MASTER BUILDERS AFRICAN WEAVER ANTS (*OECOPHYLLA LONGINODA*) PAY ATTENTION TO EVERY DETAIL WHEN THEY BUILD A NEST. IF A LEAF IS TOO LONG OR STIFF TO BE TURNED BY A SINGLE ANT DURING NEST BUILDING, GROUPS OF WORKER ANTS ARRANGE THEMSELVES INTO LIVING CHAINS AND PULL TOGETHER. BERT HÖLLDOBLER STUDIED WEAVER ANTS IN KENYA'S SHIMBA HILLS RESERVE.

Could lessons for human survival lie buried within the society of ant colonies?

When the Ants get together

by Skip Derra photos by Bert Hölldobler

Hundreds of ants are housed in clear interconnected boxes. The ants have access to a large foraging area. In writhing groups the ants form dark swarming masses of organic material. They move and dart from side to side, back and forth, up and down. All movement is visible in the stark, well-lit laboratory room.

To the untrained eye, the ants in the tubes seem to be moving in indiscriminate directions. There appear to be few if any guiding principles. The ants start, they stop, they run into each other.

Look closer. As a whole, the ant colony is following a well choreographed act that has evolved over eons. Each member of the colony cooperates to find food. The ants mark their paths as they gather food and then return it to the colony for the nourishment of all. This particular ant colony exists in the laboratories of Bert Hölldobler, a Foundation professor in Arizona State University's School of Life Sciences.

The ASU scientist is testing the trail marking endeavors of several ants on this day. A white plastic runway slides into place to connect with the foraging arena. A single "scout" ant jumps onto the runway and starts walking up it, searching for food. The runway slowly moves to the side to prevent other ants from jumping on.

The ant finds a drop of honey water at the end of the runway. She imbibes as much as her "social stomach" can carry. As she makes her way back to the nest arena, she leaves a chemical trail. The chemical is a recruitment signal. It will attract and allow other nest mates to follow the route of the scout to the food.

Hölldobler says it is this kind of communication that ensures the success of the colony as a whole. Hölldobler studies social insects. He and scientists like him are at the cutting edge of research aimed at understanding the evolution and ecological significance of social systems in nature.

Their work is designed to tease out new information about the diversity of social organizations in the animal kingdom. They want to better understand the behavioral mechanisms that make insect societies so successful.

Insect societies appear to be excellent models for the study of cooperation and conflict in nature. By studying insect societies, researchers can better assess the various degrees of complexity of biological social systems.

Hölldobler has traveled around the world to study ants. He has studied ant colonies in the rain forests of Argentina, Central America, Africa, India, and Australia. He also studies ant colonies right here in the arid lands of the southwestern United States.

Biologists need to get into the field to study their subjects. That is just one portion of the research. Hölldobler's experimental analysis of social behavior takes place in the laboratory. He uses plenty of sophisticated instruments and techniques to do the work.

AFRICAN GOLDEN-HAIRED *POLYRHACHIS* ANTS HAVE HOOK-LIKE SPINES THAT RISE FROM THEIR WAISTS. THEIR COLOR MAY ADVERTISE THESE FORMIDABLE WEAPONS.

Ants are one of this planet's most successful life forms. Hölldobler studies them to learn how they survive in what often are harsh and almost always demanding environments. He has studied how they overcome insects and other prey much larger than themselves. He has learned how they build their nests and how they thrive in them. But most importantly, the ASU scientist studies how neighboring colonies of ants compete with one another.

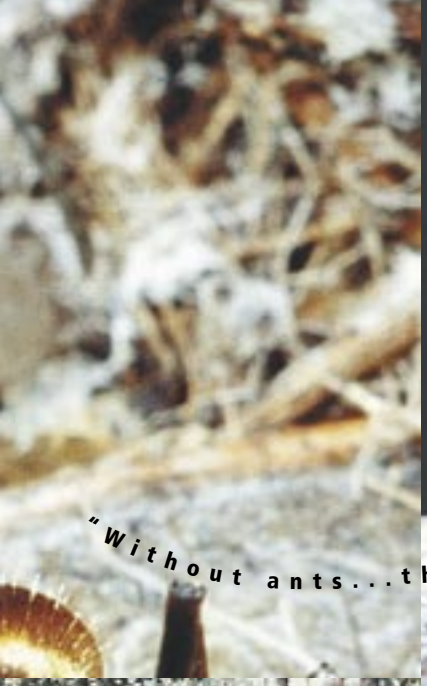
"To scientists, ant colonies often appear to be much like a secret society. We want to decode their social organization and communications systems," he says. But Hölldobler has found much more during his many years studying ants. His findings hold clues to the long-term survival of ants. The insects have inhabited Earth for more than 100 million years.

However, the ASU scientist says that buried deep within an ant colony's social structures are lessons for the long-term survival of humans as well. "Ants are the most successful animals on Earth," Hölldobler explains. "The very nature of our planet without ants would be very different than a world without humans.

"Without humans, culture, art, and music would vanish. But nature would recover," he says. "Without ants, however, the Earth would lose one of its most integrated and useful life forms. The planet would be significantly altered. Many natural habitats would go extinct, including many of the plant and animal species living today."

Ants are found in virtually every terrestrial environment (not to mention the kitchen). They live on the tundra, in the rain forests, and in the deserts. Ants live on every continent except Antarctica.

Looked at individually, ants are tiny creatures. But added together, their total collective mass on the planet rivals that of humans. Hölldobler estimates there are about ten thousand trillion (10×10^{15}) ants living on Earth at this moment. There are 11,000 known ant species. Hölldobler thinks that there may be a total of 20,000 species. In the life-rich Amazon, for example, ants make up a third of the total animal biomass.



"Without ants...the Earth would lose one of its most integrated and useful life forms."

An African *Polyrhachis* worker of another species carries a piece of twig to the nest of her colony. This twig fell into a honey-bait used by us to elicit recruitment behavior in the ants. The sweet tasting twig was an unusual piece of booty for this ant.

A large mound of the red wood ant *Formica polyctena* in the primeval forest of Finland. This mound is over 2 meters high.

Most city dwellers consider ants to be pests that are best stomped or sprayed. However, ants play a critical role in many ecosystems. Ants are the primary predators of other insects. A single colony of ants can consume as many as 10 million insects per year. Ants also are a major force in processing and turning the soil. And they are one of nature's main distributors of nutrients and plant seeds.

The many thousands of ant species are highly specialized. Ants eat everything from aphid secretions to plant and animal materials to fungus (which they farm themselves). Hölldobler says that the tremendous ecological significance and evolutionary success of the ants is based on the diversity of their social organizations.

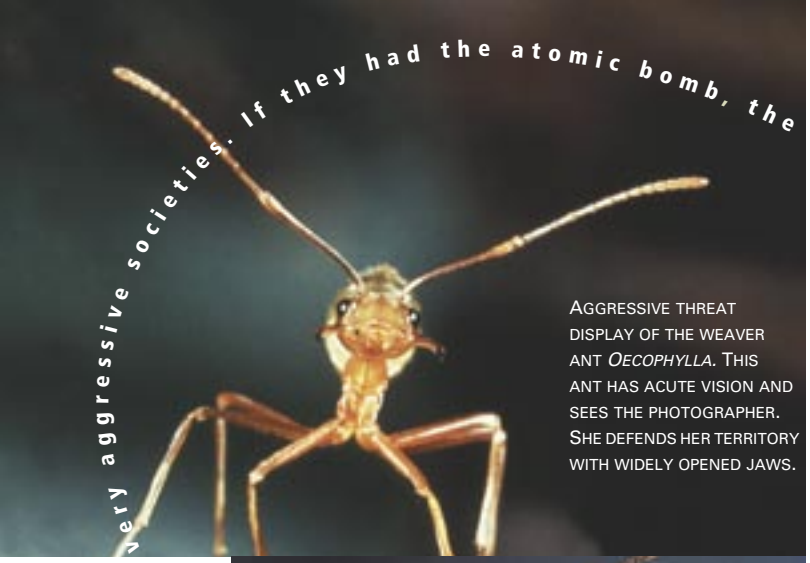
"We learn from the ants that division of labor makes any animal species superior to solitary or less well organized animal species," Hölldobler says. "But division of labor can only function by means of communication. Communication is the key to social life."

Ants communicate primarily by using chemical signals called pheromones. "Ants are walking batteries of glands that are constantly excreting chemical signals," he adds. "They are walking chemical factories."

In his office, Hölldobler keeps an extensive library of ant specimens on specially prepared microscope slides. The ants are sliced in many directions and stained with different media to highlight various structures. Using these histological preparations, researchers can map the location of numerous glands on an ant's body that produce pheromones.

Holding a cross section of an ant on a glass slide, Hölldobler explains how he and his collaborators dissect the glands from an ant. They make a chemical extract from the glandular secretions that they then test in behavioral experiments.

Hölldobler wants to know exactly which chemicals influence ant behavior. To do that, he and his colleagues recreate the chemicals on a molecular level. Just as a human's life is highly visual, the ASU team has found that an ant's life is highly scent or chemical driven.



AGGRESSIVE THREAT DISPLAY OF THE WEAVER ANT *OECOPHYLLA*. THIS ANT HAS ACUTE VISION AND SEES THE PHOTOGRAPHER. SHE DEFENDS HER TERRITORY WITH WIDELY OPENED JAWS.

"Ants have very, very aggressive societies. If they had the atomic bomb, the world wouldn't exist anymore."

SOCIAL FOOD SHARING BY REGURGITATION ARE ALTRUISTIC ACTS ALMOST UNIVERSAL IN ANT SOCIETIES. THEY ARE DISPLAYED HERE BY WORKERS OF THE SOUTH AMERICAN ANT *DACETON ARMIGERUM*.

Ants use scent to recognize nest-mates and to identify intruders. They also use scent to distinguish dominant from subordinate individuals, to mark their territories, and to send out alarm and rescue signals. Chemical markers are used to recruit and direct nest-mates to newly discovered food sources, as well as to organize a territorial raid against neighbors. Hölldobler's group has made many discoveries related to each of these types of chemical communication.

Scent is important, but the scientists have learned that ants do not entirely depend on chemical communication. Consider the leaf cutter ants, which are deaf. Hölldobler's group discovered why leaf cutter ants "sing" when they find high quality food.

The noise they make is not "heard" by others of their species. However, vibrations from the noise are sensed in the legs of other leaf cutter ants. They might be up to one meter away. The vibrations make an effective mechanical signal to summon nest-mates to a harvesting site of high quality.

Many ant species can walk on smooth, slippery plant surfaces without falling off. Hölldobler's group found out why in a series of tests with weaver ants. A weaver ant can hang upside down from a glass plate and hold a piece of metal with its jaws that is 100 times the ant's weight. The scientists found that the source of such strength is a microscopic film that spreads between the ant's feet and the glass.

Hölldobler's interest in ants goes well beyond their ecological importance. His scientific focus is on the real reason for their success—their highly evolved social behavior.

Like their cousins—bees and wasps—ants were among the first organisms to develop true social organizations. They did this more than 100 million years ago. Hölldobler says that ants have taken social organization to levels that rival the sophistication of ancient human societies. Of course, ant societies are almost entirely based on biology. Modern human societies are mainly cultural constructs built on a biological blueprint.

Social insects are important objects of study for naturalists, ecologists, and entomologists. But they also are favorites for any researcher interested in social behavior.

"We can learn a lot by studying social insect behavior," Hölldobler says. "In the 1980s, I wrote a paper called *Territorial Strategies in Ant Societies*. I was amazed by all the places from which I got requests for reprints. I heard from researchers at Harvard's Kennedy School of Government as well as from the Pentagon. I wondered, 'Why do they want to know about this?'

"A Harvard researcher told me: 'We are interested in how, through evolution, territorial strategies have been optimized.'"

"Ants have very, very aggressive societies," Hölldobler continues. "If they had the atomic bomb, the world wouldn't exist anymore.

"Or perhaps it would," he says. "The way that ants conduct warfare depends very much on resource distribution. And depending on that, they have very different kinds of territorial strategies. No colony really invests more energy in territorial defense than they get back in resources. It's a cost-benefit relationship, even in conducting warfare."

Hölldobler does not want to be seen as someone who compares human societies and ant societies. He does not see ants as little humans. "Ant societies and human societies are totally different things," Hölldobler explains.

"However, we can learn a lot by studying the biodiversity of animal societies. We learn that there are certain common principles that evolved independently. These include division of labor, social hierarchies, social networks, communication systems, kin recognition, and helping behavior. Helping behavior can be strikingly similar to altruism in human societies," he adds.

"No ant species is solitary. All ants are social," Hölldobler says as he gets to the core of his research. "Ants are great at employing the principle of sacrificing one life for the life of the group. A single ant's life is not any more important than that of the group. They act collectively as a 'super organism.'"

With a smile, the ASU scientist adds, "Karl Marx was right; he just chose the wrong species."

RESEARCH ON ANTS AT ASU IS SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION, THE GERMAN SCIENCE FOUNDATION, AND THE KRUPP FOUNDATION. FOR MORE INFORMATION, CONTACT BERT HÖLLDOBLER, PH.D. SCHOOL OF LIFE SCIENCES, 480.727.8415. SEND E-MAIL TO: BHOLLDOB@ASU.EDU

a passion for ants

Bert Hölldobler has had an unrivaled passion for ants since he was seven years old. It began in southern Germany during a walk in the forest with his father. That was when the world-renowned biologist first became awestruck with the tiny creatures that live beneath the soil.

Hölldobler's father, Karl, was a physician and a zoologist who by age 34 had become a hospital director. He later served as a surgeon during World War II. During this particular outing, he was on leave. The walk in the woods was his way to nurture the insect interests of his son.

"It was an early summer morning," Hölldobler recalls. "We were in the forest. My father turned over a rock, exposing a colony of carpenter ants underneath. I was fascinated to see a whole society revealed to me, and then to watch it quickly disappear underground." He was hooked.

As a child, Hölldobler kept an ant colony on the window benches at home. He had many other animals in aquariums and terrariums as well. But the ant colony was his favorite. It contained carpenter ants.

Carpenter ants forage at night. The young scientist allowed the ants to roam his room to find food. He would even instruct his mother not to vacuum before the afternoon, so that the foragers could safely make their way home. The scientist says that his mother was not entirely happy with the situation. But she was an understanding woman who tolerated her young son's idiosyncrasies.

Hölldobler is one of the newest members of the faculty at Arizona State University's School of Life Sciences. He came to ASU in 2005 from the University of Würzburg in Germany. He is part of the effort to develop a center devoted to the study of social dynamics and social complexity to which the new social insect research groups at ASU will make significant contributions. This group will interact with members of other disciplines, such as anthropology, sociology, psychology, and mathematics. All share interests in the diversity and commonality of social dynamics and social complexity on Earth.

In 1969, Hölldobler first met E.O. Wilson, the noted naturalist. That meeting began a nearly 40-year relationship of scientific collaboration. The two are also close friends. "We were both professors at Harvard. We had separate research groups but we often had lunch together," Hölldobler recalls. "Our backgrounds are remarkably similar. Ed Wilson grew up in the southern United States (Alabama). I grew up in the south of Germany in Bavaria. We were both hooked on bugs from childhood. In fact, we never got out of our 'bug phase.'"

"He is the systemacist and synthesizer on large scales. I am the experimentalist and analytical person. I synthesize on a much smaller scale," Hölldobler says of the relationship. "Neither of us could have written the book alone."

The "book," referred to by Hölldobler, is *The Ants*. It is the definitive book on ants that earned Hölldobler and Wilson a Pulitzer Prize in 1990 for nonfiction. It is the only scientific book to ever have won a Pulitzer. The ASU biologist describes the 732-page tome as a sweeping survey of the systematics, ethology, ecology and evolutionary biology of ants that includes information about sociogenetics, chemical ecology, and behavioral physiology.

The accolades don't end there for Hölldobler. His passion for ants has earned him wide distinction, ranging from scientific (election to the National Academy of Sciences in 1998) to film awards (winning a special jury prize at the Jackson Hole Wildlife Film Festival in 2005). The film award was for "The Ants—Nature's Secret Power." The film describes Hölldobler's research with ants and the methods he uses to decipher how they communicate.

"It was a total surprise to me that this film won this award," Hölldobler says. In the world of wildlife films, the award is comparable to winning an Oscar.

The ASU scientist also has been elected to the American Academy of Arts and Sciences, to the American Philosophical Society, and to several other international academies.

Hölldobler was the Alexander Agassiz Professor of Zoology at Harvard University's Museum of Comparative Zoology. He has been the recipient of the U.S. Senior Scientist Prize of the Alexander von Humboldt Foundation as well as the Gottfried Wilhelm Leibniz Prize of the German government, two of the most prestigious science prizes given in Europe.

Skip Derra