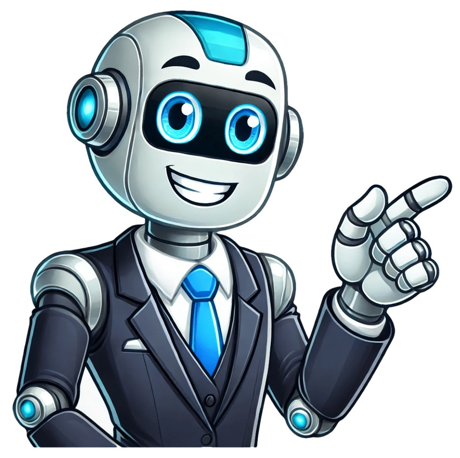

The photo was taken in May 1952 by Rosalind Franklin and her PhD student Raymond Gosling in the basement underneath the chemistry laboratories at the MRC Biophysics Unit. Franklin, a biophysicist, had been recruited to the unit to work on the structure of DNA. The unit was then part of the King's College campus on the Strand in London. It was run by Sir John Randall, who had turned some of the university's physics department over to studying biological problems. The MRC Biophysics Unit moved to Drury Lane in the 1960s and later became the Randall Institute. I now work in its most recent incarnation, the Randall Centre for Cell and Molecular Biophysics at King's College's Guy's Hospital campus. So, Photo 51 is doubly significant for me. I'm an X-ray crystallographer so it's part of my heritage in that respect, but all of us in the centre are proud of this link with the work in the 1950s. Photo 51. Credit: King's College London What is X-ray crystallography? It's a long-established method of determining the structure of molecules by bombarding them with X-rays. The molecules are in a crystal or otherwise ordered form, so when the X-rays bounce off the electrons in the molecule's atoms, they scatter in a particular unique pattern. You can use that pattern to infer the structure. These days we take thousands of images from different angles and digitally build up a 3D image of the structure. How would it have been done in the 1950s? The technique in principle wouldn't actually have differed too much, although it would have been a much more painstaking and time-consuming process. Franklin and Gosling used a very pure form of DNA and they became expert in pulling it into strands for analysis. Within each strand would have been a vast number of DNA helices lined up next to each other. The DNA strand was fixed to a support and sealed in a camera, in front of a piece of X-ray film, and then exposed to X-rays for days at a time. Rather dangerously, hydrogen was bubbled through water and into the camera to stop the X-rays from bouncing off molecules in the air. The film was then developed and the patterns emerged before the researchers' eyes. Raymond Gosling often spoke of the great excitement of developing the films in the King's basement. Rosalind Franklin's lab at Birkbeck College. Credit: @JohnFinch/MRC Laboratory of Molecular Biology What are we actually looking at when we look at Photo 51? Photo 51 is an image of the more hydrated 'B' form of DNA. Franklin and Gosling had been experimenting with whether the humidity at which they kept the samples would affect the images. They had taken a series of images, and Photo 51 was taken at the highest humidity, around 92%. The darker patches indicate where the film has been repeatedly bombarded by diffracted X-rays from regular, repeating features within the molecule. The dark patches at the top and bottom of the picture, for example, represent DNA's 'bases', the four parts of DNA which make up the genetic code. These patches are dark because there are so many bases all arranged in a regular fashion. You can work out the distance between bases in the structure by measuring the distance between the dark patches on the film. This involves a calculation based on how far the DNA sample was from the X-ray film and how it was orientated in the X-ray beam. What about the cross shape of spots? For people like Watson and Crick, who were already building models, this cross really spells out helix. Maurice Wilkins, who had worked on DNA separately from Franklin, showed this photo to Jim Watson when he came to visit and it really excited him. A lot has been said and written about that moment and some people think that Wilkins shouldn't have shared the photo, certainly not without Franklin's knowledge or permission. But he had it legitimately as part of Rosalind's papers as she was soon to leave for Birkbeck College. He was keen that research on the structure progressed, particularly because he wanted the UK to beat Linus Pauling in the US to discovering the structure. The reason that the cross indicates a helix is that the arms of the cross represent the planes of symmetry in a helix viewed from the side. The 'zig' and the 'zag', so to speak, of the turns of the helix. It's difficult to see clearly, but there are ten blobs on each arm of the cross before you reach the large black patch at the top. This tells you that there are ten bases stacked one on top of the other in each turn of the helix. In fact, one of the blobs is missing, the fourth if you count out from the centre of the pattern. This indicates that one strand of DNA is slightly offset against the other. If Franklin had all this information, why didn't she suggest the structure? Rosalind Franklin by Elliott and Fry. Credit: © National Portrait Gallery, London Well, it's difficult to say but one reason is probably that Rosalind had chosen to focus her attention on her X-ray photos of a less hydrated 'A' form of DNA. This form appeared to show much more information and she hoped to calculate the structure directly, rather than build models. In fact, these photos of the 'A' form had revealed a key piece of information, namely that the two strands of DNA ran in opposite directions. Neither Rosalind nor the others had appreciated this, until Francis Crick realised its significance just before building the final model. She didn't turn her attention to Photo 51 until early in 1953. You can see from her notebooks that once she did concentrate on it, she gleaned all the key information about the structure from it. I fully believe that given more time she would have cracked the structure. She was so close. Watson was surprised that she accepted the correctness of their model immediately upon seeing it. It must have been because she could see that it fitted so well with all of her evidence. What happened after the structure was published? Franklin was already working at Birkbeck College by the time Franklin and Gosling's paper, showing Photo 51, was published in Nature, alongside that of Watson and Crick's model. Of course, Watson and Crick's model was just that, only a model, so it needed to be verified. Wilkins built the first accurate model of DNA in the summer of 1953 and checked it against diffraction data such as Photo 51. Of course, the structure was right, it was too beautiful not to be. This blog post has been refreshed from our archive. Maurice Wilkins, James Watson and Francis Crick at the 1962 Nobel Prize ceremony (K/PP178/15/3/1). Credit: King's College London Top image: Credit: hh5800, iStock, Getty Images Plus via Getty Images Share this page Twitter LinkedIn Facebook Professor of Molecular Biophysics, Head of Structural Biology, Randall Centre for Cell & Molecular Biophysics, King's College London Brian's research over many years at King's has involved the application of X-ray crystallography to study the molecular structures of antibodies, in particular those involved in allergy and asthma. He was a founding member of the MRC-Asthma UK Centre for Allergic Mechanisms of Asthma. His work has led to the development of potential new therapeutics for allergic disease. Image source, King's College LondonImage caption, Photo 51: DNA X-ray diffraction imageIt may not look very exciting, but the photograph above has an important place in history. Known as Photo 51, it's an X-ray diffraction image of DNA and has at least a claim to be the most important image ever taken. It's one of about a million artefacts being put online by the Wellcome Trust as part of an ambitious project to tell the story of genetics, from Mendel to the Human Genome Project.The material includes research documents, notebooks, letters and images which are currently housed in six institutions in Britain and the United States. These are the Wellcome Library, King's College London, the Churchill Archive Centre Cambridge, University of Glasgow, University College London and Cold Spring Harbor Laboratory.So why is Photo 51 an iconic image? King's College archivist Geoff Browell says: "Photo 51 was taken by Rosalind Franklin and Ray Gosling in the Biophysics Department here in 1952. It is arguably the most important photo ever taken. "It was this image that gave the final clue that enable Maurice Wilkins, James Watson and Francis Crick to put together research from the previous two decades and understand that DNA was a double helix." Photo 51 is not the sort of image you would take with a normal camera. A tiny sample of hydrated DNA was mounted inside and then an X-ray beam shone at it for more than 60 hours. The beam of X-rays scatter and produce an image from which a 3D structure can be determined. The resulting striped cross shape you can see may not mean much to the casual observer, but to a small group of scientists it proved to be a revelation. It was shown by Maurice Wilkins of King's College to James Watson at the Cavendish Laboratory in Cambridge, who said "my mouth fell open and my pulse began to race".I'd be delighted to know what your suggestions are for the most important photo ever taken.The image of Photo 51 is tiny - just a few centimetres across - and holding the glass plate in my hands felt like handling a piece of history.The story of the discovery of the structure of DNA is fascinating. It was Crick and Watson from Cambridge who published the key paper in 1953 and they later shared the Nobel prize with Wilkins from Kings. Franklin died of cancer and the prize cannot be awarded posthumously so she never got to share in the glory.As well as all the scientific documents that will go on display there is also plenty of personal material such as the cartoons of Maurice Wilkins. I was lucky enough to interview him in 2003 on the 40th anniversary of the DNA milestone. Considering his crucial role in 20th century biology and genetics he was one of the most unassuming and modest scientists I've met. Wilkins was concerned about social impact of his work. The cartoon below shows a man pulling a DNA shaped corkscrew from a bottle marked "Secrets of Life - Pandora's Brewery". He says: "When we find the good gene we will be Masters of the Universe."Image source, King's College LondonImage caption, One of Maurice Wilkin's cartoonsAnother revealing image is shown below. It's a postcard that Francis Crick had printed and used to be sent in response to the mass of unsolicited requests he received: "Dr Crick thanks you for your letter but regrets that he is unable to accept your kind invitation to: send an autograph, provide a photograph, cure your disease, be interviewed, talk on the radio, appear on TV etc."Crick, or his assistant, would put a tick next to the relevant section. I find it both rude and hilarious. I have a sneaking admiration for such a masterly putdown. Have you ever received a better one?Image source, Wellcome LibraryThe Wellcome Library's history of genetics should be available online from October and will give free access to all.Media caption, The BBC's Fergus Walsh sifts through documents tracing the history of geneticsI did a report for the Today programme which includes contributuions from Sir John Sulston, former director of the Wellcome Sanger Institute. You can listen to by clicking on the black box on the right. Today also has some images from the archive on its website., externalThe BBC is not responsible for the content of external sites. Each Monday, this column turns a page in history to explore the discoveries, events and people that continue to affect the history being made today.There are many historical snapshots that have captured popular imagination, from the flag-raising at Iwo Jima to a wild-haired Albert Einstein sticking out his tongue, but few pictures are both so important and so unrecognizable as the one scientists call Photo 51.Captured by English chemist Rosalind Franklin in 1952, Photo 51 is a fuzzy X -ray depicting a strand of DNA extracted from human calf tissue — the clearest shot of life's building blocks ever seen up to that point, and the first one that seemed to prove once and for all the double-helix structure of DNA. You may like Fatefully, a colleague would hand Photo 51 over to James Watson and Francis Crick before Franklin could publish her results. Watson and Crick, fellow scientists also working on DNA, immediately recognized the importance of the picture's contents and, not long after, published their famous Nature journal article in 1953, heralding a new era in genetics.X marks the spot With all the frenzied advancement in the world of genetics in the early 1950s, it was two pairs of scientists working just 50 miles apart — Watson and Crick at Cambridge and Franklin and Maurice Wilkins at King's College in London — who managed to close in on the Holy Grail of DNA science at precisely the same time.By that time, scientists were using the term "gene" to describe the smallest unit of genetic information that was passed from one generation to the next, but they did not know what the material actually looked like.Get the world's most fascinating discoveries delivered straight to your inbox.Watson and Crick spent the better part of 1951 investigating the structure of DNA. They did no genuine DNA experiments of their own, instead creating cardboard stick-and-ball models with each new piece of information they gathered from the vast amounts of data that was continuously being released in the field.Some of that data belonged to Franklin. Working in the lab alongside Wilkins in 1952, Franklin had taken a startling, high-resolution photograph of a piece of DNA using X -ray crystallography, a technique whereby X -rays are shone on a crystalline structure (in this case, the DNA protein), to create a scattered reflection pattern on film.To the naked eye the photo looked merely like an X diced up into bits, but to Franklin it confirmed what she and all the other genetics suspected: DNA was a double-helix.Whether out of competitive animosity or disrespect — female scientists still did not have the right to eat in the dining rooms at King's College, after all — Wilkins took Photo 51 without her knowledge to Watson, who immediately recognized its significance.With the double-helix structure established, other pieces of the DNA puzzle fell into place. When they'd finally unraveled the complicated relationships between the four types of protein "rungs" (A, T, C and G) and their twin sugar-phosphate backbones in 1953, Watson and Crick published their landmark findings.We're all a bunch of corkscrewsDespite having no personal experiments included in the research and a drawing by Crick's wife, Odile, to illustrate their structure, Watson and Crick's findings would go on to revolutionize the field of genetics.Knowing how the corkscrew-like DNA strand was configured, scientists could determine just how genes, those building-blocks of life, actually did their job.The most important corresponding leap forward concerned copying. Unzipping all the A-T and C-G pairs of a double-helix straight down the middle makes for a neat and tidy way for the body to reproduce its own cells, Crick suggested in a second Nature article, since the two strands left behind served as templates for the complementary new chains. His theories on how genetic information was transmitted were validated by experiments in the late 1950s.Rosalind Franklin would have come to the same conclusions before Watson and Crick, some historians and biologists such as California State University's Lynne Osman Elkin think, had Photo 51 not made its ways into James Watson's hands.Watson and Crick, along with Wilkins, went on to win the 1962 Nobel Prize for their work. Franklin died four years earlier and the award is never awarded posthumously, so it is uncertain whether she would have been included with that group. Before Watson and Crick Brenda Maddox, author of Rosalind Franklin: The Dark Lady of DNA, describes the discoveries that lead scientists to focus on DNA as the secret behind life. DefendingFranklin's Legacy Hear one biologist's perspective on why Rosalind Franklin should have shared the Nobel Prize for the discovery of DNA's structure. Picturing theMolecules of Life Over the past 50 years, scientific images of DNA, ribosomes, and RNA have catalyzed our understanding of these amazing molecules. Anatomy of Photo 51 When you know how to look at it, this shadowy X-ray photograph speaks volumes about the shape of DNA. Journey into DNA Where does DNA live inside the human body, and how is it packaged? Take an animated journey into the tiny world of DNA to find out. TV Program Description NOVA News Minute Watch a news clip related to NOVA's "Secret of Photo 51" program. Links & Books Program Transcript Buy the Video/Watch a Preview Credits Don't miss upcoming NOVA broadcasts and companion Web sites—subscribe to our e-mail bulletin. Photo 51 is a seminal X-ray diffraction image that played a critical role in unraveling the structure of DNA, fundamentally altering our understanding of genetics. Captured in 1952 by Rosalind Franklin and her team at King's College London, this image served as a crucial piece of evidence in establishing the double helix model of DNA. The creation of Photo 51 occurred during an era characterized by intense research into the molecular biology of cells, and the mystery surrounding genetic material was a primary focus of scientific inquiry. In the early 1950s, the quest to uncover the structure of DNA was underway, with various scientists competing to elucidate the genetic blueprint of life. Franklin, a skilled crystallographer, utilized X-ray diffraction techniques to obtain images that revealed the helical structure of DNA. Photo 51, in particular, provided a distinct diffraction pattern that suggested a helical organization, indicating that DNA consisted of two intertwined strands. This finding was pivotal not only for molecular biology but for the broader field of genetics, linking the physical structure of DNA to its biological function in encoding genetic information. The significance of Photo 51 extends beyond its technical contribution; it also underscores the collaborative, yet competitive nature of scientific research during this period. The eventual interpretation of Photo 51 by James Watson and Francis Crick, who integrated Franklin's findings with their own research, culminated in the proposal of the double helix model for DNA. This groundbreaking moment set the stage for modern genetics, providing insights that would lead to advancements in molecular biology, medicine, and biotechnology. Overall, Photo 51 remains a symbol of the intersection between technology and discovery in the scientific narrative of DNA. The journey of DNA research has evolved significantly since its early contemplation in the latter part of the 19th century. Initially, the building blocks of heredity were obscure, and the scientific community largely perceived traits as resultant phenomena without a molecular basis. The field began to take shape with the foundational work of Gregor Mendel in the 1860s, who established the concept of inheritance through his meticulous pea plant experiments. Mendel's laws of inheritance set the groundwork for future genetic exploration, albeit his findings were largely overlooked until the early 20th century. In the 1900s, the understanding of chromosomes and their role in heredity began to emerge. Pivotal figures such as Thomas Hunt Morgan and his fruit fly experiments revealed the significance of chromosomes in genetic traits, paving the way for the chromosomal theory of inheritance. This marked a crucial shift towards molecular biology, where scientists started to manipulate and delve into the genetic material itself. By the 1940s, the field entered a new paradigm with the discovery that nucleic acids, namely DNA, served as carriers of genetic information. The work of scientists like Erwin Chargaff contributed to understanding the composition of DNA. Chargaff's rules, which explained the consistent ratios of adenine to thymine and cytosine to guanine, indicated a potential structure of DNA, yet the three-dimensional structure remained elusive. Overall, the efforts of these researchers laid the groundwork for a deeper comprehension of molecular genetics. Their contributions, combined with advancements in technology and the burgeoning field of biochemistry, created an environment ripe for the groundbreaking discovery of Photo 51. This pivotal moment would ultimately illuminate the double helical structure of DNA and revolutionize biological sciences, leading to numerous breakthroughs in genetics and molecular biology. X-ray diffraction (XRD) is a powerful analytical technique utilized to determine the atomic and molecular structure of a crystal. It involves directing X-rays onto a crystalline sample and analyzing the resulting scattering pattern. When X-rays penetrate a crystal, they are scattered by the electron clouds surrounding the atoms within the crystal lattice. This scattering produces a unique pattern of diffraction, which can be recorded on a detector. The arrangement of atoms in the crystal affects the angles and intensities of the scattered X-rays, enabling researchers to deduce information about the atomic structure. The fundamental principle of X-ray diffraction lies in Bragg's Law, which states that constructive interference occurs when X-rays reflect off the crystal planes at specific angles. This law can be mathematically expressed as $n\lambda = 2d\sin\theta$, where n is an integer, λ is the wavelength of the X-rays, d is the distance between crystal planes, and θ is the angle of incidence. By varying the angle and measuring the intensity of the diffracted beams, scientists can derive a three-dimensional picture of the electron density within the crystal, leading to the identification of atomic positions. This method has proven particularly effective for studying biological macromolecules such as DNA due to their crystalline nature. Crystallization of DNA allows for a well-ordered arrangement of molecules, creating a suitable environment for X-ray diffraction analysis. The resulting diffraction patterns can reveal vital information about the molecular structure, including helical features, spacing between base pairs, and overall conformational arrangements. In the case of Photo 51, the X-ray diffraction technique played a crucial role in elucidating the double helix structure of DNA, paving the way for groundbreaking discoveries in molecular biology and genetics. Rosalind Franklin was an eminent scientist whose work in the field of X-ray crystallography was pivotal to understanding the molecular structure of DNA. Born in 1920 in London, Franklin pursued her education in physical chemistry at the University of Cambridge, where her exceptional analytical skills emerged. Her expertise in techniques for studying crystallized substances enabled her to capture the now-famous Photo 51 in 1952, a remarkable X-ray diffraction image of DNA. This image provided crucial insights into the helical structure of DNA, yet Franklin's contributions were often overshadowed by her male counterparts. Franklin's methodology was characterized by meticulous attention to detail and stringent experimental rigour. She employed advanced X-ray techniques to analyze samples of DNA, successfully producing high-quality images despite the challenges posed by the complex molecular structure. Her systematic approach allowed her to deduce vital information about DNA, including its dimensions and the orientation of its phosphate backbone. This dexterity in handling intricate tools demonstrated her profound scientific acumen, positioning her as a leading figure in this domain. However, her journey was fraught with challenges, particularly as a woman in a predominantly male scientific community. Franklin faced significant gender bias, which contributed to her work being undervalued and often misattributed. While James Watson and Francis Crick capitalized on her findings to propose the double-helix model of DNA, Franklin continued to pursue her own research, unyielding in the face of adversity. Her analysis of the diffraction patterns of DNA was vital in corroborating the helical structure, making her an essential pioneer in the field of genetics. In light of her steadfast efforts and groundbreaking insights, Rosalind Franklin's contribution to DNA discovery remains an integral part of scientific history. In the early 1950s, James Watson and Francis Crick were engaged in an intense pursuit to unravel the structure of deoxyribonucleic acid (DNA), a goal that had eluded many scientists before them. Their groundbreaking discovery was significantly influenced by the X-ray diffraction image known as Photo 51, produced by Rosalind Franklin. Upon encountering this image, Watson and Crick experienced a profound moment of realization regarding the molecular configuration of DNA. The distinct "X" pattern observed in Photo 51 provided Watson and Crick with crucial insights into the helical structure of DNA. They interpreted the symmetry and spacing of the diffraction patterns as indicative of a double helix, a structure composed of two intertwined strands. This image served as the catalyst for their theoretical framework, leading them to postulate that DNA consists of two sugar-phosphate backbones with bases pairing in the interior. Their interpretation was not only a pivotal moment in their research but also laid the foundation for molecular biology as a whole. Watson and Crick's collaborative efforts, informed by the pivotal information from Photo 51, underscored the importance of teamwork and shared scientific knowledge in the field of genetic research. The image illuminated aspects of DNA's structure that had remained obscure, allowing them to envision a model that resonated with a broad range of biological functions, from replication to genetic encoding. The impact of their proposal was immediate and far-reaching, transforming the understanding of heredity and genetics. Ultimately, the reaction to Photo 51 catalyzed a revolutionary shift in molecular biology, securing Watson and Crick's place in scientific history. Their ability to appropriately leverage the insights gained from this critical X-ray image enabled them to elucidate the structure of DNA, revolutionizing the field and influencing generations of research thereafter. The discovery of the double helix structure of DNA, elucidated through Photo 51, has had profound implications across various scientific disciplines, particularly genetics, molecular biology, and biochemistry. This groundbreaking model transformed our understanding of heredity and the mechanisms of genetic inheritance. Prior to this discovery, the precise molecular basis of heredity remained unclear, but the double helix provided a clear framework for understanding how genetic information is stored, replicated, and transmitted across generations. The structure of DNA as a double helix suggests a methodical approach to genetic replication, where each strand of the helix serves as a template for creating a new complementary strand. This insight laid the foundation for understanding mutations—a change or alteration in the DNA sequence. The double helix model enables scientists to explore how mutations occur, their potential effects on organisms, and their role in the evolutionary process. In the realm of molecular biology, the double helix model has been pivotal in guiding research on gene expression, regulation, and protein synthesis. The interactions between DNA, RNA, and proteins are essential for understanding cellular functions, leading to advances in biotechnology and genetic engineering. For instance, the ability to manipulate DNA through technologies such as CRISPR-Cas9 derives largely from the understanding gained through the double helix model. Moreover, in biochemistry, the implications of the double helix extend to comprehending the biochemical pathways that govern cellular processes. The understanding of molecular interactions and the behavior of biomolecules in various environments has propelled research in pharmaceuticals, diagnostics, and therapeutic strategies, showcasing the transformative power of the double helix model. As our genetic comprehension expands, the double helix remains central to the ongoing exploration of life's molecular basis and the complexities of biological systems. Photo 51, taken by Rosalind Franklin in 1952, has left an indelible mark on modern science, particularly in the fields of molecular biology and genetics. This iconic X-ray diffraction image provided the first clear evidence of the helical structure of deoxyribonucleic acid (DNA), fundamentally transforming our understanding of genetic material. The implications of this discovery extend far beyond its initial revelation, influencing numerous biotechnological advances and genetic engineering practices today. The clarity and precision of Photo 51 illuminated the path towards various innovations in genetic manipulation, such as CRISPR technology. By understanding the structure of DNA, researchers have been able to develop methods to edit genes with unprecedented accuracy. This capability paves the way for therapeutic interventions in genetic disorders, ushering in a new era of medicine. Techniques derived from insights gained from Photo 51 facilitate the study of gene functions and interactions, thereby enhancing our capacity to design targeted treatments that were previously unimaginable. Moreover, the legacy of Photo 51 reverberates in forensic science, where DNA evidence plays a crucial role in criminal investigations. The methodologies established from the initial understanding of DNA structure enable forensic scientists to analyze genetic material effectively, leading to crucial breakthroughs in solving cases and exonerating the wrongly accused. The profound impact of Photo 51 is also evident in evolutionary biology. It has spurred studies on the genetic relationships among species, enhancing our comprehension of evolutionary processes and biodiversity. In essence, the influence of Photo 51 is enduring, continuing to foster research and innovation across various scientific disciplines. This single image serves as a reminder of the intricate dance between discovery and technological advancement, inspiring countless scientists to explore the mysteries of life at the molecular level. The advancements in scientific research, particularly in the study of DNA, exemplified by the discovery behind Photo 51, raise significant ethical considerations, particularly concerning credit and recognition. Central to this discussion is the role of Rosalind Franklin, whose meticulous work and pioneering efforts were pivotal, yet often inadequately acknowledged in the broader scientific narrative. Franklin's contributions were instrumental in elucidating the structure of DNA, and her X-ray diffraction images provided critical insights that shaped subsequent research. One of the notable ethical implications in this context is the challenge of ensuring appropriate recognition for all contributors in collaborative scientific endeavors. The case of Photo 51 highlights how the dynamics of scientific discovery can sometimes prioritize certain figures over others, leading to the overshadowing of key contributors like Franklin. This neglect raises questions about the integrity of scientific practice and the ethical responsibility of researchers to acknowledge all voices in collaborative settings. Furthermore, the historical narrative surrounding the discovery of DNA often emphasizes the roles of James Watson and Francis Crick while neglecting to give due credit to Franklin. This discrepancy not only highlights a need for a more equitable approach to recognizing contributions in scientific work but also underscores the significance of transparency and inclusivity in research practices. Ethical considerations extend beyond mere acknowledgment; they are foundational to fostering a scientific culture that values diverse contributions and uplifts those who have been historically marginalized. As the scientific community reflects on the legacy of Photo 51, it serves as a critical reminder of the importance of equitable recognition. By striving for an ethical framework that honors all contributors, the integrity of scientific research is fortified, paving the way for a more inclusive and responsible approach to discovery in the future. Photo 51 is an X-ray diffraction image of DNA captured in 1952 by Rosalind Franklin and her team at King's College London. It provided crucial evidence for the discovery of the double helix structure of DNA. Photo 51 was instrumental in confirming that DNA has a helical structure. It helped James Watson and Francis Crick develop their double helix model, which became the foundation of modern molecular biology and genetics. Rosalind Franklin used X-ray diffraction techniques to analyze crystallized DNA fibers. The resulting diffraction pattern provided key structural details about DNA. James Watson and Francis Crick used insights from Photo 51—without Franklin's direct permission—to finalize their double helix model of DNA in 1953. During her lifetime, Franklin's contributions were largely overlooked. The 1962 Nobel Prize for the discovery of DNA's structure was awarded to Watson, Crick, and Maurice Wilkins, omitting Franklin, who had passed away in 1958. X-ray diffraction is a technique used to determine the structure of crystalline substances by analyzing the way X-rays scatter off a sample. This method helped reveal DNA's helical shape and precise molecular arrangement. Photo 51 showed a clear X-shaped diffraction pattern, indicating a helical structure with repeating elements, confirming that DNA consists of two intertwined strands. Maurice Wilkins, Franklin's colleague at King's College, showed Photo 51 to Watson and Crick without Franklin's direct approval, enabling them to refine their DNA model. The discovery of DNA's double helix has led to major advancements in genetics, biotechnology, medicine, forensic science, and genetic engineering. Photo 51 is preserved at King's College London, where it remains an important historical artifact in the history of molecular biology. Subscribe to get the latest posts sent to your email. In April 1953, Rosalind published her findings in the scientific journal Nature. In another piece appearing in that same issue, Cambridge scientists James Watson and Francis Crick announced their double helix model of DNA. Rosalind's data corroborated this new model, but it's not clear if she knew that her unpublished research had helped inspire and construct it. At the beginning of that year, Gosling had showed Photo 51 to Wilkins, who in turn showed it to Watson. Because he and his research partner were already immersed in DNA research, Watson immediately understood the stunning implication of the photo: The helical structure was essential to the replication of DNA. Rosalind had left King's College a few months before Nature reported the groundbreaking discovery of the structure of DNA. In search of collaboration and a more supportive research environment, she went to work for the Biomolecular Research Laboratory at Birkbeck College, also in London. There, under the direction of her old mentor J.D. Bernal, she adapted her excellence in X-ray crystallography to the field of virology, making important contributions to the understanding of the structure of the tobacco mosaic virus. Over time, Watson and Crick — and Wilkins, to some extent — would receive much of the credit for revealing the secrets of DNA. The three were awarded the Nobel Prize in 1962 for "discoveries concerning the molecular structure of nucleic acids." For her part, Rosalind was magnanimous. According to Gosling, when she was made aware of Watson and Crick's model, she said, "We all stand on each other's shoulders." Page 2 Another important aspect of Dr. Franklin's legacy has been the example she set for women everywhere. Though she faced a number of obstacles, many brought about by the sexist attitudes of the time, she didn't let those keep her from striving toward what she knew to be her life's work. There are several "what ifs?" surrounding her life. If she hadn't been forced to work in isolation at King's College, would she have unlocked the structure of DNA first? What other discoveries might she have made had she lived longer? As it stands, though, her accomplishments help show that women can excel in intellectually demanding fields, but also could measure up to men in performing the most critical, groundbreaking work in these areas. Women who study STEM (science, technology, engineering and math) subjects or go into these professions — and there are more of them every day — have trailblazers like Rosalind Franklin to thank for paving the way. The modestly named "Photograph 51" proved to be a critical piece of evidence leading to the identification of the structure of DNA Rosalind Elsie Franklin, 25 July 1920 - 16 April 1958; click photo for larger version; original image archived at the Ann Ronan Picture Library—World History Archive In 1952, between May 2 and May 6 at King's College, London, molecular biologist Rosalind Franklin and graduate student Raymond Gosling take Photograph 51. By today's standards a rather blurry image that reminds one of a minimalist kaleidescope, this is an X-ray diffraction image of a paracrystalline gel composed of DNA fiber. Its unassuming name stemmed from the fact that it was the 51st such diffraction photo Franklin and Gosling had taken in that particular series, but it proved to be an important one, even emerging as the critical piece of evidence leading to the identification of the structure of DNA. Franklin joined the Biophysical Laboratory at King's College as a research fellow under the directorship of John Randall. At that time, little was known about the chemistry or anatomy of DNA. Working with X-ray diffraction methodologies she discovered that DNA was much denser than previously thought and, most importantly, found that it seemed to conform to a helical structure. By most accounts, this provided the revelatory moment that led James Watson and Francis Crick to suggest in 1953 that the structure of DNA is a double-helix polymer, a spiral consisting of two DNA strands wound around each other. At the start of 1953, Franklin was preparing to move to Birkbeck College where John Desmond Bernal, chair of the physics department, offered her her own research team. Raymond Gosling had returned to working under Maurice Wilkins's supervision at Kings College. Gosling had been told to share all his data with Wilkins, and on 26 January 1953 Wilkins saw Photograph 51. Four days later, on January 30, Wilkins showed the photograph to James Watson. Crystallographic photo of Sodium Thymonucleate, Type B, "Photo 51." Rosalind Franklin and Raymond G. Gosling, May 1952. Original held in the Ava Helen and Linus Pauling Papers Collection. Watson described Photograph 51 to Francis Crick and they decided this was strong enough evidence to confirm a 20Å diameter, with a 3.4Å distance between bases. This, plus the repeat distance of 34Å, helix slope about 40°, and the likelihood of 2 chains, not 3, seemed to be sufficient to begin building their model. The next day, on January 31, Watson went to Lawrence Bragg, the laboratory director, to get approval to order model components from the Cavendish Laboratory machine shop. Rosalind Elsie Franklin died in 1958 of ovarian cancer at the age of 37. In 1962 Francis Crick, James Watson, and Maurice Wilkins shared the Nobel Prize in Physiology or Medicine. Watson portrayed Franklin somewhat negatively in the early chapters of his history of the research on DNA structure, The Double Helix: A Personal Account of the Discovery of the Structure of DNA. Watson later recanted and said that Franklin and Wilkins should have been awarded the prize in chemistry, but it was the Nobel Committee's policy at the time not to make posthumous nominations. If she had shared the prize in 1962, Franklin would have been only the fourth woman Nobel laureate in the sciences, and two of those were named Curie. Franklin's file copy of Photograph 51, labeled in her handwriting, is preserved at the J. Craig Venter Institute. J.D. Watson and F.H.C. Crick. "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." Nature 171, no. 4356 (25 Apr 1953): 737–738. . View a PDF file of the original publication at Scribd.com. M.H.F. Wilkins, A.R. Stokes and H.R. Wilson. 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Howard Markel. The Secret of Life: Rosalind Franklin, James Watson, Francis Crick, and the Discovery of DNA's Double Helix (New York: W.W. Norton & Company, publication scheduled for September 2021). Related Items On 6 May 1952, at King´s College London in London, England, Rosalind Franklin photographed her fifty-first X-ray diffraction pattern of deoxyribosenucleic acid, or DNA. Photograph 51, or Photo 51, revealed information about DNA´s three-dimensional structure by displaying the way a beam of X-rays scattered off a pure fiber of DNA. Franklin took Photo 51 after scientists confirmed that DNA contained genes. Maurice Wilkins, Franklin´s colleague showed James Watson and Francis Crick Photo 51 without Franklin´s knowledge. Watson and Crick used that image to develop their structural model of DNA. In 1962, after Franklin´s death, Watson, Crick, and Wilkins shared the Nobel Prize in Physiology or Medicine for their findings about DNA. Franklin´s Photo 51 helped scientists learn more about the three-dimensional structure of DNA and enabled scientists to understand DNA´s role in heredity. X-ray crystallography, the technique Franklin used to produce Photo 51 of DNA, is a method scientists use to determine the three-dimensional structure of a crystal. Crystals are solids with regular, repeating units of atoms. Some biological macromolecules, such as DNA, can form fibers suitable for analysis using X-ray crystallography because their solid forms consist of atoms arranged in a regular pattern. Photo 51 used DNA fibers, DNA crystals first produced in the 1970s. To perform an X-ray crystallography, scientists mount a purified fiber or crystal in an X-ray tube. The X-ray tube generates X-rays that strike the purified material. X-rays are electromagnetic waves that have a shorter wavelength and higher energy than visible light. Because of their short wavelength, X-rays can pass through a crystal and interact with the electrons of the atoms within the crystal. When X-rays interact with electrons in a crystal the X-rays scatter, or diffract, at angles that indicate the arrangement of atoms in the crystal, or its structure. When the X-rays scatter, they strike a film mounted behind the crystal and leave a pattern of dark marks. The pattern of dark marks on the film gives scientists information about the structure of the crystal. Scientists began collecting X-ray diffraction patterns of DNA in the 1930s before they confirmed that DNA contained genes. William Thomas Astbury, a crystallographer working at the University of Leeds in Leeds, England, gathered the first diffraction patterns of DNA in 1937. However, Astbury´s diffraction patterns were blurry and difficult to interpret. At the time of Astbury´s experiments, scientists had determined the chemical composition of DNA. However, at that time scientists generally agreed that DNA merely provided structural support for cells and that protein must be genetic material. In 1944 Oswald Avery, Colin MacLeod and Maclyn McCarty published an experiment that isolated DNA as the material that contained genes. Maurice Wilkins, a scientist working at King´s College London, collected X-ray diffraction patterns of DNA in 1950. Wilkins and his graduate student, Raymond Gosling, later Franklin´s graduate student, collected X-ray diffraction patterns of DNA purified in a way that produced longer fibers than those accessible to Astbury. When mounting the DNA fibers for viewing, Wilkins and Gosling were able to bundle many of the thin fibers together and pull them tight to provide a larger sample to better diffract X-rays. Furthermore, the two researchers kept the DNA fibers wet with water by keeping them in a humid environment. The resulting X-ray diffraction pattern of DNA was of a higher quality than any patterns collected prior. Franklin, a specialist in X-ray crystallography, continued previous X-ray crystallography experiments on DNA with Gosling when she joined the King´s College London lab in 1951. Before joining the lab, Franklin conducted X-ray diffraction experiments on carbon compounds at a government lab in Paris, France, and published several papers on X-ray crystallography of coal and coal compounds. Throughout Franklin´s early work at King´s College London, she found that DNA fibers with a higher water content produced a different diffraction pattern than DNA fibers with a lower water content, indicating that wet and dry DNA adopted different three-dimensional conformations. Franklin later defined the drier DNA conformation as the A-Form DNA and the wetter DNA conformation as B-Form DNA. As of 2018, scientists continue to use the A Form and B Form designations for the two conformations of DNA. In addition to identifying the two forms of DNA, Franklin determined that Asbury´s diffraction patterns of DNA came from a mixture of A and B-Forms of DNA. By improving her methods of collecting DNA X-ray diffraction images, Franklin obtained Photo 51 from an X-ray crystallography experiment she conducted on 6 May 1952. First, she minimized how much the X-rays scattered off the air surrounding the crystal by pumping hydrogen gas around the crystal. Because hydrogen only has one electron, it does not scatter X-rays well. She pumped hydrogen gas through a salt solution to maintain the targeted hydration of the DNA fibers. Franklin tuned the salt concentration of the solution and the humidity surrounding the crystal to keep DNA entirely in the B-Form. After exposing the DNA fibers to X-rays for a total of sixty-two hours, Franklin collected the resulting diffraction pattern and labeled it Number 51 that became Photo 51. Photo 51 presents a clear diffraction pattern for B-Form DNA. The outermost edge of the diffraction pattern consists of a black diamond shape. The diamond has rounded corners with the darkest corners situated at the top and bottom of the film. The diamond shape of the DNA diffraction pattern is not made of fine, definite lines, but rather thick, fuzzy boarders that vary in darkness such that the boarders fade on the left and right hand sides of the film. Inside the diamond is a cross shape like the letter "X." The X shape is not made of continuous lines. Instead, along each line of the X are four horizontal dashes, called spots that become darker moving closer to the center of the film. There is a hole at the center of the film, with dark spots lining the outside of the center hole. Researchers could interpret an X-ray diffraction pattern of DNA with knowledge about DNA´s composition, which scientists had at the time Franklin collected photo 51. Years prior to Franklin´s work, scientists determined that DNA consists of a chain of repeating units called nucleotides. Each nucleotide has three key features. Each nucleotide consists of a center sugar ring called deoxyribose. Attached to one end of the deoxyribose ring is a negatively charged phosphate group consisting of phosphorus and oxygen atoms. Attached to the other end of the deoxyribose ring is a molecule called a base consisting of either single or double rings of carbon and nitrogen. There are four types of bases in DNA. Using the available knowledge about DNA´s composition and mathematical techniques, Franklin learned of some key features regarding the structure of B-Form DNA from Photo 51. The presence of the X shape in the diffraction pattern indicated to Franklin that DNA strands were helical. Each dash of the X shape marks the repetition of atoms, or atomic repeats, in DNA. Therefore, based on the distances between the dashes, Franklin determined the distance between nucleotides, the smallest repeating units in DNA. The angles of the X shape revealed to Franklin the radius of DNA, or half the horizontal distance from one side of the molecule to the other. From the distance between the top and bottom of the outer diamond shape, Franklin found that there are ten nucleotides between each turn of the DNA molecule. Lastly, the lighter nature of the diamond on the top and bottom of the film showed Franklin that the DNA bases face the inside of the helix whereas the phosphate groups face outside. With knowledge of the density, mass per unit volume, of her DNA samples, Franklin also concluded that DNA contained two strands. While Franklin obtained Photo 51 in May 1952, she did not complete her analysis of Photo 51 until early 1953. 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With knowledge of the density, mass per unit volume, of her DNA samples, Franklin also concluded that DNA contained two strands. While Franklin obtained Photo 51 in May 1952, she did not complete her analysis of Photo 51 until early 1953. In January 1953, Watson visited King´s College London. While visiting, Wilkins showed Watson one of Franklin´s X-ray diffraction images of DNA, which historians claim was one of the clearest image of DNA, Photo 51, without Franklin´s knowledge. From the image, Watson concluded that DNA was helical. During his meeting with Wilkins, Watson also obtained necessary dimensions of DNA derived from Photo 51 that he and Crick later used to develop their proposed structure of DNA. Later, Watson and Crick received an internal King´s College London research report written by Franklin about her DNA diffraction images. From that report, Crick determined that DNA contains two strands, with each strand running in opposite directions. Watson and Crick, two scientists at the University of Cambridge in Cambridge, England, relied on Franklin´s Photo 51 to propose a three-dimensional structure of DNA and in April 1953, they suggested a three-dimensional structure of DNA partly based on Photo 51. The model they suggested consisted of two helical strands of repeating nucleotides wound around each other making a double helix. The double helix had ten nucleotides between each turn. The phosphate groups faced outside the double helix and the DNA bases faced horizontally inward of the helix. The two strands held together through interactions between the bases of each strand. The DNA strands ran in opposite directions. As of 2019, Watson and Crick´s proposed DNA structure has remained the verified structure with a few variations of B-Form DNA, the major form of DNA in living cells. Later, in May 1953, Watson and Crick proposed a replication mechanism for DNA using their DNA structure. Their replication mechanism, later called semi-conservative replication, described how to copy the DNA molecule that contained the genes and to pass the genes from cell to cell and from parent to offspring. Many features of B-Form DNA present in Photo 51 are necessary for semi-conservative replication, such as the DNA bases facing horizontally inward in the double helix. In addition, some aspects of B-Form DNA as indicated in Photo 51 posed challenges for semi-conservative replication. Watson and Crick proposed that the DNA strands needed to unwind and separate in order to replicate. However, because of the helical nature of DNA, as shown in the X-ray diffraction pattern of Photo 51, some scientists argued that the DNA strands would be too difficult to unwind and separate. Some years passed before scientists accepted semi-conservative replication due to the perceived difficulty of unwinding the helical strands. For their findings related to DNA, Watson, Crick, and Wilkins received the 1962 Nobel Prize in Physiology or Medicine. Franklin also contributed to understanding DNA structure, especially through her collection of Photo 51. She also determined many important features about DNA´s structure independently using Photo 51. The award of the Nobel Prize is never posthumously and Franklin died in 1958 before the award of the 1962 Nobel Prize. Some controversy and speculation surrounds the 1962 Nobel Prize concerning Franklin and her contributions to Watson and Crick´s DNA model. Only after the publication of Watson´s, book The Double Helix: A Personal Account of the Discovery of the Structure of DNA in 1968 was the roll that Franklin played in the discovery of the structure of DNA realized. Photo 51, a clear X-ray diffraction pattern of DNA, showed structural features of DNA necessary for scientific understanding of DNA´s three-dimensional structure. By understanding DNA structure, scientists could learn about how DNA functioned as genetic material. The DNA structure revealed in Photo 51 related the essential functions of a gene how its information is preserved and carried from cells to cell and from parent to offspring. Asbury, William Thomas, Sylvia Dickinson, and Kenneth Bailey. "The X-ray Interpretation of Denaturation and the Structure of the Seed Globulins." Biochemical Journal 10 (1935): 2351–60. Avery, Oswald, Theodore, Colin Munro MacLeod, and Maclyn McCarty. "Studies on the Chemical Nature of the Substance Inducing Transformation of Pneumococcal Types: Induction of Transformation by Deoxyribonucleic Acid Fraction Isolated from Pneumococcus Type III." Journal of Experimental Medicine 79 (1944): 134–58. (Accessed March 8, 2018). Franklin, Rosalind E., "Influence of the Bonding Electrons on the Scattering of X-Rays by Carbon." Nature 165 (1950): 71–2. Franklin, Rosalind E. and Raymond G. Gosling. 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