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UNLOCKING THE WONDERS IN THE GRAND LIBRARY OF OPEN SCIENCE

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YOUNG REVIEWERS:

MANANYA
AGE: 8

ZI-AN
AGE: 8

In a world where scientists often guard their research like hidden treasures, open science is a new and exciting concept. Rather than keeping experiments and results secret, open science encourages the wide sharing of scientific knowledge, to speed up research and improve human lives. Imagine a grand library where scientists unlock their safes and deposit their valuable information where everyone can access it! The power of open science was clearly seen during the response to the COVID-19 pandemic, and it is central to important scientific collaborations like the Human Cell Atlas project, which aims to map all the cells in the human body. By embracing open science, we unlock a world where knowledge is freely accessible, collaboration thrives, and scientific discoveries are accelerated, leading to a brighter future for everyone.

OPENING THE SAFE

Imagine a world in which every scientist has a secret safe, hidden away in their laboratory. Inside each safe, scientists store their most precious treasures—their experimental procedures and research data. These scientists keep their safes tightly locked, guarding their discoveries like hidden gems. While this "high security" may protect their life's work, it also makes it difficult for scientists to know what other scientists are doing, or whether any other labs have generated information that might help them to answer their own scientific questions. Now imagine a world in which all scientists unlock their safes and deposit their important information into a giant library. Further, imagine that *anyone* can visit this library. Scientists can browse shelves of data and "borrow" any information that might be helpful to them—kind of like checking out a library book. Even non-scientists can spend time in this library, exploring topics that interest them or even adding to the library's collection!

OPEN SCIENCE

The practice of sharing scientific publications and data freely, so that everyone can learn and discover new things together.

Which seems like the more effective way of improving human lives through science—keeping scientific experiments and results "secret" or sharing them openly, so that everyone can learn from them? Supporters of the **open science** movement believe that sharing information openly is a much better way to do science. Get ready to open the doors of this grand library and reveal the wonders within (Figure 1)!

Figure 1

Instead of keeping their research data locked up in "secret safes" in their laboratories, open science encourages scientists to share their publications and data openly and for free. This is like a grand library where anyone—even kids!—can learn from the latest scientific findings and even see the valuable data they are based on. We think open science is a much better way to do science, because it can save time and money and allow everyone to access fascinating scientific information! (figure created by carlottacat.com).

WHY KEEP SCIENCE SECRET?

In certain situations, keeping scientific data "secret" is definitely the right thing to do—and in some cases it is even illegal to share such information. For example, the information in patients' medical records, or other kinds of data that can be linked to a specific person (like names, addresses, or phone numbers of study participants), is personal and should be kept secret to protect people's privacy (to

learn more about data privacy, see this article and this one, from the same Collection).

In the past, scientists had other good reasons for keeping their information secret, too. Scientific research can be highly competitive, and researchers often work extremely hard to be the first to make significant discoveries. Like all of us, scientists want to be recognized for their efforts—but that is not all. Have you ever heard the phrase "publish or perish"? This expression refers to the pressure researchers often feel to continuously publish new results. Publications in prestigious scientific journals often help researchers get money to do more research, get promotions, and be seen as successful in the scientific community. By keeping their data private and not talking openly to others about their discoveries, scientists give themselves enough time to write articles before others can publish first and take the credit.

Some scientists might have exciting ideas that they want to turn into products or technologies that can be sold. In such cases, keeping their data secret gives them an advantage when working with companies or investors. Other scientists may want to keep their data secret until they have double checked to make sure their findings are correct—so that others do not find errors in their data and question the quality of their research.

While some kinds of "secretive" practices were seen as normal for many years, things are changing, thanks to open science! Many scientists are beginning to open their safes, tearing down the walls of secrecy and creating the worldwide science "library" where knowledge is freely available to everyone. But how exactly do we create such a "library"... and what is in it?

OPEN ACCESS PUBLISHING: THE "BOOKS" IN THE "LIBRARY"

One very important aspect of open science is called **open access publishing**. This is the process that adds the books to the library! When scientists get enough results from their experiments to support their hypotheses, they write articles describing their results and explaining what those results mean. As we mentioned earlier, scientists try to get those articles published in prestigious scientific journals. In the past, most journals had expensive subscription fees, so anyone who wanted to read one of the articles had to pay to do so—or be part of a university that paid the subscription fees. This drastically limited the number of people who could access the information—which means the information was not as useful as it could be.

OPEN ACCESS PUBLISHING

A process used by some scientific journals, in which they provide scientists' research papers for free, so that anyone can read them and learn from them without having to pay a fee.

Well, some brave scientists decided to create their own journals that are open to everyone—open access journals. With open access

publishing, anyone, anywhere, can read scientific articles—without paying a cent! Somewhere between 28 and 54% of all scientific journals are currently open access, and this number is growing [1]. Did you know that Frontiers for Young Minds is part of a family of Frontiers journals containing more than 200 journals on many topics—and every single one of them is open access online? Open access publishing allows other scientists, students, teachers, and anyone else with an internet connection and a curious mind to enter the science "library", explore the latest research, learn new things, and get inspired.

OPEN DATA: LOGGING ON TO THE LIBRARY'S COMPUTERS

Open science is not just about free access to research articles—it is also about sharing the valuable scientific data that research articles are based on—or even data from experiments that never make it into a publication. This is called **open data**. Instead of keeping their data secret in a locked-up lab notebook, scientists deposit their data with large organizations that organize, analyze, store, and share that data with other scientists and the public. This is like having free wi-fi in the grand library of science—you can log on any time to get all the information that you need to do projects at school or at home. The amount of open data that exist—and thus the amount of data sharing—is enormous. For example, one data-handling organization, the European Molecular Biology Laboratory's European Bioinformatics Institute (EMBL-EBI) is working hard to be one of the top open libraries for biological data in Europe. EMBL-EBI receives 100 million web requests for data *per day*. *Every 5 min*, a scientific article is published that uses EMBL-EBI data, and *every 3 s*, this organization receives new data from scientists! (For more information on EMBL-EBI, see this talk.)

When data are open, they become shared global knowledge—anyone can examine them, analyze them, and use them to design new experiments or create new things. Using data to answer a question other than the one those data were collected to answer is called **repurposing** the data. Repurposing shared data can save lots of time and money that scientists would otherwise have to spend collecting those data themselves. Thus, open data can speed up the pace of scientific research, helping scientists to solve big problems more quickly (for more information on using and repurposing scientific data, see another article in this Collection).

In addition to speeding up the pace of science, open data also contribute to data **transparency** and **reproducibility**. Transparency means that everyone can easily see and understand the data that scientists use to reach their conclusions. This helps people to trust scientists and their findings. Reproducibility means that other scientists

OPEN DATA

Valuable research information and experimental data that are shared openly with everyone, allowing anyone to access, analyze, and use those data for their own projects and discoveries.

REPURPOSING

Using shared data in new ways, beyond its original purpose, to answer new questions, solve problems, or create something new. Data repurposing saves time and resources.

TRANSPARENCY

A quality of scientific findings that makes them clear and easy for everyone to understand, so that people can see how research was conducted and reach their own conclusions. Transparency increases trust in science.

REPRODUCIBILITY

The ability to repeat a study and get similar results. Reproducibility helps ensure that scientific findings are reliable, increasing trust in science.

in totally different labs, or with different types of equipment, can try to replicate the data to make sure that it is correct.

THE POWER OF OPENNESS

We will now briefly explore two examples that showcase the tremendous power of open science to improve human health and change the world for the better!

The global response to the COVID-19 pandemic is a dramatic example of how openly shared scientific publications and data can save lives. The genetic sequence of the SARS-CoV-2 virus was figured out and openly shared only *weeks* after COVID-19 was first reported in China. The development of sensitive ways to detect the virus and the creation of a vaccine began almost immediately. Sharing of COVID-related research between scientists, governments, and vaccine-development companies resulted in the fastest development, testing, and approval of a vaccine ever seen in human history [2, 3]! This amazingly speedy response, clearly boosted by open science and worldwide collaboration, is estimated to have saved millions of lives [4, 5].

A project called the Human Cell Atlas is another excellent example of how open science can help people to cooperate and do great things. As you know, the human body is made of many kinds of cells—but does it surprise you to learn that, even after many years of research, scientists still do not know all of the cell types that make up the body? To understand topics like how to keep people healthy or how a disease like COVID-19 makes people sick, scientists and doctors need a deep understanding of all of the body's 37 trillion cells—where they are located and what they do. The aim of the Human Cell Atlas project, which began in 2016, is to create something like a Google Map of the human body, allowing users to view the body at various levels of detail, from a "planet-wide" view of the body as a whole, to a "street view" showing specific cell types present in a tiny area (Figure 2). To create this Atlas, more than 2,000 groups are working together, sharing their varied data and expertise about various systems of the body (nervous system, reproductive system, immune system, etc.) When the Human Cell Atlas is complete, anyone will be able to use it to learn more about the cell types that make us human! (To learn more about the Human Cell Atlas, see this talk.)

ENCOURAGING OPEN SCIENCE

While the shift toward open science is steadily opening the secret safes and moving information to the grand library, there are still scientists who choose to keep their scientific information private, often for the reasons mentioned earlier in this article. Many journals remain subscription based and much scientific data is still not open, either. It

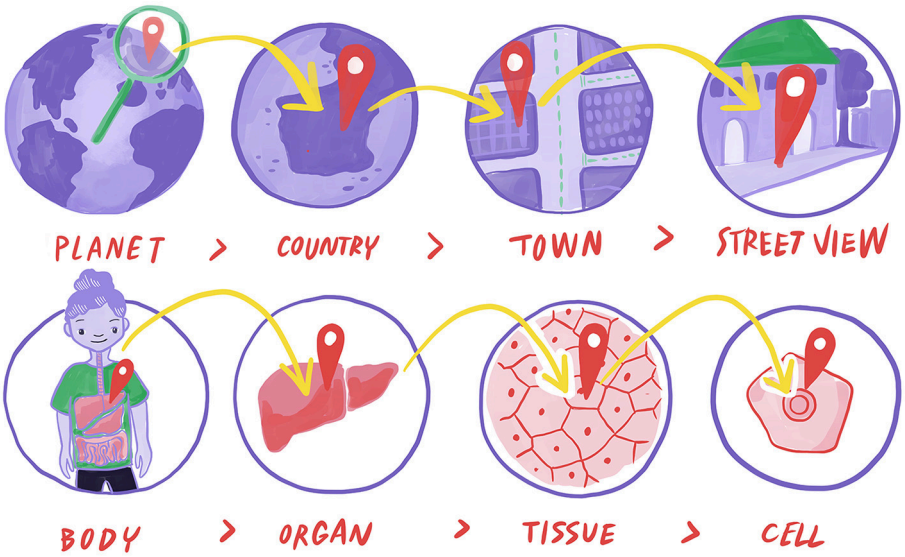

Figure 2

The Human Cell Atlas project aims to identify all of the cell types and map them—kind of like a Google Map of the human body, where you can "zoom in" from a "planet-wide" view of the whole body all the way down to a "street view" showing the specific types of cells in a tiny area! More than 2,000 groups are working together to create this Atlas. (figure created by carlottacat.com).

can be quite difficult for scientists to find the right balance between openness and protecting their work. Some scientists are motivated to publish in open access journals because they want their work to be accessible to a broader audience—not just scientists. What more can be done to encourage all scientists to join the open science movement? This is an important question and, all over the world, universities, funding organizations, and governments are trying to find ways to get *all* scientists to embrace open science, so that it eventually becomes the new normal.

For example, Horizon Europe, which provides research money to scientists in the European Union, looks at the open science practices of scientists who apply to them for funding. By using open science as one of their requirements, this organization encourages more labs to switch to open practices. Researchers who receive funding from Horizon Europe agree to publish their results in open access journals and to make their data as open as possible. The scientific community is also exploring new prizes or other ways to recognize scientists—ways that are more closely aligned with the values of open science. For instance, IBM Quantum sponsors an Open Science Prize, offering $30,000 (in 2023) to recognize "the best open source solutions to some of quantum computing's most pressing problems".

OPEN SCIENCE, OPEN MINDS

To sum up, open science is when scientists share their research with everyone (including kids!) so that everyone can learn and discover new things. It is like having a grand library where all the books are free to read, and anyone can come in, learn, and contribute! Open science has unlocked a new era of exploration, collaboration, and discovery.

With open access publishing, open data, and open minds, scientists and curious minds from all over the world can work together to solve the mysteries of the universe. This "new" way of doing science has many advantages over the old "secretive" way. Everyone can learn from each other, build upon each other's discoveries, invent new things more quickly, and generally make the world a better place. The secrets of science are waiting to be discovered, and you hold the key to the grand library!

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YOUNG REVIEWERS

MANANYA, AGE: 8
Hello, I am Mananya and I am in third grade. I love doing piano and art. I enjoy swimming, acting and reading comics. I have not thought about my career yet, but I do like science and engineering.

ZI-AN , AGE: 8
Hi, I am Zi-An, 8 years old, coming from a family of teachers, I have inherited a love for knowledge and learning. But my biggest joy? That is definitely my little brother. I absolutely love goofing around and making him laugh! I am fascinated about science. I want to research the secrets of everlasting life, so that people I love will never grow old or die.

AUTHORS

SUSAN J. DEBAD
Susan has been the main editor for FYM since 2015, making all our science clear and interesting—so that nobody feels it is "boring" or "too hard". She has a Ph.D. in viral immunology (how the immune system protects us against viruses). Susan lives outside Washington, DC, and has a teenage son, two birds, and four dogs. She fosters beagles and helps them to get adopted, which means that sometimes she has more than four dogs! In her spare time, she enjoys reading, crossword puzzles, and being outdoors. *susan@sjdconsultingllc.com

ROLF APWEILER
I was born in Germany and studied biology in both Heidelberg, Germany, and Bath, UK. Since 1987, during my studies, I worked as a student helper at EMBL in Heidelberg, reading articles about functions of proteins and adding this information into a database. That was my start in bioinformatics and, in 1994, I moved with my wife and our two children to Cambridge to set up (with a few colleagues from EMBL Heidelberg) a new institute of EMBL, called the European Bioinformatics Institute

(EBI). Now, for 8 years, I have been one of the two directors of this institute, which has grown to nearly 900 staff members and handles more than 100 million daily web requests to our databases from millions of researchers worldwide.