

It All Starts with a Baby Egg Cell

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What is the very first thing you can remember? Maybe you were splashing in a puddle at preschool or feeling the breeze while riding on your dad's bike. However, from a biological perspective, your story goes back even further than that, to the moment you were a fertilized egg in your mother. A fertilized egg is nothing more than a sphere only 0.1 mm in diameter. Yet, inside the sphere, a vast amount of genetic information was folded into itself, and an elaborate molecular machine was quietly at work, ready to assemble the body of the future. This tiny cell, only a tenth of a millimeter wide, already carries all the instructions to build your whole body.



The fertilized egg begins to split into two, then four, then eight, and so on, according to the cell cycle. Within a short period, the number of cells grows exponentially and becomes a tightly packed embryo - a miniature ball of cells - under a thin, transparent membrane like a wrapping paper. The proliferating cell population soon shows complex movements inside the embryo. Some cells spread outward while others burrow inward, forming three main layers: one will become skin and nerves, another becomes muscle and bone, and the last turns into the stomach and lungs. Cells pull and push against

each other, fine-tuning their positions to form organs. In the process, the speed of division and the trajectory of migration are seemingly chaotic, but eventually they land on a structure that is consistent with the individual. This robustness is a mysterious phenomenon that cannot be explained simply by cells “working hard.”

The greatest mystery that emerges here is how individual cells decide that “I will be a skin” or “I will be a nerve” in the future; in other words, how cells choose their own fate and complete development as a whole without failure. It is now believed that there is a concentration gradient of chemicals in the embryo, and cells obtain rough positional information by reading it. Evidence is also accumulating that contact between neighboring cells and mechanical stress can also provide clues to fate determination. However, concentration gradients diffuse and blur with time, and contact information must be constantly updated between moving cells. Still, the overall pattern of the embryo is not broken. The mechanism by which millions or billions of cells make individual decisions that result in a unified form is still not fully understood.

Furthermore, while embryos of the same species reach nearly the same result with little individual variation, the form and time scale vary greatly among different species. What guarantees “human-like” or “fish-like” development, while at the same time guaranteeing flawless development? This question continues to stimulate fundamental interest in basic science and is exactly what pulled me into this field.

A human embryo never turns into a fish in the process. Human embryos follow their developmental programs faithfully as humans, a zebrafish as a zebrafish, and a frog as a frog. If embryonic development were merely an accumulation of coincidences, such

stability would never be maintained. In other words, the species-specific blueprint is highly protected and at the same time equipped with mechanisms to absorb fluctuations and disturbances in the developmental process. From the perspective of comparative embryology, this compatibility between “species-specificity” and “robustness” is the product of evolution and is proof of the fact that living systems have been able to reproduce themselves in the face of environmental change.

Developmental biology is a field that investigates these phenomena from a multilayered level, from molecules to individuals. The latest experimental techniques, such as visualization using optical and electron microscopes, live imaging using fluorescent proteins, and functional analysis by gene editing, are used, and at the same time, a framework of physics and mathematics is essential. The intersection of knowledge from different fields is making it possible to understand developmental processes.

My goal in this field is not only to catalog the functions of individual genes and proteins, but also to clarify the universal principles by which they interact to cause self-organization. For example, questions such as how cell fate is determined or how physical constraints determine the course of evolution can only be answered by comparing various plants and animals, not just humans. If we find the universal rules, we will be able to even predict what life on another planet could look like - how many hands do they have?

So far, we have looked at the mysterious mechanisms of development. In fact, there are many things you can explore on your own. First, think carefully about the things that

make you wonder "why?" Look at the small wonders around you, such as splashes of water in a puddle or fallen leaves swaying in the wind. Then, talk to various people and information, such as family, friends, teachers, books in the library, and the Internet, and investigate and incorporate new perspectives. Every time you see a new world, your own thoughts will expand and deepen.

Just as life begins in a small fertilized egg, great scientific discoveries begin by looking at the small wonders around you. Take in the opinions and knowledge of various people and cherish and nurture your own "why?". Great discoveries of the future may be born from your curiosity and inquisitiveness.

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