H is students tend to freak out at first, says Presley Martin, describing the introductory biology course he teaches at Hamline University in St. Paul, Minnesota. When they walk into the course's laboratory section for the first time, the students find themselves face-to-screen with the Genetics Construction Kit (g ck)—a computer simulation of Mendelian inheritance that will compel them to do some real science.

To begin an experiment, the g ck generates a “field collection” of, say, fruit flies, each with a combination of traits—white eyes or red eyes, bent wings or stubby wings or straight wings and so on. The program also provides the tools for performing genetic crosses, plus a spreadsheet to analyze the outcomes statistically. It does not explain the hidden genetic mechanisms that produced those outcomes. Nor does it offer a traditional lab manual that tells the student how to find out. Instead, the student is expected to decide what traits to look at, what crosses to try, what hypotheses to consider and, perhaps most important, when to be satisfied that a hypothesis is correct, just as a scientist faced with a real field collection must do.

“They’re really uncomfortable” says Martin, who is chairman of the Hamline biology department. “They’re used to problems where they’re expected to get the right answer,” so it’s hard for them to deal with the fact that the program isn’t going to tell them when they get the right answer.” Instead it confronts them with the task of learning firsthand the most fundamental principles of science—that hypotheses have to be tested, alternatives have to be ruled out, objections have to be satisfied and a conclusion requires evidence: “Ask for supportive evidence,” says Martin, “and at first they’re just puzzled.” As the exercises progress, however, at least some of the students really do begin to get it.

Stories like Martin’s are being heard more and more often. Thanks to the proliferation of high-powered personal computers on campus and the rapid growth of the Internet, colleges and universities are experimenting with computer-based learning as never before—frequently with biologists among the leaders. Indeed, many of those biologists believe that online learning is the best hope for maintaining high-quality, individualized education in the face of undergraduate enrollments that have surged dramatically during the past decade. Some biology educators would use online resources to help change the method of learning itself, regardless of class size. They find that the g ck and similar software programs can be powerful tools for giving students an experience as close as possible to real scientific research—what curriculum reformers call “inquiry-based” learning. Students are encouraged to ask their own questions, struggle toward the answers and, in effect, teach themselves.
with biologist John N. Callery, then at the University of Arizona. In a 1988 article, Jungck and Nils S. Peterson of Washington State University explained that the teaching and the software work together to reinforce the “3 Ps” of research: problem-posing, problem-solving and peer persuasion—the peers in this case being the other students.

That 3-Ps approach has, in turn, been the guiding principle of the BioQUEST consortium, which Jungck and a group of like-minded software authors founded in 1986. The consortium, which is located at Beloit College and funded partly with hhm grants, maintains a library of some 70 tools, simulations, databases and other resources developed for undergraduate biology. Each resource is peer-reviewed, available on cd-rom and enhanced by data readily retrieved from the Internet. Among the offerings are the original Genetics Construction Kit, Sequence It! (a simulated protein-sequencing lab) and Bird It!—Beagle Investigation Returns with Darwinian Data (a tool for exploring evolution through a database of taxonomy, song recordings, DNA sequences and measurements on some 650 specimens of Galápagos finches).

Jungck is especially taken with how such tools, complemented by e-mail, discussion groups and chat rooms, have raised the skills and expectations of students to a whole new level. “You see them engaged in collaborative problem-solving, looking at multiple hypotheses, sharing data. A teacher in one of our workshops told me recently that their worst project this year is better than their best project three years ago. Another said, ‘we never knew our students were that creative.’”

He admits that this kind of science teaching is never going to be as easy as the traditional approach, Internet or no Internet. “For teachers, it’s more intense,” he says. “With oodles of projects going on all the time, and with students accessing all these complex tools, you have to be willing to let the students teach you things. And that’s being designed at Stanford to give large introductory physiology classes hands-on, lab-like experiences without going to a lab. Other virtual labs will focus on human gastrointestinal, cardiovascular, respiratory and neurobiological systems.

“This is more than a digital textbook,” says Camillian Huang, virtual labs project manager. “It is fun, and it helps students understand difficult concepts and relate what they are learning to their everyday lives.” In a preliminary comparison of student achievement, students who used the virtual lab scored higher than those who only attended lectures and read the text. Huang reports.

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More information and demonstration labs can be found online at: summit.stanford.edu/hhm/
a huge change in the social contract of the classroom.”

Meanwhile, Jungck says, "for the students this is a lot more work
than just passively sitting in front of an instructor, taking notes. But even
so, from all of our studies, the students who go through this process
retain more. They stay in the courses longer. They more often go on and
take additional science courses. They are better at applying what they’ve
learned to social and legal issues. And they seem to have a conversant,
speaking knowledge of science for a long time after they finish.”

**FIRST-YEAR BIOLOGY ONLINE**

None of the software in the BioQUEST library was specifically
designed to help teachers cope with overcrowded classes, but that is
definitely an issue at Michigan State University, where an interdiscipli-
inary team of biologists and education specialists is attempting to
put the school’s entire first-year biology curriculum online. After all,
notes microbiologist John Merrill, one of the leaders in that effort,
“unless the state suddenly throws a huge amount of money at us so
that we can have everybody in small classes, I still have to teach these
huge courses with 400 students.”

The project, called “First Year Online,” began in 1998 as part of a five-
year, $1.6 million grant from the HHMI, says project director Estelle McGroar-
key and it soon proved to be an even more daunting task than the team had
imagined. “It took us over a year before we were ready to figure out
how to approach online biology,” she says. “Early on, for example, we made
the decision that we would not provide a complete virtual course. Biolo-
gists more than the physicists, feel that there has to be a face-to-face
component in teaching.”

Materials are presented using one of the Lecture Online platforms that
had just been developed at Michigan State by physics research associ-
ate Gerd Kortemeyer. Like commercial course management software,
L O! offers tools for keeping track of administrative details such as
enrollment and grades, and, most importantly, it allows instructors to
customize the online content to suit their particular needs.

**HOW TO HELP STUDENTS LEARN**

“There is a pretty strong body of evidence that students don’t learn
much by just being told about science, as in being lectured to, or just
reading about it,” says team member Joyce Parker of the division of sci-
cence and mathematics education. “They first have to be engaged in some
sort of problem, so that they can see a purpose ‘Here’s something
intriguing, let’s try to understand it.”

The online modules are designed to start by piquing the students’
interest and curiosity. For example, the photosynthesis module is
presented as an animated play in eight acts, with the water molecule
anthropomorphized as a tragic hero who sacrifices himself for the good
of the cell. Cellular respiration and the electron transport chain are pre-
sented in a comic book style, complete with a caped crusader: “The Story
of Electron Man.”

“We use what works,” laughs Merrill, who particularly enjoys the
large biomolecules module. “We start each subtopic with a picture of a
nice juicy hamburger with a side of French fries, and then we have
arrows pointing to, say, protein in the meat.”

Once you've got the students' attention, then what? “The student
has to wrestle with the material,” says plant ecologist Diane Ebert-May,
director of Michigan State's Lyman Briggs School—a residential com-
community for students in the natural sciences—and a frequent consult-