Research Horizons

IN THIS ISSUE
- The Gene Detective
- The Fungus Among Us
- Engineering High-Speed Racing Boats
- Success in Artful Robotics
- Flying Boats

Research Horizons

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Lessening the Risk from Major Earthquakes *Page 5*

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Lessening the Earthquake Risk

Civil engineers, structural engineers, seismologists and city planners at Georgia Tech are pursuing programs in prediction, engineering, risk assessment and damage mitigation.
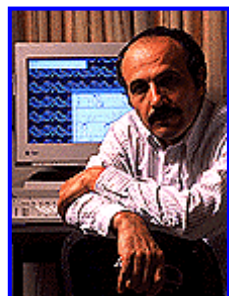
By James E. Kloeppel

The Gene Detective

A computer server at Georgia Tech has helped identify and annotate about 5,500 genes in more than 30 creatures since May 1992.

By Lea McLees

The Fungus Among Us

Researchers believe that Sick Building Syndrome may be triggered in part by the volatile organic compounds given off by mold and fungi.

By James E. Kloeppel

Departments

Research Notes

Diversity on the Web; caring for the elderly ... structures; smart guitars make better sounds; carpet drying using less energy.
Honors and Awards: Tech joins the Field Emission Display Consortium, Walsh and Steffes recognized for outstanding work.

Updates:

- **A look at the advantages of "flying boats."**

- **An autonomous robotic helicopter sails to victory in an annual competition.**

Research Communications Office Page

Research Horizons Welcome Page

Georgia Tech Home Page

GTRI Home Page

Lessening the Earthquake Risk

Georgia Tech research blends many disciplines to find needed solutions

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By James E. Kloeppel

Photography by Stanley Leary

Because of Emir Macari's birth, his family lives. Dr. Macari, a professor in Georgia Tech's School of Civil and Environmental Engineering, was born in Mexico City on July 22, 1957, six days before a major earthquake rocked the city. His family had planned on moving into a larger apartment complex, but delayed their move because the baby was late in arriving.

"It was a good thing, too," says Macari. "The building we were to move into collapsed during the earthquake. We all could have been killed."

Now, Macari wants to help protect the lives of others living in earthquake-prone areas.

He is not alone in his quest. Across the Tech campus, civil engineers, structural engineers, seismologists and city planners are pursuing a number of programs ranging from earthquake prediction and earthquake engineering to risk assessment and damage mitigation. The programs are diverse, but the goals remain the same: to lessen the risk posed by major earthquakes.

Earthquake Hazards Mapping

Dr. Emir Macari (standing) and doctoral student Pedro Arduino view a virtual reality model of cyclic triaxial testing.

Major earthquakes seem to be occurring with more frightening regularity, says Macari ,and they are causing much more damage and loss of life than in the past. A recent quake in Russia, for example, caused billions of dollars in property damage and claimed 2,000 lives. The earthquake that struck Kobe, Japan, early this year, killed more than 5,000, injured more than 26,000, and left some 300,000 homeless. Damage estimates topped $200 billion.

"We can't stop earthquakes from occurring," says Macari, "but we can come up with effective ways of reducing the risk and mitigating the damage.

"Common geotechnical hazards that occur during earthquakes include soil liquefaction, ground motion amplification and landslides," says Macari. "Soil liquefaction occurs when water-saturated, sandy soil is shaken during an earthquake. The intense vibrations disrupt the normal character of the soil, transforming it from a solid to a fluid state. In essence, liquefaction turns the ground into quicksand, causing building foundations lose their footing and sink."

Ground amplification occurs when the surrounding soil goes into resonance, thereby magnifying the intensity of earthquake-induced vibrations. Mexico City offers a classic example.

"Mexico City was buiit on top of an old lake bed," says Macari. "The underlying sediments can be compared to a huge bowl of gelatin. When you shake this 'bowl' at the bottom, the lake bed can resonate, substantially increasing the vibrational amplitude at the surface. So even a small earthquake can have devastating consequences to the buildings located above."

With funding from the National Science Foundation and the U.S. Geological Survey, Dr. J. David Frost, associate professor in the School of Civil and Environmental Engineering, is developing a framework for identifying and mapping geotechnical hazards through the use of Geographic Information System (GIS) technology. Researchers and practitioners using the advanced computer code will be able more accurately to predict where major damage will occur in a given area and make better plans for mitigating it.

Frost's research focuses on the development of a methodology that evaluates geotechnical earthquake hazards spatially using GIS. The impact of these hazards on other geo-referenced information (such as demographics, infrastructures and life lines) is assessed in a spatial environment, in order to mitigate possible consequences. Currently, this methodology is being used to assess the earthquake hazards in various parts of the United States, including Treasure Island, Calif., Evansville, Ind. and Western Puerto Rico.

Frost and colleagues Mike Rowan, a senior research scientist in the Georgia Tech Research Institute, post-doctoral fellow Ronaldo Luna and graduate assistant Tom Rockaway have spent four years linking

GIS, geostatistics and a data visualization software with custom algorithms they wrote to analyze various earthquake hazards.

"We can overlay maps of buildings and roads and see which ones are in areas where we may see liquefaction or amplification during an earthquake," he says. "We also digitized photos of the buildings at several locations and linked them to the map, so users can see which types of buildings are located on potential problem areas."

On top of the maps this data produces, one may superimpose other information such as population centers, transportation networks or even building types and densities. Ultimately, this information will help planning agencies in earthquake-prone areas better assess what types of structures should be built in various locations, and determine which areas should be avoided altogether. The information would also assist emergency response teams in dealing with the aftermath of a disastrous quake.

"This software helps identify where the problems are and where they aren't," Frost continues. "I don't think you can design a completely quake-proof building, but you can certainly design to minimize the impact of an earthquake on structures during and after the event. You can understand the consequences, and then design to minimize the impact."

Measuring Soil Properties

To better forecast the potential effects of ground amplification at a specific site, Dr. Glenn Rix in the School of Civil and Environmental Engineering is developing a non-invasive field method for measuring an important dynamic soil property, damping. The research is being funded by grants from the National Science Foundation and the U.S. Geological Survey.

"For many years, the standard approach to measuring damping involved going out in the field and bringing back a soil sample to test in the lab," says Rix, an associate professor. "In the lab you have tremendous control over the testing, but the act of removing the soil sample from the ground may fundamentally change the very properties you want to measure. Also, you are left with the nagging question of whether this small sample is really representative of a huge site."

Rix uses a small mechanical vibrator to generate miniature seismic waves in the field. A series of receivers -- called geophones -- measure the amplitude of the seismic waves at scattered locations, revealing how quickly the energy is being attenuated.

Structural damage from an earthquake is very dependent upon the nature of the ground below, says Rix. Every soil profile has a particular natural frequency, and will tend to amplify motion in certain frequency ranges. If the natural frequency of the soil column coincides with the natural frequency of the buildings above, the structures may resonate and substantial damage could result.

"When a building resonates, it vibrates with an increasing amplitude until the materials cannot withstand

the force," says Rix. "Then the building likely suffers substantial damage. No structure can withstand resonance for a long period of time."

Dr. Glenn Rix (right) and civil engineering graduate student Wesley Spang use a series of receivers to measure the amplitude of seismic waves generated in the soil by a mechanical device.

The natural frequency of a structure is highly dependent upon its height, says Rix. "Taller buildings will resonate at lower frequencies. By understanding the damping characteristics of the soil profile at a particular site, we can better determine which buildings are at greater risk."

Architects, city planners and structural engineers would know in advance not to build a certain type of building (a 20-story skyscraper, for example) on a given site. If such a building already existed, the information could be used to design some type of retrofit to either strengthen the structure or in some way counteract the effects of an earthquake.

"Given the fact that earthquakes will continue to occur with little or no warning," says Rix, "the question becomes: 'What can we do to mitigate the damage?' In the field of geotechnical earthquake engineering, we are making some progress in terms of being able to identify in advance those sites which will likely experience damage during an earthquake."

(Sidebar on testing Georgia's 14,000 bridges: "A Bridge Over Troubled Waters?")

Earthquake Engineering

On Jan. 17, 1994, the most costly earthquake in U.S. history struck the community of Northridge, Calif. Damage estimates exceeded $20 billion. Fifty-seven people lost their lives, including l6 residents of the three-story Northridge Meadows apartment complex who died when the lower floor collapsed.

"Northridge once again brought home the painful message that we need to improve our building codes," says Dr. Larry Kahn, associate professor of civil engineering.

Kahn is a structural engineer whose major interest is in earthquake engineering: more specifically, in strengthening existing buildings for improved earthquake resistance. In the late 1970s, Kahn explored the rehabilitation of brick-masonry construction. His work, sponsored by the National Science Foundation, helped form the basis of design recommendations for the seismic rehabilitation of unreinforced masonry buildings in the Los Angeles area.

"These recommendations were used in over 8,000 masonry structures within the city of Los Angeles itself," says Kahn, "and most of those buildings survived the Northridge earthquake.... This really showed that even fairly simple techniques can work remarkably well."

To prevent masonry walls from collapsing, Kahn suggests applying a fiber-reinforced coating to the walls. The coating provides a certain amount of ductility, he says. The walls might crack in an earthquake, but they won't fall apart. Another highly useful technique involves securely fastening the walls to the rest of the structure.

"Many masonry walls collapse because they are inadequately connected to the adjoining floors or roofs," says Kahn. "Oftentimes, joists and rafters are simply laid into slots in the masonry and not connected at all. Joist anchors should be used to tie the entire structure together, whether the building is a residence or a warehouse. Such modifications are easy to make and cost very little, but provide a great deal of seismic safety."

Passive Control of Buildings

To protect a modern office building of steel and concrete, more elaborate and expensive techniques must be employed. Proposed methods range from mounting the building on huge rollers or gigantic shock-absorbing pads, to placing active controllers -- which propel immense weights -- in the upper floors.

Aerospace engineering professor Dr. Jim Craig and civil engineering professor Dr. Barry Goodno have a radically different concept. They want to use the building's external facade, or cladding, to dissipate energy in an earthquake and thereby reduce the building motion and resulting damage.

Cladding, which generally consists of heavy panels of precast concrete or stone veneers, typically offers no structural support to a building.

"At the present time, cladding is a purely decorative building enclosure," says Craig. "It just hangs on a building's superstructure like scales on a fish, offering no structural support whatsoever. We want to take this nice-looking architectural treatment and make it do its part in resisting lateral forces."

Craig and Goodno are developing advanced cladding attachments that could be "sacrificed" in a strong earthquake. The novel energy-absorbing cladding connections could provide an effective means of protecting a building's structural integrity and its economic viability.

"The pattern of earthquake-inflicted damage to buildings is strikingly similar," says Goodno. "There's a lateral motion that's almost always accompanied by a twisting component."

This combined motion can crack walls, cause ceilings to fall, disrupt electrical, plumbing, and ventilation systems, or even weaken the structure, leading to collapse. Even if the building remains structurally sound, it may be a total financial loss due to the high costs of repairing all the nonstructural systems.

"Located on the perimeter of the building, the cladding is ideally positioned to help control lateral and twisting motions and absorb energy during an earthquake," says Goodno. "This would reduce damage to both the building structure itself and the non-structural systems. And, since the cladding is on the outside of the building, it is much easier and less expensive to repair than structural members buried deep within the building."

Craig and Goodno have designed, built and tested various types of cladding connectors in the laboratory. Using detailed computer models, they have used their laboratory data to simulate the behavior of advanced cladding systems on typical buildings when subjected to strong earthquakes. They have also measured the actual dynamics of typical real buildings to accurately calibrate their computer models.

"Advanced cladding connections take advantage of the relative movement between the architectural cladding panels and the building structure to dissipate energy and provide additional lateral stiffness," says Craig. "Due to this increased damping, the overall building response can be reduced by 25 percent, and displacements and interstory drifts can be maintained within acceptable limits. And, the advanced cladding connections can be applied to both new and retrofitted buildings."

In related work, Craig and Goodno are working with Dr. Tony Calise in aerospace engineering to develop new "hybrid" methods for controlling a building's earthquake response. The new methods involve the simultaneous use of advanced cladding systems along with the added benefits of robust active control.

"In this case, special devices called actuators would be used to introduce controlled forces into the structure during the earthquake that would counter the seismic-induced forces and thereby reduce the dynamic response," explains Craig. "This would combine the passive nature of the cladding system -- which would always be there, no matter how small or large the earthquake -- with a more robust active control system that would respond only to more severe earthquakes."

Active Bridge Control

Like other major earthquakes, the temblor which struck Loma Prieta, Calif., on Oct. 17, 1989, came without warning. Centered in the Santa Cruz mountains near San Francisco Bay, the earthquake rattled 60,000 fans in Candlestick Park waiting for Game 3 of the World Series and wreaked havoc in the Marina District. Across the bay, huge portions of the upper deck of Interstate 880 were shaken loose and collapsed onto the lower roadway. Forty-three motorists were crushed to death.

In an effort to make bridges and elevated highways more earthquake-resistant, Dr. C.-H. Chuang is applying control theory to the active control of bridge supports. Chuang, an assistant professor in the School of Aerospace Engineering, has investigated control applications in aircraft, spacecraft and flexible space structures. He says modern control theory can be applied to reducing the potentially dangerous vibrations of a 200-ton bridge span.

"Bridge spans are not rigidly fastened to their piers," explains Chuang. "Some freedom of movement is built in to allow for thermal expansion, traffic-induced vibrations and seismic disturbances. But if the motion becomes too large -- like during a major earthquake -- the span can slip off its bearings, endangering motorists and necessitating costly repairs."

To prevent the span from moving too far, actively controlled hydraulic actuators could be installed at the support bearings, says Chuang. "During minor disruptions, the oscillations would passively dampen out by themselves. But during a major earthquake, the actuators would apply appropriate forces to counteract and limit the oscillations, and keep the span from slipping off the bearings."

Chuang has recently completed the computer modeling and simulation for his active bridge controllers. His next step will involve constructing physical models and evaluating their performance on a shaker table.

Danger in the East

During the winter of 1811-1812, three of the largest earthquakes the United States has ever witnessed struck near present-day New Madrid, Mo. The shaking was so severe, massive tree trunks were snapped in two. The quakes toppled chimneys as far away as Savannah and rang church bells in Boston.

"The only reason why nothing is recorded as to what happened in Atlanta," says Larry Kahn, "is that there wasn't any Atlanta at that time. Another New Madrid-type earthquake could occur in the East at any time, and the damage would be devastating. The danger is very real." (See "The Faults in Earthquake Prediction ")

Kahn is a firm advocate for incorporating earthquake-resistant standards into building codes throughout Georgia and the eastern United States -- if not for every structure, then at least for critical structures like schools, hospitals, high-rise buildings and fire and police stations.

Normally, if a building is designed with some thought given to earthquake resistance, it will survive and

a lot of life is protected," says Kahn. "On the other hand, if a structure is designed without regard to earthquakes, there is significant danger of collapse, with huge damage and potential loss of life."

From a civil engineering standpoint, structural engineers are the ones ultimately responsible for public safety, says Kahn. "We are the ones who stamp the drawings and say the buildings are safe. We really need to incorporate more stringent earthquake-resistant standards into our building codes, in order to better protect ourselves from ourselves.

"Perhaps the best statement was made by Professor Vitelmo Bertero, who recently retired from the University of California-Berkeley. Bertero, one of the nation's greatest earthquake engineers, said, 'If we just built buildings the way we know we should, we would have seismic safety in North America.' The problem is, too few building owners are willing to pay the additional cost."

(Sidebar on a new view of quake causation: "The Fault in Earthquake Prediction")

Land Use Planning

Fortunately, risk assessment has improved dramatically over the past 20 years. Elaborate vulnerability models have been developed that can estimate the amount of damage likely to occur in a given area. By knowing in advance the nature and extent of the damage likely to be caused by an earthquake, local planning agencies can develop mitigation policies and plan how to respond to emergencies.

"Since the 1971 San Fernando earthquake, the state of California has required all cities and counties to include seismic safety as a part of their comprehensive planning process," says Dr. Steve French, director of Tech's graduate program in city planning. "The plans should seek to decrease both the amount and the vulnerability of development in the most hazardous areas."

Because the 1994 Northridge earthquake affected many of the same areas that were heavily damaged in the 1971 quake, researchers can now accurately evaluate how effective land use planning has been in mitigating damage. With sponsorship provided by the National Science Foundation, French and his students are working on one such project.

"We have collected the comprehensive plans for 22 jurisdictions in the San Fernando Valley," says French. "We have evaluated those plans on how well they addressed seismic safety. We have also digitized the seismic hazard information out of those plans onto a Geographic Information System, so we have a graphic representation of where the different hazards are located. And, we have plotted the locations of over 100,000 buildings damaged during the Northridge earthquake, along with information concerning when each building was built and the nature and extent of the damage."

The tedious and time-consuming task of data entry is nearly completed, says French, and soon he and his

students will concentrate upon analyzing the data. They anticipate preliminary results in a few months.

"We will be able to look at a community and see how well its plan dealt with seismic hazards," explains French. "Then we will examine how well the plan was actually implemented, in terms of how much development went into hazardous areas. Lastly, we'll take a close look at the resulting damage. This information will help us understand and evaluate how well land use planning in California has worked in terms of a mitigation strategy, and how it might be improved."

Infrastructure Damage Modeling

In another project, French and his students are developing a GIS model that estimates the societal impacts of earthquake-related damage to urban infrastructure. The model links physical components of the water supply system in Memphis, Tenn., with population and economic data from the U.S. Census.

The model, which is being developed through a grant provided by the National Center for Earthquake Engineering, operates at three distinct levels. First, a simulation module allows specific damage to the system to be input. Then, an assessment module presents the impacts of the damage in terms of selected demographic data. And last, a repair module suggests optimal repair strategies.

"All pipes are not created equal," says French. "Some pipes are more important in the configuration of the network and have larger service populations. To decide which pipe should be repaired first, however, the model allows the user to select which particular characteristic of the population should be optimized."

Although the current model deals only with issues related to water supply, a similar approach could be taken with gas lines, electric power distribution, transportation and other elements of a city's infrastructure. Such a method could be used to allocate emergency response resources in the most effective manner and to set priorities for hazard mitigation efforts.

"Infrastructure damage modeling and other types of risk analysis procedures can be applied not only to existing land use patterns, but also to future land use scenarios" says French. "In this way, we can estimate the type and amount of damage that would be associated with alternative land use patterns. This information is extremely valuable in making decisions about the location of new development."

Protect the Life Lines

In today's highly technological society, people and businesses have grown highly dependent upon life lines -- those critical elements of a city's infrastructure which sustain life, society and the local economy. As a result, we have become increasingly susceptible to greater economic damages from natural disasters, says Georgia Tech President Wayne Clough. With a background in Civil Engineering, Clough has pursued research interests in geotechnical engineering, including measuring the liquefaction response of coastal soils. (See "Engineering Georgia Tech's Future" in the Winter 1995 RESEARCH

HORIZONS.)

"It is vitally important to keep our life lines open and operating, or we risk financial ruin," says Clough. "For example, the city of San Francisco was saved from real financial disaster in the days following the Loma Prieta earthquake largely because the Bay Area Rapid Transit (BART) system had survived intact."

When a span on the Oakland Bay Bridge collapsed during the quake, commuter traffic was disrupted for well over a month, he explains. Although many people could not drive to work, they could ride BART.

"The tunnel across the bay had been specifically designed to withstand an earthquake, and escaped unscathed," says Clough. "BART kept running, so the city's commerce kept running."

Another prime example of a critical life line is communications, says Clough. "In the past, news of a major earthquake might have taken weeks to traverse the globe. Today, a business might not survive in a globally competitive market if it loses communications for even a day.

"We are a society now that is much more tightly tied together, and when those knots are loosened -- during a major earthquake, for example -- we are much more susceptible to severe economic loss. That's a natural consequence of this incredible, incredibly connected global society in which we live."

As the recent earthquake in Russia demonstrates, these natural disasters will continue to disrupt both our lives and our livelihoods. Ultimately, the best earthquake hazard mitigation program will consist of a blend of strategies which include accurate hazards mapping, better structural design, tougher building codes, sensible land use planning and appropriate emergency response preparation. Only in these ways will we truly be able to lessen the immense risk posed by major earthquakes.

Further information is available from Lea McLees, Research Communications Office, Georgia Institute of Technology, Atlanta, GA 30332-0828. (Telephone: 404/894-4259) (FAX: 404/894-6983) (E-mail: lea.mclees@gtri.gatech.edu)

R-H Table of Contents

The Gene Detective

## Researcher's work provides new insight into gene identification.

By Lea McLees

Photography by Gary Meek

MARK BORODOVSKY is not a private investigator, but he is a sleuth of sorts. He tracks genes. Molecular biologists from all over the world e-mail DNA sequences to GeneMark, a computer server developed in Dr. Borodovsky's lab. The server helps find genes, specific regions hidden in long strands of DNA molecules, that carry genetic codes for proteins.

"What GeneMark does is very important to the current stage of molecular biology," says Borodovsky, a senior research scientist in the Georgia Institute of Technology's School of Biology. "The goals of many research projects are to sequence entire genomes of particular organisms. For all of these projects, accurate analysis of DNA that shows where genes are is vitally important."

GeneMark was named after the mathematical theory of Markov models that it uses, and the notion of "marking" genes. Since it was estahlished in May 1992, the GeneMark server has helped identify and annotate about 5,500 genes in more than 30 creatures-about half are bacteria such as Escherichia coli, Haemophilus influenzae and Mycoplasma tuberculosis. The others are higher organisms ranging from plants and fruit flies to rodents and primates. GeneMark's development has been supported by a research grant from
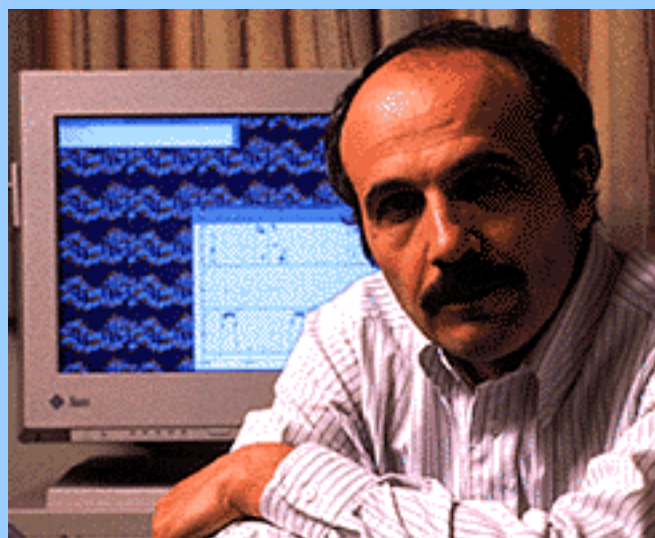
the National Institutes of Health (NIH).

Kenneth Rudd, staff investigator for the National Center for Biotechnology Information (NCBI) at the NIH in Bethesda, Md., says GeneMark is helpful in his work monitoring for accurate annotation of DNA sequences. As part of his ongoing research project, Rudd examines new E. coli sequences for genes that might not have been annotated by their submitters.

Dr. Mark Borodovsky's GeneMark server has helped identify and annotate some 5,500 genes in 30-plus living creatures.

"GeneMark is like giving a pair of new glasses to a nearsighted man," he says. "In my experience, it is superior to other available programs for the detection of new genes, and it allows me to see putative genes as never before."

What Is A Gene?

A gene is the basic unit of inheritance. Each cell in a human body contains about 70,000 of them. The cell molecule that harbors all human genes is called DNA-deoxyribonucleic acid. DNA is an almost infinite double-stranded helix, consisting of innumerable numbers of elementary sections called nucleotides. Four possible types of nucleotides-adenine, thymine, cytosine and guanine-are designated by the letters A, T, C and G.

Genes carry important information that is translated via cell mechanisms into tricky structures of newly synthesized proteins. These proteins are the building blocks of vital substances such as blood, muscle and bones, as well as active agents of any biochemical process in living cells. DNA and proteins predetermine whether a fertilized egg cell will grow into a frog or a woman with black hair.

In humans, abnormal gene functioning is responsible for the development of cancer, sickle cell anemia and cystic fibrosis. Some quite normal genes are expected to be confirmed as the origins of less dramatic characteristics, such as the tendency to go bald.

In the 1980s, with the advent of efficient DNA sequencing technologies recognized later with Nobel prizes, the application of advanced computer technologies to DNA sequence analysis became an important issue for molecular biologists. In the 1990s, gene hunting is very much a computer-aided process. It is still very difficult to identify a specific gene within a formidably long DNA molecule, particularly that of humans-there are 3.5 billion nucleotides in human DNA. In humans, genes must be differentiated from the other 95 percent of a strand of DNA that contains anything but genes: materials such as regulatory codes and other information.

How GeneMark Identifies Genes

GeneMark applies the power of mathematical models to determine whether sequences of the nucleotides A, T, C and G are indeed genes. This sequence, or genetic text, is a string of letters with no spaces-it looks, Borodovsky says, like text perhaps penned by an alien. As soon as a researcher running a sophisticated biochemical experiment identifies a large fragment of DNA text, this fragment can be sent to the GeneMark server via e-mail. The server's core program "reads" and interprets puzzling text based on accumulated knowledge about genes and non-gene sequences already characterized in the species under consideration. The reading process spots sequence characteristics believed to be typical of known real genes.

"Once we set a mark where a gene is, we forward the corresponding part of a sequence to the next step of analysis to discover the function of the encoded protein," Borodovsky explains.

At this step, a nucleotide sequence of the predicted gene is translated according to genetic code rules into a text written in an alphabet of 20 amino acid symbols. This new sequence represents a linear primary structure of a protein molecule. A similar process actually takes place in a living cell, where cellular mechanisms accept the gene sequence and synthesize a protein. The computer now has to compare the new and still mysterious amino acid sequence with sequences from a constantly growing protein database. It was shown by many researchers that proteins having similar functions or common evolutionary origins also have similar primary amino acid sequences-even if these proteins come from different organisms. Therefore, if a significant similarity is found between the new sequence and one with known function stored in the database, it gives a strong indication of the function of a new protein.

Analysis on the protein level is done in close collaboration with the NCBI/NIH. The protein sequence travels through the Internet from the GeneMark server to another server searching for similarities among protein sequences. This server, called BLAST, is installed at NCBI on the same powerful computer which handles the protein sequence database. Since the information about the person investigating the DNA sequence is attached to the protein sequence file, all similar search results are directed by e-mail to the researcher who initiated the analysis and is already busy reading the e-mail message from GeneMark describing the predicted genes.

"In many cases GeneMark predicts that genes will encode for proteins, even with no similarity to any protein in the database," Borodovsky says. These bold predictions will have to wait until someone, perhaps in a remote corner of the world, biochemically characterizes a protein having a similar sequence, and puts it into the protein database.

The GeneMark program produces various types of output for researchers. They can receive a short list indicating the predicted genes by their boundary positions; a file containing nucleotide sequences of predicted genes; or translated amino acid sequences of putative proteins. GeneMark also can output a file a researcher can print out as an easy, readable profile of a DNA text, indicating by gray bars the regions where the protein coding properties are most pronounced and which are, therefore, the predicted genes.

"Since GeneMark has a success rate of 93 to 97 percent in predicting genes, it is often cited as a sequence annotation tool," Borodovsky says. GeneMark is different from many genetics servers in that it is able to work with more than 30 different species. Preparing initial information for GeneMark requires little work, and does not use much computer time.

Nucleotide sequences needing identification have been sent to GeneMark from regular users in countries around the world, including Australia, Korea, Spain and Venezuela. Some researchers, such as Antonio Covacci of Italy, staff scientist at a pharmaceutical company, travel to the United States to learn in detail how to apply GeneMark analysis to bacteria such as Heliobacter pilori, which causes peptic ulcers in humans. Another recent visitor, Pierre Rouze of Belgium, was interested in applying GeneMark's analysis to the DNA of a plant called Arabidopsis thaliana, a model organism for studying plant genetics.

Borodovsky has been an invited speaker at major conferences on DNA sequence analysis in the United States, Canada, France, Japan and Israel. More than 20 copies of GeneMark's programs have been distributed to major research centers in Canada, France, Germany, Israel, Japan, South Africa, the United Kingdom and the United States. For his recent work with Eugene Koonin and Kenn Rudd of NCBI on the discovery of more than 350 previously unnoticed genes in E. coli DNA, Borodovsky won the 1995 Sigma Xi Georgia Tech Faculty Best Paper Award.

Tracking Genes

Computer analysis is particularly helpful on genetics projects because of the almost infinite possibilities for alternative interpretation of DNA sequences. "This task is better performed by a computer than a human because the computer can much more easily read and understand the language of DNA," Borodovsky says.

He credits two graduate students for their work on the project.

"I am lucky to have gifted and hardworking assistants," Borodovsky says of James McInich and William Hayes. McInich, who has a bachelor's degree in biology, was looking for an area in which to apply his exceptional knowledge of computers. Hayes, who holds a bachelor's degree in aerospace engineering, decided to apply his interdisciplinary expertise in a biology doctoral program. Both are excited about opportunities GeneMark is providing the scientific community, as well as the potential for further strengthening its analytical functions.

The cell biology community already has sequenced several genomes of the most simple creatures-many bacteriophages, viruses that cannot function outside bacterial cells. The genome of E. coli is about 70 percent sequenced, and the genome of Heliobacter pylori is almost complete.

Could GeneMark be used to identify and catalog human genes?

"One of the most interesting issues is using GeneMark for predicting genes in human DNA," Borodvsky says. "For humans, as well as for other higher organisms, gene analysis is complicated. The structure of human genes is different from the structure of bacterial genes. Quite often within a human DNA, you have a gene divided into many pieces with non-coding sequence fragments, or introns, between them. With bacteria, non-coding sections only appear between genes."

Borodovsky has collaborated with several research groups at a variety of institutions, including Emory University and Georgia State University in Atlanta; the University of Minnesota and the University of Wisconsin-Madison; the Institute Pasteur in France; Kobe University in Japan; the Weizmann Institute in Israel; Free University in Germany; and The Institute for Genomic Research (TIGR) in Maryland. TIGR has presented the first fully sequenced bacterial genome, Haemophilus influenzae, to the scientific community. Researchers there asked Borodovsky to provide a GeneMark program, which they used for gene annotation in a newly sequenced DNA strand of 2.4 million nucleotides.

"We have a clear feeling that we are on the cutting edge," says Borodovsky.

Further information is available from Dr. Mark Borodovsky, School of Biology, Georgia Institute of Technology;, Atlanta, GA 30332-0230. (Telephone: 404/894-8432) (E-mail: mark.borodovsky@biology.gatech.edu)

 Table of Contents

The Fungus Among Us

Microbes, not materials, may produce irritating emissions in buildings

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By James E. Kloeppel

In the past few years, "Sick Building Syndrome" has been blamed on a variety of causes, from particle board partitions to paints, from carpets to cleaning supplies. Recent research funded by a seed grant from the Georgia Environmental Technology Consortium, a division of the Georgia Research Alliance, indicates that these may be blamed when they are not the primary culprits, however.

The obnoxious emissions that congest our lungs and irritate our eyes may be coming from microbial infestations lurking in the floor beneath us, in the walls around us, and in the ceiling above us. Our buildings may be sicker than we thought.

Dr. Charlene Bayer, principal research scientist and director of Tech's Indoor Environment Research Program, and biologist Sidney Crow at Georgia State University have investigated a number of "sick" buildings. They believe that many of the indoor problems found in the Southeastern United States are caused by volatile organic compounds (VOCs) given off by molds and fungi.

Dr. Charlene Bayer of Georgia Tech Research Institute (shown) and biologist Sidney Crow of Georgia State University gather fungi from from buildings afflicted with microbial contamination, grow samples of the microbes, then identify the VOCs released. Their work will lead to healthier workplaces.

"As molds and fungi grow, they give off metabolic gases that contain VOC emissions," says Bayer. "Some of the volatile compounds that we are finding are primary solvents, and we think some of the manufacturers are being blamed for emissions from their products when the emissions may actually he coming from the microbes. Because the VOCs have usually been attributed to other types of sources, the source control may be incorrect."

Bayer and Crow collected fungi samples from a number of buildings that were afflicted with microbial contamination. The samples were allowed to grow in the laboratory, and the VOCs released from the microbial broths were collected and identified. These VOCs were then compared to those detected in the ambient air within the buildings.

"Many of the volatile compounds produced by the cultured fungi are identical to those originating from solvent-based building materials and cleaning supplies," says Bayer. "These VOCs included hexane, methylene chloride, benzene and acetone."

The microbial VOCs may contribute heavily to the overall level of ambient VOCs in buildings, says Bayer. In one building the researchers investigated, for example, the microbial contamination was clearly evident on the walls, the carpets and other locations.

"The concentration of hexane-a solvent commonly used in cleaning fluids, paints and adhesives-was extremely high," says Bayer, "but no source of the hexane could be found. The microbiological contamination could have been the source of the hexane."

Lessening the Risk

Cladosporium, Penicillium and *Aspergillus* are among the host of commonly occurring microbes that can infest our homes, schools and offices. Usually, the first indication of their presence is a foul, musty odor. When growth runs rampant, then the headaches, itchy eyes, rashes and respiratory problems begin.

Conditions favorable for microbial growth include heat and moisture, says Bayer. In the Southeast, with its semi-tropical climate and high humidity, buildings are prime targets for microbial contamination.

Molds and fungi are not particular about what they eat. They will happily devour just about any organic material, including the dirt and dust trapped within our ventilation systems.

What can be done to lessen the risk of microbial contamination? First of all, you can look for ways to reduce the necessary nutrient base. "Under ideal conditions, a building's ventilation system should filter out both the microbes and the dirt they feed upon," says Bayer, "Unfortunately, however, many homes, schools and small office buildings use cheap, throwaway filters in their ventilation systems." Cheap furnace filters are merely "boulder catchers," says Bayer. "They only catch the big stuff-they don't catch the fine dust particles and they don't catch the microbes. So, they really don't do anything to help human health."

Bayer's advice: simply throw away the cheap filters and replace them with higher quality, albeit more expensive, filters.

But, the bigger the building, the bigger the problems with ventilation systems become.

In larger office buildings, fiberglass-lined ductwork is often used for noise control, says Bayer. The fibers tend to trap a lot of dirt, and that provides a rich nutrient base for microbes.

"Add a little moisture, and you have a mold garden growing in your ductwork," says Bayer. "The microbes grow and multiply, and then get blown all over the building to infest other areas."

Moisture control is extremely important in preventing microbial contamination, says Bayer. When the humidity goes up, microbial growth can skyrocket.

"Many buildings erected in the Southeast simply were not designed to handle the heavy humidity loads we have, particularly during our hot, muggy summers," says Bayer. "And most building owners don't run their ventilation systems continuously."

Schools typically turn their systems off during the summer months (the prime time of year for microbial growth), and most office buildings cycle their systems over nights and weekends, often resulting in an unpleasant "Monday morning cocktail" for the workers. Such intermittent operation allows the humidity to increase and the molds to multiply.

Preventive maintenance involves proper filtration, correct moisture control, and periodic cleaning of the entire ventilation system--including the humidifier assembly on residental furnaces.

"Typical reservoir humidifiers are little mold factories," says Bayer. "They are just pools of standing, stagnant water throughout much of the year that allow mold to grow and infiltrate the ducts. They should be cleaned regularly."

Future Work

A great deal of research remains to be done, including identifying individual metabolic gases and their respective odors, and acquiring a better understanding of the microbes that are producing them. Once a knowledge base is developed in these areas, the human response to molds and fungi and the sources of complaints in buildings can be better understood.

"Ultimately, we want to identify the microbial contamination on the basis of the odors which are present," says Bayer. "That way, we will be able to identify the source much more quickly and accurately, and deal with the problem faster and more effectively... before it becomes a major problem requiring expensive remediation."

Further information is available from Dr. Charlene Bayer, Georgia Tech Research Institute, Electro-Optics, Environment and Materials Laboratory, Georgia Institute of Technology, Atlanta, GA 30332-0820. (Telephone: 404/894-3825) (E-mail: charlene. hayer@gtri.gatech.edu)

[R-H] Table of Contents

Send all questions and comments to Webmaster@gtri.gatech.edu

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RESEARCH NOTES

The World Wide Web: User Population More Diverse

Data collected this spring from more than 13,000 users of the World Wide Web suggests commercial online services are significantly broadening the population using this rapidly growing part of the Information Superhighway. The work is believed to be the first to examine the impact of Web access provided through major national services such as Prodigy.

Web access offered by the large national services and expansion of local Internet service providers is helping change the age, gender, income, occupation and other demographics of Web users. Though African-Americans remain poorly represented, the research suggests more women are now entering the traditionally male-dominated computer network.
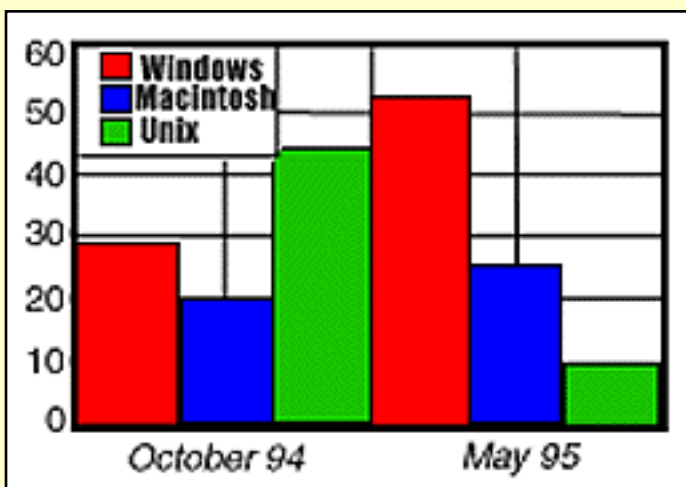
"The respondents we are seeing now are less technically-oriented and more likely to be female than those we have seen in the past," said James E. Pitkow, a College of Computing researcher who has been studying demographic trends on the Web for more than a year. "Overall, there are more people coming from outside the educational domain. This shows that the people browsing the Web are becoming more like the general population."

Another key finding: Since similar research was conducted in October 1994, Windows has replaced Unix as the predominant computer operating system for those browsing the Web.

The information was gathered from questionnaires posted on the Web from April 10 to May 10. At the time the questionnaires were posted, only Prodigy had made its Web browser software widely available,

and approximately 20 percent of those answering the questions entered the Web through that service. The researchers advertised the questionnaire on Prodigy, and in other Internet locations and popular sites on the Web.

"We found that Prodigy brings both a younger population and an older population, compared to the typical Internet user," Pitkow explained. "The service brings a larger population in the K-12 age, as well as more older and professional people."

Results are available on the Web at [http://www.cc.gatech.edu/gvu/user_surveys/ survey-04-1995](http://www.cc.gatech.edu/gvu/user_surveys/survey-04-1995). Further information is available from James Pitkow, College of Computing, Georgia Institute of Technology, Atlanta, GA. 30332-0280. (E-mail: pitkow@cc.gatech.edu)

Georgia Tech a Member of Field Emission Display Consortium

Georgia Tech is one of six members of the Field Emission Display Consortium working to develop next-generation field emission display technology. The consortium, led by Texas Instruments, Inc. of Dallas and Raytheon Co. of Lexington, Mass., also includes EG&G Power Systems of Covina, Calif; Lockheed Sanders, Inc., of Nashua, N.H.; and MRS Technology, Inc., of Chelmsford, Mass.

Field emission displays, a newly developed display technology, are suited for applications ranging from miniature displays for cockpit instrumentation to laptop or desktop computer displays. Field emission displays are expected to provide greater power efficiency, wider viewing angles and operating temperature ranges, and lower manufacturing costs compared to today's standard active matrix liquid crystal displays.

Consortium researchers will:

- develop improved electronics and packaging technology needed to realize the performance benefits described above

- improve manufacturing technology, resulting in lower cost, higher yield fabrication

- produce a unique, high-brightness display architecture for cockpit displays

The consortium recently received funding from the Defense Advanced Research Projects Agency (DARPA), and will also receive support from the Georgia Research Alliance and industry.

Further information is available from:

● **Rich Combes, Electro-Optics, Environment and Materials Lab, Georgia Tech Research Institute, Atlanta, GA 30332-0834. (Telephone: 404/894-4261) (E- mail: rich.combes@gtri.gatech.edu)**

● **Dr. Chris Summers, Phosphor Technology Center of Excellence, Georgia Tech Research Institute, Atlanta, GA 30332-0861. (Telephone 404/894-3420) (E-mail: chris.summers@gtri.gatech.edu)**

"Smart" Guitars Improve Acoustic Performance

You've heard of smart highways, smart cars, smart homes and even smart credit cards. Now aerospace engineers at the Georgia Institute of Technology want to bring you smart guitars.

If they are successful, musicians could one day use "smart structures" built into inexpensive acoustic guitars to create sound as rich as that produced by high quality instruments costing thousands of dollars. The smart structures -- material systems with the ability to change their mechanical properties -- also would provide a better method for customizing guitars and tuning them for different performance halls.

Dr. Sathya Hanagud and other Georgia Tech researchers use smart structures for simplifying helicopter control systems and reducing harmful vibration in complex structures. In the guitar, they use similar sensors, electronic controllers and piezoelectric actuators to alter the manner in which the guitar's wooden components vibrate.

In good guitars, the second mode doesn't have much damping, says doctoral student Steve Griffin. "We realized that if we could reduce the damping in a bad guitar, we could perhaps make it sound like a good guitar," he adds.

Researchers Steve Griffin (right) and Sathya Hanagud

Griffin used a model of guitar acoustics he developed to make a smart structure system duplicating the amount of damping built into expensive guitars. Using a sensor, simple electronic controller and a small piece of piezoelectric actuator, he tested a prototype control system on a crude single-string cookie tin

guitar. Griffin then developed a full-fledged control system for a $200 guitar, which noticeably improves the sound of the chords he plays.

Though they have demonstrated the principle, Hanagud and Griffin say they have a long way to go before musicians will get their fingers on the strings of a smart guitar. The next step will be improving stability of the electronic controller, which Griffin built for approximately $20. The control scheme also must also be fine enough for precise control by musicians.

Patent protection has been sought for the technique through Georgia Tech's Office of Technology Licensing.

Further information is available from Dr. Sathya Hanagud, School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0150. (Telephone: 404/894-3040) (E-mail: sathyanaraya.hanagud@aero.gatech.edu

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Caring For Special Structures

Deciding how to evaluate, repair or rehabilitate older and/or historic buildings can be difficult for their owners, who often lack information about resources, treatment materials and techniques.

Georgia Tech's Center for Public Buildings helps owners and managers make better maintenance and preservation decisions. The center develops standardized and automated methods for evaluating older buildings, or archaic building materials. It has produced several PC-based applications for national programs of building evaluation, and created the first expert system in the historic preservation field. The center provides a full range of assistance and information on addressing the challenges of preserving these special structures.

The center's research is supported by government and private sponsors. It works with groups including the U.S. Department of the Interior, the U.S. General Services Administration, the National Park Service and the U.S. Army Corps of Engineers. The center also participates in the leadership of several national historic preservation organizations.

Further information is available from center director John Myers, Center for Public Buildings, Georgia Institute of Technology, Atlanta, GA 30332-0157. (Telephone: 404/894-3390) (E-mail: john.myers @edi.gatech.edu)

Reducing Energy Consumption in Carpet Drying

Carpet's feet-friendly fibers could become even friendlier to the environment with the application of Georgia Tech's studies of carpet drying during manufacturing.

Researchers from the School of Textile and Fiber Engineering, School of Mechanical Engineering, and Institute of Paper Science and Technology are studying the drying process with funding from the National Textile Center and the National Science Foundation. Computer models of the process will be developed and used to optimize drying technologies and methods.

"If we can establish where the water is, and how it moves in the carpet, we will be in a position to devise techniques to remove the water faster and more efficiently," says associate professor Wallace Carr. "This could make cost and energy savings possible."

Carpet gets wet when it is immersed in dyeing and finishing (e.g. stain blocker) solutions. Most carpet is dried as it moves through large, natural-gas heated drying ovens that can measure about 15 x 60 feet.

Researchers will identify the distribution of water in wet textiles and how that moisture leaves carpet using Nuclear Magnetic Resonance imaging (NMR) -- the same Magnetic Resonance Imaging (MRI) technology used in medical applications. They will test their model's validity using a laboratory drying system that closely simulates industrial moisture removal processes.

Other potential applications include the development of improved baby diapers and the enhancement of moisture management in engineered footware for athletes.

Further information is available from Wallace Carr or Haskell Beckham, School of Textile and Fiber Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0295. (Telephone: 404/894-2538, Carr; 404/894-4198, Beckham) (E-mail: wallace.carr@tfe. gatech.edu, haskell.beckham@textiles.gatech.edu)

Walsh Named ASTM Fellow

A Georgia Tech Research Institute (GTRI) employee has been honored with a 1995 American Society for Testing and Materials (ASTM) Award of Merit, and also was made a Fellow of that organization.

Jim Walsh, director of Georgia Tech's Waste Reduction and Environmental Compliance Program, was among 20 ASTM members presented the award and title this year. He was recognized for "distinguished service and outstanding participation in ASTM technical committee activities," according to ASTM Standardization News. Walsh was nominated by an ASTM committee on biotechnology and biomass, and was selected by ASTM's board of directors. ASTM has about 35,000 members.

Among Walsh's accomplishments are developing standards for biomass testing that make it possible to characterize biomass just as one does coal. He also helped devise guidelines for alcohol that can be mixed with gasoline, and has contributed to standard development for manufacturing the latest anaerobic digesters used in waste treatment.

Walsh holds bachelor's and master's degrees in aerospace engineering from Georgia Tech, and a master's degree in systems management from the University of Southern California. He is also a registered professional engineer. Before coming to Georgia Tech, he worked for EBASCO Services and served in the U.S. Air Force. Walsh's work covers waste handling, treatment, minimization and recycling, as well as pollution prevention. He also researches the design and analysis of advanced pollution control systems for food processing wastes and biomass energy systems.

Walsh's future goals include contributing to and implementing ISO 14000 standards for environmental management systems. Similar to ISO 9000, the 14000 rules set standards companies must meet to trade with the European Community and other countries. But the 14000 standards relate to environmental safety and health compliance, while the 9000 standards govern quality programs.

The ISO 14000 standards may level the playing field for the United States when it competes with companies that supply cheap labor, Walsh noted. He and GTRI colleagues Paul Schlumper and Roc Tschirhart are finding ways to help industries audit their own compliance -- they are working on a project with the Georgia Manufacturing Extension Alliance (GMEA) through Georgia Tech's Economic Development Institute.

Steffes Wins Prestigious IEEE Resnik Award

A researcher in the School of Electrical and Computer Engineering has been honored with the Judith A.

Resnik Award by the Institute of Electrical and Electronics Engineers (IEEE), in recognition of his work in space engineering.

Dr. Paul Steffes was recognized for "contributions to an understanding of the Venus atmosphere through innovative microwave measurements." For more than a decade, his work in planetary atmospheres has been a major focus of his academic career. Steffes' research has concentrated on laboratory measurements of the microwave absorptive and refractive properties of the simulated atmospheres of Venus and the outer planets.

Most recently Steffes and his former student, Dr. Jon M. Jenkins of the SETI Institute/NASA Ames Research Center, conducted the Magellan Radio Occultation Experiments, using the spacecraft's microwave telecommunications system for measuring the Venus atmosphere.

Steffes has also made contributions in studying satellite interference location and noninvasive monitoring of blood glucose levels for diabetics. He is director of Georgia Tech's Satellite Earth Station, which plays a vital role in continuing education, and he founded the Radio Astronomy and Propagation Laboratory, where the atmosphere of any planet in the solar system can be simulated and microwave properties measured.

Established by the IEEE Board of Directors in 1986, the Judith A. Resnik Award recognizes an electrical engineer for contributions to space engineering and is one of the Society's major field service awards. The award is named in honor of IEEE member Judith Resnik, who was a mission specialist on the NASA Space Shuttle Challenger, which exploded on January 28, 1986. Dr. Resnik was a biomedical engineer and staff Fellow with the National Institutes of Health when she was selected by NASA in 1978 to join the space program.

-- Compiled by: Lea McLees, Jackie Nemeth, John Toon

 Table of Contents