

Oxford's Secret Graph Theory, Carroll's Hidden Satire and the Unsolvable Topology of the Dreaming Spires

The present tense of a bright summer afternoon in Oxford is an experience defined almost entirely by its overwhelming, historic aesthetics. A tourist wandering through the heart of the city might begin their journey by crossing the sweeping stone arches of Magdalen Bridge, pausing to lean over the balustrade and watch the gentle, unpowered glide of wooden punts navigating the River Cherwell.¹ They might proceed southward, stepping off the bustling pavement and descending into the lush, enclosed sanctuary of Christ Church Meadow, a vast peninsula of grazing land where the roar of city traffic is suddenly swallowed by the canopy of ancient trees.¹ From there, they might traverse the modern, sweeping steel curve of the Jubilee Footbridge, before winding their way along the Thames Path toward the historic, heavily fortified masonry of Folly Bridge.¹

Surrounded by the golden hue of corallian ragstone, the intricate Gothic tracery of the collegiate architecture, and the cinematic nostalgia of Harry Potter filming locations, the visitor is entirely consumed by the physical and visual beauty of the oldest university city in the English-speaking world. They are immersed in the poetry of Matthew Arnold's "dreaming spires."

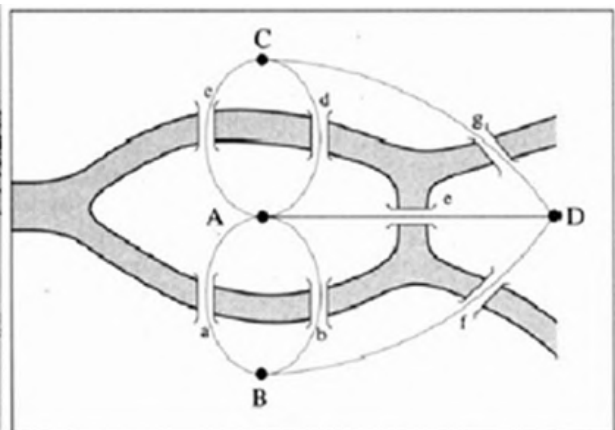
Yet, beneath the cobblestones, beneath the flowing river currents, and behind the towering architectural facades, a fundamentally different, invisible reality dictates the shape of the city. The casual pedestrian navigating Oxford's waterways and ancient alleys has absolutely no idea that they are inadvertently engaging with one of the most famous and foundational problems in the entire history of mathematics. With every bridge they cross, they are physically attempting to solve the exact same topological puzzle that, in 1736, gave birth to an entirely new branch of human knowledge.

Oxford is globally renowned as a crucible of mathematical thought, housing centuries of brilliance within the walls of the Mathematical Institute, the Bodleian Library, and its historic constituent colleges. However, the most interesting mathematical facts about Oxford are not the theorems proved on chalkboards inside its buildings, nor the academic papers published by its laureates. Rather, they are baked directly into the city's physical geography, its braided rivers, its labyrinthine street layout, and even its most beloved work of Victorian children's fiction. The city itself operates as a grand mathematical construct. This essay uncovers that hidden layer, revealing how the city's physical and cultural landscape operates as a silent syllabus of structural logic, laid down by historical forces centuries before the language of modern mathematics existed to describe it.

To comprehend the invisible mathematical architecture of Oxford's geography, one must first look eastward to the 18th-century Prussian city of Königsberg. In the early 1700s, Königsberg was a bustling commercial port carved into four distinct landmasses by the River Pregel: two mainland riverbanks and two large central islands.⁶ Connecting these four disparate landmasses to one another were seven heavily trafficked bridges.⁶ The citizens of Königsberg amused themselves with a seemingly simple recreational puzzle: was it possible to devise a continuous walking route through the city that crossed every single one of the seven bridges exactly once?⁷ Despite countless empirical attempts by the townsfolk, no one could do it. Yet, conversely, no one could definitively prove it was impossible.

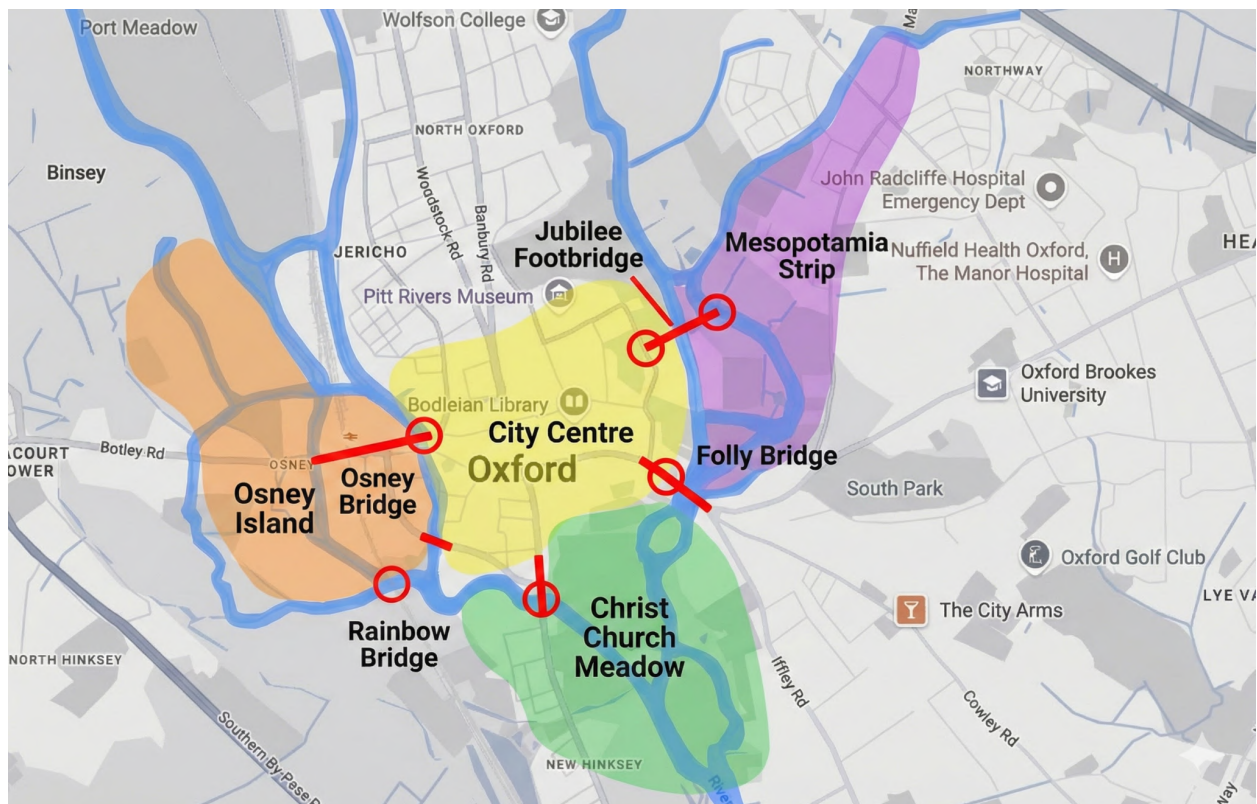
In 1735, the puzzle was brought to the attention of the brilliant Swiss mathematician Leonhard Euler.⁹ Euler realized that the exact physical length of the bridges and the geometric angles of the riverbanks were entirely irrelevant to finding a solution.⁶ By stripping away all the superfluous geographical details, Euler abstracted Königsberg into a pure framework of connections. He represented each of the four landmasses as a single abstract point, which today we call a "node," and he represented each of the seven bridges as a simple line connecting these points, known as an "edge."⁶ This act of ultimate abstraction gave birth to Graph Theory—the mathematics of networks and connections.⁹

Euler's genius lay in analyzing a concept we now call the *degree* of a node: the total number of bridges touching a single landmass.⁷ He deduced a simple, unbreakable rule. Whenever a pedestrian enters a landmass via one bridge, they must eventually leave it via another, unless that landmass is the absolute starting point or the final destination of their walk.¹⁵ Therefore, for any intermediate landmass on the journey, the bridges must be used in distinct pairs. This strictly requires that any intermediate node in a successful path must have an *even* number of bridges attached to it.¹⁵ Consequently, a continuous path traversing every bridge exactly once—an Eulerian path—can only exist if the entire network contains at most two nodes with an odd number of bridges.¹⁶



When Euler applied this elegant law back to Königsberg, the verdict was devastating. All four of the city's landmasses had an odd number of bridges connecting them (three of the landmasses had three bridges, and the central island had five).¹⁸ Because there were more than two odd-degree nodes, Euler proved with absolute mathematical certainty that the Königsberg bridge walk was structurally impossible.¹⁸

With Euler's trick firmly established, we can apply this exact mathematical lens to Oxford. This reveals the centerpiece surprise of the city's layout: Oxford is a massive, highly complex iteration of the Königsberg problem. Oxford's relationship with water is fundamental to its existence, built precisely at the confluence of two dynamic rivers: the Thames (locally called the Isis) to the west and south, and the Cherwell to the east.³ Over a millennium, these rivers have braided and split, creating a marshy, fragmented landscape of islands and peninsulas.²⁰ To navigate this watery world, generations of residents built an extensive array of bridges. Unlike a planned grid city, Oxford's bridge network grew organically from the 13th century onward.²²

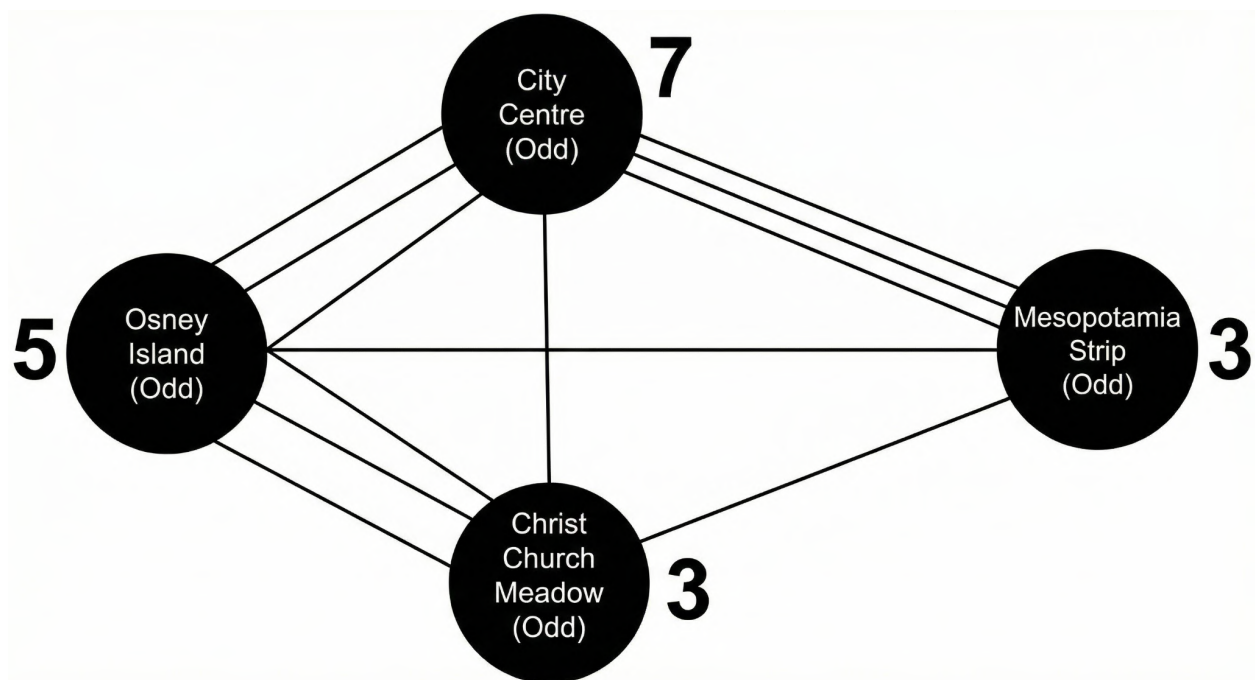


If we abstract the historical core of Oxford into a graph just as Euler did, the city becomes a fascinating, unsolvable puzzle. First, we identify our landmasses, or nodes. The main city centre sits elevated to the north of the Isis and west of the Cherwell.² Just south lies Christ Church Meadow, a large peninsula sharply bounded by both rivers.¹ To the west is Osney Island, a densely residential neighbourhood completely surrounded by the main navigation channel of the Thames and various mill streams.²⁴ Finally, to the east, we have the Mesopotamia Strip, a remarkably narrow tongue of land situated between two branches of the upper Cherwell—its

name derived directly from the ancient Greek meaning "between the rivers."²⁵

Connecting these landmasses is a complex web of edges. Magdalen Bridge serves as a grand, multi-arch stone crossing over the Cherwell.¹ The modern Jubilee Footbridge leaps from Christ Church Meadow to the east bank.¹ Historic Folly Bridge crosses the Isis to the south, while Osney Island is tethered to the city by the main Osney Bridge and parallel railway crossings.²⁴ Up north, the steeply arched Rainbow Bridge connects the University Parks to the Mesopotamia Strip, which itself links back to the east via the King's Mill footbridges.²⁵

We can easily estimate the degree of each node by counting the bridge connections touching these specific landmasses. The main city centre is highly connected by multiple asymmetric bridges, giving it an odd degree. Christ Church Meadow relies on a handful of primary crossing points like the Jubilee Bridge and the Folly Bridge approach, also resulting in an odd degree. Osney Island has roughly five primary vehicular, rail, and footbridge connections, making it an odd node. The Mesopotamia Strip connects via three main footbridges, making it yet another odd node.



When the mathematical rigidities of Euler's theorem are applied to the organic, rambling geography of Oxford, the result is definitive. Because the city features an abundance of islands and peninsulas connected by a haphazard assortment of bridges, Oxford possesses far more than two nodes of odd degree. Therefore, just like Königsberg, Oxford is mathematically unsolvable. It is entirely impossible for a tourist—or a seasoned local—to devise a continuous walking route across the historic river bridges of central Oxford that crosses every bridge exactly once. What makes this mathematical reality particularly poetic is the timeline. Euler published his theorem in 1736, yet Oxford's core bridge network was largely cemented in stone

by the 13th century.²² The city was mathematically unsolvable for five hundred years before anyone had the language to say so.

If Oxford's exterior geography is an accidental monument to graph theory, its most famous literary export is a highly intentional, meticulously crafted monument to abstract algebra and topology. On the golden afternoon of July 4, 1862, a 30-year-old mathematics lecturer from Christ Church named Charles Lutwidge Dodgson took three young girls—the Liddell sisters—out on a rowing boat on the Isis.²⁹ He rowed them from Folly Bridge upstream toward the village of Godstow.³⁰ To keep them entertained, he improvised a story about a girl named Alice who tumbled down a rabbit hole into a world of pure absurdities.³¹

Under the pseudonym Lewis Carroll, Dodgson published this story as *Alice's Adventures in Wonderland*.³² For over a century, the book was universally celebrated as a masterpiece of pure literary nonsense. However, modern literary and mathematical scholarship—championed prominently by researchers like Melanie Bayley—has argued that *Wonderland* is actually one of the most elaborate works of mathematical satire ever penned.³³ While this interpretation is not universally accepted by all scholars—with some historians of mathematics arguing the connections are overstated or unintentional³⁸—Bayley's reading remains a compelling and thrilling way to decode the madness.

To understand the satire, one must understand the man. Dodgson held the position of Mathematical Lecturer at Christ Church for 26 years.²⁹ His research specialty was symbolic logic, linear algebra, and the geometry of Euclid. He was a deeply conservative mathematician who distrusted the radical new developments sweeping through Victorian-era math: new algebras that broke old rules, geometries that didn't require parallel lines to stay parallel, and symbolic systems where letters didn't stand for numbers anymore.³⁴ Unable to halt the tide of abstract mathematics in the academic journals, Dodgson took his revenge in fiction, pushing the premises of the new mathematics to their extreme logical conclusions to expose their inherent madness.³⁷

The emergence of "symbolic algebra" proposed that algebraic symbols didn't have to represent fixed physical quantities; they could transform and change.³⁴ Dodgson found this unsettling, parodying it through the Caterpillar's mushroom. After eating it, Alice finds her physical dimensions fluctuating wildly from nine feet to three inches.³⁴ The Caterpillar, calmly smoking, represents the new algebraist who sees nothing wrong with variables that refuse to stay fixed.



The famous Mad Hatter's Tea Party serves as an exquisitely targeted critique of another new mathematical framework: the theory of quaternions, an extension of complex numbers used to calculate 3D rotations, which relied on three spatial dimensions and a crucial fourth dimension of "pure time."³⁴ At the table, the Hatter, the March Hare, and the Dormouse represent the three spatial dimensions, but they explain to Alice that they have had a falling out with "Time."³⁴ Without Time, they are literally stuck in a loop. They rotate endlessly around the flat plane of the tea table, moving from seat to seat, going nowhere.³⁴ Dodgson brilliantly physicalized a mathematical handicap.



In the chaotic scene set in the Duchess's kitchen, Dodgson takes aim at projective geometry, specifically the "Principle of Continuity," which held that shapes could be continuously

deformed into other shapes while preserving certain fundamental projected properties.³⁴ As Alice holds the Duchess's baby, it slowly, continuously transforms into a pig.³⁴ They have the same number of limbs, the same number of facial holes, and make similarly incoherent sounds. By the Principle of Continuity, a baby and a pig are topologically the same.³⁴ Dodgson found this conclusion ridiculous and said so in the most entertaining way possible.

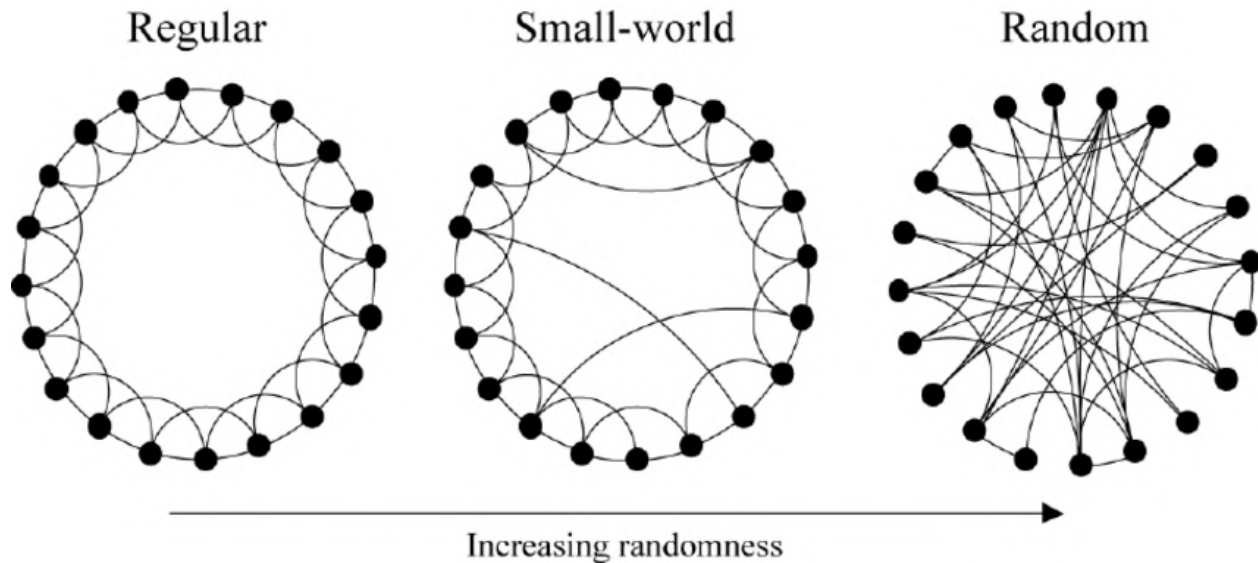
Finally, Dodgson addresses topology itself, a branch of mathematics concerned with properties preserved through stretching and deforming, entirely detached from rigid physical geometry. The ultimate distillation of Dodgson's contempt for pure, substance-less abstraction is the Cheshire Cat.³⁴ When the Cat vanishes, it leaves only its grin behind. To a Victorian audience, this is absurdity. To a topologist, it is a completely reasonable operation—a smile can persist after the shape containing it has vanished. Dodgson thought topological reasoning was nonsense dressed up as mathematics, so he rendered it literally as nonsense.³⁸ When Dodgson rowed his boat back down the Isis toward Oxford that evening, he had invented one of the most beloved children's books ever written, which was secretly a furious mathematical argument. The dreaming spires would have been visible on the horizon. He undoubtedly would have found this funny.



Zooming out from the isolated river islands and the whimsical literary satires, the macro-structure of Oxford itself presents another astonishing mathematical phenomenon. Oxford did not grow according to a master plan. Unlike many American cities built on rational grids or post-war European rebuilds based on logical blocks, Oxford grew organically over a thousand years.²² It expanded college by college, alley by alley, resulting in a street network

that is a medieval tangle.

This seemingly chaotic layout turns out to have incredibly specific and optimized mathematical properties. Network scientists, using the tools of graph theory that Euler invented, have heavily studied the connectivity of city street networks. Oxford's layout exhibits what mathematicians call "small-world" network properties. In a small-world network, any two points are connected by a surprisingly short path, but the local clustering—the tendency for nearby places to be tightly connected to each other—is unusually high.

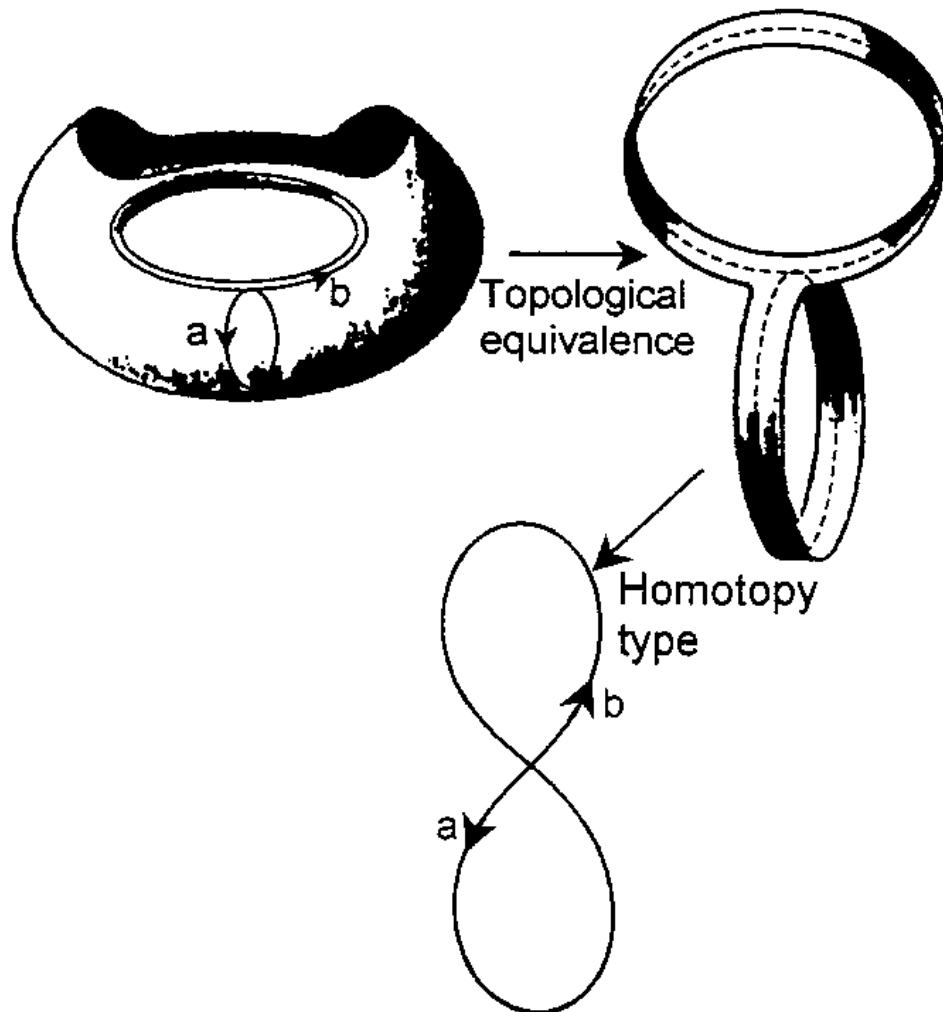


This is the exact same mathematical structure found in social networks, neural networks in the brain, and the internet. The formal mathematical name for it is a Watts-Strogatz graph, named after the researchers who defined it in 1998. Oxford's urban layout has been an immaculate, stone-carved Watts-Strogatz graph since the 13th century. The colleges themselves are densely clustered, highly connected hubs arranged around enclosed quads. Connecting these dense academic clusters are Oxford's famous winding alleys, unexpected footpaths, and narrow lanes—such as Logic Lane and Magpie Lane. These asymmetrical passages act as vital, long-range shortcuts. They bypass the main thoroughfares, allowing a pedestrian to leap from one dense collegiate cluster to a completely disparate one in just a few short steps.

Zooming in one final time, from the city streets to the architecture of the individual colleges, one finds a fascinating mathematical object hidden in plain sight. The architectural heart of almost every Oxford college is the quadrangle (the "quad")—a central, enclosed courtyard surrounded by a continuous perimeter of buildings and cloisters.

If a student walks out of their dormitory and proceeds in one direction down the continuous internal corridors of a quad, they will eventually wrap completely around the courtyard and return exactly to their starting point. In the realm of topology, a closed, continuous surface with a single hole in the middle (the open-air courtyard) is mathematically defined as a torus—the

exact geometric shape of a doughnut ($S^1 \times S^1$).⁴⁴



However, a college quad requires a gate, usually a grand archway leading out to the main street, breaking the continuous outer wall. The moment a hole is punched through the exterior of the toroidal structure, its topology fundamentally changes. A torus with a hole (a punctured torus) is a fascinating topological object; it can be continuously stretched and deformed without tearing into a shape known as a "bouquet of two circles," commonly visualized as a figure-eight.⁴⁶

Every single day for 26 years, Charles Dodgson walked the perimeter of Tom Quad at Christ Church. As a conservative geometer who fought bitterly against the abstract deformations of topology, he spent his entire adult life living, working, and walking inside a punctured torus. He probably enjoyed this subtle irony more than his students ever realized.

Oxford is globally famous for its mathematics. But the mathematics people usually talk about is

the mathematics done inside Oxford—theorems proved, papers published, careers launched. This essay has tried to show a different kind: the mathematics of Oxford itself.

The city's bridge network was topologically unsolvable before topology existed. Its most famous work of children's fiction is a disguised argument about abstract algebra. Its street layout is a small-world graph that predates the concept by seven centuries. The dreaming spires that Matthew Arnold made famous aren't just beautiful architectural achievements. They are the skyline of a city whose shape, rivers, and stories are saturated with mathematical structure that its inhabitants laid down before they had the words for what they were doing. Sometimes the most interesting mathematical discoveries aren't made by looking at equations. They're made by looking up, and seeing a city you thought you already knew.

Works cited

1. Cherwell below Magdalen Bridge - WHERE THAMES SMOOTH ..., accessed on February 22, 2026, <https://thames.me.uk/s02410.htm>
2. Natural History Walk - University Parks, accessed on February 22, 2026, <https://www.parks.ox.ac.uk/natural-history-walk>
3. Parks and Meadows in Oxford, accessed on February 22, 2026, <https://www.oxfordcityguide.com/frmParksMeadows.aspx>
4. OXFORD ARCHAEOLOGICAL RESOURCE ASSESSMENT 2011 POST MEDIEVAL (1540-1800), accessed on February 22, 2026, <https://www.oxford.gov.uk/downloads/file/698/post-medieval-oxford-1540---1800>
5. Christ Church Meadow, accessed on February 22, 2026, <https://www.chch.ox.ac.uk/sites/default/files/2023-08/meadow-trail-winter21-min.pdf>
6. Seven Bridges of Königsberg - Wikipedia, accessed on February 22, 2026, https://en.wikipedia.org/wiki/Seven_Bridges_of_K%C3%B6nigsberg
7. Königsberg bridge problem | Mathematics, Graph Theory & Network Theory | Britannica, accessed on February 22, 2026, <https://www.britannica.com/science/Konigsberg-bridge-problem>
8. Solving the Bridges of Königsberg Puzzle - Eulerian Path - Jdhwilkins, accessed on February 22, 2026, <https://www.jdhwilkins.com/the-impossible-bridges-of-k%C3%B6nigsberg>
9. The Essential Guide to Graph Theory: From an 18th Century Riddle to AI Frameworks, accessed on February 22, 2026, <https://medium.com/data-science/the-essential-guide-to-graph-theory-from-an-18th-century-riddle-to-artificial-intelligence-c441cb9400de>
10. Leonhard Euler Publishes the Problem of the Königsberg Bridges: The Birth of Network Science - History of Information, accessed on February 22, 2026, <https://historyofinformation.com/detail.php?id=3406>
11. Leonard Euler's Solution to the Königsberg Bridge Problem - MAA.org, accessed on February 22, 2026, <https://old.maa.org/press/periodicals/convergence/leonard-eulers-solution-to-the-konigsberg-bridge-problem>
12. Lecture 2. Traversing Nets of Curves, accessed on February 22, 2026, <https://www.math.stonybrook.edu/~oleg/courses/mat150-spr16/lecture-2.pdf>
13. Euler Paths and Circuits - Discrete Mathematics, accessed on February 22, 2026, https://discrete.openmathbooks.org/dmoi2/sec_paths.html
14. Journal of Nonlinear Analysis and Optimization Vol. 14, Issue. 2, No. 4: 2023 ISSN : 1906-9685 THE SEVEN BRIDGES OF KÖNIGSBERG - MKJC, accessed on February 22, 2026, <https://mkjc.in/download/downloads/2005241231518896.pdf>
15. 9.4 Traversals: Eulerian and Hamiltonian Graphs, accessed on February 22, 2026, <https://faculty.uml.edu/klevasseur/ads/s-traversals.html>
16. Euler Paths | Mathematics | Research Starters - EBSCO, accessed on February 22, 2026, <https://www.ebsco.com/research-starters/mathematics/euler-paths>

17. accessed on February 22, 2026,
https://en.wikipedia.org/wiki/Seven_Bridges_of_K%C3%B6nigsberg#:~:text=The%20degree%20of%20a%20node,two%20nodes%20of%20odd%20degree.
18. Seven bridges and a graph theory theorem | the Quantum Universe, accessed on February 22, 2026,
<https://www.quantumuniverse.nl/seven-bridges-and-a-graph-theory-theorem>
19. Euler Paths & the 7 Bridges of Königsberg | Graph Theory - YouTube, accessed on February 22, 2026, <https://www.youtube.com/watch?v=dSK5jTEe-AM>
20. Medieval Oxford | British History Online, accessed on February 22, 2026,
<https://www.british-history.ac.uk/vch/oxon/vol4/pp3-73>
21. Of Mice and Merchants: Connectedness and the Location of Economic Activity in the Iron Age - MIT Press, accessed on February 22, 2026,
<https://direct.mit.edu/rest/article/103/4/652/97649/Of-Mice-and-Merchants-Connectedness-and-the>
22. The Western Approach to Anglo-Saxon Oxford - Oxoniensia, accessed on February 22, 2026, <https://www.oxoniensia.org/volumes/2018/Crossley.pdf>
23. OXFORD ARCHAEOLOGICAL RESOURCE ASSESSMENT 2011 NORMAN (1066-1205), accessed on February 22, 2026,
<https://www.oxford.gov.uk/downloads/file/697/norman-oxford-1066---1205>
24. Osney Bridge - Wikipedia, accessed on February 22, 2026,
https://en.wikipedia.org/wiki/Osney_Bridge
25. Bridge and pathways - University Parks, accessed on February 22, 2026,
<https://www.parks.ox.ac.uk/bridge-and-pathways>
26. Mesopotamia, Oxford - Wikipedia, accessed on February 22, 2026,
https://en.wikipedia.org/wiki/Mesopotamia,_Oxford
27. Botley Road and its bridges - Osney Island, accessed on February 22, 2026,
<https://osneyisland.org.uk/botley-road-and-its-bridges/>
28. Osney Railway Bridges - WHERE THAMES SMOOTH WATERS GLIDE, accessed on February 22, 2026, <https://thames.me.uk/s01740.htm>
29. If Charles Dodgson (Lewis Carroll) had not written Alice's - Mathematical Institute, accessed on February 22, 2026,
<https://www.maths.ox.ac.uk/system/files/attachments/Lewis%20Carroll.pdf>
30. Charles Lutwidge Dodgson - A Mathematical History Tour, accessed on February 22, 2026, <http://mathsab.blogspot.com/2016/04/charles-lutwidge-dodgson.html>
31. Lewis Carroll in the Museum - O.U.M.N.H. Learning more, accessed on February 22, 2026, <https://www.oum.ox.ac.uk/learning/htmls/dodgson.htm>
32. Charles Lutwidge Dodgson (1832 - 1898) - Biography - MacTutor History of Mathematics, accessed on February 22, 2026,
<https://mathshistory.st-andrews.ac.uk/Biographies/Dodgson/>
33. Alice's Adventures in Wonderland: Carroll's Symbolic Attack on Mathematical Symbolism - Scholarship @ Claremont, accessed on February 22, 2026,
<https://scholarship.claremont.edu/cgi/viewcontent.cgi?article=1896&context=jhm>
34. Alice's adventures in algebra: Wonderland solved | New Scientist, accessed on February 22, 2026,
<https://www.newscientist.com/article/mg20427391-600-alices-adventures-in-alg>

[ebra-wonderland-solved/](#)

35. Alice's Adventures in Wonderland and the Mad Hidden Mathematical Satire of Dodgson's "Lewis Carroll" - ARTpublika Magazine, accessed on February 22, 2026, <https://www.artpublikamag.com/post/alice-s-adventures-in-wonderland-and-the-mad-hidden-mathematical-satire-of-dodgson-s-lewis-carroll>
36. Alice's Adventures in Wonderland: Carroll's Symbolic Attack on Mathematical Symbolism, accessed on February 22, 2026, https://www.researchgate.net/publication/358261290_Alice's_Adventures_in_Wonderland_Carroll's_Symbolic_Attack_on_Mathematical_Symbolism
37. Melanie Bayley: Alice in Wonderland is a Parody of Nineteenth Century Math, accessed on February 22, 2026, <https://www.historynewsnetwork.org/article/melanie-bayley-alice-in-wonderland-is-a-parody-of->
38. Alice's Adventures in Wonderland: Is it really about math? : r/books - Reddit, accessed on February 22, 2026, https://www.reddit.com/r/books/comments/1ioxgeh/alices_adventures_in_wonderland_is_it_really/
39. It's My Own Invention - Mathematical Mysteries, accessed on February 22, 2026, <https://mathematicalmysteries.org/2022/02/15/its-my-own-invention/>
40. Continuity Principle -- from Wolfram MathWorld, accessed on February 22, 2026, <https://mathworld.wolfram.com/ContinuityPrinciple.html>
41. Poncelet, the Projective Properties of Figures | Request PDF - ResearchGate, accessed on February 22, 2026, https://www.researchgate.net/publication/389527419_Poncelet_the_Projective_Properties_of_Figures
42. Alice and Algebra - Maths from the Past, accessed on February 22, 2026, <https://maths-from-the-past.org/alice-and-algebra/>
43. Mathematics: A Practical Odyssey, 7th ed. - Air University Central Library catalog, accessed on February 22, 2026, http://111.68.96.114:8088/get/pdf/Mathematics_%20A%20Practical%20Odyssey%207th%20ed_%20-%20s.anurag_15912.pdf
44. Torus - Wikipedia, accessed on February 22, 2026, <https://en.wikipedia.org/wiki/Torus>
45. If you lived in a 4-torus, what would the doughnut hole look like from the inside?, accessed on February 22, 2026, <https://math.stackexchange.com/questions/4885570/if-you-lived-in-a-4-torus-what-would-the-doughnut-hole-look-like-from-the-inside>
46. "Topological Equivalence" of Double Torus and a Torus with another hole - Mathematics Stack Exchange, accessed on February 22, 2026, <https://math.stackexchange.com/questions/2374959/topological-equivalence-of-double-torus-and-a-torus-with-another-hole>
47. holes in a torus : r/topology - Reddit, accessed on February 22, 2026, https://www.reddit.com/r/topology/comments/jpcn4l/holes_in_a_torus/
48. How much drug use was involved in the making of Alice in Wonderland? - Quora, accessed on February 22, 2026,

<https://www.quora.com/Psychedelic-Drugs-How-much-drug-use-was-involved-in-the-making-of-Alice-in-Wonderland>