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## The Little Things That Run the World\* (The Importance and Conservation of Invertebrates)

On the occasion of the opening of the remarkable new invertebrate exhibit of the National Zoological Park, let me say a word on behalf of these little things that run the world. To start, there are vastly more kinds of invertebrates than of vertebrates. At the present time, on the basis of the tabulation that I have just completed (from the literature and with the help of specialists), I estimate that a total of 42,580 vertebrate species have been described, of which 6,300 are reptiles, 9,040 are birds, and 4,000 are mammals. In contrast, 990,000 species of invertebrates have been described, of which 290,000 alone are beetles—seven times the number of all the vertebrates together. Recent estimates have placed the number of invertebrates on the earth as high as 30 million, again mostly beetles—although many other taxonomically comparable groups of insects and other invertebrates also greatly outnumber vertebrates.

We don't know with certainty why invertebrates are so diverse, but a commonly held opinion is that the key trait is their small size. Their niches are correspondingly small, and they can therefore divide up the environment into many more little domains where specialists can co-exist. One of my favorite examples of such specialists living in microniches are the mites that live on the bodies of army ants: one kind is found only on the mandibles of the soldier caste, where it sits and feeds from the mouth of its host; another kind is found only on the hind foot of the soldier caste, where it sucks blood for a living; and so on through various bizarre configurations.

Another possible cause of invertebrate diversity is the greater antiquity of these little animals, giving them more time to explore and fill the environment. The first invertebrates appeared well back into Precambrian times, at least 600 million years ago. Most invertebrate phyla were flourishing before the vertebrates arrived on the scene, some 500 million years ago.

Invertebrates also rule the earth by virtue of sheer body mass. For example, in tropical rain forest near Manaus, in the Brazilian Amazon, each hectare (or 2.5 acres) contains a few dozen birds and mammals but well

over one billion invertebrates, of which the vast majority are not beetles this time but mites and springtails. There are about 200 kilograms dry weight of animal tissue in a hectare, of which 93 percent consists of invertebrates. The ants and termites alone compose one-third of this biomass. So when you walk through a tropical forest, or most other terrestrial habitats for that matter, or snorkel above a coral reef or some other marine or aquatic environment, vertebrates may catch your eye most of the time—biologists would say that your search image is for large animals—but you are visiting a primarily invertebrate world.

It is a common misconception that vertebrates are the movers and shakers of the world, tearing the vegetation down, cutting paths through the forest, and consuming most of the energy. That may be true in a few ecosystems such as the grasslands of Africa with their great herds of herbivorous mammals. It has certainly become true in the last few centuries in the case of our own species, which now appropriates in one form or other as much as 40 percent of the solar energy captured by plants. That circumstance is what makes us so dangerous to the fragile environment of the world. But it is otherwise more nearly true in most parts of the world of the invertebrates rather than the nonhuman vertebrates. The leafcutter ants, for example, rather than deer, or rodents, or birds, are the principal consumers of vegetation in Central and South America. A single colony contains over two million workers. It sends out columns of foragers a hundred meters or more in all directions to cut forest leaves, flower parts, and succulent stems. Each day a typical mature colony collects about 50 kilograms of this fresh vegetation, more than the average cow. Inside the nest, the ants shape the material into intricate sponge-like bodies on which they grow a symbiotic fungus. The fungus thrives as it breaks down and consumes the cellulose, while the ants thrive by eating the fungus.

The leafcutting ants excavate vertical galleries and living chambers as deep as 5 meters into the soil. They and other kinds of ants, as well as bacteria, fungi, termites, and mites, process most of the dead vegetation and return its nutrients to the plants to keep the great tropical forests alive.

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\* Address given at the opening of the invertebrate exhibit, National Zoological Park, Washington, D.C., on May 7, 1987.

Much the same situation exists in other parts of the world. The coral reefs are built out of the bodies of coelenterates. The most abundant animals of the open sea are copepods, tiny crustaceans forming part of the plankton. The mud of the deep sea is home to a vast array of mollusks, crustaceans, and other small creatures that subsist on the fragments of wood and dead animals that drift down from the lighted areas above, and on each other.

The truth is that we need invertebrates but they don't need us. If human beings were to disappear tomorrow, the world would go on with little change. Gaia, the totality of life on Earth, would set about healing itself and return to the rich environmental states of a few thousand years ago. But if invertebrates were to disappear, I doubt that the human species could last more than a few months. Most of the fishes, amphibians, birds, and mammals would crash to extinction about the same time. Next would go the bulk of the flowering plants and with them the physical structure of the majority of the forests and other terrestrial habitats of the world. The earth would rot. As dead vegetation piled up and dried out, narrowing and closing the channels of the nutrient cycles, other complex forms of vegetation would die off, and with them the last remnants of the vertebrates. The remaining fungi, after enjoying a population explosion of stupendous proportions, would also perish. Within a few decades the world would return to the state of a billion years ago, composed primarily of bacteria, algae, and a few other very simple multicellular plants.

If humanity depends so completely on these little creatures that run the earth, they also provide us with an endless source of scientific exploration and naturalistic wonder. When you scoop up a double handful of earth almost anywhere except the most barren deserts, you will find thousands of invertebrate animals, ranging in size from clearly visible to microscopic, from ants and springtails to tardigrades and rotifers. The biology of most of the species you hold is unknown: we have only the vaguest idea of what they eat, what eats them, and the details of their life cycle, and probably nothing at all about their biochemistry and genetics. Some of the species might even lack scientific names. We have little concept of how important any of them are to our existence. Their study would certainly teach us new principles of science to the benefit of humanity. Each one is fascinating in its own right. If human beings were not so impressed by size alone, they would consider an ant more wonderful than a rhinoceros.

New emphasis should be placed on the conservation of invertebrates. Their staggering abundance and diversity should not lead us to think that they are indestructible. On the contrary, their species are just as subject to extinction due to human interference as are those of birds and mammals. When a valley in Peru or an island in the Pacific is stripped of the last of its native vegeta-

tion, the result is likely to be the extinction of several kinds of birds and some dozen of plant species. Of that tragedy we are painfully aware, but what is not perceived is that hundreds of invertebrate species will also vanish.

The conservation movement is at last beginning to take recognition of the potential loss of invertebrate diversity. The International Union for the Conservation of Nature has an ongoing invertebrate program that has already published a Red Data Book of threatened and endangered species—although this catalog is obviously still woefully incomplete. The Xerces Society, named after an extinct California butterfly, was created in 1971 to further the protection of butterflies and other invertebrates. These two programs are designed to complement the much larger organized efforts of other organizations on behalf of vertebrates and plants. They will help to expand programs to encompass entire ecosystems instead of just selected star species. The new invertebrate exhibition of the National Zoological Park is one of the most promising means for raising public appreciation of invertebrates, and I hope such exhibits will come routinely to include rare and endangered species identified prominently as such.

Several themes can be profitably pursued in the new field of invertebrate conservation:

It needs to be repeatedly stressed that invertebrates as a whole are even more important in the maintenance of ecosystems than are vertebrates.

Reserves for invertebrate conservation are practicable and relatively inexpensive. Many species can be maintained in large, breeding populations in areas too small to sustain viable populations of vertebrates. A 10-ha plot is likely to be enough to sustain a butterfly or crustacean species indefinitely. The same is true for at least some plant species. Consequently, even if just a tiny remnant of natural habitat exists, and its native vertebrates have vanished, it is still worth setting aside for the plants and invertebrates it will save.

The *ex situ* preservation of invertebrate species is also very cost-effective. A single pair of rare mammals typically costs hundreds or thousands of dollars yearly to maintain in a zoo (and worth every penny!). At the same time, large numbers of beautiful tree snails, butterflies, and other endangered invertebrates can be cultured in the laboratory, often in conjunction with public exhibits and educational programs, for the same price.

It will be useful to concentrate biological research and public education on star species when these are available in threatened habitats, in the manner that has proved so successful in vertebrate conservation. Examples of such species include the tree snails of Moorea, Hawaii, and the Florida Keys; the Prairie

sphinx moth of the Central States; the birdwing butterflies of New Guinea; and the metallic blue and golden ants of Cuba.

We need to launch a major effort to measure biodiversity, to create a complete inventory of all the species of organisms on Earth, and to assess their importance for the environment and humanity. Our museums, zoological parks, and arboreta deserve far more support than they are getting—for the future of our children.

A hundred years ago few people thought of saving any

kind of animal or plant. The circle of concern has expanded steadily since, and it is just now beginning to encompass the invertebrates. For reasons that have to do with almost every facet of human welfare, we should welcome this new development.

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