* clonal expansion to WT levels (Fig. 4.5D). Tissue cross-sections of fully transduced epidermis revealed that *Eif2b5* depletion completely resolves *Hras^{G12V}* hyperplasia in both basal and suprabasal layers, reflecting the reduction in proliferation and differentiation rates in basal progenitors (Fig. 4.5E). This rescued the thickened and raised skin found in *Hras^{G12V}* animals, restoring the smooth appearance of WT skin (Fig. 4.5F). *Hras^{G12V}* primary keratinocytes also

displayed eIF2B5-dependent elevation in growth rate, further reproducing the behavior of basal cells *in vivo* (Fig. 4.3C). However, *Eif2b5* depletion in WT epidermis did not significantly alter tissue growth or epidermal morphology. Although *Eif2b5* is an essential gene and homozygous knockouts are embryonic lethal (Leegwater et al., 2001; Scali et al., 2006), the lack of phenotypic changes in WT epidermis upon moderate *Eif2b5* depletion suggests it is expressed in excess of normal physiological need in this tissue. However, oncogene activation and the ensuing translation upregulation may increase dependence on the translation machinery, causing $Hras^{G12V}$ progenitor cells to be highly sensitive to *Eif2b5* levels.

4.3 eIF2B5 mediates the translation of a specific subset of oncogenic mRNAs

To gain a molecular understanding of eIF2B5's role in $Hras^{G12V}$ epidermis, we identified the eIF2B5-regulated translational changes in $Hras^{G12V}$ basal progenitors using *in vivo* ribosome profiling (Fig. 4.6A) (Sendoel et al., 2017). This strategy quantifies active translation by comparing ribosome footprints to total mRNA, allowing us to assess translation efficiency on a per-transcript basis (Ingolia et al., 2009). E9.5 $Hras^{G12V}$ and WT epidermis were transduced with shScrambled control or sh*Eif2b5* B3, our most efficient shRNA targeting *Eif2b5.* We transduced embryos at comparable levels across each condition, which resulted in suppression of $Hras^{G12V}$ epidermal overgrowth without tissue damage (Fig. 4.6B). Well-transduced E18.5 skin was enzymatically dissociated in the presence of translation elongation inhibitor cycloheximide to generate a basal cell-enriched population (Fig. 4.6B-C). This *in vivo* profiling strategy successfully preserved polysomes (Fig. 4.6D) and depleted *Eif2b5* transcript (Fig. 4.6E). Our ribosome footprint libraries displayed expected enrichment of 28nt reads, triplet periodicity, and alignment

to coding regions (Fig. 4.7A-C). Across biological replicates, our sequencing libraries were highly reproducible (Pearson $r^2 > 0.9$) (Fig. 4.7D-E).

To assess differences in active translation independent of transcriptional changes, we used Xtail analysis to identify genes with significant differential translation efficiencies ($Log_2FC>0.5$, FDR<0.1) (Xiao et al., 2016) and then used EdgeR analysis to excluded genes whose transcripts were significantly changed ($Log_2FC>0.5$, FDR<0.1) (Robinson et al., 2010). First, we compared *Hras*^{G12V}+shScram to WT+shScram (HS/WS) profiling and identified 1324 genes that were translationally altered upon *Hras*^{G12V} activation, comprising the *Hras*^{G12V} translatome (Fig. 4.8A, Table B.1). We then compared *Hras*^{G12V}+sh*Eif2b5* to *Hras*^{G12V}+shScram (HE/HS) profiling and identified 1517 genes whose translation was regulated by eIF2B5 (Fig. 4.8B, Table B.2). Strikingly, a large portion of the *Hras*^{G12V} translatome was significantly rescued by *Eif2b5* depletion, as demonstrated by the strong negative correlation between significantly altered genes in HS/WS and HE/HS analyses (Pearson r = -0.8074, $r^2 = 0.6518$) (Fig. 4.8C-D, Table B.3). Overall, we found 554 shared genes between the two analyses, all of which had negatively correlating translation efficiencies, which comprise the subset of the *Hras*^{G12V} translatome regulated by eIF2B5 (Fig. 4.8E). Ingenuity pathway analysis revealed that this gene set was enriched for cancer-related pathways and functions involving transcription, cell cycle progression, and post-translational gene regulation (Fig. 4.8F-G) (Krämer et al., 2013). Interestingly, these functions were also enriched for amongst high turnover proteins identified by mass spectrometry of embryonic stem cells (Bulut-Karslioglu et al., 2018), suggesting that their expression is especially dependent on active translation. Top upregulated genes include *Mgarp, Fgf20, Klf9,* and *Banf1,* which have all been implicated in stem cell maintenance or fate choice (Fig. 4.8D) (Barak et al., 2012; Cox et al.,

2011; Tiemann et al., 2014; Ying et al., 2014). Collectively, these studies reveal that eIF2B5 selectively controls the translation of a distinct subset of oncogenic genes that may be involved in regulating *Hras*^{G12V} progenitor cell behaviors and tissue growth.

The ability of translation machinery components to preferentially translate a subset of mRNAs has previously been reported for several translation initiation factors, including eIF3, eIF4E, and eIF6 (Brina et al., 2015; Lee et al., 2015; Truitt et al., 2015). This specificity may be responsible for the increased dependence of oncogenic tissues on the translation machinery (Bhat et al., 2015; Truitt and Ruggero, 2016). A possible factor in eIF2B5's translational specificity is the presence of secondary structures, upstream ORFs (uORFs), or *cis*-regulatory elements in the 5'UTR of its target mRNAs (Schuster and Hsieh, 2019). To identify any potential regulatory mechanisms, we examined the 5'UTRs of genes that were translationally upregulated in *Hras*^{G12V} basal cells (from HS/WS analysis) or translationally upregulated by eIF2B5 activity (from HE/HS analysis). In comparison to the entire mouse genome, no differences were found in 5'UTR lengths between any conditions (Fig. 4.9A). However, a decrease in 5'UTR folding energy and increase in %GC content was observed in both *Hras*^{G12V} translationally upregulated genes and those dependent on eIF2B5 (Fig. 4.9B-C). These findings suggest that translationally altered genes have more complex secondary structures and fewer uORFs (Chew et al., 2016; Ringnér and Krogh, 2005). We probed the 5'UTRs of translationally altered genes for the presence of shared motifs and identified significant enrichment for a 41-nt guanine-rich motif (Fig. 4.9D), which was found in 62.48% of *Hras*^{G12V} translationally upregulated genes and 70.97% of those dependent on eIF2B5, in comparison to 26.86% of the genome as a whole. It remains unclear if these 5'UTR differences are necessary for eIF2B5-specific translation or simply a characteristic of the entire

Hras^{G12V} translatome, and additional validation studies are needed to test whether the guanine-rich motif is necessary translational effect of are needed to determine the significance of the identified.

Summary

In this chapter, we showed through *in vivo* functional genetic screens that, while the majority of the translation machinery was necessary for *Hras*^{G12V} progenitor cell proliferation, only a small subset could regulate cell fate choice. Amongst these, eIF2B5 emerged as a central driver of *Hras*^{G12V} progenitor cell behaviors and tissue growth. While eIF2B5 appears sufficient to account for *Hras*^{G12V} epidermal overgrowth, its additional role in coordinating differentiation with oncogenic hyperproliferation suggests that it simultaneously acts to restrain excess growth. Surprisingly, despite the essentiality of eIF2B5, moderate eIF2B5 depletion did not affect WT epidermis, suggesting significant oncogene specificity in its function. Using *in vivo* ribosome profiling, we found that eIF2B5 selectively regulates a significant proportion of the *Hras*^{G12V} translatome, a gene set that is enriched for stem cell regulators and cancer-related pathways. 5'UTR analysis for regulatory mechanisms governing eIF2B5-specific translation has identified a candidate guanine-rich translational element for future study.

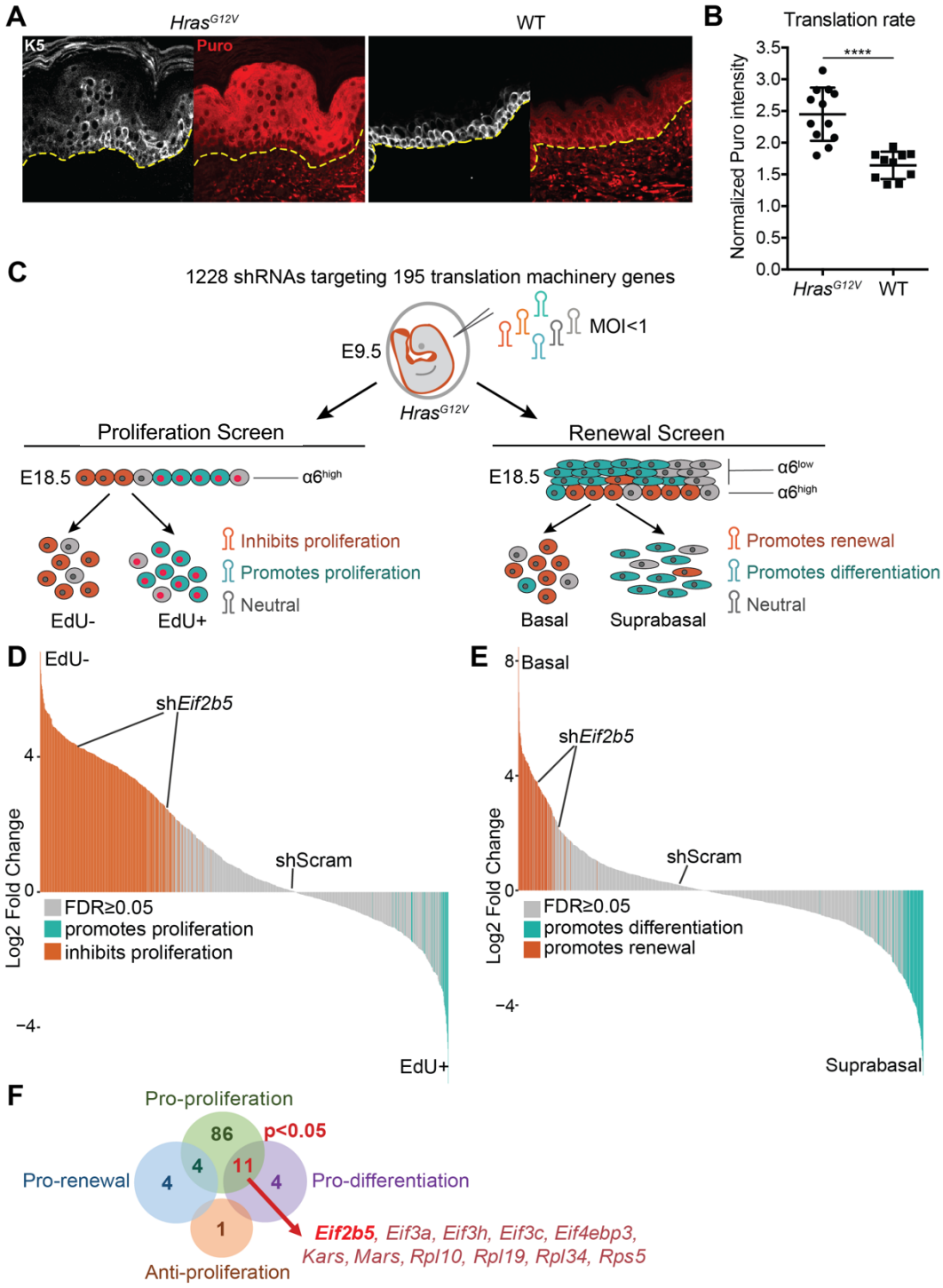


Figure 4.1 *Hras^{G12V}* progenitor cell behaviors are regulated by the translation machinery

A-B) Representative immunofluorescence staining **(A)** and quantification **(B)** of puromycin-injected E18.5 animals for incorporation of puromycin (red) in IFE basal cells (K5, white)

normalized to dermal puromycin incorporation. Yellow dashed line marks basement membrane. Each data point represents one imaging field containing epidermis and dermis. 3 animals were assessed per condition. Scale bars, 25 μm. (****:P-value<0.0001; ns=not significant)

C) Schematic of *in vivo* genetic screens for regulators of epidermal progenitor proliferation and renewal among 195 translation machinery genes. Assays are based on enrichment (orange) or depletion (blue) of shRNAs in non-dividing EdU- relative to dividing EdU+ epidermal progenitors (proliferation screen) or a6-Integrin^{high} basal progenitors relative to differentiated suprabasal a6-Integrin^{low} cells (renewal screen).

D-E) Needle plots of fold change for individual shRNAs in *in vivo* **(D)** proliferation and **(E)** renewal screens. Statistics are based on 3 biological replicates (DeSeq2 FDR<0.05).

(F) Genes are classified as renewal or proliferation promoters if at least two shRNAs are significantly changed with the same directionality. Statistics for gene overlap significance using hypergeometric test.

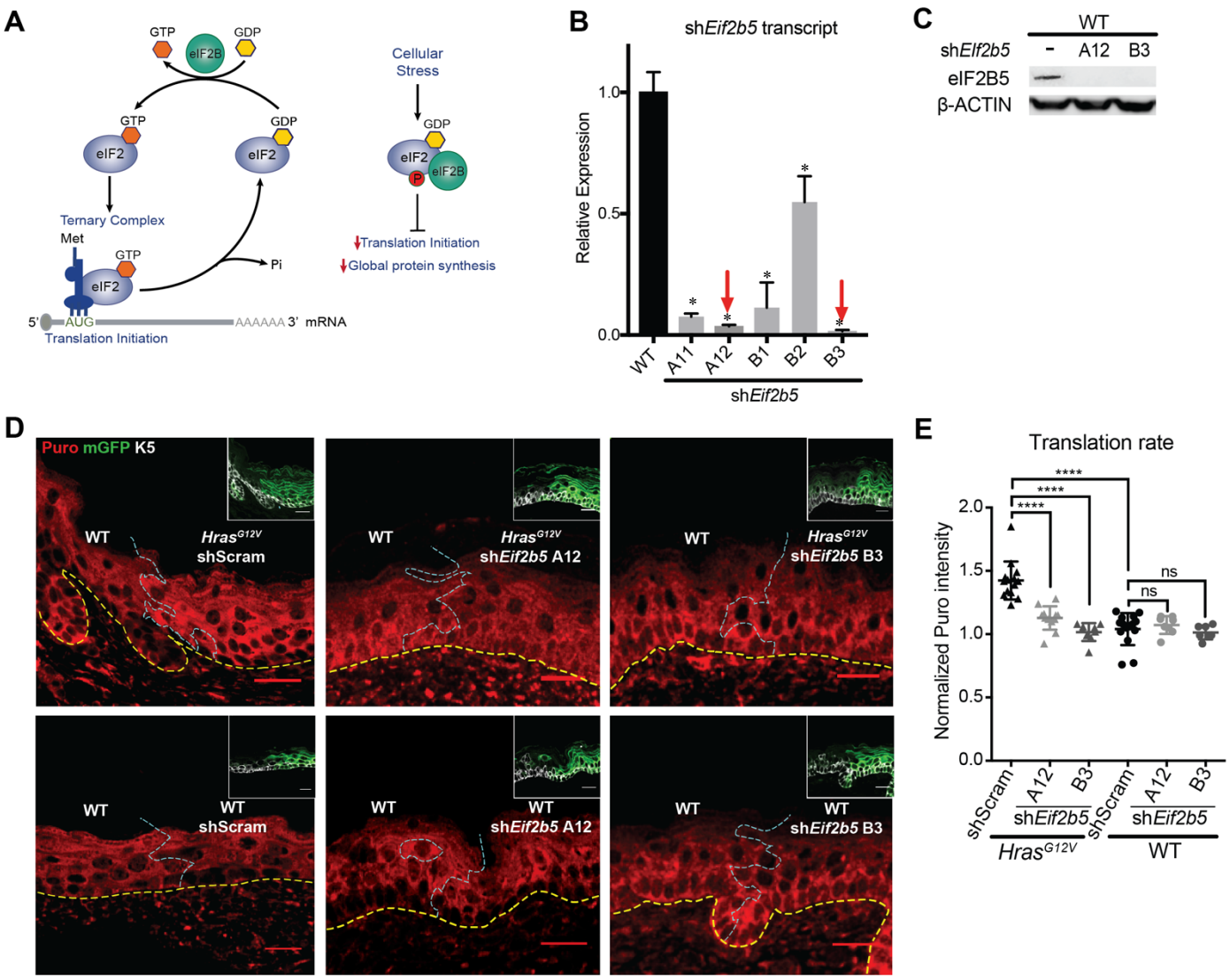


Figure 4.2 *Hras^{G12V}* translation upregulation is mediated by eIF2B5

A) Role of eIF2B complex in translation initiation and inhibitory regulation of eIF2B by eIF2α phosphorylation.

B) mRNA expression of *Eif2b5* in WT keratinocytes transduced with shScram or *Eif2b5* targeting shRNAs. Two shRNAs that induced strongest transcript depletion (red arrows) were used for functional studies *in vivo*. (*:P-value<0.001)

C) Representative western blot of EIF2B5 in WT keratinocytes transduced with two most efficient shRNAs targeting *Eif2b5.*

D-E) Representative immunofluorescence staining **(D)** and quantification **(E)** of puromycin-injected E18.5 animals for incorporation of puromycin (red) in IFE basal cells (K5, white, inset) of transduced clones (mGFP, green, inset), normalized to neighboring untransduced basal cells (K5+mGFP-). Yellow dashed line marks basement membrane, and blue dashed line marks border of transduced clone. Each data point represents one imaging field containing transduced and untransduced epidermis. 3 animals were assessed per condition. Scale bars, 25 µm. (****:P-value<0.0001; ns=not significant)

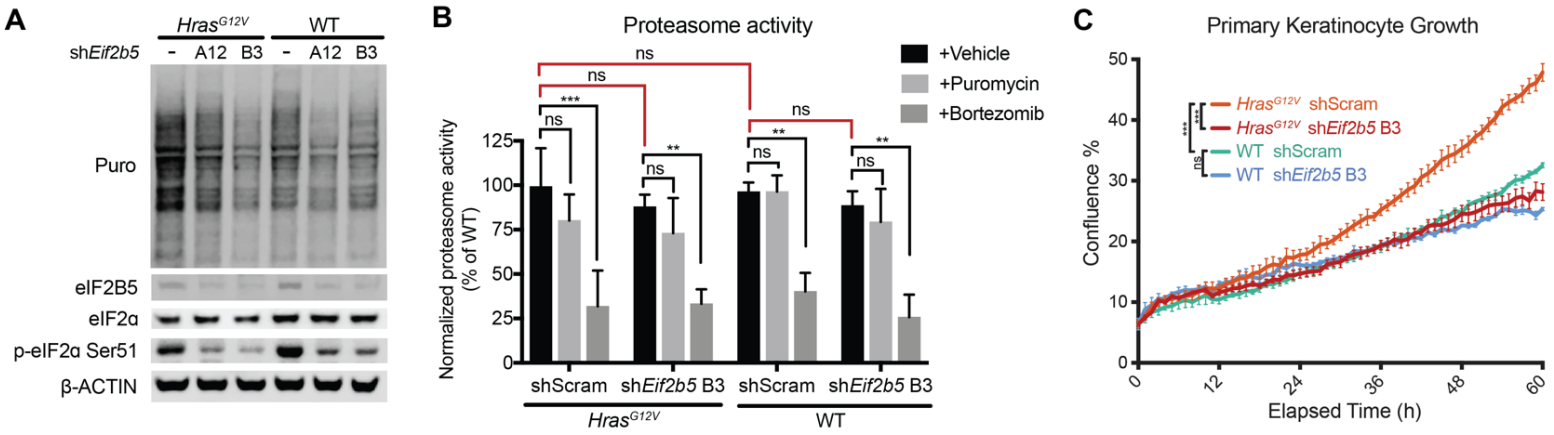


Figure 4.3 Cultured primary keratinocytes phenocopy *in vivo* epidermal basal cells

A) Representative western blot of puromycin incorporation (Puro) following 30 min puromycin incubation in primary keratinocytes transduced with control shRNA or sh*Eif2b5*.

B) Proteasome activity was evaluated by measuring chymotrypsin-like activity in primary keratinocytes with vehicle (DMSO), puromycin, or bortezomib treatment. Activity is expressed as percentage of vehicle-treated WT activity. Statistics based on 3 biological replicates. (**:P-value<0.01; ***:P-value<0.001; ns=not significant)

C) Growth of transduced primary keratinocytes as measured by live cell imaging of percentage confluence in culture dish. (***:P-value<0.001; ns=not significant)

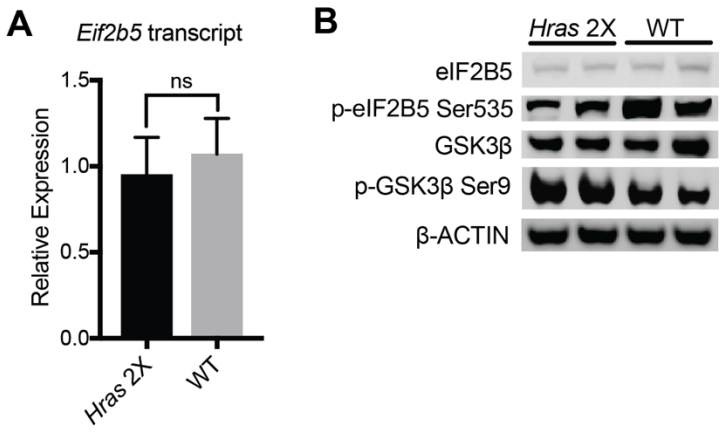


Figure 4.4 *Hras^{G12V}* regulation of eIF2B5

A) mRNA expression analysis by quantitative PCR of *Eif2b5* in E18.5 *Hras^{G12V}* and WT basal cells. N=3 animals/condition. (ns=not significant)

B) Representative western blot of GSK3β, p-GSK3β, EIF2B5, and phospho-EIF2B5 in *Hras^{G12V}* and WT basal cells.

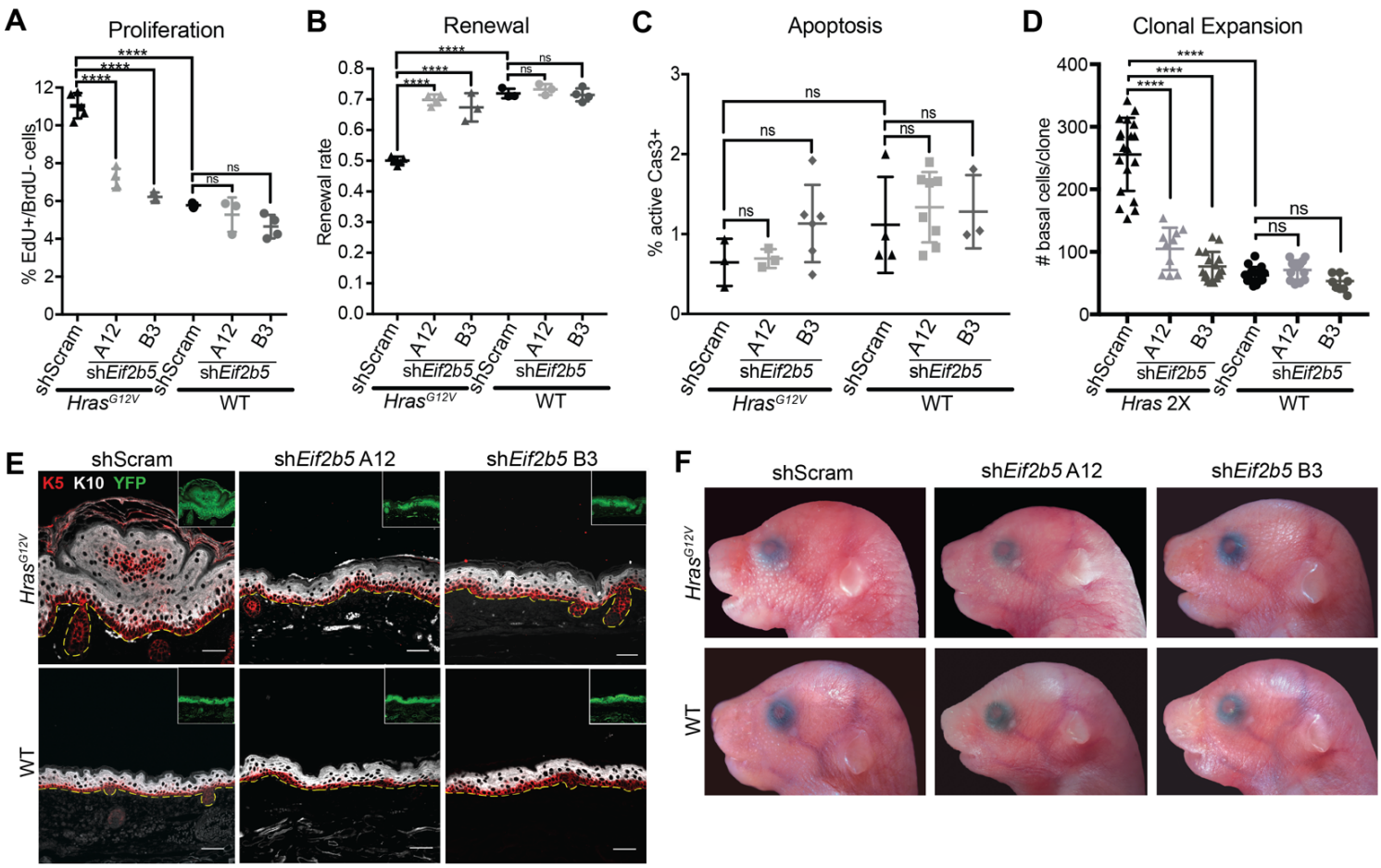


Figure 4.5 *Hras^{G12V}* progenitor cell behaviors and tissue growth are dependent on eIF2B5

A) Quantification of proliferation rate in transduced IFE basal cells nucleoside incorporation. *Hras^{G12V}* or WT epidermis is transduced with control or sh*Eif2b5* shRNA. Each data point represents an individual animal. Approx. 100 basal cells were scored per animal per condition. (****:P-value<0.0001; ns=not significant)

B) Quantification of EdU/BrdU pulse-chase renewal assay in transduced epidermal basal cells. P(renewal) = (# of EdU+/BrdU-/K10- daughter cells) / (total # of EdU+/BrdU- daughter cells). *Hras^{G12V}* or WT epidermis is transduced with control or sh*Eif2b5* shRNA. Each data point

represents an individual animal. Approx. 100 cell divisions were scored per animal per condition. (****:P-value<0.0001; ns=not significant)

C) Quantification of apoptosis by flow cytometry for activated Caspase 3 in E18.5 epidermis transduced with control shRNA or sh*Eif2b5*. Each data point represents an individual animal. (ns=not significant)

D) Quantification of basal cell numbers per clone in E18.5 epidermis. Each data point represents a single clone. Three animals were assessed per condition. (****:P-value<0.0001; ns=not significant)

E) Representative immunofluorescence staining of keratin 5 (K5, red) and keratin 10 (K10, white) in WT and $Hras^{G12V}$ E18.5 epidermis transduced with control or sh*Eif2b5* shRNA. Cre reporter YFP (green) marks the transduced epidermis (inset). Dashed line indicates basement membrane. Scale bars, 50 μm.

F) Gross skin morphology of E18.5 $Hras^{G12V}$ and WT mice transduced with control shRNA or sh*Eif2b5*.

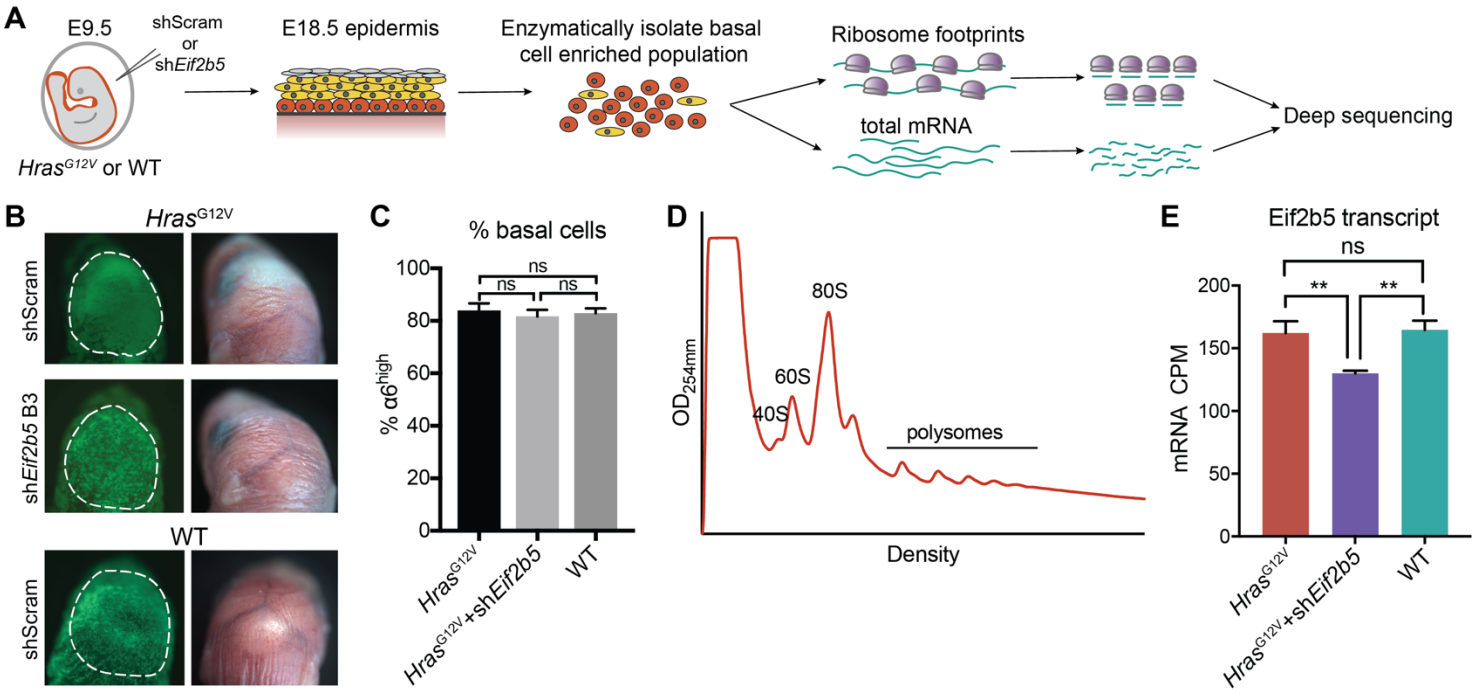


Figure 4.6 ***In vivo*** **basal cell ribosome profiling**

A) Schematic of *in vivo* basal cell ribosome profiling strategy. Transduced epidermis is enzymatically digested at E18.5 to yield a basal cell enriched population for profiling.

B) Fluorescence and bright field imaging of well-transduced (marked by GFP) E18.5 headskin. Dashed line marks area processed by enzymatic digestion to isolate basal cells.

C) Flow cytometry quantification of percentage basal cells, marked by high integrin α6 expression, after enzymatic digestion of epidermis. (ns=not significant)

D) Polysome profile of WT basal cells isolated by enzymatic digestion in presence of cycloheximide (CHX) translation inhibitor.

E) *Eif2b5* transcript depletion is observed in total mRNA libraries from basal cells transduced with sh*Eif2b5* lentivirus. Statistics based on 3 biological replicates. (**:P-value<0.01; ns=not significant)

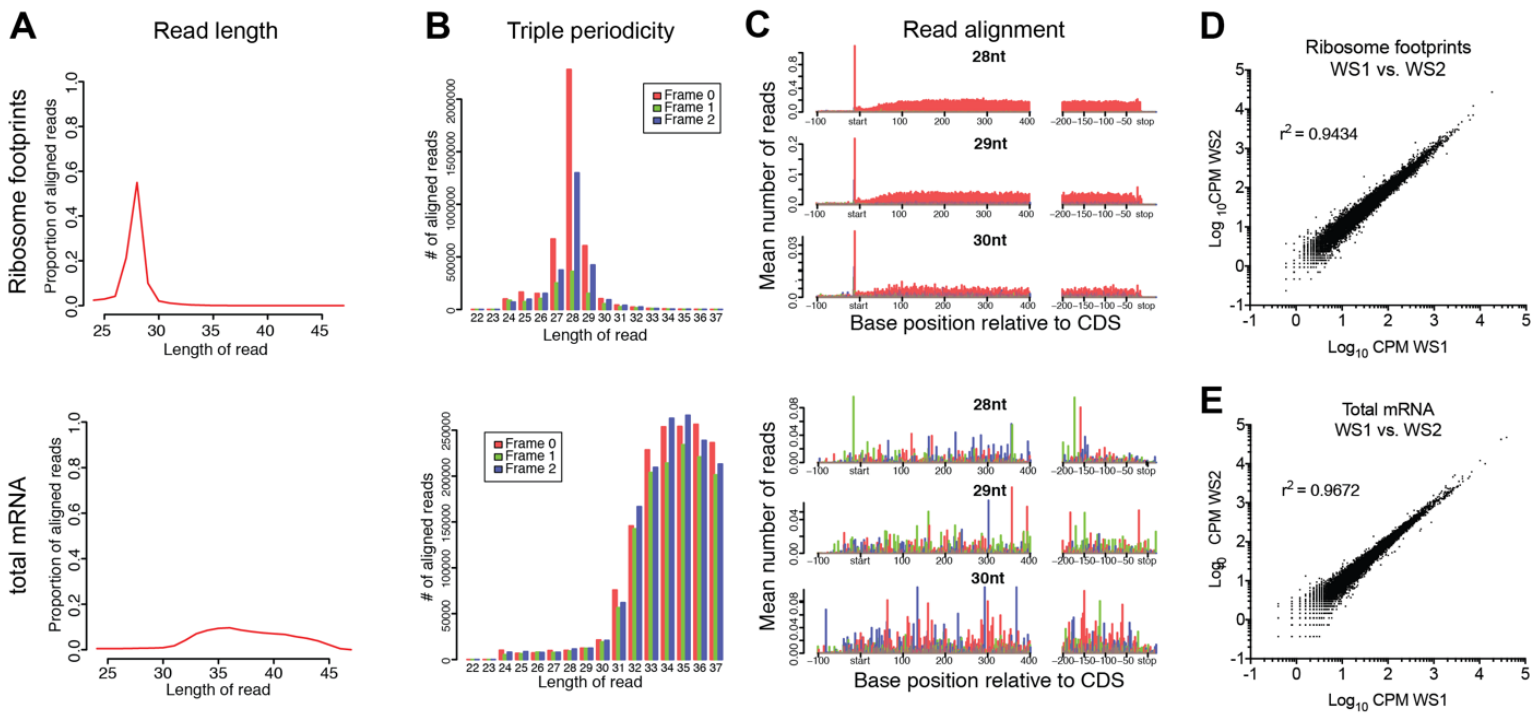


Figure 4.7 ***In vivo*** **ribosome profiling generates high quality, reproducible libraries**

A-C) Representative **(A)** read length, (**B)** reading frame, and **(C)** read alignment distributions for ribosome footprint and total RNA libraries. Ribosome footprint libraries are enriched for 28nt reads which are in frame with the start codon (Frame 0, in red) and distributed along the entire length of the coding sequence (CDS).

D-E) Representative plots of CPM correlation in **(D)** ribosome footprint and (**E)** total mRNA libraries for independent biological replicates. *In vivo* basal cell ribosome profiling strategy results in highly reproducible quantifications. Pearson coefficient used to evaluate replicate correlation.

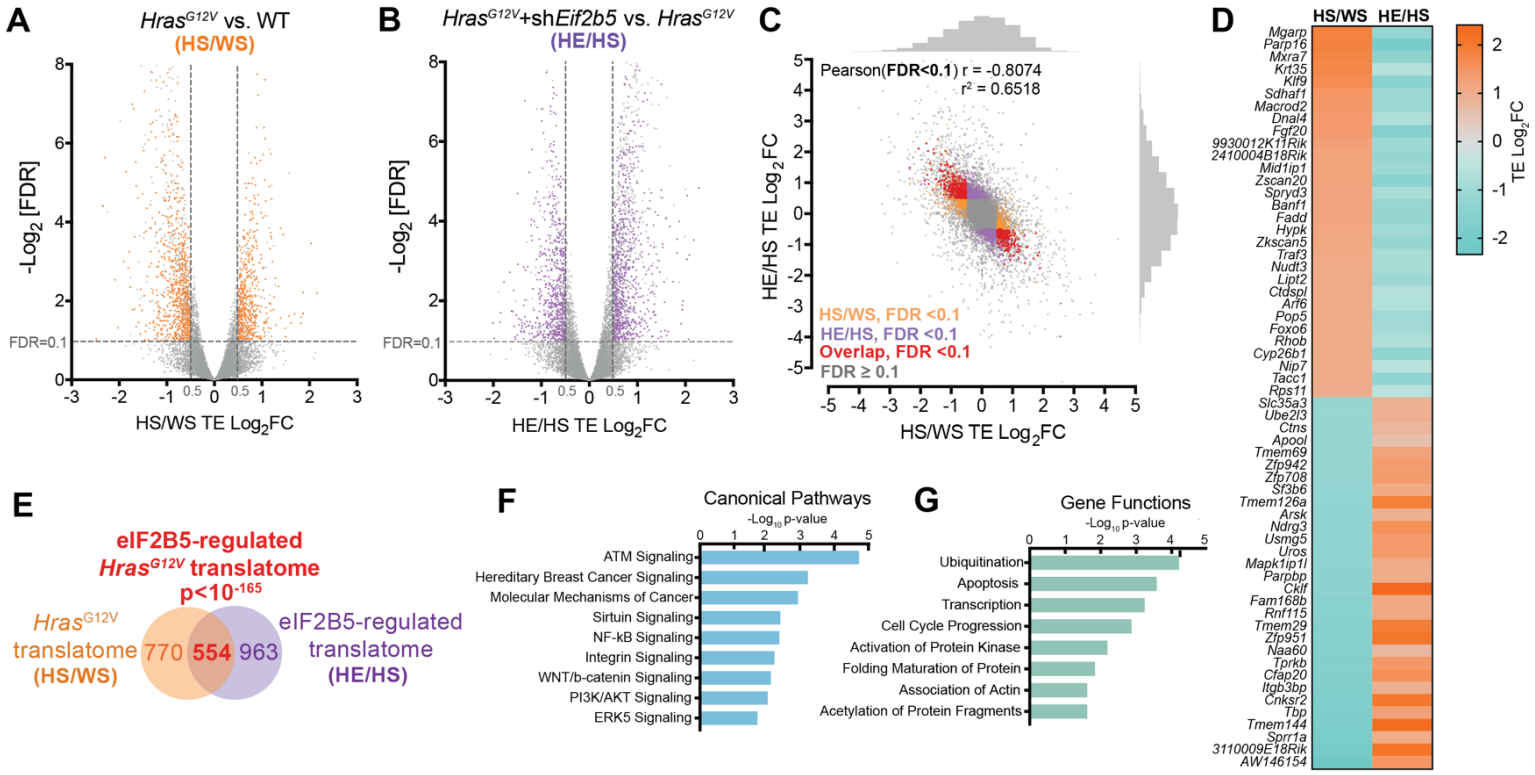


Figure 4.8 eIF2B5 regulates translation of a specific subset of oncogenic mRNAs

A-B) Volcano plots of translation efficiency (TE) changes in E18.5 basal cells comparing **(A)** *Hras*^{G12V}+shScram (HS) with WT+shScram (WS) and **(B)** *Hras*^{G12V}+sh*Eif2b5* (HE) with *Hras*^{G12V}+shScram (HS). Significant genes (colored) have Log_2TE fold change>0.5, FDR<0.1 (dashed lines) by Xtail analysis and insignificant transcriptional changes by EdgeR analysis (FDR>0.1 or Log_2FC<0.5). Statistics are based on 3 biological replicates.

C) Comparison of genes with significant translation efficiency changes in **(A)** (HS/WS; in orange) and **(B)** (HE/HS; in purple) reveal strong negative correlation and overlap (red). The overlapping gene set comprises the eIF2B5-regulated *Hras*^{G12V} translatome. Statistics for correlation of genes with significant translation efficiency changes using Pearson correlation coefficient.

(D) Heatmap of top 30 translation efficiency (TE) up- and down-regulated genes in *Hras*^{G12V}+shScram vs. WT+shScram (HS/WS) basal cells and corresponding TE changes in *Hras*^{G12V}+sh*Eif2b5* vs. *Hras*^{G12V}+shScram (HE/HS) basal cells.

E) The eIF2B5-regulated *Hras*^{G12V} translatome (red) exhibits significant overlap between HS/WS and HE/HS translation efficiency analyses. Statistics for gene overlap significance using hypergeometric test.

F-G) Ingenuity pathway analysis of overlapping genes for enriched (**F)** canonical pathways and **(G)** gene functions.

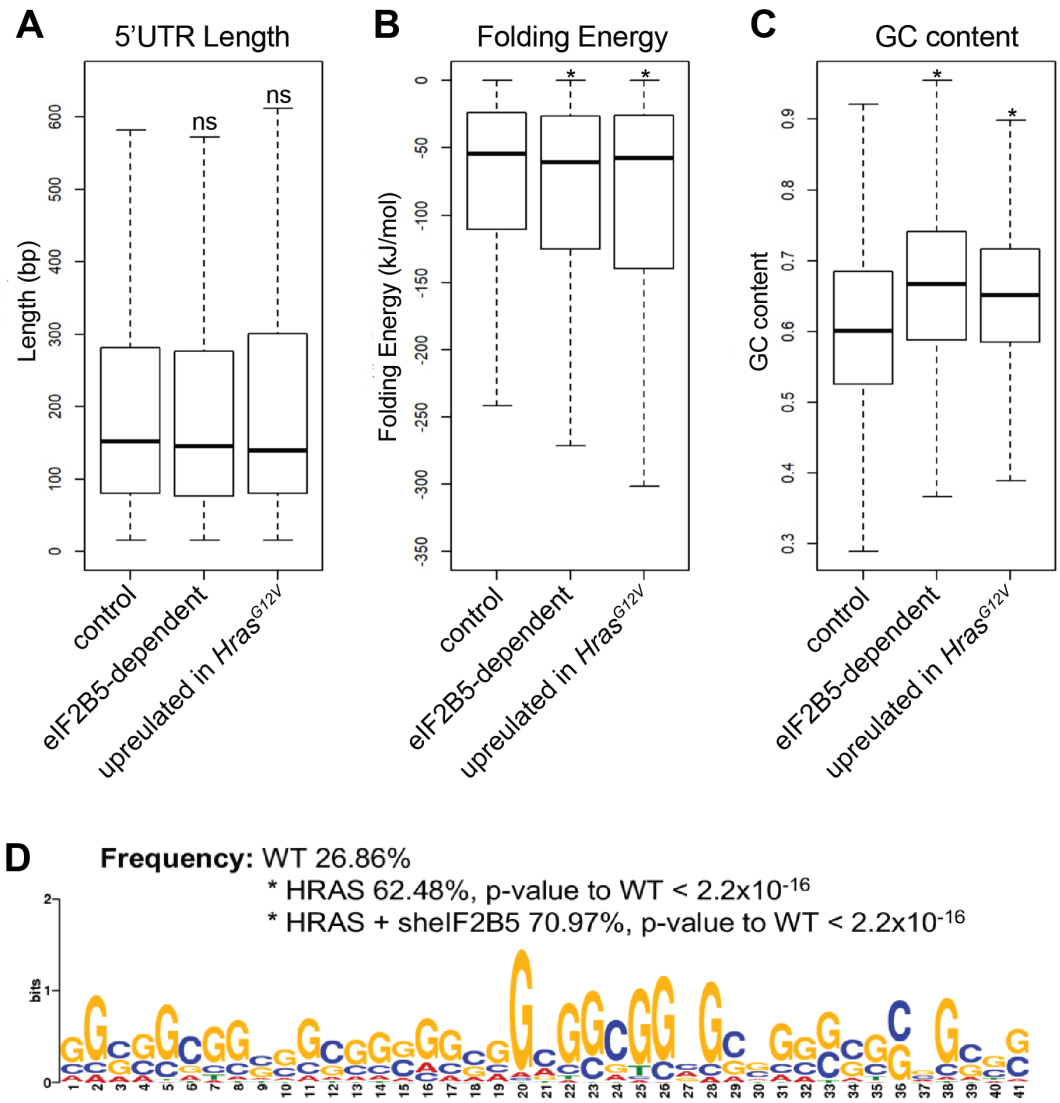


Figure 4.9 *Hras*^{G12V} and eIF2B5 mRNA specific translation is associated with a functional guanine-rich *cis*-regulatory element

A-C) Length **(A)**, folding energy **(B),** and GC content **(C)** of 5'UTRs of mRNAs that are translationally dependent on eIF2B5 or upregulated by *Hras*^{G12V} activation in comparison to entire the mouse genome (control). (*p<0.05; ns=not significant)

D) The guanine-rich translational element (GRTE) is enriched in the 5' UTRs of Hras^{G12V} and eIF2B5 translationally regulated mRNAs compared to all other 5' UTRs genome-wide.

Table 4.1 Regulators of *Hras*^{G12V} progenitor proliferation within translation machinery

Candidates for proliferation regulation as identified by DESeq2 analysis of shRNA enrichment in non-dividing (EdU-) relative to the dividing (EdU+) basal progenitors. Positive fold-change value indicates enrichment in the EdU- population of shRNAs targeting the gene.

Positive proliferation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Rpl34	7	0	3.88664922
2	Eif3i	6	0	3.83136936
3	Rpl18a	6	0	3.76944919
4	Rpl10	6	0	3.60658495
5	Rpl14	5	0	4.10118548
6	Eif4a1	5	0	3.8520461
7	Eif5b	5	0	3.73075048
8	Rps19	4	0	4.6379763
9	Rpl39l	4	0	4.37236479
10	Rpl38	4	0	4.31505814
11	Rpl18	4	0	4.2960013
12	Rps4x	4	0	4.25733034
13	Rpl4	4	0	4.11008752
14	Rpsa	4	0	3.91399836
15	Rps6ka4	4	0	3.90041221
16	Rps3	4	0	3.86123828
17	Rpl15	4	0	3.84852414
18	Rpl21	4	0	3.7996577
19	Rps13	4	0	3.79150606
20	Rpl9	4	0	3.78677927
21	Rps5	4	0	3.74679186
22	Rps3a	4	0	3.7147863
23	Rpl27	4	0	3.5669342
24	Eif4a3	4	0	3.54481123
25	Rps15a	4	0	3.33439254
26	Rps23	4	0	3.33335393
27	Rplp0	4	0	3.32758691
28	Eif4e2	4	0	2.72937478
29	Rps10	4	0	2.08145882
30	Eif4e	3	0	4.83992268
31	Rpl23a	3	0	4.52332061
32	Rpl24	3	0	4.38233826
33	Rpl5	3	0	4.37632243
34	Rpl35	3	0	4.35346176
35	Rpl19	3	0	4.3499516
36	Rpl6	3	0	4.19086564
37	Rps7	3	0	4.1676922
38	Eif3a	3	0	4.15589731
39	Qars	3	0	4.11709834
40	Eif4ebp3	3	0	4.10188194

41	Rpl37a	3	0	4.02446196
42	Rplp1	3	0	4.01027768
43	Rpl36a	3	0	3.956055
44	Rpl30	3	0	3.90974904
45	Rpl11	3	0	3.90758467
46	Eif3c	3	0	3.86592676
47	Rpl36	3	0	3.84761292
48	Rps27	3	0	3.76043967
49	Rpl29	3	0	3.72556767
50	Rps11	3	0	3.65963846
51	Rps27a	3	0	3.60268659
52	Rps6	3	0	3.56041715
53	Rps6ka2	3	0	3.54941825
54	Rpl12	3	0	3.54862715
55	Eif4g2	3	0	3.54427867
56	Rpl39	3	0	3.54145874
57	Rpl13	3	0	3.48601766
58	Eif3b	3	0	3.47349506
59	Rps2	3	0	3.34313445
60	Rpl8	3	0	3.21926587
61	Rpl35a	3	0	3.09134317
62	Rps6ka5	3	0	2.89203502
63	Eef1g	3	0	2.40776035
64	Eif2s2	2	0	5.2299704
65	Rps6kc1	2	0	5.11052105
66	Rplp2	2	0	4.86871732
67	Rps19bp1	2	0	4.62419625
68	Rpl17	2	0	4.58917049
69	Rps16	2	0	4.58148089
70	Wars	2	0	4.53209187
71	Eif5	2	0	4.5104917
72	Eif4ebp1	2	0	4.48374801
73	Aimp2	2	0	4.33631797
74	Eif4g1	2	0	4.3258673
75	Kars	2	0	4.31408515
76	Rps17	2	0	4.27112881
77	Rpl27a	2	0	4.2625012
78	Rps8	2	0	4.20709826
79	Rpl13a	2	0	4.15829147
80	Rps20	2	0	4.11262912
81	Rps28	2	0	4.1017119
82	Eif2s3y	2	0	3.98095667
83	Eif4e3	2	0	3.9410493
84	Mars	2	0	3.91342344
85	Eif3h	2	0	3.90997278
86	Eif3g	2	0	3.84212046
87	Rpl26	2	0	3.7440536
88	Etf1	2	0	3.73891602
89	Eef2k	2	0	3.65894987
90	Eif3d	2	0	3.6038958

91	Rps24	2	0	3.58643954
92	Rps14	2	0	3.3732769
93	Rps25	2	0	3.35290158
94	Rpl7l1	2	0	3.23407053
95	Eif4ebp2	2	0	3.22883754
96	Rsl24d1	2	0	3.21918161
97	Farsa	2	0	3.15013576
98	Eif2b5	2	0	3.07370739
99	Eif2s3x	2	0	3.03309835
100	Eif1ay	2	0	2.72373808
101	Eef1a1	2	0	2.34143382
Negative proliferation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Eif2a	0	3	-2.5761438

Table 4.2 Regulators of *Hras*^{G12V} progenitor renewal within translation machinery

Candidates for differentiation regulation as identified by DESeq2 analysis of shRNA enrichment in the basal progenitor relative to the differentiated suprabasal compartment. Positive fold-change value indicates basal enrichment of shRNAs targeting the gene.

Positive differentiation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Nars	3	0	4.29303765
2	Mars	2	0	5.45269238
3	Tars	2	0	4.48466265
4	Eprs	2	0	4.16472229
5	Rpl34	2	0	4.02529232
6	Eif3c	2	0	4.0227853
7	Eif4ebp3	2	0	3.68550017
8	Rpl10	2	0	3.60622888
9	Rps19	2	0	3.54545722
10	Eif3a	2	0	3.53765971
11	Eif3h	2	0	3.26356425
12	Rps5	2	0	3.24650267
13	Kars	2	0	3.23753468
14	Eef1b2	2	0	3.150272
15	Eif2b5	2	0	2.8619166
Negative differentiation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Rps6kl1	0	2	-4.5169702
2	Rps26	0	2	-4.0239614
3	Rplp2	0	2	-3.8663313
4	Eif1b	0	2	-3.4722414
5	Eef2k	0	2	-3.3750622
6	Rps6ka5	0	2	-2.3220881
7	Eif2b1	0	2	-1.6885105
8	Aimp2	0	2	-1.6492974

Chapter 5 – eIF2B5-regulated FBXO32 drives *Hras*^{G12V} differentiation to restrain tumorigenesis

To identify the molecular mechanisms by which eIF2B5 drives *Hras*^{G12V} epidermal progenitor cell behaviors, we functionally dissected the eIF2B5 translatome for direct regulators of progenitor cell proliferation and differentiation. A shared mechanism that completely couples proliferation with differentiation would be problematic for tissues like the epidermis, which requires rapid baseline proliferation for its development and function (Fuchs and Raghavan, 2002). Therefore, we hypothesized that eIF2B5 co-regulates *Hras*^{G12V} progenitor cell behaviors through the translation of separate mRNA networks that independently drive either proliferation or differentiation. This segregation would allow the epidermis to dynamically adapt its cell fate choices without compromising its physiological need for frequent proliferation.

5.1 Oncogenic RAS-induced differentiation is driven by eIF2B5-regulated ubiquitination

To separate the eIF2B5-regulated oncogenic translatome into independent promoters of proliferation or differentiation, we utilized our *in vivo* functional screening strategy (Fig. 4.1C). We generated a lentivirus pool of 3607 shRNAs targeting the 554 eIF2B5-regulated oncogenic genes identified by ribosome profiling (Fig. 4.8E) (Moffat et al., 2006). E9.5 *Hras*^{G12V} embryos were transduced with the lentivirus pool at MOI << 1, and transduced epidermis was processed for sequencing at E18.5. Our screens identified 72 genes that specifically promoted proliferation and 40 genes that specifically promoted differentiation in *Hras*^{G12V} progenitor cells (Fig. 5.1A-C, Table 5.1, 5.2). Supporting the validity of our screens, negative regulators of p53, *Mdm2* and *Dnajb9*, were identified as top proliferation promoters (Fig. 5.1A) (Lee et al., 2014; Wade et al.,

2013). In our renewal screen, *Sox4* was a top renewal promoter, while peroxisome biogenesis factor *Pex16* was identified as a differentiation promoter, supporting the recent finding that peroxisome function is required for epidermal stratification (Fig. 5.1B) (Asare et al., 2017; Bergsland et al., 2006; Lourenço and Coffer, 2017).

Ingenuity pathway analysis revealed that, in addition to the expected mitotic cell division genes (Duronio and Xiong, 2013), proliferation-specific promoters were enriched for transcription factors (Fig. 5.1D). This finding is consistent with the transcriptional changes found in our ribosome profiling, where a large proportion of transcriptionally altered genes were upregulated in $Hras^{G12V}$ progenitor cells and rescued by *Eif2b5* depletion (Fig. 5.1F). In contrast to transcriptional control of cell proliferation, differentiation-specific promoters were enriched for genes involved in ubiquitination and protein metabolism (Fig. 5.1E). Specifically, shRNAs targeting ubiquitination genes from our screening pool showed strong bias towards inhibiting progenitor cell differentiation (Fig. 5.1G). Furthermore, 4 of the differentiation-specific ubiquitination genes contained our previously identified guanine-rich translational element in their 5'UTRs, which may indicate preferential translation mediated by eIF2B5 (Fig. 5.1H). These findings suggest the provocative idea that the epidermis, which relies on stochastic cell fate choice and frequent turnover, employs highly dynamic post-translational gene regulation to adapt cell fate choice to tissue needs or oncogenic stress (Mesa et al., 2017; Park et al., 2017; Rompolas et al., 2016).

5.2 eIF2B5-regulated FBXO32 drives RAS-induced differentiation

We focused on the differentiation arm of eIF2B5 progenitor cell regulation in order to investigate the growth-restrictive mechanisms behind epidermal oncogene tolerance. We hypothesized that translationally-controlled ubiquitination genes that specifically drive differentiation may represent a growth-suppressive signaling core within the oncogenic translation landscape. Amongst the eIF2B5-regulated ubiquitination genes that specifically promote *Hras*^{G12V} differentiation, we chose to further investigate *Fbxo32* (also known as *Mafbx*/*Atrogin1*). FBXO32 acts as the substrate-recognition subunit of the Skp1-Cullin1-Fbox (SCF) E3 ubiquitin ligase complex (Fig. S7C) (Zheng et al., 2016) and has been extensively studied in skeletal and cardiac muscle development, where it regulates muscle atrophy (Al-Yacoub et al., 2016; Bodine and Baehr, 2014; Gomes et al., 2001). While FBXO32 targets have not been extensively characterized, its known substrates include MyoD, KLF4, and c-Myc (Lagirand-Cantaloube et al., 2009; Mei et al., 2015; Zhou et al., 2017). In cancer, FBXO32 has separately been implicated in both tumor suppression and oncogenesis (Mei et al., 2015; Sahu et al., 2017; Zhou et al., 2017; 2016). The *Fbxo32* promoter is epigenetically repressed via methylation in esophageal, ovarian, and gastric cancer cell lines (Chou et al., 2010; Guo et al., 2015; 2014). In contrast, FBXO32-mediated ubiquitination of CtBP1 facilitates a transcriptional landscape that drives epithelial-mesenchymal transition in breast cancer cell lines (Sahu et al., 2017). However, its epidermal function and role as a stem cell regulator is unknown.

We began by verifying if FBXO32 is indeed regulated by eIF2B5. FBXO32 is specifically elevated at the protein level *in vivo* in *Hras*^{G12V} basal cells compared to WT, and *Eif2b5* depletion in *Hras*^{G12V} cells reduced FBXO32 protein without affecting *Fbxo32* transcript levels (Fig. 5.2A-B).

To examine the role of FBXO32 *in vivo*, we first tested all shRNAs targeting *Fbxo32* from our screening pool and identified two independent shRNAs that efficiently depleted *Fbxo32* transcript and protein (Fig. 5.3A-B). Strikingly, *Fbxo32* depletion completely rescued $Hras^{G12V}$ basal cell renewal rate to WT levels without altering $Hras^{G12V}$ hyperproliferation (Fig. 5.3C-D). This is the first demonstration that the two phenotypes downstream of RAS and eIF2B5 can be separated. Because FBXO32 only promotes $Hras^{G12}$ differentiation, our model of oncogene-induced differentiation as a growth-suppressive mechanism predicts FBXO32 to restrict clonal expansion and tissue growth. We depleted *Fbxo32* in individual $Hras^{G12V}$ basal cells at E9.5 and observed a significant increase in the number of basal cells per clone by E18.5 (Fig. 5.3E-F), indicating accelerated clonal expansion. Therefore, FBXO32-driven differentiation is necessary to limit $Hras^{G12V}$ clonal expansion. *Fbxo32* depletion in WT progenitors only had a small effect on renewal rate and did not significantly affect clonal expansion, demonstrating that eIF2B5-regulated differentiation via FBXO32 has oncogene-specificity in its effect size.

Next, we asked if the ubiquitin ligase activity of FBXO32 is necessary for its pro-differentiation function. To abrogate its ability to bind to SKP1 and form the SCF complex, we deleted the F-box domain (aa223-271) in FBXO32 ($FBXO32^{\Delta Fbox}$) (Fig. 5.4A) (Jin et al., 2004). Lentivirus co-expression of sh*Fbxo32* #2, targeting the 3'UTR of *Fbxo32*, with $Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$ ORF allowed us to deplete endogenous FBXO32 protein and replace it with exogenous wild type $FBXO32^{WT}$ or mutant $FBXO32^{\Delta Fbox}$ (Fig. 5.4B-D). *In vivo*, $Hras^{G12V}$ and WT progenitor cell differentiation was fully rescued by expression of $Fbxo32^{WT}$, while expression of $Fbxo32^{\Delta Fbox}$ resulted in only a modest differentiation increase (Fig. 5.4E). This suggests that FBXO32 ubiquitin ligase activity via the SCF complex is the primary driver of differentiation, but

deletion of the F-box domain may not fully abrogate SCF complex interaction, or FBXO32$^{\Delta Fbox}$ may have additional moonlighting functions that also promote differentiation. Proliferation rate remained unaffected across test conditions (Fig. 5.4F), demonstrating that the ubiquitin ligase function of FBXO32 only regulates differentiation. Furthermore, reflecting the growth-suppressive effect of differentiation drivers, rescue *Fbxo32^{WT}* rescue substantially suppressed *Hras^{G12V}* clonal expansion, while *Fbxo32$^{\Delta Fbox}$* expression resulted in a moderate decrease in clonal expansion (Fig. 5.4G).

Together, these studies establish translationally-regulated FBXO32 ubiquitin ligase function as necessary and sufficient to drive RAS-induced differentiation and suppress oncogenic growth.

5.3 FBXO32 drives differentiation to restrain RAS tumor initiation and growth

The ability of eIF2B5-mediated translation to co-regulate stem cell fate choice and proliferation suggests that it acts as an adaptive coordinator of tissue response to oncogenic insult. Post-embryogenesis, translational control may remain a critical mechanism for adjusting cell fate choice to limit progenitor pool expansion. A notable skin complication of Costello syndrome is the development of facial papillomas, which is phenocopied in our mouse model. While the majority of skin in *Hras^{G12V}* animals is tolerant to oncogene activation and do not form tumors, some permissive regions such as the muzzle eventually develop squamous papillomas (Beronja et al., 2013; Chen et al., 2009). We hypothesized that tumorigenesis reflects a failure of the renewal block in these permissive regions, and additional loss of differentiation could further exacerbate tumorigenesis. Therefore, we explored whether modulating the cell fate arm of the

eIF2B5-regulated translation program could disrupt stem cell equilibrium and disinhibit tumorigenesis. To specifically disrupt differentiation, we depleted *Fbxo32* in $Hras^{G12V}$ epidermis at E9.5 and tracked postnatal animals for long-term skin morphology changes. *Fbxo32*-depleted animals displayed significantly faster papilloma initiation and accelerated papilloma growth compared to $Hras^{G12V}$-activated animals alone (Fig. 5.5A-D). Furthermore, *Fbxo32*-depleted animals also exhibited increased tumor burden per animal (Fig. 5.5E). In keeping with our observations in embryonic epidermis, tumors from *Fbxo32*-depleted animals also had an elevated rate of progenitor cell renewal without changes in proliferation rate compared to $Hras^{G12V}$-activated tumors alone (Fig. 5.5F-G). These findings indicate that specific ablation of the cell fate axis of translational stem cell regulation hinders the skin's ability to manage oncogenic lesions, resulting in unrestrained tumor formation and growth. Since FBXO32 is sufficient to promote $Hras^{G12V}$ progenitor cell differentiation in embryonic epidermis (Fig. 5.4E), we further asked if FBXO32 is also sufficient to limit tumorigenesis in the adult epidermis. To test this, we simultaneously depleted endogenous *Fbxo32* and overexpressed $Fbxo32^{WT}$ ORF, which entirely rescued the acceleration of $Hras^{G12V}$ tumorigenesis seen upon *Fbxo32* depletion (Fig. 5.5H). Together, these studies demonstrate that translationally coordinated progenitor cell differentiation is necessary and sufficient to restrain tumor initiation and growth.

5.4 Concurrent manipulation of progenitor cell behaviors downstream of eIF2B5

Since FBXO32 is able to limit oncogenic growth by driving only differentiation, we asked if FBXO32 is able to rescue the pro-renewal phenotype observed with *Eif2b5* depletion to produce a maximal anti-growth effect. Simultaneous *Eif2b5* depletion in conjunction with *Fbxo32*

overexpression should exploit the anti-proliferative axis of eIF2B5 loss while preserving the pro-differentiation function of FBXO32. Lentivirus co-expression of sh*Eif2b5* B3 with *Fbxo32* ORF restored FBXO32 protein during *Eif2b5* depletion (Fig. 5.6A-B). By E18.5, many transduced clones were completely differentiated out of the basal cell population into suprabasal layers (Fig. 5.6C), such that we were unable to directly assay progenitor cell proliferation and renewal rates. Concurrent manipulation of both genes also resulted in substantial loss of $Hras^{G12V}$ clonal expansion at E18.5 (Fig. 5.6D). Given the growth suppression observed at E18.5, we next examined the effect of concurrently targeting progenitor cell renewal and proliferation on tumorigenesis. Compared to *Eif2b5* depletion alone, we found a striking inhibition of $Hras^{G12V}$ tumor initiation (Fig. 5.6E), slower tumor growth (Fig. 5.6F-H), and lower tumor burden per animal (Fig. 5.6I), demonstrating the additive anti-growth effect of inhibiting both proliferation and renewal.

Surprisingly, although depletion of *Eif2b5* alone resulted in a significant reduction in clonal expansion at E18.5 (Fig. 5.6D), these animals had accelerated tumor initiation in comparison to $Hras^{G12V}$ animals, on par with what was observed with depletion of *Fbxo32* (Fig. 5.5A, 5.6E). In contrast, *Eif2b5* depletion greatly reduced the rate of $Hras^{G12V}$ tumor growth and number of tumors per animal (Fig. 5.6F-H). Since eIF2B5 is a dual regulator of both progenitor cell renewal and proliferation, which have contrasting effects on overall tissue growth, it may have a complex role in tumor initiation and growth. Furthermore, the axes of progenitor cell behaviors may be shifted in the adult epidermis during hyperplastic growth to bias the significance of one behavior over another in contributing to tumorigenesis. Our *Eif2b5*-depletion studies suggest that despite differences in proliferation rate, tumor initiation is primarily a

function of progenitor cell renewal rate, whereas post-initiation, tumor growth is highly dependent on proliferation rate.

Summary

Using *in vivo* functional screens, we segregated the eIF2B5-regulated *Hras*^{G12V} translatome into distinct regulators of progenitor cell proliferation and differentiation, allowing us to probe each stem cell behavior separately. We found the proliferation promoters were enriched for transcription factors, while differentiation promoters were enriched for ubiquitination genes. We identified E3 ubiquitin ligase FBXO32 as an eIF2B5-regulated differentiation driver that mediates epidermal tolerance to oncogene activation. As a result, FBXO32 is necessary and sufficient to restrain *Hras*^{G12V} tumor initiation and growth. Simultaneous inhibition of both proliferation and renewal, through depletion of *Eif2b5* and differentiation rescue with FBXO32, resulted in a substantial tumor suppression. Together, our studies demonstrate that progenitor cell proliferation and fate choice are the key determinants of aberrant growth and are functionally coordinated through translation regulation to restrain tumorigenesis.

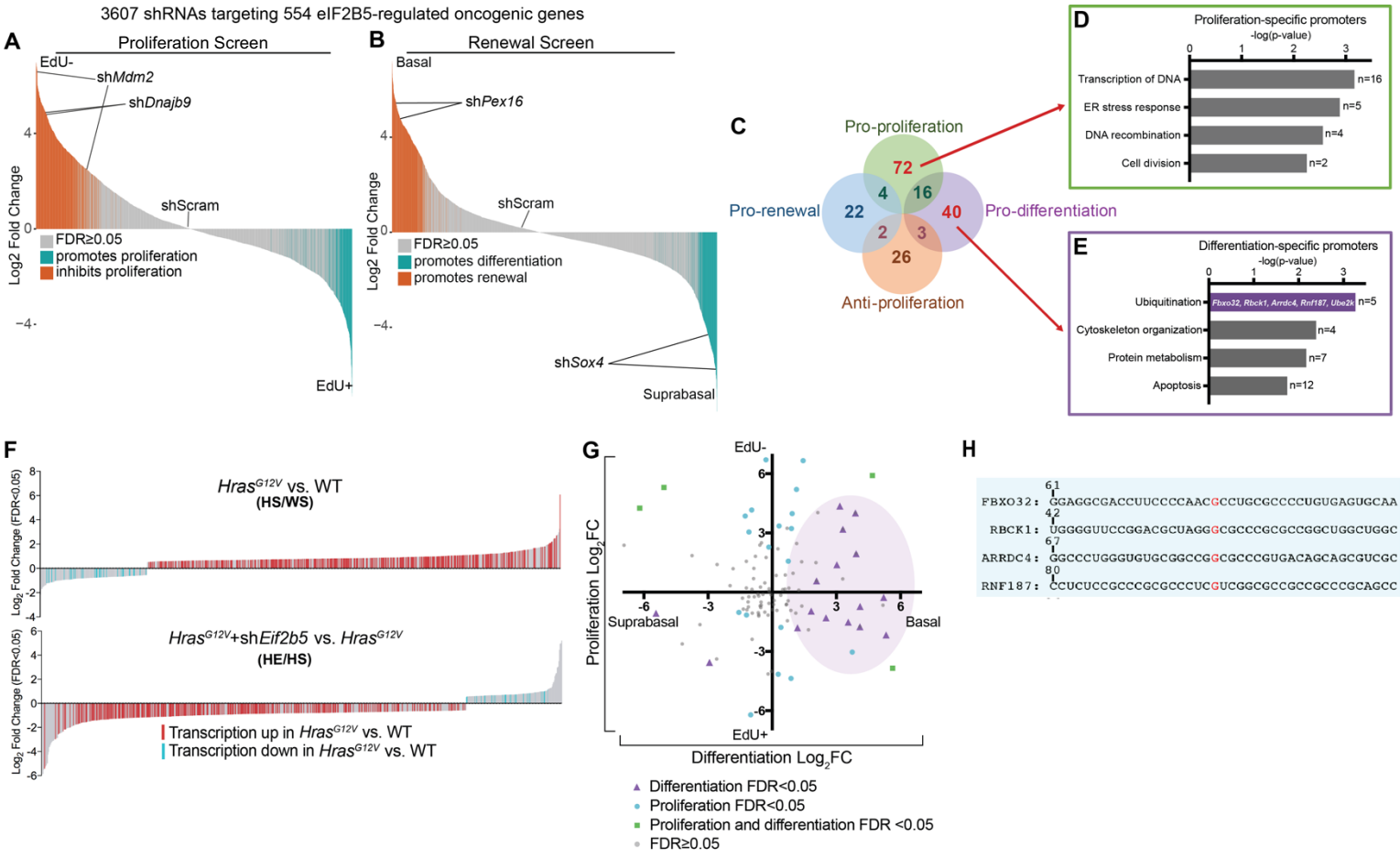


Figure 5.1 eIF2B5 regulates oncogenic translation of distinct gene sets that uniquely promote proliferation or differentiation

A-B) Needle plots of *in vivo* **(A)** proliferation and **(B)** renewal screens using a lentivirus pool of 3607 shRNAs targeting 554 eIF2B5 translationally-regulated oncogenic genes. Statistics are based on 3 biological replicates (DESeq2 FDR<0.05).

C) Genes are classified as renewal or proliferation regulators if at least two shRNAs are significantly changed with the same directionality.

D-E) Ingenuity pathway analysis of pro-proliferation **(D)** and pro-differentiation **(E)** gene sets for enriched gene functions.

F) Needle plots of significantly altered transcripts ($Log_2FC>0.5$, FDR<0.05) from EdgeR analysis of total mRNA libraries. Genes that are transcriptionally upregulated (red) or downregulated (blue) in *Hras*^{G12V} compared to WT basal cells is rescued by *Eif2b5* depletion. Statistics based on 3 biological replicates.

G) Individual shRNAs targeting all ubiquitination genes in the screening pool. Purple shading indicates clustering of significantly altered shRNAs towards the pro-renewal axis.

H) The guanine-rich translational element identified in Fig. 4.9D is enriched in the 5'UTRs of ubiquitination regulators identified as differentiation-specific promoters. Red lettering indicates consensus guanine residue at 20th position of the translational element.

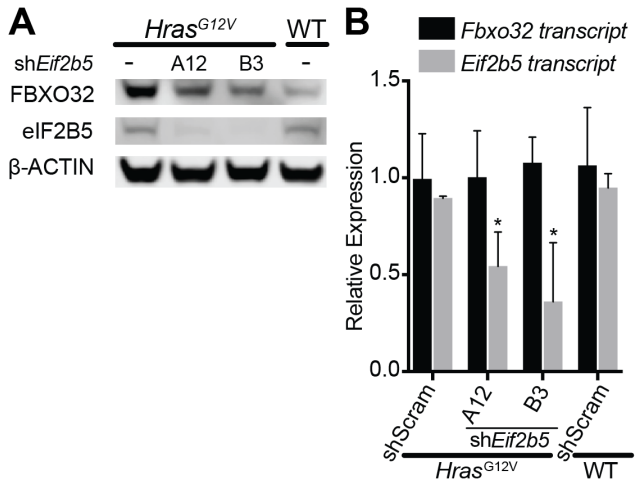


Figure 5.2 FBXO32 is translationally regulated by eIF2B5

A) Representative western blot of FBXO32 in *Hras*^{G12V} and WT basal cells with control and sh*Eif2b5* knockdown.

B) mRNA expression analysis by quantitative PCR of *Fbxo32 and Eif2b5* in E18.5 basal cells. n=3 animals/condition.

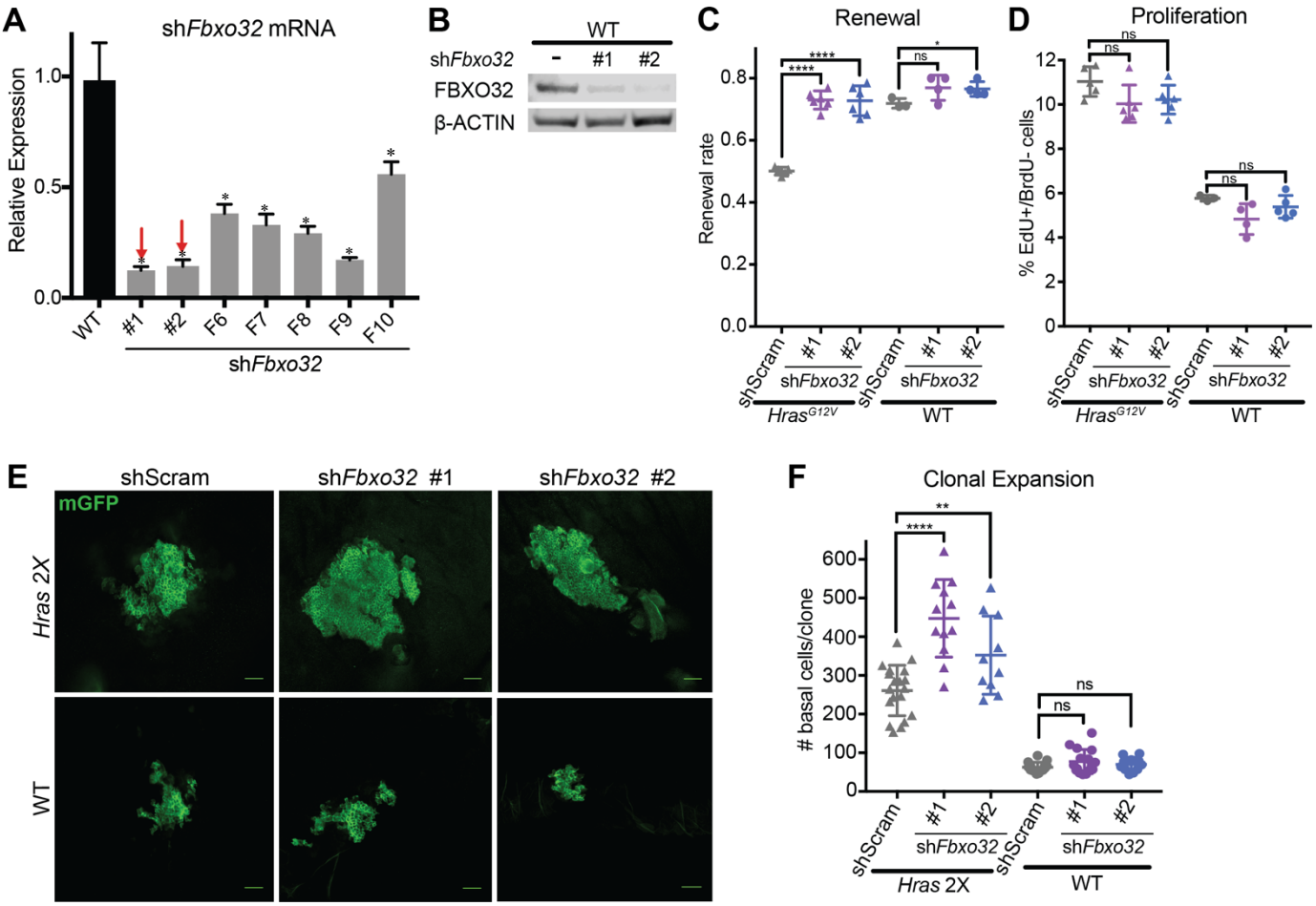


Figure 5.3 FBXO32 drives RAS-induced differentiation to suppress clonal expansion

A) mRNA expression of *Fbxo32* in WT keratinocytes transduced with shScram or *Fbxo32* targeting shRNAs. Two shRNAs that induced strongest transcript depletion (red arrows) were used for functional studies *in vivo*. (*:p-value<0.001)

B) Representative western blot of FBXO32 in WT keratinocytes transduced with two most efficient shRNAs targeting *Fbxo32.*

C-D) Quantification of (**C)** renewal rate and **(D)** proliferation rate in IFE basal cells transduced with control shRNA or sh*Fbxo32.* Approx. 100 cell divisions (for renewal assay) or 100 basal cells

(for proliferation assay) were scored per animal per condition. (*:P-value<0.05; ****:P-value<0.0001; ns=not significant).

E-F) Representative immunofluorescence staining **(E)** and quantification **(F)** of basal cell numbers per clone in E18.5 epidermis with control or sh*Fbxo32* knockdown. Transduced cells are marked by mGFP. Each data point represents a single clone. Three animals were assessed per condition. (**:P-value<0.01; ****:P-value<0.0001; ns=not significant).

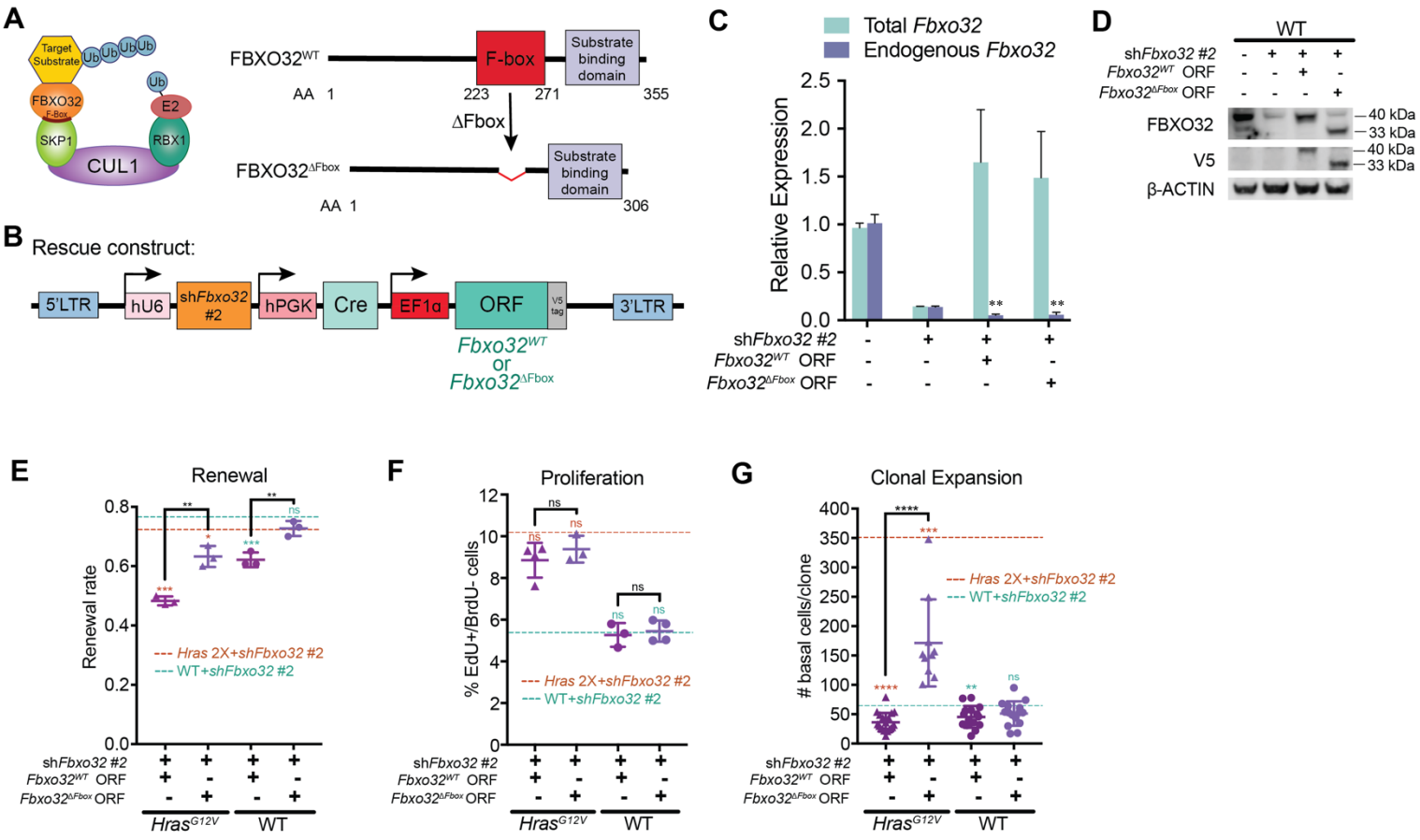


Figure 5.4 FBXO32 ubiquitin ligase function drives RAS-induced differentiation to restrain clonal expansion

A) The Skp1-Cullin-Fbox (SCF) E3 ubiquitin ligase complex requires interaction of SKP1 with the F-box domain of FBXO32 to acquire substrate specificity. Deletion of 49aa F-box domain in *Fbxo32* generates $Fbxo32^{\Delta Fbox}$ ORF.

B) Lentivirus rescue construct co-expresses Cre to activate oncogenic $Hras^{G12V}$, sh*Fbxo32* #2 to deplete endogenous *Fbxo32*, and V5-tagged rescue ORF ($Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$) driven by strong constitutive promoter EF1α.

C) mRNA expression of endogenous and total *Fbxo32* transcript in WT keratinocytes transduced with sh*Fbxo32* #2 + $Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$ ORF. Endogenous transcript is detected using primers against the 3'UTR, and total transcript is detected using primers against the CDS between exons 3 and 5. (**:p-value<0.001)

D) Representative western blot in WT keratinocytes of wild type (40kDa) or mutant (33kDa) FBXO32 and V5 tag upon shRNA depletion of *Fbxo32* and rescue with $Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$ ORF.

E-F) Quantification of **(E)** renewal rate and **(F)** proliferation rate in IFE basal cells transduced with sh*Fbxo32* co-expressing $Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$ ORF. Each data point represents an individual animal. Orange and green dashed lines represent average clone size of sh*Fbxo32* #2 knockdown in $Hras^{G12V}$ and WT epidermis, respectively. Colored asterisks represent significant differences with dataset indicated by colored dashed lines. Approx. 100 cell divisions (for renewal assay) or 100 basal cells (for proliferation assay) were scored per animal per condition. (*:P-value<0.05; **:P-value<0.01; ***:P-value<0.001; ns=not significant).

G) Quantification of basal cell numbers per clone in E18.5 epidermis transduced with sh*Fbxo32* co-expressing $Fbxo32^{WT}$ or $Fbxo32^{\Delta Fbox}$ ORF. Each data point represents a single clone. Three animals were assessed per condition. Orange and green dashed lines represent average clone size of sh*Fbxo32* #2 knockdown in $Hras^{G12V}$ and WT epidermis, respectively. Colored asterisks represent significant differences with dataset indicated by colored dashed lines. (**:P-value<0.01; ***:P-value<0.001**;** ****:P-value<0.0001; ns=not significant).

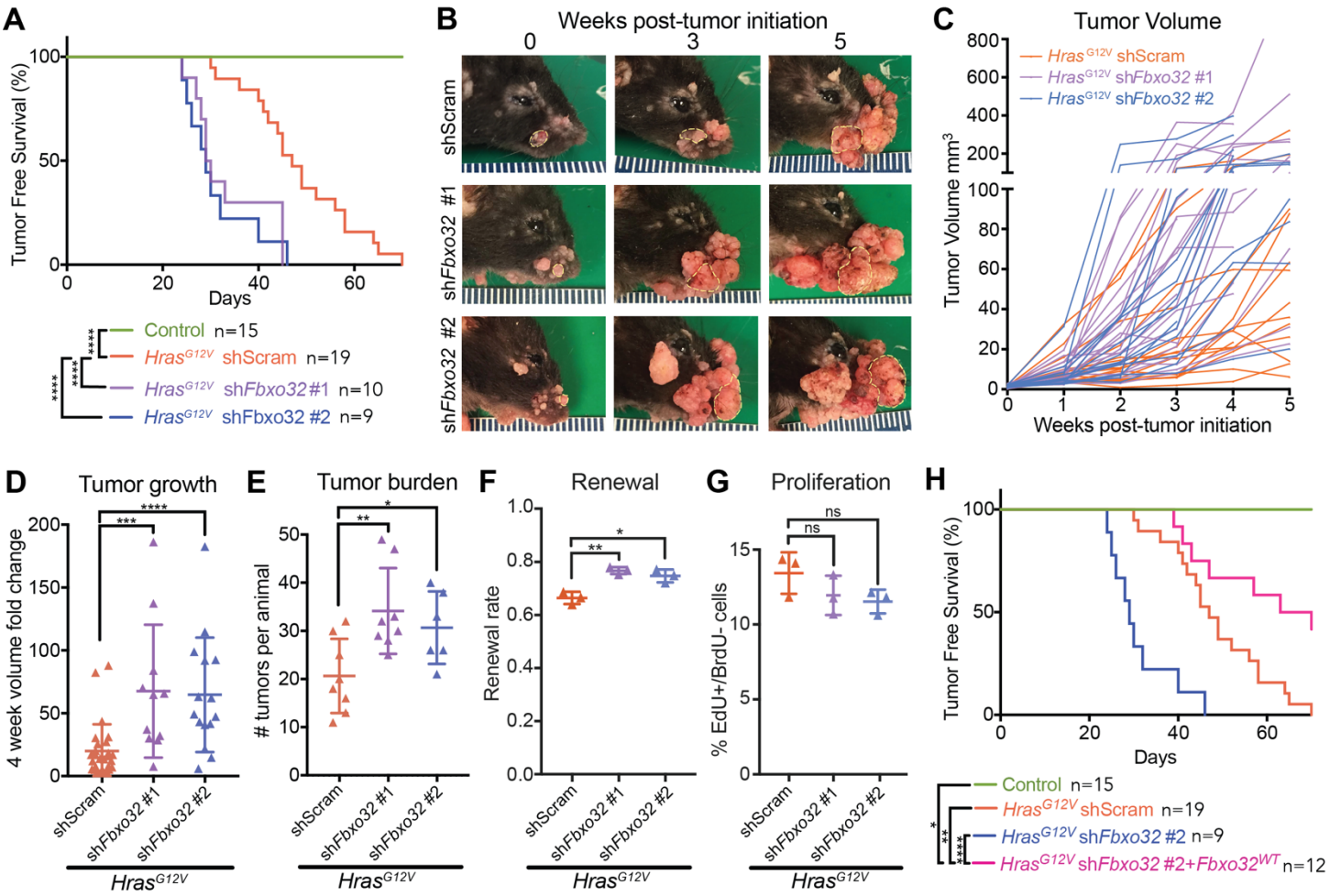


Figure 5.5 FBXO32 is necessary and sufficient to restrains RAS tumor initiation and growth

A) Tumor-free survival of WT (control) or *Hras*^{G12V} animals transduced at E9.5 with indicated shRNA knockdown. (****:P-value<0.0001)

B) Representative images of tumor growth up to 5 weeks post-tumor initiation in *Hras*^{G12V} animals with *Fbxo32* depletion. Dashed outlines track the same tumor across time. (Scale: 1 tick = 1mm)

C) Tumor volume as measured by formula V=(π/6)x(LxWxH) was tracked up to 5 weeks post-tumor initiation. Each line represents an individual tumor. Tumors across 4 individual animals were tracked per condition.

D) Tumor volume fold change 4 weeks after tumor initiation. Each data point represents an individual tumor.

E) Number of tumors per animal within 4 weeks of first tumor initiation. Each data point represents an individual animal.

F-G) Quantification of **(F)** renewal rate and **(G)** proliferation rate in tumors of *Hras*^{G12V} animals transduced with shScrambled or sh*Fbxo32.* Each data point represents an individual animal. Approx. 100 cell divisions (for renewal assay) or 100 basal cells (for proliferation assay) were scored per animal per condition. (*:P-value<0.05; **:P-value<0.01; ***:P-value<0.001; ns=not significant).

H) Tumor-free survival of WT (control) or *Hras*^{G12V} animals transduced at E9.5 with sh*Fbxo32* alone or co-expressing rescue *Fbxo32*^{WT} ORF. (*:P-value<0.05; **:P-value<0.01; ****:P-value<0.0001)

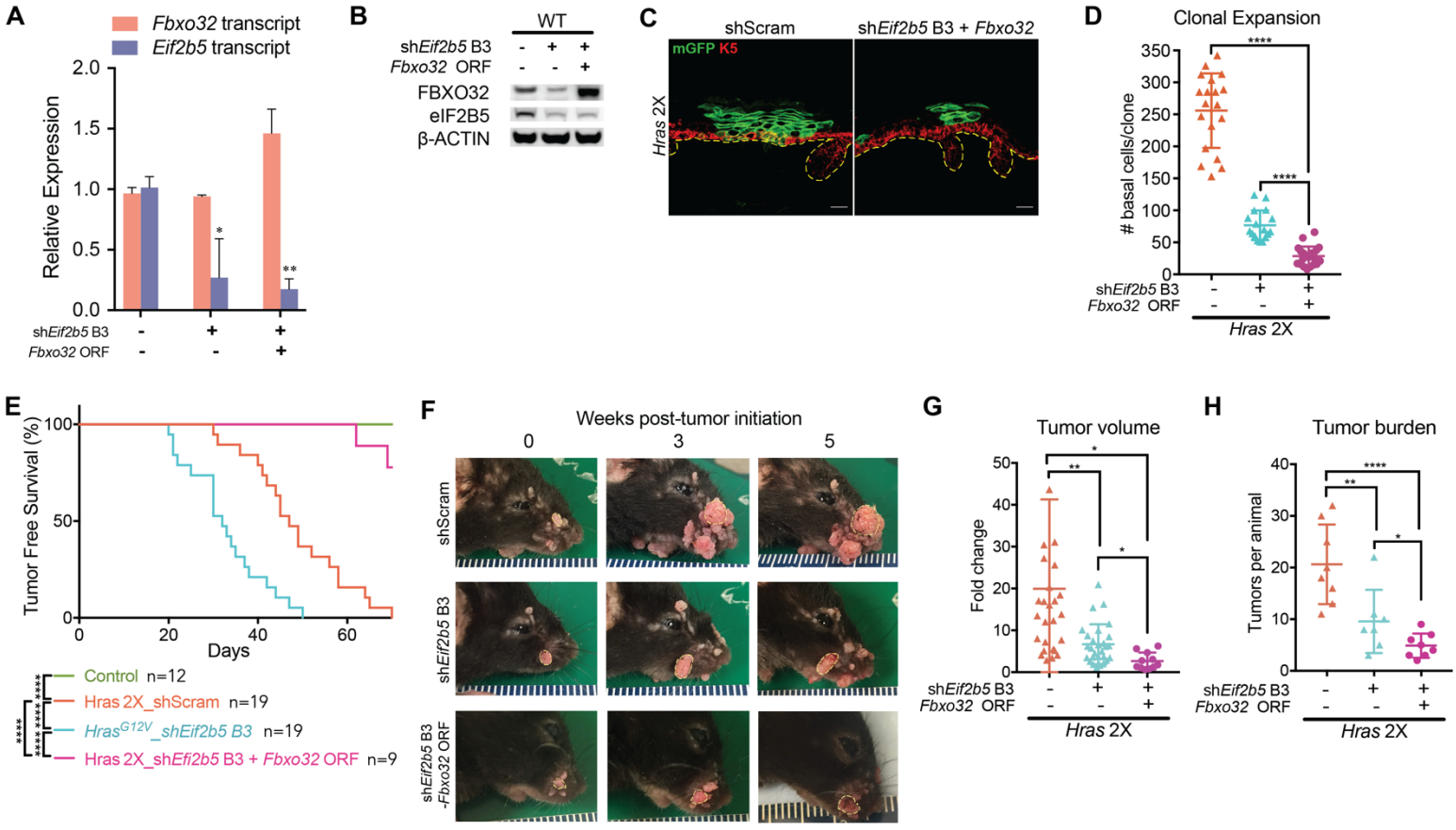


Figure 5.6 ***Hras*^{G12V} growth inhibition through simultaneous targeting of proliferation and differentiation mechanisms**

A) mRNA expression of total *Fbxo32* and *Eif2b5* transcript in WT keratinocytes transduced with sh*Eif2b5* B3 + *Fbxo32*^{WT} ORF. (*:P-value<0.01; **:p-value<0.001).

B) Representative western blot in WT keratinocytes of FBXO32 and eIF2B5 upon shRNA depletion of *Eif2b5* and overexpression with *Fbxo32*^{WT} ORF.

C) Representative cross-section of *Hras*^{G12V} clone transduced with shScrambled or sh*Eif2b5* B3+*Fbxo32*^{WT} ORF. mGFP marks transduced epidermal cells, K5 marks basal progenitors, and dashed line marks basement membrane.

D) Quantification of basal cell numbers per clone in E18.5 epidermis transduced with sh*Eif2b5* B3 alone or co-expressing *Fbxo32*^{WT} ORF. Each data point represents a single clone. Three animals were assessed per condition. (****:P-value<0.0001; ns=not significant)

E) Tumor-free survival of WT (control) or *Hras*^{G12V} animals transduced at E9.5 with indicated shRNA knockdown. (****:P-value<0.0001)

F) Representative images of tumor growth up to 5 weeks post-tumor initiation in *Hras*^{G12V} animals with sh*Eif2b5* B3 alone or co-expressing *Fbxo32*^{WT} ORF. Dashed outlines track the same tumor across time. (Scale: 1 tick = 1mm)

G) Tumor volume fold change 4 weeks after tumor initiation. Each data point represents an individual tumor. (*:P-value<0.05; **:P-value<0.01)

H) Number of tumors per animal within 4 weeks of first tumor initiation. Each data point represents an individual animal. (*:P-value<0.05; **:P-value<0.01; ****:P-value<0.0001)

Table 5.1 Regulators of *Hras*^{G12V} progenitor proliferation within eIF2B5-regulated oncogenic translatome

Candidates for proliferation regulation as identified by DESeq2 analysis of shRNA enrichment in non-dividing (EdU-) relative to the dividing (EdU+) basal progenitors. Positive fold-change value indicates enrichment in the EdU- population of shRNAs targeting the gene.

Positive proliferation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Sdhc	2	0	5.62184811
2	Sfrs11	3	0	5.43109274
3	4930432O21Rik	2	0	5.37965623
4	Mobkl1b	2	0	5.34262193
5	Arsk	3	0	5.30498028
6	Sdhd	2	0	5.06076487
7	Mrps26	2	0	5.0232682
8	Grina	2	0	4.90310119
9	Slc31a2	2	0	4.88516351
10	Mapksp1	2	**0**	4.79159816
11	Kdelr2	2	0	4.75405198
12	Dimt1	2	0	4.68762346
13	Akr1b8	2	0	4.68262183
14	Nudt2	2	0	4.68127659
15	Terf2ip	2	0	4.51130753
16	Mdm2	2	**0**	4.47145204
17	Rras2	2	0	4.39641752
18	Qrich1	5	0	4.39167362
19	BC003331	2	0	4.32948922
20	Rnase1	3	0	4.24596315
21	Slc7a6	3	0	4.24076808
22	Arfgap1	2	0	4.20895541
23	Zfp763	2	0	4.20295621
24	Psmc3ip	3	0	4.16674974
25	Isca1	3	0	4.13550225
26	Nup153	5	0	4.12463325
27	0610007P14Rik	2	0	4.07121308
28	Purb	2	0	4.04977473
29	Dnajb9	4	0	4.04168053
30	Tmem126a	4	0	3.93002399
31	Rps6ka4	4	0	3.90041221
32	Fzd3	4	0	3.89809375
33	Efemp1	2	0	3.87604233
34	Sp4	2	0	3.85680967
35	Lrrn1	2	0	3.83252612
36	Mid1ip1	2	0	3.8222166
37	Sem1	2	0	3.817547
38	Ncaph2	3	0	3.81471523
39	Ufm1	3	0	3.79666824

40	Nat15	4	0	3.76979261
41	Ftsj1	2	0	3.75131162
42	Diap3	2	0	3.68311493
43	Sec24b	2	0	3.67529157
44	Rps11	3	0	3.65963846
45	Klf9	2	0	3.65403858
46	Ntan1	4	0	3.63033836
47	Trim23	2	0	3.60795235
48	Mtf2	3	0	3.60123878
49	Nudt3	2	0	3.60027526
50	Rnasek	4	0	3.59416235
51	Ubxn2b	2	0	3.53903541
52	Polr2f	2	0	3.52281894
53	Mtx2	4	0	3.47103353
54	Ints6	4	0	3.46336646
55	Rbbp8	2	0	3.42813292
56	Fam32a	2	0	3.41903444
57	Ltbp4	2	0	3.39625201
58	Tpm4	2	0	3.37597377
59	Rps14	2	0	3.3732769
60	Zfp354c	2	0	3.37214456
61	Ctns	3	0	3.36716024
62	Rer1	2	0	3.3667685
63	Id3	2	0	3.35971548
64	Psrc1	2	0	3.35586955
65	Rps15a	4	0	3.33439254
66	Ndrg3	2	0	3.33217474
67	Btf3	3	0	3.31591939
68	Zfyve27	4	0	3.29265537
69	Cdc37	3	0	3.25893307
70	Slmo2	2	0	3.24654495
71	Pawr	2	0	3.21377979
72	Sltm	2	0	3.21183645
73	Depdc7	2	0	3.17509766
74	0610009D07Rik	2	0	3.13604362
75	Slc7a2	2	0	3.12512074
76	Tprkb	2	0	3.116284
77	Cops2	2	0	3.11535453
78	Ghitm	2	0	3.08684673
79	Kif18b	2	0	3.08229079
80	Itgb5	4	0	3.07872626
81	Hltf	5	0	3.03650715
82	Zfp788	2	0	3.02263493
83	Ppp2r5e	2	0	2.99669599
84	1700019E19Rik	2	0	2.8882735
85	Cavin1	2	0	2.77921281
86	Ddx27	3	0	2.7052838
87	Lsm2	3	0	2.6946086
88	Camk2g	2	0	2.67513026
89	Prim1	2	0	2.6634729

90	Rsu1	2	0	2.48733016
91	Ociad2	2	0	1.99179156
Negative proliferation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Yaf2	0	2	-4.0864121
2	Zfp157	0	2	-3.9873448
3	Hypk	0	2	-3.9788159
4	Aga	0	2	-3.7992281
5	Manf	0	2	-3.5661542
6	Pon2	0	2	-3.3345515
7	Tmem135	0	2	-3.3306672
8	Itga2	0	2	-3.2846769
9	Creld2	0	2	-3.2084531
10	Snap23	0	2	-3.1643501
11	Trappc3	0	2	-2.9803577
12	Cyp26b1	0	2	-2.9547631
13	Gpatch2	0	2	-2.9190634
14	Kansl3	0	2	-2.7017268
15	Commd7	0	2	-2.5150709
16	Cdc42ep4	0	2	-2.5004752
17	Arl4a	0	2	-2.449881
18	Telo2	0	2	-2.2082542
19	4930453N24Rik	0	2	-2.1291018
20	Ube2l3	0	2	-2.0920388
21	Nipal4	0	2	-2.0316991
22	Tmbim4	0	2	-2.0123476
23	Nup43	0	2	-1.9203395
24	Mgarp	0	3	-1.8281421
25	Rnaseh2b	0	2	-1.8180817
26	Grb14	0	2	-1.8156861
27	Tmem60	0	2	-1.7104723
28	Tet2	0	2	-1.5836634
29	Sike1	0	2	-1.5441443
30	Ttc19	0	2	-1.3380939
31	Alg3	0	2	-1.2817567

Table 5.2 Regulators of *Hras*^{G12V} progenitor renewal within eIF2B5-regulated oncogenic translatome

Candidates for differentiation regulation as identified by DESeq2 analysis of shRNA enrichment in the basal progenitor relative to the differentiated suprabasal compartment. Positive fold-change value indicates basal enrichment of shRNAs targeting the gene.

Positive differentiation regulators				
Rank	**Gene Symbol**	**Enriched shRNAs**	**Depleted shRNAs**	**Average Fold Change**
1	Zcchc7	5	0	4.28739766
2	Zfp763	4	0	5.17940356
3	Fam32a	3	0	5.50909242
4	Diap3	3	0	5.22361238
5	Mid1ip1	3	0	4.71524308
6	Arg2	3	0	4.55128521
7	Qrich1	3	0	4.365389
8	Zfp760	3	0	4.3021497
9	Creld2	3	0	4.23094081
10	Mapksp1	3	0	4.11135354
11	Pcdh7	3	0	3.64507447
12	Ppp1r14b	3	0	3.59231376
13	Ptdss1	2	0	5.7553217
14	Ppp1r9b	2	0	5.2955177
15	Tmem135	2	0	5.18490466
16	Stau2	2	0	5.06912082
17	Rbms1	2	0	4.99779075
18	Efna1	2	0	4.87809649
19	Rnf187	2	0	4.86775974
20	D14Ertd436e	2	0	4.86145243
21	Gbe1	2	0	4.70560567
22	Gstm2	2	0	4.65082627
23	Nln	2	0	4.61402681
24	Gstp1	2	0	4.56460412
25	Ntan1	2	0	4.54143123
26	Dhfr	2	0	4.49477227
27	Tmed3	2	0	4.47479681
28	Phax	2	0	4.44364323
29	Rras2	2	0	4.40084097
30	Pex16	2	0	4.37489555
31	Krit1	2	0	4.36104229
32	Ccdc75	2	0	4.35780476
33	Ndufb10	2	0	4.29299448
34	Ddx27	2	0	4.2753849
35	Sdhd	2	0	4.22617869
36	A830080D01Rik	2	0	4.17315031
37	Abcg2	2	0	4.09782253
38	Ppp2r5e	2	0	3.96691654
39	Tmem39a	2	0	3.90721508

40	Nob1	2	0	3.88911725
41	Anpep	2	0	3.88181531
42	Icosl	2	0	3.85254693
43	Tmem126a	2	0	3.81455936
44	Mad2l1	2	0	3.77599389
45	Rbck1	2	0	3.73775711
46	Smc2	2	0	3.68280472
47	Ube2k	2	0	3.60103008
48	Rsu1	2	0	3.54685743
49	Elmo1	2	0	3.44237061
50	Polr2f	2	0	3.41695552
51	Zc3h18	2	0	3.17869121
52	Rbbp8	2	0	3.04747247
53	Fbxo32	2	0	2.97810567
54	Ppap2c	2	0	2.97728367
55	Serf2	2	0	2.88725725
56	Kmt5b	2	0	2.82409493
57	Pon2	2	0	2.69314622
58	Arrdc4	2	0	2.56514664

Negative differentiation regulators

Rank	Gene Symbol	Enriched shRNAs	Depleted shRNAs	Average Fold Change
1	Pign	0	3	-5.0467082
2	Terf2ip	0	3	-4.7780348
3	Tbck	0	3	-3.0596953
4	Fadd	0	2	-5.9320215
5	Rnase1	0	2	-5.6910159
6	Fdx1	0	2	-5.4126705
7	Slc7a6	0	2	-4.5001049
8	Coq4	0	2	-4.3941624
9	Sox4	0	2	-4.3869109
10	Stil	0	2	-4.2584184
11	Brca2	0	2	-4.1906497
12	Ctdspl	0	2	-3.8840909
13	Nup153	0	2	-3.8822854
14	Nipal4	0	2	-3.795883
15	Stard10	0	2	-3.7788179
16	Zwilch	0	2	-3.5991326
17	Tmem29	0	2	-3.5901441
18	Rif1	0	2	-3.5854954
19	Foxj3	0	2	-3.5118387
20	Otub1	0	2	-3.4403598
21	Fos	0	2	-3.4248198
22	Gdpd1	0	2	-3.4137775
23	Mrpl14	0	2	-3.352835
24	Pcdhga10	0	2	-3.1252225
25	Timm10	0	2	-2.9749178
26	Sec61a2	0	2	-2.6248617
27	C1galt1	0	2	-2.5823742
28	Tmbim4	0	2	-2.5809031

Chapter 6 – Discussion

How tissues tolerate oncogenic lesions to restrain tumorigenesis is of fundamental interest to cancer biology (Greaves and Maley, 2012; Lowe et al., 2004). While suppression of mutant clones has been described in homeostatic adult epidermis (Brown et al., 2017; Martincorena et al., 2015; Ying et al., 2018), tissue response to oncogene activation during rapid embryonic growth, such as in RASopathies, has not been examined. In this context, the absence of self-renewing WT neighbors to displace mutant cells necessitates an alternative molecular mechanism to contain tissue overgrowth (Ying et al., 2018). Here we uncover translationally-regulated progenitor cell differentiation as a central mechanism of epidermal tolerance to embryonic oncogene activation. Translation coordinates differentiation in response to oncogenic hyperproliferation, which preserves the frequent proliferation necessary for epidermal development while limiting the tissue's progenitor pool size and pathological growth. Our findings also challenge the view that oncogenic translation is inherently tumor-promoting and demonstrates how it redirects cell fate to prolong normal tissue development.

6.1 Coordinated progenitor cell behaviors mediate RAS oncogene tolerance

We characterized the changes in epidermal tissue morphology and progenitor cell behavior induced by oncogenic RAS activation. Following RAS activation, the increase in progenitor cell proliferation was substantially in excess of what could be explained by our observed embryonic tissue expansion. We found that a loss of progenitor cell renewal compensated for hyperproliferation to limit tissue growth. In contrast to the expulsion of mutant cells observed during clonal *Pik3ca* activation (Ying et al., 2018), which led to a complete block of

tumorigenesis, *Hras*^{G12V} oncogene tolerance during development manifests as a containment of pathological growth. Interestingly, despite the transition in progenitor cell dynamics from high renewal and low proliferation in WT tissue to low renewal and high proliferation in *Hras*^{G12V} tissue, epidermal development remained robust, suggesting that there is significant plasticity within development as long as balanced stem cell behavior is maintained. The hyperplastic but functional epidermis in mouse embryos reflects the clinical finding of redundant but intact skin in Costello syndrome patients (Gripp and Lin, 2012).

Beyond the cell-autonomous translational mechanism identified here, mechanical restraints in the developing embryo may also mediate progenitor cell coordination. A number of studies have demonstrated that tissue overcrowding can induce epithelial cell extrusion and differentiation in order to relieve mechanical stress, a process that is mediated by the activation of cell-surface mechanosensors (Eisenhoffer et al., 2012; Marinari et al., 2012). Furthermore, integrin-mediated contact with the basement membrane is necessary for epidermal basal cells to maintain their progenitor potential (Benitah et al., 2005). Therefore, RAS-induced hyperproliferation may cause basal layer compaction that in turn induces delamination and differentiation. This potential mechanism is supported by our finding that *Hras*^{G12V} epidermis has increased basal cell density compared to WT tissue (Sandoval, M., unpublished), and by recent intravital imaging observations that epidermal progenitor cell divisions initially occur laterally within the basal layer before subsequent suprabasal delamination to establish terminally differentiated cells (Rompolas et al., 2016). Additional functional and intravital imaging studies are needed to probe this mechanical strategy for progenitor cell coordination.

6.2 eIF2B5 coordinates RAS progenitor cell behaviors to regulate oncogenic growth

We found that RAS activation induces translational upregulation in epidermal progenitors. Elevated protein synthesis rate has recently been correlated with proliferation and differentiation (Blanco et al., 2016; Liakath-Ali et al., 2018; Signer et al., 2014), but little is known about how this fundamental process drives discreet stem cell behaviors. We utilized *in vivo* genetic screens and direct functional assays to identify translation initiation factor eIF2B5 as uniquely required for $Hras^{G12V}$-induced progenitor cell behaviors. While eIF2B5 was sufficient to explain $Hras^{G12V}$ epidermal overgrowth, its role in coordinating differentiation with hyperproliferation suggests that it simultaneously acts to restrain excess growth. Notably, *Eif2b5* depletion did not significantly affect WT epidermis. This suggests that oncogene-activated tissues have increased dependence on the translation machinery, consistent with the differential requirements for translation in normal development and oncogenic transformation (Miluzio et al., 2011; Truitt et al., 2015). This translational dependence may be due to initiation factor-mediated selective translation of mRNAs that support oncogenic tissue needs (Brina et al., 2015; Lee et al., 2015; Truitt et al., 2015; Truitt et al., 2016). It remains unclear whether eIF2B5 exerts its effect on epidermal progenitor cells as part of the eIF2B complex, or whether eIF2B5 has a moonlighting function in conferring translational specificity outside of its canonical role in translation initiation. Additional studies analyzing the regulatory role of other eIF2B and eIF2 components can elucidate whether the observed eIF2B5 functions are generalizable to the eIF2B-eIF2 translation initiation axis.

To probe the molecular mechanisms behind eIF2B5-mediated oncogene tolerance and translational specificity, we performed *in vivo* ribosome profiling of basal progenitors. Critically,

by performing these analyses *in vivo*, we were able to uncover regulators of both proliferation and cell fate, a behavior that cannot be modeled in tissue culture. Instead of being the product of global translation rate differences, which can dictate cellular behavior through broad changes in biomass or metabolism (Good et al., 2013; Lindqvist et al., 2018; Polymenis and Aramayo, 2015), our analyses revealed that eIF2B5-mediated oncogene tolerance was the result of differential translation of specific networks of mRNAs. In particular, the eIF2B5-regulated translatome covered a substantial proportion of genes that were translationally reprogrammed by oncogenic RAS and was enriched for many pathways involved in stem cell regulation and oncogenesis.

A number of regulatory elements exist within the 5'UTR of mRNAs to confer translational selectivity (Hinnebusch et al., 2016). The presence of complex secondary structures in the 5'UTR inhibits efficient mRNA translation, and extensive studies have revealed that overexpression of eIF4E and its subsequent recruitment of eIF4A helicase is able to unwind these secondary structures to facilitate selective (Feoktistova et al., 2013; Koromilas et al., 1992; Svitkin et al., 2001). Complex secondary structures have been identified in a number of pro-oncogenic mRNAs that are translationally induced by eIF4E, including *Vegfa* and *Fgf2* (Kevil et al., 1996; 1995), illustrating the translational specificity conferred by mRNA regulatory elements. The presence of sequence-specific elements also mediates selective translation. uORFs can initiate translation from scanning ribosomes, resulting in ribosome stalling or decreased reinitiation efficiency at the downstream primary ORF (Morris and Geballe, 2000). uORF-mediated translational repression can be overcome during conditions of low global translation, such as in cell-stress induced eIF2α phosphorylation (Baird et al.). Recent work also suggests that 5'UTR motif sequences can direct

selective translation by recruiting trans-acting factors to interact with translation initiation components (Hsieh et al., 2012; Truitt et al., 2015). In our investigation, we found that the 5'UTRs of genes whose translation was upregulated by RAS activation or regulated by eIF2B5 had lower folding energy and higher GC content than the genome as a whole, indicative of more complex 5'UTRs. We identified a guanine-rich translational element that was highly enriched in both RAS-altered and eIF2B5-regulated genes. It remains unclear whether these 5'UTR features are necessary for eIF2B5-specific translation or if they are attributes of the *Hras*^{G12V} translatome in general, and functional studies are needed to analyze their significance. Additional underlying factors behind eIF2B5 translational specificity remain important subjects for future studies.

6.3 eIF2B5-driven differentiation restrains RAS tumorigenesis

We functionally dissected the RAS-induced translation landscape and establish translationally-regulated differentiation as a bona fide tumor-suppressive mechanism. By coupling our *in vivo* ribosome profiling findings with unbiased and systematic screening, we were able to separate the progenitor cell behaviors downstream of RAS activation and distinguish distinct drivers of each. This segregated regulation of proliferation and differentiation reflects the embryonic epidermis' need for rapid proliferation to maintain physiological growth while modulating fate choice to restrain pathological growth. Intriguingly, we found unexpected enrichment of ubiquitination and protein metabolism genes amongst promoters of oncogene-induced differentiation. These post-translational processes may provide a dynamic mechanism to modulate cell fate choice in rapidly growing tissue. Intravital imaging has revealed that epidermal basal cells are highly responsive to local tissue stresses and can rapidly adapt their fate

choices to meet tissue needs (Brown et al., 2017; Mesa et al., 2017; Park et al., 2017), suggesting that the mechanisms governing fate choice are also highly dynamic. In contrast, we observed that promoters of oncogenic proliferation were enriched for transcription genes. Genetic regulation of cell division may create a permissive state for subsequent post-translational regulation of daughter cell fate, consistent with lineage tracing observations (Rompolas et al., 2016). We identified E3 ubiquitin ligase *Fbxo32* as a novel driver of epidermal differentiation during oncogene activation. Outside of its well-characterized role in muscle atrophy, *Fbxo32* target substrates and functions in other tissues remain largely unknown and warrant further investigation. Moreover, our screens uncovered other ubiquitination molecules that may promote differentiation by targeting shared substrates and are important candidates for future study.

A critical finding of our study is that translationally-regulated differentiation is a bona fide tumor-suppressive mechanism in skin. Recent work has described oncogenic *Pik3ca*-induced differentiation as a stringent inhibitor of clonal expansion that completely exhausts the clone's progenitor population, leading to its expulsion from the tissue (Ying et al., 2018). As a result, the precise effect of oncogene-induced differentiation on tumor initiation and growth is unclear. Furthermore, oncogenic lesions in *Pik3ca* are often acquired late in SCC progression and regulate subclonal growth (Hao et al., 2016), while RAS-MEK pathway lesions are frequently found throughout human tumors and represent early driver events during tumor initiation (McGranahan et al., 2015). Using an oncogenic $Hras^{G12V}$ model, which forms tumors in permissive regions such as the muzzle (Chen et al., 2009), we demonstrated that differentiation functions as a growth-suppressive mechanism to restrain tumorigenesis. Specific ablation of differentiation

allows oncogene-activated epidermis to expand unrestrained while retaining higher proliferation rates, resulting in accelerated tumorigenesis and tumor growth. This finding suggests that reactivating the pro-differentiation signaling behind tissue-wide oncogene tolerance may be a therapeutic strategy to counteract field cancerization, which is often seen in skin and digestive epithelia(Curtius et al., 2017). Notably, terminal differentiation that removes excess cells from the mitotic progenitor pool is not a common feature of all epithelia, but instead seems specific for high turnover tissues that employ continual proliferation and differentiation for their self-maintenance, such as the skin, esophageal, and intestinal epithelia (Fuchs, 2007; Srinivas et al., 2001; van der Flier and Clevers, 2009). Like skin, physiologically normal human esophagus also harbors unexpectedly high prevalence of oncogenic driver mutations(Martincorena et al., 2018), suggesting that other epithelia could also employ differentiation to control field cancerization and tumorigenesis.

6.4 Translation dysregulation as a therapeutic target

The discovery of translation deregulation following oncogene activation has instigated broad efforts to develop therapies that target the translation machinery (Bhat et al., 2015; Hsieh and Ruggero, 2010; Xu et al., 2019). This strategy is particularly appealing because the translation apparatus integrates almost all oncogenic pathways and its components are often upregulated in cancer (Ruggero, 2013; Truitt and Ruggero, 2016), suggesting that rapidly proliferating oncogenic cells are addicted to elevated protein synthesis and can be selectively targeted. While many direct translation machinery inhibitors are in development for clinical use (Bhat et al., 2015), our finding that translation coordinates cell fate with proliferation to

balance growth provides a cautionary tale. Although *Eif2b5* depletion in oncogenic RAS animals reduced tissue growth rate, it resulted in a surprising acceleration of tumorigenesis. Thus, general translation inhibition may initially limit cancer cell proliferation but could facilitate disease relapse through its pro-renewal effect. Moreover, tissue-wide oncogene activation may create a susceptible field whose growth is initially contained by translational control but can be deregulated through the acquisition of additional driver mutations (Curtius et al., 2017). Tissue physiology may also change throughout aging to bias selective pressure against one regulatory axis over the other, which can cause unbalanced shifts upon broad translation inhibition. Instead, functional understanding of the specific genes that are differentially translated during oncogene activation will allow us to more precisely target the cancer translatome through its downstream effectors.

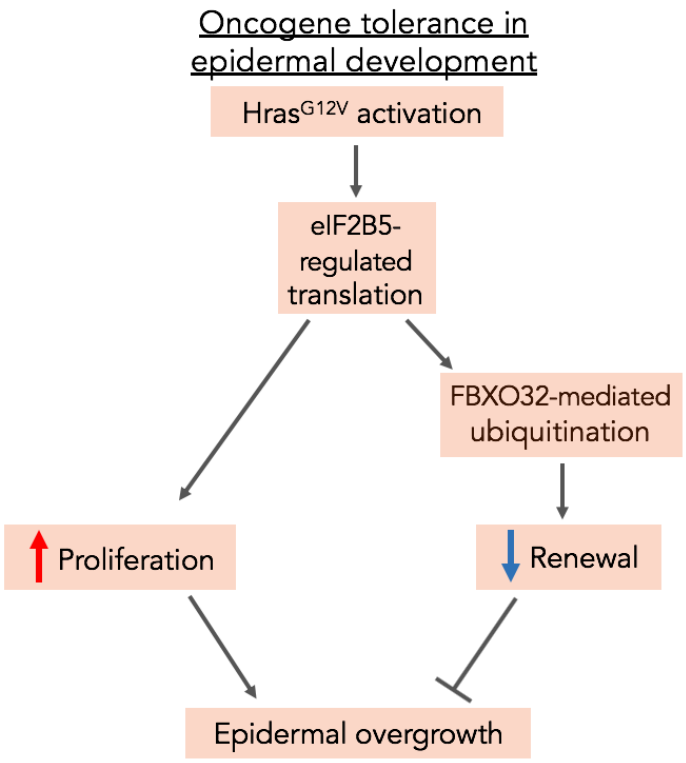


Figure 6.1 Model of translational regulation in epidermal oncogene tolerance

Hras^{G12V} activation results in an increase in basal progenitor cell proliferation and decrease in basal progenitor cell renewal that is mediated by eIF2B5-regulated translation of specific proliferation and differentiation promotors. Amongst differentiation promoters, FBXO32-mediated ubiquitination was identified as necessary for epidermal oncogene tolerance to restrain tumorigenesis.

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Appendix A – Translation screen to identify essential oncogenic growth genes

Translation upregulation has been reported in many oncogene models, and dependence on the translation machinery has been suggested as a targetable vulnerability in cancer cells (Barna et al., 2008; Hsieh et al., 2012; Truitt et al., 2015). We sought to identify genes whose translation is essential for oncogenic growth and are therefore particularly susceptible to translational inhibition. To do this, we performed a genome-wide ORF overexpression screen in the presence of translation inhibitor puromycin, which allowed us to identify ORFs that can overcome translation inhibition to restore growth. The screen was conducted by lentiviral transduction of $Hras^{G12V}$ and WT primary keratinocytes at MOI<<1 with the human ORFeome CCSB-Broad Lentiviral Expression Library (Dharmacon), followed by dilution of cells into individual selection wells. Keratinocytes were selected with puromycin and wells that contained successfully expanded clones were collected for gDNA extraction. The ORF region of each collected well was PCR amplified, fractionated, and sequenced. The 30 ORFs with the greatest number of sequencing reads from each well were collated to identify ORFs that were enriched across multiple wells. ORFs enriched in $Hras^{G12V}$ and WT keratinocytes were compared to isolate genes that specifically promote oncogenic growth, normal growth, or both. Single-gene validation studies are needed to determine whether the translation of candidate genes is essential for oncogenic growth.

Table A.1 Genes essential for *Hras^{G12V}* keratinocyte growth only

Rank	Gene Symbol	Frequency (# wells)	Gene name
1	SLA	4	Src-like-adaptor
2	GRAMD1A	4	GRAM domain containing 1A
3	TEF	4	TEF, PAR bZIP transcription factor
4	HINT3	3	histidine triad nucleotide binding protein 3
5	RAP1A	3	RAP1A, member of RAS oncogene family
6	TRNAU1AP	3	tRNA selenocysteine 1 associated protein 1
7	CD63	3	CD63 molecule
8	TIRAP	3	TIR domain containing adaptor protein
9	HIST3H2A	3	histone cluster 3, H2a
10	RPL27	3	ribosomal protein L27
11	DCUN1D1	3	defective in cullin neddylation 1 domain containing 1
12	HTR1D	3	5-hydroxytryptamine receptor 1D
13	TAX1BP3	3	Tax1 binding protein 3
14	RPL7L1	3	ribosomal protein L7 like 1
15	C1orf174	3	chromosome 1 open reading frame 174
16	HARS	3	histidyl-tRNA synthetase
17	LYZL6	3	lysozyme like 6
18	RPS24	3	ribosomal protein S24
19	AFTPH	3	aftiphilin
20	EPHB4	3	EPH receptor B4
21	PTRHD1	3	peptidyl-tRNA hydrolase domain containing 1
22	RCVRN	3	recoverin
23	HN1	3	hematological and neurological expressed 1
24	NDRG1	3	N-myc downstream regulated 1
25	PDXK	3	pyridoxal (pyridoxine, vitamin B6) kinase
26	SLC25A11	3	solute carrier family 25 member 11
27	MAPRE2	3	microtubule associated protein RP/EB family member 2
28	SALL2	3	spalt like transcription factor 2
29	MRPS7	2	mitochondrial ribosomal protein S7
30	REEP2	2	receptor accessory protein 2
31	CAMTA2	2	calmodulin binding transcription activator 2
32	CENPN	2	centromere protein N
33	PSMG1	2	proteasome assembly chaperone 1
34	C17orf64	2	chromosome 17 open reading frame 64
35	IL18BP	2	interleukin 18 binding protein
36	GPX3	2	glutathione peroxidase 3
37	VBP1	2	VHL binding protein 1
38	ANKRD13D	2	ankyrin repeat domain 13D
39	SPCS3	2	signal peptidase complex subunit 3
40	RNF144A	2	ring finger protein 144A
41	SERPINA7	2	serpin family A member 7
42	CELA3A	2	chymotrypsin like elastase family member 3A
43	EXOC7	2	exocyst complex component 7
44	PDPN	2	podoplanin
45	ABHD14A	2	abhydrolase domain containing 14A
46	CNPY3	2	canopy FGF signaling regulator 3

47	B4GALT2	2	beta-1,4-galactosyltransferase 2
48	MBD5	2	methyl-CpG binding domain protein 5
49	ZNF302	2	zinc finger protein 302
50	NSA2	2	NSA2, ribosome biogenesis homolog
51	UBE2V2	2	ubiquitin conjugating enzyme E2 V2
52	SLC30A6	2	solute carrier family 30 member 6
53	RIT2	2	Ras like without CAAX 2
54	MTFR2	2	mitochondrial fission regulator 2
55	AK3	2	adenylate kinase 3
56	ZC2HC1C	2	zinc finger C2HC-type containing 1C
57	TM2D3	2	TM2 domain containing 3
58	PHB2	2	prohibitin 2
59	PEX19	2	peroxisomal biogenesis factor 19
60	WT1	2	Wilms tumor 1
61	SLC25A38	2	solute carrier family 25 member 38
62	SLC29A2	2	solute carrier family 29 member 2
63	PTHLH	2	parathyroid hormone like hormone
64	MIF	2	macrophage migration inhibitory factor (glycosylation-inhibiting factor)
65	COA3	2	cytochrome c oxidase assembly factor 3
66	DAD1	2	defender against cell death 1
67	PTMS	2	parathymosin
68	CDC26	2	cell division cycle 26
69	MAK16	2	MAK16 homolog
70	UBE2M	2	ubiquitin conjugating enzyme E2 M
71	TPM1	2	tropomyosin 1 (alpha)
72	ZNHIT1	2	zinc finger HIT-type containing 1
73	EEF1D	2	eukaryotic translation elongation factor 1 delta
74	MYH7B	2	myosin heavy chain 7B
75	OMP	2	olfactory marker protein
76	FLOT2	2	flotillin 2
77	TTC32	2	tetratricopeptide repeat domain 32
78	GBP3	2	guanylate binding protein 3
79	NDUFAF5	2	NADH:ubiquinone oxidoreductase complex assembly factor 5
80	RFK	2	riboflavin kinase
81	ALKBH3	2	alkB homolog 3, alpha-ketoglutaratedependent dioxygenase
82	SYCE1	2	synaptonemal complex central element protein 1
83	NUP43	2	nucleoporin 43
84	HEATR1	2	HEAT repeat containing 1
85	HLA-DOA	2	major histocompatibility complex, class II, DO alpha
86	GM2A	2	GM2 ganglioside activator
87	ABHD14B	2	abhydrolase domain containing 14B
88	PDE4D	2	phosphodiesterase 4D
89	LRRC61	2	leucine rich repeat containing 61
90	MT1H	2	metallothionein 1H
91	TMEM216	2	transmembrane protein 216
92	HMGN2	2	high mobility group nucleosomal binding domain 2
93	LINC00638	2	long intergenic non-protein coding RNA 638
94	PHLDB1	2	pleckstrin homology like domain family B member 1
95	SMIM2	2	small integral membrane protein 2
96	POLR2I	2	RNA polymerase II subunit I

97	C11orf70	2	chromosome 11 open reading frame 70
98	ADTRP	2	androgen dependent TFPI regulating protein
99	OSM	2	oncostatin M
100	SCGB1A1	2	secretoglobin family 1A member 1
101	SAP18	2	Sin3A associated protein 18
102	CDK2AP2	2	cyclin dependent kinase 2 associated protein 2
103	CMTM5	2	CKLF like MARVEL transmembrane domain containing 5
104	LHFP	2	lipoma HMGIC fusion partner
105	VAMP5	2	vesicle associated membrane protein 5
106	TMEM135	2	transmembrane protein 135
107	SDS	2	serine dehydratase
108	CA13	2	carbonic anhydrase 13
109	DHRS2	2	dehydrogenase/reductase 2
110	TSEN15	2	tRNA splicing endonuclease subunit 15
111	DKKL1	2	dickkopf like acrosomal protein 1
112	KLF3	2	Kruppel like factor 3
113	IGF2	2	insulin like growth factor 2
114	BLOC1S2	2	biogenesis of lysosomal organelles complex 1 subunit 2
115	TMTC1	2	transmembrane and tetratricopeptide repeat containing 1
116	R3HCC1L	2	R3H domain and coiled-coil containing 1 like
117	SUMF2	2	sulfatase modifying factor 2
118	COG8	2	component of oligomeric golgi complex 8
119	EFNA1	2	ephrin A1
120	OLFML3	2	olfactomedin like 3
121	EPHA4	2	EPH receptor A4
122	EDEM3	2	ER degradation enhancing alpha-mannosidase like protein 3
123	HIST1H2BK	2	histone cluster 1, H2bk
124	GPX1	2	glutathione peroxidase 1
125	NPC2	2	NPC intracellular cholesterol transporter 2
126	NDUFB11	2	NADH:ubiquinone oxidoreductase subunit B11
127	MYL1	2	myosin light chain 1
128	DNAL1	2	dynein axonemal light chain 1
129	PMP22	2	peripheral myelin protein 22
130	CAV2	2	caveolin 2
131	TSNAX	2	translin associated factor X
132	KCNE3	2	potassium voltage-gated channel subfamily E regulatory subunit 3
133	FAHD2A	2	fumarylacetoacetate hydrolase domain containing 2A
134	TRIT1	2	tRNA isopentenyltransferase 1
135	TMEM18	2	transmembrane protein 18
136	ZFP36	2	ZFP36 ring finger protein [
137	VPS11	2	VPS11, CORVET/HOPS core subunit
138	NBPF3	2	neuroblastoma breakpoint family member 3
139	MRPS25	2	mitochondrial ribosomal protein S25
140	AMACR	2	alpha-methylacyl-CoA racemase
141	CAPSL	2	calcyphosine like
142	COX7B	2	cytochrome c oxidase subunit 7B

Table A.2 Genes essential for WT keratinocyte growth only

Rank	Gene Symbol	Frequency (# wells)	Gene name
1	THY1	9	Thy-1 cell surface antigen
2	RNF24	5	ring finger protein 24
3	ATXN7L1	4	ataxin 7 like 1
4	SLC31A2	4	solute carrier family 31 member 2
5	CCL13	4	C-C motif chemokine ligand 13
6	SOD1	4	superoxide dismutase 1, soluble
7	SMCO4	3	single-pass membrane protein with coiled-coil domains 4
8	RAB17	3	RAB17, member RAS oncogene family
9	ERP27	3	endoplasmic reticulum protein 27 [
10	STX6	3	syntaxin 6
11	CCDC115	3	coiled-coil domain containing 115
12	C6orf106	3	chromosome 6 open reading frame 106
13	COX6B1	3	cytochrome c oxidase subunit 6B1
14	UCN3	3	urocortin 3
15	MXI1	3	MAX interactor 1, dimerization protein
16	TMEM86B	3	transmembrane protein 86B
17	CXCL13	3	C-X-C motif chemokine ligand 13
18	CCDC59	3	coiled-coil domain containing 59
19	OCIAD2	3	OCIA domain containing 2
20	FUNDC2	3	FUN14 domain containing 2
21	CDKN1B	3	cyclin dependent kinase inhibitor 1B
22	FKBP1A	3	FK506 binding protein 1A
23	RPL34	3	ribosomal protein L34
24	SF3B6	3	splicing factor 3b subunit 6
25	EIF4EBP2	3	eukaryotic translation initiation factor 4E binding protein 2
26	CPLX3	3	complexin 3
27	ISL1	3	ISL LIM homeobox 1
28	COX17	3	COX17, cytochrome c oxidase copper chaperone
29	EBP	2	emopamil binding protein (sterol isomerase)
30	EI24	2	EI24, autophagy associated transmembrane protein
31	UCP2	2	uncoupling protein 2
32	REG1B	2	regenerating family member 1 beta
33	TYROBP	2	TYRO protein tyrosine kinase binding protein
34	FTO	2	fat mass and obesity associated
35	MBOAT2	2	membrane bound O-acyltransferase domain containing 2
36	WDR6	2	WD repeat domain 6
37	DFNA5	2	DFNA5, deafness associated tumor suppressor
38	CLIC4	2	chloride intracellular channel 4
39	BIK	2	BCL2 interacting killer
40	DDAH2	2	dimethylarginine dimethylaminohydrolase 2
41	MTX1	2	metaxin 1
42	MAMDC2	2	MAM domain containing 2
43	SMG9	2	SMG9, nonsense mediated mRNA decay factor
44	MYH9	2	myosin heavy chain 9
45	JTB	2	jumping translocation breakpoint
46	THRSP	2	thyroid hormone responsive

47	PAGE1	2	PAGE family member 1
48	GRP	2	gastrin releasing peptide
49	MEPCE	2	methylphosphate capping enzyme
50	KLF7	2	Kruppel like factor 7
51	OGN	2	osteoglycin
52	RAPSN	2	receptor associated protein of the synapse
53	DUSP3	2	dual specificity phosphatase 3
54	MTMR10	2	myotubularin related protein 10
55	P2RY10	2	purinergic receptor P2Y10
56	AKT2	2	AKT serine/threonine kinase 2
57	RBP7	2	retinol binding protein 7
58	DCUN1D4	2	defective in cullin neddylation 1 domain containing 4
59	CNPY2	2	canopy FGF signaling regulator 2
60	BUD31	2	BUD31 homolog
61	EFNB2	2	ephrin B2
62	LEP	2	leptin
63	SH3RF2	2	SH3 domain containing ring finger 2
64	GRPEL2	2	GrpE like 2, mitochondrial
65	ALG1L	2	ALG1, chitobiosyldiphosphodolichol beta-mannosyltransferase like
66	CD3D	2	CD3d molecule
67	PTPN11	2	protein tyrosine phosphatase, non-receptor type 11
68	FAM71F1	2	family with sequence similarity 71 member F1
69	CENPU	2	centromere protein U
70	BOC	2	BOC cell adhesion associated, oncogene regulated
71	FAIM	2	Fas apoptotic inhibitory molecule
72	EAF1	2	ELL associated factor 1
73	TGFBR2	2	transforming growth factor beta receptor 2
74	LRRC3B	2	leucine rich repeat containing 3B
75	SUSD6	2	sushi domain containing 6
76	NUDT16P1	2	nudix hydrolase 16 pseudogene 1
77	HMG20A	2	high mobility group 20A
78	HDAC11	2	histone deacetylase 11
79	GLYATL1	2	glycine-N-acyltransferase like 1
80	C12orf65	2	chromosome 12 open reading frame 65
81	IZUMO4	2	IZUMO family member 4
82	ZBED6CL	2	ZBED6 C-terminal like
83	CALCB	2	calcitonin related polypeptide beta
84	PIGP	2	phosphatidylinositol glycan anchor biosynthesis class P
85	ACBD7	2	acyl-CoA binding domain containing 7
86	NUDCD2	2	NudC domain containing 2
87	MRPL30	2	mitochondrial ribosomal protein L30
88	CLIC2	2	chloride intracellular channel 2
89	RPP40	2	ribonuclease P/MRP subunit p40
90	TMEM116	2	transmembrane protein 116
91	HIST1H4A	2	histone cluster 1, H4a
92	HIST1H2AL	2	histone cluster 1, H2al
93	HIST1H4F	2	histone cluster 1, H4f
94	NIPBL	2	NIPBL, cohesin loading factor
95	SAMD4B	2	sterile alpha motif domain containing 4B
96	HOXA10	2	homeobox A10

97	SFT2D2	2	SFT2 domain containing 2
98	PAPD4	2	poly(A) RNA polymerase D4, non-canonical
99	C6orf226	2	chromosome 6 open reading frame 226
100	EXOSC8	2	exosome component 8
101	SLC31A1	2	solute carrier family 31 member 1
102	AKAP7	2	A-kinase anchoring protein 7
103	TM4SF4	2	transmembrane 4 L six family member 4
104	TCEANC2	2	transcription elongation factor A N-terminal and central domain containing 2
105	PRKCH	2	protein kinase C eta
106	VAMP1	2	vesicle associated membrane protein 1
107	NUTF2	2	nuclear transport factor 2
108	INSIG2	2	insulin induced gene 2
109	APOL4	2	apolipoprotein L4
110	CXCL5	2	C-X-C motif chemokine ligand 5
111	TMEM263	2	transmembrane protein 263
112	RNASE1	2	ribonuclease A family member 1, pancreatic
113	PRKRA	2	protein activator of interferon induced protein kinase EIF2AK2
114	MAGEB2	2	MAGE family member B2
115	EML2	2	echinoderm microtubule associated protein like 2
116	CISD2	2	CDGSH iron sulfur domain 2
117	ANKRD1	2	ankyrin repeat domain 1
118	COPZ1	2	coatomer protein complex subunit zeta 1
119	LRRC20	2	leucine rich repeat containing 20
120	TXN2	2	thioredoxin 2
121	TEX30	2	testis expressed 30
122	PPP1R2	2	protein phosphatase 1 regulatory inhibitor subunit 2
123	POLD4	2	DNA polymerase delta 4, accessory subunit

Table A.3 Genes essential for both *Hras*^{G12V} and WT keratinocyte growth

Rank	Gene Symbol	Frequency in *Hras*^{G12V}	Frequency in WT	Gene name
1	MZB1	2	12	marginal zone B and B1 cell specific protein
2	SLC12A7	5	11	solute carrier family 12 member 7
3	LAMC1	3	9	laminin subunit gamma 1
4	C7orf34	4	8	chromosome 7 open reading frame 34
5	MUM1	3	6	melanoma associated antigen (mutated) 1
6	BDH2	2	5	3-hydroxybutyrate dehydrogenase, type 2
7	TBX3	2	5	T-box 3
8	NKG7	3	4	natural killer cell granule protein 7
9	GOLGA2	2	4	golgin A2
10	NTS	2	4	neurotensin
11	BRK1	2	4	BRICK1, SCAR/WAVE actin nucleating complex subunit
12	MCEE	2	4	methylmalonyl-CoA epimerase
13	CFL1P1	3	4	cofilin 1 pseudogene 1
14	KXD1	2	4	KxDL motif containing 1
15	GLT1D1	3	3	glycosyltransferase 1 domain containing 1
16	MEI1	2	3	meiotic double-stranded break formation protein 1
17	TIPIN	2	3	TIMELESS interacting protein
18	SH3GL3	2	3	SH3 domain containing GRB2 like 3, endophilin A3
19	TM2D3	2	3	TM2 domain containing 3
20	APLN	3	3	apelin
21	UBE2E2	3	3	ubiquitin conjugating enzyme E2 E2
22	ZNF593	5	3	zinc finger protein 593
23	TRIM69	2	3	tripartite motif containing 69
24	PLPP2	3	2	phospholipid phosphatase 2
25	CSAG1	2	2	chondrosarcoma associated gene 1
26	SPRY1	3	2	sprouty RTK signaling antagonist 1
27	HIST1H4I	3	2	histone cluster 1, H4i
28	NXT2	2	2	nuclear transport factor 2 like export factor 2
29	VTCN1	3	2	V-set domain containing T cell activation inhibitor 1
30	DUSP13	3	2	dual specificity phosphatase 13
31	HOPX	3	2	HOP homeobox
32	LEPROT	2	2	leptin receptor overlapping transcript
33	CYTH4	3	2	cytohesin 4
34	CCL24	3	2	C-C motif chemokine ligand 24
35	IFT27	2	2	intraflagellar transport 27
36	SOD3	2	2	superoxide dismutase 3, extracellular
37	CHMP2A	3	2	charged multivesicular body protein 2A
38	TSACC	2	2	TSSK6 activating cochaperone
39	PDCD5	2	2	programmed cell death 5
40	MMS19	2	2	MMS19 homolog, cytosolic iron-sulfur assembly component
41	EEF2KMT	2	2	eukaryotic elongation factor 2 lysine methyltransferase
42	NAA20	2	2	N(alpha)-acetyltransferase 20, NatB catalytic subunit
43	TOMM7	3	2	translocase of outer mitochondrial membrane 7

Appendix B – *In vivo* ribosome profiling results

Table B.1 Translationally altered genes in *Hras*^{G12V} epidermal progenitors *Hras*^{G12V}+shScram vs. WT+shScram (HS/WS)

Genes with translational efficiency changes were identified by Xtail analysis and excluded genes with significant transcriptional changes (as determined by EdgeR). Positive fold-change value indicates translational upregulation in *Hras*^{G12V}+shScram basal progenitors.

Gene Description		EdgeR on total RNA			Xtail		
Gene Symbol	Entrez ID	Log_2 Fold Change	p-value	FDR	Log_2 Fold Change	p-value	FDR
Nr4a3	18124	-0.1264115	0.71944526	1	2.1584256	0.00042117	0.00639609
Cdkn2b	12579	-0.5276913	0.01976271	0.21987477	2.03474134	1.0345E-05	0.0003465
Eaf2	106389	-0.8885439	0.12172495	0.551839	1.86792269	0.00214857	0.0214321
Mgarp	67749	-0.9235336	0.11398323	0.53654287	1.86525543	0.0003988	0.00613396
Parp16	214424	-0.7660607	0.08731571	0.47874649	1.86479038	0.00202284	0.02050344
Mxra7	67622	-0.5451761	0.1312369	0.5649456	1.82362057	0.00279623	0.02582355
Dpf1	29861	-1.0507708	0.01504056	0.18759217	1.81648177	0.00442771	0.03686594
Krt35	53617	-0.8422513	0.00213442	0.05659964	1.75973524	8.991E-13	3.8276E-10
Klf9	16601	-0.195854	0.40472518	0.92328773	1.68156937	0.00213197	0.02130554
Pdxp	57028	-0.4840959	0.01980666	0.2199081	1.61740659	0.00428577	0.03598708
Aif1l	108897	0.1689697	0.74275695	1	1.56682494	0.00251825	0.02397754
Syt11	229521	0.53508335	0.27325422	0.75164918	1.49730812	0.01291052	0.08054594
Sdhaf1	68332	-0.0189413	0.94230339	1	1.49236403	0.00657753	0.04942295
Macrod2	72899	-0.3555506	0.31864015	0.81745668	1.44483851	5.3177E-06	0.00020701
Dnal4	54152	-0.3300828	0.0777735	0.44722945	1.3916271	3.3979E-06	0.00014559
Fgf20	80857	-0.8347248	0.06995952	0.42091189	1.39117644	0.00300845	0.02747582
Stx2	13852	-0.5269063	0.03690661	0.30849888	1.34619281	0.00025037	0.00429111
BC016579	212998	-0.1860928	0.60034217	1	1.29727747	0.00509074	0.04098996
Fbxo9	71538	-0.0856887	0.62473879	1	1.27898593	0.0001385	0.00266055
9930012K11Rik	268759	-0.6856625	0.01068166	0.15186528	1.25941524	0.00056801	0.00799092
Arhgap40	545481	-0.7339385	0.02395335	0.24324521	1.24423998	0.00152506	0.01660574
2410004B18Rik	66421	-0.3659837	0.11323423	0.53644212	1.22169419	3.9977E-05	0.00100325
Mid1ip1	68041	0.01735805	0.93192704	1	1.20440502	4.3982E-07	2.6264E-05
Zscan20	269585	-0.7319422	0.00375618	0.08124855	1.20413895	0.0124239	0.07844498
Spryd3	223918	-0.3175899	0.11202891	0.53486958	1.19718824	7.1279E-06	0.00025701
Mbp	17196	0.23060702	0.23025586	0.73851831	1.18995403	0.00163336	0.01749626
Mif4gd	69674	-0.2885572	0.16267387	0.63920493	1.18920678	6.0492E-06	0.00022744
Snx11	74479	-0.289376	0.11528665	0.54049057	1.18321946	0.00097646	0.0120772
Banf1	23825	-0.2495241	0.15685432	0.62704007	1.18296109	1.789E-08	1.859E-06
Slc26a9	320718	-0.2179686	0.51720551	1	1.18200853	0.00672319	0.05009931
Fadd	14082	-0.2042315	0.32048745	0.81945596	1.17931541	4.6261E-06	0.000185
Klhl18	270201	0.13330748	0.45696553	0.98413628	1.17235378	1.5251E-05	0.00046855
Hypk	67693	-0.297942	0.20649868	0.72387713	1.15959803	0.00089263	0.0113008
Fkbp2	14227	-0.5418959	0.00408208	0.08534963	1.15685372	1.7967E-07	1.268E-05
Id1	15901	-0.2953939	0.15512591	0.62308058	1.14742813	1.7274E-11	5.0658E-09
Fam89a	69627	0.60713162	0.05136072	0.36229929	1.13573482	0.00296599	0.02716358
Zkscan5	22757	-0.2184678	0.27676845	0.75654379	1.13460914	0.00626728	0.04792331
Rdh9	103142	-0.0091152	0.96397838	1	1.09948481	0.00393535	0.03372392
Traf3	22031	-0.0571896	0.74446747	1	1.09838452	0.00208293	0.02096754
Gnmt	14711	-0.6869629	0.08719741	0.47820526	1.08686607	0.00127061	0.01461927
Ubtd1	226122	-0.3319856	0.13979747	0.58549029	1.08578915	0.00341071	0.03026978
Nudt3	56409	-0.3707976	0.06723769	0.41562686	1.08060915	1.387E-06	6.9332E-05
Crabp2	12904	0.31753279	0.17492452	0.66343093	1.08054686	5.1263E-07	2.9287E-05
Lipt2	67164	-0.7495895	0.04063256	0.3206852	1.07750426	0.00441657	0.03681962
Ctdspl	69274	-0.1563342	0.36472492	0.87460206	1.077077	0.00014555	0.00277578
Arf6	11845	0.01575949	0.93845004	1	1.06194606	1.1242E-10	2.4728E-08

Pop5	117109	-0.3842611	0.04284981	0.328801	1.06079062	6.5947E-09	7.7018E-07
Foxo6	329934	-0.6706814	0.02437149	0.24583893	1.05797162	0.00920068	0.06281498
Rhob	11852	-0.254091	0.17373088	0.66100505	1.05749721	1.0958E-07	8.5573E-06
Rab15	104886	-0.5852587	0.00274626	0.06726827	1.05588799	0.00401587	0.03434703
Rilpl1	75695	-0.3941107	0.18420984	0.68265016	1.04715699	0.01273319	0.07985523
Ipmk	69718	0.128878	0.49222457	1	1.04246026	0.00431051	0.03611801
Plec	18810	-0.6518787	0.00826433	0.13109209	1.04033605	2.9875E-09	4.023E-07
Cyp26b1	232174	-0.6450173	0.05581351	0.37735931	1.03890932	0.00626841	0.04792331
Hebp1	15199	-1.0910422	0.00477035	0.09402214	1.0368771	6.1063E-05	0.00139421
Tpd52l1	21987	0.55351104	0.14056556	0.58693515	1.03162016	0.00754885	0.05482782
Nip7	66164	0.15172169	0.50186259	1	1.02811653	1.9034E-08	1.9473E-06
Tacc1	320165	-0.0417717	0.81487035	1	1.02746718	0.00033255	0.00534557
0610010K14Rik	104457	-0.5421305	0.0058332	0.10575548	1.02026401	1.6083E-06	7.8318E-05
Plekhh3	217198	-0.7326376	0.00699497	0.11805396	1.01807735	6.6138E-05	0.00148439
Rps11	27207	-0.3673235	0.12810261	0.55895215	1.01639515	1.7037E-11	5.0658E-09
Pbxip1	229534	-0.3395868	0.21058291	0.73215338	0.98763568	0.00117175	0.01375763
Egln2	112406	-0.3324376	0.08252939	0.46321539	0.98728519	0.01507917	0.08956044
Tsc22d4	78829	-0.3748334	0.06865613	0.41818302	0.98606375	0.00057608	0.00806288
Iffo2	212632	-0.5536704	0.00405794	0.08506357	0.98487278	3.1541E-05	0.0008495
Spred1	114715	0.56766987	0.00356502	0.07871732	0.98412264	2.3431E-05	0.00066355
Polr2f	69833	-0.3755976	0.10394312	0.51903427	0.9829458	1.1172E-06	5.7592E-05
Krt14	16664	-0.4609608	0.03384365	0.29339437	0.97204086	0.01367391	0.08432459
Gng12	14701	0.19064465	0.29654398	0.78485854	0.96979437	2.8934E-08	2.7475E-06
Atf5	107503	-0.1549655	0.5950194	1	0.96818697	0.01219529	0.07726418
Glt1d1	319804	0.43161334	0.21914284	0.73474314	0.96680875	0.01631075	0.09453892
Rassf5	54354	-0.2171803	0.27160567	0.74905499	0.96116782	0.00186159	0.01926853
Sptan1	20740	-0.3717292	0.03503087	0.29985586	0.95868829	7.9084E-12	2.7296E-09
Oas1f	243262	-0.4730974	0.02058117	0.22528582	0.9494716	4.3683E-05	0.00107956
Sytl4	27359	-0.4051123	0.34232952	0.84681575	0.93579136	0.01467759	0.08815769
Isca1	69046	-0.1629161	0.34735116	0.85351253	0.9350751	0.00031526	0.00513009
Ttc19	72795	-0.2369961	0.35312039	0.86106371	0.92777195	0.00110525	0.01317615
Eva1a	232146	0.38475585	0.11926885	0.5494512	0.92525393	0.00564483	0.04413198
Polr3gl	69870	-0.4462552	0.18981812	0.69278013	0.92466235	0.01275456	0.07991182
Wdfy2	268752	-0.3186566	0.09011112	0.48632127	0.9240589	0.00018418	0.00336187
Eppk1	223650	-0.5270987	0.00195714	0.05403242	0.92354001	6.508E-07	3.5936E-05
Mt2	17750	0.0962242	0.66675408	1	0.92294715	3.2662E-10	6.0709E-08
Hspa2	15512	-0.3882412	0.06186238	0.39819218	0.92101949	3.1058E-07	2.0191E-05
Evpl	14027	-0.8014698	0.00363691	0.07965655	0.90544864	3.8122E-06	0.00016022
Dsp	109620	-0.3904791	0.04959254	0.35645311	0.89848922	7.5312E-11	1.8071E-08
Ltb4r2	57260	0.70714563	0.00370792	0.08077709	0.89800071	0.00245543	0.02358393
Wdr83	67836	-0.2569953	0.20912192	0.7290459	0.89798565	0.00112674	0.01336745
Lzic	69151	-0.3154928	0.08069115	0.45710013	0.89719579	2.4458E-06	0.00011054
Atg101	68118	-0.1395327	0.48501747	1	0.8952957	1.2193E-05	0.00039471
Arrb2	216869	-0.4269689	0.06420208	0.40597589	0.89435066	0.00145495	0.01616242
Trappc3	27096	-0.3519879	0.08026642	0.45585726	0.89338144	3.6303E-08	3.2591E-06
Zfp568	243905	-0.0123716	0.9517369	1	0.89306517	0.01256746	0.07916601
Uqcc3	107197	-0.4233095	0.12155774	0.551839	0.89042779	0.00023953	0.00415386
Ppif	105675	0.33891137	0.06085236	0.39565378	0.88977771	1.5357E-05	0.00046926
Fam96b	68523	-0.3274079	0.23601261	0.73917364	0.88832354	0.00012602	0.00247481
Hebp2	56016	-0.0302946	0.86327007	1	0.88783091	0.00014456	0.00276092
Eef2k	13631	-0.5045779	0.00602078	0.10748055	0.88258684	2.9452E-09	4.007E-07
Polr2d	69241	-0.3105386	0.07451442	0.43530261	0.8787649	9.306E-06	0.00031982
Gtpbp6	107999	-0.5569022	0.00261275	0.06517458	0.87688377	0.01284369	0.08025484
Coa5	76178	0.55694311	0.00206048	0.0557861	0.87385965	0.00227082	0.02236416
Gskip	66787	-0.0126979	0.95836928	1	0.87358878	0.00304592	0.02770348
Sbk1	104175	-0.2643808	0.12550525	0.5559786	0.8735705	0.00263083	0.02472864
Krt10	16661	-0.5755423	0.03378711	0.29321786	0.87180199	8.2314E-06	0.00028891
Klhl26	234378	-0.4402444	0.0395273	0.31836942	0.86673143	0.00558445	0.04375279
Ppp1r9b	217124	-0.4914152	0.09957704	0.50881528	0.86437285	0.00014881	0.00282967
Cenpo	52504	-0.1252608	0.65037653	1	0.86395955	0.00919033	0.0627768
Mrps26	99045	-0.2641086	0.33560575	0.83827637	0.86293194	0.00053593	0.00765447
Rnf187	108660	-0.2460544	0.13068699	0.56358555	0.86236306	1.5777E-07	1.1377E-05
Oraov1	72284	-0.1830325	0.42255692	0.94274278	0.86215478	0.00248234	0.02372155

Gpatch11	53951	-0.1428876	0.58801471	1	0.86131216	0.00048849	0.00714696
Timm10	30059	0.12110093	0.66117463	1	0.85982869	0.00104832	0.0127157
Pex16	18633	-0.4935188	0.05573263	0.37735931	0.85949593	0.00170344	0.01801744
Calml3	70405	-0.4897063	0.0214164	0.22949894	0.8568186	2.3554E-08	2.3198E-06
Ndufb10	68342	-0.2993459	0.09956932	0.50881528	0.85220605	4.20E-07	2.531E-05
Hk2	15277	-0.0455518	0.82070093	1	0.85105034	4.14E-06	0.00017081
Id3	15903	0.25122032	0.15405225	0.62060543	0.85099847	6.1162E-07	3.4494E-05
Pole4	66979	-0.0316033	0.87993556	1	0.8509198	7.9428E-05	0.00171837
Cep131	12009	-0.8517081	0.002093	0.05616823	0.85074113	0.00288732	0.02657176
Il34	76527	-0.5130745	0.00635963	0.11103226	0.85032268	0.00423374	0.03568125
Bok	51800	-0.2690444	0.12458708	0.55469927	0.85014332	0.00528672	0.04213094
Dus3l	224907	-0.5171705	0.01001195	0.14652066	0.84867867	0.00029222	0.00485093
Tnfaip3	21929	-0.0487955	0.84473789	1	0.84840736	0.00418321	0.03538833
Vhl	22346	0.27925606	0.19857738	0.70836375	0.84837603	0.00374321	0.03239291
Zfyve27	319740	-0.3499055	0.07138085	0.42584827	0.84610772	0.00297141	0.02719396
Rab3d	19340	-0.1993562	0.26518117	0.74309288	0.8459188	6.1715E-07	3.4658E-05
Rbp1	19659	0.46141623	0.23426174	0.73917364	0.84533663	0.00670453	0.05004506
Acap3	140500	-0.428056	0.01002995	0.14652066	0.84426151	0.00015748	0.00295201
Pmaip1	58801	-0.0156884	0.93819981	1	0.8419527	0.00494898	0.04009315
Ndufv3	78330	-0.5649579	0.0060042	0.10726948	0.83610404	3.3717E-07	2.1705E-05
Ywhag	22628	-0.2886372	0.0895515	0.48518872	0.83508494	5.7937E-06	0.00022098
Hist1h4f	319157	-0.3298308	0.22748983	0.73474314	0.83488692	6.9658E-06	0.00025385
Akr1b8	14187	0.68777196	0.10249345	0.51533713	0.83278493	0.00428671	0.03598708
Commd7	99311	-0.2311121	0.22730217	0.73474314	0.83273557	0.00011591	0.00231417
Wnt7a	22421	-0.5796048	0.00986026	0.14499681	0.83072262	0.01060577	0.06991227
Triobp	110253	-0.552452	0.01471588	0.18501839	0.82941548	1.4305E-05	0.00044629
Pgp	67078	-0.6165492	0.00213344	0.05659964	0.82923937	0.00258611	0.0244476
Adck4	76889	-0.7232537	0.00269035	0.06618196	0.82894698	0.00183891	0.0190728
Pdf	68023	-0.1592619	0.40264317	0.92104245	0.82244461	0.00160494	0.01727599
Man1a	17155	-0.022713	0.91765381	1	0.81919213	5.0548E-05	0.00121069
Sart1	20227	-0.6249539	0.01014182	0.14751249	0.81858831	4.3698E-06	0.00017854
Spag1	26942	-0.559102	0.07674315	0.44358449	0.81852696	0.01263827	0.07946179
Fos	14281	-0.3999943	0.05051367	0.35936201	0.81851583	8.7911E-05	0.00186154
Stard3nl	76205	-0.0726087	0.79620399	1	0.81845683	0.01176792	0.07517002
Tpm4	326618	0.21581725	0.19144471	0.69500092	0.8162215	1.6507E-06	7.9256E-05
Cby1	73739	0.02827424	0.91892566	1	0.81606977	0.00646937	0.04895431
Sike1	66641	0.13613836	0.53757157	1	0.81241074	1.266E-05	0.00040065
Cox6a1	12861	-0.3860948	0.01665124	0.19827861	0.80921777	9.59E-08	7.5345E-06
Krt17	16667	-0.085733	0.71389789	1	0.80830945	1.232E-06	6.3266E-05
Hs6st1	50785	-0.2715119	0.09676337	0.50406534	0.80801585	0.00022339	0.00393084
Mpv17l2	234384	-0.5106293	0.01492661	0.18676858	0.80799191	0.00235401	0.0228426
Tmem198b	73827	-0.1761012	0.43681895	0.96069484	0.80720432	0.00968256	0.06528566
Map3k11	26403	-0.3550046	0.07357618	0.43265205	0.80370901	0.00427478	0.03593262
Tnrc18	231861	-0.6177673	0.00836213	0.13183444	0.80227821	3.26E-05	0.00086961
Tpgs1	110012	-0.5620226	0.00511739	0.09817898	0.80218532	0.00056792	0.00799092
Ccdc91	67015	-0.4941152	0.00734639	0.12179652	0.80206023	0.00018739	0.00340628
Rbp2	19660	-0.2297331	0.27276826	0.75081985	0.80199249	0.00078777	0.01026284
Tmx4	52837	0.04166253	0.87556168	1	0.8011324	0.00120041	0.01400689
Hars2	70791	-0.5261216	0.0340525	0.29385025	0.80102207	1.2575E-05	0.00039893
Rnf11	29864	-0.1753223	0.3580363	0.86719149	0.80072211	0.01684372	0.09677253
Tmem263	103266	0.19439259	0.3669041	0.87718464	0.79990971	0.00516118	0.04138038
Dnase1l2	66705	0.06512131	0.88165928	1	0.79945752	0.00716027	0.05261365
Yaf2	67057	0.01665016	0.93915783	1	0.79816318	0.01131178	0.07285583
Arpc5	67771	0.10592446	0.53921852	1	0.79608987	1.0583E-06	5.4984E-05
Nob1	67619	-0.2302704	0.22496616	0.73474314	0.79542655	1.7569E-05	0.00052576
Ccdc97	52132	-0.2406473	0.17278213	0.65932652	0.79440836	0.00087473	0.01113194
Ppl	19041	-0.535952	0.01976093	0.21987477	0.79321938	2.8557E-05	0.00077864
Mettl7a1	70152	-0.5576832	0.00512182	0.09817898	0.79133595	3.3126E-05	0.00087608
Pawr	114774	-0.3390495	0.15203511	0.61561628	0.78905806	0.0004973	0.00721782
Tchh	99681	-0.3742419	0.1280939	0.55895215	0.78798662	0.00217071	0.02161434
Fdx1	14148	-0.1448612	0.50270278	1	0.78752611	0.00100892	0.01237508
Dync1h1	13424	-0.4381134	0.01510202	0.18791619	0.78646224	1.4506E-07	1.0577E-05
Cox20	66359	0.03669725	0.89520764	1	0.78615066	0.00134552	0.01521457

Dnaja4	58233	-0.1743438	0.53328177	1	0.78260726	0.01493216	0.08894127
Zbtb14	22666	0.0879361	0.68500834	1	0.78124938	0.0009098	0.01143484
Suv420h1	225888	-0.1060088	0.5552081	1	0.77976088	9.3867E-05	0.00196629
Rabif	98710	0.3119864	0.12208816	0.551839	0.77919525	0.00304598	0.02770348
Tmem40	94346	-0.3412701	0.1253468	0.5559786	0.77873662	0.00388988	0.03339931
Snrnp35	76167	-0.2337683	0.47985913	1	0.7764742	0.00328566	0.02941712
Notch3	18131	-0.4654997	0.0080063	0.12875048	0.77334474	7.4127E-05	0.00162862
Fam25c	69134	-0.1425683	0.50435111	1	0.77306031	3.4716E-08	3.138E-06
Sltm	66660	-0.4825876	0.01677326	0.19846154	0.77122485	1.80E-06	8.5636E-05
Ddx27	228889	-0.3510315	0.05737745	0.38379306	0.7696851	2.3025E-05	0.00065487
Wnt3	22415	-0.3649445	0.04687112	0.34539628	0.76849652	0.00012718	0.00248288
Fjx1	14221	0.06693399	0.79794895	1	0.76737918	0.00778869	0.05592348
Suv420h2	232811	-0.3606168	0.07463552	0.43552841	0.76719058	0.01097988	0.07124157
Tmem154	320782	0.13492647	0.48285323	1	0.76518064	0.00261775	0.02462331
Rnf113a1	69942	-0.4093914	0.17837357	0.67132414	0.76516224	0.00530977	0.04223863
Rgl2	19732	-0.3617438	0.03943068	0.31801075	0.76157961	0.01569411	0.09229138
Pgrmc1	53328	0.03971489	0.82842261	1	0.76116997	1.0531E-06	5.4935E-05
Myo18a	360013	-0.690085	0.00420033	0.08692901	0.76091204	3.77E-06	0.00015914
Atf4	11911	0.4178029	0.01457942	0.18412075	0.76084748	0.00219733	0.02178357
Fahd1	68636	-0.0787227	0.77042911	1	0.75973889	0.00671918	0.05009776
Telo2	71718	-0.5120582	0.01594952	0.19397571	0.75756931	0.00386356	0.03321654
Tpcn1	252972	-0.0366623	0.84189904	1	0.75732587	0.0071901	0.05274475
Gadl1	73748	-0.0619802	0.71996552	1	0.75716267	7.001E-06	0.00025385
Cwc25	67480	-0.1293567	0.51060699	1	0.75643994	0.00083262	0.01068883
Oaz2	18247	-0.101097	0.58714871	1	0.7546431	0.00165852	0.017637
Notch2	18129	-0.4198123	0.02723805	0.26157315	0.75377377	5.09E-07	2.919E-05
Sh3bp5	24056	-0.5040509	0.04286894	0.328801	0.75349801	0.00054862	0.00778096
Mea1	17256	-0.1474996	0.50409979	1	0.75304848	0.00028537	0.00478534
Bcl7b	12054	-0.6110783	0.00695407	0.11777068	0.75113767	0.00899688	0.06187173
Gadd45b	17873	0.15005921	0.48142235	1	0.75021306	0.00093597	0.01168012
Hnrnpul2	68693	-0.3864479	0.06694965	0.41496889	0.74979431	1.93E-06	9.0088E-05
Tecpr1	70381	-0.3230802	0.10275091	0.51601524	0.74976724	0.00737499	0.05386148
Mzt2	72083	-0.2274916	0.33127354	0.83249991	0.74726129	0.00036481	0.00573222
Dhx16	69192	-0.6075733	0.00327967	0.07422875	0.74566746	0.00011381	0.00228614
Chchd4	72170	-0.0682066	0.77313909	1	0.74454982	0.00335564	0.0299017
Pacsin3	80708	-0.448875	0.06881892	0.41818302	0.74143628	0.00186653	0.01928055
S100a3	20197	0.36264826	0.11222242	0.53530319	0.74106705	0.00069808	0.00932446
Krt5	110308	-0.4440641	0.03916721	0.31676117	0.74030895	4.4306E-06	0.00018046
Exosc6	72544	-0.4424825	0.04355834	0.33173611	0.73956804	0.0101069	0.06780922
Eif1ad	69860	-0.031895	0.86384321	1	0.73682939	0.00155489	0.01684715
Rpl41	67945	-0.1109366	0.54908628	1	0.73649659	2.033E-05	0.00058707
Mdm2	17246	-0.2301584	0.2285124	0.7347599	0.73541399	0.00048151	0.00707987
Ralb	64143	0.08163533	0.68631934	1	0.73487455	0.00238895	0.02302919
Prdx5	54683	-0.4547388	0.01144517	0.15759461	0.73214609	4.09E-05	0.00102102
Alyref	21681	-0.0729483	0.71853209	1	0.73207584	8.2346E-05	0.00176415
Tnks1bp1	228140	-0.6318378	0.00212364	0.05659964	0.73192261	1.5633E-05	0.00047645
Tpm3	59069	-0.171121	0.37816908	0.89235397	0.73002435	1.3907E-07	1.0376E-05
Psmc3ip	19183	-0.1746585	0.45695836	0.98413628	0.72872368	0.00603946	0.04652819
Ccdc64b	212733	-0.8008298	0.006358	0.11103226	0.72834985	0.0161256	0.09391418
Ankmy2	217473	-0.1717151	0.43178336	0.95391546	0.72799118	3.1688E-05	0.0008517
Tatdn2	381801	-0.2646717	0.11914881	0.54921348	0.72508912	0.00873555	0.06080445
Trim41	211007	-0.2963629	0.16168749	0.6369689	0.72493571	0.0079627	0.05680201
Trappc6a	67091	-0.5295468	0.02965433	0.27317556	0.72436382	0.00053222	0.00761725
Hspa12a	73442	-0.2332106	0.23879892	0.73917364	0.72317472	0.00543202	0.04287461
Vimp	109815	-0.1532138	0.41717745	0.93607983	0.72261409	2.3335E-05	0.00066228
Lrp1	16971	-0.5064272	0.00404674	0.08490158	0.72248513	2.5934E-05	0.00072052
Mrfap1	67568	-0.1199629	0.50955628	1	0.72211703	2.6332E-05	0.00073005
Cox11	69802	-0.2509874	0.2092591	0.72942	0.71838407	0.00189422	0.01945373
Matn2	17181	0.28058279	0.36326935	0.87282574	0.71637265	0.0031855	0.0287618
Upf3a	67031	-0.5763612	0.02462732	0.24678862	0.71375169	0.00012506	0.00246694
Cltb	74325	-0.3121433	0.1845417	0.68324634	0.71342768	5.4997E-06	0.00021099
Rpl11	67025	0.0289908	0.88129076	1	0.71321478	3.778E-05	0.00096813
Nhp2	52530	0.11763633	0.52872746	1	0.71184998	8.78E-06	0.00030338

Hk1	15275	-0.0809652	0.68761224	1	0.71172681	2.47E-05	0.00069229
Bcl7c	12055	-0.2979068	0.42527073	0.94585943	0.70998274	0.00540003	0.04276425
Shfm1	20422	-0.3048944	0.12398228	0.55354187	0.70901771	1.3926E-07	1.0376E-05
Yrdc	230734	-0.3178701	0.13202709	0.56635053	0.70852405	0.00296603	0.02716358
Scube1	64706	-0.6263255	0.00289735	0.06936877	0.70719703	0.00767211	0.0552668
Setd7	73251	-0.1617281	0.32765357	0.82746926	0.70642055	0.00165602	0.017637
Ccdc9	243846	-0.6520069	0.07914647	0.45201964	0.70624885	0.00277384	0.02567035
Nr2c2ap	75692	-0.440967	0.04975414	0.35677013	0.70519608	0.01423362	0.08652283
Nat9	66176	-0.0701022	0.81548503	1	0.70442466	0.00903953	0.06213267
Polr3d	67065	-0.418789	0.07058931	0.42348191	0.70236588	0.0074134	0.05405227
Dll1	13388	-0.4711942	0.05681566	0.38175152	0.70174384	0.00413469	0.03513378
Snrk	20623	-0.2544145	0.15137985	0.61409423	0.70147003	0.00033516	0.00536791
Fuk	234730	-0.4651947	0.04593192	0.34115066	0.6997938	0.01018153	0.06820621
Polr3g	67486	0.39994688	0.01606364	0.19478161	0.69769721	8.802E-05	0.00186154
Fbxo32	67731	-0.0758885	0.77862349	1	0.69690784	0.01527434	0.09035205
E2f4	104394	-0.2423288	0.18014356	0.67491829	0.69685691	0.00011641	0.00232059
Atg14	100504663	-0.3262219	0.13182283	0.56600184	0.69588893	0.00642277	0.04879751
Csk	12988	-0.214421	0.22133228	0.73474314	0.69583128	0.00054675	0.00776695
Daxx	13163	-0.2422855	0.17034109	0.65479296	0.6955548	0.00437199	0.03649407
Epha2	13836	-0.0147175	0.93169556	1	0.69055762	4.8612E-06	0.00019265
BC005624	227707	-0.3006555	0.12548829	0.5559786	0.69011108	0.00099578	0.01224725
Bahd1	228536	-0.3344046	0.07745893	0.44616784	0.68784602	0.00149955	0.01649132
Sash1	70097	-0.3251796	0.0593132	0.39042794	0.6845679	0.00057675	0.00806288
Ncaph2	52683	-0.3760495	0.02281079	0.2371487	0.68451297	1.0867E-05	0.00035852
Eps8l1	67425	-0.4542355	0.0528572	0.3677417	0.68348588	0.0065151	0.04915939
Kif1c	16562	-0.5582212	0.00838752	0.13206419	0.68266674	6.35E-05	0.00143602
Ankrd29	225187	-0.2501704	0.32625001	0.82623958	0.68252336	0.01539734	0.09103884
Safb	224903	-0.5278081	0.00884962	0.13617926	0.68208042	9.1632E-05	0.00192558
Atxn7l3b	382423	0.05296441	0.76238798	1	0.68205468	0.00037665	0.005856
Zrsr2	22184	-0.4971263	0.03133636	0.28269865	0.68163819	0.01041115	0.06922403
Iqce	74239	-0.3585137	0.10798727	0.52543069	0.68101866	0.01211542	0.07694285
Krt1	16678	-0.4941465	0.02672586	0.25809641	0.67739412	0.00059269	0.00822812
Use1	67023	-0.2832952	0.11494631	0.53972386	0.67616761	0.00013291	0.00257556
Rras2	66922	0.05862474	0.79206602	1	0.67607565	0.00628303	0.04795667
Tiam1	21844	-0.4218353	0.01840789	0.21045835	0.675446	1.9508E-07	1.3553E-05
Serf2	378702	-0.1641096	0.41169686	0.9306881	0.67449483	4.95E-05	0.0011891
Zcchc3	67917	-0.2289717	0.30216579	0.79363205	0.67425907	0.01557464	0.09179643
Clspn	269582	-0.5049662	0.00983013	0.14487731	0.67312319	0.00072287	0.00957802
Manf	74840	-0.090449	0.61898328	1	0.67015964	2.1974E-05	0.00062906
Rnf220	66743	-0.4895966	0.01093979	0.15416073	0.67005032	0.00242659	0.02337499
Gadd45a	13197	-0.2350874	0.31169686	0.80728453	0.66937486	0.00541152	0.04276425
Pcsk6	18553	0.23406534	0.20715778	0.72509675	0.66771261	7.2795E-05	0.00161187
Gan	209239	-0.5090671	0.00519262	0.09883792	0.66714715	0.00124116	0.01436801
Paip2b	232164	-0.0973398	0.5628726	1	0.6637777	0.0023821	0.02299678
Leng1	69757	-0.4873493	0.083391	0.46687108	0.66348758	0.00806871	0.05734129
Pycard	66824	0.02282465	0.89668211	1	0.66306048	4.02E-07	2.4531E-05
Rmdn3	67809	-0.1921767	0.30020431	0.79122598	0.66165455	0.00355616	0.03114178
Gcsh	68133	0.17629884	0.37263939	0.88463367	0.65843446	0.00144698	0.01610099
Epn1	13854	-0.2334342	0.19665298	0.70510385	0.65813931	0.00271664	0.02531371
Lrrc8a	241296	-0.1858702	0.26526375	0.74309288	0.65811013	0.00244934	0.02354259
Phldb3	232970	-0.4371164	0.1019883	0.51380483	0.65794404	0.00310332	0.02812812
Zfand1	66361	0.1294645	0.53088301	1	0.65766617	0.00205211	0.02073635
Ube2g2	22213	-0.1978264	0.27695312	0.75669769	0.65736631	0.00044448	0.00663557
Kctd15	233107	-0.3654108	0.02407635	0.24397033	0.6573152	0.00061681	0.00846376
Mvk	17855	-0.1985694	0.25536813	0.74309288	0.65691356	0.0008999	0.01134291
Wdr4	57773	-0.2392798	0.28178635	0.76419637	0.65668124	0.0062079	0.04760354
Ppfia1	233977	-0.2006784	0.21869144	0.73474314	0.65632198	3.2542E-05	0.00086935
Mapkapk3	102626	-0.0430044	0.79361921	1	0.65607913	0.00017004	0.00314281
Vamp3	22319	0.57307261	0.01068361	0.15186528	0.65607452	0.00024991	0.00428882
Coa7	69893	-0.2610851	0.26355186	0.74309288	0.65456606	0.0087906	0.06100596
Gpatch2	67769	-0.301	0.12982349	0.56193182	0.65210111	0.01687182	0.09685943
Kank1	107351	-0.4879798	0.00402559	0.08490158	0.65197108	0.00088165	0.01120919
Eya3	14050	0.00553605	0.9757913	1	0.65179456	0.00061131	0.00842119

Lypd3	72434	-0.0775147	0.67300942	1	0.65133888	5.2581E-05	0.00124135
Trim35	66854	-0.3518557	0.08352645	0.46714809	0.6507391	0.00021177	0.00376135
Edn2	13615	0.27434059	0.30091671	0.791917	0.65066319	0.01291469	0.08054594
Ubxn1	225896	-0.2725202	0.14001591	0.58592514	0.65042805	0.00048323	0.00708573
Micu2	68514	-0.4539927	0.00935983	0.140749	0.64668938	1.2665E-06	6.4532E-05
Cdk5rap3	80280	-0.4569983	0.02004617	0.22122923	0.64638126	0.00060842	0.0083989
Cyhr1	54151	-0.2366525	0.23508617	0.73917364	0.64622855	0.00147042	0.01627623
Nars	70223	-0.1898798	0.34560914	0.85217672	0.64460855	7.31E-06	0.00026073
Lgals7	16858	-0.3060358	0.10661364	0.52386628	0.64328287	1.45E-07	1.0577E-05
Krt73	223915	0.17957906	0.46208343	0.98926445	0.64322237	0.00015021	0.00285228
Tab1	66513	-0.4151294	0.03945712	0.31801394	0.64267172	0.00416731	0.03531316
Sptbn1	20742	-0.3470916	0.03394198	0.29375104	0.64253485	0.00015539	0.00292122
Phpt1	75454	-0.3944317	0.05742149	0.38379306	0.6413055	1.2423E-05	0.00039893
Ccdc94	72886	-0.2938467	0.2632379	0.74309288	0.64114156	0.01214407	0.0770877
Exosc3	66362	-0.0015095	0.99379038	1	0.6408277	0.00030731	0.00503168
Ift43	76411	-0.4376044	0.04412113	0.3342066	0.64030853	0.00049321	0.00720014
Clk4	12750	-0.3744425	0.06641574	0.41354889	0.63798304	0.01701952	0.09740661
Wdr55	67936	-0.1479461	0.44762015	0.9732222	0.63680341	0.00511476	0.04113318
Chchd1	66121	-0.0015561	0.9943064	1	0.63623998	0.00023919	0.00415337
Pim3	223775	-0.2923789	0.0824937	0.46321539	0.63598023	0.00154747	0.01680817
Elof1	66126	-0.1632986	0.3437454	0.8489691	0.63532314	0.00094135	0.01171987
U2af1	108121	-0.2856355	0.1157729	0.54198538	0.63483699	0.00134535	0.01521457
Sema4d	20354	-0.2463089	0.16164479	0.6369689	0.63482659	0.00218368	0.02170035
Prkd2	101540	-0.261243	0.13797108	0.58050968	0.63388439	0.00231293	0.02259974
Clasrp	53609	-0.3213245	0.18001787	0.6747838	0.63383114	0.01466962	0.08815769
Purb	19291	0.30668664	0.07687567	0.44388063	0.63369956	0.00027186	0.00460559
Naga	17939	-0.3000078	0.21471852	0.73474314	0.63351229	0.00155077	0.01681641
Ltbp4	108075	-0.4180393	0.02636848	0.25563503	0.63323311	5.47E-05	0.00127921
Pdcd4	18569	-0.248135	0.2641502	0.74309288	0.63185898	6.3166E-06	0.00023548
Cnpy4	66455	-0.1116604	0.57581364	1	0.63044732	0.0009075	0.0114168
Mis18a	66578	-0.0335742	0.87489007	1	0.62959628	0.00205558	0.02075554
Agpat3	28169	-0.0770596	0.64736951	1	0.62859377	4.29E-05	0.00106421
Stk11	20869	-0.559288	0.00309258	0.07172268	0.62510698	0.01242922	0.07844498
Cd2bp2	70233	-0.2325127	0.16868336	0.65180639	0.62479041	0.00108886	0.01304868
Lztr1	66863	-0.1067611	0.56764443	1	0.62468418	0.00130233	0.01482449
Mvb12a	73711	-0.1945936	0.30196081	0.79334965	0.62461605	0.00182081	0.01892063
Rbck1	24105	-0.3552589	0.04302871	0.32950897	0.62381602	0.01299257	0.08084063
Diap3	56419	-0.4404486	0.10166466	0.51277761	0.62103624	0.00052582	0.00754267
Isy1	57905	-0.2643252	0.16586528	0.64698618	0.62087484	0.00037673	0.005856
Zbtb7a	16969	-0.5039108	0.01472056	0.18501839	0.62082709	0.00092832	0.01161239
Ppig	228005	-0.2052511	0.27804984	0.75733384	0.61974183	7.48E-06	0.00026472
S100a13	20196	-0.1550344	0.59678676	1	0.61890957	0.00967672	0.06528566
Angptl2	26360	-0.465431	0.05268994	0.36701112	0.61751096	0.00277849	0.02567766
Fam32a	67922	0.00029197	0.99870255	1	0.61606685	0.00037245	0.00581002
Denr	68184	-0.0531471	0.75521048	1	0.61496696	0.00022628	0.00396061
Rac1	19353	0.09962878	0.6032869	1	0.61476135	3.86E-06	0.00016109
Klc1	16593	-0.459598	0.02415806	0.24429146	0.61461458	0.00019069	0.00345203
Snx3	54198	-0.2904768	0.08428744	0.4692007	0.61454751	6.5203E-05	0.0014684
Ovol1	18426	0.27270481	0.12489356	0.55497446	0.61454385	0.00139656	0.01563221
Nsl1	381318	-0.3126909	0.13325493	0.56969417	0.61409541	0.01586997	0.09300002
Sart3	53890	-0.6112461	0.00703745	0.11860709	0.61158468	0.00061766	0.00846376
Cmas	12764	-0.0254699	0.90284564	1	0.61009763	0.00486611	0.03954313
Cited2	17684	0.26643758	0.17026125	0.65458912	0.61004834	0.00475522	0.03892966
Eef1d	66656	-0.1212128	0.48776109	1	0.6070772	4.77E-05	0.00115169
Naa30	70646	0.38152142	0.0520438	0.36511391	0.60605246	0.00587556	0.04565599
Mob2	101513	-0.4783533	0.00739579	0.12219234	0.60601741	0.00035782	0.00565526
Ddx28	71986	-0.1678498	0.41328446	0.93244514	0.60577983	0.00927468	0.0632221
Diap1	13367	-0.2568705	0.1289598	0.5598804	0.60542085	0.00042916	0.00648019
Paf1	54624	-0.0584803	0.76295499	1	0.60517099	0.00029644	0.00490242
Rrp15	67223	-0.1040545	0.63520308	1	0.60391742	0.00691615	0.0513055
Csad	246277	-0.3045902	0.13027525	0.56318852	0.6033376	0.00236582	0.02288983
Cpox	12892	-0.112663	0.52724444	1	0.60127288	0.00111619	0.01327059
Rplp2	67186	0.00353336	0.98769145	1	0.60076924	6.28E-06	0.00023488

Yae1d1	67008	0.21709286	0.38733787	0.90354171	0.60046807	0.00465714	0.03836468
Cactin	70312	-0.4772299	0.07490254	0.43645788	0.60033766	0.00567538	0.04434456
Tbc1d14	100855	-0.1329853	0.41730892	0.93607983	0.59854697	0.00221729	0.02191879
Terf2ip	57321	-0.1288709	0.48542176	1	0.59846266	0.00662561	0.04968079
Dlg5	71228	-0.4780947	0.01597161	0.1941477	0.59820834	0.00839128	0.05885781
Megf6	230971	-0.2273481	0.33620057	0.83905379	0.59656761	0.00066318	0.00893058
Ltbp3	16998	-0.3272528	0.07205226	0.42768283	0.59615805	0.00078204	0.01019825
Sfr1	67788	-0.0452891	0.81213886	1	0.59613392	0.00099858	0.01227028
Cdkn1b	12576	-0.2073639	0.22230826	0.73474314	0.59343665	0.00132262	0.01500831
Srsf9	108014	-0.0438604	0.80887128	1	0.59248381	0.00035319	0.00560214
Qsox1	104009	-0.2030956	0.28559987	0.76940257	0.59182602	0.00079574	0.01033342
Ptrf	19285	-0.4006561	0.06617699	0.41269362	0.59097297	0.00163936	0.01753214
Pmvk	68603	0.41149742	0.02380464	0.24303224	0.58971029	0.00405818	0.03468644
Gemin2	66603	-0.5443804	0.0406254	0.3206852	0.58957409	0.00556928	0.04367074
Susd2	71733	-0.8037597	0.00219143	0.05756	0.58907614	0.00774249	0.05568262
Kremen2	73016	-0.5630128	0.00678126	0.1155653	0.58833975	0.00332019	0.02966591
Atp5d	66043	-0.1937982	0.25685636	0.74309288	0.58779501	0.00017139	0.0031634
Ankrd11	77087	-0.3616231	0.10116629	0.51203769	0.58765799	0.00033862	0.00541017
Hexim1	192231	-0.3841998	0.03886334	0.31596952	0.58703058	0.00065834	0.00890177
Gopc	94221	-0.1500247	0.39043946	0.90739645	0.58701758	0.0007755	0.01013291
Polr3h	78929	-0.1365557	0.47840543	1	0.58698302	0.01471539	0.08827227
Tubg1	103733	-0.2554913	0.21774318	0.73474314	0.58454298	0.00343687	0.03044048
Hsdl1	72552	-0.3205935	0.14017995	0.58608707	0.584523	0.01708022	0.0975791
Pfas	237823	-0.2178504	0.24140576	0.73950955	0.58440848	0.00548536	0.04319684
Swap70	20947	-0.6310167	0.00344724	0.07695371	0.58408333	0.00322895	0.02904733
Zfand3	21769	-0.2581551	0.16221966	0.6380095	0.5834365	0.00693822	0.05141139
Mpzl2	14012	0.21022678	0.27479779	0.75411133	0.58296178	0.00042989	0.00648366
Pvrl1	58235	0.1018662	0.63462953	1	0.58284444	2.11E-05	0.00060627
Zc3h11a	70579	-0.3306268	0.05459049	0.37414056	0.58219009	0.00143871	0.01602246
Psrc1	56742	-0.2534686	0.2994137	0.79005747	0.58185909	0.01229717	0.07772309
Zfp740	68744	-0.1810394	0.30395012	0.79600706	0.58108119	0.01456603	0.08780512
Arfgap1	228998	-0.4083251	0.02840222	0.26647704	0.58072165	0.00685963	0.05094347
Hip1r	29816	-0.2725199	0.16807589	0.65048832	0.5789013	0.00033692	0.00538946
Cttn	13043	-0.1557521	0.34029974	0.84387286	0.57888364	1.39E-05	0.00043535
Man2c1	73744	-0.5342787	0.00883798	0.13608595	0.57887473	0.00477326	0.0390289
Ikbkg	16151	-0.1358465	0.44332125	0.96724277	0.57861368	0.00449742	0.0373071
Mettl6	67011	0.1116764	0.61502228	1	0.57836553	0.01650977	0.09535207
Eif3b	27979	-0.2241284	0.18235929	0.67879654	0.578117	7.5806E-05	0.00165905
Bag5	70369	-0.0976636	0.57506505	1	0.5774591	0.00269726	0.02520945
Slc30a1	22782	0.15914151	0.37187787	0.88351292	0.57696739	0.0004081	0.00625518
Adrbk1	110355	-0.3039324	0.06503436	0.40880413	0.57695239	0.0007783	0.01015949
Dnmbp	71972	-0.2935132	0.09872963	0.50881528	0.5758171	0.01273738	0.07985523
Pcdh7	54216	0.24320279	0.20289697	0.7171684	0.57500567	0.00879703	0.06100596
Rps14	20044	-0.1776823	0.32648223	0.82656258	0.57411347	0.00029172	0.00484858
Ap3s2	11778	-0.0853665	0.64476975	1	0.57400434	0.00022525	0.00395289
Aatf	56321	-0.391224	0.0656612	0.41115699	0.57376122	0.00251891	0.02397754
Gatad2a	234366	-0.1851045	0.2836895	0.76628483	0.5723929	0.00019011	0.00345096
Kirrel	170643	-0.0906947	0.59503738	1	0.57176635	0.00230204	0.02258737
H2-Ke6	14979	-0.1439692	0.53771945	1	0.56980888	0.01373869	0.08463185
Phax	56698	-0.3258885	0.08064439	0.45708056	0.56967821	0.00058836	0.00819049
Tradd	71609	-0.2478172	0.22354739	0.73474314	0.56917041	0.01126765	0.07264251
Atg13	51897	-0.2418767	0.16298334	0.63990613	0.56867314	0.00180505	0.01881611
Ikbkb	16150	-0.3124589	0.06483836	0.40820255	0.56821847	0.00237581	0.02295286
Akap1	11640	-0.1857187	0.34167689	0.84582782	0.56759077	0.00092203	0.01155559
Dlgap4	228836	-0.2083009	0.24679364	0.74309288	0.56703775	0.00151013	0.01655372
Srsf11	69207	-0.117425	0.51451064	1	0.56582291	0.0001224	0.00241816
Sdf4	20318	-0.126665	0.45823046	0.98516121	0.5656089	0.00027869	0.00469865
Slc27a4	26569	-0.3643306	0.03876701	0.31596952	0.5654216	0.00025311	0.00433246
Bicd2	76895	-0.2187507	0.2316908	0.73917364	0.56331984	0.00028279	0.00475413
Gas1	14451	-0.5512986	0.05487206	0.37533559	0.56263873	0.00324979	0.02919505
Creld2	76737	0.0453845	0.80137274	1	0.56190377	0.0023144	0.02259974
Hira	15260	-0.2953888	0.09243242	0.4884315	0.56124527	0.0082033	0.05795444
Cdc42ep4	56699	-0.2728557	0.09969306	0.50881528	0.5612136	0.00819201	0.05792464

Coq5	52064	-0.3261884	0.11708222	0.54420724	0.561104	0.00791946	0.05655471
Pex14	56273	-0.3122821	0.13700546	0.57875981	0.56086686	0.00882928	0.0611779
Pkm	18746	-0.1161932	0.50805744	1	0.56015689	3.13E-05	0.00084611
Itgb5	16419	-0.5705534	0.00242798	0.06176736	0.55957679	3.94E-05	0.00099357
Ccdc124	234388	-0.409573	0.10569393	0.52177547	0.55873514	0.00318728	0.0287618
Stard10	56018	-0.4633261	0.01138081	0.1575571	0.55858774	0.00087133	0.01109936
Junb	16477	0.37756756	0.18275112	0.67960486	0.55850075	0.00325609	0.02921185
Klc3	232943	-0.4256372	0.02584433	0.25260211	0.55825957	0.00302156	0.02753835
Dohh	102115	-0.2800755	0.11308156	0.53644212	0.55761203	0.01302688	0.0810159
Tmprss4	214523	-0.2926187	0.13290102	0.56870088	0.55751001	0.00170385	0.01801744
Adsl	11564	-0.1972139	0.36960806	0.88000376	0.55481344	0.00011244	0.00226197
Rnf126	70294	-0.4426939	0.01053854	0.15068013	0.55418881	0.00084324	0.01079366
Ywhaz	22631	0.15021037	0.39440851	0.91183396	0.55385716	0.00022729	0.00396766
Fkbp8	14232	-0.4115238	0.0233424	0.2404238	0.55380566	9.7511E-05	0.00202973
Cd3eap	70333	-0.119801	0.57619557	1	0.55360834	0.002317	0.02259974
Ptms	69202	-0.2826326	0.52008518	1	0.55356104	0.004064	0.03471368
Safb2	224902	-0.5927797	0.00334305	0.07538388	0.55318418	0.00254198	0.02413414
Pvrl4	71740	-0.3477852	0.04186884	0.32528263	0.55306183	0.00171789	0.0181223
Mllt1	64144	-0.3491427	0.04001907	0.31904172	0.55297717	0.00270511	0.02523742
Rps3a1	20091	-0.0874642	0.69164542	1	0.5520277	0.00190885	0.01955826
C1d	57316	0.2298102	0.19623872	0.70392857	0.55195993	0.00711477	0.05242524
Tssc1	380752	-0.4141807	0.0675634	0.41598351	0.55167164	0.01411791	0.08609708
Adprhl2	100206	-0.2371519	0.18511058	0.68441871	0.55156806	0.00617405	0.047399
Pml	18854	0.12050791	0.5380409	1	0.55152246	0.01294209	0.08063326
Ttc1	66827	-0.0415803	0.8346852	1	0.55144882	0.00412255	0.03510023
Bach1	12013	0.22914211	0.18495451	0.68425603	0.54977125	0.00076444	0.01003806
Slbp	20492	-0.0859856	0.6344657	1	0.54867903	0.00423406	0.03568125
Cdc37	12539	-0.4216319	0.05016992	0.35887512	0.54846526	1.6852E-05	0.00050891
Fgfr3	14184	-0.3089133	0.07100904	0.42476704	0.54757684	0.00052497	0.0075386
Sox4	20677	-0.5845337	0.01668343	0.1983121	0.54642685	0.00044095	0.00659032
Vps51	68505	-0.6102113	0.00177328	0.05023824	0.54631046	0.0089193	0.06156278
Ralbp1	19765	-0.438979	0.01255337	0.16669094	0.54484651	6.8627E-05	0.00152727
Wnt6	22420	-0.300797	0.1138734	0.53644212	0.54478318	0.00101976	0.01247241
Prom2	192212	-0.2210466	0.20522845	0.72186146	0.54356978	0.00195605	0.01993832
Rps23	66475	-0.3593289	0.05882972	0.38850207	0.54344601	0.00060994	0.00841102
Akt1	11651	-0.1861992	0.26248769	0.74309288	0.54322237	0.00071132	0.00946305
Ap2s1	232910	-0.2418381	0.14868083	0.6077895	0.54210424	0.00010602	0.00217602
Kansl3	226976	-0.2628838	0.13672298	0.5779664	0.54101416	0.00806513	0.05734129
Dstyk	213452	-0.2345753	0.19486798	0.70096789	0.54093096	0.00776153	0.05578917
Bax	12028	-0.2739852	0.11432445	0.53773446	0.54087148	0.00754092	0.05480037
Ppp1r14b	18938	-0.0946387	0.71921503	1	0.54052331	0.00186859	0.01928055
Jag2	16450	-0.4471233	0.02475361	0.24724248	0.54052125	0.00243337	0.02342315
Fam46a	212943	0.15155264	0.35285878	0.86090935	0.54003795	0.00125387	0.01445177
Chst14	72136	-0.4134547	0.0476067	0.34746064	0.53882633	0.01005907	0.06752263
Bccip	66165	0.09700381	0.57084709	1	0.53859615	0.00394553	0.03378922
Clpp	53895	0.04105434	0.83821038	1	0.53820475	0.00177391	0.01856488
Tut1	70044	-0.2805437	0.19501262	0.70128157	0.5354633	0.00799976	0.05703558
Pdcl3	68833	-0.0778895	0.70042219	1	0.53459471	0.00128894	0.01474017
Ldhb	16832	-0.2436937	0.19049648	0.69333917	0.53411077	0.00029497	0.00488413
Lonp1	74142	-0.4055438	0.01368249	0.17648626	0.53406531	0.00013812	0.00265703
Axin2	12006	-0.5245594	0.00436471	0.08889127	0.5339497	0.00230944	0.02259281
Tenm4	23966	-0.1971171	0.23719927	0.73917364	0.53369625	0.00224004	0.022094
Arrdc4	66412	-0.4120797	0.0217291	0.23134998	0.53343919	0.01353216	0.08368504
Clip1	56430	-0.4062016	0.02201651	0.23253379	0.53320165	0.00010982	0.00222852
Snf8	27681	-0.3678834	0.0369956	0.30885583	0.53132472	0.00147136	0.01627623
Tgfbr2	21813	0.1383122	0.48265228	1	0.53057632	0.00787624	0.05633755
Rnf7	19823	-0.0507605	0.82296624	1	0.53055153	0.01116929	0.07222002
Sbf1	77980	-0.4143566	0.01435134	0.18206442	0.53039374	0.01059483	0.06989818
Eef1b2	55949	-0.1696424	0.3597906	0.86893853	0.53019713	0.0005653	0.0079704
Prkch	18755	-0.0256799	0.87562257	1	0.53018473	0.00889835	0.06145032
Tom1	21968	-0.2387428	0.20806048	0.72678653	0.53001452	0.01068007	0.07014157
Rpl36	54217	-0.1443517	0.46066629	0.98778923	0.52993861	0.00053079	0.00760566
Ezr	22350	-0.042494	0.81762784	1	0.52956195	0.00010898	0.00221951

Rptor	74370	-0.3438086	0.04250614	0.32756152	0.52786597	0.01482078	0.08866267
Ccdc71	72454	-0.263909	0.17084973	0.65592224	0.52775049	0.01049125	0.06953943
Rplp1	56040	0.05381959	0.78905298	1	0.52691108	1.2424E-05	0.00039893
Xdh	22436	-0.035478	0.84189637	1	0.52648179	0.00129363	0.01478101
Cerk	223753	-0.3212255	0.06631815	0.41334299	0.52568335	0.00923736	0.06300021
Eif5b	226982	-0.3015903	0.08778556	0.48035206	0.52563519	0.00011763	0.0023414
Nabp2	69917	-0.2132962	0.32194029	0.82222377	0.52531791	0.00475408	0.03892966
Map2k6	26399	-0.3546302	0.15817466	0.62993859	0.52523636	0.00740899	0.05404998
Pdcd11	18572	-0.2427641	0.19071942	0.69361166	0.52507128	0.01063227	0.07000006
Wasl	73178	0.03075188	0.85986869	1	0.52425667	0.00248203	0.02372155
Zc3h13	67302	-0.4626478	0.01680594	0.19855731	0.52420595	0.00276891	0.02564301
Wwc2	52357	-0.4900292	0.00473754	0.09345358	0.52307778	0.01746774	0.09925565
Pafah2	100163	-0.0528431	0.76674423	1	0.52288814	0.01689942	0.09692381
Ssfa2	70599	-0.5098081	0.00582401	0.10575548	0.52235235	0.00035989	0.00567447
Dnmt3a	13435	-0.2042038	0.2721602	0.74998742	0.5216736	0.00154412	0.01678563
Aldoc	11676	0.09627033	0.65684246	1	0.52046924	0.0071381	0.05250918
Cbr3	109857	0.00989041	0.96191809	1	0.52016695	0.00678637	0.0504846
Metrnl	210029	-0.3065021	0.08669659	0.47642157	0.51990988	0.01393469	0.08537421
Fbxw8	231672	-0.3999424	0.0364957	0.30690825	0.51889621	0.0049331	0.03998904
Bhlhe40	20893	0.56349951	0.01166659	0.15902173	0.51846757	0.00698114	0.0516714
Leo1	235497	-0.2416488	0.2542325	0.74309288	0.51711445	0.00222229	0.02195172
Myh9	17886	-0.3773093	0.09853126	0.50881528	0.51696403	0.00219107	0.02174103
Calcoco1	67488	-0.5955015	0.00458038	0.09191249	0.516955	0.00152162	0.0166044
Chmp7	105513	-0.335161	0.06180921	0.39816479	0.51692984	0.01318417	0.08179104
Reep5	13476	-0.1897078	0.32013417	0.81915304	0.51691594	0.00171615	0.01811841
Timm13	30055	-0.0359882	0.83314145	1	0.51489919	0.00343206	0.03041836
Grwd1	101612	-0.0489919	0.81172736	1	0.51408979	0.01074644	0.0703536
Rps6ka4	56613	0.26945618	0.09984862	0.50881528	0.51391768	0.00541156	0.04276425
Exosc7	66446	-0.1262841	0.57282869	1	0.5135968	0.00049453	0.00721143
Sdf2	20316	0.00110722	0.99576966	1	0.51332261	0.00246586	0.02363957
Psmg1	56088	-0.0306513	0.8855396	1	0.51269452	0.00160391	0.01727599
Tex2	21763	-0.1345517	0.41169737	0.9306881	0.51151611	0.01342648	0.08314842
Msrb1	27361	0.09587437	0.61825394	1	0.51112997	0.0162131	0.09409159
Calm4	80796	0.27936763	0.17789082	0.67055614	0.51089237	0.00030941	0.00505574
Map2k2	26396	-0.4522418	0.0053263	0.10013369	0.51020098	0.00349386	0.03082121
Cbx5	12419	0.30962971	0.10094028	0.51162059	0.51016223	0.00053672	0.00765742
Unc45a	101869	-0.2590459	0.17243602	0.65904631	0.51016058	0.00418164	0.03538833
Zc3h18	76014	-0.2777589	0.28961924	0.77561042	0.51009795	0.00372302	0.03226044
Nfe2l1	18023	-0.5117226	0.00668447	0.11503983	0.5100634	0.0003721	0.00581002
Map4k4	26921	-0.4551622	0.01388998	0.17787481	0.50949268	0.00071402	0.00948937
Drg2	13495	-0.183479	0.31594208	0.81328361	0.50945535	0.00049135	0.00718086
Rab12	19328	0.14182272	0.4821225	1	0.50928372	0.01343653	0.08317164
Rhot2	214952	-0.1774594	0.29817087	0.78771821	0.50917752	0.00531304	0.04223863
Gjb3	14620	-0.3612333	0.04926582	0.35514533	0.50850317	0.00127946	0.01466991
Pfkp	56421	0.15621836	0.44312285	0.9670691	0.50547047	0.00339961	0.03023224
Pik3r2	18709	-0.5084127	0.00445249	0.08986312	0.50532781	0.00466116	0.0383739
Mettl9	59052	-0.0868302	0.59583857	1	0.50522284	0.010635	0.07000006
Dapk3	13144	-0.3940688	0.06726273	0.41562686	0.50504768	0.01065478	0.07002545
Lmna	16905	-0.374587	0.07956823	0.45347391	0.50455827	0.00294779	0.02705288
Stard5	170460	0.43603391	0.01615662	0.19522109	0.50414513	0.00188729	0.01941277
2210016F16Rik	70153	-0.2376714	0.17653597	0.66709948	0.5040473	0.0025666	0.02431545
Nfu1	56748	-0.2161683	0.40233321	0.92062529	0.50396711	0.00476117	0.03895419
Hmgn1	15312	-0.0938272	0.65690214	1	0.50023863	0.01671652	0.0963393
Bysl	53414	-0.1358124	-0.1358124	0.97692704	0.50021339	0.01065119	0.07002545
Capn6	12338	0.29334434	0.24907598	0.74309288	-0.5002597	0.00128602	0.01471956
Nudt2	66401	0.73979193	0.0050789	0.09807455	-0.5002738	0.00913409	0.06248974
Alg9	102580	0.1396978	0.48572866	1	-0.5004496	0.01558112	0.09179643
Rfx7	319758	0.34732806	0.04145749	0.32356455	-0.5010715	0.00668328	0.04998861
Tgm5	74176	0.09716262	0.63337954	1	-0.5035492	0.01571297	0.09229138
Tollip	54473	0.21835533	0.22750805	0.73474314	-0.5049461	0.0108921	0.07094915
Cdca3	14793	0.29012683	0.11601949	0.54226065	-0.5052453	0.00538403	0.04272322
Kif22	110033	0.26449201	0.17379768	0.66100505	-0.5055143	0.00359479	0.03145922
Prkab1	19079	0.34556677	0.10676577	0.52429657	-0.5055752	0.01631167	0.09453892

Wbp2	22378	0.15487538	0.41029192	0.92989635	-0.5055966	0.00380454	0.03283752
Hltf	20585	0.2246918	0.39805796	0.91562923	-0.5056864	0.00342021	0.03033365
Cd320	54219	0.1863262	0.39040558	0.90739645	-0.5056916	0.01687352	0.09685943
Hnrnpf	98758	0.58993968	0.0023613	0.06070038	-0.5063269	4.08E-05	0.00101903
Tgfbi	21810	-0.4471044	0.02971608	0.27335941	-0.5084541	0.00152818	0.01662602
Mau2	74549	0.25485467	0.18694286	0.68758528	-0.508483	0.00134111	0.01519198
Mitd1	69028	0.85420872	0.00176059	0.05005284	-0.5091924	0.01428686	0.08678992
Trim23	81003	0.58979787	0.02084804	0.22638055	-0.510133	0.00984117	0.06626219
Med6	69792	0.77985335	0.00410846	0.0854622	-0.510153	0.00409783	0.03493477
Slc29a3	71279	0.48671728	0.03200813	0.28609688	-0.5112535	0.01702051	0.09740661
Cks1b	54124	0.2336437	0.19944945	0.71002259	-0.5131786	0.00177295	0.01856488
Mrpl17	27397	0.25283957	0.16380463	0.64154037	-0.5132563	0.00193657	0.01976969
Ssbp1	381760	0.62672843	0.00295099	0.07010331	-0.5137036	0.00592309	0.04592658
Erbb2ip	59079	0.27220498	0.18940601	0.69222328	-0.5142193	0.00035651	0.00564128
Anpep	16790	0.24003742	0.26206753	0.74309288	-0.5142524	0.01227375	0.07768666
Zfp280d	235469	0.45494122	0.02617216	0.2542364	-0.5148481	0.00309941	0.02811199
Fam172a	68675	0.20384599	0.38673234	0.90272974	-0.5149772	0.00277575	0.02567035
Sgol2a	68549	0.36687057	0.07347904	0.43228897	-0.5151654	0.00325534	0.02921185
Creb5	231991	0.37097384	0.08748794	0.47926044	-0.516606	0.01376187	0.08466915
Nusap1	108907	0.26041476	0.23313972	0.73917364	-0.5180833	7.69E-05	0.00167499
Hiatl1	66631	0.39633917	0.02995551	0.27480972	-0.5187981	0.00858396	0.05990614
Sh3bp1	20401	0.03977771	0.8452385	1	-0.5197962	0.0155291	0.09161268
Tmem65	74868	0.36840254	0.03655232	0.3071728	-0.519892	0.01216074	0.07715641
Rbmxl1	19656	0.15274079	0.41154166	0.9306881	-0.5216763	8.87E-05	0.00187346
Fam83b	208994	0.56765686	0.00186068	0.0519905	-0.5217139	0.00176325	0.01849731
Usp9x	22284	0.5543267	0.01038398	0.14962302	-0.5217235	5.71E-05	0.00132909
Sacm1l	83493	0.70017657	0.00307972	0.07157775	-0.5218424	0.00020815	0.00370704
Elk4	13714	0.16959583	0.36032748	0.86934967	-0.5222219	0.01496399	0.08907521
Lrig2	269473	0.31904566	0.10235729	0.5149706	-0.5242073	0.0018737	0.01931662
Vta1	66201	0.55010954	0.02810333	0.26488282	-0.5242348	0.00227819	0.0224123
Zfp385a	29813	0.04869054	0.79520175	1	-0.5243604	0.00227014	0.02236416
Ankrd28	105522	0.50379804	0.00349852	0.07748784	-0.5244358	0.00366366	0.0318717
Trpm7	58800	0.27391434	0.22576362	0.73474314	-0.5244611	0.00454052	0.03761532
Bub1	12235	0.56308496	0.02859746	0.26729011	-0.5251256	0.00829966	0.05844747
Nedd1	17997	0.55968253	0.02926236	0.27113804	-0.5254721	0.00801094	0.05708445
Atp6v1e1	11973	0.24094202	0.15356394	0.61944874	-0.5257627	0.00058903	0.00819117
Emc3	66087	0.35362199	0.04323373	0.33014728	-0.5259766	0.0004667	0.00691245
Eif4g2	13690	0.35977005	0.05538509	0.3771777	-0.5268798	6.77E-06	0.0002479
Xrn1	24127	0.23174931	0.27238422	0.75018553	-0.5287908	0.00220703	0.02185011
Thoc2	331401	0.50158127	0.00683564	0.11629179	-0.5300685	0.00021279	0.00376947
Chmp5	76959	0.56528915	0.0024065	0.06134557	-0.5302944	9.10E-05	0.00191505
Arl4a	11861	-0.0747934	0.67125438	1	-0.5304684	0.0083293	0.05858295
Pole2	18974	0.37137385	0.24471207	0.74309288	-0.5306354	0.0051734	0.04144086
Ten1	69535	-0.0335537	0.87871134	1	-0.5333703	0.01054938	0.06978451
Mut	17850	0.56198935	0.0093817	0.1408178	-0.5338729	0.00149862	0.01649132
Phf6	70998	0.74947949	0.00873526	0.13492973	-0.5343527	0.00057819	0.00807453
Ssbp3	72475	0.06302164	0.73301263	1	-0.5343564	0.00059293	0.00822812
Casp6	12368	0.47765596	0.05336038	0.36999255	-0.534423	0.00065333	0.0088612
Dym	69190	0.22502834	0.23006724	0.73808522	-0.5357525	0.005175	0.04144086
Med28	66999	0.40548885	0.02774605	0.26314034	-0.535855	0.00130077	0.01482449
Ppp2r5c	26931	0.3412137	0.04162675	0.32457436	-0.5382058	0.00024982	0.00428882
Atg3	67841	0.2924825	0.16717175	0.64925276	-0.5383281	0.00136678	0.01537713
Arhgap1	228359	0.37416941	0.03894025	0.31596952	-0.538521	0.00016964	0.00313984
Tet2	214133	0.40559158	0.02396495	0.24324521	-0.5390888	0.01217734	0.07721294
Kif18b	70218	0.37540284	0.08203247	0.46138071	-0.5400579	0.01251197	0.07887307
Bzw1	66882	0.59192663	0.01005631	0.14679321	-0.5403376	3.18E-06	0.00013833
Ost4	67695	0.7407464	0.00490849	0.09604419	-0.5405332	0.01491473	0.08894127
Abcg2	26357	0.94045804	0.0051121	0.09817898	-0.5412644	0.00941878	0.06397425
Hddc2	69692	0.32764707	0.20807269	0.72678653	-0.5433367	0.00387465	0.03329017
Acsl3	74205	0.56648339	0.01403529	0.17924651	-0.5435572	0.00067456	0.00906528
Sppl2a	66552	0.49112089	0.00655458	0.11352443	-0.5442953	2.78E-05	0.00076389
Mrpl14	68463	0.46806897	0.0627003	0.40135676	-0.5457703	0.00484833	0.03942292
Lin9	72568	0.44319769	0.06548136	0.410481	-0.5458315	0.01276458	0.07991182

Nfatc3	18021	0.28039375	0.15538307	0.62349818	-0.5460769	0.00604681	0.04655764
Cog6	67542	0.41969321	0.05233412	0.3659004	-0.5460919	0.00333854	0.02976942
Prdx4	53381	0.34988882	0.14652126	0.60259275	-0.5478928	0.00044011	0.00659032
Nck1	17973	0.62504265	0.01767331	0.20530785	-0.5479032	0.00066052	0.00891675
Aldh6a1	104776	0.61839882	0.005712	0.10444083	-0.5479188	0.00101809	0.01246358
Itfg1	71927	0.46692297	0.01276101	0.16854333	-0.5483558	0.0010904	0.01304868
Gng5	14707	0.34318892	0.03748612	0.31042677	-0.5483832	0.00213235	0.02130554
Fam69a	67266	-0.0337522	0.90282508	1	-0.5500136	0.00709731	0.05235508
Mrpl54	66047	-0.1400216	0.44871101	0.9741285	-0.5511447	0.00313489	0.0283753
Golt1b	66964	0.22881328	0.32968428	0.83062532	-0.5530802	0.00179071	0.01871105
Zfp26	22688	0.62672607	0.00205412	0.05567544	-0.5531621	0.00165804	0.017637
Lrrc40	67144	0.56617696	0.00595171	0.107023	-0.5531712	0.00165371	0.01762844
Alcam	11658	0.0870163	0.66849325	1	-0.5540542	2.88E-06	0.00012715
Narf	67608	0.37251009	0.035647	0.30283352	-0.5565871	0.00050706	0.00732131
Casd1	213819	0.61623481	0.01793704	0.20711136	-0.5573668	0.01493475	0.08894127
Gtf2a1	83602	0.49359906	0.01114748	0.15567811	-0.5574645	0.00203834	0.02062884
Tmem126b	68472	0.71385969	0.04305887	0.32953326	-0.557467	0.01490595	0.08894127
Fzd3	14365	0.58628418	0.00180505	0.05107895	-0.557499	0.01156789	0.07432394
Glrb	14658	0.50156878	0.04553262	0.34069022	-0.5579349	0.01474054	0.08834285
Eny2	223527	0.43238176	0.06468148	0.40774042	-0.55816	0.00370493	0.03218364
Eef1e1	66143	0.75228251	0.00984559	0.14499681	-0.5583099	0.00272867	0.02539509
Ythdf1	228994	0.46026945	0.015857	0.19333196	-0.5589021	0.00089722	0.01132722
Prim1	19075	0.70538871	0.01759136	0.20503098	-0.5606444	0.00069125	0.00925195
Ndufa5	68202	0.60562789	0.01243731	0.16579239	-0.5606662	0.00058558	0.00816046
Tgfb2	21808	-0.2758161	0.11311584	0.53644212	-0.5608048	0.00033378	0.00535547
Gtf2h2	23894	0.20889093	0.44514624	0.96975169	-0.5615961	0.00413118	0.03513378
Tmem135	72759	0.57250875	0.03341611	0.29144819	-0.561765	0.00269437	0.02520025
Poglut1	224143	0.61576814	0.01269828	0.16796817	-0.5618284	0.00340279	0.03024011
Kpna4	16649	0.34963513	0.03411674	0.29419665	-0.5620346	3.83E-05	0.00097734
Ube2k	53323	0.36285508	0.03755365	0.31077522	-0.5635207	0.00106996	0.01289516
Btf3	218490	0.28720657	0.10393166	0.51903427	-0.5635444	1.44E-05	0.00044754
Arid1a	93760	0.14967314	0.43144738	0.95333093	-0.5637266	0.00015867	0.00297017
Strap	20901	0.30484215	0.126326	0.55746429	-0.5660101	0.00010714	0.00219207
Bmp7	12162	0.08155552	0.62886314	1	-0.5662293	7.80E-05	0.00169242
Sgk3	170755	0.45318884	0.07928249	0.45247903	-0.5670752	0.00150551	0.01654311
Exoc5	105504	0.35706827	0.04295013	0.32921689	-0.5672698	0.0018681	0.01928055
Cebpg	12611	0.26564914	0.19724257	0.70591767	-0.5674957	0.00121976	0.01422012
Nln	75805	0.56329553	0.01654199	0.19780629	-0.5680947	0.00498986	0.04032528
Gjb6	14623	0.14677739	0.46469784	0.99129856	-0.5691145	0.00803956	0.0572266
Pon2	330260	0.34193488	0.09121698	0.48740869	-0.5701226	0.00025974	0.00442287
Ncapg	54392	0.54932832	0.02035581	0.22362084	-0.5719945	0.00099208	0.0122245
Rnf139	75841	0.63249769	0.01245308	0.16582156	-0.5722981	0.00320402	0.02884585
Ccnt1	12455	0.35218211	0.13764338	0.58025012	-0.5735189	0.0015665	0.01695902
Zc3h14	75553	0.54641492	0.00317039	0.0730417	-0.5743647	3.90E-05	0.00098945
Rev3l	19714	0.31805889	0.12573945	0.5559786	-0.5747361	0.01674175	0.09637947
Mb21d2	239796	0.41114741	0.03386291	0.29339437	-0.5750792	0.00838018	0.0588262
Gpd2	14571	0.35672866	0.13279142	0.56843105	-0.5755646	0.01183677	0.07553669
Tbc1d5	72238	0.01268072	0.95043723	1	-0.5759361	0.01056259	0.0698369
Slc7a6	330836	0.17400979	0.52986501	1	-0.5771438	0.0034515	0.03050869
Strbp	20744	0.45885542	0.0094845	0.14149105	-0.5774869	0.00238893	0.02302919
Pxmp4	59038	0.24768684	0.38491886	0.90116993	-0.5776774	0.00634929	0.04835061
Rhobtb3	73296	0.38190204	0.06097019	0.39599812	-0.5779296	0.00695395	0.05149903
Rgs2	19735	0.24547652	0.24754383	0.74309288	-0.5784827	0.00043884	0.00659032
Dmd	13405	0.49622554	0.00919238	0.13917367	-0.5786468	0.00035516	0.00562676
Ubqln1	56085	0.26162573	0.13900459	0.58337017	-0.5786948	0.00038658	0.00598094
1110059G10Rik	66202	0.55205464	0.06830433	0.41790843	-0.5812097	0.01072064	0.07026904
Klhl24	75785	0.08461302	0.6613024	1	-0.5816803	0.00077303	0.0101207
Pop4	66161	0.48598728	0.03370868	0.29274522	-0.581746	0.00054336	0.00773545
Hist2h4	97122	0.1196698	0.48442666	1	-0.582138	0.00091165	0.01144724
Mrpl50	28028	0.570749	0.00671163	0.11509193	-0.5821775	0.00037304	0.00581227
Etfa	110842	0.41685615	0.02818756	0.26513573	-0.5827406	7.00E-06	0.00025385
Cdc20	107995	0.32037392	0.06803544	0.41725099	-0.5832695	0.00024725	0.00426914
Golga7	57437	0.14208483	0.48520167	1	-0.5840246	0.00338036	0.03010164

Hmces	232210	0.16909791	0.55036565	1	-0.5865091	0.00848331	0.05926639
Fam3c	27999	0.38635562	0.08836075	0.48196858	-0.5868481	0.00669723	0.0500189
Arl14ep	212772	0.16646098	0.43127557	0.95329171	-0.5869609	0.00088345	0.01121046
Klhl28	66689	0.74075077	0.01973158	0.21987477	-0.5870638	0.01410486	0.08605725
Cops2	12848	0.45012154	0.01287868	0.16945595	-0.5873926	0.00024903	0.00428482
Lamtor2	83409	0.55914061	0.006739	0.11516666	-0.5877468	0.00028177	0.00474297
Scfd1	76983	0.50633425	0.02244937	0.23499188	-0.5878727	0.00015494	0.00292122
Cep57	74360	0.4106691	0.0625332	0.40053109	-0.5879574	0.0023494	0.0228426
Orc3	50793	0.47488078	0.07122989	0.42541089	-0.5888091	0.0015078	0.01655372
Tbck	271981	0.32082396	0.11699802	0.54405869	-0.5890373	0.00421207	0.03556408
Prps2	110639	0.54385155	0.03675516	0.30781817	-0.5892956	6.15E-05	0.00139844
Ndufs3	68349	0.52953363	0.00437522	0.08889127	-0.5895296	7.38E-05	0.00162607
Parm1	231440	-0.3392787	0.16776629	0.64993183	-0.5897857	0.00303014	0.02759751
Arpc1a	56443	0.38185779	0.03042217	0.27752705	-0.5904317	4.46E-05	0.00109763
Pggt1b	225467	0.43396678	0.01999165	0.22101232	-0.5914151	0.00103513	0.01261365
Cbl	12402	0.48533397	0.01090313	0.15397165	-0.5921609	0.00017545	0.0032338
Kdelr1	68137	0.22609068	0.17202507	0.65826139	-0.5921894	0.00012716	0.00248288
Gtf3a	66596	0.18793638	0.28558758	0.76940257	-0.5929318	0.00142862	0.01592353
Ufsp2	192169	0.63501723	0.02814971	0.26511537	-0.5931021	0.00175596	0.0184649
Nipal2	223473	0.58347159	0.01284685	0.16922734	-0.5932004	0.0101929	0.06824747
Alg14	66789	0.72570064	0.00676879	0.11543336	-0.5932958	0.01098557	0.07124157
Itga1	109700	0.72461353	0.00428333	0.08774179	-0.5933027	0.01175098	0.07514488
Cnot6	104625	0.46649321	0.00525736	0.09949187	-0.5937718	0.00159896	0.01726798
Ift74	67694	0.49220916	0.15409179	0.62066231	-0.5938167	0.00130538	0.01483811
Cryzl1	66609	0.2803139	0.34863572	0.85499167	-0.5952162	0.00360506	0.03152811
Ube2d2a	56550	0.53374499	0.00216389	0.05706735	-0.5957417	0.00042775	0.00646624
Itga2	16398	0.72252514	0.00560637	0.10325284	-0.596183	0.000393	0.00606002
Mtf2	17765	0.38978335	0.07211946	0.42768283	-0.5964148	0.00109015	0.01304868
Scyl2	213326	0.48268261	0.01494983	0.18693798	-0.5964275	0.00048011	0.00707935
Sema3e	20349	0.57737557	0.0177134	0.2055007	-0.5964515	0.00097168	0.01202927
Nae1	234664	0.59142487	0.0096738	0.14309139	-0.5965064	0.00019912	0.00356558
Ldah	68832	0.05709308	0.76628459	1	-0.5966765	0.00095203	0.01181786
Slc7a2	11988	0.3596594	0.05617755	0.37929553	-0.59776	2.37E-05	0.00066965
Lypd6b	71897	0.12305497	0.52529081	1	-0.5999972	0.00896506	0.06171719
Fam216a	68948	0.51612248	0.04145344	0.32356455	-0.6007778	0.00459529	0.03794992
Aurkaip1	66077	0.25436374	0.15794068	0.62941732	-0.6009777	0.000155	0.00292122
Nt5dc2	70021	0.30901556	0.06508311	0.4090053	-0.6014421	0.00050071	0.00725344
Ap3m1	55946	0.71488612	0.00345049	0.07695371	-0.6015004	7.64E-05	0.00166677
Zmpste24	230709	0.53095584	0.0142328	0.18103089	-0.6015771	0.00042324	0.0064127
Btaf1	107182	-0.1341428	0.5254341	1	-0.6019497	3.73E-05	0.00095815
Ghitm	66092	0.52376163	0.00341553	0.0765235	-0.6028766	5.00E-06	0.00019656
Msl3	17692	0.65066282	0.00470538	0.09310208	-0.6036855	0.00211017	0.02114499
Cbll1	104836	0.67205528	0.01176837	0.1598417	-0.6042755	0.00515989	0.04138038
Tspan7	21912	0.46344067	0.0144748	0.18324993	-0.6060528	0.00037168	0.00581002
Prss35	244954	-0.0724667	0.70637813	1	-0.6064156	6.79E-05	0.00151466
Mycbp	56309	0.50140483	0.01878883	0.21321658	-0.6066111	0.00442203	0.03684185
Sec22a	317717	0.44411805	0.0983112	0.50881528	-0.6089669	0.00205848	0.02076894
Zfp703	353310	0.05319357	0.79462019	1	-0.6092267	0.00148875	0.01639989
Slc35b1	110172	0.42848369	0.03671744	0.30760773	-0.609808	0.00018557	0.00338261
Cxadr	13052	0.47305605	0.02825679	0.26561164	-0.6103737	2.46E-06	0.00011088
Erap1	80898	0.64981874	0.01458198	0.18412075	-0.6104004	9.22E-05	0.00193545
Rnft1	76892	0.45286429	0.04160408	0.32450121	-0.6107712	0.01367373	0.08432459
Ube2d1	216080	0.49082262	0.0308789	0.28032681	-0.6109431	0.01104219	0.0715033
Nfia	18027	0.18642387	0.30064944	0.79155353	-0.6109559	0.00054228	0.00772832
Gli3	14634	0.45272774	0.02748645	0.26242365	-0.612122	0.0094922	0.06433927
St7l	229681	0.45853802	0.03637487	0.30650349	-0.6121311	0.00437062	0.03649407
Pigp	56176	0.13105192	0.651779	1	-0.6121997	0.00983854	0.06626219
Celf2	14007	0.49576627	0.00809335	0.12935053	-0.6122508	0.00595191	0.04606882
Ube2c	68612	0.30164647	0.07656706	0.44298605	-0.6138207	0.00111151	0.01322682
Cops3	26572	0.47138901	0.0351642	0.30036547	-0.6156808	2.00E-05	0.00058002
Sec61a2	57743	0.60447661	0.01312749	0.17152834	-0.6159313	0.00522462	0.04171162
Fem1c	240263	0.32376276	0.09009093	0.48631977	-0.6163578	0.00039643	0.0061047
Fpgt	75540	0.76196183	0.00327238	0.07420123	-0.6179791	0.00692929	0.0513741

Sdhc	66052	0.26803497	0.17186646	0.65796378	-0.6191424	4.96E-05	0.0011891
Btf3l4	70533	0.42715141	0.08573302	0.47432849	-0.6192661	0.00018384	0.00336039
Cstf2	108062	0.40326183	0.02953635	0.27259086	-0.6193913	5.77E-05	0.00133368
Wac	225131	0.42312565	0.02613729	0.25399867	-0.6195295	5.12E-05	0.0012227
Psma7	26444	0.43349024	0.01466296	0.1845795	-0.6195527	2.49E-05	0.00069633
Atp6ap1	54411	0.45067722	0.01189586	0.16085753	-0.6195554	3.58E-05	0.00092904
Rbm12	75710	0.48310727	0.0312465	0.28230079	-0.6195587	3.55E-05	0.00092622
Nfat5	54446	0.45616341	0.01305513	0.17085713	-0.6195909	0.00216818	0.02161134
Uchl5	56207	0.52159337	0.00672049	0.11509193	-0.6196049	2.65E-05	0.00073352
Acer1	171168	-0.1688473	0.41214903	0.9312631	-0.619792	0.00207892	0.02094315
Ubqln2	54609	0.43332432	0.02607654	0.25372864	-0.6197937	5.69E-06	0.00021771
Cr1l	12946	0.7151635	0.01924006	0.21632669	-0.6214812	0.00054584	0.0077624
Orc5	26429	0.50709731	0.06326628	0.40362384	-0.6225633	0.00308262	0.02799821
Qrich1	69232	0.38941511	0.02256453	0.23576449	-0.6235645	8.60E-06	0.00030025
Tcf12	21406	0.37282325	0.04088368	0.32155247	-0.6236167	2.91E-05	0.0007929
Mrps22	64655	0.79825651	0.00749798	0.1228089	-0.6239834	0.00013451	0.0026028
Hiat1	15247	0.65448935	0.0037903	0.08176926	-0.6247942	0.00141125	0.01576987
Rnf130	59044	0.30662714	0.08938099	0.48484521	-0.6253053	0.00079632	0.01033342
Pik3c2a	18704	0.37122671	0.08978736	0.48543217	-0.6259671	0.00029854	0.00493102
Ppa1	67895	0.45100289	0.02234451	0.23419545	-0.6279094	1.03E-05	0.00034619
Sdr16c6	242286	0.5082802	0.01531608	0.18950802	-0.6285374	0.00010648	0.002182
Btg1	12226	0.14900989	0.38372147	0.90035185	-0.6286752	0.00013473	0.00260334
Cnot6l	231464	0.55271252	0.00410255	0.0854622	-0.6312127	0.00041903	0.00638243
Tfg	21787	0.26722745	0.16005025	0.63429551	-0.6328634	3.40E-05	0.00089106
Cln6	76524	-0.1189541	0.5360482	1	-0.6341272	0.0050346	0.04063704
Paqr5	74090	0.05039563	0.76790765	1	-0.6344444	0.01521437	0.09008261
Kansl1l	68691	0.27283123	0.19034491	0.69301307	-0.6344536	0.00064122	0.00873811
Stt3a	16430	0.72139092	0.00207923	0.05592166	-0.6344537	8.10E-07	4.38E-05
Fam208b	105203	0.4913274	0.01673126	0.19839851	-0.6344555	0.00065571	0.00887528
Kdelr2	66913	0.4849374	0.00437425	0.08889127	-0.6349665	3.16E-07	2.05E-05
Glmp	56700	0.38419311	0.04483201	0.33778114	-0.6354408	0.0009541	0.01182282
Tmem70	70397	0.66056053	0.00279188	0.06783967	-0.6363835	0.00036682	0.00574929
Pomp	66537	0.38412024	0.03394478	0.29375104	-0.636701	1.02E-05	0.00034225
Tmsb4x	19241	0.47895128	0.00496978	0.09647611	-0.6367079	6.51E-06	0.00024077
Ezh1	14055	0.05178339	0.79610377	1	-0.6368878	0.0139629	0.08550738
Anapc11	66156	0.06409224	0.72660048	1	-0.6372797	2.10E-05	0.0006057
Lin54	231506	0.40333193	0.03857087	0.3157776	-0.6376865	0.00823209	0.05810228
Slc31a2	20530	0.53388517	0.00299806	0.07060334	-0.6377469	0.00766404	0.0552411
Cdc16	69957	0.369535	0.033962	0.29379598	-0.6379746	3.29E-05	0.00087384
Psmf1	228769	0.46062997	0.05075527	0.35989432	-0.6380362	0.00615771	0.04730112
Ptar1	72351	0.75239197	0.00323087	0.07360173	-0.6398594	0.00323912	0.02911896
Cyp39a1	56050	0.1983152	0.35690398	0.86583347	-0.6406031	0.0018898	0.01942343
Polr3f	70408	0.39588852	0.06009803	0.39336746	-0.6411395	0.00152262	0.0166044
Smchd1	74355	0.46397866	0.03347979	0.29179851	-0.6411974	1.53E-05	0.00046855
Cd59a	12509	0.77847336	0.03244716	0.28824736	-0.6449421	0.01740045	0.09902273
Hist1h2bf	319180	0.89053393	0.00202044	0.05513971	-0.6451155	0.00209722	0.02103118
Fbxo25	66822	-0.0253258	0.93064382	1	-0.6452131	0.01679109	0.09658072
Atp6v0d1	11972	0.42589376	0.02600998	0.25366998	-0.6456185	1.30E-05	0.00040959
Myadm	50918	0.49030545	0.05908564	0.38941149	-0.6459827	0.00271801	0.02531371
Zfp397	69256	0.54521715	0.02493163	0.24783068	-0.6459888	0.0042948	0.03603207
Rbm45	241490	0.37936155	0.05816417	0.3858669	-0.6460162	0.00019953	0.00356797
Lsm2	27756	0.27767531	0.1965345	0.70488604	-0.646326	0.00070862	0.00944169
Myl12b	67938	0.24268151	0.27771201	0.75711368	-0.6463366	0.00015721	0.00295115
Ube2a	22209	0.59768544	0.00515812	0.09848823	-0.6464045	0.00016546	0.00307116
Pafah1b2	18475	0.44374749	0.0476871	0.34752811	-0.6464121	9.30E-07	4.93E-05
Gdpd1	66569	0.02770628	0.90457723	1	-0.6466372	0.00179709	0.01874802
Mrpl40	18100	0.1603785	0.42468144	0.9454615	-0.6481051	0.00010027	0.00207399
Psmd14	59029	0.56966861	0.00508826	0.09807455	-0.64944	1.20E-05	0.0003889
Ska2	66140	0.34339608	0.11927096	0.5494512	-0.6504919	0.00123672	0.01432921
Mtmr1	53332	0.46479876	0.02524113	0.24905606	-0.6505136	0.00152367	0.0166044
Mios	252875	0.39269512	0.07486686	0.4363541	-0.6506473	0.00148044	0.01634186
Smc2	14211	0.4156977	0.05748802	0.38379306	-0.6506632	6.58E-06	0.00024261
Ift22	67286	0.37693222	0.26996947	0.74580594	-0.6507704	0.01162858	0.07460825

Mrpl45	67036	0.44383846	0.03180679	0.2854662	-0.6510885	0.00016227	0.00302463
Tmbim1	69660	0.49727442	0.00587272	0.10615674	-0.6512308	0.00032239	0.00521387
Pou2f1	18986	0.03431348	0.84605167	1	-0.6552492	0.003553	0.03114178
Mall	228576	0.14914049	0.41611987	0.93572375	-0.6558333	0.000239	0.00415337
Snai2	20583	0.54516938	0.00740296	0.12219234	-0.6560008	0.00176234	0.01849731
Erlec1	66753	0.6043003	0.00823777	0.13105126	-0.6566024	0.00095281	0.01181786
Eri2	71151	0.5753978	0.00973536	0.14374074	-0.6569768	0.00488041	0.03963497
Alg3	208624	0.17882913	0.46422182	0.99104893	-0.6569985	0.00556121	0.04365927
Nbn	27354	0.49870414	0.0157947	0.19295764	-0.6571918	0.00038362	0.0059491
Ube2v2	70620	0.74484298	0.00511834	0.09817898	-0.6577646	0.00013003	0.00252724
Rad18	58186	0.49279921	0.03198981	0.28605756	-0.658497	0.00115935	0.01363628
5730455P16Rik	70591	0.6166478	0.01003163	0.14652066	-0.6592955	0.01457117	0.08780512
Sec24b	99683	0.38644581	0.02467836	0.24691	-0.6604625	3.35E-05	0.00087921
Arg2	11847	-0.146662	0.62252025	1	-0.6606646	0.00031955	0.00517435
Nfyc	18046	0.40638934	0.04209575	0.32583847	-0.6607569	1.79E-05	0.00053529
Alg10b	380959	0.54906746	0.02635929	0.25563503	-0.660906	0.00028874	0.00482337
Med31	67279	0.03746119	0.91453917	1	-0.6614221	0.00829133	0.05841999
Fopnl	66086	0.35811058	0.10243345	0.51514154	-0.6627948	0.00041833	0.00638233
Tmem106b	71900	0.66070226	0.00305784	0.07126598	-0.6630067	0.00044936	0.00669326
Atp5h	71679	0.3881076	0.02606207	0.25372864	-0.6634442	3.91E-07	2.42E-05
4921524J17Rik	66714	0.04967546	0.88923059	1	-0.6634691	0.00596434	0.04611093
D230025D16Rik	234678	0.02348183	0.90841835	1	-0.6642134	0.0019926	0.02024349
Mynn	80732	0.46111964	0.06475208	0.40778289	-0.6642719	0.00307196	0.02792055
Commd1	17846	0.4366175	0.03693017	0.3085432	-0.6652902	5.14E-05	0.0012237
Vwa5a	67776	0.44574295	0.05210618	0.36534166	-0.6657393	1.13E-05	0.00036984
Sp1	20683	0.55922387	0.00450184	0.09070906	-0.6659968	4.28E-06	0.00017596
Eif2ak2	19106	0.41730499	0.06170093	0.39767705	-0.6670583	0.01443222	0.08728784
Itgb8	320910	0.15219102	0.52586452	1	-0.668017	0.00218915	0.02173831
Nipa2	93790	0.38918588	0.04971263	0.35677013	-0.6685023	0.0091347	0.06248974
Gmppa	69080	0.48953982	0.06668639	0.41411888	-0.6695604	0.00176289	0.01849731
Dync2li1	213575	0.43909557	0.13961159	0.58495942	-0.6696824	0.00173701	0.01830939
Ano10	102566	0.46191972	0.03240749	0.28808	-0.6697767	0.00235261	0.0228426
Gps2	56310	0.21661975	0.36778458	0.87805918	-0.6697986	0.00163707	0.01752183
Mtmr6	219135	0.30091197	0.12271788	0.551839	-0.6699505	0.00208602	0.02098262
Ssbp2	66970	0.6193557	0.00259687	0.06500561	-0.6703742	1.61E-05	0.00048727
Tex10	269536	0.62337255	0.00573855	0.10466104	-0.6705229	4.91E-05	0.00118161
Acot13	66834	0.35297694	0.13569639	0.57541962	-0.6711179	7.64E-05	0.00166677
Cdk1	12534	0.60606217	0.02168289	0.23123046	-0.6715807	3.42E-08	3.11E-06
Casc5	76464	0.60941862	0.00600456	0.10726948	-0.6717345	0.00030357	0.00498906
Mrps16	66242	0.25367822	0.18865398	0.69099513	-0.6727958	0.0015115	0.01655372
Sephs1	109079	0.41600846	0.02069033	0.22597428	-0.6728441	5.31E-05	0.00124552
Ugdh	22235	0.34407091	0.06721852	0.41562686	-0.6729729	6.60E-05	0.00148389
Tex30	75623	1.00968275	0.0055604	0.10294963	-0.6735875	0.00104379	0.01267238
Btd	26363	0.35604488	0.23645425	0.73917364	-0.6736913	0.00350009	0.03085554
Rabl3	67657	0.66607195	0.00683817	0.11629179	-0.674277	0.01025334	0.06851309
Mob1a	232157	0.49347489	0.02746589	0.26242365	-0.6745452	1.26E-05	0.00039893
Ndc1	72787	0.74669377	0.00401935	0.08490158	-0.674547	3.05E-05	0.00082577
Nfib	18028	0.15057132	0.44349179	0.96745272	-0.6752858	2.07E-07	1.42E-05
Serpine2	20720	0.12909018	0.61752839	1	-0.6773376	4.65E-05	0.00112606
Foxi3	232077	-0.2166329	0.33418182	0.83615684	-0.6776802	4.42E-05	0.00109112
Efemp1	216616	0.32079705	0.21591606	0.73474314	-0.6778861	2.59E-05	0.00072013
Ubald1	207740	-0.0243889	0.89333882	1	-0.6783369	0.01206483	0.07669536
Otub1	107260	0.37352009	0.03087271	0.28032681	-0.679446	1.25E-05	0.00039893
Pin4	69713	0.57302343	0.05739853	0.38379306	-0.6803786	0.00330288	0.02953128
D15Ertd621e	210998	0.31197427	0.14033985	0.58655478	-0.681668	0.00016225	0.00302463
Dph1	116905	0.35816739	0.23845916	0.73917364	-0.6817853	0.00812817	0.05767071
Suox	211389	0.36494738	0.2048047	0.72126289	-0.6818998	0.01592131	0.09321807
Perp	64058	0.54254153	0.00383837	0.08251479	-0.6822646	0.00048229	0.00707987
Ets1	23871	0.35434793	0.07827742	0.44863009	-0.6824249	0.00197365	0.0200665
Serpinb5	20724	0.5382395	0.00245251	0.0623234	-0.6835281	1.65E-06	7.93E-05
Tmem30a	69981	0.48886593	0.00679845	0.11577746	-0.6840688	1.01E-05	0.00034115
Ergic1	67458	0.23388322	0.22405576	0.73474314	-0.684517	1.97E-05	0.00057446
Aga	11593	0.18898872	0.52673211	1	-0.6858098	0.00756377	0.05483145

Rbm14	56275	0.39566213	0.0351007	0.30003298	-0.6861761	0.00015277	0.00289673
Acp1	11431	0.50226153	0.01029935	0.14882868	-0.6863932	7.01E-05	0.00155441
Lgr5	14160	0.67710344	0.00872061	0.13487405	-0.6865079	0.00010151	0.00209323
Gclm	14630	0.53314465	0.00612462	0.10861971	-0.6873955	2.70E-05	0.00074612
Nek7	59125	0.44790703	0.01842966	0.21051014	-0.6874332	0.00138277	0.01553057
Ptbp2	56195	0.55634699	0.02148987	0.2299281	-0.6887862	0.00424125	0.03569625
Zc3h3	223642	0.20072564	0.3355049	0.83811018	-0.6893295	0.01472436	0.08828593
Sall2	50524	0.2285132	0.36066205	0.86936138	-0.6893303	0.01268462	0.07964218
Scd1	20249	0.69020629	0.00212176	0.05659964	-0.6904661	0.00103308	0.01260036
Dnpep	13437	0.3221349	0.10481669	0.51942542	-0.6914683	0.00011458	0.00229463
Zfp706	68036	0.26418854	0.12165181	0.551839	-0.6933983	0.00276119	0.02558945
Acadsb	66885	0.51140013	0.01054859	0.15073563	-0.6939641	5.48E-06	0.00021085
BC003331	226499	0.30342281	0.16405492	0.64194604	-0.69541	0.00382801	0.03299692
Ntan1	18203	0.60975318	0.01077252	0.15241934	-0.6955763	0.00022629	0.00396061
Bmpr1a	12166	0.5792674	0.00458578	0.09194519	-0.697008	0.00010168	0.00209337
Slc45a2	22293	0.59551783	0.01039108	0.14962302	-0.6989882	0.00072573	0.00960628
Mgll	23945	0.10785379	0.58141813	1	-0.6990101	0.00065407	0.00886217
Emp1	13730	0.39110589	0.0266042	0.25710379	-0.7006529	3.83E-07	2.42E-05
Tmbim4	68212	0.57227418	0.06672773	0.41411888	-0.7014049	0.00049771	0.00721782
Rnasek	52898	-0.0515325	0.79539729	1	-0.7016754	3.33E-05	0.00087762
0610007P14Rik	58520	0.48644512	0.01212843	0.16269749	-0.7035081	0.00016479	0.00306303
Zdhhc18	503610	-0.10211	0.58813773	1	-0.7037887	0.01452596	0.08773416
Zfp68	24135	0.3027911	0.12248142	0.551839	-0.7060548	0.00142655	0.01591391
Hist1h2ab	319172	0.40870516	0.02229272	0.23396625	-0.7068811	0.00091701	0.01150365
Jrkl	77532	0.71940635	0.01103241	0.15496383	-0.7073498	0.00644384	0.04888882
Cdc26	66440	0.66108853	0.0030446	0.07108239	-0.7096527	0.00400276	0.03425711
Abhd13	68904	0.30764674	0.14795848	0.60595238	-0.7111903	0.00094743	0.01177325
Siae	22619	0.46758902	0.22638263	0.73474314	-0.7115191	0.01581328	0.09275016
Fbxl3	50789	0.46540167	0.00924127	0.13974053	-0.7121496	2.25E-05	0.0006411
Cnn2	12798	0.40805279	0.01141886	0.1575646	-0.7123273	6.29E-05	0.00142558
Lap3	66988	0.43499883	0.01233361	0.16495016	-0.7125681	4.61E-08	3.98E-06
Pigb	55981	0.3335673	0.25862021	0.74309288	-0.7126598	0.01487473	0.08890483
Dlx3	13393	0.00935114	0.96514935	1	-0.7130865	0.00081354	0.01048987
Gstm2	14863	0.13688962	0.54208583	1	-0.713148	2.78E-06	0.00012304
Tspan13	66109	0.4140929	0.06018193	0.39381107	-0.7143961	0.00512176	0.04115327
Smg7	226517	0.2978384	0.0711445	0.42521287	-0.7169769	2.16E-05	0.00061956
Mmgt1	236792	0.62291413	0.002115	0.05659964	-0.7171326	0.00068201	0.00914687
Ints6	18130	0.41542136	0.03439333	0.29581832	-0.7173128	5.20E-05	0.00123273
Nupl1	71844	0.68341354	0.00511073	0.09817898	-0.7175576	7.32E-05	0.00161879
Pam16	66449	0.24359646	0.30779462	0.80109267	-0.7184227	0.00114634	0.0135437
Fbxo8	50753	0.81945616	0.0020026	0.05494644	-0.7195612	0.01658289	0.09573243
Ripk2	192656	0.38579326	0.13314927	0.56936411	-0.7198783	0.01490908	0.08894127
Zfp958	233987	0.48848152	0.10096234	0.51162059	-0.7208161	0.01191097	0.07586344
Ppp2r5e	26932	0.35716507	0.02843148	0.26647704	-0.7224147	1.06E-05	0.00035105
Actr10	56444	0.57627325	0.00319263	0.07316095	-0.7226976	4.94E-07	2.89E-05
Sdhaf2	66072	0.4069663	0.04321729	0.33012491	-0.7229168	6.02E-05	0.00137969
Fam49b	223601	0.50888819	0.0330095	0.28996758	-0.7229268	3.33E-05	0.00087762
Snrpe	20643	0.41342682	0.12868836	0.5592539	-0.7234876	0.00035014	0.00556058
Dcaf10	242418	0.20656646	0.26597762	0.74352559	-0.7235214	0.00364105	0.03177976
Ncoa6	56406	0.53099874	0.00540238	0.10098531	-0.7236679	0.00019062	0.00345203
Gstp1	14870	0.31296281	0.17237049	0.65896567	-0.728739	0.0001618	0.00302447
2810474O19Rik	67246	0.59087781	0.00329569	0.07452216	-0.7287937	0.00022668	0.00396223
B230219D22Rik	78521	0.42543451	0.0475724	0.347343	-0.7290327	0.00019508	0.00351696
Gosr1	53334	0.38747237	0.06276082	0.40143584	-0.7291309	0.0001309	0.00254051
Lamtor3	56692	0.33529455	0.15024341	0.61135025	-0.7301795	0.00030434	0.00499553
Abhd12	76192	0.12136651	0.50508209	1	-0.7307519	0.0004403	0.00659032
Chek1	12649	0.59070684	0.04963203	0.35659423	-0.7308403	0.00092713	0.01160846
Cxcr4	12767	0.20477097	0.35655259	0.86554383	-0.7321832	1.65E-06	7.93E-05
Yipf6	77929	0.67569463	0.00267101	0.06600092	-0.7325232	0.00651249	0.04915939
Rbms1	56878	0.31488167	0.08151175	0.46004125	-0.7329907	4.63E-05	0.00112606
Gstm5	14866	0.6170328	0.01107543	0.1552659	-0.733296	1.07E-05	0.00035333
Atp11c	320940	0.67817245	0.01414143	0.17996237	-0.7344575	0.00178601	0.0186767
Mis18bp1	217653	0.67656059	0.00487753	0.09575098	-0.7352239	0.00030202	0.00497603

Snapin	20615	0.58617097	0.02023987	0.22264766	-0.735744	0.00540191	0.04276425
Zfp825	235956	0.8093006	0.00712212	0.11962133	-0.7359212	0.00538694	0.04272322
Fam111a	107373	0.6218722	0.02882379	0.26815461	-0.7360629	0.00034838	0.00554766
Nt5c2	76952	0.39704787	0.05034482	0.35936201	-0.7364703	0.00028862	0.00482337
Cnot7	18983	0.39597684	0.0492041	0.35508668	-0.7369824	0.00261335	0.02459938
Lhfpl1	237091	0.83915682	0.00257693	0.06461112	-0.7372627	0.0020966	0.02103118
Tia1	21841	0.47930187	0.04334545	0.33069014	-0.7379398	3.53E-05	0.0009236
Rnf5	54197	0.02598781	0.89162545	1	-0.7391957	0.01674609	0.09637947
Cfap36	216618	0.38617247	0.11217824	0.53530319	-0.7397373	0.00646869	0.04895431
Rictor	78757	0.52500118	0.01598094	0.19416446	-0.7403993	6.94E-05	0.00154137
Cyp2g1	13108	-0.1497583	0.62806316	1	-0.7412433	0.00056037	0.00791771
Rae1	66679	0.47712098	0.02683915	0.25886216	-0.7419222	4.80E-06	0.0001909
Rel	19696	0.3002411	0.26730747	0.74460094	-0.743601	0.00112738	0.01336745
Nanp	67311	0.46271403	0.09718993	0.50531726	-0.7436578	0.00057103	0.00801686
Mterf3	66410	0.55785096	0.01699925	0.19983721	-0.7479869	0.00018636	0.00339223
Litaf	56722	0.36933922	0.04660562	0.34458244	-0.7487366	1.16E-05	0.00037813
Tomm7	66169	0.59530919	0.0096148	0.14275358	-0.7495363	4.04E-08	3.56E-06
Brca2	12190	0.30998329	0.23710319	0.73917364	-0.7500841	0.00444475	0.03696112
Rfc3	69263	0.60934922	0.04936623	0.35552133	-0.7512294	5.50E-07	3.12E-05
Tmem60	212090	0.94376061	0.02937762	0.27185705	-0.7515802	0.01042277	0.06925948
Zfp7	223669	0.57246942	0.0384065	0.31505716	-0.7517478	0.00716717	0.05263501
Alms1	236266	0.37804467	0.13258125	0.56780205	-0.751767	0.01012492	0.0678956
Atl3	109168	0.26693954	0.19129146	0.69490679	-0.7517827	5.74E-09	6.86E-07
Gbe1	74185	0.60113688	0.09445987	0.49566062	-0.7518564	0.01026395	0.06851471
A730017C20Rik	225583	0.32077012	0.21362345	0.73474314	-0.7527677	0.00041025	0.00627359
Ndufa11	69875	0.59050348	0.00206718	0.05584692	-0.7538409	7.48E-06	0.00026472
Slc35e1	270066	0.37183595	0.03140221	0.28308356	-0.7542782	0.00571313	0.04456037
Ppap2c	50784	0.19384231	0.31749574	0.8158359	-0.7548721	0.00171527	0.01811841
Dzip3	224170	0.56853504	0.01130746	0.15689741	-0.7555816	0.00062393	0.0085326
Fam58b	69109	0.39017856	0.11150646	0.53338488	-0.7569586	0.00332425	0.02968208
Ccdc107	622404	0.35189652	0.21213393	0.73474314	-0.7578533	0.00253248	0.02407862
Zwilch	68014	0.31203852	0.23776294	0.73917364	-0.7587961	0.00029054	0.00484122
B4gat1	108902	0.34325431	0.1512232	0.61376463	-0.7592334	0.00035848	0.00565891
Ep300	328572	0.37147776	0.04343187	0.33124601	-0.7607704	1.94E-07	1.36E-05
Coq4	227683	0.59394501	0.00945838	0.14127405	-0.762472	0.00057489	0.00806248
Sass6	72776	0.38665067	0.13926094	0.58394425	-0.7630274	3.58E-05	0.00092904
Arhgap18	73910	-0.1074449	0.72084339	1	-0.7644037	0.00290424	0.02669026
Ostc	66357	0.51338409	0.0171368	0.20071839	-0.7663939	5.45E-07	3.10E-05
Ube2i	22196	0.20932017	0.2081597	0.72693665	-0.7677902	1.44E-07	1.06E-05
Mad2l2	71890	0.40789933	0.20948895	0.72987286	-0.7678604	0.00118674	0.01389655
Mpc1	55951	0.75173111	0.00349982	0.07748784	-0.7679086	5.30E-05	0.0012436
2610002M06Rik	67028	0.66762702	0.01670457	0.19839851	-0.7680834	8.01E-05	0.00172962
Zcchc7	319885	0.26175905	0.22770924	0.73474314	-0.7697007	0.00076564	0.01004385
Wls	68151	0.61910444	0.00240261	0.06131807	-0.7697763	1.45E-10	2.99E-08
Fv1	14349	0.51151033	0.10148987	0.51240111	-0.772448	0.00281886	0.02599614
Nup153	218210	0.55912359	0.00262126	0.06518726	-0.7728474	7.70E-09	8.84E-07
Bri3	55950	0.00900824	0.96978288	1	-0.7747543	0.007258	0.05318372
Dus4l	71916	0.52702147	0.27446575	0.75387787	-0.7754082	0.00807667	0.05736694
Tmem39a	67846	0.58087185	0.00559826	0.10324243	-0.7779565	0.0013476	0.01521457
Rps15a	267019	0.83622308	0.00480247	0.09450537	-0.7795293	1.36E-09	2.16E-07
Prdx1	18477	0.71203869	0.00320154	0.0732068	-0.7796225	1.91E-09	2.83E-07
Zyg11b	414872	0.2816912	0.1206564	0.551839	-0.7807563	1.05E-06	5.49E-05
Celf1	13046	0.12533652	0.46589063	0.99287751	-0.7812224	2.06E-08	2.08E-06
Kdelc2	68304	0.27103265	0.28748345	0.77268692	-0.7827134	0.01608887	0.09380338
Dclre1c	227525	0.80786344	0.00421986	0.08725793	-0.7830316	0.01453562	0.08775231
Med19	381379	0.49831865	0.01401707	0.1791265	-0.7855055	1.54E-05	0.00046926
Zmiz1	328365	0.10663858	0.54769829	1	-0.785863	2.45E-05	0.00069064
Pstk	214580	0.11096882	0.66462154	1	-0.7861102	0.00274027	0.02548509
Dcn	13179	0.49164245	0.02716142	0.26125977	-0.7866509	5.77E-09	6.86E-07
Dpm2	13481	-0.1115491	0.61804854	1	-0.7869246	0.00041966	0.00638243
Nprl3	17168	0.35229967	0.14524977	0.59988917	-0.7869915	0.0139123	0.08527668
Ociad2	433904	0.40537118	0.10761732	0.52543069	-0.7876313	0.00077393	0.01012245
Hadhb	231086	0.71402168	0.00184138	0.05174726	-0.7879349	3.48E-06	0.00014843

Hist1h4d	319156	0.29453398	0.12839976	0.55895215	-0.7889838	3.93E-07	2.42E-05
Tram2	170829	0.61841603	0.08745477	0.47926044	-0.790691	0.0048082	0.03919722
Rab5a	271457	0.42979734	0.01700429	0.19983721	-0.7908531	1.25E-06	6.37E-05
Nfya	18044	0.47080573	0.03712254	0.30907659	-0.7909738	3.24E-06	0.0001405
Slitrk6	239250	0.4491643	0.1127486	0.53610464	-0.7918044	0.00181159	0.01885457
Akirin1	68050	0.57019157	0.00724186	0.12052473	-0.7918942	0.00104996	0.0127239
Mrps6	121022	0.55344318	0.06078922	0.39555918	-0.7938634	0.00019797	0.00355465
Zfp87	170763	0.37886678	0.22733458	0.73474314	-0.7947473	0.0006608	0.00891675
Nup43	69912	0.85620749	0.00578119	0.10512469	-0.7947641	8.51E-05	0.0018121
Traf6	22034	0.31588211	0.07710679	0.444739	-0.7950793	0.00015521	0.00292122
Slc35f5	74150	0.41730206	0.04386119	0.33291272	-0.795166	0.00049569	0.00721239
Cyb5r4	266690	0.3009425	0.09526786	0.49861475	-0.7960008	0.00017635	0.00324129
Zfp943	74670	0.68810733	0.03268944	0.28937356	-0.7960408	0.01173158	0.0751197
Zfp518a	72672	0.76968556	0.02519977	0.24884902	-0.7961117	0.00021824	0.00386083
Ggps1	14593	0.58970584	0.00288671	0.06918184	-0.7984487	0.00109227	0.01304868
Crip1	12925	1.12872565	0.00265347	0.06572046	-0.7986742	0.01047013	0.06947821
Ssr2	66256	0.51276491	0.00246942	0.06249305	-0.8009592	2.84E-07	1.87E-05
Ids	15931	0.30786514	0.14658163	0.60263803	-0.8010293	0.01442851	0.08728784
Ankrd32	NA	0.74105999	0.00606817	0.10793207	-0.8010551	0.00062686	0.00855499
Cers6	241447	0.52669327	0.00900052	0.13780671	-0.8015068	1.85E-06	8.72E-05
Pts	19286	0.72899248	0.00308255	0.07157775	-0.8020105	0.00044899	0.00669326
Pgap1	241062	0.49505867	0.01855291	0.21142347	-0.8021258	1.58E-06	7.72E-05
Cpne8	66871	0.26043323	0.26080575	0.74309288	-0.8022293	0.00011447	0.00229463
Zfp384	269800	0.18341606	0.28820547	0.77359582	-0.8056554	0.00079536	0.01033342
Sdhd	66925	0.31627996	0.15228538	0.61613009	-0.8065047	7.38E-05	0.00162607
Slmo2	66390	0.32721387	0.05174414	0.36363842	-0.8067874	1.59E-05	0.00048265
Crtc1	382056	-0.1791527	0.35846552	0.86760025	-0.8077166	0.00579736	0.04516396
Mfap3	216760	0.52975363	0.01220603	0.16351257	-0.8085442	4.53E-05	0.0011116
Cln3	12752	0.20199987	0.46759984	0.99506038	-0.8098087	0.01126133	0.07263721
Usp3	235441	0.55152679	0.02582574	0.25257927	-0.8106332	1.38E-07	1.04E-05
Pign	27392	0.68371364	0.00941121	0.14096553	-0.8117558	0.00326877	0.02928582
Zfp1	22640	0.06301116	0.7804239	1	-0.8120083	0.00079088	0.01029317
Bgn	12111	0.17481656	0.41379367	0.93299374	-0.812995	1.75E-05	0.00052535
Zfp719	210105	0.78221816	0.00596027	0.107023	-0.8135268	0.0095442	0.06459224
Rsu1	20163	0.52325722	0.0420538	0.32583847	-0.8143734	1.22E-05	0.00039471
Ube2n	93765	0.32022131	0.0924928	0.4884315	-0.8149361	3.57E-05	0.00092904
Pum2	80913	0.45464443	0.01534161	0.18950802	-0.8180733	1.11E-09	1.85E-07
Rnase1	19752	-0.3968529	0.1899816	0.69278013	-0.8184692	0.00952098	0.06446813
Gtpbp10	207704	0.54760704	0.03679759	0.30796229	-0.8186314	0.00020968	0.00372923
Ranbp9	56705	0.49111041	0.00988221	0.14520662	-0.8198108	1.94E-05	0.00056737
Mapk8	26419	0.54285646	0.04231812	0.32662792	-0.8213324	0.00072959	0.009638
Ccdc14	239839	0.53298751	0.06931518	0.41899656	-0.8229703	0.01264535	0.079467
2700060E02Rik	68045	0.50213226	0.00477407	0.09402214	-0.8230269	1.28E-09	2.08E-07
2810006K23Rik	72650	0.3981266	0.16424381	0.64227351	-0.8232187	0.01189102	0.07580953
Ptdss1	19210	0.36910913	0.02929257	0.27127559	-0.823587	4.97E-06	0.00019572
Grina	66168	0.33386012	0.06795083	0.41725099	-0.825339	0.00017935	0.0032828
Sc5d	235293	0.50134435	0.00693036	0.11745064	-0.8259444	3.02E-05	0.00082087
Rer1	67830	0.25316074	0.157454	0.62819543	-0.8262284	1.40E-07	1.04E-05
Slc15a1	56643	0.79174998	0.00298626	0.07043409	-0.8267263	0.0040732	0.03474729
Rbm4b	66704	0.57555947	0.13468477	0.57318907	-0.8272943	0.01074736	0.0703536
Tmed3	66111	0.38177732	0.05676456	0.38167601	-0.8300555	4.34E-07	2.60E-05
Tbc1d19	67249	0.63381321	0.03425454	0.29507233	-0.8302907	0.00161814	0.01737555
Bak1	12018	-0.0647404	0.72013386	1	-0.8305725	0.00893443	0.06160275
Efna1	13636	0.50983788	0.00408919	0.0854252	-0.8308034	3.89E-07	2.42E-05
Zfp772	232855	0.35281524	0.14458961	0.59817429	-0.8319657	0.01671721	0.0963393
Gjc1	14615	0.27791794	0.22738165	0.73474314	-0.8340422	0.00234391	0.02281162
Tmem222	52174	0.35318859	0.06701914	0.41519177	-0.8342752	0.00031641	0.0051361
Dhfr	13361	0.49675354	0.02633951	0.25555709	-0.8345792	3.83E-06	0.00016031
Slc10a7	76775	0.41614653	0.07899673	0.45146132	-0.8362406	0.00108058	0.01297585
Trim13	66597	0.76626892	0.03607644	0.3048522	-0.8367663	0.00233275	0.02271974
Ftsj1	54632	0.67617141	0.00426975	0.08773081	-0.8386599	6.14E-05	0.00139844
Fbxo33	70611	0.60499823	0.0064122	0.11161242	-0.8386694	0.0035154	0.03092852
H60c	670558	0.29811827	0.21962758	0.73474314	-0.8405204	4.10E-07	2.49E-05

Smim14	68552	0.6231343	0.00376365	0.08133804	-0.8421709	0.00229152	0.02250085
Fam118b	109229	0.73819024	0.00802184	0.12879773	-0.8448869	0.00102531	0.01252869
4930453N24Rik	67609	0.47803345	0.06258325	0.40071988	-0.8451663	0.00014587	0.00277776
Katnbl1	72425	0.60671483	0.00650751	0.11294938	-0.8474043	0.00082239	0.01058832
Zfp800	627049	0.83107948	0.00334694	0.07540193	-0.8490256	0.0003667	0.00574929
Mrpl42	67270	0.74135423	0.00200004	0.05494135	-0.8508277	8.31E-05	0.00177658
Nicn1	66257	0.77013491	0.01785994	0.20682394	-0.8509215	0.01506659	0.08956044
Atad2	70472	0.50651646	0.01278114	0.16871801	-0.8517155	2.32E-07	1.55E-05
Trappc6b	78232	0.09156127	0.70161606	1	-0.852766	0.00109258	0.01304868
Dctd	320685	0.36406049	0.1177326	0.54577595	-0.8573899	3.68E-05	0.00094912
Lmbrd2	320506	0.42018123	0.06318268	0.40328915	-0.8577851	0.00010742	0.00219442
Tmem184c	234463	0.40887173	0.13994764	0.58581785	-0.8580868	0.01509979	0.08956044
4930402H24Rik	228602	0.62575757	0.01618797	0.19522298	-0.8580977	0.01398387	0.08551672
Fam168a	319604	0.28113759	0.13424343	0.57223929	-0.8581769	0.00416892	0.03531316
Krit1	79264	0.4556448	0.04705178	0.34587625	-0.8582031	0.00079842	0.01034036
Dph7	67228	0.36574306	0.09383768	0.49353858	-0.8585983	0.00454358	0.03761709
Hist1h2bl	319185	0.29716349	0.30712042	0.80002003	-0.8596227	0.00266105	0.02499256
A830080D01Rik	382252	0.79012386	0.00588614	0.10632066	-0.8625534	0.00023142	0.00402903
2210018M11Rik	233545	0.57926595	0.00714268	0.1197195	-0.8629725	0.00043793	0.00658988
Rpl29	19944	0.28752766	0.12771883	0.55895215	-0.8636801	1.15E-05	0.00037634
Yipf5	67180	0.62714753	0.00814164	0.12978264	-0.8636824	5.82E-06	0.00022122
Snap23	20619	0.67129353	0.00489712	0.09598125	-0.8640909	4.13E-06	0.00017081
Zmym5	219105	0.52531154	0.00464615	0.09269896	-0.8672926	1.59E-05	0.00048328
Tox	252838	-0.0824805	0.87939336	1	-0.8720057	0.01405312	0.08586069
Rbbp8	225182	0.44940364	0.0484485	0.35129475	-0.8724741	4.74E-09	6.01E-07
Gpr155	68526	0.87378905	0.0032651	0.07410494	-0.875068	0.00113178	0.01340761
Slc39a14	213053	0.53788082	0.01360409	0.17587958	-0.8755553	0.00083262	0.01068883
Nipal4	214112	0.43791957	0.0275028	0.26242365	-0.8759144	0.00591154	0.04587815
Hcfc2	67933	0.75620756	0.01097183	0.15446911	-0.8760603	0.0003231	0.00521907
Haus2	66296	0.75108341	0.00524061	0.09938152	-0.8774065	6.07E-05	0.00138939
Mbnl3	171170	0.52227546	0.01482734	0.18607934	-0.8789108	5.45E-06	0.00021026
Pigm	67556	0.53994417	0.00205186	0.05567544	-0.8802401	0.00061512	0.00845597
Ska1	66468	0.36866153	0.27607251	0.75591062	-0.8826943	0.00036486	0.00573222
Gyg	27357	0.87454451	0.00394252	0.08401428	-0.8827106	0.00032444	0.00523427
Soat1	20652	0.15498929	0.49554528	1	-0.8852451	3.73E-05	0.00095815
Prcp	72461	0.72248306	0.00715087	0.1197747	-0.8878537	0.00029169	0.00484858
Acot9	56360	0.93128762	0.00606688	0.10793207	-0.8881704	8.26E-08	6.61E-06
4931406C07Rik	70984	0.51400317	0.13717893	0.5791237	-0.8899217	0.00025888	0.00441966
Zfp157	72154	0.52815314	0.06617007	0.41269362	-0.8900682	0.00020557	0.00367104
Depdc1a	76131	1.08645888	0.00221608	0.05795827	-0.8901239	0.00022209	0.00391544
Ppp2r3c	59032	0.72709985	0.00542666	0.10121781	-0.8902087	4.15E-05	0.00103049
Qser1	99003	0.63886656	0.0030834	0.07157775	-0.8903016	1.36E-06	6.84E-05
Cnih4	98417	0.60599303	0.00193404	0.05355006	-0.8921127	2.77E-06	0.00012304
Prelid2	77619	0.68431386	0.10711439	0.52543069	-0.8932045	0.00656676	0.0493798
Depdc7	211896	0.76819261	0.02783642	0.26358789	-0.8949374	0.00037065	0.00580243
Lyrm2	108755	0.69688207	0.00276783	0.0675932	-0.8969994	0.00022997	0.00400919
Mob1b	68473	0.56321388	0.00867337	0.13431352	-0.898995	2.47E-09	3.43E-07
Mbtd1	103537	0.37669131	0.03897057	0.31596952	-0.9015448	1.20E-07	9.28E-06
Tmem208	66320	0.71248707	0.00264895	0.06567524	-0.9020486	6.68E-05	0.00149686
Tmem14c	66154	0.32310096	0.17633061	0.66648659	-0.9038356	2.33E-09	3.31E-07
Ufm1	67890	0.38749551	0.05034917	0.35936201	-0.904272	1.49E-05	0.00046071
Sh3bgrl	56726	0.63624931	0.00304291	0.07108239	-0.9085285	2.38E-06	0.00010819
Sdhaf4	68002	0.57514418	0.05287012	0.3677417	-0.9111429	0.00021216	0.00376325
Pparg	19016	0.50590104	0.27397878	0.75304848	-0.9111748	0.00657999	0.04942295
Zfp760	240034	0.45159774	0.12602337	0.55644508	-0.9112418	0.00161279	0.01733228
Bre	107976	0.54050626	0.01981973	0.2199081	-0.915858	5.70E-05	0.00132909
Far2	330450	0.81031925	0.01257007	0.16672216	-0.9166201	0.00040275	0.00618038
Rfk	54391	0.2649787	0.31429638	0.81109921	-0.9177166	0.00014134	0.00270337
Elmo1	140580	0.60266979	0.00214424	0.05661033	-0.9210947	7.49E-07	4.07E-05
Lamtor1	66508	0.1944218	0.27132766	0.74871105	-0.9213871	1.51E-06	7.46E-05
Slc2a4	20528	0.82500471	0.0030275	0.07090726	-0.9219661	0.01093137	0.07114652
Copz2	56358	0.37042345	0.20055098	0.71259357	-0.9240203	0.0016067	0.01728087
Rmdn1	66302	0.8623997	0.11076501	0.53233598	-0.9273819	0.00054892	0.00778096

Mad2l1	56150	0.25298029	0.21785938	0.73474314	-0.9274504	2.68E-07	1.78E-05
Fastkd1	320720	0.61128365	0.05282114	0.36771522	-0.9310224	0.00647848	0.04898187
Zfp58	238693	0.8210259	0.00813879	0.12978264	-0.9310891	0.00466675	0.03839593
Pus3	67049	0.72584049	0.02105599	0.22735247	-0.9322495	9.83E-05	0.00203674
Cd47	16423	0.04910398	0.82382214	1	-0.9329327	1.52E-06	7.46E-05
Mpc2	70456	0.32444642	0.09244643	0.4884315	-0.935277	4.57E-06	0.00018369
Stil	20460	0.53508938	0.02760091	0.2627843	-0.9355412	3.86E-05	0.00098394
Ythdf3	229096	0.56779598	0.0042912	0.08776837	-0.9355425	1.46E-08	1.56E-06
Sp4	20688	0.41222154	0.11153184	0.53338488	-0.9373031	0.00266749	0.02501976
Cdk19	78334	0.25751355	0.19137574	0.69490679	-0.9374033	0.00038341	0.0059491
Ythdf2	213541	0.49285659	0.00583181	0.10575548	-0.9391567	5.12E-11	1.32E-08
Cox7a2l	20463	0.19341327	0.28755329	0.77278957	-0.9413981	1.64E-09	2.55E-07
Mettl5	75422	0.74073772	0.02776734	0.26324002	-0.9435923	9.74E-06	0.00033209
Alg6	320438	0.49400073	0.12152405	0.551839	-0.9436752	0.00089399	0.0113008
Ap5m1	74385	0.49011428	0.2072488	0.7253114	-0.9437382	0.00230567	0.02258941
Pdk3	236900	0.66328609	0.00264232	0.06557743	-0.9448786	3.67E-07	2.33E-05
Rab30	75985	0.44595664	0.25519209	0.74309288	-0.946295	0.01047148	0.06947821
Zbtb44	235132	0.51021743	0.02767931	0.26286159	-0.9472851	0.00016954	0.00313984
Ackr3	12778	0.06203756	0.83836915	1	-0.9483915	5.41E-09	6.67E-07
Slc16a7	20503	0.28858679	0.28541855	0.76925355	-0.9495358	1.86E-05	0.00055163
Dcp1a	75901	0.32285979	0.0912166	0.48740869	-0.9502201	2.83E-05	0.00077246
Mastl	67121	0.50025235	0.03713323	0.30907659	-0.9562699	3.35E-05	0.00087921
Otub2	68149	0.42673589	0.15145944	0.61412161	-0.9571972	0.0137866	0.08470284
Foxj3	230700	0.26163095	0.1307268	0.56364391	-0.957813	4.89E-07	2.87E-05
Rnaseh2b	67153	0.58908264	0.00642594	0.11177204	-0.9609732	2.95E-06	0.00012878
Rpgr	19893	0.7818778	0.01462513	0.18438842	-0.9648077	0.00259802	0.02450757
Glce	93683	0.46141071	0.03228524	0.28722691	-0.9661354	3.45E-09	4.55E-07
Dimt1	66254	0.74345997	0.02454664	0.24678398	-0.9668364	2.09E-06	9.75E-05
Vkorc1	27973	0.51178943	0.01111186	0.1555979	-0.9674217	2.31E-06	0.00010567
Zfp763	73451	0.53249055	0.07608164	0.44080419	-0.9685841	0.00034849	0.00554766
Camk2g	12325	0.00611823	0.97676684	1	-0.9688568	1.75E-07	1.24E-05
Anapc10	68999	0.91182511	0.00640244	0.11159197	-0.9705799	4.58E-06	0.00018376
Ccdc122	108811	0.05683838	0.84080497	1	-0.9722661	0.00372259	0.03226044
Zfp65	235907	0.72076163	0.00737532	0.12200805	-0.97394	0.00257489	0.02437649
Fam76b	72826	0.59712728	0.00200753	0.05496185	-0.9739636	1.71E-06	8.19E-05
Iqcb1	320299	0.37752627	0.18706078	0.68777648	-0.9768052	0.00026717	0.00453197
Thyn1	77862	0.60617185	0.04193928	0.32552683	-0.9776997	0.00045866	0.00681638
Rgl1	19731	0.28909267	0.26588503	0.74352064	-0.9780777	0.01763488	0.09993479
Hells	15201	0.74408081	0.00260945	0.0651589	-0.9800903	6.63E-11	1.63E-08
Elmod2	244548	0.30951117	0.27140677	0.74884474	-0.9840984	1.31E-05	0.00041153
Tctn1	654470	-0.0893169	0.72086994	1	-0.9857924	0.00730887	0.05340817
Rnf170	77733	0.46204902	0.03706841	0.30906373	-0.9868774	0.00107952	0.01297585
Fads2	56473	0.80007837	0.02081573	0.22638055	-0.9884767	0.00365266	0.03183892
Foxj2	60611	0.10220057	0.58641343	1	-0.9889481	0.01097375	0.07124157
Id2	15902	0.82380583	0.00298324	0.07043409	-0.9891219	0.00016421	0.00305662
Trim68	101700	0.53476783	0.12695143	0.55895215	-0.9891606	0.0110757	0.07165001
Zdhhc2	70546	0.56688498	0.00940632	0.14096553	-0.9921582	0.00256385	0.02430688
Vangl1	229658	0.25187109	0.19428756	0.69995447	-0.9945206	2.69E-07	1.78E-05
Tlr2	24088	0.3899489	0.26664648	0.74426697	-1.0094198	0.01713538	0.09785185
Krtcap2	66059	0.39376407	0.05478299	0.37485441	-1.0122006	0.01310433	0.0813825
Ppil3	70225	0.60538516	0.0107716	0.15241934	-1.0135315	1.43E-06	7.13E-05
Zfp414	328801	0.07980892	0.75753977	1	-1.0198285	0.00204929	0.02072376
Neil3	234258	0.45608739	0.2398771	0.73917364	-1.020302	8.46E-05	0.00180703
Cenpl	70454	0.55143095	0.02876633	0.26792674	-1.0249181	0.00013896	0.00266552
Psenen	66340	0.11618891	0.54281762	1	-1.0249532	5.07E-07	2.92E-05
Rpa3	68240	0.87930492	0.00184631	0.05181399	-1.0257627	6.85E-08	5.65E-06
Rnf38	73469	0.45821531	0.04041532	0.32055296	-1.0259837	8.33E-06	0.00029157
Ccne2	12448	0.70247439	0.00515462	0.09848823	-1.0266629	4.08E-08	3.57E-06
Manea	242362	0.69224587	0.02192288	0.23176565	-1.0287655	0.00539937	0.04276425
Fads1	76267	0.64882755	0.00318062	0.07313913	-1.0364231	8.07E-05	0.00174028
Tmem230	70612	0.21026055	0.34925485	0.85582509	-1.037515	0.0026836	0.02513522
Dnajb9	27362	0.87700482	0.01538154	0.18980935	-1.0380648	3.20E-05	0.00085918
Leprot	230514	0.29938931	0.1111286	0.53290003	-1.0381318	4.59E-07	2.71E-05

Kctd14	233529	0.03952957	0.92607727	1	-1.0387739	0.00364781	0.03181766
Cnep1r1	382030	0.03203711	0.89677762	1	-1.0404771	1.14E-05	0.00037475
Lpar6	67168	0.70467354	0.00732783	0.12157121	-1.0434261	2.22E-05	0.00063531
Tm2d2	69742	0.52555906	0.01159852	0.1585044	-1.0476864	1.23E-05	0.00039642
Tmem161b	72745	1.05022634	0.00225235	0.05870288	-1.0489698	0.00160393	0.01727599
Mr1	15064	0.4304835	0.10633822	0.52346012	-1.0527549	0.00055828	0.0078967
Cenpq	83815	0.63188345	0.02806367	0.26471332	-1.0531414	2.75E-05	0.00075786
Pias1	56469	0.4197783	0.03995532	0.31904172	-1.0539419	1.99E-08	2.02E-06
Stau2	29819	0.5508839	0.04318553	0.33008887	-1.0576508	0.00038723	0.00598394
Cmtm3	68119	0.04016403	0.86129545	1	-1.0588122	0.00148101	0.01634186
Skint2	329919	1.11058841	0.0546709	0.37450718	-1.0646866	0.00500935	0.04045804
Gm4944	240038	0.85797071	0.00465751	0.09284985	-1.0647066	0.00251446	0.023977
Scoc	56367	0.69014596	0.01954518	0.21844983	-1.0685269	0.00012573	0.00247339
Mtx2	53375	0.4947843	0.00782449	0.12671215	-1.0698029	1.35E-10	2.82E-08
C1galt1c1	59048	1.11925833	0.00207477	0.05586334	-1.0707195	5.72E-08	4.80E-06
Vps37a	52348	0.41421974	0.04033718	0.32022241	-1.072589	1.33E-06	6.73E-05
Rpusd1	106707	0.295051	0.37644535	0.89003503	-1.0746198	0.00362848	0.03171199
Polr2j	20022	0.64305155	0.00346947	0.07723356	-1.0772364	1.08E-05	0.00035615
Higd2a	67044	0.61788557	0.00268261	0.06617378	-1.07883	4.00E-09	5.17E-07
Steap4	117167	0.55885323	0.02352096	0.24103883	-1.0809554	3.86E-07	2.42E-05
Mterf2	74238	0.86241015	0.12840267	0.55895215	-1.0841411	0.01054332	0.06977945
Immp1l	66541	0.77854043	0.00517787	0.09871095	-1.0847971	0.00010884	0.00221951
Skint3	195564	0.8783839	0.00228596	0.05929399	-1.0901659	0.00048608	0.00711964
Cdc27	217232	0.62017832	0.00608883	0.10814202	-1.0995676	5.27E-13	2.32E-10
Slc35a1	24060	0.76495245	0.00685665	0.11652491	-1.1013287	0.0001112	0.00224319
Ubxn2b	68053	0.17381747	0.50700736	1	-1.1014216	8.62E-05	0.00182885
Lrrn1	16979	0.46959303	0.19618127	0.70390902	-1.1016744	8.60E-05	0.00182856
Zfp950	414758	0.58356265	0.02843909	0.26647704	-1.1036801	0.00658988	0.04946547
Ube2b	22210	0.62656677	0.00267219	0.06600092	-1.103701	2.47E-08	2.41E-06
Zfp442	668923	0.86194715	0.04830033	0.35063686	-1.1065658	2.78E-05	0.00076389
Pqlc3	217430	0.53485059	0.07340253	0.43208403	-1.1070472	7.22E-06	0.00025966
Rapgef4	56508	0.47283881	0.15069274	0.61252786	-1.1095454	0.01038098	0.06908613
2210408I21Rik	72371	0.95260357	0.00649673	0.11284258	-1.1106074	0.00370684	0.03218364
Flywch2	76917	0.07429957	0.80549053	1	-1.1108753	0.01756019	0.09958826
Hist1h2bk	319184	0.40814291	0.09755661	0.50641617	-1.1141816	0.01753716	0.0995432
Hist1h4h	69386	0.24776858	0.19033238	0.69301307	-1.1148221	0.00665864	0.04987179
Grb14	50915	0.06423997	0.87386637	1	-1.1174134	0.00763929	0.05515084
Rps26	27370	0.82593155	0.00212473	0.05659964	-1.1213043	2.13E-15	2.34E-12
Kctd12b	207474	0.4025232	0.39892416	0.9167367	-1.1213411	0.01079545	0.07049359
Inpp5k	19062	0.14379741	0.57156213	1	-1.1226026	8.73E-06	0.00030241
Pigu	228812	0.57110225	0.04508914	0.33893676	-1.1247691	3.31E-08	3.03E-06
Mrps11	67994	0.48657067	0.08205184	0.46138339	-1.1299797	9.64E-05	0.00200897
C1galt1	94192	0.52213376	0.01695469	0.19973497	-1.1359728	0.00134772	0.01521457
Hist1h2bp	319188	0.32999686	0.34181925	0.84598446	-1.1386369	0.00353512	0.03106057
Acp2	11432	0.57255219	0.05626093	0.37964854	-1.1466604	3.65E-06	0.00015493
Zfp788	67607	0.6351644	0.12442315	0.55447769	-1.1468253	0.0019116	0.01957127
Bet1	12068	0.79841939	0.00671411	0.11509193	-1.1562115	1.82E-05	0.00054073
Pcdhga10	93722	1.07559491	0.01517604	0.18846338	-1.1576106	0.00169604	0.01796365
Fmo1	14261	0.15096172	0.624999	1	-1.1577118	1.11E-06	5.73E-05
Slc35e3	215436	-0.032153	0.88337782	1	-1.1618101	0.00125056	0.01443192
Zfp182	319535	0.66503708	0.03679624	0.30796229	-1.163529	0.00513379	0.04121088
2700062C07Rik	68046	0.47221383	0.08651711	0.47608308	-1.164377	3.96E-05	0.00099824
Kctd6	71393	0.45813438	0.0690569	0.41818302	-1.1686681	0.00175257	0.01844395
Tmem184a	231832	0.34353649	0.25354782	0.74309288	-1.1709166	0.0022791	0.0224123
Siah1b	20438	0.37691201	0.13089467	0.56406893	-1.1735889	0.00301898	0.02753388
Fbln5	23876	1.24104287	0.00537941	0.10082155	-1.1749842	0.0094977	0.06434349
Slc15a2	57738	0.462988	0.09197677	0.48740869	-1.1845168	5.73E-05	0.00133178
Ybey	216119	0.01864887	0.94322128	1	-1.1852865	0.00106368	0.0128462
Tmem177	66343	0.44432105	0.18326669	0.68079643	-1.1864622	0.00080596	0.01040727
Icosl	50723	1.04703741	0.01099047	0.15460734	-1.1885897	0.01228667	0.07772309
Eif1	20918	0.57395632	0.00227939	0.05921816	-1.1906441	9.72E-14	6.41E-11
Zfp933	242747	0.49873712	0.03565154	0.30283352	-1.1978959	0.00049527	0.00721239
Osgin2	209212	0.28220064	0.31322588	0.80970564	-1.1981555	0.00012621	0.00247494

Lrif1	321000	0.77699269	0.01061435	0.15123277	-1.2019186	5.97E-05	0.00137049
Zbtb2	381990	0.39445628	0.09287526	0.48973111	-1.2042509	9.55E-06	0.00032713
Zfp874b	408067	1.25052765	0.00302934	0.07090726	-1.2051999	0.01059053	0.06989818
Hist2h3b	319154	0.6306186	0.0024281	0.06176736	-1.2057086	0.01549937	0.09151912
Zfp354c	30944	0.52614498	0.05149064	0.36279654	-1.206841	0.00012185	0.00241096
Higd1a	56295	0.48246016	0.01658408	0.19794711	-1.2075512	0.00283835	0.02615759
1810055G02Rik	72056	0.29738266	0.21396818	0.73474314	-1.2105617	0.00471901	0.03875344
Atp6v0e	11974	0.6813396	0.00301605	0.07089014	-1.2132427	4.77E-08	4.06E-06
Slc29a1	63959	0.60708178	0.01341064	0.17429551	-1.2145534	4.47E-06	0.00018108
Ccdc15	245902	0.86725245	0.0053762	0.10082155	-1.2155806	0.00033153	0.00533566
Slc35a3	229782	0.49966476	0.00639618	0.11157215	-1.2200753	2.77E-07	1.83E-05
Ube2l3	22195	0.39182425	0.04107875	0.32204945	-1.2215741	1.19E-10	2.52E-08
Ctns	83429	0.48678351	0.06179023	0.39814754	-1.2275664	9.01E-10	1.52E-07
Cd74	16149	0.12360545	0.75728876	1	-1.2292139	0.00088287	0.01121046
Apool	68117	0.65075011	0.01839687	0.21043084	-1.235987	5.92E-09	6.98E-07
Tmem69	230657	0.51305969	0.0866155	0.47608308	-1.2468919	2.23E-06	0.00010277
9030624G23Rik	66808	0.05436624	0.84082796	1	-1.252815	0.00582772	0.04534692
Zfp942	73233	0.83141907	0.05182608	0.36400479	-1.2565328	0.01577201	0.0925904
Zfp708	432769	0.7260976	0.06111226	0.39660441	-1.2671901	0.0075615	0.05483145
Tbccd1	70573	0.4491019	0.10376868	0.51903427	-1.2781657	0.00376707	0.03257803
Gm438	329993	0.65816882	0.15947039	0.63299392	-1.2811182	0.0043031	0.03607875
Nupl2	231042	0.4976228	0.12902373	0.56000578	-1.2894243	0.00033398	0.00535547
Iqcc	230767	0.69721948	0.01815191	0.20831197	-1.2920308	0.00040861	0.00625577
Sf3b6	66055	0.68894524	0.007861	0.12713474	-1.2936828	2.02E-09	2.96E-07
Tmem126a	66271	0.89589367	0.00807471	0.12922186	-1.3062858	1.62E-06	7.85E-05
Zdhhc21	68268	0.55008876	0.01410573	0.17982905	-1.3213495	3.91E-09	5.12E-07
Rab28	100972	0.18877309	0.33191853	0.83341379	-1.3219922	4.61E-05	0.00112518
Arsk	77041	0.96670837	0.00586369	0.10607196	-1.3264416	3.31E-06	0.00014256
Ndrg3	29812	0.55104534	0.01508103	0.18782807	-1.3285446	2.74E-12	1.01E-09
Usmg5	66477	0.49113001	0.02292837	0.23796585	-1.3288705	6.15E-11	1.56E-08
Trappc2	66226	1.0184248	0.01480862	0.18602949	-1.3356591	1.86E-05	0.00055168
Ormdl2	66844	0.55164206	0.01003067	0.14652066	-1.3449873	2.30E-09	3.30E-07
Zfp160	224585	0.80447596	0.002192	0.05756	-1.3451849	6.68E-07	3.68E-05
Fam221a	231946	0.1742429	0.68908022	1	-1.3496954	0.00079843	0.01034036
BC023829	236848	0.53882959	0.0156784	0.19230645	-1.3537566	3.35E-06	0.00014417
Zbtb26	320633	0.71463178	0.00280338	0.06783967	-1.3559104	0.00433836	0.03630524
Uros	22276	0.62745458	0.0322752	0.28722691	-1.367205	5.85E-05	0.00134793
Mapk1ip1l	218975	0.44866974	0.00746404	0.1226122	-1.3873243	7.09E-09	8.21E-07
AI413582	106672	0.81079456	0.04065523	0.3206852	-1.3899216	0.01693048	0.09705975
Tspan6	56496	0.97574648	0.001848	0.05181399	-1.3992493	4.56E-13	2.23E-10
Esco2	71988	0.78449969	0.00275807	0.06742228	-1.4065792	4.68E-13	2.23E-10
Zfp873	408062	0.89557668	0.00373368	0.08112109	-1.4143848	0.00012135	0.00240454
Parpbp	75317	0.91384268	0.00337923	0.07598917	-1.4185127	8.36E-07	4.48E-05
Crb3	224912	-0.0102511	0.96817138	1	-1.429047	0.00526369	0.04199812
Cklf	75458	1.27328568	0.00332892	0.07513445	-1.4340805	4.07E-06	0.00016923
P2rx7	18439	0.85272475	0.05003793	0.35803585	-1.443443	0.00835295	0.05869748
Izumo4	71564	0.55410402	0.41983791	0.9395951	-1.4618008	0.01707673	0.0975791
Calhm2	72691	1.05003104	0.00238739	0.0611676	-1.4695035	0.00051384	0.00741112
Tmem256	69186	0.61008682	0.00347802	0.07728549	-1.4696647	2.53E-10	4.77E-08
Skint4	320640	0.23210102	0.37977834	0.89453769	-1.4755594	4.55E-06	0.00018369
Fam168b	214469	-0.1384252	0.42577707	0.94672693	-1.4807094	1.43E-08	1.55E-06
Rnf115	67845	0.6943114	0.00632952	0.1108847	-1.4853075	1.23E-12	5.06E-10
5730507C01Rik	236366	0.89127879	0.00203517	0.05534616	-1.5045581	2.95E-07	1.93E-05
Pcgf5	76073	1.23034335	0.0031075	0.07193203	-1.5239146	0.00159289	0.01721649
Tspyl3	241732	0.23441209	0.46808426	0.99539236	-1.5440578	0.00031333	0.0051049
Tmem29	382245	0.7392521	0.03741514	0.31036522	-1.5555124	0.01049076	0.06953943
Zfp951	626391	1.04547787	0.03479777	0.29869815	-1.5715686	0.00106481	0.0128462
Armc7	276905	0.37166684	0.27770157	0.75711368	-1.5905146	0.00415653	0.03527571
Naa60	74763	0.33926161	0.11098932	0.53250886	-1.6013309	4.00E-07	2.45E-05
Zfp14	243906	0.77893421	0.06065781	0.39512519	-1.6434109	0.00580869	0.04522555
Dusp19	68082	1.00822247	0.00718156	0.11991414	-1.6443817	1.69E-07	1.21E-05
Tprkb	69786	0.44592333	0.05523848	0.3769696	-1.6516251	3.28E-08	3.03E-06
Lage3	66192	0.74201211	0.00188135	0.05250805	-1.6738749	6.47E-06	0.00023989

Serpinb6b	20708	1.05137696	0.08917132	0.48431974	-1.6786627	0.00146075	0.01618602
Cfap20	14894	0.4241731	0.07088171	0.42476704	-1.6856198	8.62E-16	1.03E-12
Muc15	269328	0.68534068	0.00543044	0.10121781	-1.6949308	7.62E-10	1.34E-07
Dclk1	13175	0.40042151	0.36691541	0.87718464	-1.720107	0.00151552	0.01658404
Itgb3bp	67733	0.62449481	0.08507139	0.47243753	-1.7251232	5.73E-10	1.02E-07
Cnksr2	245684	0.77586691	0.07269708	0.42965521	-1.7622804	0.00026472	0.004502
Tbp	21374	0.57495242	0.02597688	0.25344843	-1.7811712	2.29E-12	8.90E-10
Zfp712	78251	0.87154534	0.03719055	0.30929491	-1.7945936	1.92E-05	0.0005654
Tmem144	70652	0.99273196	0.02457016	0.24678398	-1.8074125	6.42E-05	0.00144823
Sprr1a	20753	0.83924267	0.00340117	0.0762719	-1.8559063	6.28E-08	5.25E-06
Smim10l1	381820	0.55614632	0.00280058	0.06783967	-1.9051068	3.92E-05	0.00099232
Ccl27a	20301	-0.2565543	0.52915217	1	-2.028532	0.00623933	0.04781674
3110009E18Rik	73103	1.29154425	0.00941463	0.14096553	-2.0471675	2.54E-12	9.58E-10
Cd24a	12484	0.51237241	0.00372477	0.08099966	-2.086976	0.00015402	0.00291586
C330018D20Rik	77422	0.40733384	0.28459579	0.76779868	-2.2972602	2.33E-08	2.31E-06
AW146154	101835	0.58221886	0.20417889	0.72026383	-2.3395332	7.17E-07	3.92E-05
Blcap	53619	0.20207254	0.31835933	0.81696339	-2.3495894	7.20E-07	3.92E-05
6720489N17Rik	211378	0.84998297	0.07804714	0.44783583	-2.4788528	0.01605724	0.09368143

Table B.2 Translationally altered genes regulated by eIF2B5 *Hras*^{G12V}+sh*Eif2b5* to *Hras*^{G12V}+shScram (HE/HS)

Genes with translational efficiency changes were identified by Xtail analysis and excluded genes with significant transcriptional changes (as determined by EdgeR). Positive fold-change value indicates translational upregulation in *Hras*^{G12V}+sh*Eif2b5* basal progenitors.

Gene Description		Gene Description			Xtail		
Gene Symbol	Entrez ID	Log_2 Fold Change	p-value	FDR	Log_2 Fold Change	p-value	FDR
D3Ertd751e	73852	-1.0471869	0.02596058	0.23205395	3.05744283	2.02E-08	9.26E-07
Cklf	75458	-1.1584089	0.01296703	0.15557684	2.40724875	1.02E-15	3.26E-13
Tmem144	70652	-1.0411406	0.02422936	0.22236199	2.27969844	4.82E-07	1.45E-05
Ero1lb	67475	-0.9158288	0.0571262	0.35826371	2.17354378	1.68E-05	0.00029369
3110009E18Rik	73103	-0.9851732	0.05033857	0.33352812	2.11298344	2.85E-13	4.51E-11
Zfp951	626391	-1.4438947	0.00659985	0.10588392	2.0829315	4.89E-05	0.00070438
Gm14420	NA	-0.9072226	0.00283443	0.06282472	2.06893568	0.02190227	0.09258046
Siah1b	20438	-0.5294532	0.05381801	0.34613794	2.03796505	7.94E-07	2.24E-05
Cnksr2	245684	-0.5783503	0.17243497	0.61720523	2.03320843	6.37E-05	0.00089015
Medag	70717	-0.8551389	0.07678938	0.40811488	1.95706172	0.00119584	0.01012262
S1pr3	13610	-0.6720046	0.03710121	0.27938594	1.93450604	0.0016326	0.01282706
Tmem29	382245	-0.9916492	0.01028276	0.135738	1.93421765	0.00226215	0.01657354
Morn2	378462	-0.4576054	0.38259666	0.88186815	1.91334357	0.00643542	0.03748041
Tmem126a	66271	-0.8945607	0.00861104	0.12254671	1.90871031	7.89E-13	1.12E-10
Phospho2	73373	-0.401897	0.12096742	0.52686737	1.87241163	4.39E-06	9.50E-05
Lactb2	212442	-1.1484521	0.0140609	0.16127069	1.82935165	1.55E-05	0.00027476
Glb1l2	244757	-0.6319436	0.14955335	0.59174375	1.82208828	3.89E-05	0.00059028
Cox16	66272	-0.6420809	0.1059343	0.48802521	1.7455587	0.00030299	0.00326601
Zfp788	67607	-1.081687	0.00690056	0.10825857	1.67363692	6.66E-06	0.00013411
Lhfp	108927	-1.03518	0.01896388	0.19278673	1.6407522	0.0116021	0.05876694
Cfap20	14894	-0.3663954	0.12244275	0.53017276	1.62785547	1.45E-15	4.52E-13
Zfp808	630579	-0.9822102	0.06481812	0.38489715	1.61370355	0.01551048	0.07236572
Ndrg3	29812	-0.6782936	0.00324319	0.06810148	1.60458437	4.02E-17	1.55E-14
C1galt1	94192	-0.7345294	0.00363743	0.07281126	1.60017233	3.19E-06	7.28E-05
Mei4	75033	0.18017505	0.75137818	1	1.57679944	0.01068043	0.05518434
Icosl	50723	-0.6765077	0.10460482	0.48649045	1.56642772	0.00128302	0.0107428
Grb14	50915	-0.5701801	0.21700434	0.67098797	1.557727	0.00030688	0.00330245
Rab30	75985	-0.5200774	0.20904472	0.65533775	1.53120939	2.82E-05	0.00045327
Kbtbd8	243574	-1.1405609	0.0026599	0.06070786	1.52942559	2.22E-05	0.00036817
Ppil3	70225	-0.7419459	0.01049176	0.13679615	1.52705603	9.64E-12	9.37E-10
Slc5a1	20537	-0.7145118	0.02823396	0.24057974	1.52063837	9.00E-07	2.47E-05
Dnajb9	27362	-0.9511277	0.01493063	0.16748781	1.50295478	5.26E-10	3.53E-08
Rnf122	68867	-0.3504222	0.24756913	0.72300952	1.50019976	4.89E-07	1.46E-05
Hrnr	68723	-0.5904131	0.00850939	0.12138313	1.49526052	0.01806556	0.08075679
AW146154	101835	-0.2108046	0.6487567	1	1.48781111	0.01138695	0.05790055
Bcl2l15	229672	-1.1512131	0.02020411	0.19951659	1.46645587	0.00015394	0.00184745
Slc5a8	216225	-1.2026607	0.00535743	0.09302898	1.44934933	7.13E-05	0.00097306
2810021J22Rik	69944	-0.7280981	0.03017928	0.2473182	1.43575651	0.01981982	0.08616371
Tprkb	69786	-0.6939658	0.00417567	0.07923394	1.43011296	2.90E-06	6.69E-05
Uros	22276	-0.9181571	0.0040578	0.07775755	1.412151	0.00011413	0.00145759
Synj2bp	24071	-0.5280807	0.00548093	0.09452674	1.40007309	0.00041601	0.00427033
Osgin2	209212	-0.6564488	0.05068582	0.33508349	1.40002238	4.38E-05	0.00065003
Usmg5	66477	-0.6512102	0.00269967	0.06121513	1.3863525	1.94E-13	3.18E-11
Zfp708	432769	-1.0575636	0.01521686	0.16913125	1.38086222	0.00566973	0.0341458
Lyrm7	75530	-0.2355977	0.53459285	1	1.37857374	0.00334606	0.02241347
Aldh1a7	26358	-0.8453233	0.01618024	0.17546079	1.37207236	2.43E-06	5.77E-05
Mapk11	19094	-0.0755233	0.83146267	1	1.3560772	0.00336738	0.02253332
Zfp942	73233	-1.2102932	0.01068376	0.13837857	1.3533837	0.00151624	0.01211928
2210408I21Rik	72371	-1.0549611	0.00818234	0.11906154	1.35138096	0.00072966	0.00677965

Pcdh9	211712	-1.0435046	0.02854862	0.24155545	1.35031037	0.00255777	0.01819118
Rnase1	19752	-0.8616746	0.01561428	0.17153234	1.34476273	2.79E-05	0.00044938
Ubxn2b	68053	-0.3627572	0.19154429	0.62353341	1.33990355	6.00E-06	0.00012288
Cd55	13136	-1.0947301	0.04332994	0.30595692	1.32400153	0.0170057	0.07730879
Gabrp	216643	-0.4672053	0.18373867	0.61720523	1.32217612	0.00272438	0.01903583
Nt5e	23959	-0.4992205	0.16247747	0.61720523	1.32082499	0.00039071	0.00404225
Atp5s	68055	-0.8530749	0.06591204	0.38572682	1.31573975	0.0006203	0.00593847
Pla2g4e	329502	-0.6198381	0.02057763	0.20180307	1.31073958	0.00017839	0.00209677
Trim12c	319236	0.11684161	0.85020527	1	1.30356406	0.01756274	0.07907449
Lrrn1	16979	-0.9015131	0.02246243	0.21270069	1.29651641	9.89E-05	0.00129797
Ap5m1	74385	-0.8722802	0.00881076	0.12415896	1.28960207	6.79E-07	1.94E-05
Tmem216	68642	-0.5534208	0.07985344	0.41802804	1.27861448	0.00066332	0.00628334
Sectm1a	209588	-0.4200999	0.21016163	0.65757298	1.27790204	0.004247	0.02722599
Zfp809	235047	-0.7969023	0.01223678	0.15069812	1.27771403	2.49E-05	0.00040708
Tbp	21374	-0.7059426	0.00381414	0.07499605	1.26346723	1.15E-06	3.03E-05
Zfp874b	408067	-0.7702835	0.06015889	0.37006049	1.24579445	0.01036369	0.05384695
Mansc1	67729	-0.2188908	0.52414896	1	1.2387071	4.51E-05	0.00066712
Zfp449	78619	-1.224407	0.00755493	0.11386386	1.2381303	0.0026141	0.01851158
Hint3	66847	-0.9231681	0.03194359	0.25459997	1.23660486	0.00013048	0.00161004
Zfp780b	338354	-0.1473449	0.57898544	1	1.22386616	0.00110203	0.00947515
Rnasek	52898	0.12153261	0.57405158	1	1.22231725	5.75E-14	1.08E-11
Copz2	56358	-0.7605323	0.0215142	0.20725766	1.22082428	1.45E-05	0.00026025
Tmem69	230657	0.03714927	0.89823556	1	1.21899741	1.77E-06	4.38E-05
Zc4h2	245522	-0.6810314	0.16771486	0.61720523	1.21120465	0.00821384	0.04510225
Zmym6	100177	-0.2875191	0.3159394	0.80097384	1.20771395	0.00210755	0.01569749
Mbnl3	171170	-0.568554	0.00796753	0.11742616	1.20768525	1.21E-09	7.51E-08
Ints6	18130	-0.5082248	0.01664658	0.1785358	1.20087261	5.31E-12	5.45E-10
Ugt1a1	394436	-1.0831768	0.01348278	0.1579077	1.19677217	5.86E-06	0.00012099
Mtx2	53375	-0.4549195	0.01932512	0.19501596	1.18476351	3.27E-15	8.76E-13
Ackr3	12778	-0.5147471	0.05722143	0.35852386	1.18393131	9.92E-13	1.36E-10
Zfp943	74670	-1.0067323	0.00424885	0.08000084	1.179289	0.00018062	0.00211732
Zfp595	218314	-0.6772583	0.11275675	0.50664811	1.17886949	0.00604382	0.0358884
Clock	12753	-0.5183084	0.03187835	0.25424597	1.163261	0.00312014	0.02122501
Gosr1	53334	-0.4260831	0.04329025	0.30595692	1.15648762	5.72E-10	3.77E-08
Serpinb3a	20248	-0.7470384	0.00501739	0.08925086	1.15193391	0.00512354	0.03156592
Adgrf4	78249	-0.7134105	0.00365231	0.07298941	1.14899681	6.31E-07	1.83E-05
Tppp	72948	-0.461888	0.13244006	0.55598346	1.14810317	0.00934658	0.04970078
Gm561	NA	-1.2434912	0.00495408	0.08876265	1.1397483	0.00010146	0.00132811
Pcdhga10	93722	-0.812523	0.08184375	0.42354445	1.13042453	0.0012906	0.0107994
Fam168b	214469	0.08323977	0.63221899	1	1.12413892	1.46E-09	8.88E-08
Rnf115	67845	-0.6020493	0.0204659	0.20151238	1.12290907	5.88E-09	3.08E-07
Polr3f	70408	-0.2776251	0.18836409	0.61720523	1.12149706	3.02E-08	1.32E-06
Cidea	12683	-0.7025104	0.15160914	0.59692659	1.11624281	0.0008241	0.00744641
Cox7a2l	20463	-0.1575507	0.41146615	0.91342773	1.11126235	3.22E-14	6.51E-12
Tmem126b	68472	-1.0795639	0.00745468	0.11300484	1.1066975	2.48E-06	5.89E-05
Rasl11a	68895	-0.6942213	0.25283474	0.73079443	1.10611818	0.01623199	0.07469673
Bbs12	241950	-1.2283504	0.00216618	0.05397989	1.10193332	0.00471487	0.02941432
Kbtbd3	69149	-1.2519262	0.00801124	0.11780288	1.09976496	0.00444006	0.02813397
Ergic2	67456	-0.4293658	0.10076423	0.47791089	1.09797505	1.56E-07	5.34E-06
Tmem60	212090	-1.0675341	0.02055991	0.2017914	1.09245618	3.86E-05	0.00058622
Papl	NA	-0.5058301	0.08544562	0.43481296	1.09009768	5.63E-05	0.00079603
Sf3b6	66055	-0.7138413	0.00272003	0.06150543	1.08449306	1.02E-13	1.84E-11
Zfp52	22710	-1.0370241	0.00641265	0.10412451	1.08015276	0.00762366	0.0426464
Ift74	67694	-0.8382949	0.01604385	0.17444652	1.07758044	3.01E-08	1.32E-06
Slc29a1	63959	-0.5825776	0.01893808	0.19278673	1.07573414	2.26E-05	0.00037373
A830080D01Rik	382252	-0.7914332	0.00876416	0.12385966	1.0738463	9.98E-06	0.00019044
Hddc2	69692	-0.4308567	0.10190848	0.48015609	1.07080438	8.79E-11	7.08E-09
Ascc3	77987	-0.542075	0.00414378	0.07889464	1.0706199	7.63E-09	3.84E-07
4930402H24Rik	228602	-0.3651951	0.18144364	0.61720523	1.06824834	0.00088097	0.00785217
Sprr1a	20753	-0.8974649	0.00244368	0.05782657	1.06693151	0.00262142	0.01852347
Tmem251	320351	-0.6524635	0.02528623	0.22828653	1.06328687	0.01207686	0.06040271
Zfp157	72154	-0.6242881	0.03802503	0.28366018	1.06029201	4.68E-05	0.00068452
Ippk	75678	-0.8112643	0.00198863	0.0514997	1.05742224	0.00048274	0.00480875

Lipt1	623661	-0.8094984	0.10750531	0.49287317	1.05642965	0.00610329	0.0361598
Mapk1ip1l	218975	-0.5685976	0.00282612	0.06282472	1.05516347	3.85E-06	8.63E-05
Neu3	50877	-0.4396489	0.06485126	0.38489715	1.04986815	0.01802082	0.08061149
Mad2l1	56150	-0.0516366	0.79776515	1	1.0453376	2.18E-10	1.61E-08
Them4	75778	-0.9497788	0.00887298	0.12471636	1.04489163	0.00643753	0.03748041
Tex40	NA	-0.4827105	0.30398886	0.80097384	1.04476271	0.00583014	0.03490373
Cnep1r1	382030	-0.1843177	0.38308566	0.8827999	1.04027526	4.98E-06	0.00010604
Gins3	78833	-0.4255966	0.2469647	0.72237692	1.03587346	0.00386546	0.02514846
Gsta4	14860	-0.8636275	0.02015935	0.19923569	1.03329151	2.57E-08	1.15E-06
Inpp5k	19062	-0.464824	0.08774538	0.44180272	1.02872233	1.71E-05	0.0002971
Parpbp	75317	-0.9048953	0.00378152	0.0744746	1.02696616	0.00036245	0.00379471
Cpt1a	12894	-0.604674	0.00385616	0.07535741	1.02610035	8.04E-08	3.02E-06
Trdmt1	13434	-1.0922607	0.03179427	0.25371547	1.02584863	0.00089331	0.00794163
4930453N24Rik	67609	-0.6300755	0.0176411	0.18537573	1.02484074	6.90E-06	0.00013805
Pqlc3	217430	-0.6169596	0.02664471	0.2350229	1.02092926	6.18E-05	0.00086634
A230046K03Rik	NA	-0.6700988	0.00346458	0.07086132	1.0171607	6.00E-09	3.13E-07
Pvr	52118	-1.0433582	0.01311623	0.15619984	1.00557196	0.014372	0.06861456
Itgam	16409	-0.4456787	0.21242728	0.66221449	1.00204834	0.01701853	0.07734035
Tmem135	72759	-0.7999845	0.00331405	0.06882002	1.00180668	6.35E-08	2.44E-06
Ostc	66357	-0.5097448	0.01732894	0.18367804	1.00072438	6.10E-13	9.00E-11
Ldah	68832	-0.5297343	0.00707516	0.10949462	0.99837906	2.47E-09	1.42E-07
Rfc3	69263	-0.9029058	0.00326668	0.06841112	0.99465376	1.08E-10	8.34E-09
Isca2	74316	-0.6650381	0.05504827	0.34999577	0.99087858	0.00063901	0.00609711
Ska2	66140	-0.2716924	0.23181429	0.69654764	0.98907155	3.34E-07	1.06E-05
Harbi1	241547	-0.4287835	0.0824822	0.42504699	0.98867993	0.00676935	0.03899424
P2ry4	57385	-0.5034942	0.03665952	0.27725675	0.98836767	0.01522428	0.07130915
Tomm7	66169	-0.6358358	0.00281847	0.06282472	0.98563498	1.83E-12	2.38E-10
Ssbp1	381760	-0.47645	0.03614707	0.27499927	0.98481857	2.83E-12	3.33E-10
Cd59a	12509	-0.8508348	0.04455449	0.31105354	0.98441653	0.00021861	0.00248279
Gdpd1	66569	-0.4570408	0.06752316	0.38652079	0.98020111	2.34E-06	5.60E-05
Fbxo25	66822	-0.3547234	0.27050623	0.75922684	0.97737482	0.00052834	0.00516502
Elmod2	244548	-0.5150544	0.05467167	0.34839305	0.97716531	1.48E-05	0.00026384
Tmem39a	67846	-0.6281717	0.00544584	0.09405435	0.97691608	6.36E-05	0.0008899
Il1r1	16177	-0.2821167	0.14853736	0.58982616	0.97666365	0.00032887	0.00349449
Slc4a11	269356	-0.6296051	0.01945675	0.19558236	0.97632924	0.00013911	0.00169738
Snap23	20619	-0.7494099	0.00191185	0.05020353	0.97580566	2.96E-08	1.30E-06
Mob1a	232157	-0.5835108	0.01292445	0.15555845	0.97517576	5.18E-12	5.40E-10
Ube2l3	22195	-0.5048357	0.00481544	0.0871095	0.96842727	1.73E-10	1.29E-08
Dync2li1	213575	-1.0686528	0.00312344	0.06673456	0.96756811	4.74E-06	0.00010159
Tmem14c	66154	-0.5690386	0.01373229	0.1591629	0.96745217	9.63E-10	6.08E-08
Fastkd1	320720	-0.6060974	0.04553967	0.31441479	0.96250547	0.00824504	0.04516188
Rit1	19769	-0.6345736	0.01296519	0.15557684	0.96065808	0.00134975	0.01116279
Itgb3bp	67733	-1.2525554	0.00297983	0.06462599	0.96016149	0.00071833	0.00670287
Lrrc57	66606	-0.7080371	0.02794968	0.239767	0.96002765	0.00609682	0.03613779
Adgrg6	215798	-0.9532046	0.02618268	0.23333293	0.95694218	0.01319561	0.06471616
Lamtor2	83409	-0.5346194	0.00812917	0.11880457	0.95680771	2.25E-10	1.64E-08
Zfp800	627049	-0.783445	0.00228454	0.05518376	0.95665118	1.68E-05	0.00029315
Depdc7	211896	-0.8546042	0.01860028	0.19045598	0.95064561	0.00025322	0.00281744
Zyg11b	414872	-0.279799	0.12035855	0.52549251	0.9487097	1.09E-08	5.29E-07
Ap4s1	11782	-0.8456244	0.00929026	0.12803472	0.94640862	0.00281729	0.01954982
Dnpep	13437	-0.5566912	0.00627893	0.10318824	0.94639425	4.36E-08	1.79E-06
Slc35a3	229782	-0.5197203	0.00828131	0.11957392	0.9435503	1.16E-05	0.00021531
Atad2	70472	-0.449113	0.01190504	0.1478805	0.94054584	7.48E-09	3.78E-07
Ccdc15	245902	-0.7194375	0.02000832	0.19846591	0.94000506	0.00565505	0.03408866
Crem	12916	-0.8018314	0.05981602	0.36888058	0.93889039	0.01975193	0.08595398
Ctbs	74245	-0.9460749	0.03954447	0.28989423	0.93766877	0.00220805	0.01628621
Arsk	77041	-0.8527304	0.02421607	0.22232355	0.9360019	0.00096494	0.00848538
Fam208b	105203	-0.4762746	0.01919109	0.19414484	0.93505957	1.30E-07	4.56E-06
Rhog	56212	-0.6004286	0.00287606	0.06316215	0.93427045	3.87E-06	8.65E-05
Zfp935	71508	-0.5696139	0.03588379	0.27393499	0.93210429	0.00938678	0.04979356
Yipf2	74766	-0.3751393	0.13775435	0.56784129	0.93096832	0.00523806	0.03213142
Dock11	75974	-0.4627268	0.08796999	0.44233199	0.93036991	2.83E-05	0.00045467
Smchd1	74355	-0.5109332	0.01611817	0.17502086	0.92471615	5.59E-11	4.70E-09

Hltf	20585	-0.5588585	0.02892707	0.24242556	0.92410977	8.46E-08	3.15E-06
D230025D16Rik	234678	-0.2079816	0.32127325	0.80097384	0.92291435	2.07E-05	0.0003469
Cnfn	72383	-0.4220105	0.07231839	0.39500951	0.92208291	7.32E-05	0.0009956
Prcp	72461	-0.9185414	0.0025966	0.05999191	0.92013733	0.00042795	0.00435551
Cd47	16423	-0.1638566	0.48112039	0.98945919	0.91978745	4.87E-09	2.59E-07
Slc31a2	20530	-0.5959106	0.00221245	0.05455766	0.91812661	8.07E-05	0.00108543
3110043O21Rik	73205	-0.6873093	0.03081422	0.24939034	0.91798818	0.00228121	0.01668013
Iqcb1	320299	-0.4644478	0.13407385	0.56040313	0.91765853	0.00198847	0.0149654
Srp19	66384	-0.4927077	0.01622927	0.17584621	0.91680505	7.48E-06	0.00014729
Armc8	74125	-0.2196557	0.32783394	0.8063029	0.91678285	4.35E-06	9.45E-05
Lpar6	67168	-0.6834703	0.01462715	0.16544841	0.91667125	0.00027227	0.00299489
Nsun6	74455	-0.876678	0.02182874	0.20847485	0.91580908	0.00449999	0.028404
Slc15a1	56643	-0.425153	0.12037636	0.52549251	0.91550543	0.00010827	0.00140189
Shcbp1	20419	-0.7384186	0.01588868	0.17329949	0.91504635	1.31E-06	3.39E-05
Fam69a	67266	-0.7903076	0.01518298	0.16904078	0.91503899	1.16E-05	0.00021525
Casc5	NA	-0.4895262	0.0263302	0.23365182	0.91459825	3.62E-06	8.17E-05
St3gal6	54613	-0.5913114	0.05955838	0.36803525	0.91394065	0.00087963	0.00785087
Mdn1	100019	-0.006138	0.97246634	1	0.91386143	0.02182639	0.09234892
Zfp58	238693	-0.8411377	0.01087634	0.13994265	0.91233373	0.01063702	0.05498166
BC003331	226499	-0.6333325	0.00707313	0.10949462	0.91138841	0.00011366	0.00145296
Acer1	171168	-0.4031776	0.04959603	0.33056563	0.91037186	8.55E-06	0.00016602
Kpna4	16649	-0.4423991	0.01027585	0.13572015	0.90942034	2.09E-13	3.39E-11
Nup160	59015	-0.6630109	0.00274898	0.06204518	0.90923396	3.11E-08	1.34E-06
Aox4	71872	-0.4985889	0.01508065	0.16856025	0.90651022	0.01454677	0.06902226
Tex30	75623	-1.024464	0.00260705	0.06011975	0.90455568	1.48E-05	0.00026373
Cyb561a3	225912	-0.2793723	0.22612394	0.68649586	0.90378618	0.0138507	0.06700287
Abhd6	66082	-0.5452349	0.06219661	0.37658408	0.89822678	0.00091084	0.00808002
Fzd3	14365	-0.5626413	0.00248011	0.05806968	0.89765654	0.00010812	0.00140123
Foxj3	230700	-0.5016179	0.00936857	0.12869112	0.89648104	2.55E-06	6.02E-05
Cenpq	83815	-0.6385634	0.03480625	0.26864835	0.89501916	0.00039648	0.00409224
Nup205	70699	-0.4604696	0.0246288	0.22484486	0.89413951	1.59E-07	5.41E-06
Pik3c2a	18704	-0.6873997	0.00305923	0.06570757	0.89381201	4.44E-08	1.81E-06
Gtpbp8	66067	-0.9362944	0.03223348	0.25571891	0.89292916	0.00477974	0.02978319
Sdr9c7	70061	-0.4349834	0.06258356	0.37765088	0.89289475	0.02005992	0.08697711
Slc15a2	57738	-0.4384549	0.08170687	0.42328455	0.89092762	0.00500588	0.03097181
Mrps36	66128	-0.7825188	0.0034005	0.07001993	0.89090601	1.98E-06	4.85E-05
Orc5	26429	-0.5669586	0.06205113	0.37650144	0.88338141	3.23E-05	0.00050728
Dnajc19	67713	-0.8280661	0.00372621	0.07372697	0.88320665	3.04E-05	0.00048236
Abhd14a	68644	-0.6428119	0.0407173	0.29410148	0.88132417	0.02051424	0.08850854
Scpep1	74617	-0.5905757	0.00221917	0.05455766	0.87770675	8.81E-09	4.35E-07
Ociad2	433904	-0.2974976	0.23769296	0.70582439	0.87614548	0.00021145	0.0024267
Gimap9	317758	-0.9178671	0.05718712	0.35852386	0.87526916	0.00587359	0.03509374
Parp9	80285	-0.807543	0.02922838	0.24278445	0.87342249	0.00941669	0.04989172
Vps13b	666173	-0.447402	0.03829551	0.28440972	0.87259015	9.61E-06	0.00018423
Mrpl27	94064	-0.5944376	0.00480945	0.08706567	0.87219918	1.60E-07	5.44E-06
Tmem230	70612	-0.2548366	0.27818612	0.77199809	0.87216876	0.01436641	0.06861456
Mrps6	121022	-0.656133	0.02925271	0.24282133	0.87079117	2.87E-05	0.00045967
Kdelc2	68304	-0.4741477	0.09704059	0.46883817	0.86159235	0.01607685	0.07429529
Steap4	117167	-0.3827188	0.15565934	0.60569737	0.86125849	6.23E-06	0.00012632
Dsc2	13506	-0.7438626	0.0021649	0.05397989	0.86085172	3.73E-05	0.00057163
Mastl	67121	-0.4896567	0.05433404	0.34790025	0.85847932	0.0004888	0.00485071
Tmem68	72098	-0.8940346	0.01273437	0.15448889	0.85706334	0.00721936	0.04097061
Anapc11	66156	0.12031205	0.51317348	1	0.85651832	9.65E-08	3.57E-06
Sec24a	77371	-0.6729819	0.00243503	0.05773376	0.85517481	2.03E-05	0.00034168
Gbe1	74185	-0.584893	0.12042941	0.52549251	0.85473661	0.00212279	0.01579046
Bard1	12021	-0.3873588	0.14750931	0.58813801	0.85285272	0.00137097	0.01126937
Lmbrd2	320506	-0.5403695	0.02443925	0.22369166	0.85133776	5.35E-05	0.00075953
Trim23	81003	-0.8952851	0.00213013	0.05385071	0.84987584	1.61E-05	0.00028247
Klhl13	67455	-0.7892007	0.02363074	0.218925	0.84940224	0.0003172	0.00338851
Herc4	67345	-0.5984654	0.00477991	0.08685283	0.84732756	1.09E-08	5.29E-07
Efemp1	216616	-0.4959314	0.08061041	0.42054834	0.84603721	2.69E-07	8.69E-06
Slc17a5	235504	-0.445343	0.08356558	0.42907375	0.84595494	0.00266985	0.01876467
Tex10	269536	-0.6411617	0.00255778	0.05926325	0.84580812	1.08E-06	2.89E-05

Ddx19b	234733	-0.0960338	0.61287793	1	0.84530344	0.01215402	0.06069612
Wbp2	22378	-0.6131456	0.00243106	0.05769585	0.84521254	3.56E-07	1.10E-05
Sec22a	317717	-0.6079882	0.01707735	0.18195721	0.84372047	4.93E-06	0.00010519
Trmt10c	52575	-0.5539942	0.01132976	0.14343396	0.84355026	3.02E-05	0.00048169
Gstz1	14874	0.07055165	0.82265831	1	0.84199284	0.0019051	0.01449975
Nfyc	18046	-0.4916729	0.01257584	0.15345036	0.84175592	3.05E-08	1.33E-06
Ythdf2	213541	-0.4586357	0.01338767	0.15762744	0.8401112	5.50E-10	3.67E-08
Vps8	209018	-0.4114664	0.14586723	0.58425844	0.8377376	0.00012571	0.00156291
Sdhd	66925	-0.3198654	0.13627385	0.56563366	0.83666607	4.53E-08	1.83E-06
Hist1h2bf	319180	-0.7274346	0.00908217	0.12645141	0.83426399	9.58E-07	2.60E-05
D15Ertd621e	NA	-0.4575452	0.03326946	0.26040819	0.83262979	3.83E-08	1.60E-06
Ftsj1	54632	-0.3846212	0.13445412	0.5614747	0.83230109	6.87E-05	0.00094551
Lrif1	321000	-0.8149455	0.01510806	0.16870319	0.83187	0.01336407	0.06527413
Slc33a1	11416	-0.6422898	0.0033539	0.0693528	0.83152047	0.0001095	0.00141225
Gtpbp10	207704	-0.7494748	0.01063251	0.13818864	0.83149798	0.00012371	0.00154582
Sec24d	69608	-0.6138964	0.01328041	0.15698005	0.82952418	4.11E-06	9.05E-05
Ltn1	78913	-0.3571184	0.08067568	0.42070913	0.8258798	1.69E-07	5.70E-06
Tbck	271981	-0.4328831	0.0353427	0.2711352	0.82582048	1.95E-05	0.00033086
Rsu1	20163	-0.8393624	0.00675479	0.10725535	0.82394261	1.58E-06	3.96E-05
Fam49b	223601	-0.5210319	0.03040349	0.24770958	0.82393161	1.52E-06	3.84E-05
Elovl3	12686	-0.2279523	0.47715652	0.98675108	0.82379706	0.00727185	0.04113402
Bcs1l	66821	-0.262705	0.38634185	0.88752521	0.8237614	0.00673527	0.03886915
Ino80c	225280	-0.556798	0.01917031	0.19406879	0.82221225	0.00096492	0.00848538
2700049A03Rik	76967	-0.4695387	0.06245328	0.37742427	0.82162586	0.00093804	0.00827656
Vps13a	271564	-0.5142067	0.00820896	0.11919436	0.82156692	2.16E-07	7.10E-06
Dopey1	320615	-0.5488138	0.02181406	0.20842363	0.82003927	0.00012474	0.00155379
Ankrd32	NA	-0.6733394	0.01366565	0.15854102	0.81906474	0.00098176	0.00861026
Il2rg	16186	-1.0608717	0.00704821	0.10921588	0.81903978	0.00011506	0.00146668
Ly6e	17069	-0.5549743	0.04100486	0.29556662	0.81889541	3.33E-05	0.00052238
Psmd10	53380	-0.7236318	0.02912253	0.2425892	0.81862457	2.39E-06	5.69E-05
Ythdf3	229096	-0.6329194	0.00203286	0.05242299	0.81808918	1.37E-08	6.44E-07
Atl3	109168	-0.3879604	0.05162882	0.33904203	0.81808398	1.19E-09	7.42E-08
Zfp948	381066	-0.5522513	0.06105367	0.3729344	0.81694365	0.00630544	0.03697703
Zfp763	73451	-0.7772079	0.01044982	0.13654098	0.81606556	0.00534708	0.03266718
Rnf38	73469	-0.490411	0.0258801	0.2317631	0.81531523	0.0003972	0.00409646
A430005L14Rik	97159	-0.1282255	0.59442316	1	0.81453623	0.00270711	0.01895552
Zfp945	240041	-0.8725073	0.0151171	0.16872707	0.8144772	0.00200326	0.0150548
Otub1	107260	-0.4720316	0.00991954	0.13244677	0.81442305	2.30E-12	2.86E-10
Ctns	83429	-0.4455528	0.08053328	0.42041539	0.81285894	6.58E-05	0.00091369
Mrpl14	68463	-0.743825	0.00799239	0.11765049	0.81277528	1.31E-06	3.39E-05
Dimt1	66254	-0.6909066	0.0435769	0.30624213	0.81243462	7.66E-06	0.0001504
Ngf	18049	-0.5421794	0.14651226	0.58588112	0.81102961	0.02021771	0.0874879
Zfp760	240034	-0.6003549	0.05648294	0.35587461	0.81002446	0.01138036	0.05790055
Gm4944	NA	-1.007805	0.00211377	0.05360418	0.80978347	0.02128669	0.09085596
Nup153	218210	-0.480457	0.00830139	0.11960374	0.80871057	1.63E-09	9.79E-08
Zfp354c	30944	-0.5246026	0.07769317	0.41112566	0.80799257	0.0152458	0.0713336
Tpk1	29807	-1.0889682	0.00264066	0.06044995	0.807861	0.00725002	0.04106363
Id2	15902	-0.4433662	0.12490863	0.53704112	0.80777342	0.00060819	0.00583507
Serpinb3c	381286	-0.6435615	0.00511724	0.09042552	0.80722997	2.62E-05	0.00042607
L1cam	16728	-0.4358253	0.0324372	0.25677435	0.80599384	4.89E-07	1.46E-05
Rbm12b2	77604	-0.6797765	0.03005362	0.24686193	0.80461221	0.01476437	0.06975223
Inip	66209	-0.0396548	0.85004342	1	0.80443555	0.01523654	0.07131568
Zfp715	69930	-0.7028339	0.005879	0.09901458	0.80328621	0.00414848	0.02664649
Gpm6b	14758	-0.5506585	0.04121913	0.29660123	0.80219032	0.000128	0.00158842
4921524J17Rik	66714	-0.120527	0.72362335	1	0.80146213	0.00087536	0.00781946
Tet2	214133	-0.6154873	0.00211343	0.05360418	0.80109458	6.96E-05	0.00095424
Pdpn	14726	-0.2790138	0.20279472	0.64577517	0.80043636	0.00028581	0.00310885
Zbtb2	381990	-0.4182361	0.06671449	0.38617804	0.80033228	0.00525491	0.03219398
Tbc1d19	67249	-0.492071	0.13346881	0.55879337	0.79850654	0.0061105	0.03618619
Brca2	12190	-0.2993466	0.23186484	0.69656431	0.79319086	0.00240955	0.01737233
2810474O19Rik	67246	-0.4225739	0.04758644	0.32262869	0.79169585	3.61E-05	0.00055696
Yipf4	67864	-0.5434092	0.01053056	0.13722878	0.79128873	1.43E-07	4.95E-06
Rer1	67830	-0.2241842	0.22341097	0.68216044	0.79030829	1.28E-08	6.05E-07

Exph5	320051	-0.6439196	0.00306628	0.06579876	0.7898747	0.01273178	0.06298249
Ak6	102216272	-0.5251738	0.15909105	0.61154769	0.78602554	4.48E-07	1.36E-05
Ncapg	54392	-0.4704162	0.0431749	0.30543865	0.78431727	4.96E-05	0.00071292
Plxdc2	67448	-0.4182156	0.01462519	0.16544841	0.78345264	3.74E-06	8.43E-05
Eif2ak2	19106	-0.4413985	0.06167862	0.37571803	0.78312044	0.00551006	0.03342453
Sar1a	20224	-0.5007512	0.01301622	0.15589456	0.78195642	3.25E-10	2.32E-08
Maml2	270118	-0.627834	0.00354509	0.07184626	0.7813727	0.01281428	0.0633429
Eif1	20918	-0.4503695	0.01689209	0.18039132	0.78110146	3.28E-08	1.40E-06
Far2	330450	-0.665918	0.06349931	0.38024447	0.78109762	0.00118776	0.0100607
Sema3a	20346	0.18428987	0.57050832	1	0.77941229	1.17E-07	4.18E-06
Nipal4	214112	-0.4364208	0.02078819	0.20287672	0.77900065	0.0024899	0.01783408
Tmbim4	68212	-0.8474019	0.00394889	0.07636999	0.77725465	8.39E-05	0.00112228
Prkdc	19090	-0.1415824	0.51057562	1	0.77657831	0.0051546	0.03169775
Tmem41b	233724	-0.6603714	0.00192431	0.05026514	0.77558114	1.16E-05	0.00021531
Zmym4	67785	-0.3112652	0.10453702	0.48649045	0.77553722	6.87E-06	0.00013798
Slc35a1	24060	-0.6453092	0.02056174	0.2017914	0.77541762	0.00786169	0.0436432
Mocos	68591	-0.4401551	0.06961062	0.38698979	0.77476242	0.01405287	0.06763203
Alcam	11658	-0.3506963	0.07244918	0.39537013	0.77352055	2.50E-08	1.13E-06
G6pc3	68401	-0.6692202	0.03765994	0.28194154	0.77311556	0.00509132	0.03139689
Ranbp2	19386	-0.4289377	0.04798857	0.32440531	0.7712797	1.15E-06	3.04E-05
Ror1	26563	-0.5641048	0.011268	0.14287428	0.77119763	0.00162922	0.01280842
Naa60	74763	-0.2212765	0.30206826	0.80097384	0.77114441	0.02070891	0.08920184
Alg6	320438	-0.4067443	0.20578744	0.64974283	0.76908543	0.00441095	0.02800353
Tmem97	69071	-0.6367869	0.00579513	0.09807548	0.76793163	5.17E-05	0.0007379
Rbm41	237073	-0.2169247	0.35429631	0.84404157	0.76743263	0.0094664	0.05007426
Rbbp8	225182	-0.4889929	0.01445613	0.16427785	0.76550794	5.58E-08	2.18E-06
Parm1	231440	-0.1547082	0.55197536	1	0.76547257	0.00016311	0.00193799
Dtwd1	69185	-0.8201996	0.0135567	0.15840588	0.76480503	0.00414744	0.02664649
Ube2n	93765	-0.4355801	0.01614549	0.17523954	0.76460032	2.33E-07	7.59E-06
Smim19	102032	0.04823357	0.83112851	1	0.76436807	0.00156603	0.01242321
Traf6	22034	-0.4469079	0.01628263	0.17603492	0.7625695	0.0001062	0.00138181
Dhfr	13361	-0.4093672	0.07395609	0.40007203	0.76251594	7.82E-05	0.00105902
Pole2	18974	-0.6406912	0.05618972	0.3548281	0.7623465	9.83E-05	0.0012919
Mtmr6	219135	-0.4864519	0.01803035	0.18720192	0.76195545	0.00046914	0.00471258
Akap11	219181	-0.3237825	0.09863307	0.47130196	0.75938668	1.83E-05	0.00031513
Ube2k	53323	-0.4313721	0.01623019	0.17584621	0.75842713	2.71E-07	8.73E-06
Prpf8	192159	-0.0539182	0.77919932	1	0.75810281	0.0065704	0.03813565
Bgn	12111	-0.4914294	0.01782408	0.18649611	0.75721645	1.07E-05	0.00020215
Ppa1	67895	-0.6081833	0.00404863	0.07766812	0.75608039	2.95E-10	2.11E-08
Dpy30	66310	-0.5981855	0.00751055	0.11364597	0.75560222	1.96E-07	6.51E-06
Txnrd3	232223	-0.1878425	0.46455522	0.97190308	0.75299438	0.00044134	0.00447791
Fam216a	68948	-0.6013756	0.02809931	0.239767	0.7518569	0.00013516	0.00165838
Cd200	17470	-0.4238553	0.05058425	0.33474929	0.75140343	0.00344639	0.02296834
Oxsm	71147	-0.6323475	0.07947179	0.41686474	0.74784676	0.02115965	0.09046078
Reep6	70335	-0.7603076	0.00581508	0.0982294	0.7477011	0.01965483	0.08567337
Fads2	56473	0.02517238	0.93215271	1	0.74736117	0.01792068	0.08030056
Rnaseh2b	67153	-0.579207	0.00908072	0.12645141	0.74701452	3.85E-06	8.63E-05
Efna1	13636	-0.4262442	0.01818805	0.18773054	0.74683445	8.17E-07	2.28E-05
Slc6a19	74338	-0.7122665	0.02211871	0.21042505	0.74678501	0.00624735	0.03673209
Csnk2a2	13000	-0.4398028	0.01510614	0.16870319	0.74638021	2.84E-06	6.58E-05
Zfp84	74352	-0.4356289	0.02938133	0.2434752	0.74599187	0.00011332	0.00145011
Zfp292	30046	-0.5095836	0.01040938	0.13623127	0.74360821	5.65E-05	0.00079796
Dcun1d2	102323	-0.4503711	0.04693555	0.32008185	0.74332464	0.0011659	0.00990111
Cnot1	234594	-0.5098682	0.00667675	0.10667746	0.74261941	5.74E-10	3.77E-08
Asb13	142688	-0.533225	0.01536743	0.16991121	0.74256797	0.00587524	0.03509374
Ano10	102566	-0.6541295	0.00471038	0.08623107	0.74236016	0.00028223	0.00308273
Arpc1a	56443	-0.374068	0.04492283	0.31245	0.7407277	1.08E-07	3.95E-06
Ptprd	19266	-0.4170993	0.06376165	0.38048661	0.74049382	0.00019138	0.00222351
Slc30a5	69048	-0.3926749	0.03802889	0.28366018	0.74024945	0.00016453	0.00195076
Rpp38	227522	-0.5158586	0.14820743	0.5889949	0.74013542	0.00017302	0.00203914
Synj1	104015	-0.7230074	0.0032063	0.06778697	0.74004063	0.00562888	0.03396475
Rnd3	74194	-0.5886468	0.0084279	0.1206434	0.73697237	1.35E-06	3.46E-05
Fanci	208836	-0.2810277	0.31514543	0.80097384	0.73658115	0.00241888	0.01740973

Heatr5b	320473	-0.2917059	0.13497131	0.56257581	0.73494445	0.00019854	0.00229861
Trmt5	76357	-0.6212477	0.03214135	0.25525984	0.73492654	0.00140911	0.01151225
Kdelr2	66913	-0.3721255	0.03267001	0.25744895	0.73367502	3.95E-10	2.73E-08
Naa50	72117	-0.5218149	0.00356322	0.0720553	0.73224249	4.66E-08	1.87E-06
Smg7	226517	-0.3101104	0.06912988	0.38698979	0.7321229	1.62E-05	0.00028451
Fgd4	224014	-0.4551156	0.10660715	0.49006149	0.73094866	0.01864547	0.08261774
Sp4	20688	-0.2277604	0.37909997	0.87792911	0.73027203	0.02215923	0.09330612
Ept1	NA	-0.6105729	0.01032178	0.13600791	0.72799527	1.17E-06	3.08E-05
Tial1	21843	-0.5719246	0.00452286	0.08368475	0.72747992	6.54E-06	0.00013192
Mrps11	67994	-0.5314332	0.06161031	0.37539555	0.72742986	0.00880554	0.04726409
Alg8	381903	-0.6931997	0.02620295	0.23337064	0.72684735	7.40E-06	0.00014616
Stau2	29819	-0.4026511	0.13948949	0.57126829	0.72579444	0.01533968	0.07167071
Rabl3	67657	-0.854725	0.00213285	0.05386381	0.7251954	0.00618207	0.03647841
Slc26a2	13521	-0.4220748	0.03149086	0.25197844	0.72295591	8.37E-07	2.32E-05
Tollip	54473	-0.405808	0.02752415	0.23869579	0.72273204	3.74E-05	0.00057317
4932438A13Rik	229227	-0.4781974	0.02004095	0.19850247	0.72265237	0.00012308	0.00154189
Kras	16653	-0.5499175	0.00386547	0.07539346	0.72229937	2.07E-06	5.07E-05
Zfp825	235956	-0.8063696	0.00885238	0.12453	0.72156521	0.00554607	0.03358595
Pafah1b2	18475	-0.602532	0.00577347	0.09779439	0.72118291	6.19E-09	3.19E-07
Gjc1	14615	-0.4933514	0.05090006	0.33564672	0.71989124	0.01422051	0.06818885
Abca5	217265	-0.3919934	0.26340581	0.74815459	0.71971047	0.0079323	0.04392376
Nfat5	54446	-0.5741023	0.00383767	0.075203	0.71935425	0.00010886	0.00140816
Slc25a12	78830	-0.5452311	0.02818883	0.24027899	0.71896491	0.00033394	0.00353915
Pgm3	109785	-0.5478465	0.03951978	0.28989423	0.71889392	0.00091376	0.00809498
Wdr75	73674	-0.6599526	0.00499978	0.08918888	0.71883726	2.10E-07	6.96E-06
Abcg2	26357	-0.9713653	0.00363631	0.07281126	0.71806058	0.00165269	0.01292328
Msl2	77853	-0.2625983	0.15689325	0.60822633	0.71792102	0.00025804	0.00286374
Unc50	67387	-0.5611835	0.0077343	0.11547566	0.71781843	6.47E-06	0.00013117
Taf2	319944	-0.4761993	0.01170912	0.14634004	0.71765266	0.00011214	0.00143915
Slc7a2	11988	-0.1100516	0.5512198	1	0.71761296	5.31E-06	0.00011164
Tm9sf4	99237	-0.3825475	0.03128458	0.25131599	0.71738529	1.38E-08	6.45E-07
Birc6	12211	-0.3055172	0.10977059	0.49910773	0.71716352	1.01E-07	3.71E-06
Rps6ka3	110651	-0.5481031	0.00752118	0.11364597	0.71705602	4.60E-08	1.85E-06
Cdk1	12534	-0.5502987	0.02389709	0.22038927	0.71695958	5.09E-08	2.01E-06
Slc35b1	110172	-0.6761764	0.00224595	0.05486889	0.71694964	1.83E-05	0.00031516
Aar2	68295	-0.1327	0.51925333	1	0.71687686	0.00066022	0.00626585
Aga	11593	-0.3694282	0.25498817	0.73418183	0.71625974	0.00396412	0.0257012
Fam76b	72826	-0.5441429	0.00684868	0.10791847	0.71415138	0.00012302	0.00154189
Zfp626	71163	-0.036323	0.89744274	1	0.71250851	0.01389511	0.06713685
Serpine2	20720	-0.3282377	0.24354305	0.71730269	0.71204828	4.72E-05	0.0006864
Kif18b	70218	-0.404603	0.07991944	0.41810469	0.71088696	0.00080199	0.00727662
Arhgap1	228359	-0.58208	0.00329044	0.06862147	0.708631	4.67E-08	1.87E-06
1110037F02Rik	66185	-0.3852707	0.0943548	0.45992785	0.70831286	1.45E-05	0.00026026
Nsmce2	68501	-0.7331523	0.01484498	0.16668012	0.7078242	3.99E-06	8.87E-05
Plekhg1	213783	-0.464203	0.01523667	0.16921086	0.70687678	4.70E-05	0.00068452
Mad2l2	71890	-0.3783606	0.25603353	0.73551286	0.70554771	0.00122347	0.01033647
Nol11	68979	-0.6514251	0.00283933	0.06282472	0.70550468	4.66E-07	1.40E-05
Klhl9	242521	-0.5185813	0.0149072	0.1673018	0.70533486	1.88E-07	6.28E-06
AI314180	230249	-0.3005926	0.10083896	0.47807964	0.70532778	6.91E-07	1.97E-05
Vprbp	321006	-0.43017	0.0174988	0.18475495	0.70312971	7.45E-06	0.00014686
Cenpl	70454	-0.4202678	0.10226786	0.48158184	0.70309994	0.00951635	0.05025751
Pign	27392	-0.7568992	0.00633595	0.10350555	0.70279664	0.00664706	0.03847232
Vsnl1	26950	0.40917687	0.29141688	0.79188828	0.70269835	0.00658418	0.03819422
Csnk1g1	214897	-0.4616964	0.01794741	0.18701065	0.70230068	0.00592491	0.03534163
Hif1a	15251	-0.5552814	0.00281997	0.06282472	0.69997815	3.97E-07	1.23E-05
Zfp639	67778	-0.458213	0.03870171	0.28604177	0.69980942	0.00656491	0.03812061
Mgp	17313	-0.8110476	0.01262208	0.15389103	0.6990469	0.00107669	0.00930039
Pou2f1	18986	-0.0679208	0.70362888	1	0.69864444	0.00208104	0.01554151
Brinp1	56710	-0.1654872	0.41908331	0.92357268	0.69760618	0.02319453	0.09638038
Ufm1	67890	-0.1276809	0.51091559	1	0.69744439	1.46E-05	0.00026167
Srd5a1	78925	-0.4167849	0.02394696	0.22055842	0.69731382	0.01630568	0.07487839
Ttc8	76260	-0.8023462	0.06530784	0.38489715	0.69643833	0.01697505	0.07722295
Qrich1	69232	-0.5290821	0.00231457	0.05552463	0.69616361	1.32E-07	4.62E-06

Ankfy1	11736	-0.4229646	0.03226969	0.25586305	0.69569291	1.33E-06	3.43E-05
Btaf1	107182	-0.237255	0.25925211	0.74153147	0.69561141	4.72E-06	0.00010125
Lamtor3	56692	-0.1096684	0.63801756	1	0.69537827	0.00034525	0.00363788
Tgm5	74176	-0.4284778	0.03810976	0.28388035	0.69521248	0.00048613	0.00483512
Gstm2	14863	-0.3657435	0.10099988	0.47840291	0.69359761	3.89E-06	8.67E-05
Vps13c	320528	-0.2027445	0.3864216	0.88758482	0.69326644	0.0011258	0.00962906
Ice2	93697	-0.3431403	0.18267871	0.61720523	0.69296723	0.00864313	0.04672667
Acox1	11430	-0.5003063	0.00845942	0.12095287	0.69048434	4.17E-06	9.14E-05
Anpep	16790	-0.5744171	0.00734598	0.11239174	0.69037598	0.00022613	0.00255059
Htt	15194	-0.2406997	0.16295026	0.61720523	0.69029788	0.00079317	0.00722157
Gjb5	14622	-0.3509477	0.11574093	0.51364701	0.68988866	0.01647166	0.07545582
Thada	240174	-0.0951871	0.65604664	1	0.6898276	0.00060423	0.00580739
Ndel1	83431	-0.2796662	0.13581826	0.56466082	0.68941579	1.08E-05	0.00020254
Errfi1	74155	0.08190036	0.65631701	1	0.68894322	0.00495767	0.03068798
Alg11	207958	-0.2274493	0.29138263	0.79188828	0.68849714	0.00154497	0.01231025
Shprh	268281	-0.4436565	0.03807172	0.28388035	0.68646159	6.99E-05	0.00095619
Pdzd11	72621	-0.2822679	0.17540401	0.61720523	0.68619449	4.24E-06	9.24E-05
1110051M20Rik	228356	-0.4479732	0.12535018	0.53830173	0.68573047	0.00743929	0.04184682
Dhx9	13211	-0.3397085	0.11001626	0.50009048	0.68571153	6.47E-08	2.48E-06
Pdcd10	56426	-0.8726049	0.00621168	0.10245058	0.68473995	4.97E-06	0.00010596
Usp34	17847	-0.5132346	0.01170201	0.1463261	0.68395328	3.07E-05	0.00048574
Ep300	328572	-0.404198	0.03923475	0.28827621	0.68376921	6.16E-07	1.79E-05
Aspm	12316	0.01138143	0.95777539	1	0.68168567	0.00196815	0.01483638
Itga2	16398	-0.7373874	0.00383012	0.07518565	0.68126513	4.96E-05	0.00071275
Sephs1	109079	-0.4916612	0.00736815	0.11250123	0.68125491	0.00018296	0.00214089
Ggta1	14594	-0.6046489	0.00220374	0.05455766	0.68107474	0.00011105	0.00142939
Gas2l3	237436	-0.4649818	0.07639035	0.40726002	0.68026807	0.01912227	0.08410594
Nupr1	56312	-0.1712054	0.52295084	1	0.68004769	0.01790525	0.08025879
Yif1a	68090	-0.3902457	0.04006747	0.29133581	0.67943769	0.00067084	0.00630907
Pros1	19128	-0.4647391	0.07124193	0.39112212	0.67938265	1.27E-05	0.00023328
Fastkd2	75619	-0.8314917	0.00220509	0.05455766	0.67879394	0.0007335	0.00680577
Serinc1	56442	-0.7517113	0.00684808	0.10791847	0.67652306	4.37E-09	2.36E-07
Decr2	26378	-0.2783434	0.17962651	0.61720523	0.67635056	0.00409613	0.02638769
Cx3cl1	20312	-0.0819597	0.71862398	1	0.67604801	0.00140196	0.01147524
Cyp2j6	13110	-0.9655624	0.0041919	0.07941852	0.67601461	0.00372638	0.02438865
Gmppa	69080	-0.6212647	0.02288208	0.21475915	0.67583912	0.00173552	0.01349062
Zmiz1	328365	-0.1468334	0.4054587	0.9064281	0.67514783	2.00E-05	0.00033871
Nxf1	53319	-0.461638	0.02439153	0.22334665	0.67511685	5.64E-07	1.66E-05
Ppap2c	NA	-0.5516324	0.00680131	0.1076965	0.67434529	0.0180761	0.0807764
Tfb1m	224481	-0.5390731	0.21772327	0.67235964	0.67423248	0.01879543	0.08309779
Brip1	237911	-0.0873434	0.73654271	1	0.67200602	0.00931626	0.04959982
Nup98	269966	-0.3789576	0.05747351	0.35924255	0.67159885	9.84E-08	3.63E-06
Mtf2	17765	-0.4854054	0.02626015	0.23353938	0.67154815	0.00021657	0.00246605
Macc1	238455	-0.5842899	0.00498973	0.08917652	0.67143187	0.00023374	0.00262738
Sec23a	20334	-0.305784	0.17690841	0.61720523	0.67130696	8.13E-05	0.0010929
Cdk5rap1	66971	-0.674049	0.01295199	0.15557684	0.66985925	0.00285994	0.01979345
Arg2	11847	-0.7787308	0.03014956	0.24715759	0.66985224	0.00148186	0.01189929
Tab3	66724	-0.6560993	0.00421022	0.07964192	0.6695706	0.00607874	0.03604686
Eif2b1	209354	-0.63569	0.00330746	0.06876838	0.66808789	8.33E-06	0.00016243
Ten1	69535	-0.2962887	0.21219484	0.66189937	0.66776306	0.00104388	0.00907193
Adipor2	68465	-0.4297879	0.03280246	0.25786858	0.66655562	6.85E-05	0.00094394
Xpo4	57258	-0.5593642	0.00965925	0.13036944	0.66630381	0.0001117	0.00143639
4833423E24Rik	228151	-0.6738478	0.00281822	0.06282472	0.66620575	0.00060844	0.00583507
Klhl24	75785	-0.2066675	0.28632654	0.7845148	0.66609202	0.00028969	0.00314828
Slc16a1	20501	-0.4848859	0.02070079	0.20229451	0.66600091	3.90E-08	1.62E-06
Dad1	13135	-0.4890712	0.01503211	0.16831688	0.66534348	2.30E-05	0.00037881
Tmed3	66111	-0.3915578	0.06071054	0.3714889	0.66513053	3.05E-05	0.00048424
Asnsd1	70396	-0.4541573	0.03489634	0.2690738	0.66307214	0.00723917	0.04103758
Ppap2b	NA	-0.6159842	0.0023003	0.05541254	0.66204855	0.00141493	0.0115311
Cxadr	13052	-0.5696572	0.00595836	0.09986903	0.66191642	2.85E-06	6.60E-05
Anapc1	17222	-0.4260059	0.05512228	0.35028394	0.66172707	7.65E-06	0.00015034
Pafah1b1	18472	-0.5662408	0.00367446	0.07319242	0.66165886	3.96E-09	2.16E-07
Gla	11605	-0.3878516	0.24442433	0.71852236	0.66124357	0.00921812	0.04913713

Ide	15925	-0.4302736	0.02354372	0.21829479	0.66100956	6.58E-05	0.00091369
Slc12a6	107723	-0.5350039	0.01684972	0.18023958	0.65912629	0.01817121	0.08110991
Sdhc	66052	-0.5430725	0.00923607	0.1277203	0.65899045	1.14E-07	4.11E-06
Mrpl45	67036	-0.3954596	0.07079135	0.38992098	0.65830745	6.46E-05	0.00090228
Erbb2ip	NA	-0.4103638	0.05151782	0.33856744	0.65827115	4.29E-08	1.76E-06
Capn6	12338	-0.7303845	0.00833774	0.11991519	0.65814176	0.00013255	0.0016325
Nbeal2	235627	0.01274985	0.9430646	1	0.6574915	0.01750408	0.07891863
Cers3	545975	-0.3812143	0.02709486	0.23665363	0.65725135	2.62E-06	6.15E-05
Ier3ip1	66191	-0.538243	0.01695167	0.18093391	0.65594375	0.00107817	0.00930655
Cyfip1	20430	-0.2940332	0.13621986	0.56563366	0.65341403	3.89E-06	8.67E-05
Camk2g	12325	-0.0839401	0.67439434	1	0.65221482	0.00288054	0.01991504
Pin4	69713	-0.6251922	0.05215153	0.3411751	0.65212804	0.00189233	0.01442761
Ap2b1	71770	-0.2188688	0.27400513	0.76487025	0.65053242	1.84E-08	8.52E-07
Zfp369	170936	-0.644831	0.00216106	0.05397989	0.65018303	0.00726952	0.04113402
Tbc1d5	72238	-0.1168385	0.57632987	1	0.64891962	0.00342401	0.02284239
Hcfc1	15161	-0.1034315	0.54982009	1	0.64817097	0.00014089	0.00171587
Tmem115	56395	-0.412725	0.02901278	0.2425892	0.64644796	0.00122642	0.01034087
Twf2	23999	-0.4324812	0.12207065	0.52952457	0.64641685	0.00262012	0.01852347
Dcp1a	75901	-0.2537158	0.19515501	0.63032409	0.64640137	0.00152018	0.0121402
Nanp	67311	-0.5796221	0.05950092	0.36777322	0.64634423	0.00188147	0.01436988
Nt5c2	76952	-0.5142678	0.01542211	0.17026375	0.64625542	0.00013232	0.00163119
Ric1	226089	-0.4571404	0.00874654	0.12375394	0.6462208	0.00028513	0.003104
Hpcal1	53602	-0.0094375	0.96269774	1	0.64611922	0.00021406	0.00244515
Zfp280c	208968	-0.6917426	0.00491883	0.08845561	0.64611485	0.00316386	0.02149766
Pbdc1	67683	-0.3193615	0.13876426	0.56986017	0.64531093	0.00045088	0.0045641
Tsen15	66637	-0.7439769	0.03378	0.26355953	0.64510389	0.01365779	0.06633862
Ppme1	72590	-0.3239118	0.13899221	0.57028371	0.64503132	0.00036031	0.00377836
Stil	20460	-0.4092697	0.07511451	0.40328767	0.64384712	0.0064694	0.03763262
Mrpl33	66845	-0.1501743	0.47905642	0.98764001	0.64260969	3.72E-05	0.00057163
Cr1l	12946	-0.8373735	0.00786143	0.11664255	0.64192612	9.10E-05	0.00120298
Gdpd3	68616	-0.80095	0.01215422	0.14990823	0.64095861	0.01088651	0.05600665
Arpc4	68089	-0.1341685	0.43553683	0.9417525	0.63913381	5.38E-08	2.11E-06
Klhl28	66689	-1.0275074	0.00392064	0.07598888	0.63715091	0.0083152	0.0454308
Dcaf7	71833	-0.0379152	0.84809141	1	0.63639522	2.32E-06	5.58E-05
Xrn1	24127	-0.2672202	0.2290721	0.69200517	0.63583227	0.00029564	0.0031973
Heatr1	217995	-0.2218297	0.2228811	0.68096825	0.63578076	0.00017987	0.00211043
Rab7b	226421	-0.1790553	0.32038518	0.80097384	0.63569006	0.00132548	0.01101407
Ubqln1	56085	-0.3635532	0.03197842	0.25463236	0.63460147	1.09E-07	3.97E-06
Kdelr1	68137	-0.2808771	0.09959867	0.47461137	0.63439526	3.56E-07	1.10E-05
Picalm	233489	-0.5426065	0.00323129	0.06801517	0.63227093	5.15E-06	0.00010849
Gli3	14634	-0.4510192	0.02667303	0.23507111	0.63146114	0.00904386	0.04840474
Fem1b	14155	-0.553297	0.00300891	0.06479778	0.63096346	1.93E-06	4.75E-05
Dpp8	74388	-0.543569	0.00323002	0.06801517	0.63085739	0.00022318	0.00252601
Idh1	15926	-0.6967717	0.00255297	0.05921143	0.63074399	4.21E-06	9.20E-05
Clip4	78785	-0.247998	0.20516739	0.64934992	0.63057105	0.02084633	0.08958803
Atp11c	320940	-0.7830017	0.00820022	0.11919436	0.63044166	0.00540954	0.03294152
Rbm18	67889	-0.0802416	0.72659014	1	0.63029971	0.00587407	0.03509374
Ift80	68259	-0.6448977	0.03104495	0.25013151	0.6301206	0.01093458	0.05621842
Lrba	80877	-0.2589722	0.18141503	0.61720523	0.62984803	0.00094819	0.00834931
Mettl1	17299	-0.5161424	0.03744669	0.28068923	0.62944893	0.00223562	0.01642496
Sec24b	99683	-0.3966151	0.02709125	0.23665363	0.62795313	1.93E-05	0.00032971
Bet1	12068	-0.6848008	0.01805804	0.18720192	0.62753051	0.01101693	0.05650051
Map1lc3a	66734	0.06144972	0.75589045	1	0.62574103	0.0002571	0.0028557
Cltc	67300	-0.4551149	0.02446585	0.22369166	0.62525409	1.65E-07	5.59E-06
Skint1	639781	-0.9765536	0.00627293	0.10315902	0.62493105	0.00118211	0.01002581
Cers6	241447	-0.5810631	0.00305017	0.06557066	0.62468067	0.00011974	0.0015072
Asb3	65257	-0.2396571	0.42598475	0.93024008	0.62450476	0.00578467	0.03471068
Pts	19286	-0.6803418	0.00965053	0.13036944	0.62438805	0.00705802	0.04023652
Rae1	66679	-0.2916972	0.12381566	0.53403431	0.6239629	2.64E-05	0.00042846
Trove2	20822	-0.5374748	0.00278577	0.06252881	0.62377069	4.91E-05	0.00070748
Supt3	109115	-0.3914049	0.27139853	0.76059485	0.62372403	0.01929671	0.08458984
Cdc16	69957	-0.4106934	0.02228776	0.2116646	0.62366545	1.07E-05	0.00020254
Sdr42e1	74032	-0.6636744	0.00445976	0.08294885	0.62345065	0.01054876	0.05458993

Osmr	18414	-0.7120522	0.03971941	0.28989423	0.62343463	0.02264801	0.09475643
Scyl3	240880	-0.277613	0.21568422	0.66893534	0.62338072	0.00277614	0.01929482
Qtrtd1	106248	-0.326379	0.12700391	0.5431861	0.62291953	0.01865889	0.08264933
Sec61a2	57743	-0.6338401	0.0144799	0.16431863	0.62214641	0.0049199	0.03048298
Zfp397	69256	-0.662298	0.01317252	0.15652764	0.62201956	0.00435691	0.02774099
Mavs	228607	-0.4564663	0.07148745	0.39187318	0.62171404	0.00414099	0.02662439
Utp15	105372	-0.3912873	0.07266295	0.39607988	0.62130002	0.00021415	0.00244515
Ntan1	18203	-0.5745547	0.01230655	0.15110017	0.62114951	0.00042101	0.00430482
Psenen	66340	-0.0328588	0.8729477	1	0.6210669	0.00030595	0.00329518
Mga	29808	-0.3440362	0.0846588	0.43234058	0.61981648	0.00023098	0.00260303
Ncaph	215387	-0.109853	0.60633078	1	0.6194625	0.00114837	0.00978764
Tbc1d23	67581	-0.4664814	0.03097696	0.24999613	0.61892354	0.00725646	0.0410824
Malt1	240354	-0.1370465	0.51441395	1	0.61751307	0.01039481	0.05394207
Cyp2g1	13108	-0.4574019	0.22838048	0.69101353	0.61737984	0.01198213	0.0600433
Dusp14	56405	-0.5907252	0.02180515	0.20842363	0.61704056	0.0019463	0.01469403
0610007P14Rik	58520	-0.5354591	0.00703206	0.10917354	0.61643383	0.00055625	0.00541363
Nipsnap3b	66536	-1.0342014	0.00839661	0.1204542	0.61613155	0.02241	0.09397025
Slc9a9	331004	-0.6128694	0.03281829	0.25786858	0.61604051	0.02178171	0.09220989
Slc10a7	76775	-0.5516807	0.01201341	0.14869709	0.61590346	0.01863019	0.08257789
Usp7	252870	-0.532858	0.0083863	0.1204542	0.61587249	3.39E-07	1.07E-05
Apool	68117	-0.8053842	0.00621674	0.10245058	0.61582746	0.00351429	0.02325215
Elf1	13709	-0.5105703	0.00519284	0.0911022	0.6154226	1.77E-05	0.00030582
Timm23	53600	-0.5529452	0.00204403	0.05259978	0.6153672	2.04E-05	0.00034352
Cops2	12848	-0.4058462	0.03008183	0.24686193	0.61444632	2.16E-06	5.25E-05
Cd151	12476	-0.4928964	0.01323399	0.15688705	0.61422698	8.52E-07	2.35E-05
C2cd3	277939	-0.2124065	0.30024598	0.80097384	0.6123351	0.00539122	0.03289098
Zfp68	24135	-0.451998	0.0216106	0.20761313	0.61192004	0.00253663	0.01811608
Kansl1l	68691	-0.3673595	0.06194558	0.37650144	0.61182822	0.0025492	0.01816746
Krtcap2	66059	-0.1257324	0.55799536	1	0.61131288	0.00052149	0.0051132
Rpf2	67239	-0.719872	0.00358356	0.07224658	0.6112193	1.12E-05	0.00020959
Acp1	11431	-0.3581444	0.06877124	0.38698979	0.61103792	3.80E-05	0.00057949
Ocln	18260	-0.6977169	0.0047284	0.08643136	0.61093843	0.00055453	0.00540089
Rb1cc1	12421	-0.4370857	0.0140807	0.16136309	0.61087657	2.63E-05	0.00042607
Plp2	18824	-0.2341826	0.1704806	0.61720523	0.6108552	6.65E-08	2.55E-06
Tfg	21787	-0.5734602	0.00358851	0.07224658	0.61085303	3.39E-07	1.07E-05
Ralgapa1	56784	-0.4899571	0.00555269	0.09527278	0.61084068	2.10E-05	0.00035062
Ghitm	66092	-0.4987311	0.00805184	0.11809856	0.60829191	2.33E-07	7.59E-06
Tbl1x	21372	-0.5141632	0.02197954	0.20934568	0.60640492	5.87E-05	0.00082571
Jkamp	104771	-0.5071905	0.04077529	0.29443325	0.60637327	0.00750093	0.04210334
Csnk2a1	12995	-0.4936511	0.00534192	0.0928505	0.60630453	9.73E-07	2.63E-05
Fbxo30	71865	-0.5437685	0.02281343	0.214362	0.60621422	0.00066052	0.00626585
Nup43	69912	-0.487633	0.08800996	0.44233199	0.6059686	0.00066879	0.00629882
Mis18bp1	217653	-0.6601325	0.00680462	0.1076965	0.60410906	0.00550018	0.03338505
Wdr7	104082	-0.4974438	0.05609086	0.35441007	0.60396755	0.01328921	0.06507795
Nln	75805	-0.384566	0.10446265	0.48649045	0.60394548	0.00215682	0.01600726
Sepp1	NA	-0.6068342	0.00340819	0.07011918	0.60390738	0.0014031	0.01147741
Dmxl1	240283	-0.5651525	0.01010508	0.13419039	0.60334677	0.00145166	0.0117285
C330027C09Rik	224171	-0.5713088	0.02026155	0.20000299	0.60198184	5.05E-05	0.00072247
Tuba4a	22145	-0.4819433	0.01009645	0.13419039	0.60091535	0.00017602	0.00207076
Slirp	380773	-0.621197	0.05514033	0.3503075	0.60084221	0.0001854	0.0021598
Rc3h2	319817	-0.6455719	0.00262352	0.06038544	0.60070172	0.00493025	0.03053269
Rel	19696	-0.2679715	0.33058925	0.81000501	0.59974549	0.00959839	0.05060932
Serpinb11	66957	-0.5860733	0.18599459	0.61720523	0.59963996	0.00951317	0.05025751
Dcn	13179	-0.6013173	0.01295026	0.15557684	0.59906173	8.45E-06	0.0001643
Dld	13382	-0.4222662	0.03107255	0.25024915	0.59902781	6.19E-06	0.0001259
B3gnt2	53625	-0.575948	0.00499178	0.08917652	0.5982344	0.00172559	0.01342133
Pomt1	99011	-0.3774395	0.17309764	0.61720523	0.59778734	0.01284865	0.06344114
Arl4a	11861	-0.4874315	0.00829019	0.11957392	0.596178	0.00051321	0.00503585
Btf3	218490	-0.1722808	0.34758059	0.8352126	0.5959783	8.20E-09	4.06E-07
Cog6	67542	-0.681582	0.00628448	0.10318869	0.59542781	0.00291051	0.02009048
Tspan13	66109	-0.3269266	0.14222284	0.57809987	0.59539707	0.02085658	0.08959657
Myo6	17920	-0.362147	0.05985558	0.36896135	0.59532049	0.00383948	0.02505396
Ccnt1	12455	-0.6117015	0.01076566	0.13895504	0.59513781	0.0030175	0.02066604

Lin9	72568	-0.4091581	0.105737	0.48744577	0.5946823	0.00611513	0.03619726
Mtpap	67440	-0.593116	0.00428195	0.08056203	0.59465697	0.00549691	0.03338066
Mtm1	17772	-0.8603622	0.01070378	0.13837857	0.59411384	0.0175743	0.07909943
Cdk8	264064	-0.4058254	0.05080903	0.33554921	0.59390192	0.01824298	0.0813284
l7Rn6	NA	-0.477053	0.02795233	0.239767	0.59244728	0.00679127	0.03907212
Wac	225131	-0.3417749	0.07396662	0.40007203	0.59054211	4.60E-05	0.00067569
Sec23b	27054	-0.3393034	0.10086492	0.47810991	0.58905446	5.39E-05	0.00076473
Tnrc6a	233833	-0.259816	0.14003526	0.57283102	0.58897295	0.00754353	0.04230629
Tm2d3	68634	-0.6896365	0.01064918	0.1382797	0.58783574	0.00217466	0.0161033
Elmo1	140580	-0.4347663	0.05738835	0.35907784	0.58769867	0.00247104	0.01770867
Ap3s1	11777	-0.7442795	0.00263001	0.06039338	0.58737566	0.01908344	0.08399145
Pgap2	233575	-0.5710152	0.00264911	0.06052147	0.58666297	0.00822658	0.04513761
Ergic1	67458	-0.2058028	0.25750615	0.73792041	0.58518804	9.37E-05	0.00123672
Thoc2	331401	-0.4927082	0.00915568	0.12704023	0.58515407	3.59E-05	0.00055451
Grina	66168	-0.3211763	0.09060921	0.44978874	0.58370587	0.00514654	0.03166303
Arl14ep	212772	-0.3053059	0.14420632	0.58315328	0.58329707	0.00149022	0.01195181
Sec22b	20333	-0.3673755	0.12496844	0.53720373	0.58291234	0.00016996	0.0020067
Rps27l	67941	-0.5774257	0.00403367	0.07750303	0.5828706	6.73E-06	0.00013538
Fbxo3	57443	-0.5670519	0.00449779	0.08335159	0.58241267	1.92E-05	0.00032856
Cnn3	71994	-0.5278444	0.00985097	0.13189179	0.58223259	4.69E-05	0.00068452
Med10	28077	-0.0649475	0.79223546	1	0.58212832	0.00099859	0.0087403
Pnpt1	71701	-0.8503612	0.00267369	0.0609088	0.5820618	0.00107604	0.00930039
Eif3l	223691	-0.5207547	0.00825686	0.11957392	0.58198714	6.92E-08	2.63E-06
Oser1	66680	-0.4804234	0.03573779	0.27348289	0.58194142	0.00053338	0.00520653
Eif3i	54709	-0.4903835	0.02050598	0.20160081	0.58185188	5.60E-08	2.18E-06
Itgb8	320910	-0.4950241	0.03954608	0.28989423	0.58146864	0.02407285	0.0987664
2210018M11Rik	NA	-0.4490715	0.03205804	0.25468098	0.58106409	0.01437865	0.06862069
Krit1	79264	-0.2786325	0.25189894	0.72972462	0.58099291	0.007484	0.04204426
Prps2	110639	-0.5953665	0.00765144	0.11461887	0.58035107	6.12E-05	0.0008587
7-Mar	57438	-0.4560152	0.01743088	0.18435833	0.57953344	6.52E-06	0.00013172
Ttc21b	73668	-0.4049952	0.14068734	0.57444	0.57905114	0.00361165	0.0237562
Stk26	70415	-0.6318241	0.00422402	0.07977945	0.57904876	8.21E-06	0.00016058
Plbd1	66857	-0.4395095	0.01791938	0.18693261	0.57892463	5.84E-06	0.00012073
Lyst	17101	-0.2657496	0.17095473	0.61720523	0.57881154	0.00623895	0.03671804
Clca2	229933	-0.6825084	0.00298895	0.06470411	0.57830193	0.00366714	0.02406092
Derl2	116891	-0.2598431	0.23004961	0.69358538	0.57812999	0.0052398	0.03213142
Nr2c1	22025	-0.8141876	0.0021648	0.05397989	0.57770666	0.00465351	0.02913491
Bpnt1	23827	-0.4828782	0.01854781	0.19007803	0.57714524	0.00085036	0.00764157
Tia1	21841	-0.609941	0.00879518	0.1240826	0.57707605	0.00140814	0.01151152
Focad	230393	-0.4279586	0.05001578	0.33194817	0.57706124	0.0015731	0.01247179
Arhgap17	70497	-0.3096889	0.14881723	0.59012069	0.57704358	0.00341663	0.02280475
Ppp2r2a	71978	-0.4390901	0.01402061	0.16120405	0.57668713	8.71E-05	0.00116197
Timm9	30056	-0.5162207	0.02466364	0.22499472	0.57504086	0.01430533	0.06844556
Zfp60	22718	-0.6100334	0.02398447	0.22069511	0.57496194	0.00872675	0.0470221
Ahctf1	226747	-0.0263104	0.88343997	1	0.5745174	0.00025918	0.00286909
Zfx	22764	-0.5476281	0.02341817	0.21769896	0.57448894	0.00033655	0.0035605
Mlst8	56716	-0.1661243	0.55370744	1	0.57446678	0.01725469	0.07811613
Pten	19211	-0.2587417	0.15866657	0.61068501	0.57402154	0.00037925	0.00393919
Pgm2	72157	-0.3252447	0.16528629	0.61720523	0.57302381	0.00489992	0.03038785
Rab22a	19334	0.20527782	0.24598355	0.72060569	0.57234013	0.00253755	0.01811608
Itpr2	16439	0.00767648	0.96571797	1	0.5721872	0.00371268	0.02431112
Itga1	109700	-0.3712483	0.16582201	0.61720523	0.57213044	0.0076628	0.04279241
Mkl2	239719	-0.3726558	0.04299824	0.30463011	0.57211332	0.00016834	0.00198929
Kif2a	16563	-0.5972496	0.00543321	0.09396917	0.57203345	0.00014643	0.0017676
Rbms1	56878	-0.0366513	0.83450196	1	0.57197849	0.00014787	0.00178113
Ssr1	107513	-0.6244676	0.00247318	0.05806968	0.57073389	1.48E-06	3.76E-05
Coq4	227683	-0.5767756	0.01806035	0.18720192	0.56970128	0.00936842	0.04973486
Slc46a2	30936	-0.6705696	0.02099466	0.20409211	0.56912571	0.01017498	0.05301809
Wdr48	67561	-0.2553991	0.18120989	0.61720523	0.56817103	0.00049912	0.00493442
Ptdss1	19210	-0.4165377	0.0212337	0.20552842	0.56799028	0.00060376	0.00580717
Acaca	107476	-0.151075	0.41469235	0.91790102	0.56797334	0.00021387	0.00244515
Dnttip2	99480	-0.5732142	0.00268105	0.06101948	0.5674502	1.77E-05	0.00030581
Polr1b	20017	-0.2664735	0.16529715	0.61720523	0.56718434	0.00092836	0.00820772

Vangl1	229658	-0.2700374	0.14594607	0.58436017	0.56714158	0.00186812	0.01428455
Smg8	74133	-0.3792033	0.07123379	0.39112212	0.56647599	0.00829512	0.04535885
Polr2b	231329	-0.4244634	0.03400172	0.2644446	0.56627892	4.25E-05	0.00063468
Cdk7	12572	-0.2950456	0.13137943	0.55352806	0.56521982	0.00050616	0.00499274
Cnot4	53621	-0.5033623	0.02139992	0.20669764	0.56365655	0.00941293	0.04989172
Isyna1	71780	-0.3389424	0.07874327	0.41452668	0.56362893	9.99E-05	0.00131077
Vwa5a	67776	-0.5479342	0.03459451	0.2675536	0.56307571	0.0006784	0.00636648
Fem1c	240263	-0.459495	0.02641348	0.23400805	0.56242131	0.00147114	0.0118349
Smpd1	20597	-0.4361565	0.01529615	0.16960333	0.56223632	0.00122787	0.01034087
Mrpl39	27393	-0.552054	0.01107095	0.1413395	0.56195099	4.69E-05	0.00068452
Zscan21	22697	-0.5491853	0.01437519	0.16373907	0.56133868	0.00359482	0.02369237
Hist3h2bb-ps	382522	0.01655611	0.94815103	1	0.56111193	0.00763259	0.04267817
Pxdn	69675	-0.3655493	0.05809568	0.36157819	0.56012964	2.95E-05	0.0004727
Hdac3	15183	-0.4464392	0.01142186	0.14411414	0.55967514	1.53E-05	0.00027074
Golt1b	66964	-0.2775687	0.2274825	0.68950604	0.55862601	0.00227918	0.01667971
Sgol2a	68549	-0.1969246	0.37168626	0.86759511	0.55861973	0.00220242	0.01625381
Prepl	213760	-0.5426062	0.01310016	0.15619984	0.55784745	0.00176912	0.01368696
Med13	327987	-0.5993925	0.00323351	0.06801517	0.55778406	0.00283309	0.01963869
Arfip1	99889	-0.3949587	0.03492208	0.26911707	0.55749708	0.00213896	0.0159017
Gphn	268566	-0.3672974	0.0680785	0.38661538	0.55662912	0.00032898	0.00349449
Mtor	56717	0.0394472	0.81734955	1	0.55640307	0.00327266	0.02205225
Tspan5	56224	0.06541457	0.7168219	1	0.55640124	0.00319816	0.0216548
Rps15a	267019	-0.7275055	0.00642577	0.10426827	0.55609103	9.12E-06	0.00017617
Myo1d	338367	-0.234946	0.25531096	0.73442908	0.55569136	0.00662239	0.03838644
Cpne8	66871	-0.3025702	0.22399524	0.68240866	0.55540424	0.00835039	0.0456041
Xpo5	72322	-0.1018361	0.59735426	1	0.55502582	0.00018354	0.00214504
Rcbtb1	71330	-0.0927942	0.63958891	1	0.55249652	0.0231095	0.09619679
Ppp2r5e	26932	-0.3348217	0.05282809	0.34266069	0.55226648	0.00046464	0.00467453
Setx	269254	-0.27786	0.12950937	0.54890157	0.5521632	0.00059588	0.00573554
Ackr4	252837	-0.4085111	0.2768105	0.76986609	0.55199119	0.01168324	0.05899586
Chek2	50883	-0.6415884	0.0195643	0.19617714	0.55173973	0.01453431	0.06902226
Mtr	238505	-0.2701638	0.26847583	0.75578654	0.55008918	0.02025156	0.08757665
Atr	245000	-0.1380324	0.60231469	1	0.54978456	0.00814898	0.04482109
Vps45	22365	-0.195316	0.41746486	0.9218384	0.54974888	0.00828796	0.0453386
Slmo2	NA	-0.1547611	0.36802701	0.8627808	0.54970338	0.00102558	0.00894083
Sdc2	15529	-0.7774975	0.00449848	0.08335159	0.54815275	0.00164398	0.0128782
Ints2	70422	-0.439022	0.05010008	0.3322906	0.54802704	0.00246757	0.01770867
Gbf1	107338	-0.2941986	0.13148896	0.55352806	0.54753788	0.00076439	0.00702285
Kdsr	70750	-0.4433738	0.02379134	0.21979754	0.546408	0.00010135	0.00132796
Nfatc3	18021	-0.4113362	0.0264102	0.23400805	0.54634454	0.00743586	0.04184544
Prim2	19076	-0.7521769	0.00276864	0.0623735	0.54626102	0.00632284	0.03702615
Pon2	330260	-0.455417	0.0263089	0.23354771	0.54618635	7.46E-05	0.00101327
Alg3	208624	-0.3446198	0.2141283	0.66571956	0.54572143	0.0148221	0.06989921
Slc7a6	330836	-0.40418	0.12253273	0.5303743	0.54568817	0.01672636	0.07632966
Ppp6c	67857	-0.5930516	0.01100556	0.14078929	0.54561917	6.60E-05	0.00091447
Snx14	244962	-0.480256	0.02768738	0.23934635	0.54495252	0.00083275	0.00751425
Bbox1	170442	-1.2511899	0.0034248	0.07034239	0.54400062	0.01838374	0.08187248
Gjb6	14623	-0.3850116	0.06498623	0.38489715	0.54356709	0.02337847	0.09682521
Col12a1	12816	-0.3521453	0.13596318	0.56502945	0.54351212	0.00105316	0.00912671
Lsm2	27756	-0.1263083	0.55377483	1	0.5433647	0.00146073	0.01177093
Utp20	70683	-0.0135159	0.9521167	1	0.54324623	0.00077199	0.00708774
Ptgs1	19224	-0.4197347	0.01333582	0.15738769	0.54321238	0.00221162	0.01630341
Cirh1a	NA	-0.492283	0.01826201	0.18825518	0.54235323	0.00029795	0.00321426
Hadh	15107	-0.4429812	0.00848452	0.12116989	0.54190735	0.00020039	0.00231597
Dennd4c	329877	-0.4009077	0.04310175	0.3050646	0.54189231	0.00011077	0.00142715
Kpna2	16647	-0.4366042	0.03640109	0.27615748	0.54059037	1.75E-06	4.33E-05
Emc3	66087	-0.5494314	0.00264117	0.06044995	0.54052768	4.86E-05	0.00070326
Taf1	270627	-0.4251348	0.02428285	0.2226855	0.54042006	0.00098571	0.00863915
Nbas	71169	-0.0238132	0.9038977	1	0.53956392	0.02001082	0.08679289
Serinc5	218442	-0.2881331	0.11102991	0.50225589	0.53876758	0.00058105	0.00562073
Aqr	11834	-0.2266304	0.24218551	0.7144736	0.53870089	0.00042673	0.00434643
Herc1	235439	-0.1256581	0.49879882	1	0.53869939	0.00479649	0.02984507
Prim1	19075	-0.6092404	0.03072479	0.24911357	0.53862557	0.00245812	0.01765466

Wnk1	232341	-0.2731042	0.12109564	0.52704985	0.53807329	0.00020518	0.00236296
Pdlim5	56376	-0.5958693	0.00515911	0.09087559	0.53726821	1.17E-05	0.00021728
Sgpl1	20397	-0.5853488	0.00500692	0.08925086	0.53706995	3.08E-06	7.09E-05
Ppp6r3	52036	-0.4099735	0.02689145	0.23598995	0.53676828	1.07E-05	0.00020254
Lpcat3	14792	-0.3332944	0.13533182	0.56338705	0.53599179	0.00112514	0.00962906
Kdm6a	22289	-0.261433	0.19839809	0.63739656	0.5355689	0.00955179	0.0504244
Plk2	20620	-0.3147823	0.11831989	0.52012572	0.53439694	0.00079596	0.00723445
Litaf	56722	-0.5407705	0.00317117	0.06737472	0.53439115	0.0007504	0.00692164
Kpna6	16650	-0.1342745	0.4576175	0.96415123	0.53391687	0.0001158	0.00146961
Mitf	17342	-0.3273811	0.09527809	0.4631342	0.53382989	0.01845774	0.08210395
Cav1	12389	-0.369836	0.05587875	0.35343563	0.5334921	1.24E-06	3.25E-05
Zwilch	68014	0.20234494	0.36277723	0.85498771	0.5332047	0.01166277	0.05893785
Mcfd2	193813	-0.2852286	0.12505906	0.53740408	0.53071457	0.00386262	0.02514247
Ipo11	76582	-0.5001355	0.01638354	0.17672372	0.53006508	0.00066255	0.00628057
Saraf	67887	-0.392599	0.02593083	0.23204723	0.52989692	0.00021418	0.00244515
Mfsd2a	76574	-0.5709549	0.00212251	0.0537138	0.52986884	0.00032428	0.00345289
Endou	19011	-0.3443865	0.05315394	0.3434054	0.52977942	0.00025836	0.00286487
Ccnb1	268697	-0.4982723	0.02711731	0.23668043	0.52913244	8.00E-05	0.00107925
Med6	69792	-0.7955488	0.00219909	0.05452176	0.52906335	0.00150696	0.01206397
Eif2ak1	15467	-0.3725129	0.06301393	0.37893699	0.52868694	0.01707342	0.07753613
Polr3b	70428	0.16270644	0.45772565	0.96421331	0.52781252	0.02069769	0.08918278
Rpl17	319195	-0.6078356	0.0039666	0.07663643	0.52673157	5.06E-06	0.00010699
Atp7a	11977	-0.5837068	0.00350978	0.07148659	0.52605189	0.00091658	0.00811449
Pafah1b3	18476	-0.349914	0.10483672	0.48649045	0.52583273	0.0004623	0.00465454
Leprot	230514	-0.4952385	0.01286395	0.15525212	0.52578316	0.00611801	0.03619802
Sec24c	218811	-0.2690177	0.1249042	0.53704112	0.52575372	9.68E-06	0.00018527
Nudt2	66401	-0.7435874	0.00349089	0.07122051	0.52529241	0.00716168	0.04070378
Nek7	59125	-0.623882	0.0060889	0.10094844	0.52492028	0.00897042	0.04805083
Hmgcs1	208715	-0.5727255	0.00327435	0.06843172	0.52368327	1.51E-06	3.84E-05
Rab11b	19326	-0.2760167	0.10437084	0.48649045	0.52323831	7.18E-06	0.00014235
Epb4.1l5	NA	-0.3749642	0.21648301	0.67031892	0.52239821	0.01163221	0.05886033
Flrt3	71436	-0.5367312	0.00820953	0.11919436	0.52239789	0.00012399	0.00154602
Pi4ka	224020	-0.2188852	0.24657865	0.72176641	0.52221177	0.00132254	0.0109966
Foxp1	108655	-0.254516	0.1605958	0.61500864	0.52220956	0.00142162	0.01156139
Hist1h2ah	319168	-0.684771	0.00359285	0.07226325	0.52212153	0.01319099	0.06471616
Gtf2f2	68705	-0.4047181	0.05536585	0.35125027	0.52182357	0.00115376	0.00981066
Usp3	235441	-0.6180187	0.0083307	0.11988449	0.52181816	0.00066544	0.00629105
Acly	104112	-0.3131964	0.10792266	0.49327706	0.52181329	0.00036595	0.00381953
Sil1	81500	-0.3170414	0.17965745	0.61720523	0.52039177	0.00639874	0.03733733
Galk2	69976	-0.5336619	0.02084663	0.20306964	0.52033029	0.00841662	0.04581336
Gpam	14732	-0.2620499	0.15475107	0.60399166	0.51863065	0.00416372	0.02671823
Sap130	269003	-0.1859164	0.31625595	0.80097384	0.5185623	0.00431739	0.02756954
Nxt1	56488	0.05253132	0.80652871	1	0.51824017	0.00015994	0.00190547
Tcf12	21406	-0.5240837	0.00412481	0.07863535	0.51808704	0.00017058	0.00201214
Sf3b3	101943	-0.2659037	0.17073095	0.61720523	0.51796541	5.71E-05	0.00080659
Prdx4	53381	-0.3353241	0.17199885	0.61720523	0.5177815	0.00030739	0.00330523
Dyrk1a	13548	-0.2600432	0.12808686	0.54628175	0.51776464	0.00177669	0.01372867
Prmt5	27374	-0.2220673	0.26275696	0.74700671	0.51748457	0.00045344	0.00458648
Mkln1	27418	-0.3913605	0.0653295	0.38489715	0.51743648	0.00021268	0.0024387
BC055324	381306	-0.3587083	0.17158727	0.61720523	0.51734185	0.01937324	0.08481204
Kbtbd2	210973	-0.6334832	0.00231307	0.05552463	0.51676303	0.01658922	0.07586202
Dusp16	70686	-0.1968644	0.32756613	0.80591299	0.51659189	0.01533448	0.07167071
Sf3b1	81898	-0.4596609	0.02119567	0.20540453	0.51645584	6.86E-07	1.96E-05
Stk3	56274	-0.6210524	0.01418919	0.1623017	0.5161939	0.0221744	0.09333093
Nbn	27354	-0.5261188	0.02061131	0.20186011	0.51535738	0.00578835	0.03471687
Rb1	19645	-0.4294368	0.03309838	0.25934515	0.51533715	0.00800485	0.04420741
Gba	14466	-0.5844783	0.00276508	0.06235099	0.51482046	0.0025973	0.01842243
Dsg3	13512	-0.4040441	0.04658289	0.31838815	0.51452633	5.35E-05	0.00075958
Pigg	433931	-0.6112758	0.0125282	0.1529756	0.51432167	0.01025946	0.0534086
Gstp1	14870	-0.4511561	0.06932124	0.38698979	0.51411353	0.00993801	0.05196183
Dkc1	245474	-0.5479621	0.00349503	0.07124557	0.51398491	0.00024553	0.00274351
Tardbp	230908	-0.4176719	0.02578409	0.23124248	0.51358616	7.11E-06	0.0001412
Ctsl	13039	-0.6521266	0.00191962	0.05026514	0.5131321	1.20E-05	0.00022181

Kat7	217127	-0.2261343	0.22232059	0.68019183	0.51280905	0.00121095	0.01024007
Smc2	14211	-0.2019831	0.30664001	0.80097384	0.51265928	0.00074595	0.00689691
Hcar2	80885	-0.3315204	0.1219539	0.52927604	0.5115327	0.0214771	0.09137164
Tstd2	272027	-0.4422336	0.02787299	0.239767	0.51129492	0.01500747	0.07062117
0610009B22Rik	66050	-0.5875101	0.03893015	0.28722453	0.51106055	0.01157088	0.05863147
Atxn10	54138	-0.4872682	0.0088942	0.12487241	0.5107998	3.17E-05	0.0004987
Rbbp7	245688	0.23907643	0.22636615	0.68714576	0.51068678	6.88E-05	0.00094551
Tom1l1	71943	-0.4911656	0.02001729	0.19847431	0.51024941	0.00320007	0.02165653
Minos1	433771	-0.5610503	0.00352631	0.07158434	0.51021438	0.00029443	0.00318727
Rngtt	24018	-0.3587544	0.10633143	0.48920873	0.51009663	0.0068546	0.03936747
Nfia	18027	-0.46318	0.03202064	0.25463236	0.50991038	0.0041514	0.02665216
Prep	19072	-0.3884092	0.06096881	0.37260241	0.5097907	9.79E-06	0.00018713
Obfc1	NA	-0.2944103	0.28739789	0.78612723	0.50923748	0.01012331	0.05280451
Haus2	66296	-0.5934482	0.02256089	0.21321964	0.50922148	0.01436904	0.06861456
Gemin4	276919	-0.3153222	0.12993303	0.55020692	0.50915585	0.00446938	0.02827926
Nup54	269113	-0.6073333	0.00283304	0.06282472	0.50912163	0.00047463	0.00474231
Med23	70208	-0.301931	0.12073019	0.52612665	0.50837925	0.00145698	0.01174978
Sec16a	227648	-0.3047563	0.07510358	0.40328767	0.50829724	0.0013509	0.01116279
Arcn1	213827	-0.3723162	0.03775301	0.28237863	0.50648972	9.30E-06	0.00017896
Ddb1	13194	-0.2785932	0.13917574	0.57074908	0.50642763	4.29E-06	9.33E-05
Haus3	231123	-0.5645637	0.08098111	0.42140203	0.50625185	0.0208196	0.08950246
Cul1	26965	-0.6356365	0.00315474	0.06716819	0.50622392	2.52E-05	0.00041194
Nfib	18028	-0.1829873	0.35842035	0.84892641	0.50599008	2.66E-05	0.00043084
Tmem185b	226351	-0.6583696	0.01077114	0.13895504	0.5057677	0.02284581	0.09537126
N4bp2l2	381695	-0.3787287	0.04455188	0.31105354	0.50540594	0.00062748	0.0059958
Thoc1	225160	-0.6055401	0.0070198	0.10905247	0.50535431	0.00347213	0.02306963
Acsl3	74205	-0.5856751	0.00892055	0.12505663	0.50534214	0.00351554	0.02325215
Ints4	101861	-0.4659873	0.02318154	0.21632261	0.50517793	0.00079172	0.00721343
Mrpl42	67270	-0.4753978	0.04582865	0.3149745	0.50509381	0.01054083	0.05457041
Urb1	207932	-0.1969451	0.36852799	0.86338682	0.50461136	0.0236569	0.09754756
Ranbp6	240614	-0.2859617	0.31512802	0.80097384	0.50452284	0.02367017	0.09757163
Zcchc7	319885	-0.1093507	0.63197124	1	0.50450209	0.02322931	0.09645086
Nampt	59027	-0.5924922	0.00469909	0.08621815	0.50397909	0.00327898	0.02207681
Cisd2	67006	-0.5382828	0.00952591	0.12967239	0.50387154	0.00528611	0.03237002
Mios	252875	-0.4943641	0.0303503	0.24762758	0.50367523	0.01332206	0.06512554
Cpt2	12896	-0.5680188	0.00953317	0.12967552	0.50356839	0.01391222	0.0671498
Urb2	382038	-0.1811377	0.40111034	0.90211288	0.50353551	0.01343089	0.06545438
Rrm1	20133	-0.0378415	0.84829015	1	0.50257977	0.00033399	0.00353915
Fam172a	68675	-0.2228437	0.31555575	0.80097384	0.50102345	0.00465911	0.02914773
Fbxo5	67141	-0.6376946	0.00497602	0.08909047	0.50055805	0.01785201	0.08007484
Rrp8	101867	-0.4992419	0.00884703	0.12452646	0.50015348	0.01517836	0.07114486
Fopnl	66086	-0.3710142	0.09976938	0.47503762	0.5000123	0.00844844	0.04596749
Terf2ip	57321	0.12668947	0.50795849	1	-0.5000938	0.00711349	0.04048896
Trak1	67095	0.31196671	0.0727252	0.39607988	-0.5002834	0.021374	0.09111013
Cdc25b	12531	0.1788309	0.31561744	0.80097384	-0.5007077	0.00432233	0.02758767
Psmd9	67151	0.42827234	0.02724021	0.2374137	-0.5008308	0.00451285	0.02843053
Pgrmc2	70804	0.26864525	0.15114781	0.59583225	-0.5031826	0.00021361	0.00244515
Zcchc9	69085	-0.0462241	0.87886732	1	-0.5035935	0.01377967	0.066708
Tada3	101206	0.4049862	0.0461558	0.31620763	-0.503778	0.01517682	0.07114486
Pou3f1	18991	0.25073604	0.32354067	0.80263986	-0.5040669	0.01628216	0.07482273
Cdv3	321022	-0.0317801	0.85699344	1	-0.5041911	0.00347602	0.02308381
Adrbk1	NA	0.43892495	0.01146808	0.14428749	-0.5042494	0.00290158	0.0200394
Fmnl2	71409	0.28268759	0.15356917	0.60120433	-0.5058515	0.0201826	0.08739358
Ahsa2	268390	0.05428709	0.83922035	1	-0.5060343	0.01614231	0.07444059
Isy1	57905	0.48017556	0.01335534	0.1574847	-0.5083605	0.00189766	0.01445987
Utp18	217109	0.34986954	0.06295645	0.3786846	-0.5083702	0.00134515	0.01113523
Ndufb3	66495	0.07317239	0.70068178	1	-0.5085387	0.00078552	0.00717685
Tnfrsf1a	21937	0.07242158	0.66911131	1	-0.5094938	0.00053925	0.00525986
Bach2	12014	0.17134276	0.33676326	0.81921462	-0.5104368	0.00693716	0.03971623
Cdc42ep4	56699	0.21763046	0.19506302	0.63011034	-0.5115287	0.01660389	0.07587625
Lonp1	74142	0.48491103	0.00550761	0.09491381	-0.5143579	0.00024703	0.00275555
Msantd4	78100	-0.0432773	0.8413893	1	-0.515026	0.00638193	0.03725582
Sdc4	20971	0.22125925	0.2722887	0.76230224	-0.5165991	4.21E-05	0.00063096

Rps15	20054	0.67073638	0.00360118	0.07226325	-0.5167456	0.00012873	0.00159599
Exosc3	66362	0.19577168	0.31770989	0.80097384	-0.517119	0.0013915	0.01140385
Synpo2	118449	0.50628812	0.022457	0.21270069	-0.5171448	0.02048256	0.08842998
Rdh13	108841	-0.0135256	0.94743476	1	-0.5171664	0.01855241	0.08237222
Pex19	19298	0.21854338	0.20294802	0.64609107	-0.5178549	0.00034399	0.0036304
Ndufb7	66916	0.32882572	0.13146194	0.55352806	-0.5179102	0.00023711	0.00266295
Ubtf	21429	0.52521435	0.01088834	0.14002327	-0.5180162	6.92E-05	0.0009499
Snf8	27681	0.48706531	0.0075249	0.11364597	-0.5193091	0.00271735	0.01899687
Igf2	16002	0.2864795	0.30611823	0.80097384	-0.5203423	0.00939804	0.04983314
Arhgef1	16801	0.44227679	0.01406603	0.16127069	-0.5215362	0.00073141	0.00679118
Brd1	223770	0.38033503	0.03032147	0.24762758	-0.521547	0.0006074	0.00583363
Chmp4b	75608	0.37949821	0.04173288	0.29861082	-0.5221207	0.00027291	0.0029959
Arhgap10	78514	0.39483827	0.02433331	0.22294166	-0.5223453	0.00178233	0.01374055
Cd2bp2	70233	0.32036196	0.07851568	0.4136853	-0.5241632	0.00269508	0.01890154
Arhgef2	16800	0.48406359	0.00719827	0.11076808	-0.524286	0.0026088	0.01848406
Pck2	74551	0.60388321	0.00372648	0.07372697	-0.5252598	0.0051464	0.03166303
Slain2	75991	-0.0565876	0.76257528	1	-0.5253683	0.00783134	0.04351148
Ppp1r14b	18938	0.40963479	0.096662	0.46804118	-0.5254392	0.00013993	0.00170578
Foxn2	14236	-0.1575154	0.38548981	0.88636161	-0.5255873	0.02314093	0.09625928
Tfam	21780	-0.0638349	0.7672006	1	-0.5258447	0.00090712	0.00805787
Purb	19291	-0.2420828	0.19033189	0.62107097	-0.5260255	0.00086599	0.00775548
Ubr7	66622	0.08763923	0.63603115	1	-0.5261968	0.00022389	0.00253187
Pcdh7	54216	-0.0497148	0.79900846	1	-0.5275736	0.00989189	0.05174126
Rerg	232441	-0.0752977	0.72273348	1	-0.5276689	0.01206823	0.06038252
Mtif3	76366	0.25663737	0.2707443	0.75947503	-0.5279199	0.0110811	0.05674096
Polr3h	78929	0.32670405	0.0899518	0.44794308	-0.5279793	0.01254896	0.06227258
Il10rb	16155	0.02201449	0.92901371	1	-0.5279917	0.01915461	0.08418411
Fmnl3	22379	0.32643461	0.12781522	0.54560967	-0.5285202	0.01932551	0.08465955
Lemd3	380664	0.27406563	0.23541275	0.70171827	-0.5286589	0.01901265	0.0837641
1110059E24Rik	66206	-0.2704107	0.26020658	0.74321696	-0.5287542	0.00297645	0.02047001
Zc3h15	69082	-0.0239215	0.89490273	1	-0.5290925	8.24E-06	0.00016099
Stk38	106504	-0.1011673	0.60003196	1	-0.5291921	0.00236111	0.01706053
Ckap4	216197	0.15544344	0.39838327	0.8995401	-0.5293157	3.03E-05	0.00048201
Emc10	69683	0.24597444	0.20473876	0.64875116	-0.5293562	0.00255028	0.01816746
Itgb5	16419	0.53922632	0.00524752	0.09171093	-0.5296115	3.80E-05	0.00057949
Eif4a2	13682	0.15190423	0.40264187	0.90348879	-0.5298864	0.00017513	0.00206213
Lef1	16842	0.30089869	0.12113722	0.52713686	-0.5303827	0.00100367	0.00877313
Csad	246277	0.3813888	0.05653292	0.35600577	-0.530421	0.00671845	0.03880621
Grk6	26385	0.42721696	0.02547732	0.22943414	-0.5305894	0.01073509	0.05542313
Nkap	67050	-0.3572472	0.09943884	0.47420344	-0.5306254	0.00687354	0.03945898
Cir1	66935	0.17821565	0.46108211	0.96826041	-0.5310222	0.00170849	0.01331206
Ube2q1	70093	0.34071277	0.07364279	0.39920376	-0.531337	0.00191223	0.01450353
Ercc2	13871	0.51100496	0.00650134	0.10497893	-0.5333701	0.01137858	0.05790055
Stmn1	16765	0.25453008	0.16873778	0.61720523	-0.5337645	0.00110308	0.00947797
Ppp1r21	73825	0.48592836	0.01382382	0.15999597	-0.5341078	0.00299527	0.02055669
Ubl3	24109	0.29219692	0.09295694	0.45626811	-0.534122	0.02110529	0.09028719
Cbfb	12400	-0.0344892	0.85049583	1	-0.5342218	0.00016818	0.00198921
H2afv	77605	0.49116316	0.0092176	0.12765623	-0.534724	0.00075074	0.00692164
Cox6a1	12861	0.35558871	0.04185335	0.29924599	-0.5349311	1.53E-05	0.00027172
Zfp598	213753	0.34805884	0.08743051	0.44068945	-0.535636	0.00591063	0.03527303
Nip7	66164	-0.0837496	0.68091024	1	-0.5366845	4.38E-05	0.00065003
Pnrc1	108767	0.12288424	0.54173265	1	-0.5367566	0.00011578	0.00146961
Krt17	16667	0.61136389	0.00261476	0.06024063	-0.5368115	5.41E-06	0.0001134
Ptma	19231	0.03799701	0.86925232	1	-0.5368598	3.83E-05	0.00058275
Tax1bp3	76281	-0.0562532	0.76971051	1	-0.5382981	0.0002842	0.00309651
Adcy7	11513	0.24569762	0.19502081	0.63005731	-0.5388349	0.01229004	0.06119452
Panx1	55991	0.48648942	0.02732119	0.23779883	-0.5388701	0.01400113	0.06743242
Esf1	66580	0.41016631	0.05071743	0.3352017	-0.5390123	0.00045523	0.00459744
Bod1	69556	0.29214819	0.08817715	0.4430811	-0.5391216	0.01331368	0.06512491
Fbxl17	50758	0.10979454	0.57172549	1	-0.540165	0.01452066	0.06899808
Dnttip1	76233	0.25905297	0.22362791	0.68229921	-0.5401804	0.01299763	0.06393625
Otulin	432940	0.25826478	0.17480631	0.61720523	-0.5403016	0.01737742	0.07848235
Kif1bp	72320	0.42662769	0.03888116	0.28712335	-0.5408135	0.0043052	0.02750511

Ndufs6	407785	0.14779435	0.40436394	0.9056675	-0.5408269	5.19E-05	0.00074003
Pdap1	231887	0.52764377	0.01480442	0.16630122	-0.540982	5.04E-05	0.00072172
Chd3	216848	0.54183272	0.01362887	0.15854102	-0.5416799	0.00033735	0.0035661
Ncaph2	52683	0.42738463	0.01297564	0.15557684	-0.5417957	0.00011185	0.00143689
Kremen2	73016	0.48590323	0.01567542	0.17184873	-0.5421691	8.89E-05	0.00118191
Fbxw8	231672	0.58537569	0.00246365	0.05801815	-0.5433077	0.0007897	0.00720501
Aatf	56321	0.56631999	0.00505939	0.08979321	-0.5433165	0.00113054	0.009657
Axin2	12006	0.36976596	0.04568731	0.31466444	-0.5433756	0.00325653	0.02195944
Zfyve21	68520	0.20984136	0.3391526	0.82330474	-0.543592	0.02356476	0.0974124
Rps14	20044	0.47988614	0.01065084	0.1382797	-0.5438961	5.45E-06	0.00011417
Brd9	105246	0.39059938	0.05836751	0.36306495	-0.5456074	0.02049426	0.08845138
Hist1h2ac	319164	0.18233102	0.39404094	0.89482365	-0.5463239	0.00602924	0.03586629
Ankrd11	77087	0.44927221	0.034982	0.26949383	-0.5466039	0.00031649	0.00338375
Srsf1	110809	-0.2445475	0.20086782	0.64223527	-0.5470978	2.77E-07	8.91E-06
Pbx1	18514	0.01795529	0.919101	1	-0.5479227	0.00146139	0.01177093
Spats2	72572	0.50078577	0.01377573	0.15958065	-0.5479673	0.00135341	0.01116837
Rnf34	80751	0.05999587	0.76390294	1	-0.5482421	0.00240165	0.01733438
R3hdm4	109284	0.23799945	0.1710811	0.61720523	-0.5483372	0.00203149	0.0152321
Mesdc2	67943	-0.0675307	0.75035144	1	-0.5483412	0.00131085	0.0109271
Ctdsp2	52468	0.17305699	0.34336877	0.82925323	-0.5498619	0.00013509	0.00165838
Nifk	67949	0.04322078	0.83306536	1	-0.5500262	8.31E-05	0.00111357
Fam96b	68523	0.11680237	0.68321624	1	-0.5515797	0.0163856	0.07516649
N4bp3	212706	0.48591795	0.01981153	0.1974385	-0.5516467	0.01845564	0.08210395
Epb4.1l4b	NA	-0.1767502	0.31751759	0.80097384	-0.5520557	0.01210359	0.06049031
Map7	17761	0.37156946	0.09850548	0.47104019	-0.552291	0.00069316	0.00648641
Ubxn1	225896	0.48610161	0.00840383	0.1204542	-0.5523233	5.32E-05	0.00075682
Jund	16478	0.61295694	0.00468695	0.08606018	-0.5528813	0.00192299	0.01456834
Smyd3	69726	0.2634885	0.23013961	0.69368545	-0.5536207	0.00232035	0.01688294
Ak2	11637	0.15454176	0.4007456	0.90211288	-0.555702	1.28E-05	0.00023389
2810004N23Rik	66523	0.19324853	0.3222489	0.8010706	-0.5562423	0.00442611	0.02807941
Sema4d	20354	0.11255063	0.52075564	1	-0.557264	0.01141371	0.05801417
Irx5	54352	0.19523064	0.42475012	0.92991068	-0.5572734	0.00681111	0.03916913
Acap3	140500	0.42475804	0.01292445	0.15555845	-0.5575557	0.01846803	0.08210861
Tipin	66131	0.21997098	0.25024403	0.72661277	-0.5576479	0.00163453	0.01282706
9130401M01Rik	75758	0.43962185	0.01799294	0.18720192	-0.5576875	0.01652358	0.07566727
Sdf4	20318	0.31186655	0.06293454	0.3786846	-0.5582422	4.57E-05	0.0006733
2700094K13Rik	NA	0.27940679	0.13066971	0.55178276	-0.5582946	0.00270323	0.01894746
Cdc42se1	57912	-0.052309	0.75516555	1	-0.5595706	0.00014279	0.00173416
Lmna	16905	0.43913055	0.04020572	0.29199085	-0.5600263	2.01E-05	0.00033873
Pak4	70584	0.3903387	0.02405675	0.22119347	-0.5609925	0.00920327	0.04909782
Rbfa	68731	0.50752512	0.01271272	0.15448855	-0.5613842	0.00536824	0.03278119
Txndc15	69672	0.32390646	0.11240534	0.50544115	-0.5614456	0.00442957	0.028081
N6amt2	NA	0.30847985	0.16421782	0.61720523	-0.5617578	0.00318377	0.02161306
Tulp3	22158	0.40039648	0.04160311	0.29811903	-0.5624096	0.00138061	0.01132874
Stard10	56018	0.58822857	0.0023849	0.05687666	-0.5624976	0.00135234	0.01116656
Htatsf1	72459	0.29446768	0.13216521	0.55533491	-0.5626624	0.0020362	0.01525872
Psmg3	66506	0.33754967	0.12882567	0.54780633	-0.5632216	0.01110463	0.05681711
Psmc3ip	19183	0.3892131	0.11057006	0.50171522	-0.5632952	0.00884304	0.04744594
Dnajc17	69408	0.61568456	0.03692005	0.2784511	-0.5633293	0.01138384	0.05790055
Timm17b	21855	0.20501712	0.41816874	0.92227994	-0.5638765	0.01142027	0.05802505
Smo	319757	0.40038663	0.03089184	0.24947407	-0.5669389	0.00454477	0.02860419
Ltbp3	16998	0.34317434	0.05492334	0.34947444	-0.5670192	0.00096617	0.0084869
Suv420h1	NA	0.12559013	0.48208237	0.98974397	-0.567032	0.00329303	0.02212597
Hars2	70791	0.34258699	0.14476689	0.58378054	-0.5671156	0.00136195	0.01120365
Cyb5r1	72017	0.18683627	0.3913003	0.89123505	-0.5678478	0.00579807	0.03474344
Hook2	170833	0.57334566	0.00965118	0.13036944	-0.5682676	0.00084277	0.00758895
Ddrgk1	77006	0.29431685	0.31929424	0.80097384	-0.5684953	0.00220218	0.01625381
Dgkd	227333	0.17449992	0.35447667	0.84422418	-0.5688462	0.01611322	0.07436476
Sh2b1	20399	0.61213152	0.00533367	0.09283937	-0.5688649	0.02231943	0.09368026
Grip1	74053	0.27471626	0.14938217	0.59118088	-0.5692904	0.00970356	0.05095327
Rrp9	27966	0.38382867	0.06847139	0.38661538	-0.570025	0.01163398	0.05886033
Fkbp8	14232	0.50077076	0.00708477	0.10957384	-0.5712131	2.98E-05	0.00047641
Iscu	66383	0.3690502	0.07065229	0.38948073	-0.5719012	0.02153864	0.09152504

Tmed1	17083	0.19791025	0.35425908	0.84403522	-0.5720165	0.00155152	0.01234543
Sumf2	67902	0.33409344	0.10033454	0.47679897	-0.5722924	0.00380614	0.02487346
H1fx	243529	0.40900835	0.12365712	0.53389444	-0.572661	0.01074966	0.05545475
Mlf2	30853	0.49890761	0.01075236	0.13885948	-0.5741852	8.48E-05	0.00113316
Pja1	18744	0.38543398	0.04728253	0.32172933	-0.5744495	3.81E-05	0.00058071
Tsr2	69499	0.05424335	0.79667326	1	-0.574754	0.01094924	0.05626325
Acin1	56215	0.41500325	0.05059415	0.33474929	-0.5749605	1.59E-05	0.00028046
Tmem11	216821	0.31094684	0.12242953	0.53017276	-0.5752957	0.00765451	0.0427643
Mob2	101513	0.4466047	0.01291717	0.15555845	-0.576619	0.000124	0.00154602
Sash1	70097	0.39494677	0.02851662	0.24155545	-0.577265	0.00168104	0.01312149
Hs6st1	50785	0.18599649	0.2772505	0.77049519	-0.5778493	0.00793185	0.04392376
Ppfia1	233977	0.46326678	0.00628741	0.10318869	-0.5779486	3.45E-05	0.00053687
Arfrp1	76688	0.52122118	0.01040022	0.13618426	-0.5785195	0.00562269	0.03396475
Nsg1	18196	0.360237	0.06139275	0.37441239	-0.5785824	0.00165162	0.0129226
Gramd4	223752	0.24637819	0.17475591	0.61720523	-0.5786652	0.00406508	0.02621335
Ltbp4	108075	0.45775635	0.01318709	0.15655904	-0.5790271	8.37E-06	0.00016307
Wwc2	52357	0.50603691	0.00478757	0.08692732	-0.5807364	0.01137022	0.05790055
Fam207a	108707	0.33126236	0.07749407	0.41078418	-0.580805	0.01685285	0.07685344
Vps37c	107305	0.21435057	0.22978132	0.69303317	-0.5810069	0.01582046	0.07331691
Knstrn	51944	0.1322666	0.48361499	0.99077713	-0.5816201	0.00041689	0.00427608
Ccdc8	434130	0.62461068	0.01189206	0.1478805	-0.582428	0.00426818	0.02733509
Rab35	77407	0.31111514	0.07242017	0.39537013	-0.5828751	0.00014147	0.00172143
Ddit4	74747	0.49796343	0.06278567	0.37849636	-0.5829429	0.00065363	0.00621846
Kansl3	226976	0.25858609	0.13533139	0.56338705	-0.5843337	0.00433354	0.02764578
Tbc1d10a	103724	0.37765893	0.03072422	0.24911357	-0.5852607	4.49E-05	0.00066463
Timp2	21858	-0.1589262	0.48969464	0.99781668	-0.5863599	0.00722111	0.04097061
Fdx1	14148	0.14313176	0.51382423	1	-0.586882	0.00019276	0.00223766
Arfgap1	228998	0.51385108	0.00501622	0.08925086	-0.5887313	0.00132253	0.0109966
Siva1	30954	0.44327013	0.0165783	0.17811641	-0.5906406	1.01E-05	0.00019203
Ino80e	233875	0.21045435	0.37728502	0.87507622	-0.5913863	0.00062822	0.00599849
Rufy1	216724	0.18139402	0.36655684	0.86040797	-0.5917758	0.0007862	0.00717803
Gltscr2	68077	0.66723566	0.00499057	0.08917652	-0.5924087	4.39E-07	1.34E-05
Trim35	66854	0.16862746	0.37450195	0.87218311	-0.5934333	6.99E-05	0.00095619
Ythdc1	231386	0.32928281	0.09264686	0.45536296	-0.5934858	4.00E-05	0.00060233
Msl1	74026	0.32147917	0.08613911	0.43661336	-0.5938397	0.02177111	0.09220415
Cript	56724	-0.1486443	0.49072483	0.99858272	-0.5948309	0.00451145	0.02843053
Tab1	66513	0.52284871	0.01196322	0.148151	-0.5948669	0.00558839	0.03381106
Zfp444	72667	0.39969651	0.03418264	0.26500767	-0.5950989	0.02333461	0.09670279
Pdss1	56075	0.1055206	0.7897878	1	-0.5955762	0.02261555	0.09465082
Zc3h11a	70579	0.28084715	0.10640491	0.48945456	-0.5963665	0.00031317	0.00335364
Rps11	27207	0.46891228	0.03180144	0.25371547	-0.5963688	2.26E-07	7.41E-06
Prpf18	67229	0.20915477	0.28121943	0.77662103	-0.5964894	0.00018977	0.00220677
Hnrnpab	15384	0.27198611	0.13522559	0.5632516	-0.5964953	4.54E-07	1.38E-05
Csrp2bp	228714	0.36449137	0.03795384	0.28336009	-0.5975643	0.01581484	0.07331676
Nde1	67203	0.0420114	0.80982188	1	-0.597608	3.44E-05	0.00053622
Rac3	170758	0.34897349	0.08396815	0.42999443	-0.5982536	0.00218144	0.01614441
Cnpy3	72029	0.34698855	0.0878826	0.44223799	-0.5983245	0.00222179	0.0163508
St5	76954	0.36425433	0.03891573	0.2872049	-0.5986433	0.00706165	0.04023978
Sf3b2	319322	0.50449559	0.01569835	0.17195944	-0.5998062	2.80E-07	8.97E-06
Mex3a	72640	0.39110919	0.02230314	0.21168478	-0.6000787	0.00982583	0.05145723
Vkorc1l1	69568	-0.1495392	0.38791605	0.88817719	-0.6007442	0.00305636	0.02088485
Ppif	105675	-0.1188389	0.52900861	1	-0.6009095	0.00029682	0.00320474
Ctgf	14219	-0.0327464	0.86751521	1	-0.6013885	0.00022414	0.00253244
Btbd1	83962	-0.0600638	0.74402027	1	-0.6015005	0.00074812	0.00690718
Cdkn1b	12576	0.31662623	0.06908425	0.38698979	-0.6016798	0.00065145	0.00621127
Ndufa13	67184	0.4522042	0.02452598	0.22415751	-0.6020096	4.88E-05	0.00070412
Sox4	20677	0.52255905	0.02664831	0.2350229	-0.6027859	3.94E-05	0.00059564
Csrp1	13007	0.46738046	0.00563021	0.09615058	-0.6029709	5.59E-06	0.0001165
Dlgap4	228836	0.340262	0.05614103	0.35463531	-0.6037289	0.00142525	0.01156824
Ttyh3	78339	0.46103134	0.0213813	0.20662952	-0.6039391	0.00160338	0.01265567
Coa7	69893	0.11278026	0.65696291	1	-0.6039628	0.01500589	0.07062117
Mea1	17256	0.15776452	0.48085455	0.98938082	-0.6060127	0.00305941	0.02088485
Tnk2	51789	0.56817154	0.00501787	0.08925086	-0.6060923	0.01626706	0.07480567

Arpc5l	74192	0.20826581	0.28902868	0.7889623	-0.6061646	0.00049562	0.00490726
Nfu1	56748	0.35893632	0.14744918	0.58813801	-0.6065532	0.00074409	0.00688942
Mt2	17750	0.40122161	0.05858632	0.36414773	-0.6066899	1.23E-05	0.00022611
Sltm	66660	0.53709188	0.00433989	0.0812765	-0.6073039	1.23E-05	0.00022737
Ap2s1	232910	0.51679889	0.00320815	0.06778697	-0.608031	4.02E-07	1.24E-05
Lrrfip2	71268	0.32032459	0.09836965	0.47085165	-0.6103021	0.00531887	0.03254026
Cbx5	12419	-0.3654007	0.05538225	0.35125027	-0.6105078	3.83E-06	8.61E-05
Srsf4	57317	0.57126597	0.00241753	0.05748636	-0.6106794	3.57E-05	0.00055197
Cxxc1	74322	0.54212886	0.00197379	0.05122415	-0.6110325	0.00057366	0.0055666
Drap1	66556	0.37507007	0.20308962	0.64609107	-0.611179	0.00047954	0.00478405
Cactin	70312	0.64243242	0.0131351	0.15632177	-0.6115991	0.00352406	0.02328505
Thra	21833	0.51625687	0.01117681	0.14208691	-0.613822	0.02037056	0.08800432
Lrrc58	320184	-0.0624491	0.7511848	1	-0.6141056	0.00152562	0.0121762
Ptn	19242	0.41083934	0.05728557	0.35861854	-0.6145694	5.06E-06	0.00010699
Nob1	67619	0.5329298	0.00536361	0.09302898	-0.6148428	0.00012493	0.00155464
Cdc73	214498	0.02863194	0.88151887	1	-0.6155142	1.06E-05	0.00020068
Zfyve27	319740	0.26044136	0.18280159	0.61720523	-0.6172095	0.01201161	0.06014509
Timm10	30059	-0.1974738	0.48285978	0.99006485	-0.618074	0.00265069	0.01866774
Ptrf	19285	0.5543068	0.01104381	0.14120463	-0.6192978	1.90E-05	0.0003248
Adamts14	237360	0.50977375	0.02041498	0.20119215	-0.6210228	0.0128673	0.06350934
Mrps30	59054	0.56612132	0.00980202	0.13138039	-0.6212613	0.00024197	0.00271057
Atn1	13498	0.57508444	0.00673411	0.1069965	-0.6248116	0.00984658	0.05152481
Hoxc13	15422	0.27861791	0.16669698	0.61720523	-0.6249079	0.00935789	0.04972067
Dnmbp	71972	0.34458405	0.054372	0.34797302	-0.6249344	0.00740511	0.04174397
Cnpy4	66455	0.35237359	0.09060835	0.44978874	-0.6263014	0.00026802	0.002952
Gna13	14674	-0.0993306	0.57967543	1	-0.6264782	4.17E-06	9.14E-05
Rbm15b	109095	0.61724711	0.00470411	0.08623107	-0.6277914	0.00850728	0.04619193
Pdcl3	68833	0.22235596	0.30970348	0.80097384	-0.6281881	1.35E-05	0.00024564
Hnrnpa0	77134	0.41431556	0.136953	0.56682048	-0.6283415	2.40E-07	7.79E-06
Rexo1	66932	0.47045879	0.00979424	0.1313482	-0.6299283	0.02120994	0.09064624
Nf2	18016	0.22531117	0.18069596	0.61720523	-0.6302063	0.00144302	0.0116803
Ube2g2	22213	0.13735448	0.4590628	0.96596283	-0.6309173	0.00041779	0.00428195
Trim26	22670	0.25768496	0.23208967	0.69689681	-0.6314039	0.00795852	0.04403179
Zc3h18	76014	0.61723034	0.01096561	0.14042538	-0.6328748	1.94E-05	0.00033026
Ftl1	14325	0.28883636	0.13636147	0.56563366	-0.6333482	0.00022009	0.00249536
Rxrb	20182	0.45374006	0.01778734	0.18649611	-0.6336929	0.00439361	0.02793399
Ing2	69260	0.36355387	0.09641925	0.46755696	-0.6338885	0.01407879	0.06773194
Fam117a	215512	0.22883235	0.27784495	0.77131426	-0.6339767	0.01460187	0.06923622
Rbm43	71684	0.38036276	0.15400102	0.60185398	-0.6341761	0.01369204	0.06640666
Ctdspl	69274	0.14857276	0.3876963	0.88817719	-0.6365007	0.00702054	0.04005764
Impad1	242291	-0.2445989	0.16624551	0.61720523	-0.6366044	9.16E-06	0.00017656
Nol7	70078	0.43775217	0.05366254	0.34532092	-0.637584	0.00011846	0.00149404
Krt35	53617	0.31185543	0.20054126	0.64169525	-0.6380263	0.00965906	0.05078798
Serf2	378702	0.27582623	0.15222267	0.59833088	-0.6386281	5.53E-06	0.00011556
Lad1	16763	0.45446773	0.04526819	0.31352654	-0.6387436	3.51E-07	1.10E-05
Chmp6	208092	0.42118986	0.05556411	0.35199254	-0.639563	0.00409248	0.02637711
Alyref	21681	0.27316353	0.171813	0.61720523	-0.6407128	3.52E-06	7.95E-05
Srsf9	108014	0.41995736	0.02132972	0.20634963	-0.6423835	3.84E-07	1.19E-05
Hnrnpc	15381	0.15826669	0.40769193	0.90932913	-0.6429338	8.29E-08	3.10E-06
Marcksl1	17357	0.50155001	0.01145606	0.14421053	-0.64301	1.27E-06	3.30E-05
Xpa	22590	0.79673886	0.01346144	0.15779142	-0.6451765	0.02209062	0.09307693
Nat9	66176	0.33140139	0.26092775	0.74429829	-0.6452453	0.01552414	0.07240373
Uri1	19777	0.26285579	0.14085609	0.57474464	-0.6457682	0.00330008	0.02215066
Naa30	70646	-0.177651	0.35706787	0.847585	-0.6461154	0.00118144	0.01002581
Mdm2	17246	0.34825813	0.0705008	0.38899685	-0.6464318	0.00210438	0.01568907
Rps6ka4	56613	0.32466016	0.05307694	0.34336208	-0.6482382	0.00012375	0.00154582
Ccdc91	67015	0.42733965	0.02261831	0.21343787	-0.6507289	0.00161061	0.0126953
Gripap1	54645	0.49892765	0.01770455	0.18580265	-0.6521975	0.0010544	0.00913138
Tbc1d2b	67016	0.26219502	0.17971733	0.61720523	-0.6527719	0.00273821	0.01909184
Rufy3	52822	0.33578817	0.10717552	0.49197998	-0.6545639	0.00959686	0.05060932
Fam8a1	97863	0.47011175	0.09930871	0.47376793	-0.6547433	0.01175761	0.05932575
Mrps26	99045	0.49149435	0.0577243	0.36020371	-0.6556791	0.00072016	0.0067152
Naga	17939	0.29405905	0.25315882	0.73125816	-0.6562122	0.00025893	0.0028688

2310036O22Rik	68544	0.57815625	0.00793549	0.11716609	-0.6565677	0.00241121	0.01737478
Kin	16588	0.35849026	0.15822556	0.60939998	-0.6571537	0.00087551	0.00781946
Wdr4	57773	0.37853696	0.05472339	0.34839305	-0.6575844	0.0045494	0.02861177
Stx16	228960	0.08554851	0.62866941	1	-0.6576881	0.01335221	0.06524047
Nrbp2	223649	0.41060641	0.01783866	0.18654824	-0.6577466	0.01312374	0.06445998
Chmp3	66700	0.01496001	0.93597163	1	-0.6580097	8.72E-05	0.00116197
Cpox	12892	0.42463483	0.02278056	0.21430047	-0.6607103	4.45E-05	0.00065982
Snrnp48	67797	0.27380049	0.25236474	0.73035578	-0.6615376	0.00359653	0.02369237
Ado	211488	-0.0407058	0.81764676	1	-0.6616505	0.00400458	0.02589955
Tcf3	21423	0.51598491	0.00840481	0.1204542	-0.6640033	1.31E-05	0.00023808
Rrp36	224823	0.65284322	0.00493805	0.08872476	-0.6641714	0.00261614	0.0185161
Mcur1	76137	-0.0462148	0.83991681	1	-0.6643383	0.02348672	0.09715095
Tysnd1	71767	0.59959089	0.00633638	0.10350555	-0.6645512	0.01490303	0.07023039
Scaf1	233208	0.6435698	0.0078666	0.11664255	-0.6661422	0.00037861	0.00393566
Krt25	70810	0.51503433	0.00519118	0.0911022	-0.6663086	0.00029428	0.00318727
Deaf1	54006	0.52585346	0.00640561	0.10412451	-0.6669892	0.01569531	0.07302045
Jmy	57748	0.19071705	0.29925301	0.80097384	-0.6675287	7.05E-05	0.00096341
Atp13a2	74772	0.51376795	0.0052477	0.09171093	-0.668074	0.0004691	0.00471258
Glcci1	170772	0.01511016	0.94464333	1	-0.6681445	0.00802054	0.0442258
Surf6	20935	0.24650448	0.20231692	0.64472034	-0.66825	0.00036625	0.00381953
Fam76a	230789	0.42331827	0.01981778	0.1974385	-0.6683548	0.00065204	0.00621237
Zbtb7a	16969	0.62708891	0.00222064	0.05455766	-0.6684507	1.47E-05	0.00026325
Zc3hav1l	209032	-0.1055433	0.57055386	1	-0.6694643	0.00569694	0.03426255
Taf11	68776	0.43602761	0.05528697	0.3509573	-0.669731	0.00353816	0.02336644
Kti12	100087	0.37839774	0.04189137	0.29924599	-0.6698274	0.00801686	0.04422409
Ccdc71	72454	0.28136194	0.12833169	0.54684841	-0.6699944	0.00158193	0.01251905
Sap30	60406	0.47955025	0.02455379	0.2243278	-0.6700311	3.07E-05	0.00048574
Cnnm3	94218	0.33923859	0.09350114	0.45750178	-0.6700688	0.00824534	0.04516188
Creld2	76737	0.23008136	0.20392355	0.6471757	-0.6705914	1.89E-05	0.00032449
Nsmce4a	67872	0.44221191	0.06387664	0.38065674	-0.672841	7.23E-06	0.00014312
Lrrc47	72946	0.43921485	0.02630866	0.23354771	-0.6751967	2.78E-05	0.0004475
Fam212b	109050	0.18054752	0.40048258	0.90173198	-0.6758651	0.00616647	0.03641907
Coq9	67914	0.18868484	0.34906171	0.83742691	-0.6763376	0.00247071	0.01770867
Hmgn5	50887	0.10720423	0.66087842	1	-0.6764843	6.79E-05	0.00093737
2210016F16Rik	70153	0.23476372	0.19329629	0.62647495	-0.6777476	3.39E-05	0.00052971
Paip2b	232164	-0.029825	0.87068124	1	-0.678811	0.00076416	0.00702285
Hspb11	72938	0.24664621	0.48745122	0.99502151	-0.6789697	0.00977884	0.05125205
Txlna	109658	0.38002102	0.03109721	0.25028374	-0.6792071	1.33E-07	4.64E-06
Rbm25	67039	0.43964019	0.01962149	0.19639583	-0.6793874	2.78E-07	8.91E-06
Chchd1	66121	0.36826011	0.08541759	0.43476092	-0.6794435	2.62E-05	0.00042607
Cdc37	12539	0.52858306	0.01166764	0.14605578	-0.6800513	9.61E-10	6.08E-08
Timeless	21853	0.52034553	0.0166297	0.17851156	-0.680244	0.00334585	0.02241347
Phax	56698	0.42572507	0.01716918	0.18277615	-0.681771	1.98E-06	4.85E-05
Nfic	18029	0.44699892	0.01234006	0.15135941	-0.68211	0.00191097	0.01450353
Tjap1	74094	0.48250657	0.0105971	0.13782502	-0.6824007	0.01529679	0.07152121
Brms1l	52592	0.21252278	0.37048732	0.86655214	-0.6825694	0.00298621	0.02050657
Gon4l	76022	0.53437176	0.00565425	0.09622466	-0.6826296	0.01691561	0.07705934
Inhbb	16324	0.32152291	0.17777304	0.61720523	-0.6828341	0.00446945	0.02827926
Srsf11	69207	0.23327094	0.18880307	0.61814717	-0.6838085	1.75E-07	5.90E-06
Cyb561	13056	0.13560931	0.44635647	0.95287141	-0.6847203	0.00089343	0.00794163
Cirbp	12696	0.76329043	0.00242432	0.05759175	-0.6864328	0.00010648	0.00138413
Suds3	71954	0.51794423	0.01445111	0.16427785	-0.6868978	7.31E-05	0.00099517
Wibg	NA	0.5783978	0.00840058	0.1204542	-0.6875497	0.00107675	0.00930039
Ralbp1	19765	0.50138696	0.00571767	0.09703343	-0.6875722	2.61E-06	6.13E-05
Reep5	13476	0.27806664	0.15638699	0.60736746	-0.6877742	5.77E-09	3.03E-07
Arf6	11845	0.30318992	0.13775861	0.56784129	-0.6896304	4.45E-08	1.81E-06
Fbxl19	233902	0.73498781	0.00689436	0.10825857	-0.689719	0.00836655	0.04567337
Fos	14281	0.25847075	0.25779029	0.73847214	-0.6897764	0.00081967	0.00741147
Polr2f	69833	0.62529268	0.00698992	0.10886539	-0.6912437	5.75E-06	0.00011915
Wnt4	22417	0.40232848	0.01895689	0.19278673	-0.6918197	0.00011714	0.00147878
Chsy1	269941	0.40323022	0.02513208	0.22777774	-0.6926632	0.01104765	0.05663592
Cwc25	67480	-0.0218047	0.91706056	1	-0.6942714	0.00176284	0.01364643
Fam213a	70564	0.34328957	0.05351672	0.34456418	-0.6951921	1.50E-06	3.80E-05

Nudt4	71207	-0.1641639	0.36272467	0.85494636	-0.6952531	0.00041955	0.0042947
Hps1	192236	0.58885048	0.01780254	0.18649611	-0.6959722	0.02334154	0.09670279
Cenpb	12616	0.56727685	0.00962	0.13036944	-0.6972082	0.01559692	0.07263991
Zfp704	170753	-0.1396112	0.41808267	0.92227994	-0.697348	0.01374612	0.06657055
Hnrnpul2	68693	0.43320264	0.03720457	0.27990792	-0.6993235	3.36E-09	1.86E-07
Rpia	19895	0.11624819	0.56500462	1	-0.6993794	0.00075667	0.00696658
Mrps34	79044	0.53720928	0.01500779	0.16812167	-0.7022869	3.12E-05	0.00049226
Mxd1	17119	0.36872681	0.06156792	0.3752309	-0.7040672	0.01566997	0.07292841
Xxylt1	268880	-0.0410108	0.82504024	1	-0.7043962	0.01197755	0.06004322
Zgpat	229007	0.59963442	0.00336289	0.0694799	-0.7045774	0.01344816	0.0654796
Pcnxl3	NA	0.39795514	0.03203127	0.25463401	-0.7048709	0.00141114	0.01151451
Arrdc4	66412	0.39332318	0.02640473	0.23400805	-0.7064619	0.001554	0.01235376
Asap2	211914	0.34296536	0.16940157	0.61720523	-0.706715	0.00157768	0.01249302
Rmdn3	67809	0.32225353	0.08569283	0.43507371	-0.7068633	0.0017393	0.01350669
1110004E09Rik	68001	0.7065368	0.00468251	0.08604328	-0.7074699	0.00050957	0.00501062
Eva1a	232146	0.15920282	0.48152095	0.98974397	-0.7102015	0.02220066	0.09333093
Grpel2	17714	-0.0214385	0.91984735	1	-0.7111725	0.00066752	0.00629589
Rbm34	52202	0.47773489	0.01325587	0.15692695	-0.712218	4.63E-05	0.00067933
Dnal4	54152	0.48181655	0.01111724	0.14169312	-0.7122823	0.0009405	0.00829273
Scmh1	29871	0.00279657	0.98855614	1	-0.712783	0.0139545	0.06728188
Rhob	11852	0.22784656	0.21619774	0.66993592	-0.7129102	4.72E-06	0.00010125
Ccdc34	68201	0.48605778	0.0191256	0.19394615	-0.7129473	0.00147907	0.0118914
Golph3	66629	0.20111732	0.25609937	0.73558768	-0.7140785	1.65E-06	4.11E-05
Wasl	73178	0.09142765	0.60853371	1	-0.7166591	1.84E-05	0.00031637
Aggf1	66549	0.49034579	0.00616738	0.10204168	-0.7167316	0.00450309	0.0284099
Ift43	76411	0.60088111	0.00663805	0.10627166	-0.7173802	6.08E-06	0.00012441
Vars2	68915	0.5448624	0.00474066	0.08644326	-0.7176424	0.02073589	0.08925949
Nmral1	67824	0.61299846	0.0110529	0.14124691	-0.7177224	3.95E-05	0.00059653
Zfp367	238673	0.13176541	0.50874399	1	-0.7178722	0.0080071	0.04420741
Tomm22	223696	0.34246087	0.08238071	0.42488263	-0.7179954	1.67E-05	0.0002919
Mtcl1	68617	0.65856613	0.00382386	0.0751267	-0.7180228	0.02188841	0.09255167
Gna12	14673	0.42416885	0.02944817	0.2439463	-0.7184384	0.00159476	0.01259782
Cltb	74325	0.3955977	0.07649835	0.40734091	-0.7186638	8.32E-07	2.31E-05
Lrrc14	223664	0.24663787	0.23374043	0.69901727	-0.7236317	0.00397774	0.02577678
Triobp	110253	0.64520629	0.00217473	0.05413764	-0.724336	0.00047522	0.00474464
Ddx51	69663	0.57930207	0.00474205	0.08644326	-0.7247612	0.0016502	0.0129192
Extl2	58193	-0.5567903	0.07096841	0.39009773	-0.7258769	0.01516369	0.07112686
Rbm15	229700	0.44447762	0.03413195	0.26495118	-0.726875	1.71E-05	0.00029762
Mllt1	64144	0.4662171	0.00967863	0.13051452	-0.7274572	4.86E-05	0.00070326
Fbxo32	67731	-0.1075174	0.6990793	1	-0.7281286	0.01124108	0.0574034
Telo2	71718	0.55981839	0.00697413	0.10875814	-0.7300289	0.00469012	0.02929428
Atg14	100504663	0.34728042	0.09466035	0.4609572	-0.7300957	0.00394101	0.02556398
Diap3	NA	0.56427802	0.01173391	0.14649991	-0.7303346	9.15E-05	0.00120902
Sike1	66641	0.0185927	0.92843261	1	-0.7320362	9.79E-07	2.64E-05
Pdzd8	107368	0.1718422	0.33941928	0.82378835	-0.7325899	8.25E-05	0.00110586
Ndufb10	68342	0.55745926	0.00326592	0.06841112	-0.7341108	6.70E-10	4.36E-08
Trappc3	27096	0.52889861	0.00739656	0.11262547	-0.7345007	3.05E-09	1.71E-07
Fhit	14198	0.47369113	0.20365393	0.64669987	-0.7357153	0.01041542	0.05402768
Cdc42bpg	240505	0.77535665	0.00216314	0.05397989	-0.7362432	0.00048075	0.00479256
Zfp830	66983	0.54818912	0.03396717	0.26434425	-0.7369258	0.00078541	0.00717685
Ppig	228005	0.42754186	0.02100339	0.20409211	-0.7387429	2.56E-08	1.15E-06
Id3	15903	0.34332182	0.04755273	0.32262869	-0.7388285	1.28E-08	6.05E-07
6-Sep	56526	0.48513444	0.06687164	0.38617804	-0.7408299	0.00048722	0.00483868
Ajuba	16475	0.58304111	0.00211955	0.05369456	-0.7409165	4.27E-07	1.31E-05
Myzap	102371	0.79680784	0.00423664	0.07984728	-0.7420609	0.01446417	0.06881322
Bmyc	107771	0.54910939	0.05309314	0.34337592	-0.7422559	0.01847895	0.08212936
Ftsj2	NA	0.84950023	0.00331775	0.06883846	-0.7434206	0.01294836	0.06380095
Commd7	99311	0.23795425	0.21786752	0.67264322	-0.7435383	0.00075934	0.00698623
Khk	16548	0.28228208	0.30663258	0.80097384	-0.7444207	0.01931177	0.08462758
Soga1	320706	0.56767174	0.01043234	0.13642936	-0.7462016	0.00028078	0.0030694
Fam32a	67922	0.09827635	0.58344978	1	-0.7470145	4.41E-06	9.54E-05
Gadd45b	17873	0.13729469	0.51499214	1	-0.7471362	0.00052833	0.00516502

Zbtb14	22666	-0.0877384	0.67577575	1	-0.7479713	0.00142448	0.01156824
Ccdc117	104479	-0.2005868	0.33335399	0.81422411	-0.7495517	0.00073566	0.00681614
Il17re	57890	0.08268639	0.75413885	1	-0.7497417	0.00718801	0.04083574
Mnd1	76915	0.55300464	0.06915009	0.38698979	-0.7504029	0.00460354	0.02890477
Rrs1	59014	0.46471966	0.01732911	0.18367804	-0.7512727	8.20E-07	2.29E-05
Gkap1	56278	0.20356027	0.62841304	1	-0.7513232	0.01044146	0.05413545
Shfm1	NA	0.56061601	0.00324999	0.06818567	-0.7517495	4.11E-08	1.70E-06
Ywhag	22628	0.41639581	0.01664653	0.1785358	-0.7542053	2.55E-10	1.84E-08
Hist1h4f	319157	0.61665519	0.0175741	0.18529177	-0.7545044	2.89E-12	3.33E-10
Tex2	21763	0.39340368	0.0193774	0.1951738	-0.7557713	0.00083835	0.00755434
Rbm8a	60365	0.63792048	0.0089872	0.12563049	-0.7559124	1.07E-09	6.69E-08
Ski	20481	0.40681941	0.03502484	0.26973878	-0.7561356	3.17E-06	7.26E-05
Evc	59056	0.61460421	0.0019046	0.05007285	-0.7564265	0.02375789	0.09781039
Dnmt3a	13435	0.29363657	0.12024272	0.52520971	-0.7565002	1.63E-06	4.06E-05
Pex16	18633	0.45031095	0.07660909	0.40756445	-0.7585122	0.00265301	0.01866774
Wnt3	22415	0.29142023	0.12154375	0.52796514	-0.7591764	3.36E-05	0.00052528
Ccdc9	243846	0.6870224	0.0401283	0.29165869	-0.7592955	0.00059393	0.00572296
Pmaip1	58801	-0.1543217	0.43963948	0.9457403	-0.7610266	0.01910358	0.0840519
Nab2	17937	0.59937845	0.00345253	0.07067407	-0.7616959	2.81E-06	6.52E-05
Cmc2	66531	0.41576763	0.08663912	0.43840922	-0.761798	0.00455034	0.02861177
Ccdc85c	668158	0.79450614	0.0358251	0.27382932	-0.7643449	0.00485712	0.03016514
Nudt19	110959	0.22750902	0.31034328	0.80097384	-0.764417	0.01461296	0.06923622
Rrp15	67223	0.48479372	0.02624938	0.23353938	-0.7646238	3.91E-05	0.00059151
Cdkn1c	12577	0.65230302	0.00218096	0.05423749	-0.7648538	0.0179617	0.08040204
Hexim1	192231	0.42021746	0.02648739	0.23419574	-0.7664396	2.42E-06	5.76E-05
Mbd3	17192	0.53260443	0.00791672	0.11703035	-0.7693571	2.33E-07	7.59E-06
Wnt6	22420	0.59942203	0.00239364	0.05702931	-0.7694599	6.29E-07	1.82E-05
Lzts2	226154	0.64782591	0.00987503	0.13214139	-0.7695506	0.00136021	0.01119731
Rabep2	70314	0.65845876	0.00446671	0.08301491	-0.7711054	0.00045763	0.00461466
Sbk1	104175	0.30988267	0.06686967	0.38617804	-0.7711457	0.00185868	0.01422064
Irf2bpl	238330	0.47547319	0.01399499	0.16106107	-0.772461	5.73E-06	0.0001189
Chchd2	14004	-0.39848	0.04278522	0.30384143	-0.7735828	6.95E-05	0.00095351
Mkrn2	67027	0.3413151	0.08855353	0.4439675	-0.7742343	7.14E-05	0.00097306
Polr3d	67065	0.54366375	0.02082138	0.20292904	-0.7745425	0.00124873	0.01049588
Wrap53	216853	0.70626455	0.00437736	0.08185268	-0.7753353	0.01135703	0.05788294
Tef	21685	0.07119173	0.74383536	1	-0.7753795	0.00849599	0.04616879
Akr1b8	14187	0.14037757	0.72360507	1	-0.7767696	0.00343758	0.02292127
Tspyl1	22110	0.18618261	0.30909782	0.80097384	-0.7792316	9.48E-08	3.52E-06
Ginm1	215751	0.30255997	0.17959835	0.61720523	-0.7800307	5.48E-05	0.0007758
Pacsin2	23970	0.24558678	0.17157606	0.61720523	-0.7801767	4.02E-06	8.90E-05
Clcn6	26372	0.53525525	0.03460963	0.2675536	-0.7806926	0.00575835	0.03456851
Coq5	52064	0.60280922	0.00541871	0.09378471	-0.7831392	0.00012293	0.00154189
Ccdc97	52132	0.31355752	0.08453582	0.43189317	-0.7831932	0.00013883	0.00169557
Faim	23873	0.54067908	0.11481353	0.5116535	-0.7833672	0.0144478	0.06877635
Slbp	20492	0.29277097	0.1194217	0.52304109	-0.7857021	3.70E-08	1.56E-06
B3galt6	117592	0.17706494	0.38118488	0.88010928	-0.7861782	0.00161435	0.01271432
Rbck1	24105	0.42260664	0.0190824	0.19368717	-0.7866606	0.00190928	0.01450353
Klc2	16594	0.53340652	0.02504432	0.22727882	-0.7869425	0.01993787	0.08656229
Zcchc3	67917	0.50188302	0.02596959	0.23205395	-0.7877105	0.00084805	0.00762609
Mien1	103742	0.16246101	0.44011862	0.94609584	-0.7881168	0.00108955	0.00938629
Uimc1	20184	0.4699012	0.02252334	0.21302962	-0.7888435	0.00038709	0.00400801
Crnn	381457	0.70417673	0.06369707	0.38042213	-0.7918932	0.0085724	0.04644945
Zfp566	72556	0.58314832	0.06809649	0.38661538	-0.7920257	0.00847368	0.04608573
Snrnp35	76167	0.55671893	0.07969056	0.41762297	-0.793656	0.00142217	0.01156139
Manbal	69161	0.33300157	0.09402508	0.45923728	-0.793737	0.00194359	0.01468201
Mlec	109154	0.36085395	0.05959591	0.36815983	-0.794003	2.33E-11	2.11E-09
Adck4	NA	0.57852331	0.02601325	0.23235902	-0.7963883	0.00451961	0.02845948
Snx15	69024	0.52942051	0.03741028	0.28064076	-0.7988926	0.00585056	0.03501003
Wbp5	NA	0.13252363	0.55823415	1	-0.8003571	2.19E-08	9.92E-07
Gpatch2	67769	0.51445399	0.02201946	0.20964416	-0.8005601	0.00332696	0.02231972
Hgh1	59053	0.65557295	0.00240664	0.05728325	-0.8009917	0.00288693	0.01994869
Ptms	69202	0.74554895	0.0665671	0.38617804	-0.8014224	2.72E-06	6.36E-05
Gemin2	66603	0.47067988	0.09781986	0.47085165	-0.8019946	0.00013824	0.00168988

Rnaseh1	19819	0.31005622	0.2419655	0.71396471	-0.8020681	0.02218365	0.09333093
Sfr1	67788	0.47459728	0.01163872	0.14583334	-0.8040472	2.61E-09	1.49E-07
Trmt10b	69934	0.39458478	0.23677897	0.70400192	-0.8046951	0.01223895	0.06105058
Iqce	74239	0.36554647	0.11115683	0.5024744	-0.8066777	0.00327366	0.02205225
Dnajc1	13418	0.14807078	0.49018981	0.9982103	-0.806748	1.26E-05	0.00023129
Iffo2	212632	0.44470514	0.01350114	0.1579077	-0.8071775	6.15E-06	0.00012564
Mcl1	17210	0.35395775	0.1116133	0.50364203	-0.8088085	1.55E-09	9.36E-08
Cebpb	12608	0.42473016	0.1108404	0.50219542	-0.811207	2.53E-06	5.98E-05
Lemd2	224640	0.5644934	0.03635647	0.27599044	-0.8123853	2.13E-05	0.00035443
Coil	12812	0.14175072	0.51836505	1	-0.8125331	0.00081722	0.00739443
Manf	74840	0.30362034	0.11859418	0.5209909	-0.8134489	6.25E-08	2.41E-06
Spryd3	223918	0.28433801	0.14983372	0.59256508	-0.8147943	0.00036627	0.00381953
Nle1	217011	0.48695762	0.02794339	0.239767	-0.8151854	0.00198908	0.0149654
Ddx27	228889	0.57349431	0.00211379	0.05360418	-0.8161214	7.19E-07	2.03E-05
Fuk	234730	0.42396537	0.07428135	0.4008009	-0.8164655	0.0075687	0.04240775
Lurap1l	52829	0.33591739	0.07183245	0.39323475	-0.8165386	0.00678396	0.03904717
Tnfaip3	21929	0.28433674	0.25284686	0.73079443	-0.8182412	0.01122422	0.05733961
Chtf18	214901	0.68775107	0.01913174	0.19394615	-0.8191402	0.01341438	0.06539822
Msx2	17702	0.27275744	0.23978216	0.70969823	-0.8191916	0.00133042	0.01104815
Trappc6a	67091	0.49503624	0.03389359	0.26393986	-0.8198303	5.06E-05	0.00072351
Aprt	11821	0.53074442	0.00509781	0.09021284	-0.8225286	2.75E-08	1.22E-06
Pkd2	18764	0.20507294	0.27102593	0.75999139	-0.8230491	0.00183309	0.01405765
Vti1a	53611	0.30550261	0.11392844	0.509037	-0.8265033	1.47E-05	0.00026325
Trim11	94091	0.33031195	0.12346131	0.53354249	-0.8268024	0.00356521	0.02353328
Cox11	69802	0.20851584	0.33729556	0.81987542	-0.8279556	0.00038149	0.0039562
Traf3	22031	0.292147	0.1024721	0.48225336	-0.8279591	0.01339841	0.06536889
Usp20	74270	0.56921989	0.00229312	0.0553362	-0.8291644	0.00133136	0.01104897
Lzic	69151	0.51090578	0.00622146	0.10245058	-0.8294315	8.37E-07	2.32E-05
Bcl7c	12055	0.7851383	0.02648169	0.23419574	-0.8315978	0.00033198	0.00352345
Rassf10	78748	0.36912281	0.07956484	0.41714316	-0.8323064	3.23E-05	0.00050728
Pip5k1c	18717	0.35100195	0.04616964	0.31620763	-0.8369784	0.00143894	0.01165447
Rnf144a	108089	0.21391333	0.3694993	0.86494338	-0.8383665	0.01424487	0.06825919
Snn	20621	-0.1520527	0.41411571	0.91728978	-0.8390619	0.01656341	0.07579678
Otud7b	229603	0.39165108	0.03224104	0.25571891	-0.8392616	6.77E-05	0.00093598
Irgq	210146	0.36591803	0.04571956	0.31466444	-0.8425854	0.00384668	0.02507597
Brf1	72308	0.59000123	0.00230811	0.05552463	-0.844706	0.0002198	0.00249419
Jmjd4	194952	-0.0037292	0.98678535	1	-0.8484637	0.01638032	0.07516649
Rfxap	170767	0.76387879	0.00203532	0.05243105	-0.8488453	0.00050721	0.00499939
Prpf40b	54614	0.59428474	0.01304324	0.15602016	-0.8505895	0.00307136	0.02093662
Plekhj1	78670	0.55186016	0.00522798	0.09152156	-0.8514025	1.30E-06	3.37E-05
Dgcr14	27886	0.40071146	0.09557536	0.46420961	-0.8518706	0.00178079	0.01373681
Obsl1	98733	0.62358764	0.00473377	0.08644326	-0.8543027	0.00067305	0.00632528
Zbtb40	230848	0.41649121	0.04050497	0.29334869	-0.8548543	0.00917303	0.04895641
Syce2	71846	0.38532242	0.05931537	0.36709086	-0.8551303	1.14E-05	0.0002126
2610524H06Rik	330173	0.14352527	0.69953945	1	-0.8575695	0.00682809	0.03924954
Wbscr16	NA	0.52659016	0.00866585	0.12289702	-0.8585182	0.00595267	0.03545945
Fam104a	28081	0.417816	0.04162847	0.29821326	-0.8586638	0.00652353	0.03791387
Mex3d	237400	0.6181846	0.01268088	0.15442341	-0.859895	0.01506939	0.07086174
Ano8	382014	0.59276832	0.03649072	0.27649394	-0.8604449	0.01939755	0.08486185
Spred1	114715	-0.1466504	0.44367939	0.94957558	-0.8637571	1.45E-06	3.71E-05
Sox21	223227	0.61047579	0.00566307	0.09630761	-0.8656932	0.00263178	0.01856669
Zcchc10	67966	0.00793211	0.98177456	1	-0.8657481	0.00707592	0.04030359
Fam122a	68034	0.55471571	0.00921295	0.12765623	-0.8674325	0.00111308	0.00953893
Efna4	13639	0.42351015	0.02522739	0.22826165	-0.870796	0.0001419	0.00172504
Tpm4	326618	0.04609465	0.78930528	1	-0.8740242	1.34E-12	1.78E-10
Ing5	66262	0.2848587	0.24392899	0.71794976	-0.8751791	0.00112232	0.00961187
Map9	213582	0.18741814	0.45402299	0.96071291	-0.8787627	0.0076378	0.0426891
Usp21	30941	0.40962782	0.02595176	0.23205395	-0.8796536	0.01513426	0.071065
Vimp	NA	0.22286336	0.24261213	0.71554045	-0.8837086	7.96E-08	2.99E-06
Chpf	74241	0.51602491	0.03131985	0.25143392	-0.8876941	0.00817128	0.04490611
Eid1	58521	0.43173043	0.01218702	0.15023684	-0.8901974	1.19E-10	9.09E-09
Nsl1	381318	0.53216468	0.01529894	0.16960333	-0.8902707	0.00034613	0.00364425
Nudt3	56409	0.5888065	0.00369641	0.07349146	-0.890307	6.58E-05	0.00091369

Tmem194b	NA	0.08983151	0.75142009	1	-0.8909203	0.00537893	0.03283124
Tm2d1	94043	0.35268521	0.26905827	0.75655406	-0.8928968	0.00880185	0.04726409
Tpm3	59069	0.44933334	0.01976194	0.19714314	-0.8994599	1.76E-13	2.96E-11
Chmp7	105513	0.41975685	0.02373314	0.21956787	-0.9018842	1.76E-05	0.0003042
Egln1	112405	0.22550811	0.29200513	0.79286826	-0.902524	5.04E-05	0.00072172
Rras2	66922	0.12671203	0.60540871	1	-0.9037247	0.00010302	0.00134579
Urm1	68205	0.23224136	0.23033148	0.69378594	-0.9041395	9.77E-05	0.00128543
Smim12	80284	0.3327305	0.17946597	0.61720523	-0.9052145	0.00134065	0.01111201
Tatdn2	381801	0.31722653	0.07106234	0.39050705	-0.9057889	0.00114975	0.00978927
Dll1	13388	0.59673954	0.01279177	0.15487746	-0.908174	0.00020083	0.00231901
Zscan25	666311	0.5190489	0.01038022	0.13618426	-0.9088328	0.00635352	0.0371395
Fam107b	66540	-0.201674	0.27779922	0.77127499	-0.9098275	0.00037523	0.00390677
Csrnp1	215418	0.28819869	0.27997599	0.77467638	-0.912544	0.01822207	0.08126275
Igfbp7	29817	0.63093518	0.00494686	0.08872476	-0.9126923	0.00042587	0.0043444
Tcf7l2	21416	0.55158056	0.00570537	0.09689206	-0.9165981	3.14E-05	0.00049454
Slc39a2	214922	0.20557847	0.5057844	1	-0.9179896	0.00303224	0.02075616
Ccdc23	NA	0.46817079	0.02090884	0.20343219	-0.9194234	0.00340295	0.0227597
Zbtb4	75580	0.10534509	0.59102925	1	-0.9194913	0.02295018	0.09571566
Edn2	13615	0.02240313	0.94077062	1	-0.9217206	4.33E-05	0.00064412
Erich1	234086	0.74724223	0.00494833	0.08872476	-0.9241805	0.00141979	0.01155635
Crocc	230872	0.85278869	0.00956724	0.1299453	-0.9247938	0.01860071	0.08247509
Mis18a	66578	0.27332905	0.1867908	0.61720523	-0.9289012	4.18E-06	9.14E-05
Homer3	26558	0.51802432	0.01676732	0.17959417	-0.9295373	0.00113804	0.00970845
Tnrc18	231861	0.7008624	0.00315861	0.06719199	-0.9339771	2.33E-06	5.59E-05
Ccdc28b	66264	0.43718885	0.24990796	0.72602931	-0.9375421	0.0024075	0.01736706
Foxo6	329934	0.74019838	0.01203983	0.14887324	-0.9396482	0.01121226	0.05730083
Tbx1	21380	0.54010776	0.009357	0.12866408	-0.9406927	0.00020468	0.00235928
Gpatch4	66614	0.51176511	0.0251366	0.22777774	-0.9432206	4.24E-05	0.00063449
Ehd3	57440	0.05790544	0.82920949	1	-0.9438624	0.00161097	0.0126953
Pole4	66979	0.31702536	0.1363091	0.56563366	-0.9447469	9.20E-07	2.52E-05
Stard3nl	76205	0.31094709	0.26647873	0.7524196	-0.9462084	0.00328608	0.02211325
Zfp36l2	12193	0.14686348	0.46155298	0.96868215	-0.9520113	8.04E-09	4.00E-07
9930104L06Rik	194268	0.35585212	0.19221256	0.62451989	-0.953159	0.01895918	0.08361273
Klhl17	231003	0.34973157	0.19761822	0.63558997	-0.9549622	0.00689972	0.03957481
Gpatch11	53951	0.47251223	0.06538043	0.38489715	-0.9610467	4.28E-05	0.00063787
Azin2	242669	0.50510705	0.06848565	0.38661538	-0.9649116	0.01613776	0.07444059
Pkn1	320795	0.53856049	0.02266652	0.21358223	-0.9667382	0.01461184	0.06923622
Hmgn1	15312	0.47266871	0.02806962	0.239767	-0.9674446	1.07E-11	1.03E-09
Large	NA	0.32826032	0.25898436	0.74102602	-0.9676899	0.01454182	0.06902226
Gng12	14701	-0.3490889	0.05193937	0.34014785	-0.9730451	2.23E-09	1.30E-07
Gas1	14451	0.539306	0.04734355	0.32190505	-0.9753639	1.15E-07	4.12E-06
Tmem47	192216	-0.3020999	0.40517491	0.90641358	-0.9797695	0.02307088	0.09612744
Ralb	64143	0.31499191	0.11334793	0.50771638	-0.981847	4.86E-05	0.00070326
Pop5	117109	0.57537513	0.00311548	0.0666227	-0.9887869	3.67E-09	2.02E-07
Sac3d1	66406	0.62572205	0.0043092	0.08088784	-0.9921885	0.00014626	0.0017676
Pbxip1	229534	0.59790422	0.02625584	0.23353938	-0.9933718	0.00079624	0.00723445
Hypk	67693	0.60184194	0.00771299	0.11534537	-0.9974069	5.19E-14	9.88E-12
Pdcd7	50996	0.52058994	0.02641826	0.23400805	-1.0107189	0.00057782	0.00559546
Ppp1r9b	217124	0.75781237	0.00713959	0.11014279	-1.0112492	2.15E-05	0.00035703
Fgd5	232237	0.12509626	0.59245098	1	-1.0119807	0.01151691	0.05842564
Gadd45a	13197	0.51140265	0.03169345	0.25326759	-1.0138027	3.61E-05	0.00055696
Prodh	19125	0.63237789	0.0046624	0.08587791	-1.0185946	0.00026694	0.00294262
Ccdc106	232821	0.69379179	0.02063654	0.20186423	-1.02218	0.0129306	0.06374986
Trim44	80985	-0.0063911	0.96989563	1	-1.0245872	1.52E-06	3.84E-05
Yaf2	67057	-0.1193415	0.62361474	1	-1.0282312	0.00145386	0.0117391
Leng1	69757	0.58297789	0.028533	0.24155545	-1.0293535	4.47E-05	0.00066218
Cd276	102657	0.22470837	0.31403825	0.80097384	-1.033875	0.00050898	0.00500932
Cxcl12	20315	-0.6405719	0.0627473	0.37835847	-1.0339959	0.00632662	0.03702882
Wnt11	22411	0.31268292	0.21342933	0.66428699	-1.0345815	0.0075737	0.04240775
Rassf5	54354	0.07419745	0.71061355	1	-1.0350336	0.00088664	0.00789201
Traf3ip1	74019	0.53064721	0.02795991	0.239767	-1.0352313	0.00102858	0.00896102
Tmx4	52837	-0.2458976	0.35587652	0.84588992	-1.0370862	5.20E-05	0.00074028
Yrdc	230734	0.64020669	0.0038572	0.07535741	-1.0402151	1.56E-05	0.0002754

Mpv17l2	234384	0.47560513	0.05238045	0.34221055	-1.0433422	0.00016613	0.00196678
Lipt2	67164	0.4628643	0.16520225	0.61720523	-1.0441535	0.00638023	0.03725582
Irak1bp1	65099	0.641021	0.02257683	0.2132877	-1.0469751	0.00259491	0.01841827
Mid1ip1	68041	0.36401208	0.07391712	0.40007203	-1.047302	1.03E-06	2.78E-05
Brpf3	268936	0.37583377	0.04935943	0.32988686	-1.0503032	0.01415053	0.06790275
Mppe1	225651	0.35526676	0.08658696	0.43824668	-1.0527883	0.00072651	0.0067552
9930012K11Rik	268759	0.0836256	0.78201622	1	-1.0560129	0.00872822	0.0470221
Gsta3	14859	0.66118633	0.19154611	0.62353341	-1.0597673	0.01555164	0.07248047
Crebzf	233490	0.43361556	0.07607707	0.40632375	-1.0605598	0.00016129	0.00191983
Mrfap1	67568	0.3553551	0.05745356	0.35924255	-1.0606882	6.34E-22	7.56E-19
Sdhaf1	68332	0.1218622	0.64185982	1	-1.0746143	0.00428962	0.02744565
Ccdc71l	72123	0.42317767	0.03794699	0.28336009	-1.077566	0.01169815	0.05904846
Vegfb	22340	0.50173008	0.02089741	0.20340664	-1.0803903	0.01481807	0.06989921
Psrc1	56742	0.51296078	0.03406253	0.26468265	-1.0842545	7.03E-06	0.00014002
Macrod2	72899	0.43817083	0.24966814	0.72576703	-1.0867928	0.00026592	0.00293628
Isca1	69046	0.3969477	0.02897962	0.2425892	-1.0874857	4.63E-07	1.40E-05
1700066M21Rik	73467	-0.3708191	0.15875208	0.61082159	-1.0887629	0.00404979	0.02612762
Rnf187	108660	0.45936471	0.00946672	0.12937141	-1.0905003	2.19E-14	4.79E-12
Neurl1b	240055	0.45207792	0.02254781	0.21317847	-1.0995416	6.49E-05	0.00090468
Ppm1m	67905	0.71603131	0.0036985	0.07349146	-1.1086931	0.01737409	0.07848235
Pink1	68943	0.42853695	0.02193395	0.20907459	-1.1129965	9.47E-07	2.58E-05
Cep104	230967	0.42903608	0.03844701	0.28480269	-1.1161509	0.00592751	0.03534163
Asap3	230837	0.71488695	0.00647684	0.10481006	-1.1225896	0.00877754	0.04724645
Uqcc3	107197	0.39656591	0.12475867	0.53665539	-1.1472398	4.56E-06	9.82E-05
Dusp2	13537	0.09815663	0.7834749	1	-1.1486241	0.0171238	0.07765746
Mns1	17427	1.24513706	0.02559113	0.23010343	-1.1515046	0.00233781	0.01694817
Pdf	68023	0.25230524	0.19032382	0.62107097	-1.1518035	1.45E-06	3.69E-05
Banf1	23825	0.4908607	0.00530698	0.09244976	-1.1533825	3.09E-18	1.62E-15
Rcan3	53902	-0.0320733	0.8830107	1	-1.15856	0.01921544	0.08428985
Tcp11l1	320554	0.65519372	0.03512426	0.26982367	-1.1761498	0.00050882	0.00500932
Itga9	104099	0.32456664	0.40492172	0.90631483	-1.1882029	0.0138908	0.06713685
Maff	17133	0.1645538	0.49408728	1	-1.1902236	0.00912801	0.04877558
Pawr	114774	0.73524339	0.00299829	0.06470411	-1.1924829	3.07E-08	1.33E-06
Cby1	73739	0.62496154	0.01870909	0.19132942	-1.1949758	1.74E-05	0.00030165
Mpped1	223726	0.61336486	0.01535378	0.16989338	-1.1956424	0.00768905	0.04286605
Epdr1	105298	0.12059007	0.7355805	1	-1.2025513	0.02314569	0.09625928
2410004B18Rik	66421	0.55591664	0.01562826	0.17155744	-1.2056452	1.28E-05	0.00023363
Chchd4	72170	0.28250523	0.23785412	0.70609197	-1.2058261	4.16E-06	9.14E-05
Oraov1	72284	0.24231627	0.30795667	0.80097384	-1.2149635	5.87E-06	0.00012099
Zkscan5	22757	0.2178445	0.30284126	0.80097384	-1.2310894	0.0054693	0.03322835
Stx1a	20907	0.52981846	0.0912831	0.45162572	-1.2359391	0.02314651	0.09625928
Mgarp	67749	0.95241353	0.09958166	0.47461137	-1.247398	0.01366539	0.06635091
Fadd	14082	0.53426396	0.00966072	0.13036944	-1.2514281	1.43E-07	4.95E-06
4930427A07Rik	104732	0.47427663	0.02837382	0.24128324	-1.2538685	0.00732447	0.04136042
Ctf1	13019	0.4543021	0.04844142	0.32553327	-1.2757501	0.0076771	0.0428358
Pex26	74043	0.02624118	0.89909352	1	-1.2817225	0.00010348	0.00135055
Fbxo4	106052	0.59347871	0.14966914	0.59201004	-1.3046028	0.0054287	0.0330275
Nudt15	214254	0.14703612	0.69964034	1	-1.3190325	0.00803806	0.04430381
Fam98c	73833	0.77865926	0.00489001	0.08825128	-1.3319642	0.00013563	0.00166261
Sytl4	27359	0.50036197	0.25557474	0.73495723	-1.3363277	0.0011054	0.00949172
Camta2	216874	0.45751693	0.03045563	0.24793306	-1.3425239	0.00384508	0.02507597
Tacc1	320165	0.47761944	0.01268525	0.15442341	-1.3456542	1.35E-09	8.26E-08
Mrm1	217038	0.41815886	0.07335992	0.39847034	-1.3481866	0.00642041	0.03741392
Gmip	78816	0.5591534	0.01982389	0.1974385	-1.353987	0.01229874	0.06120933
Mxra7	67622	1.02663631	0.0053075	0.09244976	-1.3590458	0.01093624	0.05621842
Sox12	20667	0.6584454	0.01046053	0.1366078	-1.3643044	0.00010911	0.00140999
Cyp26b1	232174	0.08085148	0.79562426	1	-1.365405	0.00163958	0.01285135
Acot11	329910	0.2947781	0.37127309	0.86719407	-1.3696734	0.02088244	0.08959657
Ripply3	170765	0.40554207	0.15898625	0.61137904	-1.3925773	0.00746824	0.04197367
C2cd2l	71764	0.72925851	0.00285014	0.06293244	-1.4009846	0.00597134	0.03555452
Intu	380614	0.51805502	0.02472106	0.22535015	-1.4058432	0.00913476	0.04879181
Ccdc102a	234582	1.04453196	0.00233649	0.05599554	-1.4094474	0.01200005	0.06011011
Sp5	64406	0.62139986	0.0155796	0.17122836	-1.4177384	0.00479425	0.02984507

Arc	11838	-0.1417605	0.74111045	1	-1.4318084	0.011482	0.05829357
Klf9	16601	-0.010005	0.96921754	1	-1.4632793	0.00703944	0.04014807
Zscan20	269585	0.60914137	0.02233594	0.2118494	-1.4681792	0.00451269	0.02843053
Pxdc1	66895	0.52562552	0.01530392	0.16960333	-1.4840317	8.99E-05	0.00118985
Zscan2	22691	0.78406039	0.0334952	0.26167188	-1.4974219	0.01574605	0.07317872
Ttc19	72795	0.48199668	0.08271173	0.42578057	-1.4998503	7.14E-07	2.03E-05
Eid2	386655	0.87088792	0.0454238	0.31389205	-1.5190457	0.00347023	0.02306868
Rmi2	223970	0.76354151	0.00772321	0.11542742	-1.5354297	0.02206774	0.09301038
Cabp1	29867	1.5287759	0.00516342	0.09087559	-1.5457638	0.01821981	0.08126275
Rnd1	223881	0.42808187	0.37705466	0.87470807	-1.5643718	0.00771419	0.04296973
Fam118a	73225	0.48331883	0.14586376	0.58425844	-1.5735103	0.00056015	0.00544755
Fgf20	80857	0.34378729	0.49981955	1	-1.591387	0.00264194	0.01862836
Hhip	15245	0.37638732	0.3109874	0.80097384	-1.6193052	0.00250199	0.01790785
Rpl41	67945	0.48914744	0.01338321	0.15762744	-1.6398296	1.98E-23	4.32E-20
Dnal1	105000	0.39269572	0.18621587	0.61720523	-1.6535687	0.00014965	0.00180089
Doc2b	13447	0.64697178	0.01842039	0.18925085	-1.7730927	0.000312	0.00334623
Slc6a2	20538	0.30679264	0.52445642	1	-1.8455693	0.00276464	0.01923531
Parp16	214424	0.6756249	0.18260668	0.61720523	-1.8586051	0.00562932	0.03396475
Cbx7	52609	0.28146947	0.40671918	0.90834907	-1.9799664	0.01961488	0.08558451
Wnt2b	22414	0.46180716	0.17840039	0.61720523	-2.0094803	0.00602333	0.03584782

Table B.3 Translationally altered genes in *Hras*^{G12V} epidermal progenitors regulated by eIF2B5

Genes with translational efficiency changes were identified by Xtail analysis and excluded genes with significant transcriptional changes (as determined by EdgeR). Positive fold-change value indicates translational upregulation in *Hras*^{G12V} progenitors.

Gene Description		Xtail Log_2 Fold Change	
Gene Symbol	**Entrez ID**	**HS/WS**	**HE/HS**
Mgarp	67749	1.86525543	-1.247398
Parp16	214424	1.86479038	-1.8586051
Mxra7	67622	1.82362057	-1.3590458
Krt35	53617	1.75973524	-0.6380263
Klf9	16601	1.68156937	-1.4632793
Sdhaf1	68332	1.49236403	-1.0746143
Macrod2	72899	1.44483851	-1.0867928
Dnal4	54152	1.3916271	-0.7122823
Fgf20	80857	1.39117644	-1.591387
9930012K11Rik	268759	1.25941524	-1.0560129
2410004B18Rik	66421	1.22169419	-1.2056452
Mid1ip1	68041	1.20440502	-1.047302
Zscan20	269585	1.20413895	-1.4681792
Spryd3	223918	1.19718824	-0.8147943
Banf1	23825	1.18296109	-1.1533825
Fadd	14082	1.17931541	-1.2514281
Hypk	67693	1.15959803	-0.9974069
Zkscan5	22757	1.13460914	-1.2310894
Traf3	22031	1.09838452	-0.8279591
Nudt3	56409	1.08060915	-0.890307
Lipt2	67164	1.07750426	-1.0441535
Ctdspl	69274	1.077077	-0.6365007
Arf6	11845	1.06194606	-0.6896304
Pop5	117109	1.06079062	-0.9887869
Foxo6	329934	1.05797162	-0.9396482
Rhob	11852	1.05749721	-0.7129102
Cyp26b1	232174	1.03890932	-1.365405
Nip7	66164	1.02811653	-0.5366845
Tacc1	320165	1.02746718	-1.3456542
Rps11	27207	1.01639515	-0.5963688
Pbxip1	229534	0.98763568	-0.9933718
Iffo2	212632	0.98487278	-0.8071775
Spred1	114715	0.98412264	-0.8637571
Polr2f	69833	0.9829458	-0.6912437
Gng12	14701	0.96979437	-0.9730451
Rassf5	54354	0.96116782	-1.0350336
Sytl4	27359	0.93579136	-1.3363277
Isca1	69046	0.9350751	-1.0874857
Ttc19	72795	0.92777195	-1.4998503
Eva1a	232146	0.92525393	-0.7102015
Mt2	17750	0.92294715	-0.6066899
Lzic	69151	0.89719579	-0.8294315
Trappc3	27096	0.89338144	-0.7345007
Uqcc3	107197	0.89042779	-1.1472398
Ppif	105675	0.88977771	-0.6009095
Fam96b	68523	0.88832354	-0.5515797
Sbk1	104175	0.8735705	-0.7711457
Ppp1r9b	217124	0.86437285	-1.0112492
Mrps26	99045	0.86293194	-0.6556791
Rnf187	108660	0.86236306	-1.0905003
Oraov1	72284	0.86215478	-1.2149635
Gpatch11	53951	0.86131216	-0.9610467

Timm10	30059	0.85982869	-0.618074
Pex16	18633	0.85949593	-0.7585122
Ndufb10	68342	0.85220605	-0.7341108
Id3	15903	0.85099847	-0.7388285
Pole4	66979	0.8509198	-0.9447469
Tnfaip3	21929	0.84840736	-0.8182412
Zfyve27	319740	0.84610772	-0.6172095
Acap3	140500	0.84426151	-0.5575557
Pmaip1	58801	0.8419527	-0.7610266
Ywhag	22628	0.83508494	-0.7542053
Hist1h4f	319157	0.83488692	-0.7545044
Akr1b8	14187	0.83278493	-0.7767696
Commd7	99311	0.83273557	-0.7435383
Triobp	110253	0.82941548	-0.724336
Adck4	NA	0.82894698	-0.7963883
Pdf	68023	0.82244461	-1.1518035
Fos	14281	0.81851583	-0.6897764
Stard3nl	76205	0.81845683	-0.9462084
Tpm4	326618	0.8162215	-0.8740242
Cby1	73739	0.81606977	-1.1949758
Sike1	66641	0.81241074	-0.7320362
Cox6a1	12861	0.80921777	-0.5349311
Krt17	16667	0.80830945	-0.5368115
Hs6st1	50785	0.80801585	-0.5778493
Mpv17l2	234384	0.80799191	-1.0433422
Tnrc18	231861	0.80227821	-0.9339771
Ccdc91	67015	0.80206023	-0.6507289
Tmx4	52837	0.8011324	-1.0370862
Hars2	70791	0.80102207	-0.5671156
Yaf2	67057	0.79816318	-1.0282312
Nob1	67619	0.79542655	-0.6148428
Ccdc97	52132	0.79440836	-0.7831932
Pawr	114774	0.78905806	-1.1924829
Fdx1	14148	0.78752611	-0.586882
Zbtb14	22666	0.78124938	-0.7479713
Suv420h1	NA	0.77976088	-0.567032
Snrnp35	76167	0.7764742	-0.793656
Sltm	66660	0.77122485	-0.6073039
Ddx27	228889	0.7696851	-0.8161214
Wnt3	22415	0.76849652	-0.7591764
Telo2	71718	0.75756931	-0.7300289
Cwc25	67480	0.75643994	-0.6942714
Mea1	17256	0.75304848	-0.6060127
Gadd45b	17873	0.75021306	-0.7471362
Hnrnpul2	68693	0.74979431	-0.6993235
Chchd4	72170	0.74454982	-1.2058261
Rpl41	67945	0.73649659	-1.6398296
Mdm2	17246	0.73541399	-0.6464318
Ralb	64143	0.73487455	-0.981847
Alyref	21681	0.73207584	-0.6407128
Tpm3	59069	0.73002435	-0.8994599
Psmc3ip	19183	0.72872368	-0.5632952
Tatdn2	381801	0.72508912	-0.9057889
Trappc6a	67091	0.72436382	-0.8198303
Vimp	NA	0.72261409	-0.8837086
Mrfap1	67568	0.72211703	-1.0606882
Cox11	69802	0.71838407	-0.8279556
Cltb	74325	0.71342768	-0.7186638
Bcl7c	12055	0.70998274	-0.8315978
Shfm1	NA	0.70901771	-0.7517495
Yrdc	230734	0.70852405	-1.0402151
Ccdc9	243846	0.70624885	-0.7592955
Nat9	66176	0.70442466	-0.6452453

Polr3d	67065	0.70236588	-0.7745425
Dll1	13388	0.70174384	-0.908174
Fuk	234730	0.6997938	-0.8164655
Fbxo32	67731	0.69690784	-0.7281286
Atg14	100504663	0.69588893	-0.7300957
Sash1	70097	0.6845679	-0.577265
Ncaph2	52683	0.68451297	-0.5417957
Iqce	74239	0.68101866	-0.8066777
Rras2	66922	0.67607565	-0.9037247
Serf2	378702	0.67449483	-0.6386281
Zcchc3	67917	0.67425907	-0.7877105
Manf	74840	0.67015964	-0.8134489
Gadd45a	13197	0.66937486	-1.0138027
Paip2b	232164	0.6637777	-0.678811
Leng1	69757	0.66348758	-1.0293535
Rmdn3	67809	0.66165455	-0.7068633
Ube2g2	22213	0.65736631	-0.6309173
Wdr4	57773	0.65668124	-0.6575844
Ppfia1	233977	0.65632198	-0.5779486
Coa7	69893	0.65456606	-0.6039628
Gpatch2	67769	0.65210111	-0.8005601
Trim35	66854	0.6507391	-0.5934333
Edn2	13615	0.65066319	-0.9217206
Ubxn1	225896	0.65042805	-0.5523233
Tab1	66513	0.64267172	-0.5948669
Exosc3	66362	0.6408277	-0.517119
Ift43	76411	0.64030853	-0.7173802
Chchd1	66121	0.63623998	-0.6794435
Sema4d	20354	0.63482659	-0.557264
Purb	19291	0.63369956	-0.5260255
Naga	17939	0.63351229	-0.6562122
Ltbp4	108075	0.63323311	-0.5790271
Cnpy4	66455	0.63044732	-0.6263014
Mis18a	66578	0.62959628	-0.9289012
Cd2bp2	70233	0.62479041	-0.5241632
Rbck1	24105	0.62381602	-0.7866606
Diap3	NA	0.62103624	-0.7303346
Isy1	57905	0.62087484	-0.5083605
Zbtb7a	16969	0.62082709	-0.6684507
Ppig	228005	0.61974183	-0.7387429
Fam32a	67922	0.61606685	-0.7470145
Nsl1	381318	0.61409541	-0.8902707
Naa30	70646	0.60605246	-0.6461154
Mob2	101513	0.60601741	-0.576619
Rrp15	67223	0.60391742	-0.7646238
Csad	246277	0.6033376	-0.530421
Cpox	12892	0.60127288	-0.6607103
Cactin	70312	0.60033766	-0.6115991
Terf2ip	57321	0.59846266	-0.5000938
Ltbp3	16998	0.59615805	-0.5670192
Sfr1	67788	0.59613392	-0.8040472
Cdkn1b	12576	0.59343665	-0.6016798
Srsf9	108014	0.59248381	-0.6423835
Ptrf	19285	0.59097297	-0.6192978
Gemin2	66603	0.58957409	-0.8019946
Kremen2	73016	0.58833975	-0.5421691
Ankrd11	77087	0.58765799	-0.5466039
Hexim1	192231	0.58703058	-0.7664396
Polr3h	78929	0.58698302	-0.5279793
Zc3h11a	70579	0.58219009	-0.5963665
Psrc1	56742	0.58185909	-1.0842545
Arfgap1	228998	0.58072165	-0.5887313
Adrbk1	NA	0.57695239	-0.5042494

Dnmbp	71972	0.5758171	-0.6249344
Pcdh7	54216	0.57500567	-0.5275736
Rps14	20044	0.57411347	-0.5438961
Aatf	56321	0.57376122	-0.5433165
Phax	56698	0.56967821	-0.681771
Dlgap4	228836	0.56703775	-0.6037289
Srsf11	69207	0.56582291	-0.6838085
Sdf4	20318	0.5656089	-0.5582422
Gas1	14451	0.56263873	-0.9753639
Creld2	76737	0.56190377	-0.6705914
Cdc42ep4	56699	0.5612136	-0.5115287
Coq5	52064	0.561104	-0.7831392
Itgb5	16419	0.55957679	-0.5296115
Stard10	56018	0.55858774	-0.5624976
Fkbp8	14232	0.55380566	-0.5712131
Ptms	69202	0.55356104	-0.8014224
Mllt1	64144	0.55297717	-0.7274572
Slbp	20492	0.54867903	-0.7857021
Cdc37	12539	0.54846526	-0.6800513
Sox4	20677	0.54642685	-0.6027859
Ralbp1	19765	0.54484651	-0.6875722
Wnt6	22420	0.54478318	-0.7694599
Ap2s1	232910	0.54210424	-0.608031
Kansl3	226976	0.54101416	-0.5843337
Ppp1r14b	18938	0.54052331	-0.5254392
Pdcl3	68833	0.53459471	-0.6281881
Lonp1	74142	0.53406531	-0.5143579
Axin2	12006	0.5339497	-0.5433756
Arrdc4	66412	0.53343919	-0.7064619
Snf8	27681	0.53132472	-0.5193091
Ccdc71	72454	0.52775049	-0.6699944
Wasl	73178	0.52425667	-0.7166591
Wwc2	52357	0.52307778	-0.5807364
Dnmt3a	13435	0.5216736	-0.7565002
Fbxw8	231672	0.51889621	-0.5433077
Chmp7	105513	0.51692984	-0.9018842
Reep5	13476	0.51691594	-0.6877742
Rps6ka4	56613	0.51391768	-0.6482382
Tex2	21763	0.51151611	-0.7557713
Cbx5	12419	0.51016223	-0.6105078
Zc3h18	76014	0.51009795	-0.6328748
Lmna	16905	0.50455827	-0.5600263
2210016F16Rik	70153	0.5040473	-0.6777476
Nfu1	56748	0.50396711	-0.6065532
Hmgn1	15312	0.50023863	-0.9674446
Capn6	12338	-0.5002597	0.65814176
Nudt2	66401	-0.5002738	0.52529241
Tgm5	74176	-0.5035492	0.69521248
Tollip	54473	-0.5049461	0.72273204
Wbp2	22378	-0.5055966	0.84521254
Hltf	20585	-0.5056864	0.92410977
Trim23	81003	-0.510133	0.84987584
Med6	69792	-0.510153	0.52906335
Ssbp1	381760	-0.5137036	0.98481857
Erbb2ip	NA	-0.5142193	0.65827115
Anpep	16790	-0.5142524	0.69037598
Fam172a	68675	-0.5149772	0.50102345
Sgol2a	68549	-0.5151654	0.55861973
Emc3	66087	-0.5259766	0.54052768
Xrn1	24127	-0.5287908	0.63583227
Thoc2	331401	-0.5300685	0.58515407
Arl4a	11861	-0.5304684	0.596178
Pole2	18974	-0.5306354	0.7623465

Ten1	69535	-0.5333703	0.66776306
Arhgap1	228359	-0.538521	0.708631
Tet2	214133	-0.5390888	0.80109458
Kif18b	70218	-0.5400579	0.71088696
Abcg2	26357	-0.5412644	0.71806058
Hddc2	69692	-0.5433367	1.07080438
Acsl3	74205	-0.5435572	0.50534214
Mrpl14	68463	-0.5457703	0.81277528
Lin9	72568	-0.5458315	0.5946823
Nfatc3	18021	-0.5460769	0.54634454
Cog6	67542	-0.5460919	0.59542781
Prdx4	53381	-0.5478928	0.5177815
Fam69a	67266	-0.5500136	0.91503899
Golt1b	66964	-0.5530802	0.55862601
Alcam	11658	-0.5540542	0.77352055
Tmem126b	68472	-0.557467	1.1066975
Fzd3	14365	-0.557499	0.89765654
Prim1	19075	-0.5606444	0.53862557
Tmem135	72759	-0.561765	1.00180668
Kpna4	16649	-0.5620346	0.90942034
Ube2k	53323	-0.5635207	0.75842713
Btf3	218490	-0.5635444	0.5959783
Nln	75805	-0.5680947	0.60394548
Gjb6	14623	-0.5691145	0.54356709
Pon2	330260	-0.5701226	0.54618635
Ncapg	54392	-0.5719945	0.78431727
Ccnt1	12455	-0.5735189	0.59513781
Tbc1d5	72238	-0.5759361	0.64891962
Slc7a6	330836	-0.5771438	0.54568817
Ubqln1	56085	-0.5786948	0.63460147
Klhl24	75785	-0.5816803	0.66609202
Arl14ep	212772	-0.5869609	0.58329707
Klhl28	66689	-0.5870638	0.63715091
Cops2	12848	-0.5873926	0.61444632
Lamtor2	83409	-0.5877468	0.95680771
Tbck	271981	-0.5890373	0.82582048
Prps2	110639	-0.5892956	0.58035107
Parm1	231440	-0.5897857	0.76547257
Arpc1a	56443	-0.5904317	0.7407277
Kdelr1	68137	-0.5921894	0.63439526
Itga1	109700	-0.5933027	0.57213044
Ift74	67694	-0.5938167	1.07758044
Itga2	16398	-0.596183	0.68126513
Mtf2	17765	-0.5964148	0.67154815
Ldah	68832	-0.5966765	0.99837906
Slc7a2	11988	-0.59776	0.71761296
Fam216a	68948	-0.6007778	0.7518569
Btaf1	107182	-0.6019497	0.69561141
Ghitm	66092	-0.6028766	0.60829191
Sec22a	317717	-0.6089669	0.84372047
Slc35b1	110172	-0.609808	0.71694964
Cxadr	13052	-0.6103737	0.66191642
Nfia	18027	-0.6109559	0.50991038
Gli3	14634	-0.612122	0.63146114
Sec61a2	57743	-0.6159313	0.62214641
Fem1c	240263	-0.6163578	0.56242131
Sdhc	66052	-0.6191424	0.65899045
Wac	225131	-0.6195295	0.59054211
Nfat5	54446	-0.6195909	0.71935425
Acer1	171168	-0.619792	0.91037186
Cr1l	12946	-0.6214812	0.64192612
Orc5	26429	-0.6225633	0.88338141
Qrich1	69232	-0.6235645	0.69616361

Tcf12	21406	-0.6236167	0.51808704
Pik3c2a	18704	-0.6259671	0.89381201
Ppa1	67895	-0.6279094	0.75608039
Tfg	21787	-0.6328634	0.61085303
Kansl1l	68691	-0.6344536	0.61182822
Fam208b	105203	-0.6344555	0.93505957
Kdelr2	66913	-0.6349665	0.73367502
Anapc11	66156	-0.6372797	0.85651832
Slc31a2	20530	-0.6377469	0.91812661
Cdc16	69957	-0.6379746	0.62366545
Polr3f	70408	-0.6411395	1.12149706
Smchd1	74355	-0.6411974	0.92471615
Cd59a	12509	-0.6449421	0.98441653
Hist1h2bf	319180	-0.6451155	0.83426399
Fbxo25	66822	-0.6452131	0.97737482
Zfp397	69256	-0.6459888	0.62201956
Lsm2	27756	-0.646326	0.5433647
Pafah1b2	18475	-0.6464121	0.72118291
Gdpd1	66569	-0.6466372	0.98020111
Ska2	66140	-0.6504919	0.98907155
Mios	252875	-0.6506473	0.50367523
Smc2	14211	-0.6506632	0.51265928
Mrpl45	67036	-0.6510885	0.65830745
Pou2f1	18986	-0.6552492	0.69864444
Alg3	208624	-0.6569985	0.54572143
Nbn	27354	-0.6571918	0.51535738
Sec24b	99683	-0.6604625	0.62795313
Arg2	11847	-0.6606646	0.66985224
Nfyc	18046	-0.6607569	0.84175592
Fopnl	66086	-0.6627948	0.5000123
4921524J17Rik	66714	-0.6634691	0.80146213
D230025D16Rik	234678	-0.6642134	0.92291435
Vwa5a	67776	-0.6657393	0.56307571
Eif2ak2	19106	-0.6670583	0.78312044
Itgb8	320910	-0.668017	0.58146864
Gmppa	69080	-0.6695604	0.67583912
Dync2li1	213575	-0.6696824	0.96756811
Ano10	102566	-0.6697767	0.74236016
Mtmr6	219135	-0.6699505	0.76195545
Tex10	269536	-0.6705229	0.84580812
Cdk1	12534	-0.6715807	0.71695958
Casc5	NA	-0.6717345	0.91459825
Sephs1	109079	-0.6728441	0.68125491
Tex30	75623	-0.6735875	0.90455568
Rabl3	67657	-0.674277	0.7251954
Mob1a	232157	-0.6745452	0.97517576
Nfib	18028	-0.6752858	0.50599008
Serpine2	20720	-0.6773376	0.71204828
Efemp1	216616	-0.6778861	0.84603721
Otub1	107260	-0.679446	0.81442305
Pin4	69713	-0.6803786	0.65212804
D15Ertd621e	NA	-0.681668	0.83262979
Ergic1	67458	-0.684517	0.58518804
Aga	11593	-0.6858098	0.71625974
Acp1	11431	-0.6863932	0.61103792
Nek7	59125	-0.6874332	0.52492028
Dnpep	13437	-0.6914683	0.94639425
BC003331	226499	-0.69541	0.91138841
Ntan1	18203	-0.6955763	0.62114951
Tmbim4	68212	-0.7014049	0.77725465
Rnasek	52898	-0.7016754	1.22231725
0610007P14Rik	58520	-0.7035081	0.61643383
Zfp68	24135	-0.7060548	0.61192004

Gstm2	14863	-0.713148	0.69359761
Tspan13	66109	-0.7143961	0.59539707
Smg7	226517	-0.7169769	0.7321229
Ints6	18130	-0.7173128	1.20087261
Ppp2r5e	26932	-0.7224147	0.55226648
Fam49b	223601	-0.7229268	0.82393161
Gstp1	14870	-0.728739	0.51411353
2810474O19Rik	67246	-0.7287937	0.79169585
Gosr1	53334	-0.7291309	1.15648762
Lamtor3	56692	-0.7301795	0.69537827
Rbms1	56878	-0.7329907	0.57197849
Atp11c	320940	-0.7344575	0.63044166
Mis18bp1	217653	-0.7352239	0.60410906
Zfp825	235956	-0.7359212	0.72156521
Nt5c2	76952	-0.7364703	0.64625542
Tia1	21841	-0.7379398	0.57707605
Cyp2g1	13108	-0.7412433	0.61737984
Rae1	66679	-0.7419222	0.6239629
Rel	19696	-0.743601	0.59974549
Nanp	67311	-0.7436578	0.64634423
Litaf	56722	-0.7487366	0.53439115
Tomm7	66169	-0.7495363	0.98563498
Brca2	12190	-0.7500841	0.79319086
Rfc3	69263	-0.7512294	0.99465376
Tmem60	212090	-0.7515802	1.09245618
Atl3	109168	-0.7517827	0.81808398
Gbe1	74185	-0.7518564	0.85473661
Ppap2c	NA	-0.7548721	0.67434529
Zwilch	68014	-0.7587961	0.5332047
Ep300	328572	-0.7607704	0.68376921
Coq4	227683	-0.762472	0.56970128
Ostc	66357	-0.7663939	1.00072438
Mad2l2	71890	-0.7678604	0.70554771
Zcchc7	319885	-0.7697007	0.50450209
Nup153	218210	-0.7728474	0.80871057
Tmem39a	67846	-0.7779565	0.97691608
Rps15a	267019	-0.7795293	0.55609103
Zyg11b	414872	-0.7807563	0.9487097
Kdelc2	68304	-0.7827134	0.86159235
Zmiz1	328365	-0.785863	0.67514783
Dcn	13179	-0.7866509	0.59906173
Ociad2	433904	-0.7876313	0.87614548
Mrps6	121022	-0.7938634	0.87079117
Nup43	69912	-0.7947641	0.6059686
Traf6	22034	-0.7950793	0.7625695
Zfp943	74670	-0.7960408	1.179289
Ankrd32	NA	-0.8010551	0.81906474
Cers6	241447	-0.8015068	0.62468067
Pts	19286	-0.8020105	0.62438805
Cpne8	66871	-0.8022293	0.55540424
Sdhd	66925	-0.8065047	0.83666607
Slmo2	NA	-0.8067874	0.54970338
Usp3	235441	-0.8106332	0.52181816
Pign	27392	-0.8117558	0.70279664
Bgn	12111	-0.812995	0.75721645
Rsu1	20163	-0.8143734	0.82394261
Ube2n	93765	-0.8149361	0.76460032
Rnase1	19752	-0.8184692	1.34476273
Gtpbp10	207704	-0.8186314	0.83149798
Ptdss1	19210	-0.823587	0.56799028
Grina	66168	-0.825339	0.58370587
Rer1	67830	-0.8262284	0.79030829
Slc15a1	56643	-0.8267263	0.91550543

Tmed3	66111	-0.8300555	0.66513053
Tbc1d19	67249	-0.8302907	0.79850654
Efna1	13636	-0.8308034	0.74683445
Gjc1	14615	-0.8340422	0.71989124
Dhfr	13361	-0.8345792	0.76251594
Slc10a7	76775	-0.8362406	0.61590346
Ftsj1	54632	-0.8386599	0.83230109
4930453N24Rik	67609	-0.8451663	1.02484074
Zfp800	627049	-0.8490256	0.95665118
Mrpl42	67270	-0.8508277	0.50509381
Atad2	70472	-0.8517155	0.94054584
Lmbrd2	320506	-0.8577851	0.85133776
4930402H24Rik	228602	-0.8580977	1.06824834
Krit1	79264	-0.8582031	0.58099291
A830080D01Rik	382252	-0.8625534	1.0738463
2210018M11Rik	NA	-0.8629725	0.58106409
Snap23	20619	-0.8640909	0.97580566
Rbbp8	225182	-0.8724741	0.76550794
Nipal4	214112	-0.8759144	0.77900065
Haus2	66296	-0.8774065	0.50922148
Mbnl3	171170	-0.8789108	1.20768525
Prcp	72461	-0.8878537	0.92013733
Zfp157	72154	-0.8900682	1.06029201
Depdc7	211896	-0.8949374	0.95064561
Tmem14c	66154	-0.9038356	0.96745217
Ufm1	67890	-0.904272	0.69744439
Zfp760	240034	-0.9112418	0.81002446
Far2	330450	-0.9166201	0.78109762
Elmo1	140580	-0.9210947	0.58769867
Copz2	56358	-0.9240203	1.22082428
Mad2l1	56150	-0.9274504	1.0453376
Fastkd1	320720	-0.9310224	0.96250547
Zfp58	238693	-0.9310891	0.91233373
Cd47	16423	-0.9329327	0.91978745
Stil	20460	-0.9355412	0.64384712
Ythdf3	229096	-0.9355425	0.81808918
Sp4	20688	-0.9373031	0.73027203
Ythdf2	213541	-0.9391567	0.8401112
Cox7a2l	20463	-0.9413981	1.11126235
Alg6	320438	-0.9436752	0.76908543
Ap5m1	74385	-0.9437382	1.28960207
Rab30	75985	-0.946295	1.53120939
Ackr3	12778	-0.9483915	1.18393131
Dcp1a	75901	-0.9502201	0.64640137
Mastl	67121	-0.9562699	0.85847932
Foxj3	230700	-0.957813	0.89648104
Rnaseh2b	67153	-0.9609732	0.74701452
Dimt1	66254	-0.9668364	0.81243462
Zfp763	73451	-0.9685841	0.81606556
Camk2g	12325	-0.9688568	0.65221482
Fam76b	72826	-0.9739636	0.71415138
Iqcb1	320299	-0.9768052	0.91765853
Elmod2	244548	-0.9840984	0.97716531
Fads2	56473	-0.9884767	0.74736117
Id2	15902	-0.9891219	0.80777342
Vangl1	229658	-0.9945206	0.56714158
Krtcap2	66059	-1.0122006	0.61131288
Ppil3	70225	-1.0135315	1.52705603
Cenpl	70454	-1.0249181	0.70309994
Psenen	66340	-1.0249532	0.6210669
Rnf38	73469	-1.0259837	0.81531523
Tmem230	70612	-1.037515	0.87216876
Dnajb9	27362	-1.0380648	1.50295478

Leprot	230514	-1.0381318	0.52578316
Cnep1r1	382030	-1.0404771	1.04027526
Lpar6	67168	-1.0434261	0.91667125
Cenpq	83815	-1.0531414	0.89501916
Stau2	29819	-1.0576508	0.72579444
Gm4944	NA	-1.0647066	0.80978347
Mtx2	53375	-1.0698029	1.18476351
Steap4	117167	-1.0809554	0.86125849
Slc35a1	24060	-1.1013287	0.77541762
Ubxn2b	68053	-1.1014216	1.33990355
Lrrn1	16979	-1.1016744	1.29651641
Pqlc3	217430	-1.1070472	1.02092926
2210408I21Rik	72371	-1.1106074	1.35138096
Grb14	50915	-1.1174134	1.557727
Inpp5k	19062	-1.1226026	1.02872233
Mrps11	67994	-1.1299797	0.72742986
C1galt1	94192	-1.1359728	1.60017233
Zfp788	67607	-1.1468253	1.67363692
Bet1	12068	-1.1562115	0.62753051
Pcdhga10	93722	-1.1576106	1.13042453
Siah1b	20438	-1.1735889	2.03796505
Slc15a2	57738	-1.1845168	0.89092762
Icosl	50723	-1.1885897	1.56642772
Eif1	20918	-1.1906441	0.78110146
Osgin2	209212	-1.1981555	1.40002238
Lrif1	321000	-1.2019186	0.83187
Zbtb2	381990	-1.2042509	0.80033228
Zfp874b	408067	-1.2051999	1.24579445
Zfp354c	30944	-1.206841	0.80799257
Slc29a1	63959	-1.2145534	1.07573414
Ccdc15	245902	-1.2155806	0.94000506
Slc35a3	229782	-1.2200753	0.9435503
Ube2l3	22195	-1.2215741	0.96842727
Ctns	83429	-1.2275664	0.81285894
Apool	68117	-1.235987	0.61582746
Tmem69	230657	-1.2468919	1.21899741
Zfp942	73233	-1.2565328	1.3533837
Zfp708	432769	-1.2671901	1.38086222
Sf3b6	66055	-1.2936828	1.08449306
Tmem126a	66271	-1.3062858	1.90871031
Arsk	77041	-1.3264416	0.9360019
Ndrg3	29812	-1.3285446	1.60458437
Usmg5	66477	-1.3288705	1.3863525
Uros	22276	-1.367205	1.412151
Mapk1ip1l	218975	-1.3873243	1.05516347
Parpbp	75317	-1.4185127	1.02696616
Cklf	75458	-1.4340805	2.40724875
Fam168b	214469	-1.4807094	1.12413892
Rnf115	67845	-1.4853075	1.12290907
Tmem29	382245	-1.5555124	1.93421765
Zfp951	626391	-1.5715686	2.0829315
Naa60	74763	-1.6013309	0.77114441
Tprkb	69786	-1.6516251	1.43011296
Cfap20	14894	-1.6856198	1.62785547
Itgb3bp	67733	-1.7251232	0.96016149
Cnksr2	245684	-1.7622804	2.03320843
Tbp	21374	-1.7811712	1.26346723
Tmem144	70652	-1.8074125	2.27969844
Sprr1a	20753	-1.8559063	1.06693151
3110009E18Rik	73103	-2.0471675	2.11298344
AW146154	101835	-2.3395332	1.48781111