MEET ELISABETH BIK

SCIENTIFIC FRAUDSTER BUSTER

TEXT **ZARWA SAQIB** PHOTO **MICHEL & CO PHOTOGRAPHY**

Elisabeth Bik has caught a lot of public attention through her Twitter account, @MicrobiomDigest, where she reports evidence of image forgery in academic research papers - including from respected journals like *Science* and *Nature Communications*. Bik's unique image sleuthing skills and perseverance have earned her a worldwide following of around 70,000 followers on Twitter. She challenges her growing audience by posting suspected de-identified images under the hashtag, #ImageForensics, and requesting for comments on apparent problems before revealing her answers. "Once you point it out, others start seeing it more," Bik said. "Interestingly, some people have picked up the data cop skills and have started to contact me privately about problematic images they see while peer-reviewing manuscripts or reading papers." Bik estimates that she has spent more than 5,000 hours inspecting papers over the past few years in an effort to corroborate reliable science for not only researchers but also for the public.

A microbiologist by training, Bik decided to quit her full-time job at a biomedical start-up firm in California to better serve the research community as an image integrity data cop – pro bono. "It started as a hobby, but soon I realized my passion for image sleuthing was growing more than my paid job," she said.

A 2019 cross-sectional study found that for every 10,000 publications on PubMed 2.5 are retracted, with 65.3 per cent of cases being due to misconduct [1]. Scientific misconduct is not limited to plagiarizing text without giving credits, but it also extends to instances where images are reused and reported as "new data," or where parts of images are rotated, shifted, or cloned to represent experiments that were never performed. Bik's Twitter account cited many such papers with apparent problems, such as unconfessed reuse of images, or the minutely botched duplication of parts of images.

Bik first stumbled upon the reports of suspected misconduct in the literature when she found an online book chapter with text plagiarized from her published review on the microbiome. "The plagiarized paper was a patchwork of stolen sentences from various resources, including mine, without any authorship," Bik said. Then, while browsing through a doctoral thesis, she noticed multiple copies of a western blot (a test used to detect proteins in biological samples) shifted in different orientations to represent different experiments. However, a more concerning fact for her was that these thesis chapters were published as research articles, with the same errors. "Image forgery and doctoring are much worse than plagiarizing text," Bik said. "It's significantly misleading science, and if you want to publish data then it should all be done properly and honestly." In fact, studies have suggested that up to one in five papers in the life sciences include manipulated photographs or images [2]. However, rarely do reported cases lead to retractions or corrections.

In 2019, a study followed 12 retracted articles and reported that only one out of 68 papers that cited the retracted work was re-evaluated and amended to account for the retraction [3]. Frustrated by discovering plagiarized text and doctored images in publications, Bik started using her twitter account as a place to highlight potential problems in the published scientific literature.

Unlike other image sleuths who work behind closed doors and prefer not to be identified, Bik has a reputation of posting detailed comments and criticism seen in papers on PubPeer – a post-publication feedback platform for researchers. Bik estimates that since 2014 she has unfearfully published approximately more than 2,000 comments under her name on PubPeer. Her willingness to attach her name to the criticisms encourages authors and other researchers to take her allegations seriously. The avalanche of reactions and public awareness generated by her work has pressurized journals to investigate papers and have prompted dozens of retractions, including 22 papers from *PLoS ONE*. Bik estimates that her reports have contributed to more than 170 retractions and approximately 300 errata and corrections.

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Bik's courage to call-out data fraud has inspired other scientists to report instances of misconduct more publicly. In 2018, a group of scientists reported and launched retractiondatabase.org, one of the largest databases consisting of 18,000 retracted journal articles, dated since the 1970s [4]. Scientists recognized that the number of retracted papers containing flawed images rose to 24 per cent in 2002, but the number has since been oscillating. "The scourge of fraudulent image doctoring in biomedical research articles is very common," Bik said. "If your results can't be trusted then other people can waste their careers, time, and money on trying to replicate data that does not exist."

Who to blame? Technical glitch or human error?

In 2016, Bik and colleagues published a detailed study where they screened and analyzed more than 20,000 biomedical papers from 40 different journals in an effort to investigate and prove the increasing prevalence of "problematic images" in scientific papers [5]. They reported about 782 papers (or four per cent) which contained deliberately manipulated scientific images.

"Our publication was one of the first to investigate the frequency of problems in biomedical work," Bik said. "It has led to much greater awareness and scrutiny among journal editors and peer reviewers." The authors highlighted "problematic images" to be of great concern as it was evident that some aspects of the scientific literature could not be relied upon. The United States Office of Research Integrity (ORI) has reported that the surge in the use of manipulated and fraudulent images increased after the birth of Photoshop in 1990. "Numerous postdocs and students waste months or years chasing things which turn out to not be valid, so it's not only damaging science but also careers and lives," Bik said.

Bik admitted that suspicious data doesn't always indicate corrupt intent as 90 per cent of scientists are sincere and many errors are honest mistakes that don't necessarily require a paper retraction. "Sometimes authors swiftly reply to me on PubPeer under their critiqued papers to point out honest errors ranging from reasons like: images not being clearly labelled, improving image background contrast for clarity, to mistakenly uploading a file twice when preparing images," Bik said. Additionally, other honest errors can result due to defective equipment. For instance, a faulty microscope might cause the appearance of similar dark spots on every image.

Or technical artefacts from sample slices sticking together and then flipping in an orientation that can lead to an apparent mirrored duplication. "Not every issue means a paper is fraudulent or wrong," Bik said. "But some do, which causes deep concern for many researchers."

A study conducted at Arizona State University reported that the increasing pressure to secure external funds, the publish or perish mentality, and the slim odds of being exposed for fraud were the top motivators in prevailing cases of scientific misconduct [6]. These motivators in-conjunction with new and conveniently available image modifying tools has only increased misconduct. "In the days before imaging software became widely available, tasks like manipulating results or academic figures required considerable effort and professionals who had no prior knowledge about the collected data," Bik said. However, the technological advancements of the 21st century have not only increased the speed of data collection but also made it more tempting to adjust or modify digital image files before reporting them [7]. A study by Bik and colleagues found that "academic culture, peer control, cash-based publication incentives, and national misconduct policies" all affect scientific data integrity [8].

In late 2019, Bik was cast in the spotlight when she placed a prominent Chinese immunologist, Cao Xuetao, under scrutiny for having several flow-cytometry images doctored in a 2009 paper published in the *Journal of Immunology*. The wide media coverage led to an investigation of a multitude of articles by China's ministry of education and a re-examination of the manuscripts by Cao himself. Bik found that Cao's lab published 250 research papers and about 50 of them contained problems ranging from duplicated to doctored images. But even in cases where misconduct may have been deliberate, Bik explained that the primary investigator may not always be the one behind the wheel. "These situations prove that there is not enough oversight," Bik said. "Primary investigators from huge labs mostly don't have time – due to other responsibilities and busy schedules – to review papers before publishing. Although, they are not entirely responsible for conducting misconduct themselves, they are still responsible as it's a joint effort to not only support and promote true science but to also train honest scientists."

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More recently, Bik alongside other pseudonymous data cops, including mortenoxe, TigerBB8, Cheshire, schneiderleonid, and SmutClyde assembled and uncovered over 400 research papers in China that all originated from the same paper mill. The company was suspected of generating articles with fake research and fabricated images for medical students. Many students in research programs across the world are required to publish as part of their degree requirements which may encourage misconduct. "The unrealistic goal by the Chinese government requiring medical students to publish research papers during training is really jeopardizing science," Bik said. "Students don't have the time to complete research projects but are forced to publish to earn their degrees."

Open science communication to the rescue

Bik uses an old Mac with an attached monitor and her own eyes to find suspicious figures before notifying the journal in question and politely pointing out suspicious images. Although Bik is proficiently skilled at finding duplicated images, a single person can only do so much. "We need more paid staff at universities and institutes where people can use their talents to deal with these data integrity cases," Bik said.

Bik explained that combating image manipulation and duplication necessitates pre-screening of accepted manuscripts and other system-wide changes in science publishing. Many journals like *EMBO* are executing steps and standards to check submitted figures for evidence of tampering. *EMBO* has reported that inserting pre-publication check points has helped them catch manipulation in 20 per cent of accepted papers – a stubbornly high percentage considering the journal's transparency about its screening policy. Unfortunately, many journals still do not pre-screen their images or in some cases, like *Nature*, only randomly spot-check papers before publication [9]. Publishing company, Wiley, publishes some journals that pre-screen images, and is in the process of starting a screening service with the well-known *Journal of Cellular Biochemistry* and the *Journal of Cellular Physiology* [9]. *Science* has arranged for editorial coordinators to examine accepted manuscripts for suspected image manipulation. However, only looking at submissions individually may mean that images flipped, rotated, and then duplicated in a second paper will be missed [9]. Following Bik's analysis of 960 papers published in *Molecular and Cellular Biology*, which found 6.1 per cent of papers containing duplicated and images, the journal launched a pilot image screening program which has identified problems in 14.5 per cent of subsequent submissions. After Bik highlighted issues of research misconduct in *PLoS ONE*, the journal formed a three-person team dedicated to managing and investigating image integrity and other publication ethics cases in 2018. "I get a sense of job well done when I receive regular notifications of *PLoS ONE* retractions and corrections that have stemmed from my leads," Bik said. In line with open science efforts, some journals like *eLife* have allowed post-publication feedback on their papers. Other online venues like JournalReview.org and PubPeer have also been created to permit readers to discuss and

critique papers from multiple journals. For institutions and journals without internal image detection capacity, companies and organizations including Image Data Integrity (IDI) and the International Life Sciences Institute (ILSI) can provide consultation.

In 2019, the Scientific Integrity Consortium published a detailed recommendation list to encourage ethical scientific conduct [10]. Recommendations encourage scientists to consider the implications of their conducted research on the public, and suggest institutions ingrain the significance of fundamental research ethics in their scientists. This involves fostering the importance of following standardized publication expectations (from appropriate study design to proper data analysis), remaining transparent when reporting study findings, and encouraging a sense of accountability for their research. The consortium also urged journals to value research that may not always represent exciting or positive results due to the nature of the phenomena under investigation. Instead, journals should communicate all types of results by using terms such as "anticipated" and "unanticipated" instead of "positive" or "negative" results [10].

> IT'S A JOINT EFFORT TO NOT ONLY SUPPORT AND PROMOTE TRUE SCIENCE BUT TO ALSO TRAIN HONEST SCIENTISTS

These efforts of ensuring open communication and implementing clear and stringent guidelines for authors to follow highlight the responsibility on authors for ethical and accurate representation of their scientific data. "It's always good to go over your papers and make sure there is nothing wrong with the images and the text because your name is on it," Bik said. However, peer-reviewers must also be vigilant in spending time to thoroughly review and investigate articles before acceptance. Furthermore, journal editors must be the final gatekeeper in ensuring publication ethics are well regulated, and quickly following through with consequences for clear cases of image manipulation.

Can automation replace the human eye?

Many image forensic softwares are being developed to fight image doctoring in academic research. Most publishing houses use iThenticate or Turnitin.com softwares to look for textual similarities in papers, but regular softwares to pinpoint

THINK YOU'VE GOT WHAT IT TAKES?

These are all figures from retracted papers. Can you spot where sections of the images were flipped, rotated, and duplicated?

CHALLENGE #1
Fluorescence microscopy

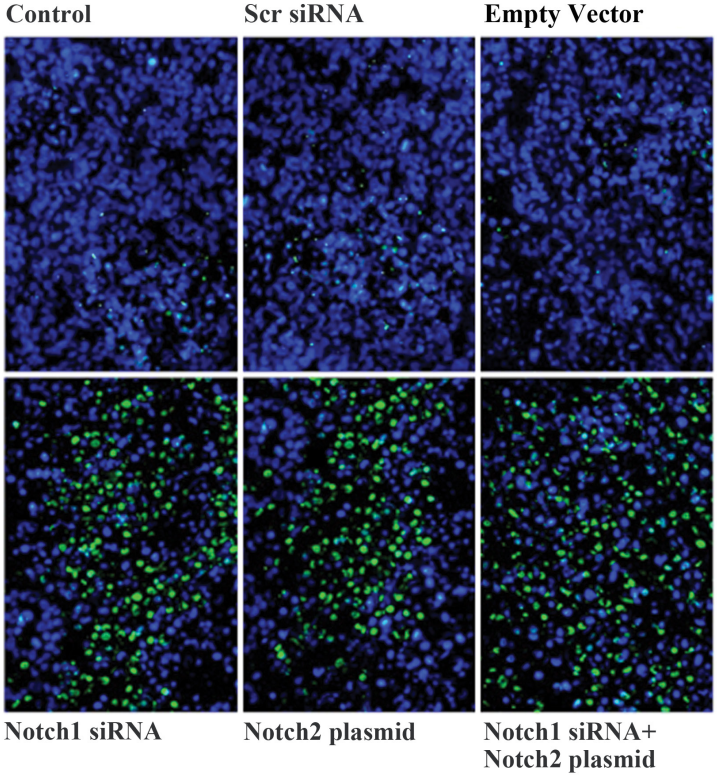


image similarities are yet to be developed. "They are being tested by publishing houses and journals," Bik said. "But they are not yet on the market."

Recently, *Nature* reported the development of an image integrity check software by a New York team led by machine learning researcher Daniel Acuna [11]. The software is intended to examine problematic images through hundreds of thousands of biomedical papers for anomalies like rotated parts, changed colors, and inappropriate reuse. The software is potentially capable of comparing every image with every other to report if a certain manipulation was intentional and hence more likely to be fraudulent. Although the software is computationally intensive, the team only accounted for cases of image reuse within and across papers by the same authors. Additionally, when the team manually examined all the flagged papers, only a handful of them actually contained fraudulent images. However, almost half of the true cases identified by the team were cases of the same image being used to represent different results in different papers [9].

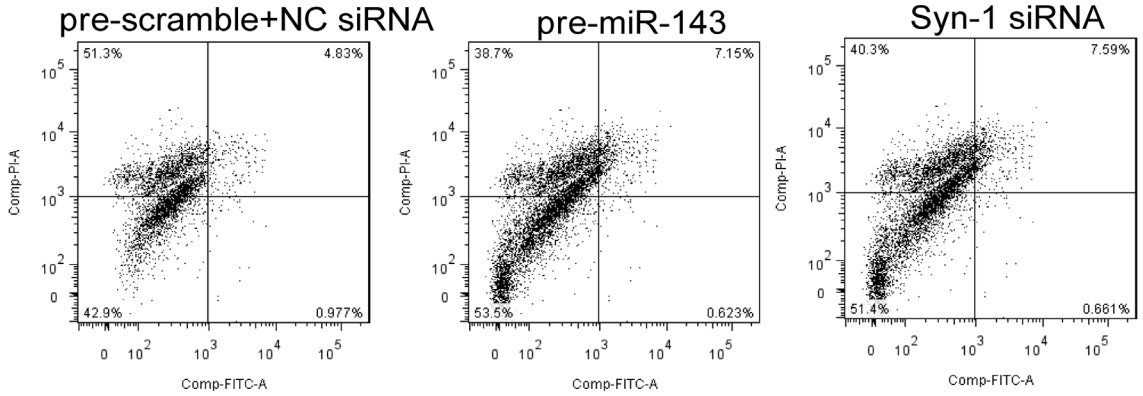
While current technology is capable of detecting obvious duplications involving flipping or rotations, the problem arises when duplications are minute, such as two images that share only a small overlapping area but are otherwise completely different. Further advances in machine learning are required to detect these subtle patterns automatically.

"[Technology] can replace the human eye for screening large numbers of papers and comparing one image against a million other published images faster," Bik said. "But human verification would still be required to help reduce false positives." Another problem with developing an advanced software is the need for more data as machine-learning algorithms require training with plenty of images known to contain duplications. To combat the problem, Bik has generously shared with Acuna's team images from hundreds of "dirty" and "clean" papers from her 2016 study.

Until technology catches up, calling out misconduct will remain a job for image integrity data-cops like Bik. "Many times, other image sleuths and I have attempted informing journals privately via email [of possible misconduct], but the cases are often neglected or go down a long road before the cases are resolved," Bik said. Although, she acknowledges and respects that misconduct investigations take time, she argues that expressions of concern should be implemented early on in the investigation to notify other researchers and readers of potential serious concerns with the paper while long investigations are pending. "I can tell you that 60 to 70 per cent of the cases [documented] in the mBio dataset have not been addressed even after five years," Bik said. "So, yes, I'm going to take this and other cases more publicly in hopes of making science more authentic and stopping scientific fraudsters from carrying out misconduct."

CHALLENGE #2

Flow cytometry



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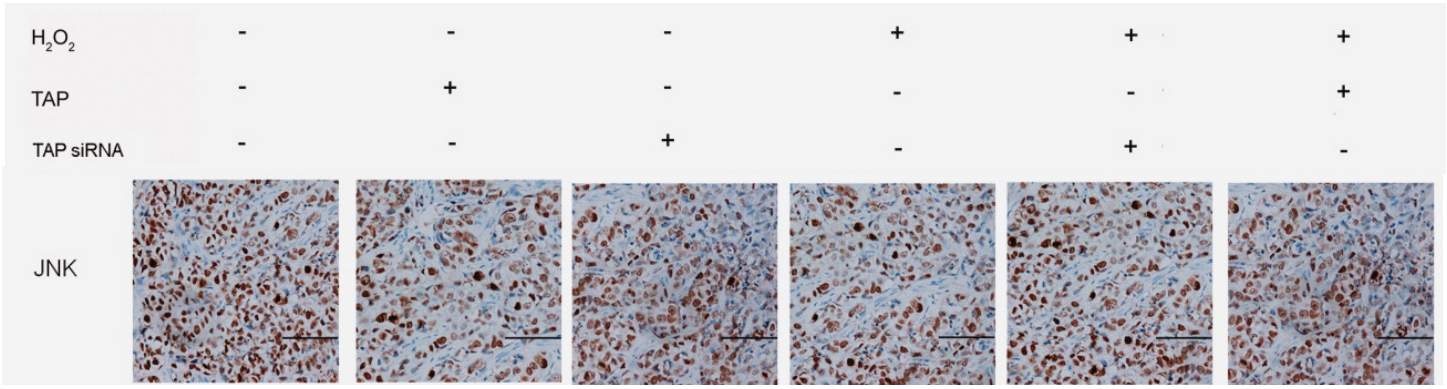
CHALLENGE #3

Immunohistochemistry



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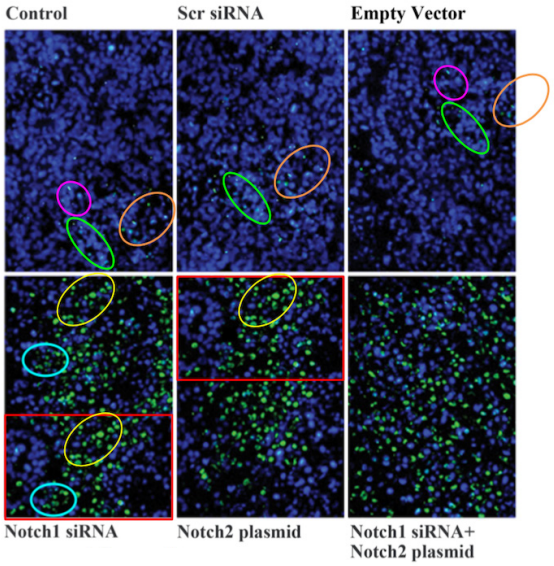
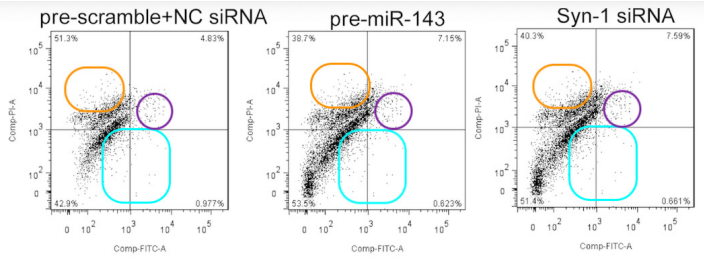
ANSWERS

Learn more about the different types of image duplications and how to report misconduct to a journal on Bik's website: scienceintegritydigest.com

CHALLENGE #1
Fluorescence microscopy



CHALLENGE #2
Flow cytometry



CHALLENGE #3
Immunohistochemistry