CenterPiece

A Quarterly Publication Featuring Achievements from Northwestern University Research Centers

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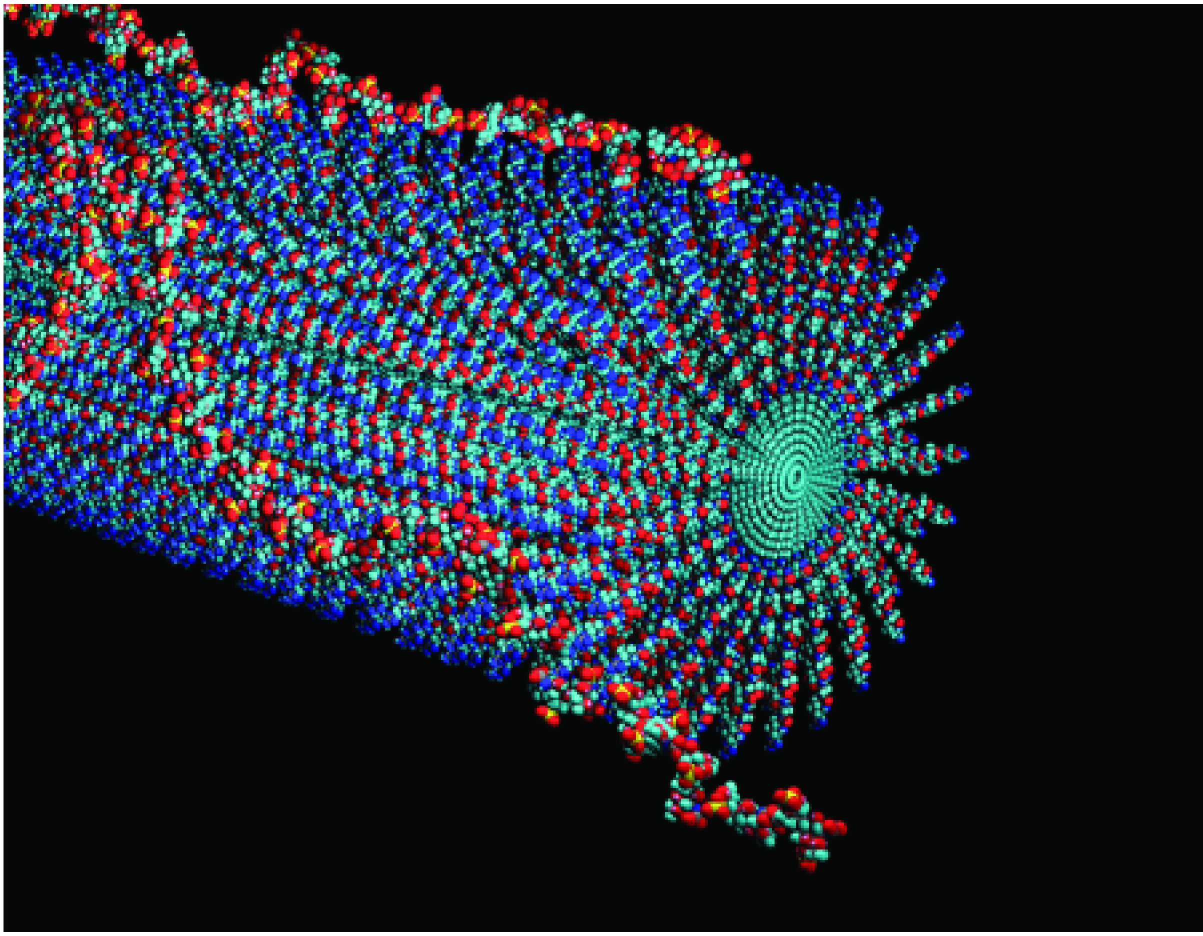
IN THIS ISSUE



This schematic image represents a chain of heparin (red) wrapped around a nanofiber (blue) made up of the peptide amphiphile molecules. The diameter of each fiber is about 6–7.5 nm. Reprinted with permission from *Nano Letters*, DOI:10.1021/n10613555. ©2006 American Chemical Society.

Nanostructure Scaffolding Promotes Blood Vessel Growth

Researchers at Northwestern have developed a new strategy to repair blood vessels by using nanofiber scaffolding to stimulate new growth. Samuel I. Stupp, materials science and engineering, chemistry, and medicine, and his colleagues Kanya Rajangam, biomedical engineering; Heather A. Behanna, chemistry; Michael J. Hui, biomedical engineering; Xiaoqiang Han, pathology; James F. Hulvat, Institute for Bionanotechnology in Medicine; and Jon W. Lomasney, pathology, developed the system that could become an important tool in regenerative medicine where new blood vessel formation is critical for healing wounds.

The delivery of angiogenic growth factors — proteins that promote blood vessel growth, is — essential for wound healing. Attaching these growth factors to a polymer matrix that has been coated with heparin, an anticoagulant, will encourage their release. The findings suggest that the defined shape and structure of the nanostructures could be contributing to optimal presentation of heparin for growth factor interaction and binding.

—see Scaffolding, continued on page 7

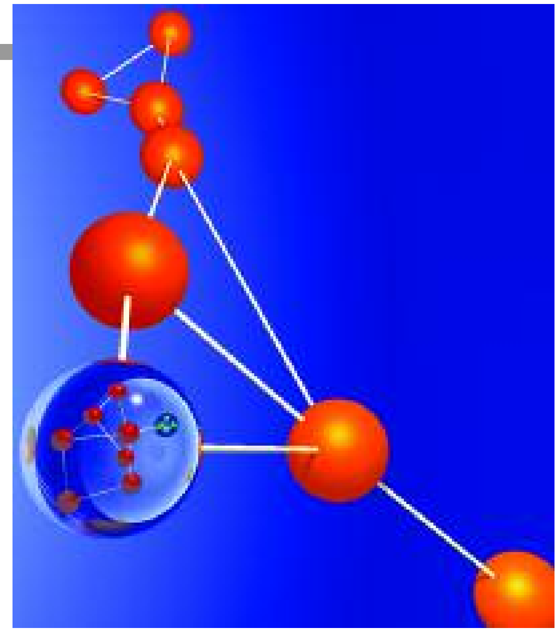
CENTERPIECE Q & A

Luis Amaral

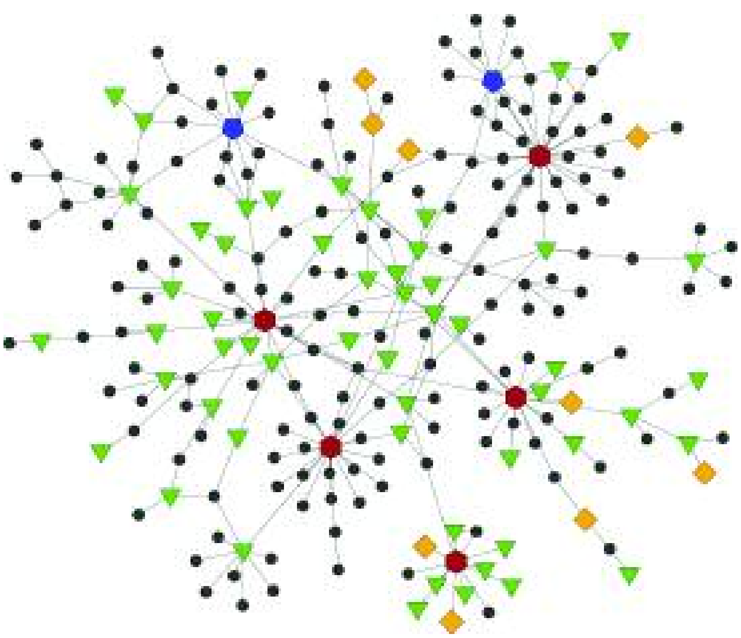
This past summer, Luis Amaral learned that he was one of five researchers in the nation to be named Distinguished Young Scholar in Medical Research by the W. M. Keck Foundation. This prestigious honor includes an award — up to $1 million over five years — paid to the institution to support the scholar's work.

Amaral, chemical and biological engineering, and a member of the Northwestern Institute on Complex Systems, is a physicist with expertise in computer-based modeling.

He sat down with *CenterPiece* to discuss the award and his work.



Network representation of the hierarchical organization of an electronic circuit. At the lowest level, green nodes represent transistors, which are organized into logic gates (red nodes), which in turn are organized into flip-flops (orange) [Sales-Pardo, Guimera, Moreira, and Amaral].



A module of the Internet. Each node represents an internet provider and each link represents a physical connection between providers. Different symbols indicate providers with distinct roles. Networks with different functions have unique patterns of connections between roles [Guimera, Sales-Pardo, and Amaral].

What does the Keck award mean to you as a researcher?

It's a very prestigious award and it's a fair amount of money. Strangely enough, the biggest feeling that I had when I received it was relief. The funding situation is hard nowadays, and I do very interdisciplinary research, which means that people in particular fields are not that aware of me. Each person only knows a "slice of me," and it's harder to get recognition when you do that sort of work. This money arrived at just the right time — if it hadn't arrived, my number one priority would definitely be getting funded. Now, I'll be able to pay salaries and I can do research, which is much more fun.

It was also a good feeling in terms of recognition for a research direction that I initiated — I think that's very important. You have to believe in what you are doing. Sometimes you have to believe even when other people don't believe. When someone else believes, it is always a good feeling. So it was very good to get the sense that others think this is very cool.

Can you talk a little bit more about that research direction?

Everybody agrees that we are in the middle of a revolution in biology. We can measure what's going on with thousands of genes. And we can learn how many proteins exist in a cell and what's going on with them. It's sort of amazing. Because I'm Portuguese, the closest analogy for me is like being a navigator in the 14th or 15th century and trying to find new continents. There is all this wealth of new information. What are we going to do with it?

The reason this is such a crucial question is that the human brain has evolved to handle a small number of pieces of information: three or four things you can organize, manage, link. But when we have a thousand or more pieces we cannot handle them — we have to start grouping them, arranging them. So right now, having thousands of pieces of information is not really useful.

This is where mapmaking comes in. What I want to do is develop cartographic methods that take information and develop real maps — such as those in Google Maps — where you can zoom in and out and find out what is important at each zooming scale. When you plot off this map, it means that you understand what is going on. And if you don't understand it, you cannot understand what you do. That's the stage where our knowledge is. We have all the information about systems; we just don't have a good understanding of how they are organized.

Is your work going to be with proteins in a cell, or is that just one example?

It's one example. The maps themselves are mathematical, they are abstract. Essentially what you are dealing with is a graph, and a graph is two kinds of objects — something called edges, and something called nodes.

Edges and nodes are mathematical entities. The edges are the "lines" connecting some of the nodes. A node could be anything: a protein, a gene, a person, or even a university. The interaction could be that these two proteins regulate this gene, or this person is a friend or business partner of another. You can abstract what the edge means and what the node is and look at it as a network.

Once you map something, do you take it any further or do you put it in the hands of someone who uses it in a different way?

We are very much at the beginning. It's not as if we solved the problem. We've made some advances. If the only information you have is that one thing interacts with some others, how are you going to decide whether it is important or not? We developed a method that is able to make that decision for you. In this aspect of cartography, we have made a lot of progress. You never want to say that a problem is solved, but that part is sort of solved.

I'm not so interested in actually using these maps. I really want to put them out there just as Google puts the maps out there.

One of the ways maps can be used is, for instance, when you are developing new drugs. One of the challenges in that process is discovering what side effects the drugs create. The only way to find out is to try it out on something or someone. Researchers do not have a global picture of everything that happens to a system because of the new drug; they are looking at a very small portion. But all of these things are connected. How do you know where the ramifications extend? If you have a global picture of that particular system, you can better assess where the repercussions will extend. People cannot model all of the interactions, so they select a portion of the system to look at. But they are disconnecting — they are pulling something out that cannot be pulled out. They need to find a way to make a mental picture of the whole system, to select a small enough number of elements for which they can then visualize what the effect of the change is going to be.

One of my hopes for mapping is that it can make drug discovery more efficient, because you can select your target more intelligently. That would be one of the goals, if we are thinking on the biological side. But as I said, the method could be used in many contexts.

Does your award put Northwestern on the map for interdisciplinary study?

I think we are already on the map. Interdisciplinary study is something that is part of the self-image of Northwestern. We know from *The Highest Order of Excellence* that the administration feels strongly about interdisciplinary study. It's something many of us — my colleagues and I — think is a good image to convey to the world outside. It is something we feel very strongly about and something we enjoy.

For example, I don't think there is any other place in the nation or in the world where there is such a strong connection between the business school and the engineering school. It's very, very unusual. I have several collaborators in the Kellogg School of Management: Daniel Diermeier [managerial economics and decision sciences] and Brian Uzzi [management and organizations] and now we are doing something with Scott Stern [management and strategy]. New knowledge seems to be created by pulling together information from areas that used to be apart.

"NEW KNOWLEDGE SEEMS TO BE CREATED BY PULLING TOGETHER INFORMATION FROM AREAS THAT USED TO BE APART."

It is not enough to have knowledge out there in the scientific literature. In a scientific paper there are lots of things that the authors don't explain. There is lots of know-how from the

—see Amaral, continued on page 6

Interdisciplinary Center Examines How New Technologies Intersect with Human Behavior

The Center for Technology and Social Behavior is opening on campus this fall to gather researchers across disciplines (including anthropology, history, learning sciences, mechanical engineering, psychology, sociology, and computer science, among others) to study how we understand and use new communication technologies. Justine Cassell, communications studies and electrical engineering and computer science, directs the center.

Questions concerning the social and cultural context of the production and use of technology form the focus of research carried out at the Center. These studies also support a new joint PhD program in Technology and Social Behavior offered by the School of Communication and the Robert R. McCormick School of Engineering and Applied Science, giving students a range of methodologies to allow them to understand technological developments in their broadest possible contexts.

Cassell's own research focuses on the premise that technologies work the way they do because they are created by and for human beings. One of her research tools is Sam, a virtual child that interacts with real children to help them learn. Sam is used in working with children with autism, among others, to help them acquire skills in reciprocal social interaction. "Kids immediately understand what this is all about and are drawn to it," says Cassell.

Children interact and play with Sam at the Center for Technology and Social Behavior.

Justine Cassell, director, Center for Technology and Social Behavior

Cassell has received a good bit of media attention from her work with the Junior Summit, an international online community of young people that she and former Massachusetts Institute of Technology colleagues started in 1998. They studied the community to delve into questions about friendship, the development of communities, and civic leadership skills. "What parents have to understand about teenagers' use of the Internet is that it's like they've moved from Iowa to New York City," she says, "It's a new space, and those who go there need to be educated about how to handle it."

Cassell is also working with industries that develop new devices like phones and web pages and intelligent cars that interact with their users to create "embodied conversational agents" that communicate more like humans than machines. "This is a hot area with lots of opportunity," remarks Cassell.

Other faculty who will participate in the activities of the new center include Darren Gergle, communication studies, who recently arrived from Carnegie Mellon University, and will teach courses on computer-mediated communication, and human-computer interaction; Eszter Hargittai, communication studies and sociology, who researches social inequities and the Internet; Jennifer Light, communications studies, history, and sociology, who studies the relationship between information technology and urban life; Louis Gomez, learning sciences and electrical engineering and computer science, who carries out research on technology and school reform; and Ian Horswill and Bryan Pardo, both electrical engineering and computer science, who research interactive entertainment technologies, such as video games and interfaces to musical databases.

The center expects to receive funding from a number of federal agencies, industries, and private foundations.

THE ART OF TEACHING: Revealing Mysteries of the Past

One of the many ways Northwestern provides outreach to the surrounding community is to offer summer programs for local teachers. Lisa Backus, chemistry teacher at Deerfield High School, participated in the Materials Research Experience for Teachers Program at Northwestern's Materials Research Center this past summer and gained hands-on experience with ancient and modern works of art to determine their underlying physical properties. The program also involved the creation of a curriculum for high school students based on her summer research projects.

Left: Anonymous, Chinese, kneeling figure, Shang Dynasty (c. 1600–c. 1045 BCE), 13th–11th century BCE. Chlorite, 19.5 x 8.8 cm. The Art Institute of Chicago: Edward and Louise B. Sonnenschein Collection (AIC 1950.671). Photography © The Art Institute of Chicago.
Right: The sculpture is being prepared for environmental scanning electron microscopy.

Backus worked with Katherine Faber, materials science and engineering, and Francesca Casadio, a conservation scientist at the Art Institute of Chicago, to examine the properties of sculptures and paintings to determine their fabrication technology and to devise conservation methods. Her projects included research on an ancient Chinese kneeling figure and several watercolors by 19th century American artist Winslow Homer.

"One important thing I learned is how closely art and science are integrated," said Backus. "To answer questions regarding famous artworks, the Art Institute of Chicago routinely turns to its Department of Conservation Science, and when scientists confront problems in nanofabrication technologies, often they turn to art techniques, such as patterning and solarization, to provide answers."

Backus' first project was to explore why the stone kneeling figure was unusually blackish-green, unlike similar figures recently excavated in China that are lighter in color and rougher in texture. She performed instrumental analyses using X-ray diffraction and Fourier-transform infrared spectroscopy on heated specimens of chlorite, the same stone the sculpture is made of, in order to support visual observations with data on structural changes taking place within the stone. The measurements indicated that the figure's material basis, clinochlore, undergoes dehydroxylation upon heating, turning the minerals into oxides and changing the stone's color from greenish-blue to dark black to a bronze hue depending on the temperature.

For her second project, Backus examined watercolors by Winslow Homer. The Art Institute is analyzing the paintings to more fully understand Homer's use of color in advance of a Homer exhibit in 2008. She used X-ray fluorescence spectroscopy to non-destructively determine the elemental composition of the pigments. The museum is conducting a thorough study of the artist's pigments with the goals of deciding on preferred conservation techniques, identifying pigments that have changed in color with time, and dating previously undated works.

Backus brings these experiences back to her chemistry classroom this fall when she will add a new unit on the art of science and the science of art. Students will work in inquiry laboratories creating their own procedures to solve materials problems. One of their projects will be to identify pigments using a live Internet connection to a scanning electron microscope with an energy dispersive X-ray analyzer at Iowa State University. This will provide elemental fingerprinting of the pigments — a process similar to that Backus used on the Art Institute's Homer watercolors. ▮

Change in MRC Management

Monica Olvera de la Cruz, materials science and engineering, is the new director of the Materials Research Center (MRC), replacing **John Torkelson**, chemical and biological engineering. Materials science as an interdisciplinary field was pioneered at Northwestern. MRC, which opened in 1960, offers programs in research, education, industrial collaboration, information dissemination, and technology transfer.

Olvera de la Cruz's research interests are in the statistical mechanics of macromolecules, including self-assembly of biomolecules. She has been involved in various MRC educational programs and serves as director of the Center's Research Experience for Undergraduates.

Among Torkelson's many contributions to MRC was the successful renewal of its materials research science and engineering center funding from the National Science Foundation. His current research focuses on glass-forming polymer systems and their nanoscale, heterogeneous relaxation processes.

—*Amaral, continued from page 3*

group that wrote the article. If you work in that group, you learn all sorts of things. The authors may say, “No, we didn’t write that in the paper, it would be too long, but you need to do it this way.” Probably, it took them months to figure out that they had to do this other step. If you only read about it, then you will have to discover it for yourself. But if you interact directly with the authors, you’ll learn it quickly.

Will you be working more now with the faculty at Feinberg School of Medicine?

My stuff is still far removed from that. I’m collaborating with Rick Morimoto, [biochemistry, molecular biology, and cell biology], and looking at stress response and seeing if mapping and network methods can help understand how the human stress response system is organized. For instance, what kinds of stresses have negative effects over time — and how long is “over time”? Alzheimer’s and dementia are stresses that accumulate, and at some point there is no return.

A cell may be stressed gently, and it may be good — it may improve its resistance. Nowadays, you have lots of people with asthma as a consequence of a period when people were obsessed with cleanliness — chlorine bleach everywhere, and don’t touch any dirt. The lack of stress on the immune system results in its ultimate weakness.

You could not sterilize everything, because then your immune system doesn’t learn how to handle stress. You cannot live in a sterile environment all the time. So it’s good to have a certain level of what would be considered stress. Some dirtiness actually turns out to be good for you.

I’m also doing some work in ecology; I’m doing a project with Kimberly Gray [civil and environmental engineering] about contaminant buildup in species in Lake Michigan.

How do you use computers in your work?

Computers are a very powerful tool to calculate things. That’s what they can do — calculations. For a while there used to be just two ways to try to understand something. You could create an experiment that measures something you expect to occur. Or you could build analytical models that you solve with a pencil. Computers enable you to use an intermediate approach. You can make something that is not as complicated as reality, as in an experiment, but it can be considerably more complicated than what you can do with paper and pencil. The things you can solve with paper and pencil are typically too far removed from what’s going on in reality. The things you can solve with a computer bring you much closer to what’s going on in reality.

With computers you can also study things based on rules. If one thing is going on, I shall do A; if something else is going on, I will do B. This is the way I think about the world.

“I SEE DOING RESEARCH AS A CREATIVE ACTIVITY. . .YOU WANT TO SHARE WHAT YOU HAVE CREATED WITH OTHERS.”

How do you translate what you see in one discipline to another?

Sometimes I can ask the right questions at one scale and then translate those questions to another scale — and some questions are definitely easier to ask of one system than of another.

The paper in *Nature* that I showed you is about metabolic networks. The exact same thing that’s talked about there is what we used for looking at a transportation network. With the air transportation network we could validate things in a very trivial way. We could ask, “What airports are our data classifying as the most important in the world?” We got the answer that the most important are New York, Chicago, Tokyo, Paris, Frankfort, London — the sorts of places that everyone knows about. If you’re traveling around the world you go through those hubs.

Then ask, “What do you find in metabolism that is equally important and play the same roles as major transportation hubs?” You find pyruvate or acetyl co-factor A in the metabolism and while this might be meaningless to you, I can give you an idea of what the meaning is by telling you that pyruvate is as important to metabolism as London or Chicago is to the air transportation network. So, you can have an analogy for the importance of something in a cell that draws on your experience from flying in airplanes. I can ask lots of good questions about the air transportation network because unfortunately I have traveled on many planes. I wouldn’t be able to ask those questions for a cell because I don’t have as much intuition there.

Why do you work on so many projects at one time?

Looking at many different systems helps my study of all of them because each one contributes to my understanding of the others. When I am doing transportation networks, I collaborate with one set of people, so I learn some of what they know. Looking at how humans make decisions, I collaborate with another set, and I learn some of what they know. When I collaborate with another set studying something else, I again learn some of what they know. So I can bring what biologists, for example, know to the study of something different, such as social networks or transportation. Maybe one person would never have the opportunity to talk to another, but they do through me. This creates new opportunities in the study of many systems because I can draw from different pools of knowledge.

I see doing research as a creative activity. And as with any creative activity — music, dance, art — you want to be able to share what you have created with others. ▮

—*Scaffolding, continued from page 1*

Stupp and his colleagues used heparin to nucleate nanofiber bundles 50 to 100 nanometers in diameter. The basic building block of these nanofibers is a peptide amphiphile that has a hydrocarbon chain on one end and a polypeptide designed to bind heparin on the other. In the presence of heparin, these chain-like molecules assemble into cylindrical fibers with the hydrocarbon chains at the core and the peptide-heparin complex at the surface. When combined with nanogram amounts of angiogenic growth factors known to interact with heparin, the nanostructures stimulate extensive new blood vessel formation.

Blood vessels in rat corneas treated with heparin bound nanofibers to which growth factors had been added increased significantly in length and area. Other preliminary experiments to treat skin wounds in rabbits and damaged heart tissue in mice also have shown promising results.

Results of the study were published online in August in *Nano Letters*, DOI:10.1021/n10613555 (2006). This work at Northwestern's Institute for BioNanotechnology in Medicine (IBNAM) is supported by the National Institutes of Health and the U. S. Army. ▮

CenterPiece

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ON THE BOOKSHELF

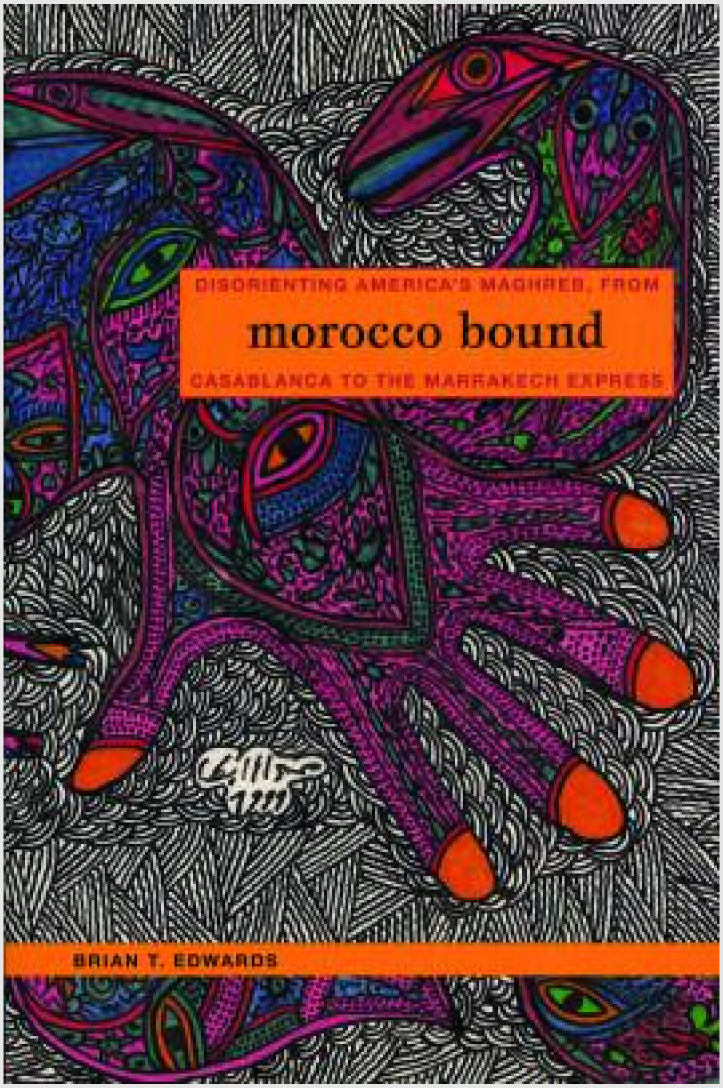
Morocco Bound: Disorienting America's Maghreb, from Casablanca to the Marrakech Express **by Brian T. Edwards**

The subtitle of Brian T. Edwards' book *Morocco Bound* is *Disorienting America's Maghreb, from Casablanca to the Marrakech Express*, which suggests the limited perceptions Americans have about the Maghreb, the region of Africa that includes Morocco, Algeria, Tunisia, and much of the Sahara.

What American hasn't seen the 1942 movie *Casablanca* and allowed it to color his or her thoughts about the U.S. presence in North Africa during World War II? And who doesn't listen to "The Marrakesh Express," the 1969 Crosby, Stills and Nash song and think of the hippies of the 1960s and '70s who followed the path of the Beat Generation into the exotic markets of Morocco and beyond?

Edwards draws on 20th-century journalism, films, and fiction to illustrate American perceptions of the African-Arab Maghreb. He uses these popular culture images of the region to help explain why Americans in Africa, unlike earlier British and French colonizers, rarely based political decisions involving the region on interest in or knowledge of Arab cultures.

Edwards, English, directs the Globalizing American Studies Project, a multi-year initiative of the Center for Global Culture and Communication and the Center for International and Comparative Studies (CICS). The centers present conferences, symposiums, and speakers throughout the year that facilitate collaborative interdisciplinary scholarship on crucial problems facing the world.



Morocco Bound: Disorienting America's Maghreb, from Casablanca to The Marrakech Express by Brian T. Edwards. Duke University Press, 2005.

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