THE NEW AMBIDEXTROUS UNIVERSE

SYMMETRY and *ASYMMETRY* from MIRROR REFLECTIONS to SUPERSTRINGS

THIRD REVISED EDITION

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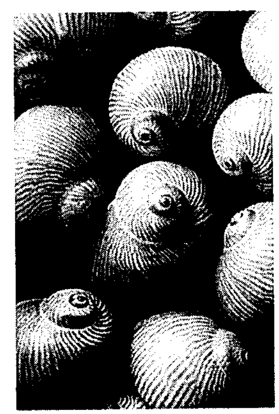

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CHAPTER

Plants and Animals

Among the billions of known galaxies scattered through space, each containing billions of stars, it seems reasonable to suppose that circling around many of these stars there must be planets, and that on some of these planets there must be life. "A sad spectacle!" exclaimed Thomas Carlyle, as he considered the possibility that the universe might contain planets by the millions. "If they be inhabited, what a scope for pain and folly; and if they be not inhabited, what a waste of space!"

At the moment, no one really knows whether life in any form is spread throughout the universe, confined to our own galaxy, or confined to our solar system. We do not even know if there is some primitive form of life on Venus or Mars, the two planets nearest the earth, though in both cases it seems extremely unlikely.

Assuming that forms of life have evolved on other planets, will these forms be wildly unlike anything that even science-fiction writers have imagined? Or will they possess certain features in common with life as we know it? It is all sheer speculation, of course, but with respect to questions of symmetry we can make some educated guesses. On the earth, life started out with spherical symmetry, then branched off in two major directions: the plant world with symmetry similar to that of a cone, and the animal world with bilateral symmetry. There are good reasons to think that evolution on any planet, if it occurs at all, would tend to follow a similar pattern.

Primitive one-celled life, floating in a sea and constantly tumbling about, would naturally assume a spherical form with planes of symmetry in all directions. But once a living form anchors itself to the bottom of a sea or to the land, a permanent up-down axis is created. The rooted end of any plant is obviously distinguishable from the upper end. There is nothing, however, in the sea or air to distinguish between the ends of a front-back axis or a left-right one. It is for this reason that plant forms, for the most part, have a rough, overall symmetry similar to that of a cone: no horizontal plane of symmetry, but an infinity of vertical planes. A tree, for example, obviously has a top and bottom, but one is hard put to distinguish the front from the back of a tree, or its right from its left. Most flower blossoms have, in a rough way, a conical type of symmetry. Fruits sometimes have spherical symmetry (if you ignore the spot where they attach to a branch): oranges, cantaloupes, coconuts, and so on. A cylindrical-type symmetry (an infinity of planes of symmetry passing through one axis, and one plane perpendicular to that axis and bisecting it) is exhibited by such fruits as grapes and watermelons. Familiar fruits with conical symmetry are the apple and pear. (Biologists use the term *radial symmetry* for symmetry of both cylindrical and conical types.) The banana furnishes an example of bilateral symmetry. Owing to its curvature and its pointed end, it is possible to cut a banana into mirror-image halves by only one plane of symmetry.

Are there examples of asymmetry (total absence of planes of symmetry) in the plant world? Yes, and the most striking examples are the plants that display helices in some part of their structure. As we learned in an earlier chapter, the helix cannot be superposed on its mirror image. It therefore has two distinct forms: the right-handed helix, which corresponds to a wood screw that turns clockwise as it enters wood; and the left-handed helix, which is the mirror image of a right-handed one. Helices abound in the plant world, not only in stalks, stems, and tendrils but also in the structure of myriads of seeds, flowers, cones, and leaves, as well as in the helical arrangement of leaves around a stalk. (Helical structures are also found in the world of animals, as Chapter 8 shows. For a cartoonist's view, see Figure 25.)

It is in the climbing and twining plants that the helix can be seen in its most regular form. The majority of twining plants, as they coil upward around sticks, trees, or other plants, coil in right-handed helices, but there are thousands of varieties that coil the opposite way. Some species have both left- and right-handed varieties, but usually a species has its own handedness, which never varies. The honeysuckle, for example, always twines in a left-handed helix. The bindweed family (of which the

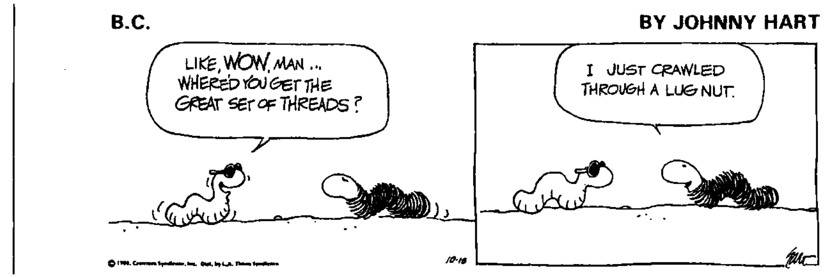

Figure 25 *Screw threads might be a status symbol among earth burrowers. (By permission of Johnny Hart and Creators Syndicate, Inc.)*

morning glory is a well-known species) always twines in a right-handed helix. When two plants of the same handedness twine around each other, the result is a fairly orderly production of interwound helices, all of the same type; when plants of opposite handedness coil around each other, they produce a hopeless tangle. The mixed-up violent left-right embrace of the bindweed and honeysuckle, for example, has long fascinated English poets. "The blue bindweed," wrote Ben Jonson in 1617, in his *Vision of Delight*, "doth itself enfold with honeysuckle." Shakespeare, in Act 4, Scene 1, of *A Midsummer-Night's Dream*, has Queen Titania describe her intended embrace of Bottom the weaver (whose top has been transformed by Puck into the head of an ass) by saying: "Sleep thou, and I will wind thee in my arms. . . . So doth the woodbine the sweet honeysuckle gently entwist . . . ."

In Shakespeare's day the bindweed was sometimes called the woodbine. Later *woodbine* became used exclusively as another term for honeysuckle, a fact that has confused dozens of easily confused Shakespeare commentators. Some of them have even reduced the passage to silliness by supposing that the beautiful Queen Titania, "sometime of the night," was speaking of herself and Bottom as entwined like honeysuckle with honeysuckle. Awareness of the opposite handedness of bindweed and honeysuckle heightens, of course, the meaning of Titania's passionate metaphor.

More recently, a charming song about the love of the bindweed for the honeysuckle has been written by Michael Flanders, a left-handed London poet and entertainer, and set to music by his friend Donald Swann. On a visit to the Natural History Museum in Kensington, Flanders had been struck by an exhibit dealing with the left- and right-handed habits of climbing plants. The result was his song "Misalliance." (You can hear it sung by Flanders and Swann on the Angel recording of their engaging two-man revue, *At the Drop of a Hat.*) With Flanders's permission, I quote the lyrics in full:

MISALLIANCE

The fragrant Honeysuckle spirals clockwise to the sun
And many other creepers do the same.
But some climb counterclockwise, the Bindweed does, for one,
Or Convolvulus, *to give her proper name.*

Rooted on either side a door, one of each species grew,
And raced towards the window-ledge above.
Each corkscrewed to the lintel in the only way it knew,
Where they stopped, touched tendrils, smiled, and fell in love.

Said the right-handed Honeysuckle
To the left-handed Bindweed:
"Oh let us get married
If our parents don't mind, we'd
Be loving and inseparable,
Inextricably entwined, we'd
Live happily ever after,"
Said the Honeysuckle to the Bindweed.

To the Honeysuckle's parents it came as a shock.
"The Bindweeds," they cried, "are inferior stock.
They're uncultivated, of breeding bereft.
We twine to the right, and they twine to the left!"

Said the counterclockwise Bindweed
To the clockwise Honeysuckle:
"We'd better start saving,
Many a mickle maks a muckle,[1]
Then run away for a honeymoon
And hope that our luck'll
Take a turn for the better,"
Said the Bindweed to the Honeysuckle.

A bee who was passing remarked to them then:
"I've said it before, and I'll say it again,
Consider your offshoots, if offshoots there be.
They'll never receive any blessing from me."

Poor little sucker, how will it learn
When it is climbing, which way to turn.
Right—left—what a disgrace!
Or it may go straight up and fall flat on its face!

Said the right-hand thread Honeysuckle
To the left-hand thread Bindweed:
"It seems that against us all fate has combined.
Oh my darling, oh my darling,
Oh my darling Columbine,
Thou art lost and gone forever,
We shall never intertwine."

Together they found them the very next day.
They had pulled up their roots and just shrivelled away,
Deprived of that freedom for which we must fight,
To veer to the left, or to veer to the right!

In this book I have adopted the convention of calling a helix right-handed if it corresponds to the helical thread of a common wood screw. Flanders adopts the opposite convention of calling such a helix left-handed because, when you look at it from either end, you see it spiraling *toward you* in an anticlockwise direction. This confusion of terminology runs through all the literature on climbing plants.

In addition to coiling around things in a helix of a certain handedness, twining plants also have stems that twist in the same way they coil. Sometimes two or more stems of the same plant will twine together in ropelike fashion. The bignonia, for example, tends to form triple strands that twist to the right; the honeysuckle tends to form double strands that twist to the left. At times the trunks of beeches, chestnuts, and other trees exhibit a violent twisting of the bark into helical patterns, though the twist may be either to the right or left regardless of the species.

Sessile animals (animals attached to something and unable to move about on their own power), such as the sea anemones, usually have a conical type of radial symmetry like that of most plants. Slow, weakly moving animals, such as the echinoderms (starfishes, sea cucumbers, and other species) and jellyfish, likewise have conical symmetry. These animals float about in the sea or lie on the bottom where food and danger approach them with equal probability from all sides. However, as soon as a species evolved strong powers of locomotion it was inevitable that features would develop that would distinguish the animal's front from its back. In the sea, for example, the ability to move about rapidly in search of food gave an animal a great competitive advantage over sessile and slow-moving forms. A mouth is obviously more efficient on the front end of a fish than on its back end; the fish can swim directly toward food and gobble it up before some other animal gets it. This single feature alone, the mouth, is sufficient to distinguish the front end from the back (or, as biologists like to say, the *cephalic* from the *caudal* part) of a fish. Other features, such as eyes, also are clearly more efficient on the front end, near the mouth, than at the back. A fish wants to see where it is going, not where it has been. In short, the mere fact of swimming through water brought about a situation in which it was inevitable that forces of evolution would devise features that would distinguish one end of a sea animal from the other.

At the same time that locomotion was leading to distinctions between front and back, the force of gravity was causing similar differences between an animal's top and bottom, or, to use the biologist's terms again, the dorsal and ventral. (When an animal such as man stands upright, then of course his dorsal and ventral sides correspond to back and front, and his cephalic and caudal ends become top and bottom, but in this section we are confining our attention to sea life.) What about right and left? A moment's reflection and you will realize that there is nothing in the sea's watery environment to make a distinction between right and left significant. A swimming fish encounters a marked difference between forward and backward because one is the direction it goes, the other is the direction it comes from. The fish also encounters a marked difference between up and down. If it swims up, it reaches the surface of the sea. If it swims down, it reaches the ocean floor. But what difference does it encounter if it turns left or right? None. If it turns left, it finds the sea, and the things in it, exactly like the sea that it finds if it turns right. There are no forces, like the force of gravity, that operate horizontally in one direction only. It is for these reasons that various features—fins, eyes, and so on—tended to develop equally on left and right sides. Had there been a great advantage for a swimming fish to see only to the right and not to the left, no doubt fish would have developed only a single eye on the right. But there is no such advantage. It is easy to understand why a single plane of symmetry remained, dividing fish bilaterally into mirror-image right and left sides.

When the reptiles crawled out on the land and evolved into birds and mammals, there was nothing in their new environment to call for a change in bilateral symmetry. Up and down now became an even stronger influence on an animal's structure, because appendages were needed for locomotion across the ground. Feet are of little value attached to the back of an animal and sticking up in the air! Of course the difference between front and back continued to be important.

There are some amusing exceptions to this in ancient mythology and modern fantasy. The *amphisbaena* (in Greek it means "go both ways") was a fabled Greek snake with a head at each end. It crawled both ways. Here is how Pope described it in his *Dunciad*:

Thus Amphisbaena (I have read)
At either end assails;
None knows which leads, or which is led,
For both Heads are but Tails.

In recent fantasy for children there is Duo, the two-headed dog in L. Frank Baum's *John Dough and the Cherub*; and the Pushmi-Pullyu of Hugh Lofting's Dr. Dolittle books. Both animals had a head at each end.

As for left and right, the situation on land or in the air remained as symmetric as in the sea. An animal in the jungle or a bird in the sky finds its environment on the left pretty much like its environment on the right. It is easy to understand why the bodies of land and air animals preserved the bilateral symmetry they had previously acquired in the sea. H. S. M. Coxeter, in his beautiful book *Introduction to Geometry* (Wiley, 1961), reminds us that it may have been this bilateral symmetry that William Blake described in those familiar lines:

Tyger! Tyger! burning bright
In the forests of the night,
What immortal hand or eye
Dare frame thy fearful symmetry?

In view of the overall symmetry of the earth and the forces acting upon it, it is hard to conceive of circumstances in the future that could alter this fundamental type of symmetry in the bodies of animals. The slightest loss of bilateral symmetry, such as the loss of a right eye, would have immediate negative value for the survival of any animal. An enemy could sneak up unobserved on the right. (See Figure 26.)

We are now in a position to understand why, if there are animals on another planet, capable of moving through its seas, through its atmosphere, or over its land, it is likely that they, too, will have bilateral symmetry. On another planet, as on earth, the same factors would operate to produce such symmetry. Gravity would provide a fundamental difference between up and down. Locomotion would create a fundamental difference between front and back. The lack of any fundamental asymmetry in the environment would allow the left-right symmetry of bodies to remain unaltered.

Can we go further than this? Can we expect more detailed similarities of extraterrestrial life with life as we know it? Yes, we can. In the strange seas of another planet, regardless of their chemical composition, it is hard to imagine a simpler form of locomotion for evolution to exploit than the motion achieved by waving tails and fins. That evolution would find this type of propulsion is supported by the fact that even on the earth it has developed independently. Fish developed tail-and-fin propulsion. Then fish evolved into amphibious forms that crawled out on the land and became reptiles. The reptiles developed into mammals. But when some of the mammals returned to the sea—those that eventually became whales and seals, for example—their legs evolved back into flippers and their tail into a finlike instrument for propelling and steering.

Figure 26 *These creatures appear to have evolved radially symmetric eyes. Have they acquired more flexibility, or just greater vulnerability? (From* Beyond the Far Side *by Gary Larson, Andrews & McMeel, 1983.)*

Similarly, it is hard to imagine a simpler mode of flying through the air than by means of wings. Again, even on earth there has been independent, parallel development of wings. The reptiles evolved wings and became airborne. So did the insects. Some mammals, like the flying squirrel, developed wings for gliding. The bat, another mammal, developed excellent wings. A species of fish, leaping out of the water to escape capture, developed rudimentary gliding wings. Even man, when he builds an airplane, builds it with "wings" on a pattern that resembles a bird in flight.

On land, is there a simpler method by which an animal can move about other than by means of jointed appendages? The legs of a dog are not much different in mechanical working from the legs of a housefly, although they had a completely independent evolution. Of course the wheel also is a simple machine for moving along the ground, but there are good reasons why it would be difficult for a wheel to evolve. For one

thing, it needs to be supported by an axle; either the wheel must be detached from the axle and free to turn on it, or the axle itself must turn and therefore be detached from the body. Then there is the huge problem of finding a way for the body to rotate a wheel. The difficulties are great, though I suppose not insurmountable. L. Frank Baum in *Ozma of Oz* invented a race of men called the Wheelers who had four legs like a dog, each terminating in a small wheel instead of a foot. In *The Scarecrow of Oz* he invented the Ork, a bird with a propeller on the end of its tail. If on some planet nature found a way of inventing the wheel, we might find there animals resembling bicycles and cars, fish resembling motorboats, and birds resembling airplanes, although the prospects seem most unlikely.

Although no known animal uses a wheel for propelling itself along the ground or through the air, there are bacteria that move through liquids by actually rotating flagella like propellers. (See "How Bacteria Swim," by Howard C. Berg, in *Scientific American*, August 1975, pages 36ff.) There may be rotary devices inside cells for unwinding twisted strands of DNA. (See *Scientific American*, February 1967, page 37.) Some one-celled animals propel themselves through water by rotating their entire body. Nor must we overlook the dung beetle, the sacred scarab of Egypt, that transports little balls of dung by rolling them across the ground.

Sensory organs such as eyes, ears, and noses also have about them a kind of inevitability if life evolves any type of advanced intelligent activity. Electromagnetic waves are ideal for giving a brain an accurate "map" of the outside world. Pressure waves transmitted by molecules provide additional valuable clues to the environment and are picked up by ears. The spread of actual molecules from a substance is detected by noses. It is not impossible that there may be advanced cultures of intelligent nonterrestrials in which smell and taste not only are the dominant senses but also provide the primary means of communication between individuals. Only in recent years have biologists discovered how much information, in terrestrial animal species, is transmitted efficiently by a direct transfer of substances now called *pheromones*. See Edward O. Wilson's nose-opening report in his article "Pheromones" in *Scientific American*, May 1963.

Since light, sound, and molecules certainly exist on other planets, it seems likely that evolution would invent senses to exploit these phenomena as a means of achieving greater control over the circumstances of life. Here on earth, for instance, the eye has had no fewer than three quite independent, parallel developments: the eyes of vertebrate animals, the eyes of insects, and the eyes of various mollusks. The octopus, for example, has a remarkably good eye—in fact, in some respects it is superior to our own. It has eyelids, cornea, iris, lens, retina—as does the human eye—yet it evolved entirely independently of the evolution of the vertebrate eye! It is hard to find a more astonishing instance of how evolution, operating along two disconnected lines of development, managed to invent two complicated instruments that have essentially the same function and structure.

There are good reasons for eyes and other sensory organs to form a kind of face. In the first place, there is an advantage in having eyes, ears, and nose close to the mouth, where they are useful in the search for food. There is an equally great advantage in having them close to the brain. It takes time for a nerve impulse to get from the organs to the brain; the quicker it gets there, the quicker an animal can react in catching food or avoiding danger. Even the brain itself, needed to evaluate and interpret sensory data, accomplishes its thinking by electrical networks: a kind of miniature electronic computer of great complexity. Nerve filaments that carry electrical impulses may be essential for the brains of advanced living creatures.

If life on another planet reaches the intelligence level of man on earth, it seems probable that it would have at least a few humanoid features. There are obvious advantages in having fingers at the ends of arms. For protection, the valuable brain would need to be heavily encased and as far from the ground as possible, where it would be best shielded from the shocks of moving about. Sensory organs, close to the brain and in front, would create something like a face. "Senator" Clarke Crandall, a Chicago entertainer, had a funny routine about the advantages of having sensory organs at other spots on the body. An eye on the tip of a finger, for example, would make it possible to see a parade by holding up a hand and looking over the heads of everybody. Ears under the armpits would be kept warm in cold weather. A mouth on top of the head would allow a man to put a sandwich under his hat and eat it on the way to work. It is easy to see why evolution has avoided such arrangements. An eye on the finger would be too vulnerable to injury, too far from the brain. Armpit ears would not be very efficient for hearing unless you kept your arms perpetually raised. A mouth on the head would expose the brain to injury, make it difficult to see what one was eating, and so on.

Of course so many chance factors are involved and environments of planets are so varied that one would not expect to find on another planet any form of life that was a close replica of any species on earth. No one expected to find an elephant or a giraffe on Mars. On the other hand, alien life may not be so wildly different from earth forms as one is tempted to think. The BEMs of science fiction (BEM is an acronym formed by the initials of Bug-Eyed Monster), unlike any earthly animal but nevertheless recognizable as animals, may prove to be not far from the truth after all. It is hard, in fact, to imagine how extraterrestrial creatures could differ from earth creatures to any greater degree than earth creatures differ from each other. The octopus, the platypus, the hornbill, the ostrich, the snake—if one had never seen or heard of these animals, their structure would seem as bizarre and improbable as that of any animal we are likely to find on another planet or a large moon. We have a fine specimen of a miniature BEM in the anableps, a small, bluish Central American carp that has four eyes! Well, not really. The huge eyes, like monstrous bubbles, are divided into upper and lower halves by an opaque band. Each eye has a single lens, but there are upper and lower corneas and irises. The little fish (it is about 8 inches long) swims with the opaque band exactly at water level, so that its two upper "eyes" can see above water while its two lower "eyes" see under water. In the next chapter we will learn something about the asymmetric sex life of this curious creature.

Animals as weird as the anableps, no doubt much weirder, are likely to roam the seas, land, and skies of alien planets, but they are not likely to be so unearthly that we do not recognize them as animals. The chief basis for this recognition, more fundamental than any other aspect of their forms, is likely to be the bilateral symmetry of their bodies.

NOTE

1. A Scottish phrase meaning "many a little makes a lot."