Molecular Biology

Cells Like It Soft

Cells behave differently in soft surroundings than on hard glass or plastic surfaces, on which they are usually investigated. Recent experiments show that forces at contact sites between cells and their surroundings influence the cells’ development and behavior. Scientists at the Max Planck Institute of Colloids and Interfaces in Golm near Potsdam have now succeeded in explaining, modeling and predicting cell behavior on and in soft materials (PNAS, August 5, 2003).

The human body consists of about two trillion (10¹²) cells, which can be classified into more than 200 different cell types. To function properly, two apparently contradictory principles must be fulfilled: Cells must adhere to each other and simultaneously be able to reorganize rapidly— for example, to react to infection or injury. Nature has evolved different strategies to do so: Firstly, tissue cells build up a porous network of proteins, the so-called extracellular matrix, which binds the cells to each other, but also leaves them enough room to move. Secondly, cells permanently assemble new strings because they prefer to react in an environment with conditions resembling their internal environment. In this way, they dynamically line up in an elastic matrix. Several cells preferentially align themselves in the direction of the largest effective stiffness. In other words, they seem to seek a stronger hold—probably because “cells can then build up higher forces at their focal contacts.”

Using calculations in elasticity theory, the researchers could predict how a cell reacts in certain situations, depending on external conditions. According to this model, in a soft environment, individual cells close to a rigid surface preferentially orient themselves perpendicular to the surface. In contrast, at freely deformable surfaces, individual cells orient themselves parallel to the surface, since in this case a perpendicular orientation would appear to be softer. In addition, the model predicts that, due to deformation of the elastic substrate located between them, several cells will preferentially line up in strings. In an external strain field, the cell orientation will align with the direction of external stretch.

These predictions for cell orientation and positioning are in excellent agreement with numerous experimental observations— which are often challenging to test in future experiments. However, it is already clear that Bischofs’ and Schwarz’s model might lead to important applications in biotechnology and medicine— for example, concerning the behavior of cells in artificial tissues or close to interfaces to implants.

View of a fluorescently labeled fibroblast cell. (a) Bundles of actin filaments (green), which are part of the cell’s inner skeleton, end at focal contacts (red) that connect the cell to its surroundings.

(a) Cells prefer the soft surroundings. (b) A parallel orientation is optimal with free (left) and rigid (right) regions. (c) Several cells preferentially line up in strings because each cell stiffens the elastic environment at its ends.

MATERIAL SCIENCES

Supersonic Cracking

In brittle materials, cracks can spread at above the speed of sound—which is a lot quicker than classical theory allows. Scientists at the Max Planck Institute for Metal Research in Stuttgart and the IBM Almaden Research Center in San José (USA) have come to this conclusion on the basis of extensive computer simulations. Their studies can help to improve understanding of how cracks originate and propagate, which is important both for conventional technologies— such as in airplanes or spacecraft, as well as for novel nanoscale science and engineering (Nature, November 13, 2003).

In spite of their strength, materials are made out of atoms and ions. It has, however, now become clear that this “continuous” way of studying materials is not adequate— and it is rather more important to understand a material’s properties and behavior at the atomic level in order to simulate suitability for specific purposes. But when it’s about dimensions in micro- and nanometer range, there is no longer any direct experimental approach to material-related phenomena: Computer simulations— which are often challenging— are the only way to finding out how materials respond in these tiny dimensions. Researchers at the Max Planck Institute for Metal Research in Stuttgart and the IBM Almaden Research Center have now used this approach to analyze the dynamics of cracks in brittle materials— and have established that conventional theories on the dynamic propagation of cracks neglect an important aspect: the fact that the elasticity of a solid depends on the extent of its deformation; the reason why metals become soft and, in contrast, polymers become hard when they are stretched to the limit of their strength. Huajian Gao, Director of the Max Planck Institute for Metal