

# Folding 3D Cell Shapes Optimized by Computational Origami

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## Abstract

The purpose of this research is to establish a technique to efficiently fold the intended 3D shape using cells. Specifically, we utilize the method of computational origami to model folding characteristics of the cells, to make an algorithm for the selection of the optimal development of the 3D shape, and to efficiently fold it with the cells.

There are various three-dimensional structures and organs in the living body, and the shape plays an important role in its function. Even a single cell, the shape of the cell is deeply involved with function and differentiation of the cell. For example, when a mesenchymal stem cell is cultured in a single cell, it differentiates into fat and bone when the adhesion areas are narrow and wide, respectively [1]. If we can freely control the shape of the cells, it becomes possible to control differentiation of the cells and organize targeted organs, giving a great impact to regenerative medicine.

Self-assembly [2] is a reasonable model of folding 3D shapes with cells called *cell origami* that we previously developed [3]. There are a few previous works about this topic [4,5]. In the previous work, they estimate all eleven developments of a cube by their geometrical properties with the experimental results. However, unfortunately, the geometrical property strongly depends on the developments of a cube, and hence it is not applicable to the other general polyhedra. In this paper, we introduce more general model which is based on the law of physics on a metric graph, which gives a geometrical structure, of the developments of a given general 3D shape. We will show usefulness of our model from the viewpoint of computational origami with experimental results using cells. We consider a regular tetrahedron as a representative 3D shape since it is one of the most basic 3D shapes in geometry (see, e.g., [6]). Here, we examined the difference in differentiation when cells were cultured in 2D plane and 3D structure. We also examined differences in cell shape and cytoskeleton due to differences in developments.

We found that differentiation of the differentiated different fat cells (DFAT: Dedifferentiated Fat Cell) were different when cultured on the 2D plane and 3D structure (Fig. 1). When we cultured the cells in 3D, it differentiated into bone, and they did not differentiate in 2D plane. Therefore, in order to differentiate cells, the 3D structure is important. Furthermore, fibroblast cells (NIH/3T3) were cultured on different developments of tetrahedrons (we also cultured on the developments of various shape such as cube and dodecahedron –details are omitted due to the space limitation) and self-folded into 3D structure

using a cell traction force (Fig 2). The orientation of actin filaments before folding was found to be different with the different development views, suggesting that the cell traction force changes accordingly. We will examine the folding time and the success rate of folding with regard to developments to efficiently fold an ideal 3D shape with the cells.

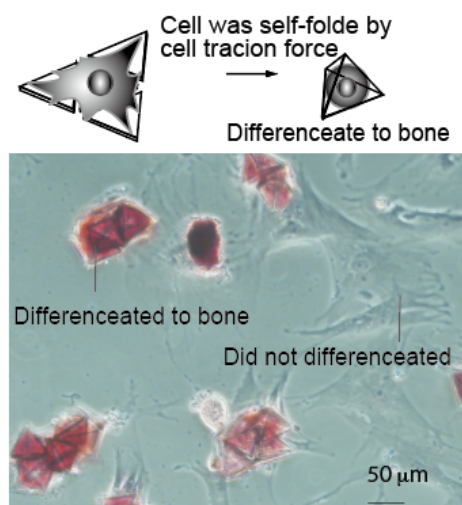


Figure1 DFAT cells were differentiated when they were cultured in 3D shape.

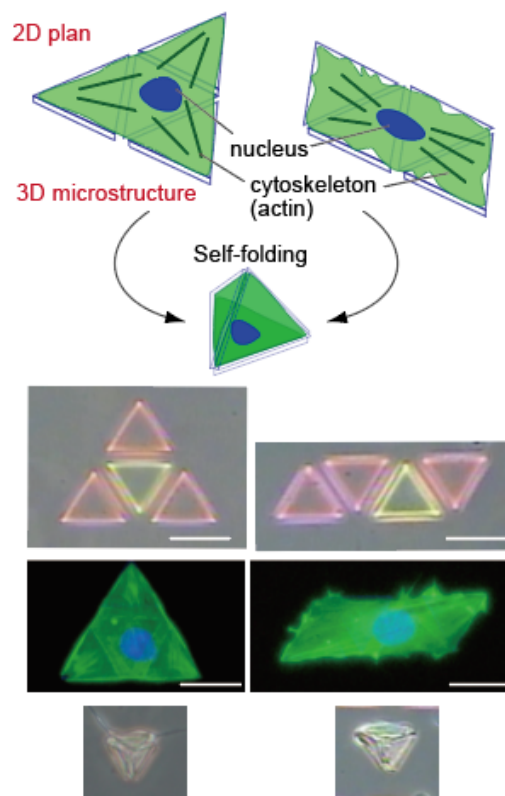


Figure2 NIH/3T3 cells were cultured on different development of tetrahedrons and were self-folded into 3D shape. The orientation of the actin filaments were different with each developed view. scale bar: 50  $\mu$ m

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