Ortholog and Paralog Expression Between *Arabidopsis thaliana* and *Mus musculus*

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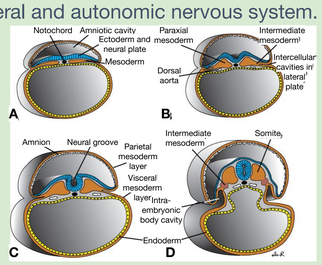
Plant neurobiology studies, a field within plant biology specific to inter- and intra- plant signaling pathways and response to environment and stimuli, show similarities in cell structure of trichoblasts and neurons, tissue structure of root hairs, muscle fibers, and nerves, and similarities in gene expression in reactionary and development specific pathways. Determining roles of these genes and their orthologs in embryonic development of seedlings and mice embryos can provide insight into cell and tissue specificity, since these genes become selectively activated during cell differentiation in different stages of embryogenesis. Arabidopsis root hair initiation and elongation genes have orthologs in mice that exhibit enhanced expression in key progenitor tissues and cell types fundamental for nervous system development and code for fundamental cellular structures that contribute to the shared function between both species' reactionary systems.

Hypothesis

Mice gene orthologs to Arabidopsis Thaliana genes that initiate root hair growth, elongation, root cell differentiation will be increasingly expressed throughout the gastrulation stages occurring before neurulation in cell types involved in the development of the nervous system, immune system, and muscular due to the necessity of cell projections, ion transport, and cellular signaling in these cells.

Introduction

During the development of the mice embryo in gastrulation, the single-layer epithelial tissue called the blastula reorganizes into three germ layers: the endoderm, mesoderm, and ectoderm. Development of the nervous system begins in late gastrulation and proceeds into the developmental stages of neurulation. In late gastrulation, the neural plate formed from a section of the ectoderm is initiated by the notochord and paraxial mesoderm to develop and differentiate into the cells of the peripheral and autonomic nervous system.



Additionally, the visceral endoderm assists in early neural patterning, the pharyngeal mesoderm influences neural tube development, mesenchymal migration initiates later development of the neural mesenchyme, and the migration of epiblast cells to the mesoderm midline cause the emergence of the neural crest from the ectoderm. The development of the muscular, cardiovascular, and immune systems in embryogenesis are essential in the differentiation of the PNS and ANS in overall central nervous system development. Similar structures in neuron and muscle cells in comparison to trichoblast root hair cells, as well as their role in signaling and response, have led to the proposal of a root-brain hypothesis by Charles Darwin that plants root-systems are analogous to the nervous and immune system of animals.

Results

Figure 1: ACT2 and ACT7 orthologs expressed in Cardiomyocyte and mesenchyme cells

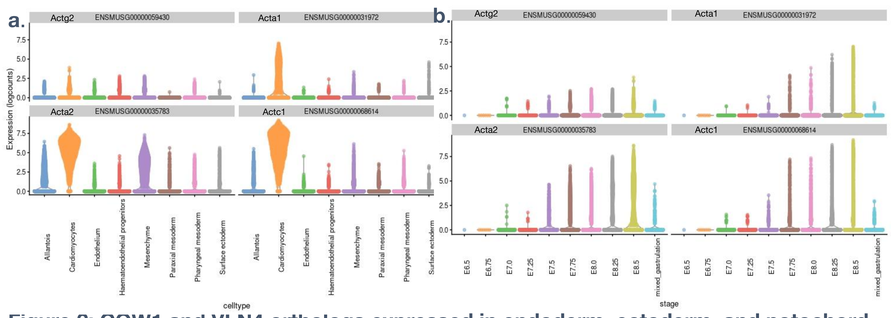


Fig1a. ACT2 and ACT7 genes of Arabidopsis Thaliana have orthologs Actg2, Acta1, Acta2, and Actc1 in Mus Musculus. These genes exhibit enhanced expression in cardiomyocyte and mesenchyme cell types.

Fig1b. Orthologs show increasing expression from stages E7.5 to E8.5 with minimal expression in stages E6.5 to E6.75

Figure 2: COW1 and VLN4 orthologs expressed in endoderm, ectoderm, and notochord

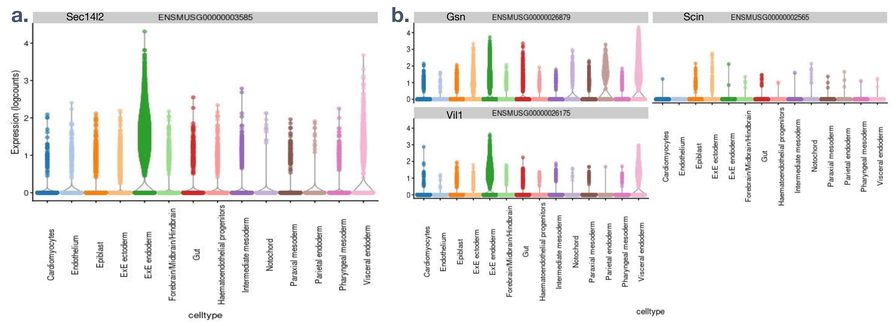


Fig2a. Arabidopsis root hair cell differentiation and root hair elongation gene COW1 has ortholog gene in mice, Sec14l2, exhibiting enhanced expression in the ExE and visceral endoderm.

Fig2b. Actin filament organization and root hair elongation gene VLN4's ortholog genes in mice, Gsn, Scin, and Vil1, are expressed in ExE, parietal, and visceral endoderm, as well as notochord, epiblast, and gut cells

Figure 3: ARAC5 ortholog expressed in blood progenitor cells

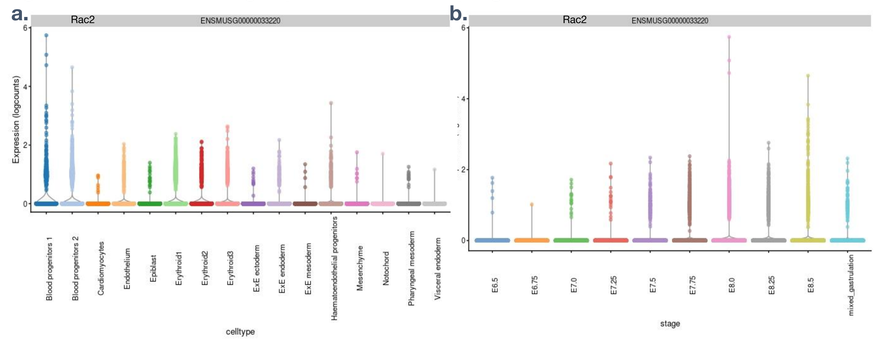


Fig3a. Arabidopsis root hair initiation and elongation gene ARAC5 has ortholog gene Rac2 in Mus Musculus. Rac2 exhibits enhanced expression in blood progenitor 1 and 2 cells as well as haemato endothelial progenitor cells.

Fig3b. Expression of this gene increases from stages E7.0 to E8.25 and peaks at stage E8.5.

Figure 4: RHD, ACT8, ABCB4, PIP2-4, and NRAMP2 orthologs expressed in epiblast and ExE ectoderm cells

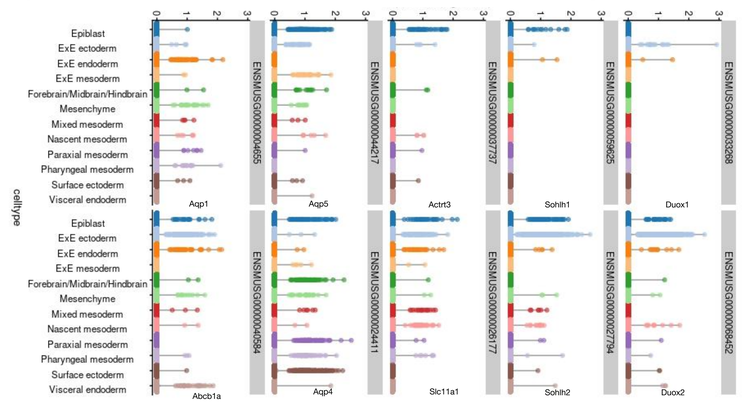


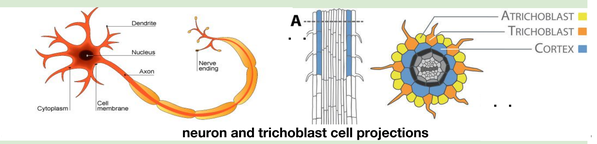
Fig4. RHD2, RHD6, ACT8, ABSB4, PIP2-4, and NRAMP2 gene orthologs in mice all show enhanced expression in epiblast, ectoderm, and endoderm cell types. Three genes in Arabidopsis that regulate root hair elongation, ABCB4, PIP2-4, and NRAMP2 also regulate auxin response, water and ion transport. Their ortholog genes in mice, abcb1a, aqp5, aqp4, aqp1, and slc11a1 are also differentially expressed in the forebrain, midbrain, hindbrain, and mesenchyme.

Methods

Using the e!EnsemblPlants database, a series of Arabidopsis Thaliana genes that were expressed in the biological pathways pertaining to root epidermis cell differentiation, root hair initiation, root hair elongation, and root hair cell tip growth. Genes were then plugged into the FlyBase database to find orthologs in mus musculus, and only those showing a reciprocal score were further filtered using e!Ensembl and KEGG pathways to select those related to the nervous, muscular, or immune systems. Cell and tissue specificity was determined using Human Protein Atlas. Using a single-cell RNA sequencing mouse gastrulation dataset, gene Ensembl IDs were plugged into RStudio plot maps using the scran, scater, ggplot2, scuttle, cowplot, and SingleCellExperiment packages to determine cell type and stage specific expression. Expression patterns in gastrulation and relation to nervous system development in mice were then compared and analyzed.

Discussion

Actin specific genes, ACT2, ACT7, and VLN4, in Arabidopsis are activated in root elongation pathways whilst their ortholog genes in mice are activated in nervous system and striated muscle development, hence their expression in the cardiomyocyte, mesenchyme, pharyngeal mesoderm, and notochord cells. These genes seems to play a key role in the creating the foundation within gastrulation for the development of the autonomic nervous system which interacts with the muscular and endocrine systems. These genes are fundamental actin organization and development genes, implying shared function of microtubule development in trichoblast and neuron elongation and projection development. This similarity in cellular structure gives rise to shared functions of these cells in their organisms' reactionary and information processing systems.



neuron and trichoblast cell projections

Further study of ortholog expression in root systems and nervous systems would benefit from using a single-cell RNA sequence neurulation dataset as well as a single-cell RNA sequence dataset for Arabidopsis Thaliana, specifically in its root systems, to better distinguish expression patterns between these organisms.

References and Acknowledgments

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