issue 3

the neurite

west virginia's STEM magazine for students

Deena Dahshan and Ian Waddell
Marshall University

Editor's Corner

Art and science go hand-in-hand, and that's why some people are using the acronym STEAM instead of just STEM because they want to incorporate an "A" for art.

As you will see in this issue, scientists sometimes use artistic concepts and translate them to fit their scientific needs. So, being a scientist doesn't necessarily mean that you can't be artistically inclined; your artistic creativity might actually be a plus!

Sometimes your scientific discovery might even turn out to be an art, hence there are scientific art competitions in which you can win prizes for photographs or an artistic replica of your science.

The same is true vice versa. Many artists use science and mathematics in the process of creating their masterpieces. For instance, when artists are trying to create the impression of distance or depth on a flat surface, they have to use mathematical principles like parallel lines, ratios and scales to make the art look realistic. Other times, artists choose to create pieces that represent scientific principles to aid in explaining them.

Sometimes, it's even fun to explain art through its underlying mathematical principles. For this issue, I loved folding paper to look at different patterns and figure out the mathematical rules applied to origami, and I hope you will too!

But the theme of this issue is chemistry, which happens to be one of the leading industries in West Virginia and thus one of the highest paying ones. Generally, with a chemistry degree you can find jobs in:

- Industry, for instance in research and development or sales
- Government as a law enforcement or quality control professional
- Academia as a high school teacher or higher education professional
- Non-profit, for example in science policy or environmental protection
- Entrepreneurship

I hope this issue of the *Neurite* gives you some insight into the world of chemistry as well as a taste of the underlying connection of art to STEM.

Elisabeth Kager

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Education, Outreach and Diversity Manager
West Virginia Higher Education Policy Commission

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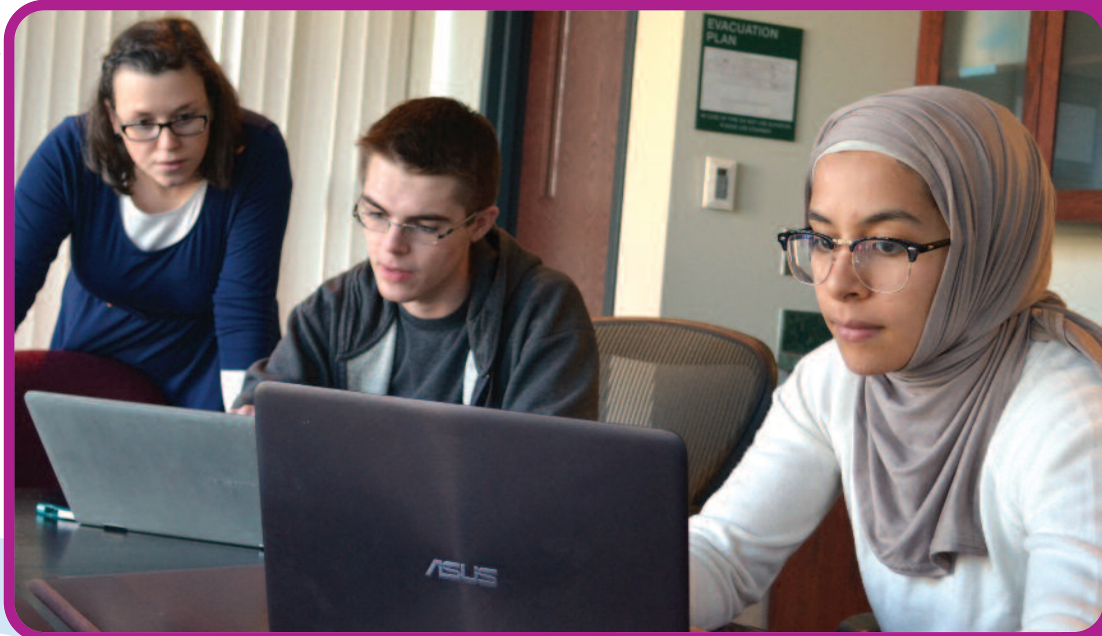
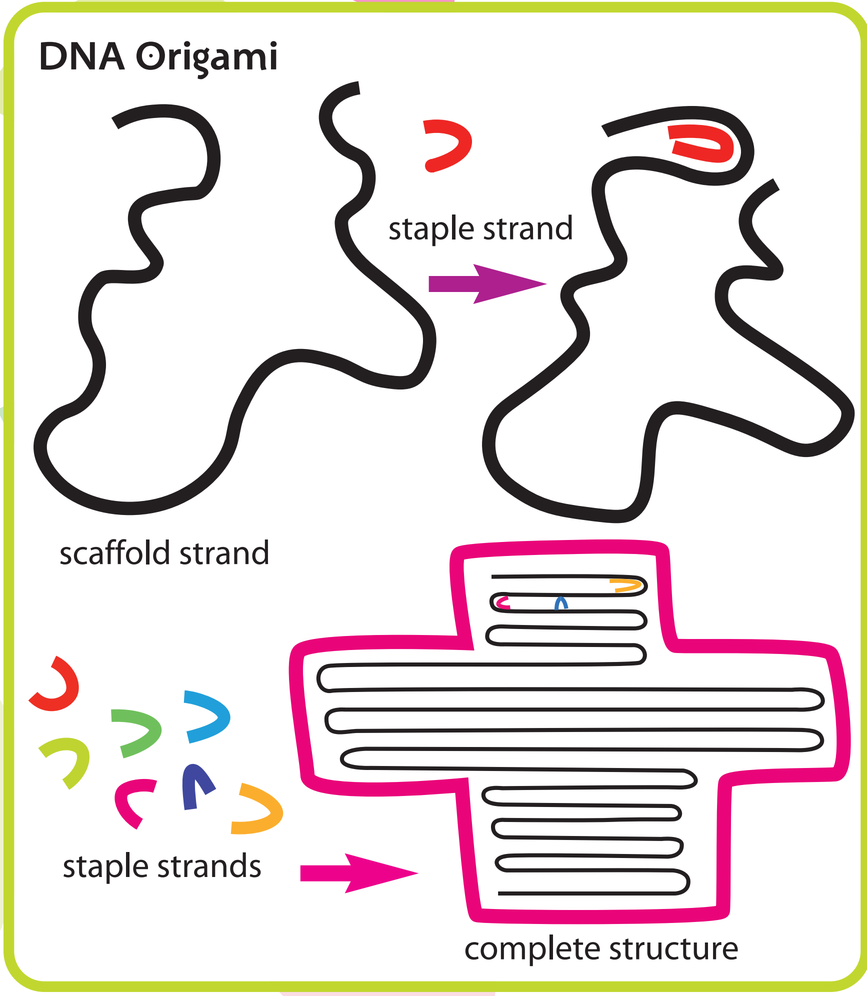
DNA ORIGAMI–Small but Powerful



This issue features two sophomore students from Marshall University (MU). Deena Dahshan graduated from George Washington High School in Kanawha County and is part of MU's accelerated BS/MD program*. In this program, Deena will complete her Bachelor's Degree in biology with a minor in chemistry in just three years and then move right into MU's four-year Doctor of Medicine program. Ian Waddell graduated from Cabell Midland High School in Cabell County and is double-majoring in chemistry and biotechnology.

During their freshman year, Deena and Ian joined Dr. Michael Norton's DNA Origami research team.

Yes, you read correctly: Origami, the Japanese art of folding paper into a sculpture! Instead of using paper, though, Deena and Ian use DNA strands to fold into a desired structure. To build DNA Origami, they are working with one long scaffold strand and about 200 short staple strands, which makes the folding a bit more complicated.



***MU's accelerated BS/MD program only accepts students from West Virginia!**

A Conversation with DNA Origamists

Neurite: **So, what's the process of making DNA Origami?**

Deena: Generally, staple strands are used to staple certain parts of a long scaffold strand together to form a shape, which in our case is a cross. To do that, a carefully-designed sequence of staple strands is created by a manufacturer so that each of these staple strands binds the scaffold strand at an exact location for it to assemble into that cross.

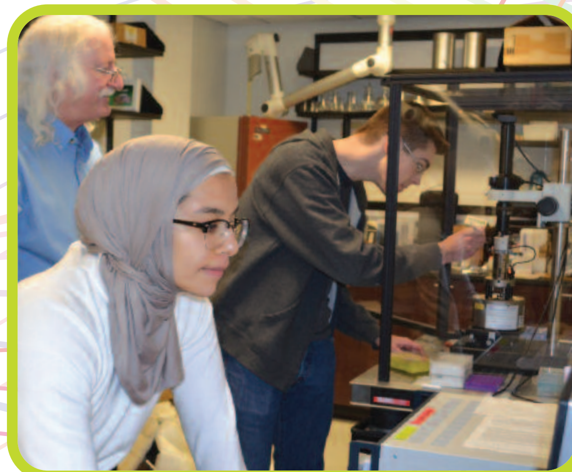
Ian: This process is done by mixing the scaffold strand with the staple strands to let the mixture go through an annealing process, which is a heating and cooling cycle that takes about 13 hours.

Deena: My project was to actually take these crosses and link them into a chain of a certain length, adding one cross at a time. It was quite tedious and, unfortunately, unsuccessful up to this point.

N: **Sorry that you haven't had any success but it still sounds really cool. Did your research stop there?**

D: For me it did. I was unable to continue research after that semester.

I: I have been involved in the lab ever since. Right now, I am working to attach carbon nanotubes (CNTs) to the DNA by having the DNA wrap around the tubes. You can imagine CNTs as rolled up sheets of graphene that can act as electric conductors.



N: **What can such a system be used for?**

I: We could use it for its electrical properties and eventually turn it into the smallest computer. Additionally, CNTs have fluorescence properties that can be used for analytical purposes, for instance to see how many molecules are present in the system.

N: **Neat! Are there other applications for DNA Origami?**

I: With DNA Origami, you could potentially make incredibly small machines that, for example, release chemotherapy to only the affected cancer cells instead of also attacking healthy cells.

Although this application is definitely needed to cure diseases, so is the application that Dr. Norton's own research group is working on: sensors that detect contaminants in water, which could cause diseases. The ultimate goal is to make it possible for anyone to test the purity of their water in an instant.

N D I N D I N D I N D I

What struggles did you two face during your research experience?

One struggle was being the expert in a field that I didn't know much about and without many people to turn to. It was challenging because this research was disconnected from everything else that I had ever done before. Once I started spending more time with it and tried to connect the research to things that made sense, it got easier.

Agreed. With research you can quite literally be the only one in the world working on a particular project, so you have to justify your own theories because existing theories might not fit or might not even exist yet. For me, it was also really hard to not measure my self-worth according to project success. Often, when a project failed, I felt like a failure although it had nothing to do with what I did or didn't do but more with the procedure itself. This feeling was and still is a hard one to overcome.

I am glad you identified the struggles and are dealing with them. Now, on a more positive note, tell us about the highlights of doing research.

One highlight was being able to work in the lab by myself. That was nice because in the beginning I would have to shadow others, like Ian, to see how to use the equipment.

The best part is when an experiment succeeds spectacularly because it can really be uplifting. It is also something that you can be proud of considering that we are only undergraduates and are working by ourselves.

It seems like you have experienced many sides of research, but do you think doing research has taught you any life skills?

Yes, to be patient. You don't get the fruits of your labor for a while so you have to stay driven and focused otherwise you get easily frustrated.

To think differently. If you use the same thought process that you've always used, it doesn't quite work because research doesn't always follow the rule book. Sometimes the best idea is the one that seems like it would never work. Yes, learning how to think differently has helped me in class, too, because some classes really require creativity.

Lastly, what advice do you have for our readers?

Don't be too focused on the process of choosing a college or a major because college is not a destination, it's part of the path that leads you to where you want to ultimately end up. You don't even have to declare a major until the end of your first year, which gives you time to try out different classes to narrow down your choices. Just remember, the best things in life are often the things that are hardest to get, which makes them so much more rewarding to attain.

I agree with Deena, during the first year there's a lot of general education happening and you can take electives. Just choose electives that you think have potential to be useful to you. Also, I think it's important to push yourself and take hard classes that take you to your limit. To be honest with you, a lot of colleges would rather see a B or C in a hard class than an A in an easy class. They like to see students who challenge themselves.

Deena and Ian know that science is advancing rapidly and by the time they reach the end of higher education, their field could have changed completely. So, neither one of them are sure what exact career they want to go into as long as it's in medicine for Deena and involves getting a Ph.D. for Ian.

Bell International Laboratories
Eagen, Minnesota
Cosmetics Research and Development (Research & Development)
Formulate a wide variety of personal care products and cosmetics.
Bachelor in Chemistry

Rothamsted Research
Harpenden, United Kingdom
Natural Product Chemist (Research & Development)
Help develop woody biomass from willow as a feedstock for the biofuel and industrial biotechnology industries.
Ph.D. in Chemistry

West Virginia Department of Agriculture
Charleston, West Virginia
Pesticide Residue Chemist (Quality Control)
Analyze commercial pesticide products for quality control.
Bachelor in Chemistry

Buffalo State College
Buffalo, New York
Assistant Professor of Art Conservation (Chemistry and the Arts)
Teach courses in paintings conservation and the history of paintings materials and techniques as well as pursue research.
Bachelor in Chemistry + Masters in Art Conservation

Agricultural Research Service
Raleigh, NC
Research Food Chemist (Food Science and Quality Control)
Develop enhanced preservation processes for vegetables that will improve quality, decrease the waste of processing salts and retain more nutrients.
Ph.D. in Chemistry or Food Science

West Virginia State Police Forensic Laboratory
South Charleston, West Virginia
Forensic Analyst for Controlled Substances (Law Enforcement)
Perform analysis required in criminal investigations.
Bachelor in Chemistry, Biochemistry, Biology, Molecular Biology or Forensic Science

American Int
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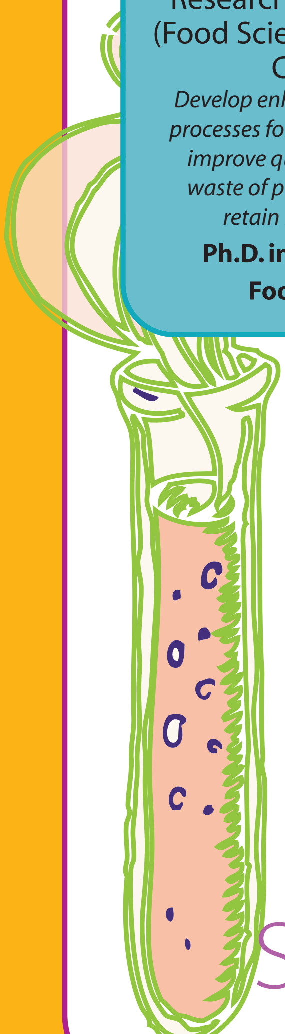
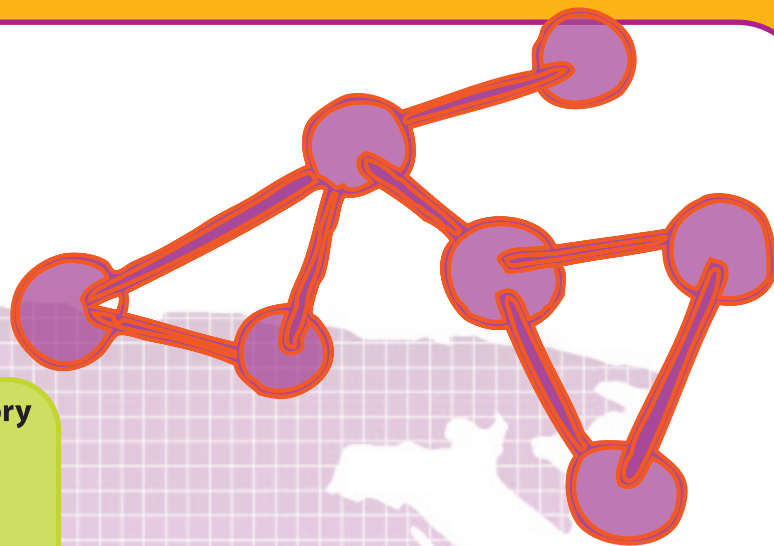
Teach students chemi
and critical thinki
integrating
Bachelor in Ch



The Nature Conservancy
Arlington, VA
U.S. Government Relations Coordinator for Water Policy (Non-profit, Science Policy)
Track legislature activities, research water-related public policy, search files and databases and organize research into reports.
Bachelor Degree

where do ch

Some job options available right n

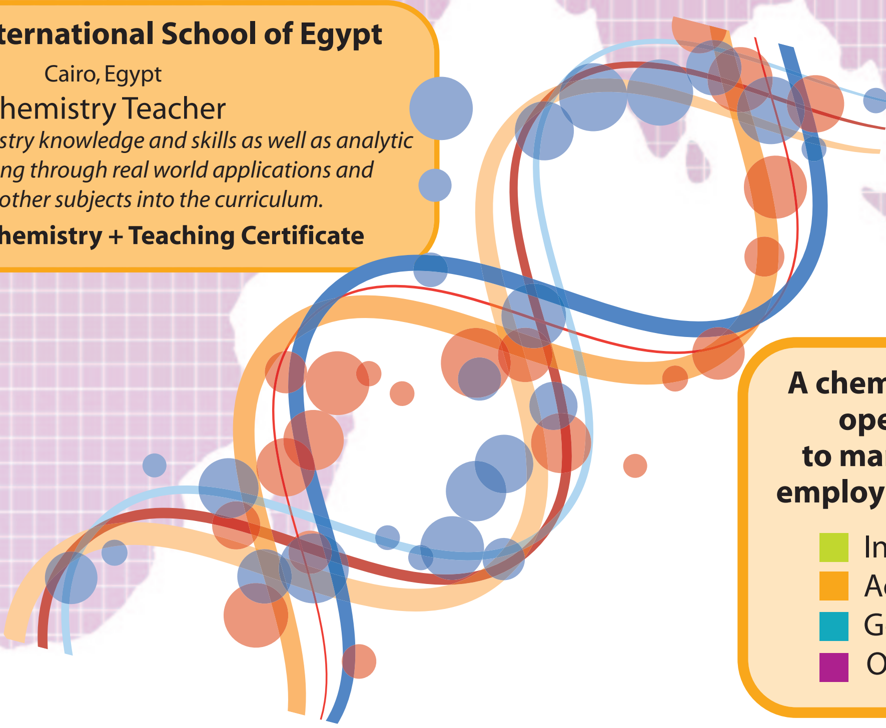


Thermo Fisher Scientific
Erembodegem, Belgium
Area Account Manager for Molecular Spectroscopy (Sales)
Sell Molecular Spectroscopy Instrumentation.
Bachelor in Chemistry

International Iberian Nanotechnology Laboratory
Braga, Portugal
Water Monitoring and Treatment Researcher (Research & Development)
Collaborate with industry and academic partners to develop new solutions for water analysis and treatment.
Ph.D. in Analytical Chemistry or Biochemistry

American Chemical Society (ACS)
Beijing, China
Managing Editor of ACS' Omega Journal (Outreach)
Choose content, manage peer-review of manuscripts, conduct outreach and promote the journal in order for the journal to grow.
Bachelor in Chemistry

ternational School of Egypt
Cairo, Egypt
hemistry Teacher
stry knowledge and skills as well as analytic ng through real world applications and other subjects into the curriculum.
hemistry + Teaching Certificate



A chemistry degree opens doors to many different employment sectors:

- Industry
- Academia
- Government
- Other

emists work?

OW in the field of chemistry

NOBEL PRIZE HISTORY*

Do you know what it means to win the Nobel Prize? It's just the most prestigious award anybody in the fields of chemistry, economics, literature, peace, physics and physiology/medicine could be awarded!

Alfred Nobel wanted to make sure this prize was established after his death. So, he wrote in his testament that the interest of his invested fortune "shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit to mankind."**

Nobel himself was a chemist, engineer and inventor–and a pretty good one at that. In his lifetime, he made 355 inventions, the most famous of which was dynamite. All these inventions led to his riches and inevitably to the recognition of many scientists.

The prize can be shared among at most three people but can also be awarded to an organization as a whole.

Considering this is such an esteemed award, there have been people and organizations who have won the prize multiple times.

The International Committee of the Red Cross, for example, won the Nobel Peace Prize three times. Or take the Curie family: Marie and her husband Pierre Curie each received ¼ of the Physics Prize in 1903. Marie Curie went on to be the sole winner of the Chemistry Nobel Prize in 1911 for the discovery of the elements radium and polonium. Marie's and Pierre's daughter Irene Curie-Joliot shared the 1935 Chemistry prize with her husband Frederic Joliot for the synthesis of new radioactive elements.

Since its initiation in 1901, only 48 individual women have been awarded the Nobel Prize. Overall, 881 individuals and 23 unique organizations have received the Nobel Prize up to this day.

But enough about the past, let's talk about who just recently won the Chemistry Nobel Prize! Jean-Pierre Sauvage, Sir J. Fraser Stoddart and Bernard L. Feringa are the 2016 Chemistry Nobel Laureates for designing and producing molecular machines.

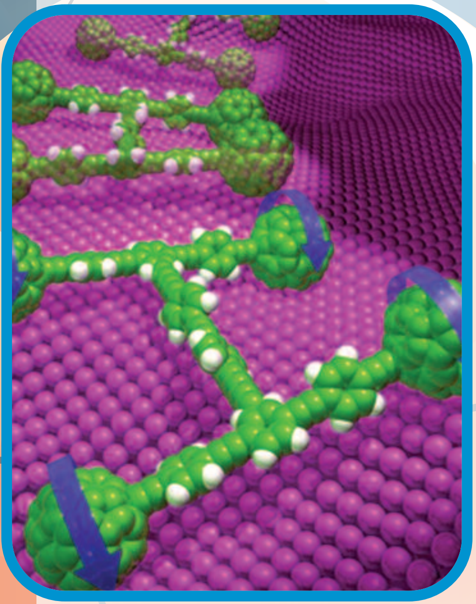
* Nobelprize.org was used to confirm this story's content.

** Quote was retrieved from "Full text of Alfred Nobel's Will". **Nobelprize.org.** Nobel Media AB 2014. **http://www.nobelprize.org/alfred_nobel/will/will-full.html**

2016 CHEMISTRY NOBEL PRIZE

Molecular Machines-The Tiniest of Machines

Machines have been part of human lives and human development for millennia. New developments keep making our lives easier, safer and more enjoyable. Today, we are at the brink of a new revolution, making machines as tiny as they can get–molecular-sized, which means machines smaller than one 1,000th of your hair's thickness!



Four-wheel-drive nanocar

Although countless such machines exist in your body to make sure that tasks like cell division and cell transports are getting done, scientists have just recently developed techniques to make man-made ones.

These manufactured machines are made of molecules that are designed to execute specific tasks. Like any ordinary machine, molecular machines are fueled by various energy sources.

Chemistry class teaches us that molecules move by using the energy around them, but their movements are rather uncoordinated.

So how can they perform specified tasks? The three 2016 Chemistry Nobel Prize winners created molecules that could be choreographed due to their structural design and controlled connectivity.

These so-called molecular machines have been in the making since 1983 when Jean-Pierre Sauvage first created molecules that were mechanically, not covalently, linked into a chain–meaning that instead of the usual shared electron bonding, Sauvage used a copper ion to interconnect molecules.

By 1991, Sir J. Fraser Stoddart had built on Sauvage's technique and created a molecular dumbbell-shaped structure, enabling him to develop a molecular lift, muscle and computer chip.

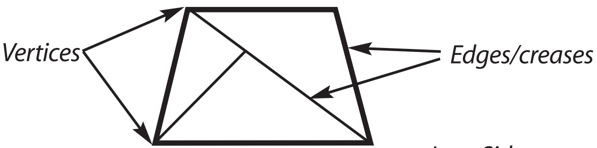
In 1999, Ben L. Feringa developed the first molecular motor and by 2011 had designed a four-wheel-drive nanocar that could move across a surface once electronically excited.

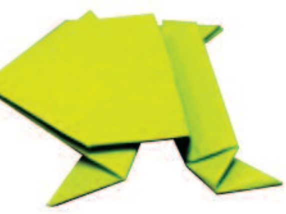
This development is a great example that scientific break-throughs don't just take time but are built on previously done research and are dependent on collaboration.

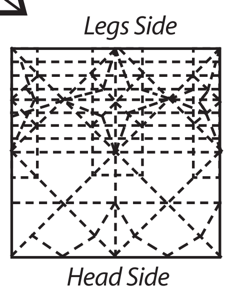
The Nobel Prize was awarded to these three chemists because of the fundamental science that they have developed to make such machines possible. We are still waiting for real-world applications but speculations of such exist. For instance, developing a machine to administer targeted drugs within the body– just like DNA Origami's application that Ian talked about but at the more fundamental level.

THE MATH behind Origami

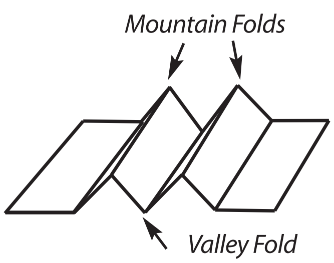
Origami is all about crease patterns and you know what that means. No? Well, crease patterns lend themselves to looking at Origami mathematically because creases represent edges of a graph and the points where these edges meet are its vertices.



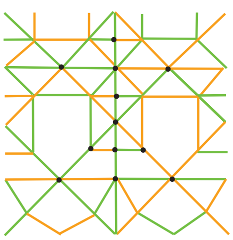




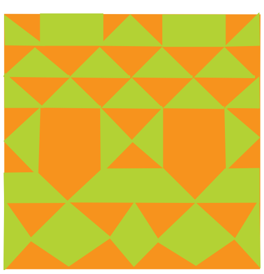
Instead of using this jumping frog's complex crease pattern, I decided to use a simplified version to demonstrate the mathematics behind Origami.



Law #1: Mountain vs. Valley Folds

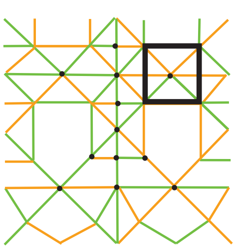


At any interior vertex, the number of mountain folds (M) and valley folds (V) always differs by 2, resulting in $M-V=\pm 2$. Count all the orange and green folds around one of the dotted vertices to see for yourself!



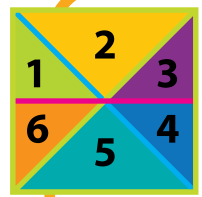
Law #2: Two-colorability—you only need two colors to paint a crease pattern without the same color ever touching.

Law #3: No matter how many layers you fold and stack on top of each other, the sheet itself will never pierce its folds.



Law #4: If you add up every other angle around a vertex, its sum equals 180˚.

Since this law is harder to digest, let's look at a step-by-step example, focusing on a more colorful version of the marked square.



1 The sum of angles along a straight line add up to a straight angle, which is, by definition, equal to 180˚.

2 Knowing that, we can say that the sum of angles (∠) above the red and the blue lines are $\angle 1+\angle 2+\angle 3=180°$ and $\angle 2+\angle 3+\angle 4=180°$, respectively.

3 Since both sums equal 180°, we can set them equal to each other: $\angle 1+\angle 2+\angle 3=\angle 2+\angle 3+\angle 4$

4 If we now subtract the common angles ($\angle 2$, $\angle 3$) from both sides, we get: $\angle 1=\angle 4$

5 Repeat the same steps with the angles below the green and the red line to show that $\angle 3=\angle 6$ and the angles below the blue and above the green line to find $\angle 5=\angle 2$.

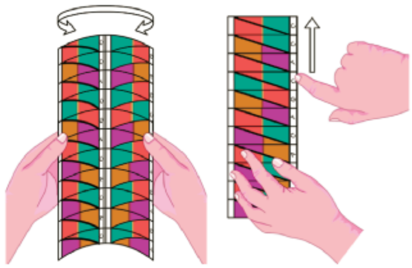
We basically just proved the vertical angles theorem—angles vertically opposite each other always equal each other.

6 Now, let's use this to show why Law #4, which says $\angle 1+\angle 3+\angle 5=180°$ and $\angle 2+\angle 4+\angle 6=180°$, is true.
Let's replace some of the angles in (6) with their equal counterparts from (4) and (5) to get $\angle 4+\angle 3+\angle 5=180°$ and $\angle 2+\angle 1+\angle 6=180°$. As the angles of each of the sums are along one line (below & above the green line, respectively) their sum must equal 180°, showing that Law #4 is true!

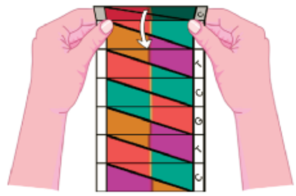
Wow, after all this math, let's have some fun doing Origami!

Origami DNA FOLDING INSTRUCTIONS

Note: All folds should have a thin line on the inside and a thick line on the outside.



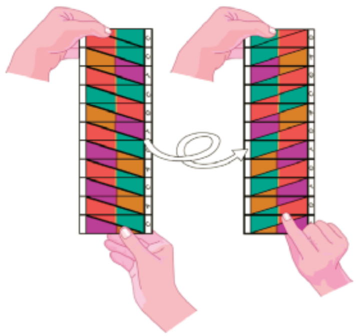
1 Fold in half lengthwise. Make all creases as firm as possible (use your fingernail!)



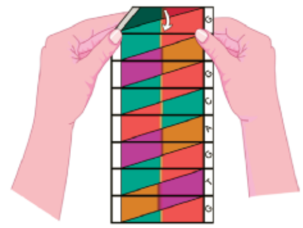
2 Hold the paper so that the thick lines are diagonal and the thin lines are horizontal. Fold the top segment down and then unfold.

3 Fold the top two segments down along the next horizontal line. Unfold.

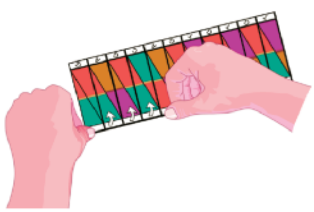
4 Repeat for all segments.



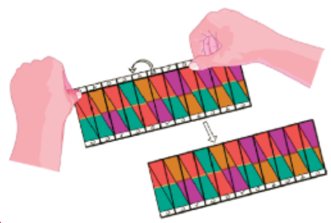
5 Turn the paper over.



6 Fold along the first diagonal line. Unfold and fold along the second diagonal line. Repeat for all diagonal lines.

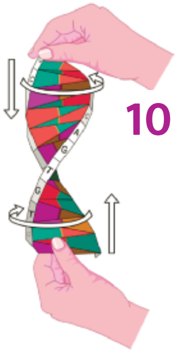


7 Fold the white edge without letters up.



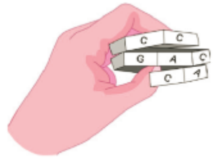
8 Fold the other edge away from you. Partly unfold both edges.

9 You can now see how the model is starting to twist.



10 Twist and turn the paper while pushing the ends towards each other.

Be brave!

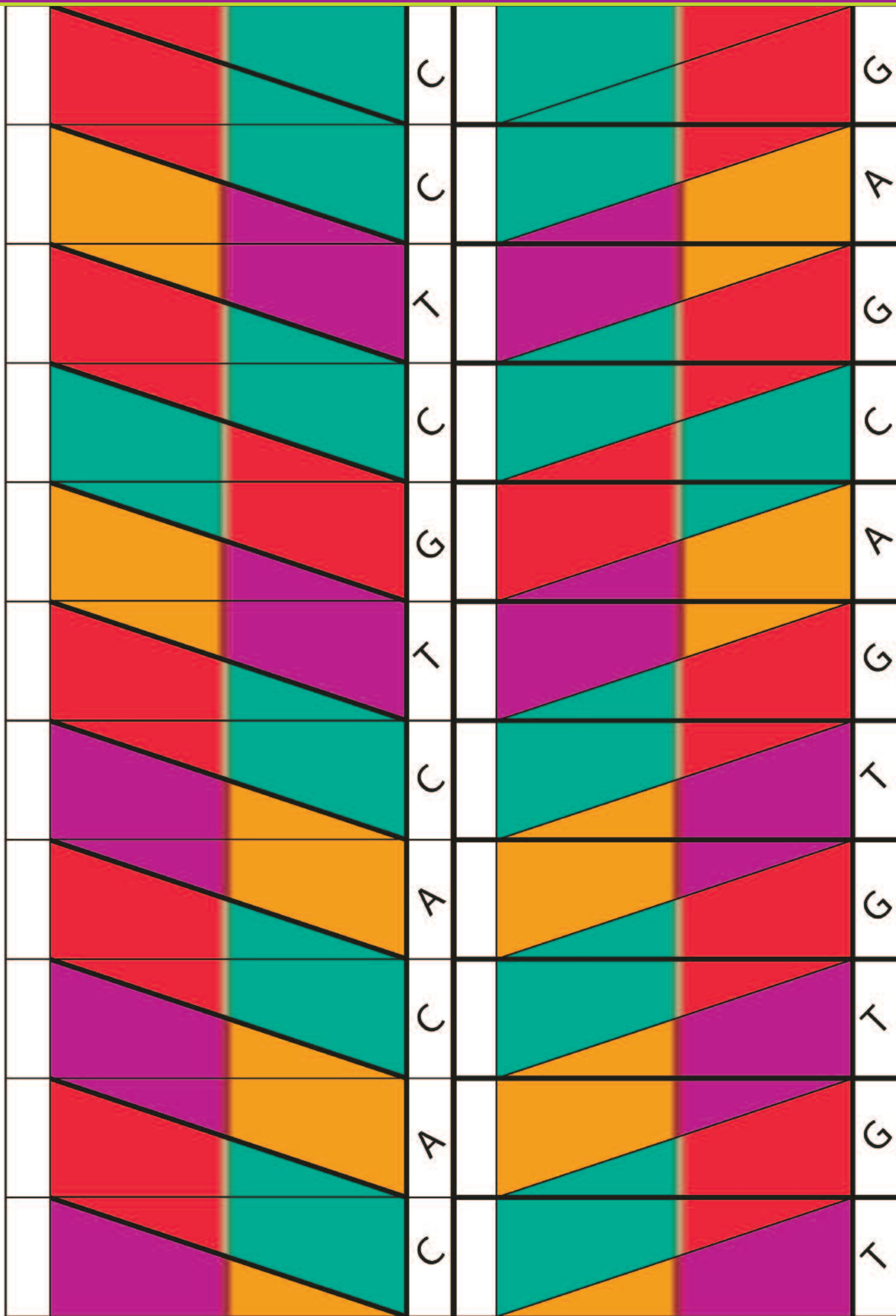


11 Now let go!

12 Admire your completed DNA double helix!

Only another 2,999,999,989 (or so) more to complete your whole genome!

Note: Please make a copy of the folding instructions before you start building your Origami DNA. If you don't want to destroy your magazine, please visit **http://www.yourgenome.org/activities/origami-dna** to download the original copy of this activity provided to you by Genome Research Limited.


C C T C G T C A C A C
G A G C A G T G T G T