The whole chain of events is the direct result of Asu’s Undergraduate Biological Sciences Education Program, which is supported by a grant from the Howard Hughes Medical Institute. The Asu program blurs the distinction between teaching and research while preparing students for admission to medical or graduate school. This tale of two seniors in the program is a classic story of scientific inquiry.

Students Carlos Rodriguez and Brad Segura, coincidentally, both come from military families. And both spent part of their childhoods in the Caribbean tropics, keenly observing and collecting the wildlife they saw near their homes. Each separately ended up at Asu and found professors whose work intrigued them. Each student boldly asked if they could go beyond normal class work and help with the research.

Rodriguez, 23, was born in Puerto Rico, where he felt drawn to the rain forest that flourished near his home. “I had easy access to bugs, assorted frogs, toads, and other creatures,” the zoology major says. “I did set up a household zoo for a little while, something my parents have not-so-fond memories of.”

While in college, Rodriguez has maintained a colony of up to 20 hamsters. He breeds and sells them to pet shops in Prescott and Phoenix. Other creatures in his zoo: a parrot, several parakeets, tadpoles, tropical fish, a cat, a dog, and a garter snake.

Parents Ramon and Mirta Rodriguez of Scottsdale encouraged their son’s scientific interests. There was plenty they could teach him. Ramon was an anesthesiologist and Mirta once worked as a microbiologist in a laboratory at the University of Puerto Rico.

Segura, also 23, was born in Jamaica. “I’m one of those kids who grew up trying to help out abandoned birds,” he says. “I was always bringing something home that mom told me to take out the door right away.”

A biology/pre-medicine major, Segura has worked with a farm veterinarian and various doctors, including one at Scottsdale’s Mayo Clinic. In addition to his Asu laboratory duties, he works as a technician for the Donor Network of Arizona, an organ-recovery organization. The Donor Network employs him on call for three nights a week in 12-hour shifts. “I go to hospitals, review medical records, perform the tissue recovery. We procure corneas for transplant,” Segura says. “I do that three or four nights a week. It makes juggling school work and finding time to come in here a little bit of a chore.”

Rodriguez and Segura had taken the same Chicano literature class. They began discussing their research projects during a Hughes Program pizza social in May 1993. “I happened to tell Brad about the 249 seed-harvester ant queens we collected in March. Almost every single colony had died,” Rodriguez recalls.

The consistency of the problem provoked his curiosity. “The queen always ends up sprouting this white substance. We started brainstorming together and Brad told me about the work that his mentor is doing.”

That’s when they began to suspect what happened to Rissing’s ant queens. Segura was getting set to work with Asu zoologist Elizabeth Davidson on a project involving a fungus that was lethal to insects.

Rissing thought his ant queens were dying and then rotting, but Rodriguez turned that theory on its head. He suggested that perhaps they were rotting and then dying. Rissing was excited. The idea had not occurred to him.

A few days later, at Rissing’s invitation, Davidson examined some of the ant carcasses. She isolated the fungus, which turned out to be a strain of an insect pathogen on which she had written her master’s thesis.

With the professors’ help, Rodriguez then began to design and conduct his comparative mortality experiments. “I had a control group that would not be exposed to the fungus and an experimental group that would be exposed,” he explains. “Mortality was significantly different. On average, the group that was exposed to the fungus had 100 percent mortality within four days. The unexposed group would live for quite awhile longer, sometimes twice or three times as long.”

Rodriguez was correct. “They’re not dying
and rotting. They’re rotting and dying. The fungus kills them,” Rissing says.

Davidson said the mystery of the dying ant queens is a typical example of scientific specialization and collaboration in action.

“I’ve known Steve Rissing for years and years, but just as I don’t recognize peculiar behavior in ants, he doesn’t recognize pathogens in ants,” she says.

Segura says that he and Rodriguez were simply chatting, not really trying to solve any scientific problem. But that’s often how science happens.

“I go to scientific meetings not to attend sessions. I go to scientific meetings to talk to people,” Davidson says.

Rodriguez’s results could turn out to be scientifically significant, especially to the U.S. Department of Agriculture’s insect biological control laboratory in Montpelier, France.

“Most of our major pests in the United States come from abroad. That’s why we have to go abroad to get their natural enemies,” Davidson explains.

The fungus that Rodriguez has been studying could be useful to the USDA because it comes from a desert habitat. Most fungi are restricted to humid environments. Davidson says that a patent already exists on a fungus of the same species for fire ant control.

“It’s been known from ants for quite a long time, but it’s interesting that Carlos should stumble upon one that seems to be specific for desert ants and is adapted for the desert environment.”

As Rodriguez’s mentor, Rissing would have been happy even if the finding had no scientific value.

“If it’s new for the scientific literature, great. We’ll get a paper out of it. That’s not really the main point here. The point is he learned about science by doing science. The pizzas were still warm from orientation, and we had students doing what they were supposed to be doing,” Rissing says.

A zoology major, Rodriguez met Rissing after a fall 1992 seminar the latter gave on his research. After the seminar, Rodriguez volunteered to work in Rissing’s laboratory without pay and without course credit.

The following semester, things got more serious, and Rodriguez received independent study credit for his work. Then came his successful application to ASU’s Hughes Program. The program helps him earn while he learns.

“The program really gave me an impetus to find a serious project to work on,” Rodriguez says.

Segura met his Hughes Program mentor-to-be during her Invertebrate Zoology class a couple of summers ago. He enjoyed her class enough to volunteer to join her research effort. Davidson had been studying microorganisms associated with Arizona’s whiteflies in collaboration with the U.S. Department of Agriculture’s Western Cotton Research Laboratory.

ASU undergraduate Sophia Cleland does more than listen to Professor Steven Rissing lecture. Cleland studies social colony structure of desert leaf cutter ants (Acromyrmex versicolor). She is using an innovative molecular genetic technique to determine how many mothers (queen ants) and fathers make up an entire colony. One technical problem she must solve involves the difficulty of extracting enough DNA from a single ant for analysis. Chemical characteristics within the molecular structure of DNA serve as genetic “fingerprints.” These fingerprints help Cleland to trace the lineage of individual ants. She obtains DNA from ant cells by crushing the ant in a solvent. Cleland then uses chemical techniques to extract and purify the DNA.
"The main reason we’re studying whiteflies is that they’re detrimental to Arizona’s agricultural community," Segura says. The barely visible whiteflies swarm into metropolitan Phoenix like a bizarre snow flurry late every summer.

Unfortunately, whiteflies are attracted to the sap of Arizona’s commercial cotton plants. Apparently, the sap ferments in the bellies of the whiteflies, then comes out as a thick, sugary substance called honeydew.

“When it gets on the cotton, we get what cotton people call sticky cotton,” Segura explains. Although it actually feels rather dry to the touch, sticky cotton is bad. Japanese manufacturers won’t buy it. “It literally clogs up the cotton gins,” he says.

Davidson and Segura have isolated about 60 different kinds of bacteria from the whiteflies, five of which look like promising candidates in the production of thick sugars. They will report their joint findings on whitefly physiology in two papers they have submitted to scholarly journals. Not bad for a student who confessed to having less-than-perfect grades.

“This has really piqued my interest. I’m at the point now where I’m having so much fun that I am excelling, even academically,” Segura says. The research also has given him a bank of experience to draw upon in medical school. His work has included everything from sterilization and microdissection techniques to critical thinking.

“In this day and age, the necessity to talk about how science works, the good and the bad of it, goes below the graduate level,” Davidson says. “We now have undergraduates who are doing publishable work in the labs. Brad is much further ahead in his understanding of how science works than I was at this stage in the game.”

Refining the Teaching Process

Rodriguez and Segura are success stories. ASU professors hope to make their experience a common one for many students.

Scientists and educators agree that a refinement of the methods used to teach science to young students is needed. Stoking student interest in scientific topics and presenting them with accurate models of how science works is the challenge. To be effective, educators must get way beyond textbooks, chalkboards, and droning two-hour lectures. There is much at stake.

For example, last March, an ASU geologist appeared on KFYI news-talk radio to comment scientifically about a Noah’s ark television special that CBS had aired several weeks earlier.

A 13-year-old girl named Courtney called in to take issue with the geologist’s views.
She also leveled a criticism at scientists in general. “They’re always changing their minds,” she complained.

Courtney’s attitude is widespread. Many people fail to realize that scientists constantly gather data, devise theories, test those theories against the evidence, then revise the theories to reflect the latest available information.

“Society needs to understand that science is a process, that it’s not just a body of facts,” Steven Rissing says.

At ASU, the zoology department is combating society’s misperceptions of science by following a simple philosophy: teach science to students as science is practiced.

“The best way to learn science is to do science, to see how science is done as a process,” Rissing says.

The program got under way in earnest last June when a dozen ASU professors took a four-week teaching strategies workshop led by zoology Professor Anton Lawson. Workshops are scheduled for each of the next three summers. Rissing, who manages ASU’s Hughes Program, is especially proud of the workshops.

“Many people use the Hughes money for this kind of thing. But nobody has faculty-development workshops like we have for our own faculty,” he says.

A specialist in science teaching methods, Lawson has long promoted teaching science as science is practiced. Lawson and scholars at other institutions nationwide have administered science-reasoning tests to students at various grade levels for years. They have found that even students at the college level have difficulty reasoning scientifically.

“We have a substantial portion of college sophomores and juniors who are reasoning at the level of between an 8-year-old and a 15-year-old,” Lawson says. “We have students here at ASU who aren’t where they ought to be, and that’s not unusual. Most universities are like that.”

The elementary and high schools often fail to teach science in a way that helps to develop scientific thinking skills, but the problems go deeper than that, according to Lawson.

“What happens in the home might also not be very conducive to developing higher thinking skills. Certainly watching TV is not going to do much to develop higher thinking skills,” he says.

Workshop participants went through a series of exercises aimed at helping students achieve three goals: develop reasoning skills, understand the nature of science, and become familiar with modern biological theories.

This approach emphasizes understanding scientific methods at the expense of memorizing extensive lists of terms and definitions.

“I don’t think that is a problem because those details are found in textbooks. If you know where to look, you can find them in a hurry. I don’t think we’re losing anything,” Lawson says. “In fact, there is a considerable amount of evidence to suggest that the less you actually attempt to cover in any particular period of time, the more you actually uncover for the students.”

Although this approach may someday pervade the zoology core curriculum at ASU, some faculty members have yet to embrace the new approach. They remain convinced that memorization is the best way to learn certain kinds of material. But zoology Professor Ronald Rutowski likes the new approach.

“The traditional way to teach invertebrate zoology is to walk in and say, ‘Today we’re going to talk about protozoans. Here are all the different kinds of protozoans. Today we’re going to talk about cnidarians. Here are all the different kinds of jellyfish and corals,’” Rutowski says.

Zoologists have referred to this approach as the “Parade of the Phyla.” It’s simply a listing of all the different kinds of animals and their definitive characteristics.

Rutowski never had fully used that approach in his lectures, but he found it difficult to avoid in his laboratory sections. The workshop gave him time to write two new laboratory exercises and try them out on fellow faculty members. He wrote more on his own.

Now, 10 of his 11 Invertebrate Zoology lab exercises reflect the “science as process” approach. When his students attended their lab on arthropods last semester, they worked in groups to develop and defend their own ideas about the evolutionary relationships between scorpions, spiders, crayfish, and insects.

“Students become a lot less involved in learning a large array of terms and become much more involved in learning about the ideas that people have developed to explain certain aspects of these animals,” Rutowski says.

If the teaching workshops conducted by the zoology department were animals, they might be frogs. As amphibians, frogs live both in water and on land. And even though Lawson’s workshops advocate teaching science as science is practiced, its methods can work in humanities classrooms as well.

“We were all taught in the same old dumb style where somebody stands up in front and just lectures a bunch of material at you,” says Joan McGregor, an associate professor of philosophy. But there are more effective ways to teach.

McGregor was the only non-scientist in a group of 12 who attended last year’s workshop. She qualified by virtue of her Environmental Ethics course, which attracts both biology and philosophy students.
During the workshop, Anton Lawson discussed how people learn in general, not just how people learn biology. One of his key points: students have difficulty passively absorbing a steady stream of technical terms. “He argues that we ought to start students with exploring a question or an issue and getting them to think up solutions,” McGregor says.

In a science discipline, that would involve pondering a natural phenomenon, offering alternative hypotheses to explain it, then trying to test them through experimentation.

“I think one could do the same sort of thing in philosophy. Not hypothesis formation, but thinking through a question, whether it be a broad, metaphysical question or a question in environmental ethics,” she says.

Lawson’s methods, which he used during the workshop, helped the participants understand that getting students to think critically means forcing them to think through the questions for themselves.

“He stresses that over and over again, and I’m really with him,” McGregor says. “I think we need to alter how we teach people because we’re too hung up on content, all the way across the board.”

The Hughes workshop emphasized how to get students working together doing experiments and other exercises in the laboratory. McGregor translated that group approach into a classroom setting.

“There’s still that exploratory exercise where you get students to sit together and puzzle something through,” she says. “I’m a real believer in making them come up with something, making them write it up, and then making them actually defend it.”

Learning science is just one by-product of practicing reasoning skills in the laboratory or the classroom, according to Lawson.

“These are the sort of reasoning skills one uses to make decisions in all walks of life. If you don’t have them, you are in a situation where someone else has to make up your mind for you.” The ability to reason is vital to everything from evaluating the contents of a newspaper article to dealing with an unexpected turn of events in the office.

“It’s fundamental to a functioning democracy,” Lawson adds.

ASU’s Undergraduate Biological Sciences Education Program is supported by grants from the Howard Hughes Medical Institute. For information, call Steven Rissing, Ph.D., manager of ASU’s Hughes Program, 602.965.5369. Undergraduate research at ASU is also supported by the USDA Western Cotton Research Laboratory. For information, call Elizabeth W. Davidson, Ph.D., Department of Zoology, 602.965.3571.
assu zoologists are well-versed in the scientific principle of adaptive radiation, which explains how populations evolve by exploiting new habitats and food sources. The zoology department has done some adaptive radiating of its own in the academic habitat over the last few years. What started as a largely informal departmental commitment to undergraduate research and instruction has evolved into four separate undergraduate research programs.

Now a $4 million enterprise, the programs support the work of more than 50 students. The two largest programs are available to virtually every life-science major, not just zoology students.

The department’s faculty have individually encouraged undergraduate research for years, but Professor James Collins made it official when he established a $3,000 fund for the purpose when he became department chair in 1989. Collins wanted to make a move both symbolic and financial, an action that stated the value of the activity.

These are the four new undergraduate research habitats into which Asu’s zoology department has expanded:

National Science Foundation’s Summer Research Experience for Undergraduates Program

Asu provides stipends, equipment, and supplies for five to 12 students each summer under the guidance of faculty mentors with about $25,000 annually from the NSF.

“This program seeks to attract students to research careers in biology,” Collins says. “Over its four-year existence, 22 student fellows have been selected from a group of highly qualified undergraduates from 40 colleges and universities.”

Last summer, students came from such institutions as Asu, the University of Arizona, Brown, and Rice universities to participate.

Howard Hughes Medical Institute Undergraduate Biological Sciences Education Program

This program began during the summer of 1992 with a five-year, $1.5 million grant from the Howard Hughes Medical Institute. An additional $1 million grant was awarded in the fall of 1994. “Faculty from all the life sciences can receive support for participating in workshops to revise courses and undergraduate curricula from all of the life sciences can be supported for conducting their own research,” Collins says.

The Hughes Program currently supports 40 undergraduates, including many women and minorities, who might not otherwise have the opportunity to pursue a career in biological research. In 1994, Asu received an additional $1 million grant from the Hughes Institute. The money will be used to support an additional 20 students as well as to design and build a model laboratory of the future. Researchers from Asu’s School of Design are collaborating with science faculty members on the project.

Students in the Hughes Program come from nine majors, including biology, chemistry and biochemistry, microbiology, psychology, and zoology. A total of 75 faculty members from 13 departments have agreed to serve as research mentors.

In 1993, the Hughes Program had 110 applicants for the 27 spots. “We eventually plan on supporting 80,” Collins says.

Minority Access to Research Careers

The Marc program kicked off with a five-year, $1.2 million grant from the National Institutes of Health during the summer of 1993. The program focuses on American Indian students, but includes other ethnic and racial minorities.

Like the Hughes Program, Marc is broadly based. Fifteen faculty members from the departments of zoology, microbiology, chemistry and biochemistry, anthropology, psychology, mathematics, and exercise science and physical education are involved.

“This program supports five minority trainees in the first year, gradually increasing to eight trainees in year five,” Collins explains. Marc students gain research experience, attend seminars, take classes in basic biomedical techniques, and have opportunities to present research results at national meetings. They also receive preparation for the Graduate Record Examination and have access to a special computer room.

NSF Ecology Research Experiences for Undergraduates

Another summer 1993 grant—this one worth $250,000 over four years—launched the program. Six Asu ecologists designed the program for first- and second-year undergraduates interested in environmental biology research careers.

“The four-year program will expose 20 undergraduates to ecological research early in their career at Asu,” Collins says.

“We plan to involve groups traditionally underrepresented in environmental biology, aiming for at least 10 Hispanic, American Indian, or African American trainees over the four-year project period.”

The zoology department’s commitment to undergraduate education stretches back to the university’s roots as a teachers’ college. Collins joined the zoology faculty nearly 20 years ago, during the transition to a more research-oriented department. He still remembers the senior faculty from that period with admiration.

“They were absolutely committed to undergraduate education, but they understood the value of research as a generally valuable thing to have in an individual’s background, regardless of what career they might go into,” Collins says.

“At the same time, they gave us a sense that undergraduate education was really important. We held onto that. Even before these programs were in place, the faculty in this department were supporting an average of 90 undergraduates a year in their research labs, which would be three students per faculty member.”

The zoology department’s resurgent commitment to undergraduate education has come during a funding drought. Faculty salaries have stagnated for years, and the Arizona state budget has had little or nothing to spare for improving university programs.

Collins says that his colleagues could have spent their time writing grant proposals to add to their research funding, which now totals more than $4 million. They also could have sought contract or consulting work to supplement their salaries. Instead, they pitched in to help improve undergraduate education.

“That’s a commendable response on their part,” Collins says. “It seems to be the right thing to do and the faculty are doing it regardless of what the reward structure looks like. It’s something they get a lot of satisfaction from.” —Steve Koppes