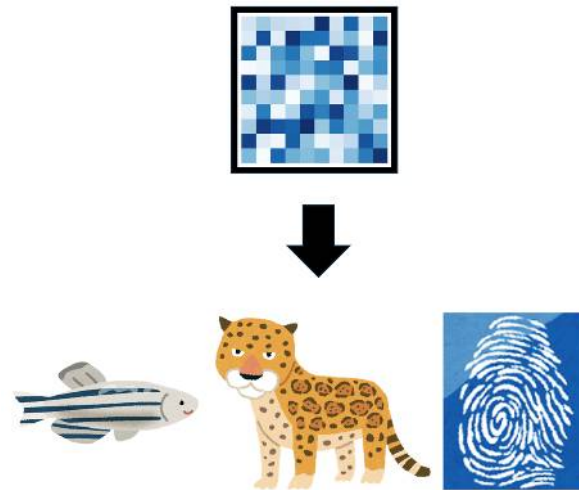


How do living organisms acquire their own patterns?

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I conduct research in the field of developmental biology—a branch of science dedicated to understanding how living organisms grow, take shape, and form the intricate structures that define them. Have you ever wondered why humans usually have five fingers on each hand? Or why zebrafish have stripes, and why the arrangement of leaves on a stem is so consistent across a species? These features aren't random or accidental—they are precise, repeatable, and highly ordered. Understanding how such biological patterns arise is one of the most fascinating and fundamental challenges in science.

One particular pattern I study is the series of cartilage rings in the trachea—the windpipe that allows air to move from the throat to the lungs. These rings are not just decorative; they play a critical structural role. They keep the airway open during breathing and help maintain its shape against the forces of inhalation and exhalation. But the pattern must be finely tuned. Too many rings can make the airway overly rigid or narrow, restricting airflow. Too few can leave it unstable and prone to collapse. In rare but serious medical cases, babies are born with defects in this ring pattern, and we still don't fully understand what causes them. That's where basic research, like the kind I do, can make a difference—by offering insights into the fundamental rules that guide such pattern formation during development.

To investigate these questions, scientists often use mathematical models. One of the most influential ideas in this area came from Alan Turing. In 1952, he proposed a theory to explain how natural patterns—like stripes on fish or spots on leopards—could

arise spontaneously through a process involving two interacting molecules that diffuse and react across space and time. This concept, known today as the reaction–diffusion model, has become a foundational framework for studying how complex biological patterns can emerge from apparently disordered conditions.

In a typical Turing system, one molecule acts as an activator—it promotes its own production as well as that of an inhibitor. The inhibitor, in turn, slows or suppresses the activator. If these two substances diffuse at different rates and interact, then striking patterns can emerge from the uniform state. Spots, stripes, waves, and rings—all can self–organize without direct genetic instructions, simply through the dynamics of diffusion and reaction. It’s a profound example of how order can emerge from disorder, and it continues to inspire not just biologists, but physicists, chemists, and mathematicians alike. My own research builds on this theory to simulate and analyze how cartilage rings form in the developing trachea.

Of course, translating mathematical beauty into biological understanding isn’t simple. While the equations are elegant, we still don’t know which specific molecules in the body play the roles of activator and inhibitor. The human body produces tens of thousands of proteins, and identifying the few responsible for specific patterns is like searching for needles in a molecular haystack. This is why collaboration with experimental biologists is essential. By combining computational simulations with experimental data—such as gene expression profiles or live imaging from model organisms like mice and zebrafish—we can begin to narrow down the possibilities and gradually map mathematical elements to real biological players.

Interestingly, the mathematical rules used to describe biological pattern formation turn out to be useful far beyond biology. The same kinds of equations that explain how cartilage rings form in a developing embryo can also model chemical waves on a petri dish, the growth of snow crystals, and the spread of viral infections. This universality suggests that pattern formation may be governed by deep, shared principles—linking living systems to physical processes across vastly different scales. For me, that’s one of the most exciting aspects of working in this field: the idea that by studying a specific developmental feature like the trachea, we might also be learning something profound about how nature organizes itself as a whole.

If I could give one piece of advice to my 12–year–old self, it would be this:
Don’t worry if you don’t know yet whether you’re more interested in biology or

physics. At your age, I wasn't particularly drawn to either. What changed things for me was discovering that math could actually explain the structure and beauty of the natural world. That realization came slowly, but it sparked a new curiosity. I started to notice connections between numbers and nature: the way leaves are spaced on a stem, the symmetry of animal markings, or how the body builds itself from a single cell.

You're growing up in an age when the world's knowledge is just a few taps away. Use the internet not only for entertainment but to explore ideas in science, art, engineering, philosophy—whatever draws your interest. Don't limit yourself too early. Dive into black holes, watch time-lapse footage of embryos developing, try coding a fractal pattern—because some of the most meaningful interests come from places you didn't plan to explore.

And most importantly: when you don't understand something, don't walk away from it. Stay with the hard parts. Try different ways of thinking. Real understanding often comes not from getting quick answers, but from the quiet, persistent work of making sense of what feels confusing. That kind of persistence is what will carry you forward in science, and in whatever you choose to pursue.

I used ChatGPT to check grammar errors and to improve the quality of my English expressions. An image is obtained from [いらすとや](#).

[1] Kishimoto, K., & Morimoto, M. (2021). Mammalian tracheal development and reconstruction: insights from in vivo and in vitro studies. *Development*, 148(13), dev198192. <https://doi.org/10.1242/dev.198192>

[2] A. M. Turing (1952)., *The Chemical Basis of Morphogenesis*, *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, Vol. 237, No. 641, pp. 37-72.