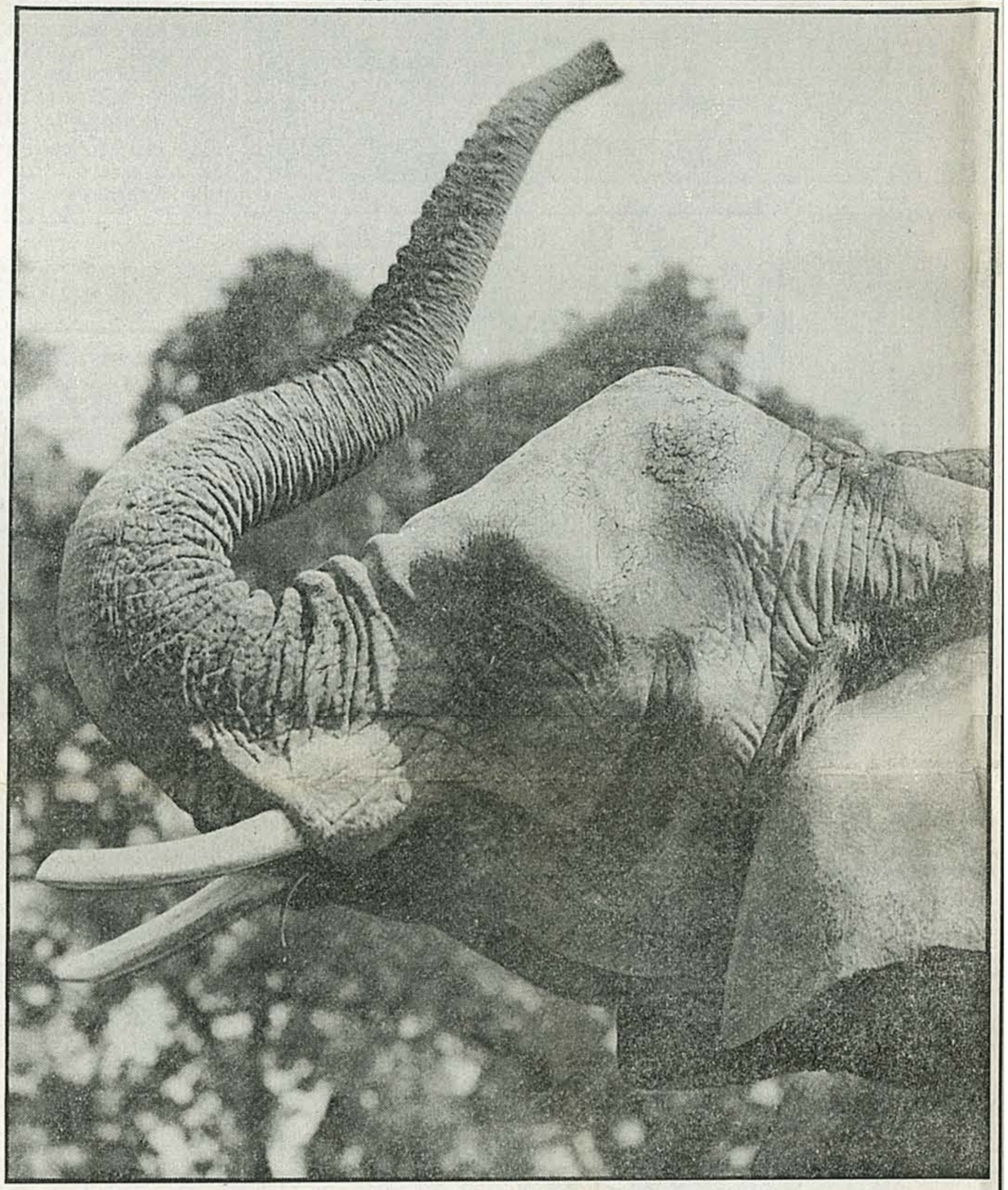
Little and Large: "The earth's rotation may seem interminably long to a shrew and insignificantly short to a busy elephant"



Size counts. It's just that the smaller you are, the quicker you have to count. Robert Temple on the elephant, the shrew and the lung power of the canary

More weight, less speed

IF MAN were "normal", he would live only 27 years, have a brain one sixth the size of the brain he has now and have a world population not exceeding five hundred million. These are the conclusions of a relatively new science called allometry, which is the science of the size of living creatures. The word was coined as long ago as 1936, but apart from a few exceptional scientists like the late Sir Julian Huxley, allometry received very little attention until recent years.

William A Calder, an American professor of ecology and evolutionary biology at the University of Arizona, has just published the first book bringing together the results of allometric studies for every conceivable bird and mammal (**Size, Function and Life History**, Harvard University Press, £28.60). The total impression one gets from the book is of an enormous intellectual vista constructed from what had until now been separate collections of dots; piled on top of one another and seen through, they reveal a scene as challenging as any panoramic view.

Calder himself is full of enthusiasm, saying: "This is an exciting time for the study of allometry, somewhat analogous to when the East and West crews building the first transcontinental railroad could dimly see each other in the distance; for we are beginning to see connections . . ."

Allometry promises to make possible a new "conceptual integration" in biology, and especially to provide "a new quantitative framework of basic principles that relate ecology and physiology". Many of the results are surprising. Calder says, for instance, that allometry has "opened the mysteries of eggshell function". Through allometry calculations, we now know that an egg does not weigh most just before hatching. By the time it hatches, an egg has lost 15 per cent of its total mass by water vapour exiting through pores in the shell, creating an air cell at the large end of the egg. Eggs also breathe; they take in 105 millilitres of oxygen per gram regardless of size through their shells.

One of the key ideas emerging from allometry is that different-sized creatures live at different rates. The size of the planet and its gravitational force are constant; so are the alternation of day and night within the limits of longest and shortest day at the different latitudes. In the midst of these constants, creatures exist at greater and larger sizes, enjoying their respective advantages and disadvantages.

Calder refers to the passage of time for the planet as "geotime" and "absolute time". But each creature has its own private "physiological time" — smaller creatures having faster time rates and living shorter lives. Calder says: "The smallest land mammal is living about 32 times as fast as the largest. Thus the earth's rotation may seem interminably long to a shrew and insignificantly short to a busy elephant."

But despite the difference in importance to each animal, the elephant and the shrew both have to come to terms with the half-day during which feeding may not be possible, unless one becomes a nocturnal feeder. Small animals are so keen to "save time" and optimise the use of their shorter lifetimes for other things than travel that they climb hills at steeper angles.

Allometry predicted this, so studies were done in labs, making different-sized animals climb slopes of 15 degrees. It was found that mice needed only 23.5 per cent more energy to run up the slope than on the level, whereas chimpanzees needed 189 per cent more. (Extrapolating to an animal weighing 1000 kg, there would be a need for 630 per cent more energy.)

This led zoologists to study 130 trails of wild animals and they confirmed that in the wild, small animals do indeed take steeper routes up hills. This is one of many discoveries that might never have been made without allometry, and as Calder says, "demonstrates the relevance of the laboratory pattern to behavious in the wild".

Calder pushes allometry as one means of overcoming "the isolation of disciplines in biology (which) has led to such under-emphasis and misunderstanding of the importance of body size in function and life history". Allometry manages to apply numbers to biology, something which has never been easy. It is widely acknowledged that biology lags far behind physics as a precise science; bringing in more mathematics can help it catch up.

Naturally, this leads to many "strange but true" facts emerging: a canary can sing for 27 seconds on one lungful of air; elephants hear an octave lower than humans but their upper range falls an octave short, and this is because the highest frequency a mammal can hear is inversely related to the distance between its ears!

Calder has worked out that Gulliver could never have heard the Lilliputians, whose voices would have been seven octaves higher than Gulliver's; the Brobdingnagians would have had voices too low to be audible either. Also, Swift's calculations for Gulliver's food requirements were wrong: the Lilliputians fed him only 16 per cent of his real food requirement calculated from allometry.

Did you know that bats cannot hear owls? That a mouse's squeak doesn't travel far, but then neither does the mouse, so that it doesn't matter? That if a vole wanted to migrate, it could only travel 81 km before dropping with exhaustion? That it takes less energy to move one unit of mass one unit of distance for larger animals than smaller? That the heaviest creature on earth which can fly is the trumpeter swan, at 12.5 kg? That the shrew eats its own mass in food every day, but a puma does so in 12.3 days? These are revealed by allometry, as well as promising to provide for the first time an answer to the question "How do birds fly?"

If you are interested in how long a creature will live, its life is normally computed to last 9.61 times the time it takes to achieve 98 per cent of adult mass, or 15.5 times that needed to reach sexual maturity. This might indicate longer lives for late developers! Also, the average lifetime of a terrestrial mammal is 200 million resting breaths, and the heart in a resting mammal beats 4.5 times per breath, regardless of body size.

Where does man fit into all this? The average body mass of a man is 70 kilograms, and agreeably with allometry, the human being generates on average 83 watts of power (what is called "basal metabolism"), rising to 20 times that when engaged in violent exertion. But beyond that, man becomes exceptional. For one thing, he is greedy, consuming 100 times the energy he generates bodily.

His brain, lifespan, and population far exceed the predictions of allometry, as already mentioned. We have six times the brain and nine times the population that we should, and we live three times longer. But then, even if we defy allometry, we have the undeniable special privilege of being able to say that we did, after all, invent it.