

SPOTLIGHT

Engaging new audiences with imaging and microscopy

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ABSTRACT

In this Spotlight, we hear first-hand accounts from five scientists and educators who use microscopy and imaging to engage, entertain, educate and inspire new audiences with science and the field of developmental biology in particular. The 'voices' that follow each convey each authors' own personal take on why microscopy is such a powerful tool for capturing the minds, and the hearts, of scientists, students and the public alike. They discuss how microscopy and imaging can reveal new worlds, and improve our communication and understanding of developmental biology, as well as break down barriers and promote diversity for future generations of scientific researchers.

Seeing is believing

Michael Barresi

Most people are only used to seeing the world around them through the scaling power of their eyes; thus, the diverse microscopic life all around us is invisible. This is akin to seeing the structure of a library but being unable to realize the written knowledge inside that building. Understanding the microscopic world has the potential to transform our comprehension of how life works, the importance of which is as profound as the millions of lives lost to COVID-19. The responsibility falls to educators and scientists to wield the microscope to make this universe visible and to more truthfully inform the perspectives of students and the broader public.

As a professor of developmental biology, I have learned that the most significant barrier to student comprehension is the lack of a contextual picture of what an embryo looks like, without which students are left making less-educated assumptions that can misguide their understanding of the concepts. Therefore, I try to expose students to the direct imagery of developmental biology, as early and as often as possible, to help build an authentic view of the embryo. However, scientific data are not particularly accessible to the public. It is extremely important that scientists endeavor to both tailor and share their image-based data in more inclusive ways through open sources and educational resources, such as the Society for Developmental Biology's CoRe website (<https://www.sdbcore.org/>) or social media platforms. Imagine the benefit if, for every research paper published, the authors also generated an open-source, educational version of the article with annotated visuals for a broader audience. Such efforts can go a long way to help the public become more visually literate in the world of cell and developmental biology.

I further argue it is also the responsibility of educators and scientists alike to translate the image-based data and concepts into relatable visual models. As an author of Developmental Biology (Barresi and Gilbert, 2019), imagining the processes that build the embryo into visuals that can communicate these complex topics presents a uniquely fun challenge in the art of translation. Historically, microscopists and embryologists in particular had to be accomplished fine-art illustrators to accurately document what they were seeing. I am fortunate to have grown up with an interest and formal training in studio art, which has afforded me many tools to help communicate abstract processes into understandable visuals. Scientist-artists, however, are now few, and therefore scientists should consider forming collaborations with artists, even art students, to arrive at novel visual representations that improve science communication.

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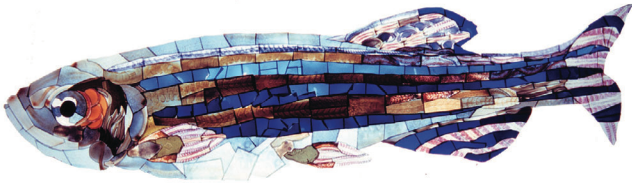
[‡]This author contributed exclusively to 'Seeing is believing'. [§]This author contributed exclusively to 'Inner Worlds'. [¶]This author contributed exclusively to 'Visualizing vision: A researcher's venture into science art'. ^{**}This author contributed exclusively to 'BioEYES'. ^{‡‡}This author contributed exclusively to 'But first, let me take a selfie'.

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It should be the responsibility of the scientific community to increase the number of diverse eyes peering through microscopes

Last, I must acknowledge the inherent biases in one individual's interpreted re-imagination of image-based data. What one sees, one often believes. It should be the responsibility of the scientific community to increase the number of diverse eyes peering through microscopes, as opposed to it being a privileged experience for a few, often socioeconomically advantaged, people. Creating the 'Student Scientists' outreach program has been one of my most fulfilling accomplishments, where we share both microscopes and live zebrafish embryos with students of all ages. For the developmental biologist reading this, don't you recall the life changing experience of seeing your favorite organism under the microscope for the first time? You have the power, pedagogy and privilege to share this experience with others, an experience that will improve how science is 'seen'.



From microscope to a mosaic understanding of our world. This mosaic of an adult zebrafish was made from pieces of slide film captured during imaging of zebrafish embryos on epifluorescent and light compound and stereo microscopes. Embryos imaged were prepared for the study of muscle development. The data were obtained by and the mosaic was created by M.J.B. during his doctoral studies in the laboratory of Dr Stephen Devoto. Image courtesy of M.J.B.

Inner worlds

Enrico Coen

In 1983, an unscheduled speaker, Ernst Hafen, took the stage at a developmental biology conference, excited about a new result he had to share. *In situ* hybridization was in its infancy, and there had been much hypothesizing about how genes control fly segmentation patterns based on genetics. Suddenly there it was: an image of seven, neatly spaced expression stripes in the embryo, just as the genetics had predicted. The audience gasped. I found myself smiling, as I always do when nature, normally so reluctant to divulge its secrets, lets down its guard. The beauty of images derives not only from their content, but also from the expectations we bring to them.

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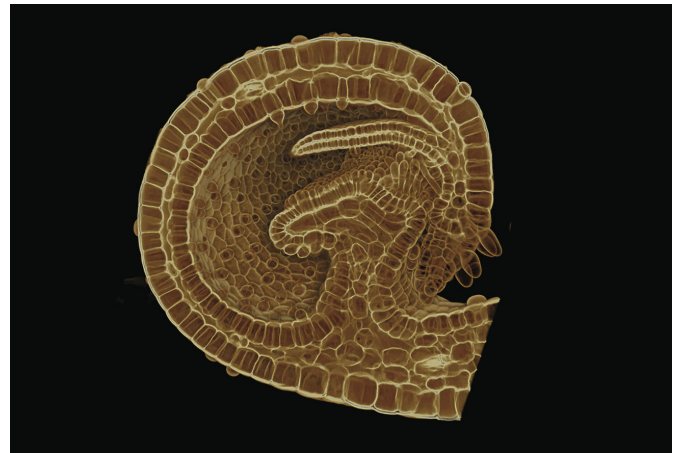
Images can confirm, refute and inspire. David Attenborough exploits these powers to convey hypotheses about survival and reproduction in nature. His movies are captivating because they use stunning imagery to reveal both the logic and remarkable idiosyncrasies of the natural world. Developmental biology is also replete with extraordinary images and stories that are no less bizarre and fascinating than those of natural history. But the task of dissemination is more challenging because its characters – genes, proteins, signaling molecules and cells – are less well known and its hypotheses more abstract.

Bioimaging has made great strides since Ernst Hafen took the stage. We are no longer restricted to still images but can follow

proteins, cell behaviors and tissue shapes through live imaging in three dimensions. We also use computational models to evaluate hypotheses through simulation. A challenge is to exploit these resources to share ideas and findings that bubble up from our research with a wider audience.

Several years ago, my research group set up a website, 'Inner Worlds' (<http://innerworlds.jic.ac.uk/>). We collated images and movies around our research questions, together with brief summaries of the hypotheses that provide possible answers. Where possible, we used juxtapositions to bring out key ideas. For example, our 'How do plants shape themselves?' page combines movies from optical projection tomography, confocal imaging, computer simulation, shrinking plastic and pottery to convey how differential growth can generate a diversity of forms. Our 'How did the variety of leaf forms evolve?' page, exploits the reversal of plant and animal roles in carnivorous plants to highlight key principles underlying the generation of tissue shapes through 3D imagery.

Sharing research findings in this way is not only effective (our website has had more than 600,000 views) but enjoyable and stimulating. As developmental biologists, we are so used to living in a world peopled by genes, proteins, cells and tissues continually playing off each other, that it can be difficult to see how weird and incomprehensible it may seem from the outside. We have all been met with bemused expressions when trying to explain what we do to others. The exercise of trying to distil, extract and juxtapose images clarifies ideas and helps convey some of the most fascinating stories biology has to tell.



A young *Utricularia gibba* carnivorous plant trap imaged by confocal microscopy. The trap is about 200 μ m wide and consists of two cell layers. *U. gibba* was used as a model system to show how gene expression boundary domains could explain repeated evolution of cup shapes from species with planar leaves. Image courtesy of E.C.

Visualizing vision: a researcher's venture into science art Elisabeth Kugler

The human visual memory is extraordinary in its capacity to remember astonishing detail of image novelty (seen/unseen), pattern (e.g. round/square) and state (e.g. open/closed) (Brady et al., 2008). More importantly, seeing an image is a sensory input, which can have a 'wow-effect', inspire curiosity, or resonate with an emotional state. Thus, an image is not only what we see, but also what we feel. This holds true across all ages, backgrounds and knowledge, making visual media invaluable to communicate research and engage with the public.

In biological sciences, a great proportion of data is imagery, particularly microscopy images, making them suitable to communicate science. However, it is no longer merely about how and what data are acquired, but also about how we visualize, represent and communicate the data and respective results.

Personally, I have always equally loved arts and science. During my education, I regularly worked on image-based projects, including studies on ciliogenesis, collective cell migration, cerebrovascular development and, lately, vision research. Thus, it became a natural path to merge science and art into visual media in my science communication. I frequently display genuine microscopy data, but artistic license is applied to aspects such as color palettes, composition or perspectives. As distribution platforms, I mainly use Twitter and my website (<https://www.elisabethkugler.com/>), which allow me to share my science art globally and without limited distribution.

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In addition to conveying information, science communication is also pivotal to inspiring curiosity. Science is not the boring cliché of pipettes and test tubes, but colorful, exciting and stimulating; this is best exemplified when looking at fluorescent microscopy to image data of cells smaller than a single spider silk strand and following their development over days. To share this passion for science, myriads of communication formats and platforms exist, such as social media, podcasts, blogs, websites, talks, events or videos. Still, barriers to participation in science communication exist (Mackay et al., 2020), with the most prominent being lack of time and dedicated training.

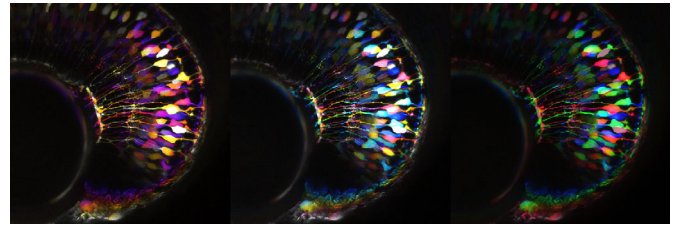
Besides, researchers are educated to critically assess and scrutinize. However, the mindset of communication has to be about clarity and simplicity not necessarily absolute accuracy (Olson, 2009). To achieve this, one can find inspiration in the many fields beyond science, such as industry, arts, music or theatre. Scientists are used to following strict protocols and guides, but science communication is an opportunity to venture outside routine ways. Experimenting with new formats allows the expansion of one's comfort zone and inter-personal relationships, which ultimately feeds back into overall improved communication skills.

The future of science communication and public engagement is an exciting one, but dedicated training, job positions and funding are needed to provide resources for effective, wide-ranging and cross-disciplinary science communication. Investing in science communication and public outreach is crucial to build public trust, share information and inspire.

BioEYES

Jamie Shuda

'The most interesting part was when I looked in the microscope to see if the baby fish grew up. The fish looked so cool!', an 8th grader shared. A high school student wrote, 'I learned that zebrafish and other things are much clearer to see using a microscope'. These types of comments are common student reactions to 'Project BioEYES' (<https://bioeyes.org/>) and our week-long classroom experiments. BioEYES focuses on providing life science and genetics content, teaching support and scientific supplies at no cost



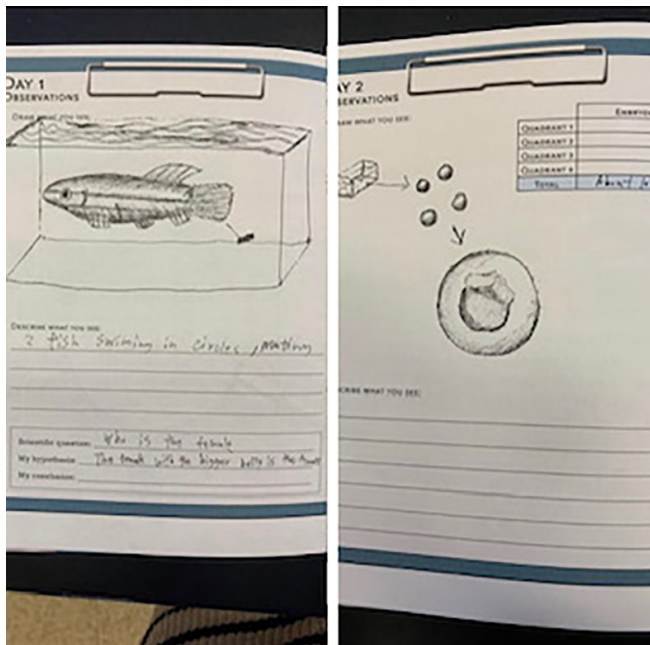
Retina support cells, called Müller glia cells, in the eye of a 3-day-old zebrafish. Linking neurons and blood vessels, these cells are crucial for healthy vision. The image is color-coded by depth, with the three images using a different color palette. Image acquired and processed by E.K.

to our most under-resourced city schools in an approach that lets the students question, explore and learn about the world around them. Microscopy is embedded in our program and provides a hands-on, exciting experience for the students to become the scientists right in their classrooms. This is not accidental. With over 85% of our student population being from communities of color and qualifying for free and reduced lunch, providing simple scientific equipment, like dissecting or stereomicroscopes, along with grade-appropriate curricula and personnel support helps fill in the science educational gaps that inhibit many of these students from seeing themselves as capable of a career in the science field.

Building scientific skills is about asking questions, collecting data and drawing conclusions based on evidence. During BioEYES, students cross adult zebrafish and then raise the offspring over 5 days to collect data on how pigment is inherited. Allowing students to compare embryo development at their desks and then again using a stereomicroscope provides the opportunity for them to see, first hand, that there is so much more that scientific investigations can provide if we learn how to use the right tools. Through the microscopes provided by our program, students clearly see black spots on the wild-type larvae as well as the live heartbeat and blood circulating throughout these developing organisms. These are the fish the students raise and study. This experience is not of a video or a picture in a textbook, it is a live demonstration of these young scientists' hard work, care and dedication to completing an experiment designed to bridge science content and real research.

BioEYES also allows students to see skin color in a scientific way. For many students, the color of their skin is built on a social construct – one the USA is working to dismantle. Within BioEYES, students use the microscope daily to look for signs of melanin, to quantify what they observe at 40× magnification, and to draw the developing embryos as they rapidly change. From seeing the visceral reactions of students and teachers peering into microscopes, recognizing the live heartbeats of the zebrafish larvae and comprehending that pigment is a dominant trait, the experience exemplifies the power of microscopy as a teaching tool. BioEYES shows students how they can contribute to science and to their own scientific understanding, no matter what their race or ethnicity, their reading age, or their first language. Having access to microscopes, coupled with rigorous curricula, can provide a lens that levels the playing field for our youngest emerging scientists.'

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(Left and right) A Philadelphia 10th grade student's observation of zebrafish fertilization and embryo development. Image courtesy of Jacqueline Davidson, BioEYES Philadelphia.

But first, let me take a cellfie

Derek C. Sung

'So what is it exactly that you do?' – this is a question that scientists are all too familiar with. For me, it is one that I am repeatedly asked from my non-scientist friends and family. Equally familiar may be the blank stares we get as we try to explain our research. As many of us live, eat and breathe science, it can be easy to forget that science is, in a way, its own language. And, unfortunately, many believe it to be a language that requires years of education and multi-lettered degrees after your name to understand.

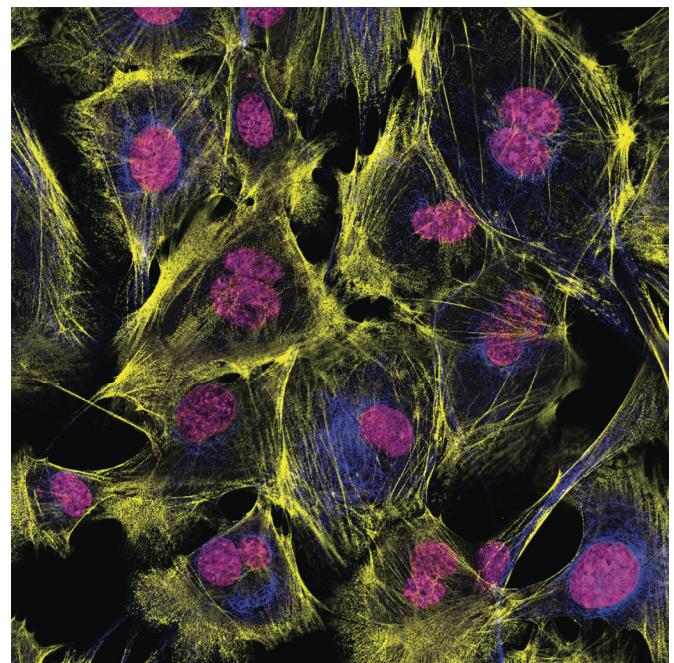
I first started my Instagram account, @Immunofluorescence (www.instagram.com/immunofluorescence), as a way to show my family and friends what I did in the lab. Even if they couldn't exactly understand what I was saying, the look of intrigue at the colorful display of immunofluorescence was universal. What I didn't expect were the strangers on the internet that flocked to my page, many of them commenting things like, 'what am I looking at?' or 'how does this work?'. They were eager to find out more and learn the biology behind the images. Over time, I began writing captions that touched upon different facets of physiology and disease (most of which coincided with my own medical and scientific education) using language that was accessible. It was gratifying to see scientists and non-scientists alike respond in wonder as they learned something new. I found social media to be the perfect platform not only to share the artistic side of my science, but also to disseminate information to the masses.

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I often wonder why people from so many different (often non-scientific) backgrounds are drawn to my work. I think they, like me,

see the inherent beauty of microscopy: a colorful crossover of nature's order and our longing to understand it. Whether it's the cytoskeletal contours of a cell or the muscular chambers of the heart, visualizing microscopic structures that exist within us almost feels magical. Being able to see the biology rather than just read about it makes all the difference. Through art, I could capture their intrigue. After that, I could introduce to them the wonderful complexity of biology.

The disconnect between scientists and non-scientists is a problem that remains unaddressed within the scientific community. As I continued to navigate the world of social media, I began to see the value in using my platform beyond sharing cool microscopy and biology. When we teach people about what we do in ways they can understand, we instill new information in them while building trust in science as an institution. Through microscopy and social media, I feel like I can give insight into the rigor and ingenuity that goes into so many ground-breaking scientific discoveries but also into flawed scientific processes. What ultimately draws someone to my microscopy is the same innate wonder and curiosity that drew all of us to science – an insatiable hunger to learn more and the daringness to ask 'why?'.



Sertoli cells in the testes provide structural integrity and support sperm maturation. One of the ways Sertoli cells do this is by forming the blood-testis barrier, a tight seal that protects developing sperm that is analogous to the blood-brain barrier. Shown here are Sertoli cells stained for the cytoskeletal components non-muscle myosin 2A (yellow) and acetylated tubulin (blue), which are important for formation and maintenance of the blood-testis barrier. DAPI-stained nuclei are in magenta. Image courtesy of D.C.S.

Acknowledgements

This Spotlight article has not been peer reviewed. M.J.B. thanks his 7th grade biology teacher, Mr Thomas Deshais, who set up a microscope with a camera specifically for Michael to take his first images of the microscopic world. E.C. thanks Matthew Couchman and Karen Lee for maintaining and continually improving the Inner Worlds website. E.K. is grateful to Ryan MacDonald for guidance, feedback and support. Project BioEYES would not be possible without the scientific advice of Dr Steven Farber, the outreach education teams, including Theresa Nelson, Jacqueline Davidson, Anthony Natale, Valerie Butler, Terrone Jasper and Rob Vary, and our partnering teachers. D.C.S. acknowledges and thanks Dr Andrea Stout and

Jasmine Zhao (UPenn CDB Microscopy Core), and Drs Christian Combs and Daniela Malide (NHLBI Light Microscopy Core) for their work in maintaining the microscopes and expertise in imaging.

Competing interests

The authors declare no competing or financial interests.

Funding

M.J.B. is funded by the National Science Foundation (IOS-1656310), the National Institutes of Health (1R15HD099028-01), the Arnold and Mabel Beckman Foundation and Smith College. E.K. is funded via a Moorfields Eye Charity Springboard award (GR001208) awarded to Ryan MacDonald. The Institute for Regenerative Medicine at the University of Pennsylvania and the Department of Embryology at the Carnegie Institution for Science continuously provides in-kind and financial support to J.S. The University of Pennsylvania BioEYES program is supported, in part, by the National Institutes of Health (P50-HD068157-06A1).

D.C.S. is supported by the National Institutes of Health (F30HL158014). E.C.'s work is supported by grants from the Biotechnology and Biological Sciences Research Council (BB/S009256/1, BBS/E/J/000PR9787 and BB/M023117/1).

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