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A Mathematical Model of Cleavage

In the present paper, we propose a mathematical model of cleavage. Cleavage is a process during the early stages of development in which the fertile egg undergoes repeated division keeping the cluster size almost constant. During the cleavage process individual cells repeat cell division in an orderly manner to form a blastula, however, the mechanism which achieves such a coordination is still not very clear. In the present research, we took sea urchin as an example and focused on the diffusion of chemical substances from the animal and vegetal pole. By considering chemotactic motion of the centrosomes, we constructed a mathematical model that describes the processes in the early stages of cleavage.

For example, in a sea urchin, the 1st cleavage and the 2nd cleavage happen along a field including an animal pole and a vegetal pole (meridional cleavage). This detects the concentration gradient of a certain chemical substance from the animal pole to a vegetal pole, and is considered to use for the determination of a cleavage plane. The 3rd following cleavage is a field which intersects perpendicularly with the 1st and the 2nd cleavage plane. However, if it inserts with glass and pressure is put and changed from two poles, it is known that the 3rd cleavage will turn into a meridional cleavage. It has suggested that the determination of a cleavage plane is not necessarily decided only by distribution of a chemical substance, and receives influence in a dynamic factor, a geometric factor, etc. from this. Cell division may think that it is prescribed by the aster. Normal division takes place, when one pair of asters exist in one cell, and cleavage does not happen without an aster. When four asters exist in a cell, being divided in four is reported. The centrosome located at the center of an aster determines the position of an aster. In order to form one pair of asters, it is required to divide a centrosome in two and to arrange it in advance of it, in a suitable position. As mentioned above, it turns out that the decisive role is played when the position of the centrosome which has opted for arrangement of the aster determines the geometry of cell division. Well then, how does this centrosphere move? The microtubule has connected with the centrosome and the aster is constituted. By work of a duplication region microtubule, an aster is repelled with another aster. Furthermore, the spindle could maintain a fixed distance within a cell, in order for an aster microtubule to receive restitution also from a film. However, only in such assumption, the directivity of division of an egg does not become settled. Then, we assumed that the factor of the diffusion which exists in an animal pole and a vegetal pole exerted taxis on a centrosphere. We did the numerical computation of the directivity and the position of a spindle from the form and the diffusion field of the egg. As a result, it found out that the convexity of a concentration gradient can determine the directivity of cell division. We introduce the details about this research.

References

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