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GULLIVER WAS A BAD BIOLOGIST

Jonathan Swift's famous fantasy gives the modern biologist an opportunity to reflect upon the way living things are tailored to their environment

by Florence Moog

WHEN Jonathan Swift's Captain Lemuel Gulliver first published his account of his remarkable adventures in undiscovered Pacific lands, his contemporaries appear to have responded with some skepticism. Their reluctance to believe in six-inch men, floating islands and educated horses is mirrored in Gulliver's overprotesting preface to the second edition of his now-famous *Travels.* Whether his contemporaries were impressed by his insistence that from consorting with the Houyhnhnms he had been able to rid himself of "that infernal habit of lying" common to Yahoos is doubtful. In any case the two centuries that have elapsed since then have seen the growth of a body of knowledge by which the improbability of the creatures of Gulliver-land may be translated into impossibility.

Much of this knowledge has been the direct concern of biologists, those present-day kindred of Gulliver's academicians of Lagado. Indeed, for a student of comparative biology Gulliver's book may serve as an unpremeditated textbook on biological absurdities and, as a corollary, on the nicety with which all living organisms are tailored to the physical conditions of their existence.

The most unlikely of Gulliver's inventions, the 60-foot Brobdingnagians, actually could have been explained away, long before the biologists got around to it, by a principle of physics first developed by Galileo almost 100 years before Gulliver's odyssey appeared. According to the principle of dimensional analysis, the weight of a system increases as the cube of its linear dimensions. The principle seems to have been well known to Gulliver's Lilliputians, for it was the means they used in calculating that Gulliver equaled 1,728 Lilliputians. Since six-foot Gulliver was 12 times as tall as a six-inch Lilliputian, they computed that he weighed as much as one Lilliputian times 12^3 ($12 \times 12 \times 12 = 1{,}728$). The weight of a 60-foot Brobdingnagian may be similarly calculated as 10^3 times that of a six-foot man, let us say 180 pounds times 1,000, which is 180,000 pounds or 90 tons!

No wonder Gulliver neglected to mention the Brobdingnagians' weight! No very acute insight into structural principles is needed to see that such a tremendous bulk could not be borne in a frame of human proportions. The upper limit of weight which a body built on the human pattern will carry is perhaps no more than the 500 pounds reached by an occasional

GIANT Brobdingnagians, here talking with tiny Gulliver, can be shown to be an engineering impossibility.

eight- or nine-foot rarity. A greater bulk would necessitate a truly ponderous skeleton. The long bones of the legs would be shortened relatively to prevent their bending under their great burden; the head would become comparatively small, for reasons we shall look into later, but its larger absolute size would entail shortening and thickening of the neck; much of the increased weight would be taken up in the trunk, for the internal organs would have to undergo relative enlargement to provide adequate power to move the huge machine.

Examination of a few hoofed mammals will neatly illustrate this adaptation of form to mass. A gazelle of 150 pounds, for example, has a rather long neck on which is mounted a head which, though large in relation to the slight body, is small as tall animals' heads go; the heavier head of a 1,200-pound horse, though smaller in proportion to body size, requires a shorter and more powerful neck to support it; while the great head of a five-ton elephant, though not large in relation to the gargantuan body, is too heavy to afford the luxury of any noticeable neck at all. Similarly, the slender legs of the gazelle may constitute two thirds of the height at the shoulder, whereas the sturdy limbs of a plow horse are only about half the height, and the pillarlike props of the elephant not much more than one-third. The mind shrinks from picturing the broad-beamed corpulence of a Brobdingnagian. In fact we need no more than the zoo-keepers' rule that once around the forefoot of an elephant is half the height of the body to make it clear that the delicacy of the feminine ankle must have been a matter of no interest in Brobdingnag.

We need have no fear of ever finding such a neckless, short-legged monster peering into our sixth-story windows, for no 90-ton animal could ever walk on dry land. Certainly such bulk could not walk on the arched structure of the human foot, which is too ready to flatten under a little additional strain in normal-sized people. A flesh-and-bone foot ten times longer than the normal human one and a thousand times heavier would have as much difficulty supporting even itself as would a covered bridge enlarged to span the Mississippi. Mount 90 tons on it and such a foot would require bones of steel bound by ligaments of wire cable.

The limiting strength of living tissues, especially muscle and connective tissues, is probably the reason why nature, in millions of years of experimentation, only once succeeded in designing a land animal even half as ponderous as a Brobdingnagian; this animal was a now long-extinct rhinoceros. The tremendous dinosaurs, in their vain attempt to make muscles outweigh brains, may have approached a Brobdingnagian weight, but they were not strictly land animals; they lived in swamps, sharing their burden with the buoyant water as the whale does today.

IF the Brobdingnagians were too big to exist, the mouse-sized Lilliputians were too small to be human. So long as the laws of physics and chemistry obtain, living cells cannot vary much in size. Hence large animals must be built of more cells than small ones. In many organs cell number is not important, but the brain is in this respect like a telephone system (*see page 14*): a small private telephone system is of limited usefulness compared with one in which a great number of individual units, with their connecting wires and central switchboard equipment, make it possible for any person or institution to get in quick touch with any other. The human cortex, which is the portion of the brain that receives sensory information and deals intelligently with it, has an estimated 14 billion cells. On the inconceivably numerous interconnections which keep this vast assemblage of units in touch with one another depend the adaptability and educability of the human being. Were this tremendous number of cortical cells to be much reduced, the apparently inexhaustible capacity of good human minds for learning, remembering, perceiving and thinking would wither; it would shrink perhaps to the low level of defectives in whom the brain is cramped by a "pinhead" skull or by the abnormal presence of fluid in the cranium.

Now if we allow to a Lilliputian nerve cells as large as those of a mouse (which have about one-fourth the volume of human nerve cells), his tiny cranium could accommodate something like 35 million cortical cells—a large number indeed, but only a small fraction of what even a chimpanzee has at his disposal. On such a small allotment of intellectual equipment the Lilliputians could never have devised their delightful court routine, which yielded nothing in intricacy or absurdity to the best that Augustan England had to offer.

The Lilliputians also would have needed disproportionately large heads to carry useful eyes. Anyone who has ever quizzically scanned an elephant, trying to determine just where the enormous beast has its diminutive eye, must realize that eye size varies far less than body size. A small animal seems to have too much eye in relation to the expanse of its head, and this is because the limits of eye magnitude are dictated by the physical properties of light, which must enter through a pupil not too small, and must impinge on a sufficient number of seeing elements—the rod- and cone-shaped cells of the retina

TINY Lilliputians have various logical drawbacks, among them the difficulty of constructing an eye that would fit their small heads. The drawings on this and the opposite page are from a 1768 edition of the works of Swift.

—of almost invariable size. The eye is thus in a sense a doorway which must admit a certain minimal amount of light, but need not admit much more; just as an architectural doorway, whether of a cottage or a mansion, must be big enough to admit a man, but need not be much bigger.

So if a Lilliputian had had a head large enough to hold an intelligent brain and serviceable eyes, he would have needed a heftier body to hold up the head. The smallest known human race, the African pygmies, stand four and a half feet high. Even the tiniest human dwarfs, who never achieve quite correct physical proportions, are almost always more than two feet tall.

But overlooking for the moment the matter of unaccountable intelligence in unreasonably small heads, let us take note of another Lilliputian character that casts doubt on their creator's veracity. The voices of the miniature people, we read, were shrill—a shrewd guess, but not shrewd enough. Had Gulliver considered the difference in pitch which a small difference in size makes among the members of the viol family, he might have been more cautious about assigning any audibility to the Lilliputian voice. Pitch, measured in cycles per second, varies inversely with the square of the linear dimensions of the vibrating surface. So the vocal cords of a six-inch human being would vibrate 144 times faster than those of a six-footer; allowing our voices to center comfortably at 256 cycles per second (middle C), the small voice would vibrate at about 37,000 cycles per second—more than seven octaves higher! This would not inconvenience a Lilliputian, whose ears would probably have a sensitivity proportioned to his voice, but Gulliver's ears must have been practically deaf to sound of more than 10,000 cycles per second. Even had the captain been a prodigy of aural acuity he could not have heard a Lilliputian voice any more than we can hear the cries that bats seem to utter constantly as they fly; to such sounds only the ears of their small confreres are attuned.

WITH Brobdingnagians the case is no better, for their voices must have been at the lower limit of audibility—averaging perhaps three cycles per second. At such a rate the vibrations, though they might be heard, would not merge into a continuous sound, but would seem like the sad undulations of a phonograph record dragging to a stop. Now and then a Brobdingnagian soprano or piccolo player might have produced some notes that Gulliver could hear normally, but the sensation could hardly have been pleasant, for the lowest (as well as the highest) tones, to which our ears are sensitive can be heard only when they are so loud that they can also be felt. Thus Gulliver was doubly wrong in claiming that he improved the giants' music by retreating from its loudness: most of it would not have sounded like music at all, and those few notes that might have had the earmarks of music would have become inaudible as soon as they became painless.

The apparently modest appetite of the Lilliputians is another reason why we may doubt their existence. Small, warm-blooded animals must take in more calories per unit of body weight than large ones, for the rate of living varies with size; small lungs breathe faster, small hearts beat faster, small bodies consume oxygen and turn out waste products faster. So a six-inch man might be expected to have about the same food requirements as a mouse,

PYGMIES of Africa are good evolutionary approximation of the smallest practical size for human being.

that is, approximately eight times as many calories per ounce of body weight as a full-scale man needs—or 24 meals a day instead of three. Gulliver missed on two counts here; he failed to realize that the creatures of his invention would have spent the larger part of their time stuffing themselves with food, and by the same token he did not see that by allowing him 1,728 times their dietary they were giving him as much food in a day as he could conveniently eat in a week.

Indeed, had Gulliver known anything of differential metabolism, his concept of a Lilliputian humanity would have been altered in every respect. For it is not difficult to see that an animal that has to provide itself with the equivalent of 24 of our meals a day would not have time enough left over for developing the nicer aspects of civilization. Worse than that, the very duration of life is related to size; an elephant may see a century pass, but fast-burning, voracious little mammals run through their lives in a space of time too brief to allow for the sort of education on which civilized society depends.

It must be concluded that the author of the Houyhnhnm hoax could have had no adequate appreciation of the physical characteristics from which human life has sprung. From the evolutionary point of view man is in essence a tall anthropoid whose big head accommodates a sizable brain and is provided with forward-looking eyes that can be used stereoscopically; he stands easily erect on flat, supple feet and carries at the end of his long, free-swinging arms a pair of instruments so beautifully designed, so perfectly adapted to uses without number, that even the products of his clever brain have never equaled them.

Our remotest apelike ancestors may not have been much more attractive than the Yahoos of Houyhnhnmland, but they were able to take the road to civilization because they were physically equipped for the journey. Their equipment did not include manual dexterity or conceptual thought, for these were goals farther along the road. Primitive man, their descendant, could enlarge the use of his brain partly because his hands, shaped by the tree-living habit of his forebears and freed by the erect posture derived from the same habit, could pick up and handle what his excellent eyes—another product of arboreal life—wished to examine; to this day the tendency to touch what we see is almost instinctive in most of us. Eyes and hands thus produced material on which the brain could work. The ideas that began to come in their turn provided work for the hands and eyes: the rock that was used as a weapon would be shaped into a blade and then mounted on a shaft; the thick-growing boughs that provided shelter would be used to construct a hut; the skins that served for clothing would be fashioned with bone needles and gut threads. Through innumerable such cycles of action and thought and action, civilization rolled slowly on toward atom bombs and prefabricated houses and the garment workers' union.

IF the indispensability of our apelike (or Yahoo-like) appointments in the development of civilization is not at once apparent, a suitable appreciation of them can be readily derived from a critical examination of Gulliver's educated horses. Even if we overlook the horse's low-browed construction, with a head so weighted down with jaws that it can hardly indulge in the luxury of a big intellectual brain, and even if we credit horse-lovers' accounts of the remarkable intelligence of the much-admired animal, we must still draw the line at Gulliver's stories of horses cooking oats, grinding flints and building houses.

An unlettered stableboy would snort at the notion of a horse threading a needle

—even if the limbs could do the trick, both eyes would be looking the wrong way! For the horse, having neither offensive weapons nor the hands to make them with, must tend first of all to his own safety; his eyes are placed to sweep a wide area for signs of danger; his limbs are designed to carry him swiftly away should danger materialize. To this end the limbs are so fixed that they swing freely in only one direction, and the body is so mounted on them that the horse, unlike certain small-clawed quadrupeds, cannot disengage his forefeet from their normal task even by sitting down. Nor is this any real disadvantage now, for the five fingers that might have led to the ability to grasp and manipulate objects were long since paid by the ancestors of the horse as the price of the stout single digit that makes such a superb running instrument. This exchange is typical of the law of compensation that nature rigidly enforces; only by refraining from specialization that might enable it to do anything perfectly has the flexible five-fingered human hand on its loose-jointed arm retained the ability to do everything after a fashion. A similar rule holds for the mind.

This brief catalogue by no means exhausts Gulliver's crimes against nature. The alterations which an increase or diminution of body size would enforce on the heart, lungs, liver and intestines could be made the subject of a large treatise. As for larks so small that they were provided with invisible feathers, eagles so big that they could not possibly pack enough power to get themselves into the air, insects far beyond the size limits imposed by the simple respiratory mechanisms of their kind—the very blades of grass in Gulliver's fantastic kingdoms cry out their impossibility. No biological principle is clearer than that every living thing—from man with his rapaciously expanding control over the environment, to the patient, insensible slime mold—lives in harmonious adjustment to the conditions of its life.

But, after all, we must not be too hard on Gulliver for failing to understand the biological conditions that made him a man—and an implausible liar. His talents, like those of his friend and teacher, the unhappy Dean Swift of Saint Patrick's, were in the psychological realm. The etymology of the name Houyhnhnm, his master horse tells us, is "the perfection of nature." Gulliver may not have understood biology, but he did understand biologists, who after his time were to endow their own species with the somewhat wishful name, *Homo sapiens.*

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WATUSI of Uganda, in East Africa, are among the world's tallest people. Many of them exceed a height of seven feet. Although there have been other kinds of big human beings, probably few were much taller than the Watusi.