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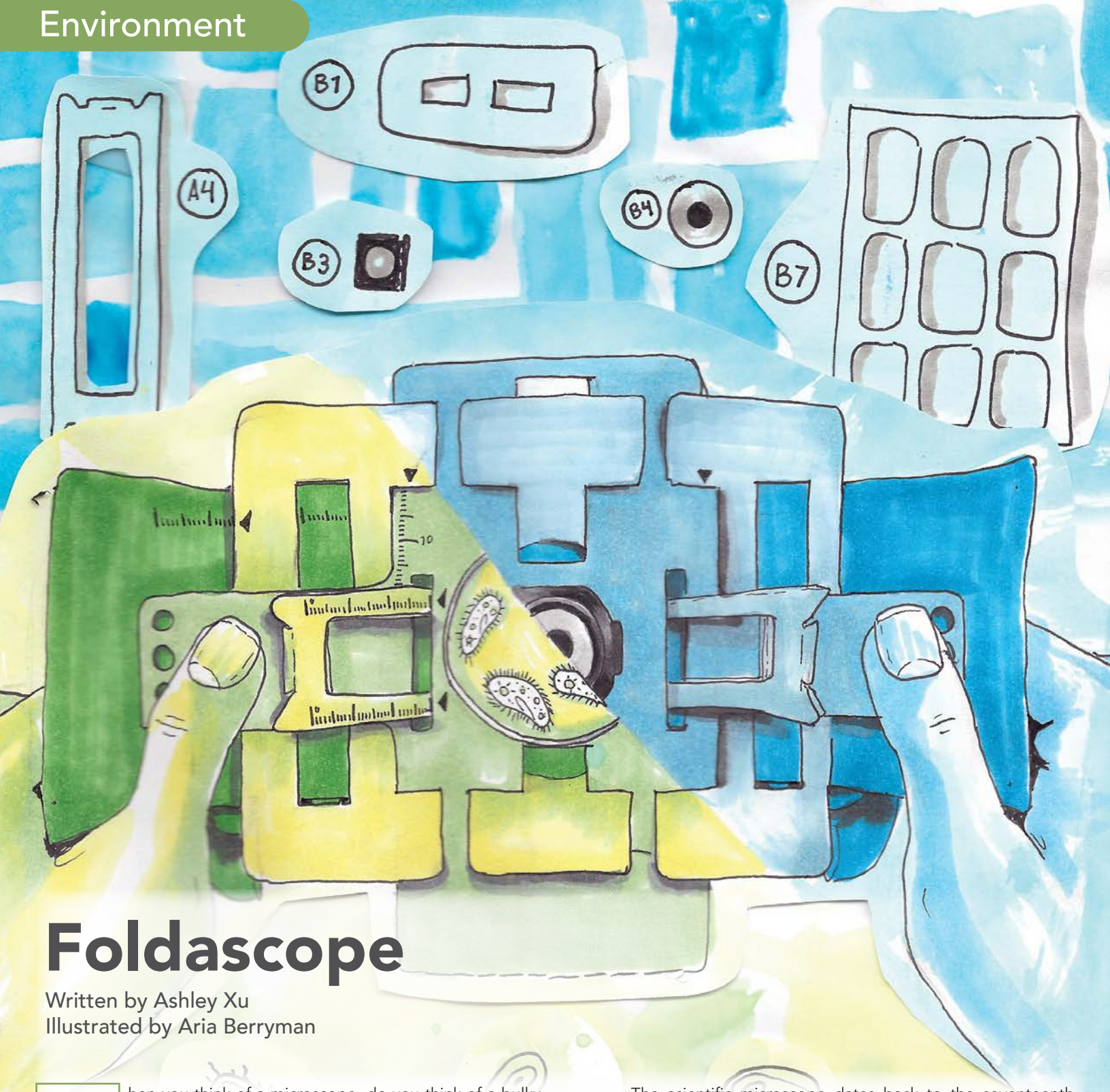

Foldascope

Written by Ashley Xu
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When you think of a microscope, do you think of a bulky, fragile piece of equipment worth hundreds, maybe even thousands of dollars? I bet you're definitely not imagining an item you would purchase for casual everyday use, let alone imagining a paper-thin, bookmark-sized object you could fit in your pocket. Well, you thought wrong! The Foldscope is a portable microscope that can be assembled simply by folding a standard-sized sheet of plastic-coated paper with a lens printed directly into it. Now, what if I told you that this über-portable microscope is also ultra-affordable, costing almost nothing to create? What if I also told you this microscope could withstand being stomped on, doused in water, and dropped from a five-story building, and still come out unscathed and completely functional?

The scientific microscope dates back to the seventeenth century, when Antonie van Leeuwenhoek (1632-1723) invented the first microscope, a small handheld device held close to the eye, created using two pieces of metal and a small spherical lens. Leeuwenhoek was no scientist—he was a Dutch textile merchant—but he had an insatiable curiosity and desire to learn about the world around him. As a result of his own experimentation, he created a microscope and was the first person to view single-celled organisms, opening up a whole new world of knowledge and leaving an indelible mark on modern science. His microscope eventually evolved into the large clunky microscopes typically used in U.S. schools, but the Foldscope is probably more similar to the first microscope.

The Foldscope, an optical microscope costing less than $1

USD to manufacture, is assembled from one standard sheet of paper and a 2.38 millimeter glass lens that is printed into the paper. With an imaging resolution of two microns and a magnification range of 140-2000 times, the Foldscope allows users to view microscopic specimens like red blood cells and live bacteria. The Foldscope accommodates a standard-sized glass microscope slide and requires only natural light to operate, but a light source can easily be attached using a simple LED light and watch battery. Findings can even be projected onto a screen or wall using a light source. The parts of the Foldscope are color-coded, to be punched out of paper and folded, assembled like origami in just several minutes. The origami assembly allows for precise alignment of each part, and the instructions are text-free and diagram-based, allowing anyone, anywhere in the world to put it together easily. A fully-assembled Foldscope is about the size of a bookmark and weighs under 10 grams, which is about the weight of two nickels!

To use a Foldscope, one simply places a sample on a microscope slide, inserts the slide in front of the lens, and then raises the Foldscope to one eye so that it almost touches the eyebrow. To adjust the viewing field, users pull tabs on the side of the Foldscope to slide the lens to different locations over the microscope slide. To focus an image, users flex and bend the paper Foldscope to adjust the distance between the slide and the lens, until the image becomes clear. The fantastic optical physics of small spherical lenses allow for the high resolution and magnification exhibited by the Foldscope.

The Foldscope was developed by Manu Prakash, an assistant professor of bioengineering at the Stanford School of Medicine, and co-inventor Jim Cybulski, a Ph.D. student in Prakash's lab at the time. Prakash was first inspired to create the Foldscope in 2011 when he was traveling in Thailand. He noticed that many field stations and remote clinics had state-of-the-art microscopes on hand. However, most people were too afraid to use these microscopes because they were anxious about possibly breaking such expensive pieces of equipment, so the microscopes often ended up under lock-and-key, almost never to be used. Prakash's observation of these clinics in Thailand was in no way unique.

Around the world, millions of people living in parts of Africa, Asia, and Latin America are plagued by infectious diseases and a lack of resources to identify and treat them. Doctors require microscopes to diagnose their patients, and most of these poor, remote regions do not have access to the necessary technology, leading to people being misdiagnosed or left untreated. Even in places that do have microscopes, parts often break or have mold grow over the lenses in humid climates, rendering the machines unusable. Without the money and knowledge to properly maintain microscopes, clinics are left powerless and ineffective.

After his trip to Thailand, Prakash was determined to find a way to develop a cheap and durable alternative to the traditional microscope that could easily be carried and used in field conditions. In 2012, the first prototypes of the Foldscope were developed and refined by Prakash and his team of researchers at Stanford. In 2012, Manu Prakash gave a presentation at TEDGlobal, bringing the Foldscope to the world's attention, and that same year, the Bill and Melinda Gates Foundation provided them with a $100,000 grant to field test the Foldscope in India, Thailand, and Uganda. In 2014, Prakash and Cybulski published a paper detailing how to build and assemble a Foldscope as well as the Foldscope's full range of capabilities.

The Gordon and Betty Moore Foundation supported Prakash and his team in distributing upwards of 60,000 Foldscopes in over 135 countries in 2014. These Foldscopes were distributed by volunteers at no cost to the recipients. All that was asked of recipients was that they share the findings made with their Foldscopes to on an online community called the Microcosmos, aptly named for the infinitesimal world, or micro cosmos, that microscopes open up to the human eye. Camera phones are compatible with Foldscopes by holding the camera up to the microscope's lens to easily record videos or take photos. Users were encouraged to document their findings on the Microcosmos website, where anyone can see Foldscope pictures from users all around the world. The site features everything from a 5-year-old's look at E. coli in a household kitchen in the U.S. to a doctor's view of a patient's malaria-infected red blood cells in Africa to a teenager's observation of tardigrades in a backyard in India. In December 2015, Manu Prakash and Jim Cybulski founded Foldscope Instruments, Inc., a for-profit business, with a nonprofit subsidiary dedicated to subsidizing costs for sending Foldscopes to resource-

> It is up to artists, archaeologists, and preservationists not only to uncover and guard artistic heritage but also to shed light on and be conscious of art's environmental issues.

poor communities all around the world. Today, Foldscopes are widely available online.

The Foldscope has revolutionized the approach to treating diseases in poor countries. It currently comes in twelve medical diagnostic variants, each designed to identify a specific disease-causing organism. Using this small microscope, scientists and health workers can identify the parasites that cause malaria, African sleeping sickness, black fever, and various other tropical diseases. Foldscopes are extraordinarily versatile and can be adapted for various different uses, such as bright-field, dark-field, fluorescence, and projection microscopy. Special LED lights, multiple lenses, and filters can all be added to the Foldscope to aid in the identification of specific organisms.

Prakash aims to put microscopes in the hands of everyday people with no extensive backgrounds in science—people like Leeuwenhoek—from young children to adults, to see what curious minds can discover about the natural world. Prakash is interested in biomimicry, which is the design and modeling of technological systems based off of natural biological processes in the world around us. Through encouraging all Foldscope users to post their discoveries on the Microcosmos online community, Prakash has made the entire world his laboratory, with everyday laymen as his researchers, in the hopes that new discoveries will be made toward better understanding how and why certain organisms behave the way they do and leveraging this knowledge to potentially create more efficient and effective tools. Foldscopes have left their mark on science education in developing countries. Their inexpensive nature allows them to be widely distributed to everyone from young children to university students in countries that would otherwise never have the financial resources to provide expensive traditional microscopes to every school, let alone every student. Prakash's biggest goal in making the Foldscope is to make people curious, with the hope that one day, every child can carry a microscope in their pocket.

As of October 2018, there are now over half a million Foldscopes distributed all around the world, and they are in use in over 140 countries.

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