



Breaking Barriers: Women's Impact on Science and Innovation, Spotlighting Zebrafish Research

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ABSTRACT

Women scientists face systemic barriers despite their pivotal role in scientific advancement. Globally, they represent just a third of researchers, with less than 4% receiving Nobel Prizes. Only 11% hold senior research roles in Europe. Organizations like Foundation L'Oréal and UNESCO support women in science, with over 100 laureates and five Nobel Prize winners. Programs like L'Oréal-UNESCO for Women in Science aid over 250 young researchers annually. Achieving gender equality requires encouraging girls in STEM (Science, Technology, Engineering, and Mathematics) supporting working mothers, and ensuring merit-based recognition. Initiatives like the International Day of Women and Girls in Science underscore the need for equal opportunities. This article explores the rich history of women in science, highlighting their remarkable achievements and pivotal contributions to zebrafish research. From unraveling genetic mysteries to unlocking the secrets of development, women scientists have been instrumental in advancing our understanding of these crucial model organisms. As we celebrate their achievements, it is essential to acknowledge and address the challenges they face, fostering an inclusive scientific community that embraces the diverse talents and perspectives of all researchers.

KEYWORDS: Women Discovery, Scientific Contribution, Zebrafish Research

1. INTRODUCTION

In a world where scientific breakthroughs are shaping our future, women scientists are leading the charge with groundbreaking research that challenges the status quo. Despite their remarkable contributions, however, women still make up just a third of researchers globally,

and their achievements often go unnoticed. Shockingly, less than 4% of Nobel Prizes in science have been awarded to women, highlighting the glaring disparity in recognition. Moreover, only 11% of senior research roles in Europe are held by women, reflecting systemic barriers that persist in the scientific community.

As we confront looming challenges like climate change and resource scarcity, there is an urgent need to acknowledge and elevate the work of women scientists. For over two decades, the Fondation L'Oréal and UNESCO have been at the forefront of empowering women in science, striving to ensure their equal participation and recognition in tackling humanity's greatest challenges.

Their efforts have borne fruit, with over 100 laureates supported by the initiative, five of whom have gone on to win Nobel Prizes. Spanning across continents and disciplines, these trailblazing women are not only changing the face of science through their discoveries but also serving as inspiring role models for the next generation of female researchers. Through initiatives like the L'Oréal-UNESCO for Women in Science programmes, over 250 talented young women researchers are nurtured each year during crucial phases of their careers, providing them with the support needed to thrive in the scientific community.

Yet, the journey towards true gender equality in science is far from over. There is still much work to be done to ensure that girls are encouraged to pursue careers in science, that women receive adequate support to balance research with motherhood, and that scientific merit, not gender, determines success. Nevertheless, with unwavering determination, we are steadily progressing towards a future where women in science are celebrated, empowered, and given the platform they deserve to change the world.

On February 11th, we celebrated the 7th International Day of Women and Girls in Science, dedicated to acknowledging and honoring the pivotal role of women in the field of science. This day serves as a reminder of the importance of ensuring that all women and girls have equal opportunities to engage and excel in scientific endeavors worldwide. At Bionomous, we deeply appreciate the significant contributions of women in science and are committed to highlighting their achievements.

In this article, we delve into the rich history of women in science, showcasing their remarkable accomplishments and groundbreaking research. We also shine a spotlight on the invaluable contributions of women to the field of zebrafish research, underscoring their essential role in advancing scientific knowledge

and innovation.

2. WOMEN IN SCIENCE

Throughout the annals of history, women have left indelible marks on the landscape of scientific progress across a myriad of disciplines, spanning from the natural world to the intricate realms of social and formal sciences. In antiquity, the corridors of early Western civilizations bore witness to women's involvement in the healing arts of medicine, while the hallowed halls of ancient Greece echoed with the voices of women engaging in the profound pursuits of philosophy. Notably, amidst the dawn of scientific exploration during the first centuries AD, women illuminated the enigmatic paths of Alchemy with their scholarly endeavours.

Amidst the tapestry of the middle Ages, convents emerged as bastions of learning for women, nurturing the seeds of education and empowering them with literacy and intellectual prowess. Yet, as the tide of time ebbed, the burgeoning influence of nunneries clashed with the entrenched hierarchy of male clerical dominance, leading to contentious conflicts and eventual closures that obscured women's access to education and impeded their scientific contributions.

The advent of universities in the 11th century heralded a new era of scholarship, yet this beacon of learning remained shrouded from the gaze of women. While cathedral schools birthed these institutions with a mission to educate the clergy in Canon law, the gates of academia remained firmly closed to women, save for rare exceptions in Italian universities, where a select few dared to tread the path of knowledge, particularly in the field of medicine. However, entrenched stereotypes persisted, perpetuating the fallacy of women's intellectual inferiority and rendering their pursuit of scholarly pursuits an uphill battle. Amidst this backdrop of societal prejudice, luminaries like Laura Bassi emerged as beacons of hope, defying the odds to carve out their rightful place in the annals of scientific history. Bassi's ground breaking achievements in chemistry, physics, mathematics, and mechanics shattered glass ceilings and paved the way for future generations of women to pursue their scientific passions. Her ascent to becoming the first woman to earn a PhD in science and her subsequent election to the esteemed Academy of Sciences of the Institute of Bologna stands as a testament

to the resilience and brilliance of women in the face of adversity.

As the centuries unfolded, the voices of women in science grew louder, gradually eroding the barriers of prejudice and paving the way for their inclusion in academia. Though the journey was fraught with challenges and setbacks, the perseverance of trailblazers like Laura Bassi illuminated the path forward, inspiring countless women to defy the constraints of societal norms and stake their claim in the realm of scientific inquiry 1.

3. TEN WOMEN WHO REDEFINED THE LANDSCAPE OF SCIENCE

Across the annals of scientific history, women have left an indelible mark on the tapestry of human knowledge, their groundbreaking discoveries reshaping the very fabric of our world. From the shadows of obscurity to the dazzling limelight of recognition, these pioneering women have defied the constraints of convention to unlock the mysteries of the universe. Join us as we unveil the stories of ten remarkable individuals who have etched their names into the annals of scientific excellence, forever altering the course of human progress.

3.1. Pioneering the Cosmos: In 1816, Sophie Germain, a French mathematician and physicist, etched her name into history as the first woman to discover a comet. Her groundbreaking work on elasticity theory earned her the prestigious Paris Academy of Sciences Prize, blazing a trail for future generations of female scientists.

3.2. Unraveling the Genetic Dance with Transposition: Barbara McClintock, a pioneering geneticist, made an indelible mark on science with her discovery of genetic transposition, which revealed the profound complexity of genetic regulation. Through meticulous research, McClintock demonstrated that genes have the ability to change positions on chromosomes, a groundbreaking concept that challenged established genetic dogma. Her insights revolutionized our understanding of inheritance and genetic variability, laying the foundation for modern molecular genetics. In recognition of her groundbreaking work, McClintock was awarded the Nobel Prize in Physiology or Medicine in 1983, cementing her legacy as one of the most influential figures in the field of genetics.

3.3. Trailblazing Achievement: In 1899, Edith Anne

Stoney broke gender barriers by becoming the first female medical physicist at the London School of Medicine for Women, a landmark achievement that propelled advancements in medical physics and opened doors for women in science. Amidst World War I, her pioneering use of X-ray machines revolutionized medical diagnostics, contributing significantly to healthcare during a tumultuous period. Stoney's enduring legacy embodies resilience and dedication, inspiring countless aspiring physicists and empowering women in STEM globally.

3.4. Radiating Excellence: In 1903, Marie Curie, a trailblazing physicist and chemist of Polish descent, etched her name into scientific annals by becoming the first woman to be honored with a Nobel Prize in Physics, jointly awarded with her husband Pierre Curie, in recognition of their transformative investigations into radiation. Marie's groundbreaking contributions not only propelled her to unparalleled heights but also set the stage for her historic second Nobel Prize in Chemistry in 1911, a feat unprecedented in Nobel history, firmly establishing her as the pioneering figure to achieve such a distinction.

3.5. Unraveling Genetic Mysteries: In 1905, American geneticist Nettie Stevens left an indelible mark on the field of genetics with her seminal discovery of sex chromosomes. Through her pioneering research, Stevens unlocked a fundamental aspect of inheritance, elucidating the role of sex chromosomes in determining biological sex and laying a cornerstone for comprehending the intricate mechanisms of genetic diversity. Her groundbreaking findings not only reshaped the landscape of genetics but also paved the way for further advancements in the understanding of chromosomal biology and its implications for heredity and evolution.

3.6. Delving into Earth's Depths: In 1929, Danish seismologist Inge Lehmann propelled seismic science into a new era with her groundbreaking revelation of the Earth's solid inner core. Her pioneering discovery shattered conventional wisdom, revealing a hitherto unknown layer within the planet's structure. Lehmann's findings not only transformed our comprehension of Earth's internal dynamics but also revolutionized the field of seismology, providing crucial insights into planetary evolution and seismic behavior. Her work continues to be instrumental in shaping our

understanding of the Earth's intricate composition and seismic processes, leaving an enduring legacy in the annals of geoscience.

3.7. **Unlocking Life's Blueprint:** In 1950, British chemist Rosalind Franklin fundamentally transformed the landscape of molecular biology with her groundbreaking research on the structure of DNA. Through her meticulous X-ray diffraction studies, Franklin generated pivotal images that offered unprecedented glimpses into the helical nature of DNA molecules. These images, though initially underappreciated, provided essential clues that played a crucial role in informing James Watson and Francis Crick's iconic double helix model of DNA. Franklin's invaluable contributions not only catalyzed one of the most significant scientific breakthroughs of the 20th century but also underscored the importance of her work in elucidating the fundamental blueprint of life.

3.8. **Forging the Path to Modern Computing:** In 1952, American computer scientist Grace Hopper spearheaded a revolution in computer science with her groundbreaking creation of the first computer compiler. This transformative innovation marked a pivotal moment in computing history, as it enabled programmers to write programs in a more human-readable form, rather than in low-level machine code, thus streamlining the process and making computers more accessible. Hopper's visionary work not only ushered in an era of user-friendly computing but also laid the foundation for the development of modern programming languages and software engineering practices, leaving an indelible mark on the evolution of technology and shaping the digital landscape we inhabit today.

3.9. **Conquering the Final Frontier:** In a historic milestone of 1963, Russian cosmonaut Valentina Tereshkova shattered barriers and defied gravity as she embarked on a groundbreaking journey into space aboard Vostok 6, marking the first woman to venture beyond Earth's atmosphere. Tereshkova's courageous mission not only propelled her into the annals of space exploration history but also served as a beacon of inspiration for countless women worldwide. Her trailblazing achievement transcended mere scientific endeavor, sparking a cultural shift and igniting the aspirations of generations of women to pursue careers in space exploration, symbolizing the limitless potential of

human ingenuity and determination beyond the confines of Earth.

3.10. **Unveiling Microscopic Marvels:** In 1964, Scottish virologist June Almeida achieved a monumental breakthrough with her identification of the first human coronavirus. Through her meticulous research, Almeida not only uncovered a novel virus but also revolutionized our comprehension of viral diseases, particularly respiratory infections. Her pioneering work not only shed light on the complex nature of coronaviruses but also provided a crucial foundation for subsequent advancements in virology and immunology. Almeida's discovery served as a catalyst for deeper exploration into the mechanisms of viral pathogenesis and the development of vaccines and therapeutics, ultimately contributing to our ability to combat infectious diseases and safeguard global public health.

4. WOMEN'S IMPACT ON ZEBRAFISH RESEARCH

Women have long been at the forefront of scientific discovery, and their contributions to zebrafish research have been particularly significant. From unraveling genetic mysteries to unlocking the secrets of development, women have played a pivotal role in advancing our understanding of these fascinating creatures and transforming them into indispensable research models.

In the 1970s, zebrafish emerged as promising biological models, offering unique advantages over traditional research organisms like mice. It was George Streisinger who first recognized their potential, but it was the groundbreaking work of Dr. Christiane Nusslein-Volhard, a pioneering German biologist and Nobel Prize laureate, that propelled zebrafish into the scientific spotlight.

Dr. Nusslein-Volhard's groundbreaking research in zebrafish genetics paved the way for their widespread use in biomedical research, enabling scientists to explore gene function, embryonic development, and disease mechanisms. In 1993, another pivotal moment in zebrafish research occurred when a pioneering scientist conducted a large-scale mutagenesis screen, identifying over a thousand mutants that shed light on key biological pathways. This discovery not only expanded our understanding of genetic variation but also elevated zebrafish as invaluable tools in scientific inquiry, showcasing the power of curiosity and innovation in

unraveling the mysteries of the natural world 2,3,4.

In a milestone achievement in 2013, the zebrafish genome was meticulously decoded and documented, cementing its status as the definitive reference for zebrafish genetics 5. Dr. Kerstin Howe, a visionary German computational biologist, played a pivotal role in this groundbreaking endeavor, spearheading the manual annotation efforts and contributing extensively to the assembly and analysis of the zebrafish genome.

The significance of this monumental feat extended far beyond the realms of zebrafish biology. With zebrafish emerging as indispensable model organisms for studying vertebrate gene function and human genetic diseases, understanding the relationship between the zebrafish and human genomes became paramount. Through meticulous research, it was revealed that an astounding 70% of human genes have counterparts in the zebrafish genome, affirming their pivotal role as invaluable tools for modeling human genetic diseases.

Dr. Kerstin Howe's contributions transcended the boundaries of species, as she also played a key role in the assembly of reference genomes for humans, mice, and chickens. Her tireless efforts and groundbreaking discoveries have not only enriched our understanding of zebrafish genetics but have also paved the way for transformative insights into the intricate workings of the human genome.

In a groundbreaking achievement in 2008, Dr. Sharon Amacher and her team pioneered an innovative approach to manipulate somatic and germline genes in zebrafish, marking a significant leap forward in genetic research. Leveraging zinc-finger nucleases, a cutting-edge genome editing technique, they devised a method to induce targeted double-strand breaks in the zebrafish genome, facilitating the generation of precise mutations in specific gene sets. This breakthrough not only enabled the creation of the first targeted mutations but also ushered in a new era of transgenic zebrafish, unlocking unprecedented possibilities for studying gene function and genetic mechanisms in this invaluable model organism 6.

Building upon her pioneering work, Dr. Amacher further advanced gene editing in zebrafish by harnessing the power of CRISPR-Cas9, a revolutionary genome editing method with immense potential. With meticulous dedication, she established a robust pipeline for reliably generating transgenic zebrafish,

revolutionizing the field of genetic research. This innovative approach not only streamlined the process of creating transgenic zebrafish but also opened up new avenues for studying gene function and molecular mechanisms with unprecedented precision and efficiency 7.

Embryologist Sreelaja Nair is a leading figure at the Tata Institute of Fundamental Research (TIFR), spearheading research into the early stages of life using zebrafish as a model organism. With a background in developmental biology from UC-Irvine and the University of Wisconsin-Madison, she established her own lab at TIFR in 2012, swiftly laying the foundation for cutting-edge zebrafish research. Her dedication to scientific inquiry extends beyond the laboratory, as she actively engages in public outreach and mentorship, fostering a collaborative environment and advocating for gender equality in science 8.

Sreelaja's journey exemplifies resilience and commitment, as she navigates the challenges of scientific research while championing inclusivity and equity. Her work not only sheds light on fundamental biological processes but also inspires the next generation of scientists, paving the way for a more inclusive and equitable future in STEM fields 8.

5. CONCLUSION

As we delve into the realm of scientific inquiry, the role of women scientists in zebrafish research stands as a testament to their pioneering spirit and unwavering commitment to advancing knowledge. Zebrafish, with their transparent embryos and rapid development, offer a unique window into the intricacies of biological processes, making them invaluable models for studying embryonic development, genetic disorders, and drug discovery.

Women scientists have been at the forefront of harnessing the potential of zebrafish, developing innovative techniques to manipulate their genomes and unlock the secrets of gene function. Through meticulous experimentation and groundbreaking discoveries, they have illuminated the pathways that govern development, shedding light on the fundamental mechanisms underlying life itself. Moreover, women scientists have leveraged zebrafish research to make significant contributions to human health. By modeling genetic diseases in zebrafish embryos, they have

identified novel therapeutic targets and potential treatments, offering hope to patients worldwide. Additionally, zebrafish research has provided crucial insights into the effects of environmental toxins and pollutants on human health, informing public policy and regulatory decisions. As we celebrate the achievements of women scientists in zebrafish research, we must also acknowledge the challenges they have overcome and the barriers they continue to face. From securing funding and resources to navigating gender bias in the scientific community, their journey has been marked by perseverance and determination. Yet, despite these obstacles, women scientists have persisted, driven by their passion for discovery and their commitment to making a difference in the world.

As we look to the future, let us continue to support and empower women scientists in their quest to unravel the mysteries of the universe. By fostering an inclusive and equitable scientific community, we can harness the full potential of zebrafish research and pave the way for transformative breakthroughs that benefit us all.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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