Modeling the Hydrodynamics in Bioreactors for the Expansion of Embryonic Stem Cells

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Embryonic stem cells have a large potential to help patients with commonly known diseases such as Parkinson's or diabetes through tissue engineering and regenerative medicine strategies. In order to generate large numbers of cells, efforts have been put into expansion of embryonic stem cells in suspension bioreactors. Usually this means multiple experiments in large volume reactors, with considerable investment of time and resources. For this reason, successful cell expansion in a microbioreactor would facilitate multiple experiments with much lower cost and higher throughout. Previously, embryonic stem cells were successfully expanded in a 100mL bioreactor, but the same expansion was not seen in a prototype 250µL microbioreactor. Using modeling software and simple geometry, it was found that the hydrodynamic environment in the microbioreactor was more heterogeneous and erratic than that of the 100mL bioreactor. In order to design a microbioreactor that will yield successful cell expansion, the hydrodynamic environment of the 100mL had to be studied first in further detail, including more accurate geometry. Modelling software (COMSOL Multiphysics) was used to analyze the velocity, shear stress, streamline, vorticity, and pressure within the 100mL bioreactor while varying multiple parameters to study their effect. Generally, shear stress and vorticity were very sensitive to changes in geometry (i.e. shape of impeller, liquid level) and agitation rate. The pattern of streamlines clearly indicated where the cells would be concentrated within the bioreactor. With the results of this analysis, the next step would be to design a microbioreactor with the most suitable geometrical configuration that will match that seen in the larger 100 mL bioreactor, and ultimately allow successful embryonic stem cell expansion.