Photographer: Michael Warren

Out of the fold

When he was 12, *Erik Demaine* talked himself into Dalhousie University in his home town of Halifax, Nova Scotia, despite having no grades or academic record to speak of. Eight years and a PhD later, he became the youngest professor at the Massachusetts Institute of Technology. He specialises in computational origami – the geometry of paper folding. *Steve Nadis* spoke to him about the advantages and pitfalls of following such an unconventional route to the academic elite

You left school at the age of seven and spent the next five years on the road with your father. Why?
Mainly because it seemed like a fun thing to do. My dad, Martin, was a craftsman, which made it easy for him to travel and sell his stuff at craft fairs throughout the US. It was a very free-form existence. Our movements weren't guided by anything more specific than "That seems like an interesting place to go."

What was the most important thing you learned in that time?
I learned a lot just from talking to people. My father always stressed communications skills, and that has served me well in academia. I'm not shy about approaching people to test out ideas. In fact, when I take on a big problem, that's the first thing I do.

What happened to your formal education during those years of wandering?
My dad taught me from home-school manuals we got from an agency in Washington DC. When I was nine, it became more efficient for me to teach myself from the same materials. That approach worked well for everything but spelling, which is hard to test yourself on. But we figured out a system for that too.

Were you ever curious about what went on inside the classroom?
I checked out normal schools from time to time to make sure I wasn't missing anything. My longest stint was a month in a Miami school because I was intrigued by a cute girl. But I left once I realised she had no interest in me. The main thing I learned was how much time is wasted in school. When you take away lunch, recess and other breaks, the nine-to-three day reduces to about one hour of real instruction. Home schooling is much more efficient. You get one-on-one training and can work right through summer when most kids forget everything they've learned in the previous months.

When did you become interested in mathematics?
It started from playing video games when I was quite young. I asked my dad how people wrote those games, and he said you first have to learn how to write a computer program. He got hold of some books on programming so he could teach me, and soon I was reading the books on my own. After a year or so of that, he said, "If you want to be good at computers, you have to be good at mathematics." So I said, "OK, let's learn some mathematics." I started with a high-school algebra text, and things took off from there.

You must have learned a lot to have talked your way into Dalhousie University as a 12-year-old.
It makes it easier when you're pursuing things you are interested in. But I still had to go through some political battles because of my age, plus the fact that I hadn't been to high school. At the time, you had to be 16 to enter Dalhousie. After some discussion, they let me in under special status. During the summer I took some mathematics and computer science courses as a test and did well enough for them to admit me in the fall.

While some view origami strictly as an art form, Erik Demaine finds great theoretical challenges in the ancient Japanese practice. In MIT's Laboratory for Computer Science, he is exploring how it might yield new insights into diverse areas such as protein folding, gift wrapping and the deployment of automobile airbags. Welcome to the arcane realm of computational geometry, in which the 21-year-old Demaine is one of the youngest and most accomplished practitioners. He also has a passion for puzzles of all kinds, developed during a childhood spent partly on the road with his father – a glass-blower, goldsmith, silversmith and puzzle maker

Do you feel any sort of age gap at MIT, being far younger than both your faculty colleagues and many of your students?
That's becoming less of an issue now that I can go to bars legally, but age has never really been important in my life. Some people who accomplished a lot when they were young have stressed their age as a way of making their achievements stand out even more. I try to downplay the age thing because eventually everyone gets older.

What's your father up to these days?
He's a visiting scientist at MIT with an office in this lab. When MIT offered me a position, they offered him a position too, which was great. Sometimes we work together; other times we work separately. He has tried to keep up in mathematics, learning this stuff as I've been learning it, but as I've got deeper into the field our roles have changed somewhat. It's amazing that he has come so far, given that he basically had to switch genres from art to mathematics, which is a pretty hard thing to do.

> "Age is less of an issue now I can go to bars, but it has never really been important in my life"

It must be especially hard for someone in his late 50s. People say you have to make your mark in mathematics before you turn 30.
I've heard that too, but I don't know where it came from, nor do I believe it. I can certainly imagine learning more slowly at some point, which is why I'm trying to learn as much as I can, as fast as I can. But I don't see the process ending, and I hope to prove that saying untrue, though I can't prove it with mathematical certainty.

Why do you list origami and computer programming as "hobbies" on your resumé, since they seem so close to what you do in your day job?
I make very little distinction between working and having fun, because work, for the most part, is fun. Still, when I have time, I like to make origami gifts. My hobby started after my research in this area, though most people do it the other way around. I also do computer programming for fun, even though it is part of my job. But my favourite hobby is juggling. For some reason, a lot of mathematicians like to juggle. There is even a mathematical theory of juggling. It's all about timing, about how things go up and down.

I gather you are also interested in puzzles, and that you and your dad used to support yourselves partly through puzzle making.
We have always had a passion for puzzles. I think there is definitely a connection between puzzles and mathematics. With a puzzle, it's usually clear what you have to do and the solution itself is often remarkably simple, yet finding it can be hard. Proving mathematical theorems is similar in many respects: the problem and the solution can be easy to understand, but finding the solution and proving it can be incredibly challenging. The solution, moreover, typically involves several pieces.

What was your first real accomplishment in mathematics?
Six years ago, when I began my PhD work in computational geometry at the University of Waterloo in Ontario, my dad remembered "the paper cut problem" from an article written in the 1960s on paper folding and mathematics. The idea is to take a piece of paper, fold it any way and as many times as you want, and then make one straight cut and see what shapes you get. The question is, are all shapes possible? I worked on this problem for two years at Dalhousie with my dad and adviser Anna Lubiw. After experimenting for a while, we realised you could make all kinds of shapes, such as butterflies, swans, hearts or stars. The hardest part was proving that any shape was possible.

How did you go about proving it?
That process, in a word, is mathematics.

What is your greatest preoccupation at the moment?
I've been working on my favourite problem for the past five years, which is a long time for me. It has to do with a centuries-old question: what three-dimensional shapes can you make by successively folding a flat sheet? Questions like this come up regularly in the sheet-metal industry: how do you cut a sheet and then use bending machines to fold it in the right sequence? Theorists could make a big contribution here, but the mathematics is not yet fully developed.

What are you doing when you are not working on folding problems?
I like to have lots of things going on in parallel because you can easily get stuck on one problem and end up doing nothing. I prefer doing something. Only about half my work relates to the geometry of folding. I have a separate project that involves a new approach to organising data. My hope is to make web searches quicker and more efficient. Last week, a mathematician from Spain visited me and we looked at the classic problem in facility location: where, for instance, would you site 100 fast-food outlets to make them closest to the most people? I also work in combinatorial game theory, studying the complexity of computer games such as Tetris, which in fact is what got me into mathematics in the first place. My goal is to keep moving into new areas of mathematics and not be confined to a single branch.

Does it seem weird to you to have a tenured job and so much stability in your life, given your nomadic past?
I guess I'm getting used to it. Stability seems like a good thing to me, and I can't see any downside. If you don't want it, you can always throw it away.

But do you wonder whether your creativity might be hampered by being tied to a single place – even if that place happens to be MIT?
It's true we moved around a lot when I was a kid and saw a lot of interesting things. But at this point I appreciate having a home base. If I get restless or feel stale, there's a simple solution: it's called travelling.

THE WORD
SAR11

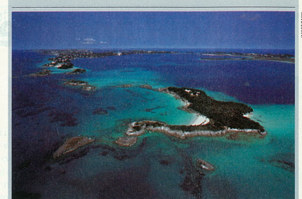

IMAGE BANK

SAR stands for Sargasso, the sea to the east of Bermuda, but the S of SAR could just as well stand for "success". SAR11 is the name of a tiny micro-organism first found in the Sargasso Sea and which now looks likely to be the most abundant life form on the planet (excluding viruses). A report last month from Stephen Giovannoni of the Oregon State University estimates that an astounding 2.4×10^{28} SAR11 cells live in the oceans (*Nature*, vol 420, p 806).

What do these vast numbers mean? Comparison with the bigger creatures we normally think of as important is little help. There are only around 6×10^9 humans on Earth. Of course, we barely figure alongside termites, which have a world population of around 2.4×10^{17} individuals. But even with 40 million termites for every one of us, their numbers are still only a hundred-billionth of those of SAR11.

Even among its microbial compatriots, SAR11 counts as an unrivalled success. There are around 1.2×10^{29} prokaryotes (the bacteria and other single-celled organisms without nuclei) living in the open ocean. That means that just one type of bacterium – SAR11 – accounts for a fifth of all the prokaryote cells living in the seas. Add the land and SAR11 still comes out on top. There are an estimated 4 to 6×10^{30} prokaryotic cells on the planet, with a combined biomass equal to all other living things put together. SAR11 thus makes up around 0.5 per cent of all prokaryotes on Earth.

Given the bacterium's abundance, it is incredible that no one had seen a SAR11 cell until last summer. They are very small, even for bacteria, and had proved impossible to grow in the lab. Only the new science of ecological genomics revealed their existence. By fishing out fragments of DNA from seawater and looking for variations in the well-known gene that codes for ribosomal RNA, it is possible to detect different bacteria without seeing them.

Giovannoni, a pioneer of the new science, first identified SAR11 back in 1990. Last year, his team made another breakthrough and finally managed to culture SAR11. It turns out to be crescent-shaped, and a mere 0.25 to 0.7 micrometres across; any smaller, and it would not be big enough to hold all the molecular machinery needed for a free-living cell.

Can such tiny bugs really be important? Indeed they are. SAR11 gets its energy from the waste products of photosynthetic organisms, metabolising dissolved organic carbon compounds and producing carbon dioxide. The bacteria are very active and Giovannoni estimates that they may be responsible for 10 per cent of all the nutrient recyling on Earth. And as the dissolved carbon they burn might otherwise disappear into the carbon sink of the deep oceans, SAR11 could also affect carbon dioxide levels and the rate of global warming. Tiny bacteria they might be, but their vast numbers may help determine the fate of the planet.