Opinion

The power of education: reflections from a Nobel laureate

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The 2023 Nobel Prize in Physics was awarded to Pierre Agostini, Ferenc Krausz, and Anne L'Huillier for their experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter. They demonstrated a way to create extremely short pulses of light that can be used to measure the rapid processes in which electrons move or change energy. These light pulses are so short that they are measured in attoseconds, showing that these pulses can be used to provide images of processes inside atoms and molecules. Yesterday, I had the privilege of attending a lecture at Chalmers University in Gothenburg, Sweden, delivered by Anne L'Huillier, the Swedish Nobel Prize winner in Physics for 2023. Before she began her talk, she took a moment to recognize and honor young minds—the winners of a contest centered around an intriguing theme: "How Can an Egg Fly?" These children had explored the whimsical yet profound question of flight through the lens of an egg. As she handed out their well-deserved prizes, I couldn't help but reflect on the significance of education. Education is more than just acquiring knowledge; it's about nurturing curiosity, fostering creativity, and empowering future generations. These children, with their imaginative ideas about egg flight, exemplify the essence of learning. They remind us that education isn't confined to textbooks and classrooms; it's about encouraging young minds to explore, question, and dream. Same discoveries are examples of how science can illuminate the mysteries of life and stimulate curiosity and innovation in today's minds. Each of these discoveries opens new doors to understanding the complexity of life at both macroscopic and microscopic levels, defying the gravity of established knowledge, igniting curiosity, and shaping a brighter future.

I. **Cardiac Regeneration**: Heart failure is a scourge in industrialized nations, often resulting from a deficiency of specialized cardiac muscle cells known as cardiomyocytes. Strategies for remuscularizing the injured heart using adult stem cells, pluripotent stem cells, cellular reprogramming, and tissue engineering are underway.

II. **Aflatoxins and Cancer**: The discovery that aflatoxins cause cancer is associated with the event known as "Turkey X". Aflatoxins were identified as the causative agents of this epidemic that resulted in the death of many young turkeys.

III. **Saccharin**: Saccharin, discovered in 1879, became the first widely commercialized artificial sweetener. However, concerns arose when scientists discovered that saccharin caused cancer in rats. Subsequent research showed that humans metabolize saccharin differently from rats, and the cancer warning label was removed.

IV. **Animal Rennet in Cheese Production**: Rennet is a proteolytic enzyme used in cheese manufacturing to coagulate milk. It acts on casein, transforming it into a solid mass called curd. Rennet helps separate the liquid (whey) from the curd, allowing the cheese to be molded and matured.

V. **Discovery of DNA**: The structure of DNA was discovered by James Watson and Francis Crick in 1953. This ground breaking discovery allowed us to understand how genetic information is passed from one generation to the next and paved the way for advancements in genetics, medicine, and biotechnology.

VI. **Candidatus Thiomargarita magnifica**: In another study, Volland et al. discovered a bacterium nearly 1 cm in length, Candidatus Thiomargarita magnifica, which is 5,000 times larger than the average bacterium. The genomes of T. magnifica contain more than 11,000 genes, three times more than the average bacterium. This giant raises questions about additional biochemistry and structural macromolecules needed to sustain life, and whether other macro-bacteria exist. Further characterization is needed to elucidate the unique functions and possible biosynthetic capabilities of these bacteria.

In Brazil, where I hail from, I wish we could embrace this perspective more fully. Imagine if every child had the opportunity to engage in such stimulating contests or participate in hands-on experiments. How might that shape our society? How many more brilliant minds could emerge? Education isn't just about preparing students for exams; it's about preparing them for life—instilling critical thinking skills, empathy, and a passion for discovery. As we celebrate the ground breaking work of Pierre Agostini, Ferenc Krausz, and Anne L'Huillier—whose experimental methods generate attosecond pulses of light for studying electron dynamics—we recognize that education plays a pivotal role. Their discoveries allow us to peer into the intricate dance of electrons within atoms and molecules—a realm previously inaccessible. Attosecond physics opens doors to understanding mechanisms governed by electrons, and it's through education that we can unlock these doors. Now, let's connect this with molecular biology. Molecular biology is the study of the molecular basis of biological activity and plays a vital role in a multitude of industrial, medical, and energy applications. It seeks to understand the interactions between the various systems of a cell, the interrelationship of DNA, RNA, and protein synthesis, and how they regulate each other. The connection between these two

fields can be seen in how attosecond light pulses can be used to study the dynamics of electrons in biological molecules. For instance, the structure and function of a molecule, including details such as the location and shape of a protein's active sites, affect how a molecule functions. With the ability to capture images of processes inside atoms and molecules, scientists can gain a deeper understanding of how biological molecules function at a very fundamental level.

Furthermore, this understanding can be used to manipulate genetic biology, which is fundamental to drug design and genetic engineering. Therefore, the research that won the 2023 Nobel Prize in Physics has significant implications for molecular biology and may open new doors for the advancement of science and medicine. The intricate dance between molecular biology and physics is a testament to the interconnectedness of all scientific disciplines. While molecular biology seeks to understand life at the molecular and cellular level, physics provides the fundamental principles that govern the universe. Together, they offer a comprehensive lens through which we can explore and understand life's complexities. The intersection of molecular biology and physics has given rise to a burgeoning field known as biophysics. Biophysics applies the theories and methods of physics to understand biological systems, seeking to explain biological phenomena in terms of physical principles. This approach provides a quantitative and predictive framework for understanding life. For instance, the principles of thermodynamics and quantum mechanics have been applied to understand the mechanisms of enzyme action and photosynthesis. Similarly, the principles of fluid dynamics have been used to understand blood flow and heart function.

Molecular biology, on the other hand, is the study of life at the molecular level. It focuses on the structure and function of life-essential molecules, delving into the mysteries of DNA, RNA, and proteins, and how these molecules interact to create and sustain life. Molecular biology has been instrumental in breakthroughs such as the Human Genome Project, which mapped the entire human genetic code, and the development of gene-editing technologies like CRISPR.

The synergy between molecular biology and physics has led to significant advancements in both fields. For example, the development of techniques such as X-ray crystallography and nuclear magnetic resonance (NMR) spectroscopy, which are rooted in physics, have revolutionized our ability to visualize biological molecules and understand their function. Moreover, the application of physical principles to biological systems has led to the development of new theories and models. For instance, the application of statistical mechanics to populations of molecules has led to the development of the field of systems biology, which seeks to understand the behaviour of complex biological systems.

In conclusion, the confluence of molecular biology and physics is not just beneficial but necessary for a comprehensive understanding of life. By integrating insights from these two disciplines, we can unravel the complexities of life at both the macroscopic and microscopic levels. This interdisciplinary approach holds the promise of new discoveries and advancements that can transform our understanding of life and potentially lead to breakthroughs in medicine, biotechnology, and other fields. Therefore, let us champion education—whether through formal institutions or informal exploration—because it holds the key to progress. Let us inspire young minds to soar like eggs defying gravity, igniting their curiosity, and shaping a brighter future.

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Conflicts of interest

The author declare that there are no conflicts of interest.

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