COMPARISONS

ZINE

CARL R. WOESE INSTITUTE FOR GENOMIC BIOLOGY
UNIVERSITY OF ILLINOIS URBANA CHAMPAIGN

NO. 2 SUMMER 19

This zine is a window into the creative minds that are at work at the Carl R. Woese Institute for Genomic Biology. As an interdisiplinary science institute, we approach science with a wide angle lens, utilizing scientific processes from chemistry to anthropology to answer questions about DNA, the building blocks of our universe. As part of our scientific mission we take on the responsibility of communicating our work with the same vigour that we approach bench science. This zine is a part of our Art of Science intitiative; we asked scientists and IGB community members to submit written amd pictorial work that deals with the broad theme of comparisons. The submissions included look at science communication and artistic expressions of comparison from a variety of perspectives. We hope you enjoy!

IF YOU HAVE QUESTIONS OR YOU WOULD LIKE TO SUBMIT WORK IN THE FUTURE PLEASE CONTACT:
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Multiverse

NICK VASI
IGB DIRECTOR OF COMMUNICATION AND ENGAGEMENT

When we started the Art of Science program back in 2011, we really had no concept of how it would develop or what it might grow into. We knew we had something pretty special that hadn't been done before in quite the way we approached it—the melding of complex and beautiful scientific imagery with the aesthetic enhancements of an artistic director curating the work. From that first show, through the years we've spanned galleries, airports, businesses, collaborative spaces, libraries, and more, and we've introduced true multimedia through video, sculpture, 3D images, interactive pieces, anything that helps to frame the concept and communicate to the viewer an additional layer of meaning in the work.

As the Art of Science program has evolved, so has the idea—we are no longer limited to a 24 by 36 inch framed image on a wall somewhere, but instead embrace the notion of what the Art of Science can be. It can be a gallery show or an art book, sure, but it can also be an essay, or a performance, or a zine. The first issue of the zine was published in the hopes it would reach audiences who had not seen the show or heard about the program, but who had an interest in science, art, and their community. We wanted the person who picked up the zine to experience a similar tone to those who had gone to an opening or viewed a gallery online, an essential quality of curiosity, expression, and inclusion. That anyone can be a scientist, or an artist, or a contributor.

That last line is especially true as our zine has an open submission format, and if you are moved to submit a piece of prose or poetry, an article or an image, or even just start a conversation with us please do so. We aim to broaden this Art of Science 'verse as far as it can go.

The Board Game; A Comparison of Science Outreach: Scientists and Pre-School Kids

REBECCA BATSTONE

"What's your favorite microbe?"
The kids stared at me blankly.
"OK, does anyone know what a microbe is?"
One girl squished her thumb and index finger together to suggest something very, very small.

"Bingo!" I said, snatching onto this fragment as I tried to engage my pre-school audience with the workings of genomics and health.

This was back in April when I had the privilege of volunteering at IGB's largest science outreach event, the World of Genomics, held this year at the National Academy of Sciences (NAS) in Washington, D.C. Families from all over the city came, bringing with them an obvious interest in science and a desire to learn something new. It was insanely fun but exhausting, as I had to stretch my communications skills and imagination in ways that only the energy, curiosity, and questions of young children can demand.

"OK, does anyone know what a microbe is?"
One girl squished her thumb and index finger together to suggest something very, very small.

My friends and I on the IGB team knew that we might have a challenge at World of Genomics, but we also felt well-equipped.

We wanted to use the event to introduce children and their parents to the importance of mobile DNA—bits of DNA that can be picked up from the environment or from another organism to encode a novel function in the bearer. Unlike DNA that is inherited, passed down from one generation to the next, mobile DNA can be acquired even within the same generation. Next generation sequencing has shown that mobile DNA elements are widespread, found in organisms from every domain of life.

Featured theme:
INFECTION GENOMICS FOR ONE HEALTH (IGOH)

But they are especially common in microbes.
We are only now beginning to grasp how profoundly mobile DNA impacts microbial functions including antibiotic resistance and infectious disease, as well as a microbe's evolution. The integration of mobile DNA into evolutionary theory is, in fact, one of the key concepts that underpins our work in the Infection Genomics for One Health (IGOH) research theme at the IGB, and though the subject is technical and specific, we wanted

Image: World of Genomics (WOG), at the National Academy of Sciences (NAS) in Washington, D.C.

to share our enthusiasm for the field and to help build awareness of its importance to humanity.

But how would you do this with young kids who have no background in genomics or biology and probably just want to play?

Perhaps playing into our gaming culture combined with the explosion in superhero movies (The Avengers: Endgame had just hit the theaters), we decided to try designing a game of our own that featured microbes that had their own superpowers or kryptonite and could gain or lose such through mobile DNA.

Most of my past experience with SciComm has involved explaining my science to other researchers and those familiar with my study system, and I did not know much about designing card games for children. But I had tremendous help from the IGB Science Outreach Team headed by Dr. Courtney Fenlon as well as IGOH's theme leader Dr. Rachel Whitaker and many of the theme members, especially my own supervisor Dr. Katy Heath.

Here is how I tackled the project:

1. Asked myself, *"What do I want the public to take away from this game?"*
2. Tried to think of simple ways to illustrate the core supporting concepts.
3. Asked other theme members to help identify superpowers and kryptonite of their favorite microbe and/or mobile DNA.
4. Got IGB's graphic designer Jillian Nickell to bring the microbes to life.
5. Arranged lab brainstorming parties to sketch out stories that would fit the game.
6. Attended SciComm workshops to listen and learn with the game in mind.

The result was a visual and fun activity that required a bit of strategy and really worked. Kids and parents seemed to love it as our booth at World of Genomics was always busy, often with lineups, and many families returned to play the game again and again.

But in meeting them and demonstrating the game, I realized that the key part of the design process is one that envelopes all the steps. That's to think all the time about why you love a field of study and why you want to share it.

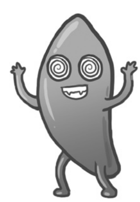
I think that it's not so important in science outreach to get facts to stick or teach a lesson. What seems more impactful and potentially enduring is making human connections, letting people see how much you enjoy your field and how someone can have fun studying, as in my case, microbes. If you can share the excitement and inspire curiosity, it works a bit like mobile DNA encoding new ideas within kids and parents, motivating them to ask their own questions, to learn from their own base of knowledge, and to observe the world around them in a new light.

"What's your favorite microbe?"
"I love the one that helps corals grow"
"I like the one that helps you break down food"
"I like the one that makes mice attracted to cats"

So after my first awkward encounters, I dropped the *"What's your favorite microbe?"* introduction and instead just launched into playing the game. I found it easier to pose the question at the end, by which time almost everyone had an answer to *"What's your favorite microbe?"* Many chose the microbe that won the game, but others said things like *"I love the one that helps corals grow"* (Symbiodinium spp.), *"I like the one that helps you break down food"* (Bacteroides spp.), and *"I like the one that makes mice attracted to cats"* (Toxoplasma gondii).

Symbiodinium spp.

Bacteroides spp.



Toxoplasma gondii

Inevitably, some kids asked me the same question, giving me another chance to share my interest and enthusiasm.

"I love them all!"

Twin embryos of *Rhogeessa minutilla*.

DANIEL URBAN

Description: Nope, that's not a mirror image. These are twin embryos of the bat species *Rhogeessa minutilla*. These embryos were extracted from a specimen at the American Museum of Natural History that was originally

collected in 1938. The 80-year-old embryos are being examined as part of a research project focused on understanding the origin of bat wing development.

THE SONIFICATION of Molecular Biology

The International Community of Auditory Display defines sonification as the use of non-speech audio to convey information. Generally, graphical visualization has been used to represent information. More recently, the significant development of computer technology and the enormous influx of data have influenced the emergence of auditory representation, which, along with the visualization, can establish a multimodality (audio-visual) platform for data analysis. Moreover, sonification helps visually impaired people to explore and manipulate data and in some instances can generate more recognizable and memorable representations, and probably, more exciting ones. Although sonification has been used in different scientific fields with different types of sound, this article will focus on the use of sonification to translate the sequences of DNA, RNA, and proteins into music.

I am a researcher in the field of virology; I am interested in understanding the behavior of viruses during infection by studying their genome sequences. I also have a keen interest in music, having played several instruments and studied different music notation systems. There is an interesting overlap between the two fields that stems mainly from the fact that both of them use a heritable coding system to generate meaningful products. This overlap has been exploited by biologists and musicians to sonify the sequences of macromolecules (DNA, RNA, and proteins), which is thought to help in characterizing some visually-unclear patterns. The sonification process involves parameterizing musical pitches by modifying their characteristics, e.g. duration and frequency, to map the genome or protein sequence. In other words, it builds a logical and audible relationship between the two coding systems.

The coding system of the DNA and RNA is mainly composed of four nitrogen bases known as adenine= A, guanine= G, cytosine= C, and thymine= T for the DNA (thymine is replaced by uracil = U in RNA.)

The orders of these bases are recognized by specific molecules in the cell that ultimately translate them into different proteins with different functions. The building blocks of proteins are chemical compounds called amino acids; there are 20 amino acids that attach in specific orders, dictated by the order of codons in each strand of DNA (every three nucleotides in the DNA constitute a unit called a codon that corresponds to a particular amino acid; there are 64 codons.)

On the other hand, the coding system of music is composed of seven unique sounds known as notes and represented by the letters C, D, E, F, G, A, B or Do, Re, Mi, Fa, Sol, La, Si in the solfège naming convention.

These seven notes have different pitches ranging between low and high (Do and Si, in this case, respectively). When they come together in the order above, they are called a musical scale. These notes, as macromolecule sequences, can come in different orders to produce distinct melodies that are usually translated by a musical instrument or computer software.

G = *Re*

C = *Mi*

T = *Sol*

A = *La*

The general method of genome and proteins sonification is based on mapping either the nucleotides, codons, or amino acids into musical notes. This mapping can be divided into two main categories, synthetic and analytic. The synthetic is the simple form of sonification where a nucleotide or amino acid is assigned to a different individual music note. For example, in one study the DNA nucleotides were assigned to different music notes with the following pattern: G = Re, C = Mi, T = Sol, and A = La. This arrangement will produce low-keyed and high-keyed pitches for the GC-rich and AT-rich regions, respectively.[1]

The same concept was applied to the amino acids, but the musical chords—which are a harmonic set of pitches—were used this time to improve the musicality.[2] In another study, different notes were assigned to individual codons to translate human and mouse interferon genes (IFN-α) into music. The authors reported that the IFN-α melody was more structured, i.e. had a higher musicality, than a randomized sequence.[3]

The analytic approach is more complicated and tends to parameterize more biological features to account for more analytical details. For example, the amino acids were translated into musical notes to study proteins folding, wherein the authors used rhythmic variations to account for secondary structure and the full range of the piano to capture the surface-to-depth relationship.[4] RNA structure is another feature that has been sonified by using a collection of sounds with different quality (sound timbre) to represent the shape information.[5]

> Furthermore, sonification was applied to a chromatin immunoprecipitation sequencing (Chip-Seq) dataset to study epigenetic modification.[6] The authors reported that the sonified chromatin signals were more harmonious, melodious, and tuneful than the randomized data. Despite the potential of sonification in enhancing the analysis of biological problems, integrative and user-friendly platforms are still limited, and only a few real-time sonification web tools are available.[7-8]

Using the same concept, the cellist and composer Thilo Krigar put together a symphony of four parts called *Transcription, Translation, Metabolism, and Replication*. He used the electrons on the atoms of the macromolecules to generate the musical scales. In his work, Kriger has devised a possible sophisticated application of sonification whereby the flow of genetic information and cell biochemistry, rather than the genome or protein sequences, are translated into music. Kriger was cautious about maintaining the balance between music and science and wanted the resulting music to be aesthetically appealing and scientifically meaningful.[9]

For the process of sonifying the biological data to be more effective and useful, a clear definition of the art/ music and science/biology must be made. Should the process be approached from the perspective of an artist, who will base the decision on aesthetic factors, or that of a scientist who will build the decisions more on factual and scientific issues? An interesting collaboration between the musician John Dunn and the biologist Mary Anne Clark exemplifies this dichotomy between science and art. [10] With more collaboration like this and the ever-increasingly available sequencing data, the sonification method can be enriched by including more essential elements in the mapping process from both sides. Dunn and Clark used one method to compose musical pieces from the amino acid sequence of the enzyme lysozyme C; the pieces were developed independently and from two different locations but with the same data. Although they used the same sonification software, they both generated different pieces in terms of rhythm, tempo, and instrumentation— crucial factors to personalize music. Describing their experience with their own words:

"Listening to these parallel compositions...gave more insight into the astounding depth of structure Nature has built into her art."

With more collaboration like this and the ever-increasing available sequencing data, the sonification method can be enriched by including more essential elements in the mapping process from both sides. For example, as a virologist who practices music, I would imagine a musical element such as ornamentation—which is an added decorative note that does not change the main melody—can be used to study the swarm of mutants within viral populations. Moreover, to analyze the hybrid nature of a virus recombinant, the technique of switching the musical mode would be a useful tool. The musical mode refers to the intervals between notes within a given musical scale; also known as Maqam in Turkey and the Middle East. A musical example for this technique can be found in *Humoresque Op. 101 No. 7* by Dvořák wherein the musical mode C-major was switched to D-minor in the second part of the piece reflecting a complete new musical context. Finally, it is worth mentioning that although music shares many features with macromolecules in terms of the structural organization and mechanism of the coding systems, it is prone to different interpretations and there is no one true realistic interpretation for any musical piece.

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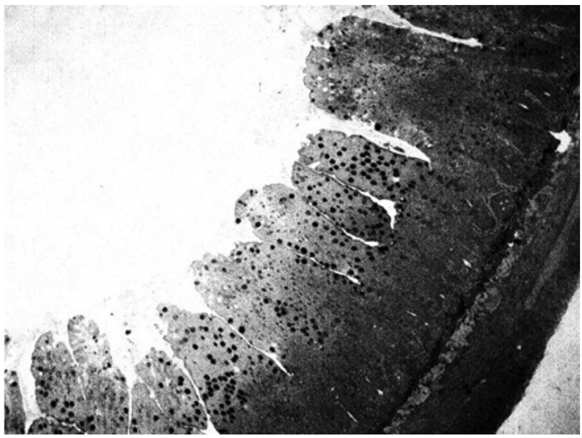
XIAOJI LIU, FSHN

Eat Your Broccoli!

These images show rat ileum sections
Image by Lou Ann Miller, Frederick Seitz Materials Research Laboratory.

Rat ileum damaged by DDS.



Cell integrity was restored in rats fed a cooked broccoli diet.

WHERE SCIENCE
MEETS SOCIETY

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