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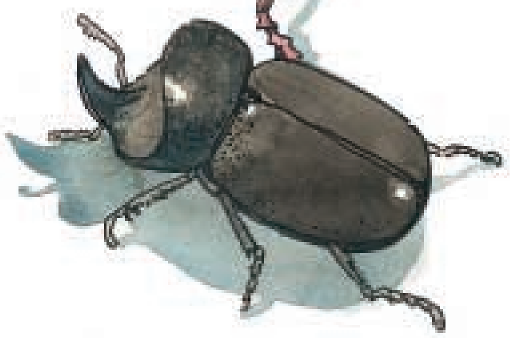


2.4 Life Uses a Few Themes to Generate Many Variations

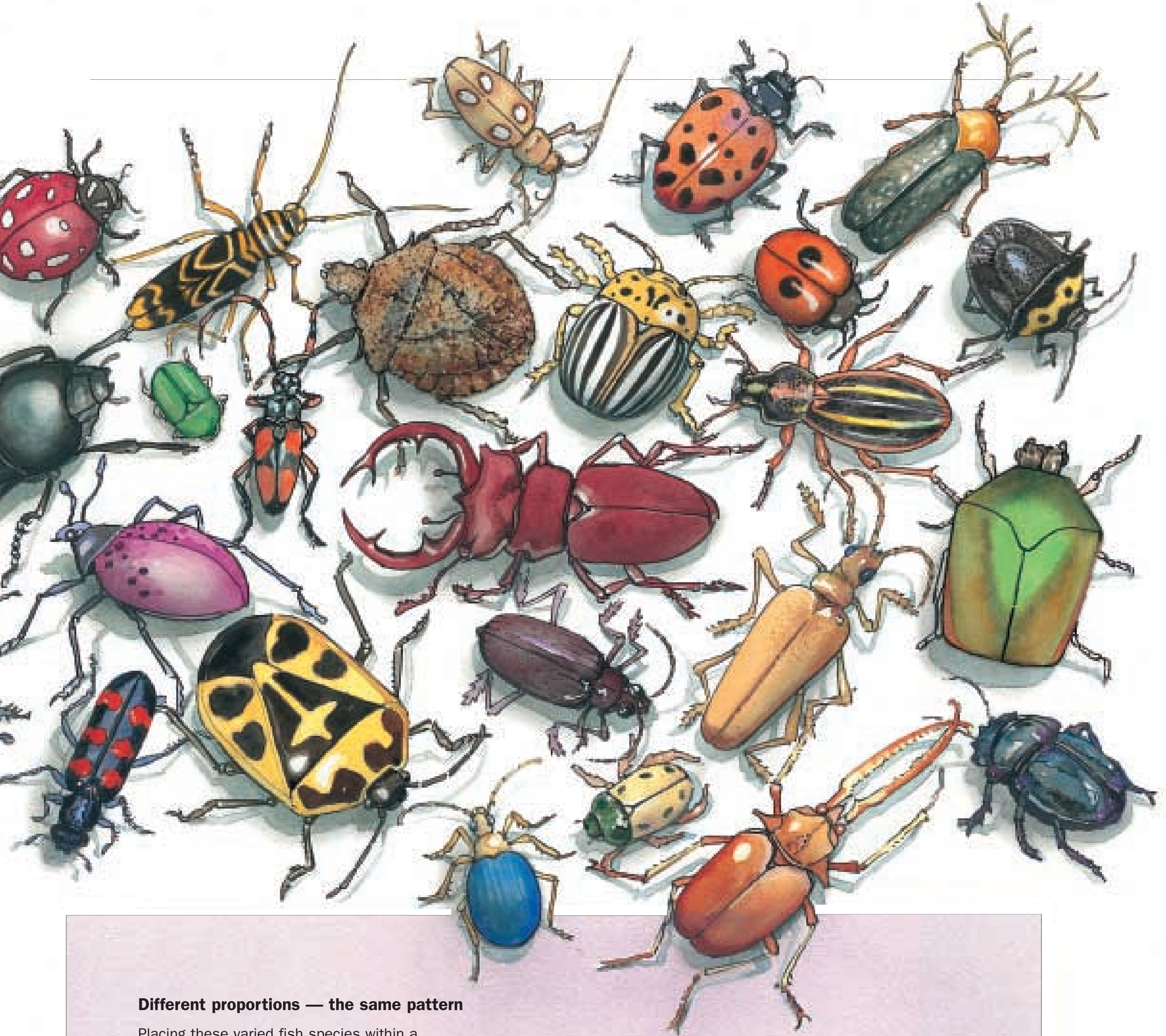
The Inward Similarity of Outward Diversity

Variations on a theme

The beetle, with some 300,000 separate species (the world's most numerous order), displays every imaginable color, decorative motif, and proportional distribution of body parts — yet the pattern of relationships that makes beetles is constant.

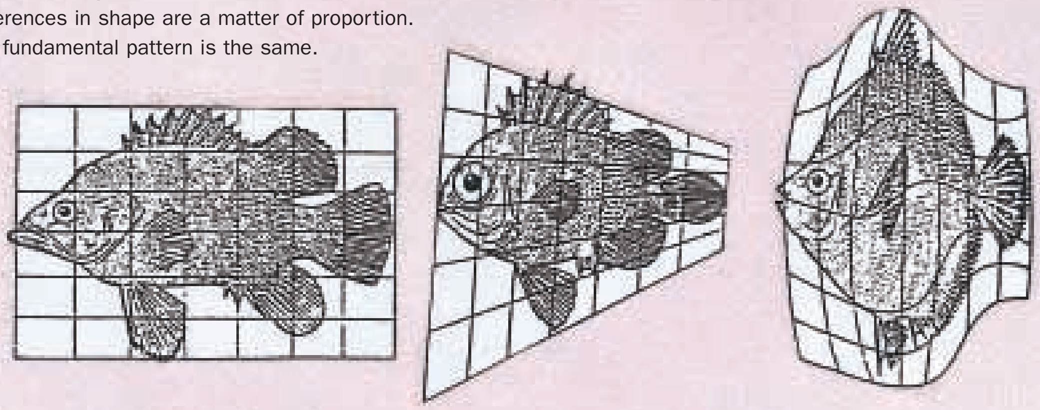
Life hangs on to what works. At the same time, it explores and tinkers. This restless combination leads to a vast array of unique living creatures based on a considerably smaller number of underlying patterns and rules. For example, when cells divide and grow, they do so in a mere handful of ways. New cells can form concentric rings, as they do in tree trunks and animal teeth. They can form spirals, as in snails' shells and rams' horns; radials, as in flowers and starfish; or branches, as in bushes, lungs, and blood vessels. Organisms may display several combinations of these growth patterns, and the scale can vary; but for all life's diversity, few other growth patterns exist.

Life, in striving for the most economical use of space, borrows mathematical rules. For instance, count the branches coming off a stem for a given number of full turns around the stem, and with surprising consistency the numbers of turns and branches relate to each other as in the series 1 1 2 3 5 8 13 21. . . — the so called Fibonacci series — in which each successive number is the sum of the two preceding it. For example, in a pine cone, there are thirteen scales for every seven turns. Similar patterns occur in the spirals of florets in sunflowers and daisies, the sections of the chambered nautilus, even the branchings of the bronchial tubes in our lungs. Such similarities in pattern give us some insight into how simple rules, used in different contexts, can produce great variety. From few notes, nature creates many symphonies.

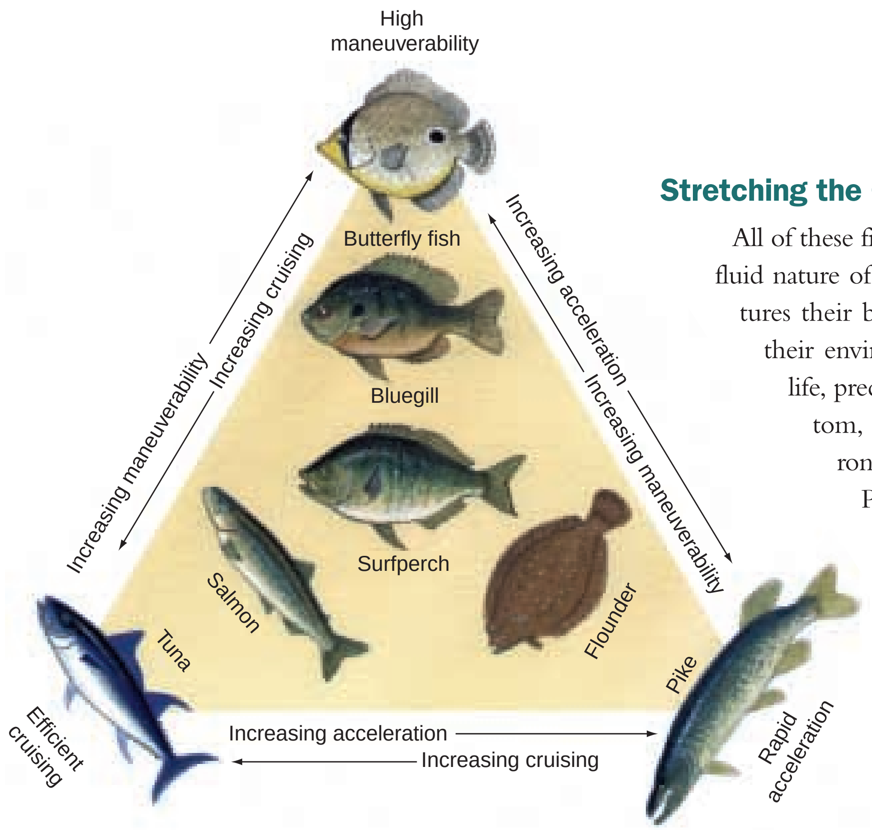


Different proportions — the same pattern

Placing these varied fish species within a "stretchable" grid demonstrates that their differences in shape are a matter of proportion. The fundamental pattern is the same.



From d'Arcy Wentworth Thompson, On Growth and



Stretching the Grid

All of these fish live in a common fluid — water — and the fluid nature of their environment is one reason for the features their body structures have in common. However, their environments differ with respect to salinity, plant life, predators, prey, amount of sunlight, type of bottom, and many other characteristics. These environmental diversities are what "stretch the grid." Predator fish, like pike, are successful if they have a shape that can provide rapid acceleration. Grazing fish, like butterfly fish for example, succeed if their shape gives them maneuverability around rocks and corals and allows them to hide from predators.

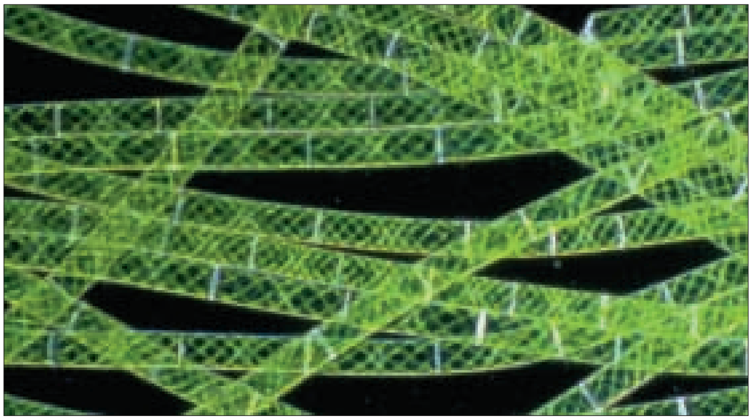
How a Slime Mold Makes Its Living

We have already seen that anything living has to have an inside protected from the outside. It's also true that the shapes living things take over time are indirectly molded by specific survival needs and by the forces of the world outside. Most living things that are the wrong color or shape or size or have the wrong kind of teeth or breathing apparatus for their environment don't survive long enough to reproduce. Ones that are better adapted to their environment do reproduce and succeed.

A branching growth pattern

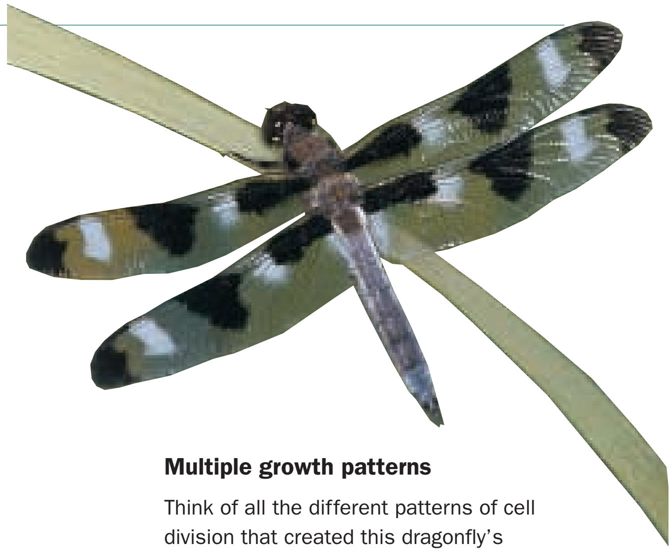
A plasmodial slime mold, *Physarum polycephalum.*

The successful growth pattern in the yellow slime mold shown at left is an adaptation that allows it to absorb food from and exchange gases with the outside. It presents a very large surface to the world, and possesses a branching pattern of veins to move materials throughout its volume. The mold lives in a moist, dark, forest underlayer, so it doesn't need a thick shell or skin to protect it from its environment. In fact, in some sense, the forest underlayer can be thought of as the mold's "skin."



A linear growth pattern

Strands of algae—cells divide in only one plane.

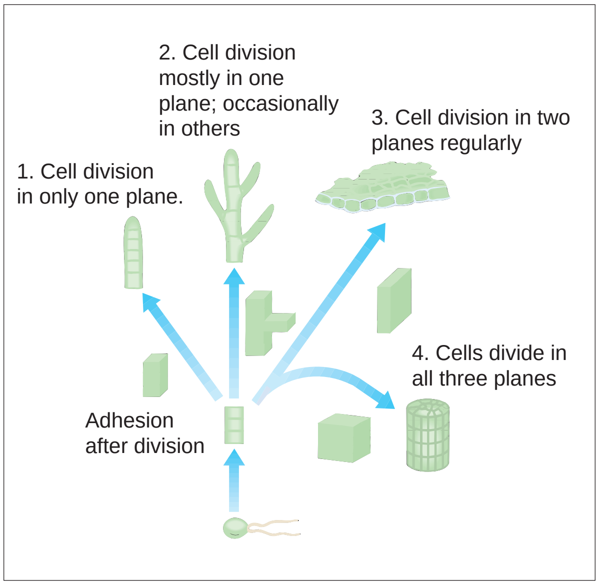


Multiple growth patterns

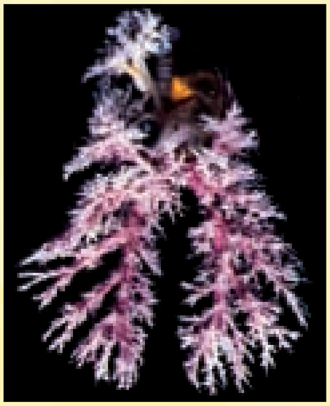
Think of all the different patterns of cell division that created this dragonfly's shapes.

Patterns of Multiplication

When a cell divides in two, which is how it reproduces itself, the two resulting daughter cells can go their separate ways as unicellular organisms, or they can stick together and function as a multicellular organism. Dividing and adhering cells can occupy space in only four basic ways (right): (1) They can grow in one plane of space, say north-south, creating a single long chain of cells. (2) They can keep extending in that one direction, with occasional offshoots east or west. (3) They can grow consistently in two directions, making a thin sheet of connected cells. (4) Or they can grow in all three spatial planes, adding up and down to east-west and north-south, making chunks, cylinders, and spirals.



The highly complex system of airways of a human lung (a) has a pattern very similar to that of the simpler slime mold. A very different kind of organism, the seaweed *Fucus* (b), also has a similar pattern.



(a)

(b)

Question.

Explain the similarity of the patterns you see here in terms of the way each structure supplies the needs of the living organism. How are the outsides of these structure adapted to protecting them (or not) from their environment?

Answer...

The branching pattern of airways in the lungs creates a large surface area for air to enter all parts of the lung. That same branching pattern exposes a large area of the seaweed to its fluid environment, allowing it to absorb nutrients and exchange gases. The "outside" of the lungs' airways is really their interior, and this is covered with cilia and mucus for protection. The seaweed, too, is covered with a kind of mucus, and has tough, leathery skin.