The Discovery of the Double Helix: An Analysis of the Seminal 1953 Publications and Their Historical Context

Chapter 1: Briefing Document: The Scientific and Historical Context of DNA's Structure

1.0 Executive Summary

The 1953 discovery of DNA's double helix structure stands as a seminal moment in scientific history, not merely for the structure it revealed, but for the complex process of its revelation. This document analyzes the discovery as a case study in the dynamic interplay between theoretical insight, empirical evidence, and the often-unpredictable course of human interaction. The breakthrough was forged in a unique crucible of competition and informal data sharing between two methodologically distinct groups: the theoretical model-builders James Watson and Francis Crick at Cambridge University, and the experimental X-ray crystallographers, primarily Rosalind Franklin and Maurice Wilkins, at King's College London. The physical evidence generated at King's College, particularly Franklin and Gosling's iconic "Photo 51" of the hydrated B-form of DNA, served as the ultimate empirical arbiter, providing the non-negotiable parameters against which any theory must be judged. The final, correct model was catalyzed by the pivotal and historically controversial transfer of this unpublished King's data to Cambridge. The subsequent, strategically coordinated publication of three papers in *Nature* cemented the discovery but also initiated decades of historiographical debate about scientific ethics and the proper allocation of credit, a controversy shaped significantly by the primary accounts of the participants themselves.

1.1 The Race for the Secret of Life: A Competitive Landscape

In the early 1950s, the physical structure of deoxyribonucleic acid (DNA) had become one of the most consequential questions in science. With mounting evidence that DNA was the carrier of genetic information, its structure was rightly seen as the "secret of life." This strategic imperative ignited an intense, if unofficial, race. The outcome was ultimately shaped by a unique convergence of factors: a sharp methodological divide between theoretical model-building and experimental crystallography, compounded by miscommunication and personal rivalries, and ultimately bridged by informal, and controversial, channels of data sharing. These conditions created the unique environment in which the breakthrough would occur not at King's College London, which held the crucial data, but at Cambridge University's Cavendish Laboratory.

The DNA research program at King's College London was initiated around 1950 by Maurice Wilkins. Applying the technique of X-ray diffraction to a highly pure DNA sample from Swiss chemist Rudolf Signer, Wilkins and his graduate student Raymond Gosling produced the first clear diffraction patterns suggesting a regular, crystalline structure. This initial work set the stage for a more rigorous, data-driven investigation.

In contrast to the experimentalists at King's, the two researchers at Cambridge's Cavendish Laboratory, James Watson and Francis Crick, did not conduct their own experimental work on DNA. Their approach was primarily theoretical, focused on building physical, scale atomic-molecular models that could account for the known chemical properties of DNA and any available experimental data. Their expertise lay in stereochemistry, helical diffraction theory, and the intellectual synthesis of disparate scientific clues into a single, elegant hypothesis.

The dynamic at King's College was irrevocably altered by the arrival of Rosalind Franklin in January 1951. An expert in X-ray crystallography, she was recruited by John T. Randall, the head of the biophysics unit, to take charge of the DNA project. This crucial ambiguity in her role—as Randall failed to clearly communicate this decision to Wilkins, who believed Franklin was his collaborator—sowed the seeds of a deep and unproductive rivalry, fracturing the King's College effort into two separate programs that communicated poorly. Franklin's methodical and rigorous approach led to a critical discovery—the distinction between the A and B forms of DNA—but her cautious focus on analyzing the more crystallographically complex A-form may have delayed her own definitive interpretation of the B-form's overtly helical nature, a tragic irony of the scientific process.

This competitive and often fraught environment formed the backdrop against which the critical experimental evidence—the language of physics that awaited a biological translator—would be produced.

1.2 The Empirical Anchor: X-Ray Diffraction Evidence from King's College

In the pursuit of DNA's structure, X-ray diffraction was not merely a technique; it was the non-negotiable physical truth. It offered a direct method to probe the internal arrangement of atoms, revealing a molecule's fundamental symmetry and dimensions. Any theoretical model, whether from Linus Pauling or from Watson and Crick, would ultimately be judged against the hard constraints of the diffraction patterns. This physical evidence, generated primarily at King's College, thus served as the ultimate empirical arbiter, capable of breaking any hypothesis that failed to conform to its reality.

The A-form and B-form Distinction

A crucial finding by Rosalind Franklin and Raymond Gosling was that DNA fibers could exist in two distinct forms depending on their water content. The drier, more crystalline state was designated the **'A' form**. When the fibers were highly hydrated, they transitioned to a different, "paracrystalline" structure known as the **'B' form**. Franklin's methodical approach yielded this critical distinction, but it was the B-form that provided the clearest and most striking evidence of a helical structure. The famous "Photo 51," an exceptionally clear diffraction image of the B-form taken by Franklin and Gosling in May 1952, became the single most important piece of experimental data in the discovery.

Interpreting the Diffraction Pattern

The B-form X-ray pattern contained a wealth of structural information. The logical deduction of the structure from this pattern proceeded as follows:

- **The 'X-shape' Pattern:** The most striking feature of Photo 51 is the prominent 'X' shape of strong reflections. This is the unmistakable signature of a helical molecule. A continuous helix, when diffracting X-rays, scatters them into a cone that, when projected onto a flat film, creates this characteristic cross shape.
- **Absence of Meridian Reflections:** The vertical axis of the pattern, the meridian, was conspicuously empty. The Wilkins, Stokes, and Wilson paper notes this "immediately suggests a helical structure with axis parallel to fibre length," providing definitive proof against simpler models, such as a stack of flat bases without any twist. The pattern also powerfully "suggests the presence of nitrogen bases arranged like a pile of pennies in the central regions of the helical system."
- **Key Periodicities:** The pattern contained precise measurements that defined the molecule's dimensions. A very strong reflection on the meridian at **3.4 Å** corresponded to the most regularly repeating feature along the central axis—the distance from one "stair" (base pair) to the next. The spacing of the horizontal "layer lines" revealed a major repeat every **34 Å**, representing the distance along the fiber axis before the molecule's pattern repeats itself perfectly—the full "turn" of the helical staircase. The ratio of these two numbers (34 Å / 3.4 Å) yielded a profound conclusion: there were exactly **10** nucleotide residues per complete helical turn.

The Role of Helical Diffraction Theory

Translating these patterns into a three-dimensional structure required a sophisticated mathematical framework. The theory of helical diffraction, developed in the early 1950s by researchers including Cochran, Crick, and Vand, provided the necessary tools. This theory describes the complex pattern of scattering from points arranged on a helix using mathematical constructs known as **Bessel functions**. At King's College, Alec R. Stokes had made crucial, though unpublished, contributions to this theory, applying it to interpret the early DNA patterns. This theoretical underpinning ensured that the interpretation of the X-ray data was grounded in rigorous physical and mathematical principles.

The raw, powerful *language* of physics captured in the diffraction patterns was now available, waiting for a *translator* capable of turning it into the biological *grammar* of a structural model.

1.3 The Cambridge Synthesis: Watson and Crick's Double Helix Model

The theoretical, model-building approach of James Watson and Francis Crick at Cambridge uniquely positioned them to synthesize disparate pieces of evidence—biochemical rules, stereochemical constraints, and the crucial X-ray data from King's College—into a single, cohesive structure. The final breakthrough at Cambridge was catalyzed by two pivotal—and historically controversial—transfers of unpublished data from King's College, which provided the last essential clues.

The first key transfer occurred when Maurice Wilkins, without Franklin's direct consent, showed James Watson the stunning clarity of "Photo 51." Watson immediately recognized the helical 'X' pattern and its implications. Shortly thereafter, Max Perutz, a senior member of the Cambridge lab, provided Watson and Crick with a copy of a formal scientific report Franklin had submitted to the Medical Research Council (MRC). This report was not intended for wide circulation, but it contained Franklin's precise measurements and her conclusion that the DNA unit cells were of the 'face centred monoclinic' type. This information was vital; Crick, an expert in crystallographic theory, immediately recognized that this symmetry indicated that the two DNA strands were antiparallel, running in opposite directions.

Armed with these critical insights, Watson and Crick rapidly constructed their final model, which they announced in their seminal paper in *Nature* on April 25, 1953. The core features of their double helix model were:

1. **Two Helical Chains:** The structure consists of two right-handed helical chains coiled around a common central axis.
2. **Antiparallel Chains:** The sequences of atoms in the two phosphate-sugar backbones run in opposite directions, a key deduction from the MRC report data.
3. **Specific Base Pairing:** The two chains are held together by hydrogen bonds between purine and pyrimidine bases on the inside of the helix. Critically, only specific pairs could form: Adenine (A) always pairs with Thymine (T), and Guanine (G) always pairs with Cytosine (C).
4. **Biological Implication:** The model's structure immediately suggested its function. Watson and Crick concluded their paper with one of the most famous understatements in scientific history: “It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.”

The announcement of this elegant and powerful structure marked the dawn of the era of molecular biology, but it also initiated a long and complex historical post-mortem regarding credit, recognition, and the ethics of scientific discovery.

1.4 Historical Aftermath: Recognition, Controversy, and a Curious Error

The legacy of the 1953 discovery is twofold. Scientifically, it launched a revolution in biology, providing the physical basis for genetics and paving the way for everything from the genetic code to modern biotechnology. Historically, the decades that followed were marked by intense debate over the contributions of the individuals involved, the ethics of data sharing, and the nature of scientific recognition.

Publication and Recognition

The announcement of the discovery was strategically coordinated. The April 25, 1953, issue of *Nature* featured a sequence of three papers: the theoretical model from Watson and Crick; the experimental validation from Wilkins, Stokes, and Wilson; and the detailed data from Franklin and Gosling. This back-to-back publication strategy ensured that the revolutionary model was immediately supported by the empirical data upon which it was built. In 1962, the Nobel Prize in Physiology or Medicine was jointly awarded to James Watson, Francis Crick, and Maurice Wilkins "for their discoveries concerning the molecular structure of nucleic acids." Rosalind Franklin, whose data had been so pivotal, had died of ovarian cancer in 1958 at the age of 37. As the Nobel Prize is not awarded posthumously, she could not be considered for the award.

The Franklin Controversy

The historical debate surrounding Rosalind Franklin's role was largely ignited by James Watson's provocative 1968 memoir, *The Double Helix*. His book must be understood as a historical artifact in its own right—a primary source that both documented the discovery and simultaneously shaped its controversial public memory for decades. His portrayal of Franklin was deeply unflattering and minimized her scientific contributions. The core of the controversy centers on the fact that the Cambridge team used two key pieces of her unpublished data—the superior "Photo 51" and the quantitative details from her MRC report—without her direct knowledge or consent. Historical analysis has concluded that this was, at minimum, a breach of scientific etiquette that deprived Franklin of the opportunity to solve the structure herself and denied her due credit at the time.

The 'Surprising Wilkins' Error'

A peculiar footnote to the history of the discovery is a "curious and inexplicable error" that appeared in a subsequent paper by Wilkins and his colleagues, published in *Nature* on October 24, 1953. In this paper (Wilkins et al., 1953b), the authors included a diagram (Figure 3) that schematically depicted the DNA molecule as a *left-handed* helix. This contradicted the right-handed model proposed by Watson and Crick. In a 1954 paper, Crick and Watson clarified that a left-handed helix was stereochemically impossible, as it would violate permissible van der Waals contacts between atoms. Remarkably, this fundamental mistake in the Wilkins paper went unnoticed for decades and, fortunately, had no detrimental effect on the progress of molecular biology.

The story of the double helix is therefore not a simple tale of a single "eureka" moment, but a complex, multi-faceted narrative of competition, collaboration, brilliant insight, and human fallibility.

Chapter 2: Study Guide for the Discovery of DNA's Structure

2.1 Short-Answer Quiz

This quiz is designed to test your comprehension of the key scientific and historical facts surrounding the discovery of the DNA double helix.

Questions

1. What were the respective primary research methodologies used by the scientific teams at Cambridge University and King's College London in the race to determine DNA's structure?
2. Identify the two distinct structural forms of DNA discovered by Rosalind Franklin and Raymond Gosling, and explain which form was more critical for deducing the helical structure.
3. What specific feature in the X-ray diffraction pattern of DNA provided the most direct evidence that the molecule was a helix?
4. Name the three key structural parameters of the DNA B-form that were determined from the X-ray diffraction data from King's College.
5. Describe the specific base-pairing rule proposed by Watson and Crick and explain its critical implication for genetic replication.
6. What was "Photo 51," who produced it, and what was its immediate impact on James Watson?
7. Explain the significance of the information from Rosalind Franklin's MRC report that was shared with the Cambridge team.
8. Why was Rosalind Franklin not awarded the 1962 Nobel Prize along with Watson, Crick, and Wilkins?
9. Describe the "surprising error" found in the October 1953 paper by Wilkins et al. and state its ultimate impact on science.
10. How did the strategic, back-to-back publication of the three *Nature* papers on April 25, 1953, shape the scientific reception of the double helix model?

Answer Key

1. The team at King's College London, including Maurice Wilkins and Rosalind Franklin, used the experimental method of X-ray diffraction to study DNA fibers. The team at Cambridge University, James Watson and Francis Crick, used a theoretical approach focused on building physical, scale atomic-molecular models to fit existing data.

2. Rosalind Franklin and Raymond Gosling discovered the drier, crystalline 'A' form and the highly hydrated 'B' form. The 'B' form was more critical because its X-ray diffraction pattern, particularly Photo 51, provided the clearest evidence of DNA's helical nature and key dimensions.
3. The most direct evidence for a helix was the prominent 'X-shape' pattern of reflections radiating from the center of the B-form diffraction image. This is the characteristic signature of scattering from a helical molecule.
4. The three key parameters were the distance between stacked base pairs (**3.4 Å**), the full pitch of the helix (**34 Å**), and the number of residues per turn (**10**), which was derived from the first two measurements.
5. Watson and Crick proposed that adenine (A) always pairs with thymine (T), and guanine (G) always pairs with cytosine (C). This specific pairing immediately suggested a "possible copying mechanism for the genetic material," as one strand could serve as a template for synthesizing the other.
6. "Photo 51" was an exceptionally clear X-ray diffraction image of B-form DNA taken by Rosalind Franklin and her student Raymond Gosling in May 1952. When Maurice Wilkins showed the photo to James Watson, Watson was stunned by its clarity and immediately recognized the powerful evidence for a helical structure, which catalyzed the final model-building effort.
7. Franklin's MRC report contained her conclusion that DNA's unit cells were of the 'face centred monoclinic' type. Francis Crick recognized that this symmetry indicated the two DNA strands must be antiparallel, running in opposite directions, which was a crucial constraint for building the correct model.
8. Rosalind Franklin died of cancer in 1958 at the age of 37. The Nobel Prize is not awarded posthumously, so she was ineligible for consideration when the prize was awarded to Watson, Crick, and Wilkins in 1962.
9. The "surprising error" was a diagram in the October 1953 *Nature* paper by Wilkins et al. that incorrectly depicted DNA as a *left-handed* helix. This error, which was stereochemically impossible, was seemingly unnoticed for decades and had no detrimental effect on the development of science.
10. The back-to-back publication presented the discovery as a logical progression from theoretical hypothesis (Watson & Crick) to immediate experimental confirmation (Wilkins et al. and Franklin & Gosling). This strategy lent instant credibility and authority to the double helix model, framing it as a conclusion firmly grounded in physical evidence.

2.2 Essay Questions

These essay questions are designed for a deeper exploration of the complex scientific, historical, and ethical themes involved in the discovery. Please formulate a comprehensive response for each question based on the provided materials.

1. Analyze the dynamic between collaboration and competition in the discovery of the double helix. Discuss specific instances of data sharing (both formal and informal) and rivalry between the King's College and Cambridge laboratories and their impact on the final outcome.
2. Evaluate the contribution of Rosalind Franklin to the discovery of DNA's structure. Beyond her creation of "Photo 51," detail her other key scientific findings and discuss the historical controversy surrounding the use of her data and her posthumous recognition.
3. Deconstruct the evidence presented in the X-ray diffraction patterns of DNA. Explain how specific observations (e.g., the 'X' pattern, layer line spacing, meridian absences) were mathematically and logically translated into a physical model of a double helix with specific dimensions.
4. Discuss the concept of a scientific "discovery" as a process rather than a single event, using the story of the double helix as a case study. Examine the roles of theoretical modeling, experimental evidence, and hypothesis validation as demonstrated by the different research groups.
5. Explore the relationship between a scientific model's structure and its biological function, using the Watson-Crick model of DNA as the primary example. How did the proposed physical structure immediately illuminate a fundamental biological process?

2.3 Glossary of Key Terms

Term	Definition
X-ray Diffraction	A technique that helps scientists see the structure of crystallized material by aiming beams of X-radiation at a crystal and recording the positions and intensities of the diffracted X-rays on film for analysis.
A-form DNA	The drier, more crystalline structural form of DNA fibers, obtained at about 75% relative humidity.
B-form DNA	The highly hydrated, "paracrystalline" structural form of DNA that persists over a wide range of humidity and provided the clearest evidence of a helical structure.

Helical Diffraction Theory	A mathematical framework developed in the early 1950s that describes the diffraction patterns caused by helical structures, forming the basis for interpreting X-ray images of DNA.
Bessel Functions	A mathematical tool used in helical diffraction theory to model the intensity distribution in the diffraction pattern of points equally spaced along a helix.
Chirality	The property of a molecule, like a helix, having a "handedness" (right-handed or left-handed) that makes it non-superimposable on its mirror image.
Double Helix	The structure of DNA, consisting of two helical chains coiled around the same central axis.
Base Pairing (Purine, Pyrimidine)	The specific hydrogen-bonded pairing of nucleotide bases that holds the two DNA chains together: Adenine (**purine**) pairs with Thymine (**pyrimidine**), and Guanine (**purine**) pairs with Cytosine (**pyrimidine**).
Antiparallel	A feature of the DNA double helix where the sequences of atoms in the two phosphate-sugar chains run in opposite directions.
Photo 51	An exceptionally clear X-ray diffraction image of B-form DNA, taken by Rosalind Franklin and Raymond Gosling in May 1952, which provided powerful evidence for the helical structure.
Paracrystalline	A state of matter, characteristic of B-form DNA fibers, that is oriented and regular but lacks full three-dimensional translational symmetry, sitting between a true crystal and an amorphous solid.

Chapter 3: Frequently Asked Questions (FAQs)

This section addresses ten of the most common and important questions about the discovery of DNA's structure, its key players, and its scientific implications.

1. **What was "Photo 51" and why is it so famous?** "Photo 51" is the nickname for a specific X-ray diffraction image of the hydrated 'B' form of DNA, taken by Rosalind Franklin and her graduate student Raymond Gosling in May 1952. It is famous because it provided the clearest and most compelling physical evidence for the helical structure of DNA. The image's prominent "X" shape was the undeniable signature of a helix, and

its precise measurements allowed for the calculation of the helix's pitch and diameter, which were essential constraints for building the correct model.

2. **Why wasn't Rosalind Franklin awarded the Nobel Prize for her work on DNA?** Rosalind Franklin died of ovarian cancer in 1958 at the age of 37. The Nobel Prize is not awarded posthumously. When the prize for the discovery was awarded to Watson, Crick, and Wilkins in 1962, she was therefore ineligible for consideration.

3. **Did Watson and Crick "steal" Rosalind Franklin's data?** The historical record is complex. Watson and Crick gained access to Franklin's key unpublished data without her direct knowledge or consent through two main channels: Maurice Wilkins showed Watson "Photo 51," and Max Perutz provided the Cambridge team with Franklin's formal MRC research report. While this was not "theft" in a legal sense, it is widely considered a serious breach of scientific etiquette that deprived Franklin of the chance to solve the structure herself and denied her proper credit at the time.

4. **What was the "surprising Wilkins' error" and did it matter?** In a paper published in *Nature* in October 1953, Maurice Wilkins's group included a diagram of DNA that incorrectly showed it as a *left-handed* helix. A year later, Crick and Watson clarified that a left-handed helix was stereochemically impossible. This error was mysteriously unnoticed for decades and had no detrimental effect on the progress of science, as the community had already accepted the correct right-handed model.

5. **What did the X-ray photos actually prove about DNA's structure?** The X-ray diffraction patterns proved several fundamental features. The "X" shape was definitive proof of a helical structure. The absence of reflections on the vertical meridian ruled out simple, non-helical stacked models. Finally, the precise spacing of the reflections allowed for the calculation of the key dimensions: the 3.4 Å distance between stacked bases and the 34 Å pitch of the full helix, which implied 10 bases per turn.

6. **If the King's College team had the data, why did the Cambridge team solve the structure first?** The King's College effort was fractured by the intense rivalry between Wilkins and Franklin, which hindered collaboration and interpretation. In contrast, Watson and Crick at Cambridge had a highly collaborative partnership focused on theoretical model-building. They were able to synthesize disparate data points—including the King's data they controversially obtained, chemical rules from Erwin Chargaff, and stereochemical principles—into a single, coherent model more rapidly than the experimentalists.

7. **What is the difference between the A-form and B-form of DNA?** The A-form and B-form are two different structural conformations of DNA that depend on the level of hydration. The A-form is found in drier, more crystalline conditions. The B-form, which is the classic double helix structure, exists in highly hydrated conditions and is

the form found in the natural state within cells. The B-form provided the clearest X-ray evidence for the helical structure.

8. **How did Watson and Crick know that the DNA helix was right-handed and not left-handed?** Their initial 1953 paper proposed a right-handed helix. This was not determined from the X-ray data alone, which can be ambiguous about chirality, but from stereochemical model-building. In a 1954 paper, they explained that when they tried to build a physical model, a left-handed helix was stereochemically impossible because it would violate the "permissible van der Waals contacts," meaning the atoms would be too close together.

9. **What was the single most important biological insight that came from the double helix structure?** The most important insight was the mechanism for genetic replication. The specific pairing of bases (A with T, G with C) means the two strands are complementary. As Watson and Crick famously noted, this immediately suggests a "copying mechanism," where the two strands could unwind, and each could serve as a template for the synthesis of a new, complementary strand, allowing genetic information to be duplicated exactly.

10. **Who were all the key scientists involved in the three foundational *Nature* papers of April 25, 1953?** The three papers and their authors were:

    1. **"Molecular Structure of Nucleic Acids"**: James D. Watson and Francis H. C. Crick (Cambridge).

    2. **"Molecular structure of deoxypentose nucleic acids"**: Maurice H. F. Wilkins, Alec R. Stokes, and Herbert R. Wilson (King's College London).

    3. **"Molecular Configuration in Sodium Thymonucleate"**: Rosalind E. Franklin and Raymond G. Gosling (King's College London).

Chapter 4: Timeline of the Discovery of the DNA Double Helix

This timeline presents the key chronological events that led to the discovery of the DNA double helix, its publication, and the major historical developments in its aftermath.

- **c. 1950:** Maurice Wilkins and Raymond Gosling, at King's College London (KCL), obtain the first clear X-ray diffraction patterns of DNA.

- **January 1951:** Rosalind Franklin joins the KCL biophysics unit.

- **1951:** At a conference in Naples, Wilkins presents his early DNA diffraction work, which sparks James Watson's interest.
- **November 1951:** Watson and Crick propose their first (incorrect) model of DNA, which has three chains with the bases on the outside.
- **May 1952:** Under Rosalind Franklin's supervision, Raymond Gosling takes the exceptionally clear X-ray diffraction image of B-form DNA known as "Photo 51".
- **Late January 1953:** Wilkins shows "Photo 51" to Watson without Franklin's direct consent.
- **Early 1953:** Watson and Crick gain access to Franklin's MRC research summary report, which provides key data on DNA's symmetry.
- **February 28, 1953:** Watson and Crick complete their final, correct model of the DNA double helix.
- **April 25, 1953:** *Nature* publishes the three seminal papers on DNA structure by (1) Watson and Crick, (2) Wilkins, Stokes, and Wilson, and (3) Franklin and Gosling.
- **October 24, 1953:** *Nature* publishes a paper by Wilkins et al. that contains a diagram (Figure 3) incorrectly showing DNA as a left-handed helix.
- **1954:** Crick and Watson publish a paper clarifying that the DNA model must be right-handed to be stereochemically possible.
- **1958:** Rosalind Franklin dies of ovarian cancer at the age of 37.
- **1962:** Francis Crick, James Watson, and Maurice Wilkins are jointly awarded the Nobel Prize in Physiology or Medicine.
- **1968:** James Watson publishes his autobiographical account, *The Double Helix*, which proves to be highly controversial.
- **2024:** Nikita Khromov-Borisov publishes an article in *Biological Communications* highlighting the "surprising error" in the Wilkins et al. (1953b) paper.

Chapter 5: List of Cited Scientific Sources

This section provides a bibliography of the key scientific papers referenced in the historical accounts of the discovery of the DNA double helix.

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