


Tesla May Have Invented a Million-Mile Electric Car Battery

Is Elon Musk's tech for vehicles built to last 76 years, or the key to a driverless car-on-demand future? Yes.

 Steve LeVine [Follow](#)
Sep 24 · 9 min read ★

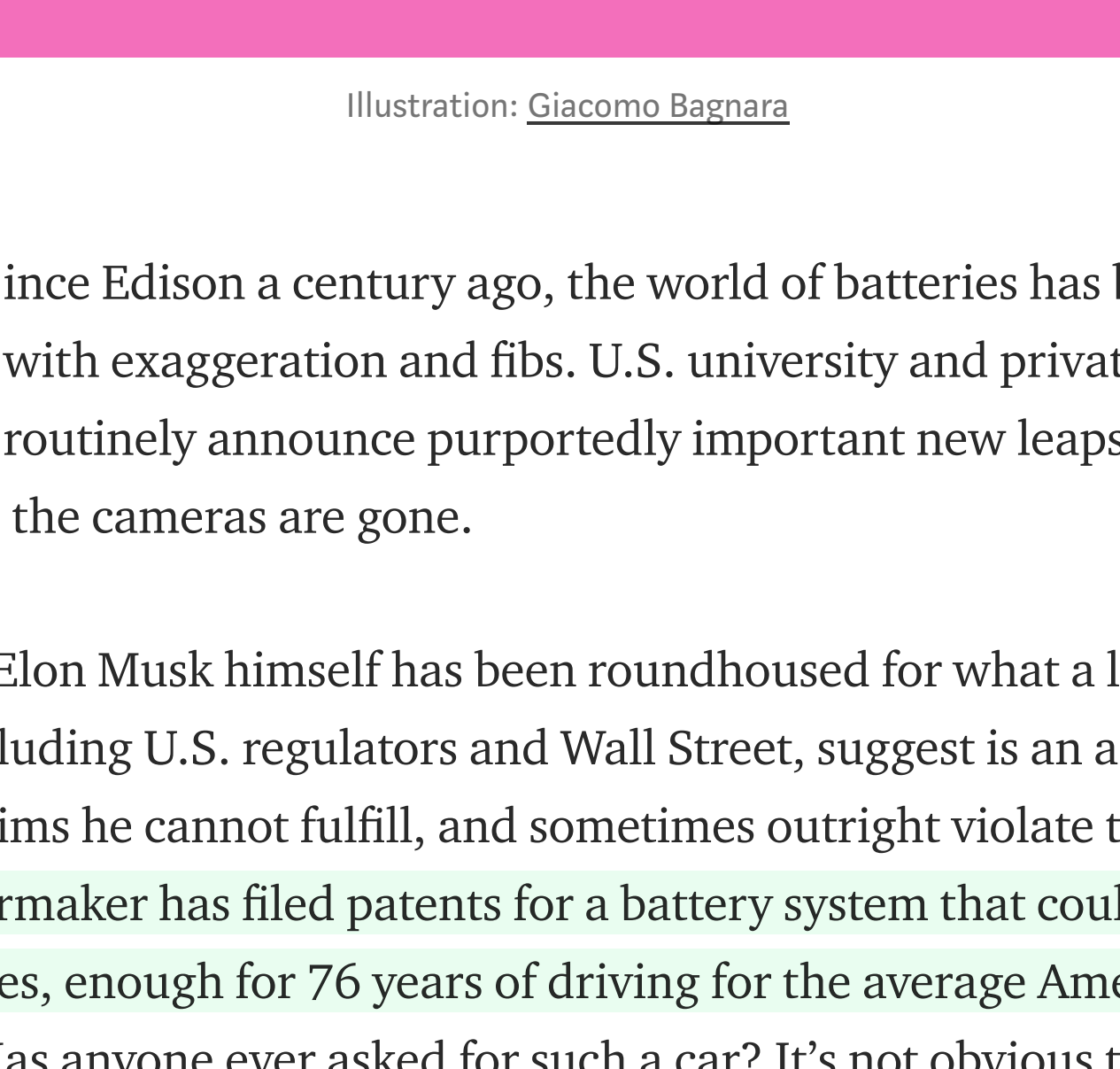


Illustration: [Giacomo Bagnara](#)

Since Edison a century ago, the world of batteries has been riven with exaggeration and fibs. U.S. university and private labs routinely announce purportedly important new leaps, only to go quiet when the cameras are gone.

Tesla CEO Elon Musk himself has been roundhoused for what a lot of people, including U.S. regulators and Wall Street, suggest is an addiction to making claims he cannot fulfill, and sometimes outright violate the law. But now the carmaker has filed patents for a battery system that could last one million miles, enough for 76 years of driving for the average American motorist. Has anyone ever asked for such a car? It's not obvious they have. But if you are in the mind of Musk, you will see past that, to a future fleet of cars that can transform into driverless, automated taxis when not being used by their owners. A fleet that he hopes will turn into a big new profit center for Tesla.

Leading battery researchers in the United States and Europe, while uncertain about the cost of the Tesla system, say a new academic paper describing the million-mile battery is rigorous and convincing. "The results are spectacular," said Gerbrand Ceder, a professor of materials science at University of California, Berkeley.

The paper, co-authored by Jeff Dahn, a professor at Dalhousie University in Canada, who is on contract with Tesla, suggests a substantial advance for driverless taxis, buses, and semi-trucks that can recharge in roughly 20 minutes, along with electric grid batteries boasting two-decade lifespans. These are among the greatest ambitions of the new electric age, and a new lithium-ion battery that does what Dahn describes would go far in reviving Musk's reputation for mastery of applied cutting-edge technology.

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Few inventions of the last four or five decades have had the impact that lithium-ion has had on the humble battery. It is this technology that enabled the breakthrough electronic masterpiece of the 20th century — the transistor — to untether from power cords in the home and office, and become the engine of the mobile electronic revolution. The heart of lithium-ion — the cathode — was invented in 1981 by John Goodenough, then a professor at Oxford and now at the University of Texas, and a decade later commercialized by Sony. The phone on which you may be reading this story almost certainly contains Goodenough's invention. Researchers, including Dahn, have invented three or four competing lithium-ion formulations since then, but they all retain Goodenough's original architecture. Four decades later, Goodenough's basic brainchild remains the battery gold standard.

The other thing to know about lithium-ion is how it differs from the transistor. Batteries have no rule akin to Moore's Law, the canon by which silicon chips double their power roughly every 18 months. If lithium-ion had improved at the pace of silicon, it might have all but pushed fossil fuels out of transportation by now and solved the woes of climate change. Lithium-ion has improved since 1981, but not nearly at that rate.

A decade ago, a lithium-ion battery cost more than \$1,100 kWh, the measure for energy density. At the time, the U.S. Department of Energy set a goal of \$100 kWh, a milestone that, if reached, would elevate electricity into a head-to-head battle for primacy with combustion cars. To those like me hearing the goal at industry conferences year after year, it seemed all but absurd. Never did I hear a researcher suggest it was possible.

Yet, according to a [recent study by BloombergNEF](#), a renewable energy research firm, we are almost there. Last year, the cost declined to an average of \$176 kWh. Within five years, it will drop to under \$100, BNEF says.

From there — to the degree that carmakers pass this savings on to consumers in the form of lower price tags — electric car sales could surge. BNEF assumes that electric carmakers will do just that. By 2040, electric cars will win the war with gasoline: 57% of all new U.S. passenger vehicle sales will be electric and, globally, electric cars will comprise almost a third of all cars on the road.

Beyond John Goodenough himself, no single person on the planet has been more instrumental in ushering in the electric car age than Musk and his company, Tesla. Electric cars are a subject of serious conversation today only because Musk decided to take over the helm of Tesla in 2008. Four years ago, Dahn — himself one of the half-dozen or dozen most important minds in batteries — decided that he wanted to be part of what Musk was doing. He abandoned a longtime exclusive commercial relationship with 3M, and signed a five-year agreement to invent for Tesla.

In an email, Dahn referred questions to Tesla, which did not respond to a request for comment. But in April, Musk uttered another couple of apparent whoppers: Battered by Wall Street after a string of miscues — smoking marijuana with Joe Rogan, fibbing on Twitter about a plan to take Tesla private, and missing one production target after another for the company-maker mainstream Model 3 — Musk blurted out that, by the end of next year, Tesla would have a million-mile battery and a million driverless robo-taxis on the road.

Drilling down, Musk said the battery would be installed in the Tesla Model 3, along with the software necessary for the cars to connect to an autonomous taxi network. If a Tesla owner wanted to earn extra cash while working or hanging around at home, the car could be summoned into use as a driverless taxi, with 25% to 30% of the cut going to Tesla, the same profit formula used by many of the major Big Tech companies. A motorist would be insane to own any other car, Musk said. And Tesla would have a lucrative new stream of revenue.

Musk's pitch ignited immediate skepticism since virtually no other major carmaker expects to produce a fully autonomous commercial vehicle for a decade, or perhaps ever. The challenge of making driverless cars truly safe, especially among unpredictable humans, has proven a far harder task than most anyone envisioned even a few years ago.

But while no one made the connection at the time, the battery claim was not the usual bombast. The prior August, Tesla had filed provisional patents for two Dahn inventions, both involving the million-mile battery. Provisional patents are used to stake a claim before you have actually finished work on an invention, giving you a year to complete it. On Sept. 12, a few days after publication of the Dahn paper, Tesla, signaling that the invention was ready, filed for the two patents ([here](#) and [here](#)).

The central fact lending Musk credibility in this pronouncement, at least within the battery field, was the presence of Dahn — a meticulous, often daring physicist known never to bullshit, and instead to call out peers who did. In other words, he is Musk's anti-Musk.

For years, Jeff Dahn has spoken of "the battery that lasts forever." To his peers, Dahn, in the context of current average human longevity, had discovered precisely that technology.

The paper, published in the Journal of the Electrochemical Society with a byline shared by Dahn and 13 co-authors, is at once breathtakingly comprehensive and rhetorically immodest. Its first lines explicitly stake a claim for establishing a "benchmark" for future research, a baseline to be used by peers and companies alike for batteries of all types. But as a sign that they were adhering to Dahn's no-BS reputation, they also disclosed their data and asked peers to replicate the findings. In an unusual twist, they attached still-live battery cells to barcodes, and made them trackable online.

None of the half-dozen researchers I contacted for this story seemed to take umbrage at Dahn's presumptions, but from what I could tell instead seemed unbrag to let him assume the lead in getting the field to a better place. A researcher who did not want to be quoted said the Dahn battery "could become the standard."

Tesla is known to move fast, but it is still hard to see how you get from Dahn's paper and patents to a motorist's driveway in a year, as Musk has promised.

One possible reason for the apparent community embrace is that the paper does not describe something entirely new, but instead is largely a composite of best practices that Dahn and others in the field have been developing for some time.

Yet there are innovations. Dahn's primary advance — the "secret sauce," according to Venkat Viswanathan, a professor at Carnegie Mellon — is the electrolyte, the crucial liquid that facilitates the movement of ions between the two electrodes. It is there that Dahn, adding chemicals such as methyl acetate, gains the ability to charge fast without damaging the battery.

And, to achieve the leapfrog in life, Dahn, among other things, fundamentally changed the battery structure. Current batteries tend to fracture during the charge-and-discharge cycle. But when you enlarge the crystals that make up the cathode — swapping out relatively small polycrystalline particles for larger, "single crystals" — the cracks diminish and even vanish. "Single crystals are more robust," says Allan Paterson, head of program management at the Faraday Institution in the U.K.

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much Dahn's method will cost, a central issue in the commercialization of electric cars and the use of solar and wind on the grid. One researcher told me that Dahn's method could cost 15% to 20% more than current cells, but that the gap will probably shrink as the million-mile battery is scaled up, and especially if it is adopted by other carmakers. Cost, in other words, may work in Tesla's favor.

Then there is the central matter of the battery chemistry itself. Batteries may not seem like a thing that can spark passions, but for Musk they do. In this case, he may be the only electric carmaker on the planet using a battery formulation called NCA. In 2010, I asked Musk directly why he did not switch to NMC, a competing formulation used by everyone else. He became visibly irritated. The first thing he would do if he were in charge of GM's electric carmaking program, he said, is switch to NCA.





The problem is that Dahn is a father of NMC, and he is partial to it. NMC is at the core of the million-mile paper, and that is clearly no accident. In a possible attempt to address this elephant in the room, Dahn framed the NMC as a solution to Musk's objectives — the robo-taxi and semi-trucks. The NMC is even compatible with the metal cylindrical battery cells used in current Teslas, Dahn suggested.

I asked some of the researchers about this tension. They responded similarly, which was, to paraphrase, "that was then and now is now: If Elon can get a million miles, robo-taxis, and fast charging without degradation from NMC, he will shift."

Indeed, in a report [flagged yesterday](#) by Tesla watcher Fred Lambert, South Korean publication [The Elec said that LG Chem](#) will supply NMC batteries for Tesla Model 3s sold in China. If accurate, the report adds another dimension to Musk's ambitions — if he can capture a significant part of the Chinese electric market, he is also open to NMC.

Dahn, in short, is the rare bearer of good news for Musk. "We kind of knew the lifetimes were good and how good well-designed batteries have become," said Ceder, the Berkeley professor. "This is the first evidence that these are much better than even we thought."

Tesla Elon Musk Future Battery Tech

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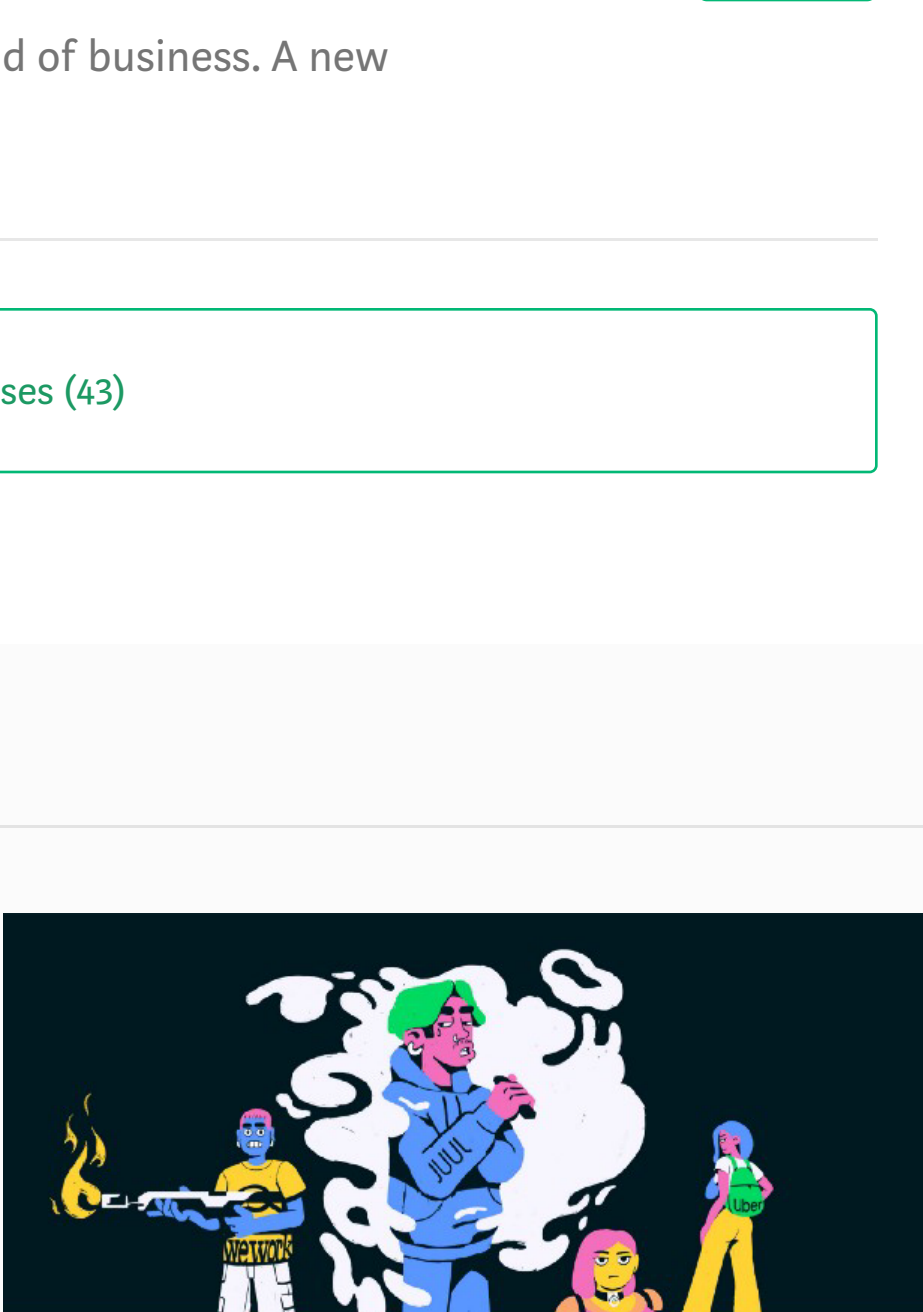
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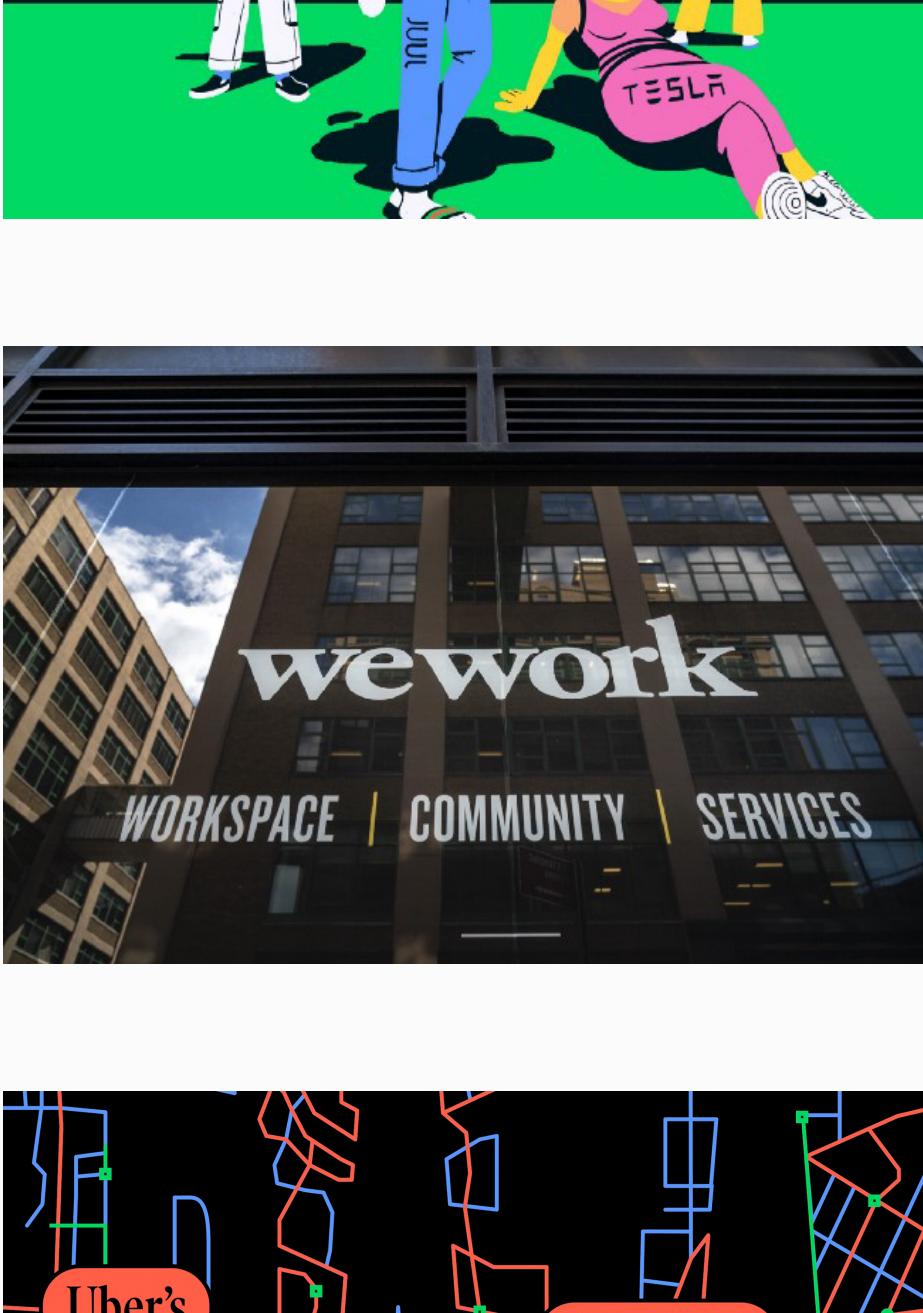
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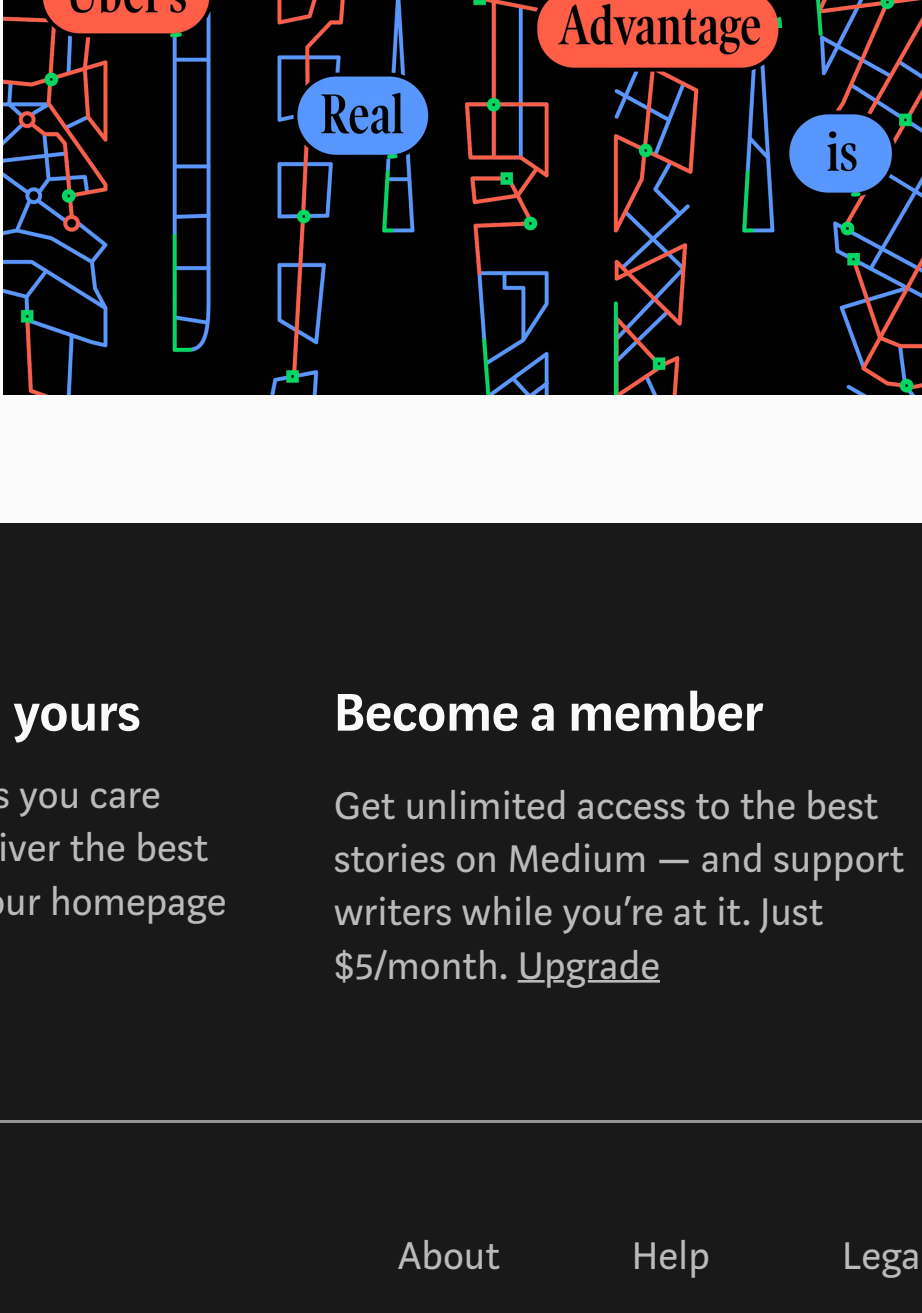
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