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HUMAN HEALTH
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"BUILDING" HUMAN HEALTH: WHEN DOCTORS AND PHYSICISTS WORK TOGETHER

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YOUNG REVIEWERS:


FILIP
AGE: 13


MIA AURELIA
AGE: 11


THE FUTURE LEADERS OF STEM
AGES: 8–12

In this article, we explore the importance of cooperation in science. Just as various construction trades must work together to build a skyscraper, scientists from separate fields can cooperate to tackle complex scientific challenges. This is called interdisciplinary collaboration, and it is a great way to do science. By bringing together knowledge and tools from multiple fields, scientists can uncover creative solutions and make meaningful connections that they might not have reached on their own. We give an example of how collaboration between particle physics and medicine—two fields that seem very different from one another—come together to improve healthcare. Using the tools of particle physics, scientists are enhancing cancer diagnosis and treatment. Interdisciplinary collaboration is the best way to address many of the complex issues we face today, like controlling climate change or fighting cancer, and it can help scientists and doctors make a lasting impact on human lives and the health of our planet.

Take a moment to look around at the building you are in right now. Buildings are such a normal part of our daily lives that it is easy to forget how complex they are and how many unique skills are required to create them. To construct any building, people from multiple construction trades must work together, each bringing their specialized tools and knowledge to produce various aspects of the structure: architects design the plans, a construction team creates a concrete foundation, carpenters construct walls and roofs and may also add woodworking details to each room, plumbers install the pipes for running water, and electricians do the wiring that allows you to plug in a computer and read this article. On their own, plumbers could not build an entire building, and neither could electricians, concrete pourers, or carpenters—but when they collaborate, they can build anything—houses, office buildings, hospitals, schools, or even brand-new kinds of buildings that no one has thought of before!

In this article, we will think about *science* as a big architectural project—a complex "building" that requires the expertise and collaboration of various "trades" to bring it to life and build solutions to some of the big challenges facing our world today.

SCIENCE IS DISCIPLINED

If you have ever told a parent or teacher that you would like to become a scientist or doctor someday, that adult might have asked you, "what type?". That is because science and medicine are huge topics, with so much to learn that no one person can master every aspect—that would be like a single person trying to build an entire skyscraper on their own. Just as a carpenter becomes an expert in woodworking or an electrician becomes a master of electrical systems, scientists choose a subject, also called a discipline, and then specialize in it. They dedicate their time to mastering their craft and understanding the minute details of that subject. There are literally *hundreds* of scientific disciplines to choose from.

Becoming specialized in a discipline is part of the very nature of science. Specializing allows a scientist to do a "deep dive" into their topic and focus all their time and energy on learning about it, which can lead to fascinating discoveries and sometimes big scientific breakthroughs. But what about building the skyscraper? How do some of the really big scientific problems get solved?

"CONSTRUCTING" CONNECTIONS: INTERDISCIPLINARY SCIENCE

Just as constructing a safe and functional building requires the collaboration of many trades, science thrives when experts from diverse disciplines come together to collaborate. Some types of

INTERDISCIPLINARY

Experts from various fields working together to solve big problems, like scientists and doctors joining forces to make new discoveries and find solutions.

scientific questions are like skyscrapers—knowledge and tools from more than one discipline are needed to "build" complete answers (Figure 1). For example, say scientists want to understand why a certain bird species is disappearing. Biologists might study the birds' behavior and habitats, while chemists might look at the pollutants in the environment that could be harming the birds, and mathematicians might analyze the patterns of rising and falling bird populations. By bringing their unique knowledge and tools together and working as a team, each discipline adds a crucial piece to the overall process. This collaboration helps scientists to make interesting connections that they might not have made on their own and could allow them to discover the full reason behind the bird's disappearance—and maybe even figure out how to protect the species. Collaborating to bring together scientific knowledge, methods, and ideas from multiple disciplines to solve scientific or medical problems is called **interdisciplinary** science—and it is a really good way to tackle complex scientific challenges and some of the real-world problems facing us today.

Figure 1

Figure 1

To build a building, experts in many trades must come together and combine their expertise—architects, carpenters, electricians, plumbers, and painters, for example. Something similar happens in interdisciplinary science! Scientists from separate disciplines collaborate to "build" the answers to big scientific problems that could not be solved by any one discipline on its own. Each scientist brings the "tools" and ideas from their specific discipline and, together, they can produce creative solutions (figure created by carlottacat.com).

PARTICLE PHYSICS

The study of the tiniest pieces of matter and energy that make up everything in the universe, like protons, electrons, and photons. Particle physicists study a broader range of particles than nuclear physicists.

BRINGING PHYSICS INTO THE DOCTOR'S OFFICE?

Did you know that some extremely important medical advances have come from interdisciplinary collaboration, sometimes involving disciplines that seem to have nothing to do with keeping people healthy? The rest of this article will describe how physicists, particularly those who study **particle physics** and **nuclear physics**, have joined forces with doctors in exciting ways that could improve, and maybe even save, many lives.

Particle physics is a scientific discipline that tries to understand the tiniest building blocks of the universe. These particles are so small that we cannot see them with our eyes or even with advanced microscopes. To study them, particle physicists use huge, powerful machines called **particle accelerators**, which get particles moving at very high speeds and then smash them into each other. Examining what comes out of these collisions, using giant **detectors**, can teach scientists a lot about the tiny particles that make up atoms, like electrons and quarks, and even the famous Higgs boson. Nuclear physicists can also use and study **radioactive isotopes**—atoms that give off a kind of energy called radiation—in their experiments.

On the surface, particle physics and medicine might seem as different as plumbing and carpentry. But some particle physicists have the same goal as doctors—they would ultimately like to see their research improve human lives. Working together, doctors and particle physicists can combine tools and ideas from these two separate disciplines to improve the way diseases, like cancer for instance, are diagnosed and treated. When particle physicists collaborate with doctors, the sky(scraper) is the limit!

TREATING CANCER USING THE TOOLS OF PARTICLE PHYSICS

The three tools that we just described—particle accelerators, detectors, and radioactive isotopes—might all be useful in the fight against cancer. Medical techniques based on these tools could improve the ability of doctors to both diagnose (find) and treat some kinds of tumors.

To treat tumors and hopefully cure a patient's cancer, **hadron therapy** uses special particle accelerators to get tiny particles, like protons and carbon ions (a form of a carbon atom with an electrical charge), moving at very high speeds (Figure 2A). These particles, which carry a lot of energy, can then be focused on the tumor like a laser beam, damaging the tumor cells with the energy they carry, while sparing the nearby healthy tissue. Hadron therapy with protons is currently being used in about 100 locations around the world. A similar technique, called Flash, delivers an ultra-high dose of radiation (X-rays, protons, ions, or electrons) in a very short pulse. The Flash technique causes more damage to cancer cells than it does to healthy tissues, which could minimize the side effects of radiation therapy. The first Flash facility will soon be built in Lausanne, Switzerland.

Smaller versions of the fast, sensitive detectors used by particle physicists in their experiments are being created to diagnose diseases (Figure 2B). For example, advanced detectors being developed at the European Organization for Nuclear Research (CERN) have shown amazing results in terms of improving the amount of information

NUCLEAR PHYSICS

The study of the particles inside the nuclei of atoms. Nuclear physicists often study radioactive isotopes because understanding those isotopes tells them about what is happening in atomic nuclei.

PARTICLE ACCELERATOR

A huge machine that makes tiny particles move really fast and crash into each other. Scientists use it to learn about the smallest building blocks of the universe.

DETECTOR

A special tool or device used by scientists to observe and collect information about particles and their behavior, helping them learn more about how the universe works on the tiniest level.

RADIOACTIVE ISOTOPE

A special kind of atom that gives off a type of energy called radiation. Scientists use it in medicine and research to study and treat diseases like cancer.

HADRON THERAPY

A type of cancer treatment that uses high-speed particles called protons to target and destroy tumor cells while minimizing damage to healthy tissue, helping patients fight cancer.

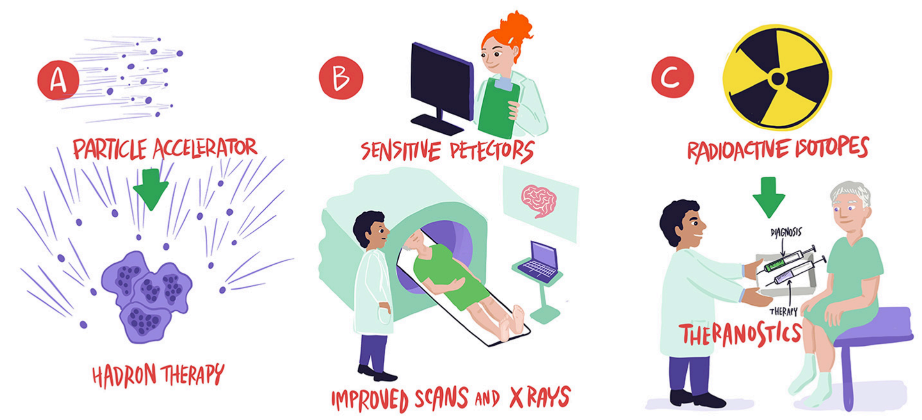

Figure 2

Figure 2

Tools from particle and nuclear physics, which study the tiniest building blocks of the universe, can be used to help diagnose and treat certain kinds of cancer. **(A)** In hadron therapy, particle accelerators can create high-speed particles, like protons or electrons, that can damage tumor cells. **(B)** Sensitive detectors can improve imaging techniques like PET scans and X-rays, so that doctors can diagnose cancers earlier and more accurately. **(C)** In theranostics, radioactive isotopes are attached to molecules that stick specifically to cancer cells and are injected into the patient's bloodstream. One type of isotope can help doctors see the tumor, and another type can kill cancer cells (figure created by carlottacat.com).

doctors can get from X-rays. Sensitive detectors can also be used to help take detailed pictures of the inside of the body, using a method called positron emission tomography (PET) scans (for more information on PET, see this Frontiers for Young Minds article). Special crystals, similar to those being studied for detectors at CERN, could make PET scan images extremely clear and detailed, which could help doctors to diagnose cancers earlier and start treatments sooner—potentially saving patients' lives [1–3].

Finally, radioactive isotopes can be used in a technique called **theranostics**. The name "theranostics" comes from a combination of the words "therapy" (treatment) and "diagnosis" (Figure 2C). In traditional cancer treatment, doctors diagnose and treat cancer using various medical procedures. They might diagnose the disease using blood tests, X-rays, or PET scans, for example, and then treat the disease using surgery, medicines called chemotherapies, or radiation therapy. But with theranostics, the story is a little different. Some cancer cells have structures on their surfaces that healthy cells generally lack. If researchers can design molecules that stick *only* to those cancer-specific structures, they can attach radioactive isotopes to the molecules and inject them into the patient, so that they travel all over the patient's body. One type of radioactive isotope can allow doctors to *detect* where the cancer is in the body (using PET), and then a second type of radioactive isotope can be injected to *treat* the cancer, by sticking to the cancer cells and killing them, while leaving normal, healthy cells unharmed [4]. A theranostics approach using radioisotopes of a substance called terbium is currently being tested in patients.

THERANOSTICS

A medical technique where diagnosis and treatment happen at the same time, using special molecules that stick to cancer cells and deliver treatment while helping doctors see where the cancer is located.

BUILDING FOR THE FUTURE

Our next generation of scientists and doctors (maybe you?) will face some extremely complex issues during their careers: the climate crisis, protecting the Earth and its species from harm as the human population continues to grow, and dealing with serious human health concerns like cancer and pandemics, just to name a few. These are extraordinarily challenging problems that cannot be answered by a single discipline.

But when scientists from various disciplines join forces, it is like a construction site that brings together the efforts of many trades. Everyone collaborates, combining their specialized knowledge and skills, to construct the building from its foundation to its intricate details. In interdisciplinary science, the disciplines of biology, chemistry, physics, mathematics, and more work in tandem to solve big problems and build a strong, integrated understanding of the world. By appreciating the unique contributions of each discipline and boosting understanding across fields, scientists and doctors can construct a scientific skyscraper that could never have been built by one discipline alone—one that stands the test of time and makes a lasting impact on human lives and the health of our planet.

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YOUNG REVIEWERS

FILIP, AGE: 13

My name is Filip, I am 13 years old. I like football, chemistry, math and physics. I also like drawing and in my free time I practice football tricks. In the future I would like to be a professional football player or a chemist. I would like to invent how to stop the climate catastrophe.

MIA AURELIA, AGE: 11

I am 11 years old and My name is Mia Aurelia. I love reading adventure books and I like writing stories. I live in Luxembourg and I speak Romanian, Polish, English, French, German and a tiny bit of Luxembourgish. My favorite subjects in school are: English, science and math. I am in 7th grade and I go to the Lycée Michel Lucius school.

THE FUTURE LEADERS OF STEM, AGES: 8–12

The Future Leaders of STEM from John P. Freeman K-8 Optional School is an after-school program for students who identify with STEM and love to dream BIG.

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

MAGDALENA KOWALSKA

Originally from Poland, I was always curious about the world around me. Therefore, I liked science and I liked traveling as a tourist and as physics student. After my studies I moved to Geneva, where I started my doctorate in experimental physics, working with unstable isotopes at CERN. Since then, I have worked on and led several projects at CERN using such isotopes. Some of them are linked to biology and medical diagnosis. In addition, I like explaining science to non-scientists, especially school pupils, just like my daughters who are 8 and 11. I still love traveling to understand other cultures and to appreciate the nature around us. *Magdalena.Kowalska@cern.ch