Systematics: Bringing order and identity to the Natural World

Entomologists Michael Schauff (left) and Douglass Miller of the Systematic Entomology Laboratory examine specimens and drawings to better understand traits for identifying papaya mealybugs.

U.S. National Arboretum

Henry A. Wallace Beltsville Area Research Center, U.S. Department of Agriculture

Washington, D.C.: World Capital for Systematics

Did you know the Nation's capital is home to over 100 million plants, insects, nematodes, fungi, and bacteria and other microorganisms? No, not living ones, but specimens that have been carefully preserved in small bottles and boxes in the area's systematics collections.

Each day, scientists from around the world visit and use these vast collections. Systematics laboratories of the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS) in the area include those at the Henry A. Wallace Beltsville Agricultural Research Center, Maryland, and at the U.S. National Arboretum.

With its partner, the Smithsonian's National Museum of Natural History, ARS maintains collections of thousands upon thousands of species from all corners of the world.

The National Museum of Natural History

Compactors that house the herbarium at the U.S. National Arboretum.

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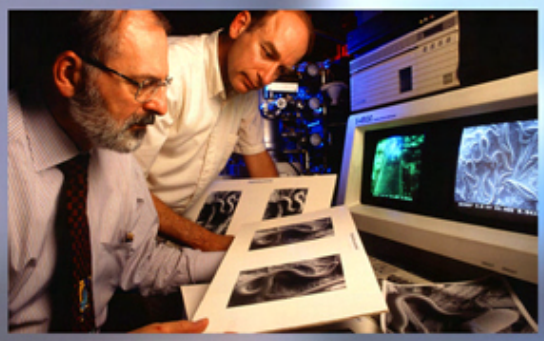
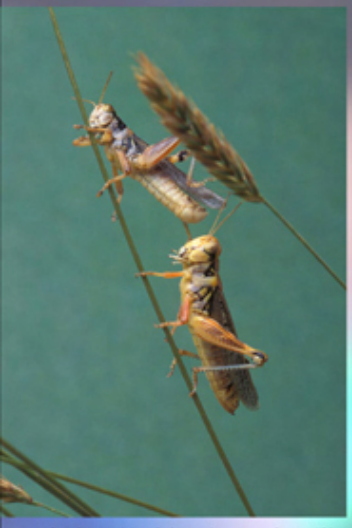


Cytologist William Wergin (left) and zoologist David Chitwood focus on *Caenorhabditis elegans*, a free-living nematode species that is serving as a model for studying the biochemistry of soybean cyst and root-knot nematodes.



Melanoplus sanguinipes, the lesser migratory grasshopper. This species is the most destructive grasshopper in North America

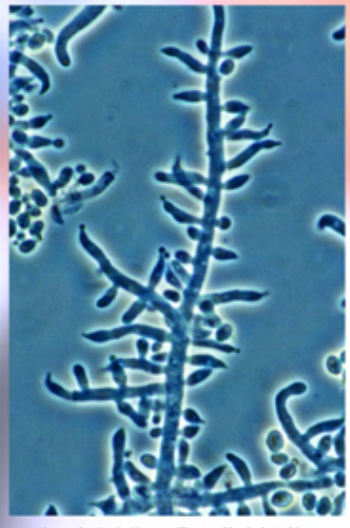
A low-temperature scanning electron microscope (at left) enables acarologist Ron Ochoa (background) and botanist Eric Erbe to observe tiny mites in detail impossible with conventional microscopes and slide-mounting techniques. Liquid nitrogen is first used to flash-freeze mites on their hosts in their natural positions.

Calling On All Systematists

Imagine the questions that come with the discovery of an insect or fungus new to our shores. Will it harm crops? Which crops? How quickly will it reproduce and spread? Can it be controlled?

These are questions for ARS systematists. Systematists provide a link between the vast biological collections and all who need to use the collections: scientists, academics, government agents, private citizens, and anyone else interested.

From local gardeners to regulatory agents who monitor imported goods at ports of entry, many people around the world rely on the expertise of ARS systematists.



Asexual reproduction in *Hypocrea* illustrated by the branching conidiophore of *Trichoderma*.

Now *That's* a Collection!

Have you ever wanted to collect one of everything you see out there? Acquiring a good sample of every living species is the goal of scientists who look after our vast biological collections. The ARS collections – the largest in the world – provide a wealth of information found nowhere else.

Picture specimens of dried mushrooms, pinned beetles, tapeworms preserved in jars, some centuries old and numbering in the tens of millions, all enclosed in drawers and cabinets that fill up large rooms. Think of having them at your fingertips to research how the organisms benefit or hinder agriculture. That's the scope and accessibility the ARS collections provide.

Pieced together over more than a century by world-renowned experts, these collections are ever-expanding treasures.

Our safe food, our homes, the protection of our environment, and our disease-fighting capabilities are ultimately linked to these collections.

Entomologists Michael Schauff (left) and Thomas Henry discuss the importance of leaf-footed bugs. Primarily seed and fruit feeders, these insects are potential pests of many crops.

Erin McCray, collections manager, and David Farr, mycologist for ARS, examine a fusiform rust of pine, one of more than 1 million specimens in the U.S. National Fungus Collections.

Curator of the U.S. National Parasite Collection, Ralph Lichtenfels retrieves a specimen, one of several hundred that are lent to researchers worldwide each year.

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Modern-Day Explorers In a Complex World

In a never-ending quest for new life, ARS explorers search the world for undiscovered plants and animals on which to build their systematics knowledge. Why? To collect new species. To find novel ways to control agricultural pests, pathogens, and parasites. And to gain a better understanding of human's place in the biosphere.

These field biologists brave dangers, diseases, and long, arduous hours as they trek across mountains and deserts and through tropical rain forests. They do this to study the web of life in faraway places. Exploration can also lead to new techniques to better control invasive threats introduced to the United States.

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An attractive white-fruited form of Hubei rowan (*Sorbus hupehensis*), a small tree with red fall foliage that has great potential for small gardens, collected on a recent National Arboretum expedition.

National Arboretum scientist Kevin Conrad helps Kunso Kim (then of Norfolk Botanical Garden) to reach seed of a *Magnolia* in China. Collecting specimens in remote parts of the world can be physically gruelling, but the economic and scientific rewards can be great.

Helleborus orientalis (Lenten Rose) grown from seeds collected in China on a recent USDA expedition. New seed sources for species may allow us to breed for new characters, such as disease resistance or cold tolerance.

Pere David's maple, *Acer davidii*. Many species of maple are grown in the United States. A recent National Arboretum expedition brought back seed of this Chinese species, which has great horticultural potential because of its brilliant fall foliage.

Pondering Plant Possibilities

Magnolias that thrive in cool climates, fuchsia-colored crape myrtle trees that won't mildew, cold-hardy flowering camellia shrubs – these are just a few of the rewards from plant explorations made by National Arboretum scientists.

Combing the world for new horticultural materials, ARS biologists are also piecing together relationships among plants, in the hope of pinpointing beneficial qualities such as resistance, hardiness, and aesthetic appeal.

For example, Arboretum scientists are trying to rescue the Eastern hemlock, a tree once common to native forests in the East. This evergreen provides critical habitat for wildlife in Eastern forests but is under attack by the invasive woolly adelgid. The researchers have found a hemlock species that can resist the destructive insect pest and are working to breed this tree's beneficial genes into the native hemlock.

Scientists from the National Arboretum, along with American and Chinese collaborators, clean seeds and prepare specimens on a recent trip in Shaanxi Province, China. USDA mounts collecting expeditions to many parts of the world, collaborating with other American researchers as well as scientists in the local countries.

Fungi: Nature's Busy Recyclers

Often invisible to us, fungi spend their lives breaking down organic matter into smaller-sized nutrients used by other plants and organisms. Without fungi, the world would be covered in a thick blanket of fallen trees, dead leaves, and other organic waste.

Fungi are all around us. For example, yeasts, which are some of the smallest fungi, cause bread to rise and beer to ferment. But, growing underground, some fungi can extend for miles and weigh over a hundred tons.

Certain fungi can cause deadly diseases in living plants. For example, the chestnut blight fungus killed almost all chestnut trees in eastern North America in the last century.

Mycologists Mary Palm (left) and Amy Rossman discuss the identification of a rust fungus.

Cultures of a destructive mold called *Phomopsis* strains that infect both crop and noncrop plants.

Plant pathologist Rick Bennett examines fungi that may be used for biological control of pernicious weeds.

Fruiting bodies of *Physarum roseum*, one of the 60,000 specimens of Myxomycetes, also known as slime molds, in the U.S. National Fungus Collections.

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Mycologists José Hernández and Mary Palm observe a digital image of teliospores of an American collection of daylily rust.

Healthy European corn borer

Invaders In Our Fields and Backyards

As their names imply, the Asian gypsy moth, Dutch elm disease, and European corn borer aren't native to the United States. That makes them invasive, or alien, species.

Invasive insects, plants, fungi, and other organisms have become one of the world's most pressing ecological problems. While you may have heard of some of them (daylily rust fungus, for example) or their effects (sudden oak death, for example), you may not realize the extent of the problem or the enormity of the damage.

It's estimated that there may be as many as 50,000 species of invasive or alien plants and animals living in the United States today. Some can be used to control pests and are thus beneficial to crops and livestock. However, many cause devastating damage and losses totaling well over $100 billion a year.

Gypsy moth caterpillar

Parasites: Our Longtime Companions

Adult specimen of the pork tapeworm, *Taenia solium*, from the intestine of a human

For as long as there have been insects, fish, and animals, parasites have crawled, flown, swum, or slithered about, looking for a free ride.

Parasites were there more than 2 million years ago, as our ancestors competed for food with the great animals of the African plains. They were there 10,000 years ago, aboard our first domesticated cattle and sheep. And since then, parasites have spread throughout the world to farms, cities, and wild lands, ever present and ever circulating.

Yes, parasites can cause diseases and death. But some can help us by attacking destructive pests. And they all provide clues to the complexity of ecological connections in the past and about today's rapidly changing world.

ARS collects, studies, and documents parasites from around the world to help people manage new and emerging invasive threats to society, agriculture, and natural environments.

A major focus is nematodes, microscopic worms that feed on plant roots. Although many are benign, certain nematodes can kill a few vulnerable plants in your backyard or thousands in a grower's cultivated field.

Unexpected Ties to the Lowly Tapeworm

Tapeworm parasites remain a problem for humans and they also cause significant livestock losses. The ability to control these pathogens has been hampered by an incomplete understanding of their biology and evolution.

It was assumed that humans first picked up tapeworms through their association with domesticated animals, like cattle and swine. But a detailed systematics study by ARS zoologist Eric Hoberg and colleagues revealed quite a different story.

Their work showed that humans picked up tapeworms on two different occasions and that, both times, the tapeworms came from wild animals living alongside early humans in Africa about 2 million years ago. This means that humans were the ones who passed tapeworms to domesticated animals like cattle and swine.

This new line of evidence is helping scientists who study tapeworms and may provide crucial information on how to control these parasites more effectively.

Zoologist Eric Hoberg examines a specimen of a *Taenia* tapeworm from a North American lynx.

Specimens and information databases of the U.S. National Parasite Collection are a unique and irreplaceable resource for parasite biodiversity research. Zoologist Eric Hoberg examines a specimen.

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In his Beltsville laboratory, mycologist Gary Samuels examines various species of *Trichoderma* fungi collected from Belgium and the United States.

Asian longhorned beetle infestation in Chicago: after cleanup. The only means of control available is to identify which trees are infested, cut them down, and chip them into tiny pieces.

Such an approach can turn a tranquil neighborhood with tree-lined streets into a barren landscape.

Systematics: Our Invisible Safety Net

When a suspicious insect, fungus, or micro-organism is spotted on plants or on other agricultural goods entering the United States, several questions naturally follow. What is it? Can it attack plants or animals? Will it spread, compromising stability and productivity?

A case of mistaken identity at this critical time can have devastating consequences. Invasive species such as the Asian longhorned beetle, a tree borer that threatens to devastate forests across the Eastern United States, cost billions of dollars in damage and control each year.

At times like these, the impact of systematists' work is most apparent. Their ability to distinguish between and classify living things is invaluable when economic, health, or even national security issues hinge on rapid and accurate identification of a suspicious organism.

An adult Asian longhorned beetle feeds on the bark of a sentinel tree.

Ryegrass infected with *Telletia wulkeri*.

Wheat infected with *Tilletia indica*.

Healthy wheat (left) and wheat infected by the wheat seed gall nematode (right).

Systematist Eric Hoberg works to identify important animal parasites.

Foods like these from around the world are finding a place on American tables.

Ensuring An Ample and Safe Food Supply

It's easy to take our safe and plentiful food supply for granted. But systematists don't.

While crop pests and diseases may take a sizable bite out of the U.S. food supply each year, systematists are unsung heroes dedicated to keeping the loss to a minimum. Many devote their lives to finding better ways to identify destructive pests and pathogens.

Their work helps halt the entry of innumerable threats to our agriculture at ports of entry, and it also helps us identify species causing current problems out in the fields and in marketing channels.

Detectives Protecting Global Trade

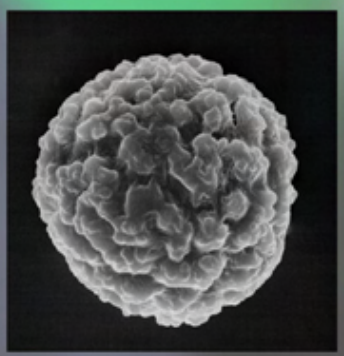
Shipping for trade.

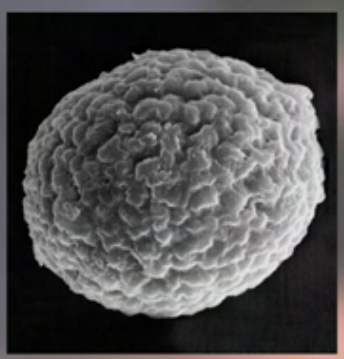
Organisms – some too small to be seen with the naked eye – can potentially bring agricultural markets to a halt. This nearly happened in the United States in the mid-1990s.

The Karnal bunt fungus, which blackens and mangles wheat seeds, is a disease that is quarantined worldwide: countries won't buy wheat that's infected. In 1996, fears that the Karnal bunt fungus had made its way into the U.S. seriously threatened the Nation's $5-billion-a-year wheat export market.

To the rescue came ARS fungal systematists, who discovered that the fungus was really just a look-alike — a ryegrass bunt fungus posing no threat to wheat.

This case is just one example of how systematists' accurate identification and knowledge of where specific pests occur can prevent false alarms that could otherwise interrupt the export of billions of dollars of U.S. agricultural commodities.





A scanning electron micrograph of a ryegrass bunt spore from Tennessee (above) displays thicker, wider ridges and grooves than those of a Karnal bunt spore (below). Magnified about 2,000x.

Entomologist David Nickle examines an unidentified thrips species found in a shipment of cut flowers from South Africa and compares it to the image on the screen of a known thrips species. His rapid identification helps to ensure safe and timely shipments at various ports of entry.

The Many Contributions of Systematics

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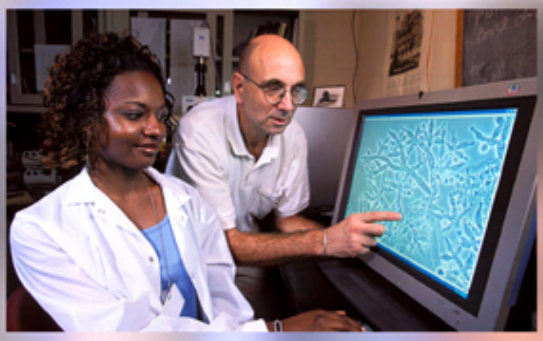

Mycologist Gary Samuels and University of Maryland student Lutorri Ashley discuss the morphology of the *Trichoderma* that causes green mold of mushrooms.

Mycologist Lisa Castlebury extracts DNA from rust spores to determine whether specimens of daylily rust from different geographic locations belong to the same species.

Whiplike larva of root-knot nematode, *Meloidogyne incognita*, magnified 500x, shown here penetrating a tomato root. Once inside, the larva establishes a feeding site, which causes a nutrient-robbing gall.

Guarding Our Borders Through Science

Harmful insects, fungal pathogens, parasites, and bacteria can be used as agents of attack against our food supply and economy. These destructive organisms could contaminate our food and water supplies, upset the balance of our ecosystems, and inflict billions of dollars of damage to our economy.

Systematists' knowledge and ability to scrutinize and identify these organisms play a vital role in the first line of defense.

In demand more than ever, systematists' expertise is being called upon in new efforts to regularly survey the country, helping to ensure that potentially harmful organisms have not slipped inside our borders or been deliberately introduced.

Black pycnidia of *Phomopsis* fungus developing in culture on stems of alfalfa.

Historically, mites have been difficult because of their minute size. But now, ARS scientists are freezing mites in their tracks and using scanning electron microscopy to observe them in detail. Here, a yellow mite, *Lorryia formosa*, commonly found on citrus plants, is shown among some fungi. Magnified about 850x.