INDUSTRIES OF INDIA

THE BARCODE

Line, Light, Ledger



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PROLOGUE

The Sound at the Checkout

Listen the next time you stand at a supermarket till, in any country, at any hour. Beneath the rustle of bags and the murmur of the queue runs a small, bright electronic note, repeated every second or two: beep, beep, beep. It is so ordinary that nobody counts it. Yet each of those notes is a tiny industrial ceremony. A pattern of black bars and white spaces has crossed a window of light; a machine has converted widths into digits; the digits have travelled to a database and returned with a name and a price; and somewhere far away, in systems nobody at the till can see, a case has been deducted from a warehouse, a reorder has edged closer to its trigger, and a data point has joined the great ledger of what the world buys, hour by hour, item by item.

The organization that governs those numbers counts more than ten billion such scans every day, on over a billion products, across more than 150 countries.[10,11] Ten billion is a difficult number to feel. It is more than one scan per human being on earth, every day. And almost nothing else so common is so invisible. The barcode has no brand you can name, no inventor whose face you know, no company whose logo it carries. It is infrastructure in the purest sense, noticed only in its absence, when the beep fails and the queue stalls and the whole choreography of a store falters over a smudged label.

This book treats the barcode the way this library treats every subject: the item comes first. Not a country, not a company, not a trend. We follow a pattern of stripes from a beach in Miami, where a graduate student dragged his fingers through the sand in 1949, to a supermarket in Troy, Ohio, where a pack of chewing gum made history in 1974, and onward into warehouses, hospitals, post offices, factory floors and aircraft holds.[1] We ask the questions that turn a mark into an industry: who first made it and why, what had to be invented before it could work, how a whole sector of manufacturing and computing grew up around printing and reading it, what constrains it now, and what it is becoming as the stripes give way to squares.

The story that emerges is not really about groceries. It is about how the physical world was made legible to computers. Before the barcode, the things a company owned were, to its machines, rumour and memory: entered by hand, counted by eye, wrong by a thousand small slips a day. After the barcode, every object could announce itself. That single capability, the self-announcing object, is the load-bearing wall of modern logistics, modern retail, modern medicine and much of modern manufacturing. It was drawn in the sand, patented ahead of its time, nearly abandoned more than once, and saved repeatedly by stubborn people who believed that the queue could be beaten. That is the story told here, from line to light to ledger.

PART I

Before the Lines

Every technology is an answer to an irritation. The barcode answered two: the grocer who could not count his stock, and the engineer on a beach who stretched Morse code until it became something new. First, the irritation.

CHAPTER 1

The Store That Counted by Hand

To understand why the barcode had to exist, walk into a mid-century American supermarket and watch how the money actually moved. The supermarket itself was barely a generation old: self-service grocery, where the customer pushed a cart and picked goods off open shelves, had spread across the United States in the 1930s and 1940s, replacing the counter-service store where a clerk fetched everything. Self-service sold more goods to more people at lower margins, and it pushed all the arithmetic of the store to one narrow choke point: the checkout.

At that choke point stood a cashier with a mechanical register, and her tools were memory and fingertips. Every item in the cart carried a small paper price sticker, applied by hand by stock clerks who spent their days with ink and pricing guns. The cashier read each sticker, keyed each price, and totalled the sale. The system worked, but it leaked money everywhere it touched. Clerks mis-keyed prices. Stockrooms lost count of what they held. Every price change meant peeling thousands of stickers and pasting new ones, and when inflation ran hot, as it did through the late 1960s and 1970s, the peeling and pasting never stopped. Grocers lived on margins of less than a penny on the sales dollar after taxes, so errors that would be rounding losses anywhere else were, to them, the difference between profit and loss.[2]

Worse, the store was blind. A manager knew, roughly, what the store had ordered and what the registers had rung up. He did not know, except by walking the aisles and counting, what was actually selling. Which brand of soup moved on Thursdays? Which sizes gathered dust? The answers lived in paper invoices and the heads of stock clerks, not in any machine. An industry that sold tens of thousands of distinct items, each with its own season and margin, was run on weekly intuition. In 1966 the Kroger Company, one of the largest chains in the country, ended a study of its own operations with a wish that reads like a prayer: could an optical scanner read the price and total the sale? Faster, more productive service was needed desperately, the company wrote. It solicited anyone's help.[1]

Kroger's wish named the problem precisely. What the grocer wanted was not a gadget but a bridge: a way for the object on the conveyor to tell the store's computer what it was, so that price, tax, discount and stock count could follow automatically. The bridge required two things that did not yet exist. First, a mark that a machine could read on every package, printed cheaply by the manufacturer. Second, a number behind the mark that meant the same thing to every company in the chain, from factory to shelf. The mark without the number was decoration; the number without the mark was paperwork. Both were missing, and inventing them, together, would take a quarter of a century.

> *Just dreaming a little… could an optical scanner read the price and total the sale… Faster service, more productive service is needed desperately. We solicit your help.*
>
> Kroger Company booklet, 1966

CHAPTER 2

A Question Overheard

The barcode began, by its inventor's own account, like a fairy tale: with a plea that fell on the wrong ears, and was picked up by the right ones. In 1948, the president of a local food chain came to the Drexel Institute of Technology in Philadelphia to plead with the dean of engineering. His problem was Kroger's problem, two decades early: checkout queues that crawled, stocktaking that devoured profit, and no machine that could help. Would the dean put his department on the problem of reading product information automatically at the checkout? The dean declined.[1,3]

A postgraduate named Bernard Silver overheard the conversation, and was intrigued. He carried it to his friend Norman Joseph Woodland, who had graduated from Drexel in 1947 and already thought of himself as an inventor. Woodland had grown up in Atlantic City, had served in the Army during the war, and as a Boy Scout had learned Morse code, a fact that would matter more than any engineering course. Woodland was confident enough in the challenge to make a strange decision: he left graduate school, cashed in some stocks, and moved into an apartment his grandfather owned in Miami Beach to think.[1,3]

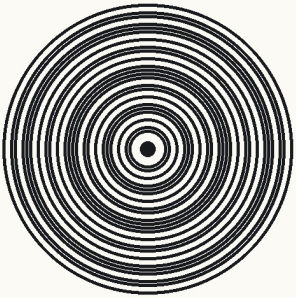
The epiphany came in January 1949, on the beach. Woodland told the story all his life, and it deserves to be told in his own words, because it contains the whole invention in miniature. He was sitting in a beach chair, turning over the checkout problem, when Morse code came into his head: dots and dashes, the alphabet of the telegraph. He poked his fingers into the sand and pulled his hand toward him. Four lines. Wide lines and narrow lines, he realized, could stand for dashes and dots. And then, seconds later, he swept his fingers round into a circle, because a circular mark could be read from any angle. Stripes, and then a bull's-eye: the barcode, twice, in under a minute.[1]

Back in Philadelphia, Woodland and Silver turned the drawing in the sand into an application. On October 20, 1949, they filed a patent for what they called a “Classifying Apparatus and Method,” built around the bull's-eye pattern of concentric circles, printed in ink and read by a lamp and a light sensor. The patent was granted on October 7, 1952, as U.S. Patent 2,612,994.[3,4] The two men even built a crude prototype in Woodland's home: a desk-sized machine with a ferocious 500-watt incandescent bulb for illumination and an oscilloscope to display the signal. By some accounts it worked, up to a point. An objective evaluation would later judge the whole idea to be about twenty years ahead of its time.[1]

That phrase, twenty years ahead of its time, is the hinge of the barcode's early life, and it is worth pausing on what it actually means. Woodland and Silver had solved the problem that could be drawn: how to make a mark that a machine could read. What they could not solve, because it did not yet exist, was everything around the mark. Their lamp was too hot and too weak; the bright, cheap light the idea needed, the laser, would not be demonstrated until

1960.[1] The computer that could turn a flickering signal into a price lookup was a room-sized machine that no supermarket could buy. And the numbers the mark would carry, the common product code shared by an entire industry, had not even been imagined as an institution. The invention was real, and it was stranded: a good answer waiting for the world to finish asking the question.

1949: the bull's-eye - data in concentric rings



Woodland & Silver's 1949 patent (granted 1952): white and dark rings encode the number.
Readable from any angle, so a cashier need not align the label.
RCA championed the pattern into the 1973 symbol contest;
ring smudging in ordinary printing was its fatal flaw.

The 1949 bull's-eye: Woodland and Silver's patent pattern put the data in concentric rings so a reader could approach from any angle.

CHAPTER 3

Earlier Dreams of Automatic Reading

Woodland and Silver were first to the barcode, but they were not first to the dream. The wish to make objects identify themselves to machines is older than the supermarket itself, and the two decades before the patent are scattered with ingenious attempts, each one solving a piece of the puzzle and sinking on the rest. Their history matters, because it shows what the barcode finally had to be: not merely clever, but cheap.

The lineage runs back to the punched card. By the 1930s, cards with holes read by metal brushes already ran census bureaus, payroll departments and railway ledgers; the whole apparatus of machine-readable data existed, so long as the data could be carried on a stiff rectangle of paper fed carefully into a reader. The obvious leap was to put the card on the product, or in the customer's hand. In one early scheme, shoppers in a self-service store picked punched cards from the shelves to represent their groceries and handed them to a cashier, whose machine read the cards and retrieved the goods from a back room; in another, the customer's entire basket was to be pushed under a scanner that identified every item at once and printed a bill.[1] None of it survived contact with the price of machinery. Punched-card equipment was capital goods for offices, not something that could ride on a tin of beans.

A closer ancestor arrived in the mid-1930s, when John Kermode and his colleagues in Youngstown, Ohio, patented a system intended to automate the post office: cards imprinted with patterns of bars that a photoelectric reader could sort automatically. The AIDC industry's own historical roll calls the Kermode patent the concept's first true ancestor, based, like the barcode after it, on a light-sensitive response technique.[7] Kermode's machine was demonstrated with some fanfare; the post office did not buy it, and the idea returned to the shelf. The pattern would repeat for forty years: a working demonstration, a cost that could not be justified, silence.

What all the precursors lacked, and what the 1949 patent also lacked, was an economic bridge: some reason compelling enough, and cheap enough, for thousands of independent companies to adopt the same mark at the same time. A reader is worthless without marked things to read, and marking things is worthless until readers exist. The economists who later studied the barcode's rise would give this trap a name, the chicken-and-egg problem of a network standard, and they would trace the barcode's eventual escape not to any single invention but to an unusual act of industrial cooperation.[2,15] Before that escape could happen, though, the invention itself had to survive its desert years, two decades in which it changed hands as an oddity and was kept alive by almost nobody. That survival is the next part of the story.

PART II

The Desert Years

From 1949 to 1969 the barcode was a patent without an industry: sold for a modest sum, tested on the sides of railway cars, and rescued twice, once by a light brighter than the sun and once by men who wanted to count trains.

CHAPTER 4

Twenty Years Ahead of Its Time

A patent is a promise that someone will pay to use an idea, and for more than a decade nobody paid. Woodland took a job at IBM in 1951, partly in the hope that the great computing company would develop the barcode; IBM's assessment was blunt. The idea was interesting, the company concluded, but the technology to exploit it did not exist, and it declined to pursue the patent. Woodland and Silver eventually sold it in 1962 to Philco, the electronics maker, for $15,000, the entire return on the invention that would later underpin world commerce; Philco in turn sold it on to RCA.[2,3,26] Bernard Silver died in 1963, at thirty-eight, before any of it came true.[3]

The reasons nobody wanted the patent are a tidy catalog of what a technology needs beyond itself. Reading the bull's-eye required a very bright, very small point of light sweeping across the mark; the 500-watt bulb in Woodland's prototype made the reading head bulky, hot, and prone to cooking the label it was meant to read.[1,26] Turning the returning flicker into digits required electronics that filled racks. And even had the hardware been free, there was still nothing to read: no manufacturer printed codes on packages, because no store could scan them, and no store bought scanners, because nothing was printed. The invention was not wrong. It was orphaned, missing its entire ecosystem.

Two rescues were coming, and they arrived from directions nobody at Drexel could have predicted. The first came from physics: on July 16, 1960, Hughes Aircraft announced that Theodore Maiman had produced a coherent beam of light, the laser, an “atomic radio light brighter than the center of the sun.” Reporters asked what it was for, and Maiman honestly did not know; he imagined surgery, welding, communications. He wrote later that he did not foresee the supermarket checkout scanner or the laser printer.[1] The laser was exactly the lamp the barcode had been waiting for: intense, narrow, cheap to aim, cool at the target. Within a decade, a helium-neon laser tube costing a few hundred dollars could sweep a hair-thin red line across a label hundreds of times a second, and the reading problem Woodland's bulb had made hopeless became an afternoon's optics.

The second rescue came from the railroads, and it gave the barcode its first real job. It is the subject of the next chapter, but its lesson belongs to this one: the barcode did not enter the world through the glamorous front door of the supermarket. It entered through the mud of rail yards, as a way to count freight cars, because a freight car is a simple thing to count and a railroad is a closed world where one authority can order everyone to comply. Technologies that need an ecosystem often survive this way, in a walled garden where the ecosystem can be commanded into being. The supermarket, where no one could command anyone, would be much harder.

CHAPTER 5

Stripes on Steel

A railroad is the largest machine most of us never think about: millions of freight cars, owned by hundreds of companies, wandering freely across a continent-wide web of track. In the 1950s the industry tracked this fleet the way the grocer tracked soup, by eye and paper. Clerks stood beside the tracks and copied car numbers onto forms; a missing car could send men walking the length of a yard, reading numbers off the sides of cars until it was found. David Jarrett Collins saw the chaos up close during college summers working for the Pennsylvania Railroad, where the punch-card system for tracking rolling stock generated errors daily. In 1959, now an engineer at GTE Sylvania, he proposed to fix it with light.[5,6]

The system Sylvania built, tested from 1961 on the Boston & Maine Railroad, was called KarTrak, and it was a barcode in everything but geometry. Each freight car carried a plate of horizontal stripes in red, white, blue and black, encoding the car's owner and number; a trackside scanner swept the plate with a light beam and read the colors with photomultiplier tubes as the train passed, at speeds up to sixty miles an hour, from nine feet away. The railroads' requirements read like a field manual for a hostile world: labels costing about a dollar, readable from zero to sixty miles per hour, durable for seven years, and scanners that could operate in isolated locations and survive, among other things, gunfire.[6,7]

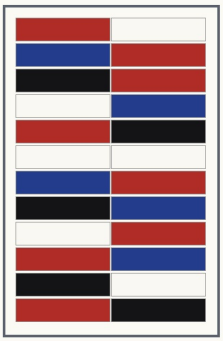
KarTrak won. In 1967, after head-to-head trials against rival systems at Spruce Creek, Pennsylvania, the Association of American Railroads declared it the standard and required every car owner in North America to label their fleet. Adoption came fast: by 1970 roughly 86 percent of the two million freight cars on the continent carried the striped plates, and by 1975, 90 percent. It was the first large-scale automatic identification system on Earth, and for a few years the barcode's future seemed to belong to the railroads.[6]

Then it failed, and the failure is more instructive than the success. The enemies were dirt, damage and discipline. Labels mounted low on flatcars collected grime; after seven years of service about a tenth of them had failed outright, and system-wide read rates sagged to around 80 percent, which meant that one car in five passed a scanner unidentified, exactly the cars a tracking system most needs to catch. Maintenance of the plates was nobody's job in particular, and the data, when it did arrive, went into computer systems the railroads had never properly built. Sylvania sold the business in 1972; by around 1977 the AAR had abandoned the requirement, and KarTrak plates faded on the sides of cars for years afterward, stripes from a future that had arrived early and left.[6]

KarTrak taught the young industry three lessons it never forgot. First, the mark is the cheapest part of the system and the part most easily destroyed; print quality and label life are everything. Second, an identification system is only as good as the computer system behind it; a number read and wasted is worse than a number never read. Third, Collins himself supplied the escape route. When Sylvania declined to chase applications beyond the rails, he

left in 1968 and founded Computer Identics, the first company built purely on barcodes, to develop scanners for the black-and-white codes he believed would follow.[5,7] The railroads had been the barcode's walled garden. Now it needed a bigger one, and it would find it, improbably, in the grocery aisle.

KarTrak: a schematic of the railway label



Horizontal pairs of coloured stripes carried the owner and car number.

Trackside readers swept passing labels. Dirt and damage reduced read rates.

Illustrative pattern, not a decoded or historically reproduced car label.

The rails proved that an identification system needs maintained labels and usable data.

A KarTrak plate: colored stripes identifying each freight car's owner and number, read trackside at speed from 1961.

CHAPTER 6

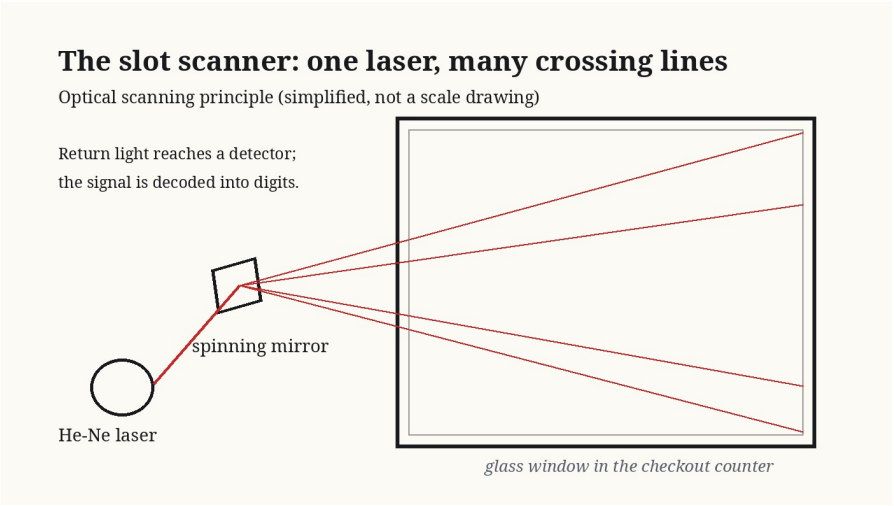
The Light That Made It Possible

The laser did for the barcode what the microphone did for the singer: it made a whisper audible at a distance. To read a stripe pattern, a scanner must throw light at the mark and catch what comes back. Dark bars swallow light; white spaces return it; the returning flicker, measured over time as the beam sweeps, is the message. Every difficulty in that sentence is in the word “throw.” Ordinary light spreads, so a lamp that illuminates a whole label returns one blurred average of everything at once. What was needed was light that stayed thin: a pencil beam that could be dragged across the label so that the stripes passed under it one by one.

The helium-neon laser, which followed Maiman's ruby laser within months, gave the industry exactly that, and by the end of the 1960s the tube had become a standard, affordable component. The first industrial barcode scanner to use one went to work in 1971, when General Motors installed a fixed-position helium-neon laser scanner, a $10,000 machine, to read codes on components moving through a plant.[7] The same year saw the first handheld wand scanners and the founding of AIM, the trade association for automatic identification, with four member companies.[7] The barcode now had light, readers, and a trade body. It still did not have a reason for a million merchants to care.

The reading machine that finally mattered, though, was not a wand but a piece of furniture: the supermarket slot scanner, built into the checkout counter itself. Its design is a small masterpiece of optical economy. A helium-neon tube fires a continuous red beam at a spinning polygonal mirror; the spinning facets fling the beam across a pattern of fixed mirrors, which fan it into a lattice of crossing lines rising through a glass window in the counter; an item dragged across the window passes its label through the lattice, and no matter how the label is tilted, at least one line of the fan sweeps across the stripes squarely. The returning light is collected by the same mirrors and falls on a photodiode, which converts the flicker into a voltage; a decoder turns the voltage into digits; the cash register sends the digits to a store computer and gets back a price. All of this happens in the time it takes to slide a can across a pane of glass, which is why the ceremony at the checkout feels like a single beep.[8]

By 1972 the pieces were demonstrably real. RCA, which had bought the Woodland and Silver patent from Philco, built a working bull's-eye scanning system and installed it at a Kroger store in suburban Cincinnati, the first retail scanning installation anywhere.[1,7] Sylvania had tested a scanner with Stop & Shop. NCR offered a color bar code.[2,7] What did not exist was the thing the whole apparatus depended on: one agreed mark, carrying one agreed number, that every manufacturer would print and every scanner would read. Seven companies had seven symbols and seven scanners. The grocery industry was about to do something almost unheard of in American business: it was about to agree.



Inside a slot scanner: a laser, a spinning mirror and fixed mirrors fan one beam into a lattice that catches the label at any tilt.

PART III

The Standard

Technologies become industries when strangers agree. Between 1970 and 1973, competitors who distrusted each other on everything else sat down and agreed on a number, and then on the shape of its stripes. The agreement is the real invention.

CHAPTER 7

The Industry That Organized Itself

By the late 1960s the American grocery trade knew it had a problem it could not solve alone. Retailers wanted a short product code they could key quickly into new electronic registers. Manufacturers, who made and labelled the goods, wanted a longer code that folded their existing internal item numbers into a common system, and they wanted it cheap. Workgroups within the manufacturers' and retailers' associations met, argued, and went home, as one participant put it, without resolution. Each chain still numbered products its own way, which meant that any automated checkout would force manufacturers to label the same can differently for different chains, an impossible burden.[2]

In 1968 the president of the National Association of Food Chains, Clarence Adamy, asked McKinsey & Company to break the impasse. McKinsey returned with a proposal for a full standardization study, five months and $100,000; the association had no money and passed. Adamy then did something more consequential: he convinced the heads of five other trade associations to join him in chartering a committee of decision-makers, not technicians. The Ad Hoc Committee on a Uniform Grocery Product Code, ten senior executives drawn from manufacturing, distribution and retail, met for the first time in August 1970 at a hotel by Chicago's O'Hare Airport, and hired McKinsey after all, not to design the answer but to run the process.[2,8]

Seven months later the committee settled the number: ten digits, all numeric, split down the middle. The first five digits would identify the manufacturer, assigned by a single central authority so that no two companies could ever collide; the second five would identify the product, assigned by the manufacturer itself. The design was a quiet stroke of institutional genius. Central assignment made the code universal; manufacturer assignment made it bearable, since no company had to ask permission to number its own goods. In May 1971, at the Super Market Institute's annual convention in Dallas, R. Burt Gookin, the chief executive of H. J. Heinz, stood up and urged the entire industry to adopt what he now named in public: a Universal Product Code. McKinsey's men had spent the preceding weeks collecting written commitments from the industry's top executives; the last signatures came in the night before the speech.[2]

The economics underwrote the diplomacy. Grocery margins ran at about a penny on the dollar, checkout and price-marking labor were among the largest controllable costs, and the consultants projected that scanning could eventually yield $1.4 billion in hard savings to the industry, most of it landing with retailers, with softer, larger gains in inventory knowledge behind. But the projections cut both ways, and everyone at O'Hare knew it: scanning paid only if manufacturers marked at least three-quarters of their goods, and marking paid only if some 8,000 supermarkets, about a quarter of the national total, installed scanners. Someone had to move first, and everyone would lose money moving first. The committee's answer was to make moving first an act of collective leadership rather than individual risk: commitments in writing, executives at the table, and one standard for everyone, announced once.[2]

What remained was the mark itself. The number was an abstraction; it still needed a body that a machine could read at speed, printed with ordinary presses on ordinary packages, small enough to sit politely beside the brand name. Choosing that body would take two more years, a field trial, a hired jury of scientists, and a last-minute entry from a company that had almost stayed out of the race.

CHAPTER 8

The Symbol War

In March 1971 the Ad Hoc Committee handed the mark problem to a Symbol Standardization Subcommittee chaired by Alan Haberman, a Massachusetts supermarket chief executive, and threw the contest open. Seven manufacturers submitted symbol-and-scanner systems, among them RCA, Singer and Pitney Bowes. The requirements the subcommittee enforced were brutal in their simplicity. The symbol had to fit in a square inch and a half, to spare precious package real estate. It had to print reliably with the ordinary label and packaging presses of the day. It had to read correctly at checkout speed regardless of the angle at which a cashier happened to drag the item. And its undetected error rate had to be below one in twenty thousand.[1,2]

RCA considered the contest a formality, and it had reasons. It owned the Woodland and Silver patent, its bull's-eye symbol was the patent's own design, and it had the only system with real store hours on it: since July 3, 1972, prototype RCA checkstands had been scanning bull's-eyes at the Kroger Kenwood Plaza store in Cincinnati, with promising results.[1] But the bull's-eye had a weakness that no amount of field success could argue away. Concentric circles are merciless to print: any smudge or spread of ink across the rings corrupts them, and package printing is a world of smudge and spread. A rotating turret of ballpoint pens, and even the pressurized astronaut pen, had been enlisted to print the circles cleanly enough to scan.[1,9] The subcommittee's scientists at the Battelle Institute in Columbus, testing every contender against print defects, kept finding the same fault: the circle asked too much of the printing press.[2]

IBM nearly missed the race entirely. The company had once built a sixty-pound key-entry checkout machine and abandoned it when the arithmetic of clerk time made the business case collapse, and it held back from the symbol contest until the last moment, despite employing, in its research ranks, one Joe Woodland. When IBM did enter, the job of designing its symbol fell to an engineer in Raleigh named George Laurer, precisely because he came empty-handed: no scanner in the field, no patent to defend, no prejudice about circles. Handed the subcommittee's requirements, Laurer concluded that the bull's-eye could not meet the print-tolerance numbers and drew instead what Woodland had drawn in the sand first and discarded: straight lines, wide and narrow, arranged in two halves with guard bars at the edges and center.[1,9]

Inside IBM the rectangular symbol was heresy, and Laurer had to prove it in front of skeptics that included his own leadership. At one demonstration, he recalled, the company's ace softball pitcher hurled beanbag ashtrays with symbols printed on their bases across the scanner as fast as he could throw; every one read correctly, and the demonstration ended the argument.[1] The committee stage was harder. In January 1973 the seven contenders presented over three days; the subcommittee asked MIT scientists for an independent appraisal of the rival symbologies; and on March 30, 1973, in a New York hotel near Grand Central, the

members met to decide. Haberman first asked each member how certain he was that the symbol he was choosing was the right one. The answers came back at about ninety percent all round, an extraordinary number for a decision of this size, and the committee chose Laurer's linear code. The industry announced its Universal Product Code and symbol on April 1 and 3, 1973, at a New York press conference.[1,2,15]

Woodland, who had drawn the first lines in 1949 and the bull's-eye that RCA still backed, was on IBM's team when the lines won. He lived to see the symbol become the most printed mark on earth, and died in 2012 at ninety-one. Laurer's design, chosen in that hotel room, has never been substantially changed. Every UPC on every package in every store today is, line for line, the answer he gave to a one-and-a-half-inch problem in 1973.[1]

CHAPTER 9

Anatomy of the Chosen Symbol

Pick up any packaged thing near you and look at the stripes. The symbol seems like noise, but it is one of the most disciplined little machines ever printed, and its discipline is why it survived. A UPC-A symbol is a rectangle exactly ninety-five modules wide, the module being the width of the thinnest bar. It opens and closes with a guard pattern, two thin bars bracketing a space, and a center guard of five elements splits the symbol into left and right halves of six digits each. Every digit occupies seven modules, encoded as two bars and two spaces; the digits on the left use one family of patterns and the digits on the right another, chosen so that a scanner can tell, from the pattern alone, which direction the label is travelling and which side it is reading. Under the bars, for humans, run the twelve digits: in the original allocation, one number-system digit, five for the manufacturer, five for the item, and a final check digit. Modern GS1 company prefixes vary in length, so the boundary between company and item is not something a reader can reliably infer by splitting every number in the middle.[9,35]

The check digit deserves a paragraph of respect, because it is the symbol's conscience. Add the digits in the odd positions and multiply by three; add the digits in the even positions; the twelfth digit is whatever brings the total to the next multiple of ten. Every scan recomputes it, so a single misread digit, a bar widened by ink spread or narrowed by a worn press, almost never passes silently; the arithmetic complains. Layered on top of that, the two bar-and-space structure per digit and the left-right pattern families give the decoder further cross-checks, and the whole construction is what let the committee write its requirement of fewer than one undetected error in twenty thousand scans and mean it.[1] The printed figure, flanked by its mandatory margins of blank space, the quiet zones, is thus not a picture of a number but a small self-verifying statement.

Just as deliberate is what the symbol does not contain. A UPC holds no price, no description, no expiry date, nothing that can change; it is a license plate, not a dossier. The price lives in the store's computer, which is why a grocer in 1974 could reprice ten thousand cans by editing one database row instead of pasting ten thousand stickers, and why the same can can cost different amounts in different towns without a single package changing. This separation, identity in the stripes, everything else in the database, is the deepest design decision in the whole system, and it is why the barcode could spread into hospitals and warehouses and airport baggage halls without changing its shape. The mark means: look me up. Everything else is somebody's software.[2]

The symbol family that grew around Laurer's design kept the same grammar. EAN-13, the European form, fits thirteen digits by using the parity pattern of the left half to smuggle in the extra digit; UPC-E compresses eligible GTIN-12 numbers by suppressing zeros. EAN-8 is different: it carries a separately assigned eight-digit GTIN, not an EAN-13 with zeros removed. These related symbols share seven-module digit patterns; compatible scanners can

distinguish their different lengths and guard arrangements. When the committee chose the symbol in 1973 it was not choosing a drawing; it was choosing an alphabet. The chapters that follow are the history of everything that has been written in it since.[22,23,35,40]



The anatomy of a UPC-A: guards, two digit halves, quiet zones, and a computed check digit that keeps misreads honest.

A check digit, worked through

The number in the diagram is 012345678905. Ignore its final digit for a moment. The digits in positions one, three, five, seven, nine and eleven sum to 0 + 2 + 4 + 6 + 8 + 0 = 20; multiply that by three to get 60. The other five digits sum to 1 + 3 + 5 + 7 + 9 = 25. Their combined weighted total is 85. Five brings it to 90, the next multiple of ten, so the final digit is 5. The scanner can repeat that arithmetic after decoding. GS1 applies the same alternating-weight principle across its fixed-length numeric identification keys.[37]

This is error detection, not error correction or proof of authenticity. Changing any one digit changes the remainder, so a single-digit substitution is detected. Swapping adjacent digits is different: exchanging digits whose values differ by five changes the weighted sum by ten, leaving the check unchanged. That limitation follows directly from the arithmetic. And a perfect copy of a valid number has a perfect check digit. The code checks the transcription of the identifier; it cannot certify the object carrying it.

PART IV

First Beep

A standard on paper is a truce, not a business. The barcode nearly died in the years right after its triumph, saved by patience, falling prices, and two very large retailers who made it mandatory.

CHAPTER 10

Troy, Ohio

The choice of birthplace was not ceremony but geography. Troy, Ohio, sat in the middle of the American checkout industry: National Cash Register, which built the registers, was an Ohio company, and so was Hobart, which built the weighing and pricing machines for meat counters. Marsh Supermarkets, a regional chain, offered a store; NCR and Spectra-Physics jointly provided the system, NCR the computerized registers and Spectra-Physics the laser scanners. The night of June 25, 1974, a team moved into the Marsh store in Troy to barcode hundreds of items by hand while the scanners and computers were installed around them.[1,8]

At 8:01 on the morning of June 26, 1974, the first “shopper” stepped up: Clyde Dawson, Marsh's head of research and development, playing the role for history, with cashier Sharon Buchanan at the register. From his basket Dawson pulled a ten-pack of Wrigley's Juicy Fruit chewing gum. It was not a lucky dip. The pack had been chosen because nobody had been sure a barcode could be printed legibly on something that small, and Wrigley's had solved the problem; scanning it first was a deliberate demonstration that the symbol worked at the hardest size. The laser swept, the register beeped, the price appeared, and the age of scanning began with a pack of gum.[1,9]

The gum's afterlife has its own small lesson about how history attaches to objects. For years it was reported that the Smithsonian's National Museum of American History had collected and displayed the original pack; in fact the museum displayed a facsimile, and the real pack remained with Dawson. The museum does hold one of the first ten Spectra-Physics Model A scanners, and its catalog entry is a tidy description of the whole 1974 machine: the helium-neon laser in the base, the rotating mirror, the glass plate on top, the photodiode catching the returning light, the computerized register matching the signal to a stored price.[1,8] Fifty years later, on June 26, 2024, GS1 US would celebrate the anniversary as the “Scanniversary,” by which time the barcode was identifying over a billion products and being scanned more than ten billion times a day.[10]

The morning itself, by the testimony of the trade paper that covered it within weeks, was almost anticlimactic. A Marsh spokesman allowed that it was a little slow going at first while employees learned the system, but the equipment, he said, was working quite well.[16] That is how infrastructure arrives when it arrives properly: not with a flash but with a working morning. The harder test was not the first beep but the next several years, in which the beep very nearly fell silent.

CHAPTER 11

The Scanner That Nearly Failed

The committee's own arithmetic had warned everyone. Scanning paid only past a double threshold: manufacturers had to mark at least three-quarters of their products, and roughly 8,000 supermarkets had to install scanners, before the network effects began to repay anyone's investment. Neither threshold was close in 1974, and the first movers bled. An early scanning installation cost on the order of $10,000 per lane; manufacturers were redesigning packaging and film for a reader base that barely existed; retailers were buying computers for shelves full of unmarked goods. “Manufacturers put bar codes on products not knowing how often they'd be scanned,” one industry researcher recalled. “Retailers overhauled their front end not knowing if there would be enough products to scan.”[2,16]

Politics piled onto economics. Unions saw a machine whose purpose was to cut checkout hours and fought it openly. Consumer advocates warned that removing per-item price stickers would let stores change prices invisibly and, worse, track what people bought. Both camps converged on the same remedy, and by 1976 six states, California, Michigan, New York, Connecticut, Massachusetts and Rhode Island, had passed item-pricing laws requiring scanned stores to keep stickering every item by hand. The laws aimed at the sticker were, in effect, aimed at the business case: as a 1999 industry retrospective put it, they cut the savings that scanning existed to create and stretched the payback period at exactly the moment when capital was most expensive.[2]

By 1976 the obituaries were being written, most famously by Business Week, which eulogized “The Supermarket Scanner That Failed.” Projections made a few years earlier, including studies that had forecast over $40 million in industry savings by the mid-1970s, had not come true on schedule, and in the high-inflation, high-interest economy of the late seventies many chains simply stopped investing.[2,15] It took a good five years from the Troy morning before most products even arrived in stores bearing the symbol; in the early years retailers printed and stuck many of the codes themselves.[16] The barcode's first decade is one of the great slow fuses in industrial history: a working system, publicly demonstrated, championed by the biggest names in its industry, and still nearly extinguished by the chicken-and-egg trap its founders had named in advance.

What saved it was, in the end, what saves most network technologies: the threshold was eventually crossed, and the other side of the threshold was profitable. Scanners shrank, improved and fell in price; by 1980 retailers, in one vendor's phrase, could see the ROI. Newer machines in the early 1980s could read codes that were crinkled, wet or partly damaged, which converted scanning from a quality-of-service luxury into a hard cost saving that even price-first stores could bank. And beyond the grocery aisle, two mass merchants were about to make the barcode compulsory for everyone who wanted to sell to them.[2,16]

CHAPTER 12

The Tide Turns

The turn came in the first half of the 1980s, and it came from outside the grocery trade. Kroger and Safeway had been aggressive early adopters among the supermarket chains, but the decisive converts were the mass merchandisers, Kmart first and then Wal-Mart, companies whose stores carried far more distinct items than any grocer and whose economics depended on knowing, daily, what was moving. Around the middle of the decade the two chains began requiring their suppliers to ship bar-coded goods, and because selling to Kmart or Wal-Mart was not optional for most manufacturers, UPC registrations spread, in the words of the Richmond Fed's history, like wildfire through the whole of retail. By about 1986 roughly seventy percent of American supermarkets were scanning.[1,2,16]

Wal-Mart's timeline shows how quickly the stripes, once adopted, became the nervous system of a company. The firm began scanning bar codes at its checkouts in 1983. In 1984 it put handheld terminals in the aisles, so that an associate who scanned a shelf label saw the item's description, its order history and its quantities; by 1985 it had 882 stores and $8.4 billion in sales; and in 1987 it completed what was then the largest private satellite communication system in the United States, binding every store's scanned sales back to headquarters in near-real time.[24] The barcode supplied the raw, trustworthy, item-level data; the satellite moved it; the computers decided what to reorder, where and when. The modern supply chain, the one the whole world now lives downstream of, was assembled out of those three parts, and the barcode was the part that touched the object.

The consumers' side of the bargain also arrived, quietly, in the price data. The economist Emek Basker, studying grocery prices across the first decade of checkout automation, found that prices fell considerably as scanning spread, with the largest declines in produce and meat, precisely the perishable categories where store managers had the most discretion and the least information before scanning.[2] The union fears and the sticker debates of the seventies had been about visible costs; the countervailing benefit, cheaper food, was invisible and diffuse, and by the time it was measurable the argument was over. The states' item-pricing laws faded with the decade that had produced them.

By the end of the 1980s the barcode's survival question was settled, and its question had become the opposite one: how far it would spread. Scanners had merged with scales at the checkout; the early 1990s brought bioptic scanners that read several faces of a package at once.[16] The symbol had long since escaped the grocery aisle into warehouses, factories, hospitals, post offices and libraries, each of which gets a chapter later in this book. First, though, it is worth stopping to learn the language properly: how a barcode actually encodes a number, what other symbologies grew up beside the UPC, and how the stripes learned to become squares.

PART V

A Grammar of Stripes

The barcode is not one invention but a family of languages, each invented for a job the others could not do. Here is how the grammar works, who wrote the dialects, and why the family eventually grew a second dimension.

CHAPTER 13

How a Barcode Works

Everything a linear barcode says is said with one trick: time. A scanner's beam crosses the label, and the decoder measures how long the returning light stays dark and how long it stays bright. A dark interval one module long is a thin bar; three modules, a thick bar; the spaces between bars are read the same way, because the message lives in both. The decoder's first job is to find the edges, converting the smooth analog flicker into a train of timed pulses; its second is to divide those pulses into modules; its third is to look the module patterns up in the symbology's table and read out characters. Guard patterns at the ends give it a known starting rhythm, the way a conductor's upbeat sets the tempo before the music starts.

This is why a suitable scanning system tolerates changes in angle and speed. Because the encoding is in relative widths, not absolute positions, the same label read by a beam moving fast or slow, near or far, yields the same sequence of ratios. Because the left and right halves of a UPC use different pattern families, the decoder can read the symbol backwards or forwards and still know which digit is which, a property called bidirectionality, and the guard-and-center structure lets the scanner assemble one full read from fragments of several sweeps, which is what the crossing lines of a slot scanner's fan are for.[8,9]

The vocabulary of the whole field is small and worth owning. A symbology is an encoding language, the rules mapping characters to bar patterns; UPC, Code 39 and Code 128 are different symbologies the way French, German and English are different languages over one alphabet of bars. A discrete symbology, like Code 39, pads every character with an inter-character gap, forgiving sloppy printing at the cost of space; a continuous one, like Code 128, packs characters edge to edge for density. A two-width symbology knows only wide and narrow elements; a many-width, or edge-to-similar-edge, code like the UPC family measures four widths and packs far more information per inch. And the quiet zone, the mandatory blank margin on either side of the stripes, is the silence that tells the scanner the sentence has begun and ended; a surprising share of real-world scan failures trace to something printed in the quiet zone.[35]

One trick never appears in the symbol at all: the lookup. A linear barcode in commerce is almost always a license plate, a short unique key whose entire meaning lives in a database somewhere else. This is why a 12-digit stripe pattern can stand for a product with a hundred attributes, and why the system degrades so gracefully: a torn label will often produce no read, but the database behind a clean read can be updated forever without touching a single package. The chapters on GS1 will show what an institution it takes to keep those lookups consistent across a planet. First, the dialects.

CHAPTER 14

The Symbology Zoo

The UPC was designed for one job, identifying consumer packages, and it does that job with almost no letters, no punctuation and no flexibility. Industry needed more: codes that could spell part numbers and bin locations, survive dirty warehouses, fit on tiny components or stretch across shipping cartons. The 1970s and early 1980s answered with a small explosion of symbologies, and a surprising number of their creators, dates and patrons are on record, because this was an industry young enough to remember its own births.[7]

Codabar came in 1971 from Monarch Marking Systems, a simple numeric-plus-symbols code that found its niches quickly and held them for decades: libraries used it on book cards, overnight couriers on airbills, and blood banks on donor units, where it became a longstanding identification format.[7] In 1972 Dr. David Allais of Intermec devised Interleaved 2 of 5, a continuous numeric code whose trick is hiding in its name: the bars encode the odd digits and the spaces the even ones, two digits woven into one, a density that made it the natural choice for printing coarse corrugated shipping cartons and, later, for the airline industry's ten-digit baggage tags.[7,32] Then, in 1974, the same David Allais, with Ray Stevens at Intermec, produced Code 39, the first alphanumeric barcode, spelling letters and digits alike with nine elements per character, three of them wide.[7,21]

Code 39 became the workhorse of the industrial world for a simple institutional reason: the military adopted it. On September 1, 1981, the U.S. Department of Defense chose Code 39 for marking everything sold to the armed forces, a program called LOGMARS, codified as Military Standard 1189; from 1982 some 50,000 defense suppliers were required to ship with Code 39 labels, and the barcode industry's own historians credit that mandate with pushing the code, and with it the whole practice of barcoding, into mainstream industrial use. The civilian standard, ANSI MH10.8M, followed in 1983, in the first batch of national barcode standards alongside Codabar and Interleaved 2 of 5.[7,21]

Density still pressed on the designers, and in 1981 Computer Identics, David Collins's company, answered with Code 128: a high-density, full-computer-character-set code named for the 128 ASCII characters it can encode, with a clever internal switching mechanism that packs pairs of digits at double density. Code 128 became the default language of shipping labels and internal logistics, the code behind the GS1-128 cartons-and-pallets standard that runs distribution today.[7,35] Rounding out the shelf: UPC-E, the zero-suppressed form of eligible twelve-digit numbers, and EAN-8, carrying a separately allocated eight-digit identifier for small packages, and, much later, the GS1 DataBar family, “reduced space” symbols approved for items like jewelry and loose produce, able to carry expiry dates and weights that the old UPC never could.[22,35,40] Appendix B lays the whole shelf out side by side.

One number, four languages

EAN-13: 0012345678905



Code 39: 012345678905



Interleaved 2 of 5: 012345678905



Code 128: 012345678905



Same identifier; equal module scale. EAN-13 includes its leading zero and check digit.

One identifier encoded in four symbologies at the same module scale. The EAN-13 form adds a leading zero; the industrial examples encode the twelve-digit string.

CHAPTER 15

Squares and Snowflakes

A linear barcode has a practical space constraint: its message runs along one axis, and adding data makes the symbol longer. The Japan Patent Office's own history of the QR code puts the conventional ceiling at about twenty alphanumeric characters. As the 1980s ended, the ambitions of industry had outgrown that sentence. Shippers wanted a whole manifest in one mark; electronics makers wanted component histories on thumbnail-sized parts; everyone wanted the mark to survive damage that would kill a line of stripes. The answer was to go upward: to encode in two dimensions.[14]

Two families of two-dimensional code appeared almost together. The stacked family stretches the old idea: PDF417, invented by Ynjiun Wang at Symbol Technologies and published in 1991, is literally a stack of tiny one-dimensional rows, each row a sequence of bar-and-space codewords, so that a fast linear scanner could read a document's worth of data, up to about a kilobyte, off a single label; airlines and governments put it on boarding passes and identity cards through the 1990s and 2000s.[7] The matrix family is more radical: it abandons bars entirely for fields of cells, read like a chessboard by a camera. MaxiCode, built by UPS in 1992, packs a shipment's data into a fixed one-inch hexagon-eyed bullseye designed to be read on parcels moving at conveyor speed. Data Matrix, from the same era, scales down to microscopic marks etched directly onto circuit boards, surgical tools and engine parts. Aztec Code, published in 1995 by Andrew Longacre and Robert Hussey, grows outward from a central target and needs no quiet zone, which is why it ended up printed in the tight margins of rail and airline tickets.[7]

Two gifts made the matrix codes practical. The first was the camera: by the early 1990s, solid-state image sensors had become cheap enough to put inside scanners, and a camera, unlike a sweeping laser, sees the whole symbol at once, so software can recover the symbol's orientation and damaged areas can be worked around. The second was error correction, borrowed from the mathematics of data transmission: matrix codes write their data with deliberate redundancy, so a symbol can be torn, stained or partly missing and still decode. The QR code, the most successful of them all, offers four selectable levels of this insurance, restoring roughly 7, 15, 25 or 30 percent of its codewords depending on the level chosen.[36]

The linear codes did not die when the squares arrived, and the reason is the oldest one in this book: cost and habit. A stripe code prints on any press, scans on any cheap laser, and says the one thing most commerce needs said, look me up. The squares took the jobs that needed more said, more reliably, in less space, and the two families settled into the division of labor the world still lives with: stripes for the checkout, squares for the hard cases. One of the squares, though, escaped industry entirely and became a public language of its own. That is the next chapter.

CHAPTER 16

The QR Detour

The most famous barcode in the world today was invented as an internal tool for a car-parts company, in a country that needed something the American stripes could not give it. In the early 1990s, DENSO, a Toyota-group components maker, was looking for business beyond automobiles after Japan's bubble economy collapsed. Its factories tracked parts with barcodes, and the limits chafed: a linear code held about twenty characters, forced workers to scan several codes per part, and, being an American invention, had no room for the kanji characters of Japanese. An engineer named Masahiro Hara, who would later say he wanted to make DENSO world-famous, concluded that one-dimensional codes were approaching a technical wall and set out to build a two-dimensional code that could be read at high speed.[14]

The design problem was speed, and the solution is the three squares you see in every QR code's corners. A factory scanner must find a symbol instantly, at any angle, on parts moving past; Hara's team hunted for a position-detection pattern that almost never occurs in print or nature, settled on a square-within-a-square with a 1:1:3:1:1 run-length ratio across its centre, and placed it in three corners so that software could locate, square up and orient the code in a fraction of a second. Around those anchors the code packs its data in a grid of modules that grows by fours from a 21-by-21 minimum to a 177-by-177 maximum, holding, at the extreme, up to 7,089 numeric characters, with kanji support built in from the start.[14,36] The name says the whole ambition: Quick Response.

Then DENSO WAVE made the decision that turned a good product into a world standard: it published the specification and waived its patent rights for standardized use, so that anyone could print or read QR codes without a license. The code was approved as an AIM standard in 1997, a Japanese industrial standard in 1999, and an ISO standard, ISO/IEC 18004, in June 2000.[36] Japanese industry adopted it first for exactly its intended purpose, parts traceability. What carried it to the public was the mobile phone: Japanese handsets gained QR-reading cameras around the turn of the century, and the code became the country's standard bridge from paper to internet, printed on posters, packaging and business cards.

The second act, global this time, arrived with the smartphone and, above all, with mobile payments. Because a QR code costs nothing to print and many camera-equipped smartphones can read one, the code became the world's cheapest point-of-sale terminal: a merchant needs no hardware beyond a printed square, and the customer pays by scanning it. In China, QR-based mobile payment grew through the 2010s into a dominant way of paying for daily life, from street stalls to taxis; in India the same pattern ran through the UPI system; across Southeast Asia, Europe and the Americas the pandemic years then scattered QR menus, tickets and check-ins through daily life. A symbol built to track carburetors had become, thirty years on, the most democratized piece of financial infrastructure ever printed, and the standards world took notice: GS1's plan to retire the retail checkout's exclusive reliance on stripes, the Sunrise 2027 program discussed later in this book, is built substantially on the QR code Hara's team designed for the factory floor.[13,14]

The QR code (1994): found fast, read at any angle



Three finder patterns: 1:1:3:1:1 across centre let software locate and orient the code instantly at any angle.

Timing patterns (alternating row and column) set the module grid.

Data and error-correction cells fill the rest: capacity depends on version and correction level.

Example payload: THE BARCODE. Maximum version can hold 7,089 numeric digits.

A real QR symbol encoding THE BARCODE: three finder squares establish orientation, timing patterns establish the grid, and data cells include error-correction codewords.

CHAPTER 17

The Machines That Read and Print

A barcode is a promise between two machines: the one that prints it and the one that reads it. The reading machines came first to market glamour, but the printing machines are half the industry, and both sides have a genealogy worth tracing, because the same few ideas recur in both: make it faster, make it smaller, make it survive the real world.

On the reading side, the 1970s offered the wand, a pen the clerk dragged across the label by hand, cheap and forgiving but slow, and the fixed laser scanner, expensive and fast. Norand shipped the first handheld wand in 1971; Symbol Technologies released the first truly successful handheld laser scanner in 1982, and the handheld gun became the universal tool of stockrooms and couriers.[7] The 1980s added the CCD reader, a row of light sensors with no moving parts; Norand shipped the first in 1981.[7] The 1990s and 2000s brought the imager, essentially a camera plus software, which reads stripes and squares alike, works off phone screens and scratched labels, and can read both linear and matrix symbols. Smartphones brought camera-based barcode reading into consumers' hands. The slot scanner at the supermarket, meanwhile, settled into its mature form early: by the late 1980s scanners had merged with scales, and the early 1990s brought bioptic units reading several faces of a package at once.[16]

On the printing side, the quiet revolution was thermal. Early labels came from typewheel imprinters and plate presses; the industry changed when Sato of Japan introduced the first thermal transfer printer in 1980, melting ink from a ribbon onto paper under a row of heated dots.[7] Thermal printing put a barcode press on the shipping desk: no printing plates, an immediate first label, and no liquid ink system to maintain. Direct-thermal stock, which darkens under heat alone, made shipping labels and receipts a consumable; thermal transfer ribbon made durable industrial tags. The companies that married thermal printers to barcode standards, Zebra above all, built one of the industry's most durable businesses, and they appear in the company chapters later.

Between the printer and the scanner stands one more machine the public never sees: the verifier. Because a barcode is a manufactured artifact, its quality can be measured, and an entire instrument business exists to do it, grading labels on contrast, edge sharpness and dimensional accuracy against international standards. A verifier is to a barcode what a gauge is to a machined part, and its existence marks the barcode's graduation from gadget to industrial component: a thing specified, measured, and warrantied. The bottleneck chapters return to what happens when the gauging is skipped.

PART VI

The Organization of Numbers

A barcode is only as good as the uniqueness of its number, and uniqueness is an administrative achievement, not a technical one. Somewhere, someone has to keep the register of who owns which digits. This is the least known and most load-bearing institution in the story.

CHAPTER 18

Europe Answers

The UPC was American by birth, and Europe watched its first years with the interest of a neighbor who wants the convenience but not the dependence. European manufacturers sold into American stores and needed compatible codes; European retailers wanted the same checkout economics; but a numbering system administered solely from the United States left no room for European companies to hold their own prefixes. The answer, pursued from 1973 onward with particular energy by Albert Heijn, president of the great Dutch grocery chain, who had attended the American committee's work as a guest, was a European system built to be a superset of the American one.[23]

The technical key came from the man who had designed the UPC. George Laurer, working in coordination with the American committee, showed that the UPC symbol had unused capacity: the left-hand digits could be printed in two parities, and the pattern of those choices could smuggle a thirteenth digit into the same bars, extending the twelve-digit code to thirteen without changing the scanner's basic job. The thirteen-digit symbol was approved in December 1976, deliberately designed for upward compatibility, so that wherever the new European symbol was scanned, American UPCs would read as well; the reverse compatibility, Americans reading European codes, arrived only decades later, formalized in 2005.[23]

The institution followed quickly. National coding organizations formed across the continent, Germany's Centrale für Coorganisation in 1974 among the first, and in 1977 twelve countries founded the European Article Numbering Association in Brussels as an international not-for-profit, with Heijn as its first chairman.[22,23] The EAN structure solved the politics with arithmetic: prefixes were allocated by country organization, so every member nation's manufacturers numbered their own goods under their own flag, inside a system whose stripes any compatible scanner on earth could read. That prefix map is why the first digits of a barcode on a jar can tell a curious shopper which national organization issued the number, a quiet fossil of the system's federal design.

The EAN's founding completed the barcode's basic geography. There were now two cooperating registries, one American, one European-led but rapidly global, one symbol grammar, and a planet of products being numbered into it. The history of the next three decades is the history of those two registries converging on a single world body, and of that body's number keys spreading far beyond products into shipments, locations, assets and patients. The name it converged on was GS1.

CHAPTER 19

GS1: The Quiet Regulator

Almost no consumer has heard of GS1, and almost every consumer uses it many times a day. GS1 is the not-for-profit standards body that administers the numbering system behind the world's barcodes: it issues company prefixes through its member organizations, maintains the specifications for how the stripes and squares are drawn and where they may sit, and runs the processes by which industries agree on new standards. Its own timeline describes the lineage plainly. In 1974 the Uniform Code Council was appointed administrator of the new UPC in the United States. In 1977 the EAN was established in Brussels. In 2005 the two merged into a single international organization, GS1, with 101 local member organizations at the time of the merger; by the fiftieth anniversary of the first scan, in 2024, the family had grown to 116 member organizations.[22]

GS1's real product is not barcodes but keys. The best known is the GTIN, the Global Trade Item Number carried by retail barcodes. Around it the system defines a family of identifiers for the whole supply chain: the SSCC, a serial code that gives every pallet or shipping container a unique license plate; the GLN, which numbers locations and legal entities, so that a warehouse or hospital ward can be addressed as precisely as a product; and attribute keys, batch numbers, serial numbers, dates and weights, encoded alongside the identifier through a grammar of application identifiers. The GS1 General Specifications, the system's core standards document, lays all of this out: how the keys are built, which symbologies may carry them, and how the barcodes should be printed and placed.[35]

Over the decades the organization kept absorbing new domains the way the EAN had absorbed countries. It published its first EDI standard for electronic data interchange; moved formally into healthcare, where the FDA later accredited it as an issuing agency for the Unique Device Identifiers on medical devices; approved the GS1 DataBar reduced-space symbols for fresh foods and small items; adopted the GS1 DataMatrix as its first two-dimensional code; built a global data-synchronization network for product information; launched a traceability standard; became an accredited issuer of Legal Entity Identifiers for financial transactions; and, in 2017, the BBC counted the GS1 barcode among the fifty things that made the modern economy.[22] A standards body is a strange kind of institution to narrate, because its successes are invisible by design: the day everything interoperates is the day nobody notices. GS1's invisibility is its report card.

It is worth pausing on the governance model, because it is the barcode's deepest difference from most technologies in this library. No company owns the barcode. The symbol specifications are public, the patents that matter have long expired or, like DENSO WAVE's QR patent, been waived for standardized use, and the numbering is administered by a neutral nonprofit answerable to the industries that use it.[22,36] The barcode won the world not by being anyone's product but by being everyone's commons, a status the Symbol Committee aimed at deliberately in 1973 when it chose one mark for an entire industry. The next chapter counts what that commons became.

CHAPTER 20

The Number Economy

The scale of the barcode commons is easiest to grasp through GS1's own ledger. The organization serves more than two million companies across more than twenty-five industries and some 150 countries; more than a billion products carry its numbers; and those numbers are scanned, by GS1's running estimate, over ten billion times a day.[10,11] Ten billion daily beeps is the figure the organization has repeated for years, through the fiftieth anniversary of the first scan and into the Sunrise transition, and even treated as a round estimate it places barcode scanning among the most frequent machine interactions on earth.[13,34]

The business model of the commons is deliberately unremarkable: companies pay their national member organization for a company prefix, the block of digits from which they may assign product numbers, with fees scaled to the size of the block and the member organization's own schedule, plus annual renewal. It is closer to a domain-name registration than to a royalty, and that is the point: the system's designers wanted numbering to be cheap enough that no maker of anything would choose to stay outside it. The barcode's universality is a pricing decision as much as a technical one. A royalty-bearing mark would have splintered into proprietary alternatives; a registration fee made joining the commons the path of least resistance.[22]

Around the commons sits the industry that manufactures its tools, and that industry is substantial. The market-research firm Grand View Research valued the global automatic identification and data capture market, barcode scanners and printers alongside RFID, biometrics and related systems, at $69.8 billion in 2024, and forecast growth to $136.9 billion by 2030, a projection this book treats as a forecast, not a fact.[25] The publicly traded specialists anchor the estimate with hard numbers: Zebra Technologies, the largest pure-play barcode printer and scanner maker, reported net sales of $4.98 billion for fiscal 2024 and $5.40 billion for fiscal 2025; Cognex, the machine-vision leader whose readers verify codes on factory lines, reported 2024 revenue of $914.5 million.[17,18,33] Behind the listed names stand thousands of unlisted ones: label converters, verifier makers, systems integrators, software houses, and the national GS1 organizations themselves.

What does the world get for this? The honest accounting is that the barcode's value is not in the industry that makes its tools but in the costs it abolishes everywhere else: the clerk-hours of hand-keyed prices, the stockouts and overstocks of blind inventory, the mis-shipped pallet, the mistranscribed medication order. McKinsey's 1970s projection of $1.4 billion in hard savings to one country's grocery trade reads today as a modest first installment.[2] The rest of the value is harder to price and easier to feel: the fact that a jar scanned in Lagos and a jar scanned in Lima resolve to the same product, because fifty years ago an industry chose one number for everyone, and an institution has kept the register ever since.

PART VII

Everywhere the Lines Went

The barcode escaped the grocery aisle within a decade and colonized every place where things must be counted, matched or found. Five environments show what the same stripes do when the stakes change: shops, trucks, hospitals, mailrooms and runways, and the factory floor.

CHAPTER 21

The Store Learns to Count

The checkout beep was the visible miracle of 1974; the invisible one arrived afterward, in the data. A scanned store does not merely sell faster: it knows. Every beep records an item, a price, a lane and a moment, and the sum of those records is a continuously updated census of the store's commercial life. Before scanning, a retailer learned what had sold by counting what was left; after scanning, the retailer knew what sold, when, at what price, beside what else, and could act on the knowledge daily. The store had learned to count itself.[2]

The first harvest was operational: automatic replenishment. When the point-of-sale system knows what left the shelf, it can draft its own orders, and the store's buyers shift from counting stock to managing exceptions. Wal-Mart built the canonical version through the 1980s: checkout scanning from 1983, handheld shelf-scanning terminals for associates from 1984, and by 1987 a private satellite network carrying every store's sales back to Bentonville, where the data drove ordering across the chain.[24] The discipline that grew from this, sharing point-of-sale data with suppliers so the manufacturer sees the shelf as clearly as the retailer, turned the barcode into a supply-chain instrument rather than a checkout convenience, and it is the direct ancestor of every vendor-managed inventory and collaborative forecasting program in modern trade.

The second harvest was analytical, and it created industries of its own. Scanner data, aggregated across stores, became the raw material of market research: where once manufacturers guessed market share from shipments and surveys, they could now buy week-by-week sales by item, by store, by promotion. Category management, the practice of designing a shelf as a portfolio of measured performers, is unthinkable without it. The consumer's side of the ledger, as the economist Emek Basker's research showed, was cheaper groceries, with the largest price declines in the perishable categories where information had been scarcest.[2] The sticker-price politics of the 1970s had imagined scanning as a way to take from shoppers; the data record shows it functioning, on average, as a way to give back, because a store that knows its costs can compete on them.

The checkout itself kept evolving around the same stripes. Scanners merged with scales; bioptic units read packages on several faces at once; self-checkout moved the beep from cashier to customer; handheld self-scanning, an idea Jerome Swartz patented decades before its time, let shoppers scan as they walk.[16,23] The newest store formats go further and remove the beep entirely, watching baskets with ceiling cameras. Yet even there, the barcode's conceptual legacy is intact: the store knows what left the shelf. The stripes taught retail to see; whatever sees next stands on that foundation.

CHAPTER 22

The Warehouse and the Truck

Inside the store the barcode counts items; outside it, the barcode counts journeys. The two problems differ in scale and in cruelty. A warehouse label must be read at arm's length by a worker in a hurry, a carton code must survive a truck ride and a pallet's rough life, and a shipment's identity must mean the same thing to the sender, the carrier and the receiver, who share nothing else. The industry's answer was to extend the grammar rather than replace it: denser codes for cartons, license-plate numbers for pallets, and application identifiers that let one string of digits say what something is, which batch it came from, and when it expires.[35]

The workhorse is GS1-128, the logistics dialect of Code 128. A GS1-128 label on a carton can carry the product's trade-item number plus, prefixed by application identifiers, its batch, weight, best-before date and quantity; a companion standard gives each pallet or container an SSCC, a unique eighteen-digit serial shipping container code that acts exactly like the UPC does at the checkout: the stripes say look me up, and the databases of sender and receiver agree on what the number means. ITF-14, built on Interleaved 2 of 5, serves the roughest job of all, printing directly onto corrugated board, where its coarse two-width bars survive the worst printing in the supply chain.[7,35]

The choreography these labels enable is worth seeing once, whole. A manufacturer prints a GS1-128 on every case as it is packed; the cases flow onto a pallet that receives its SSCC plate; the advance ship notice, an electronic message keyed to that SSCC, tells the distribution center what is coming; on arrival, one scan of the pallet plate pulls up the entire expected load, and receiving becomes verification instead of counting. Inside the building, every scan of every location label and case label keeps the inventory honest to the bin; at dispatch, scans build the load and generate the manifest; at the destination the same SSCC closes the loop. The great retail logistics inventions of the 1980s and 1990s, cross-docking, just-in-time replenishment, continuous flow distribution, are all bureaucracies of the scan: they assume that every unit announces itself, cheaply, at every handoff.[35]

E-commerce raised the tempo without changing the grammar. A fulfillment center is a warehouse whose customer orders are single items, so the barcode's unit of work shrank from the pallet to the piece, and the scan rate multiplied accordingly; totes, chutes, pick carts and robots all carry plates and labels in the same dialects. Couriers added their own layers, the tracking number scanned at every depot becoming the public face of the whole system: the parcel history a customer watches on a phone is, line by line, a diary written by barcode scanners. The industry that once begged grocers to try one store in Troy now writes several such diaries for every household on earth, every week.[7,10]

CHAPTER 23

The Hospital

Nowhere did the barcode change its meaning more completely than in medicine, where the object being identified is not a product but a patient, and a misread is not a pricing error but a harm. Hospitals adopted the supermarket's tool with the supermarket's motive, accuracy at the point of action, and produced some of the best-documented safety gains in the barcode's whole history.

The regulatory foundation came in two waves. In February 2004 the U.S. Food and Drug Administration issued its Bar Code Label Requirement for Human Drug Products and Biological Products: drug labels would have to carry the National Drug Code in a linear barcode, so that clinicians could verify, with a scan, that the right drug in the right dose was reaching the right patient by the right route at the right time; blood and blood components for transfusion came under machine-readable labeling rules with compliance required by April 2006.[27,28] A decade later the FDA extended the principle to hardware: its September 2013 Unique Device Identification rule requires most medical devices to carry a unique device identifier in plain text and in an automatic-identification form, with labelers submitting device data to a public FDA database, and GS1 among the accredited issuing agencies for the identifiers.[20,22]

The clinical evidence for the practice arrived in between, and it is unusually strong. In 2010 a team led by Eric Poon at Brigham and Women's Hospital in Boston reported in the New England Journal of Medicine a before-and-after study of bar-code-assisted medication administration, in which a nurse scans the patient's wristband and the medication before giving it, and the system verifies the match against the electronic record. Across 14,041 observed medication administrations, the units using the system saw a 41 percent relative reduction in non-timing medication errors and a 51 percent relative reduction in potential adverse drug events, while transcription errors were eliminated outright.[19,42] The finding applies to the combined barcode-assisted medication system studied, not to a printed label in isolation. A before-and-after study is not a guarantee that every implementation will reproduce its effect.

Around the bedside, the same logic colonized the hospital's supply side. Laboratory samples travel in barcoded tubes, to help link results to the intended patient; blood banks built on Codabar labels long before the FDA rule, layering machine-readable checks onto a product where a mismatch can kill; surgical instruments and implants carry Data Matrix marks under the UDI system, to support traceability and recalls. The GS1 standards body, which began in groceries, now counts healthcare among the sectors where its identifiers are formally embedded in regulation.[7,20,22] The barcode in the hospital is the same machine-readable humility as in the store: the object states what it is, and the system checks. Only the price of being wrong is different.

CHAPTER 24

The Post, the Plane, the Library, the Blood Bank

Beyond the store, the warehouse and the ward, the barcode settled into half a dozen other worlds, each adapting the stripes to its own physics and its own idea of what must never go wrong. Four of them show the range of the pattern.

The post. Mail sorting was barcoding's first grand national automation after the grocery. The U.S. Postal Service introduced the POSTNET barcode in 1982, translating five-digit ZIP codes into tall and short bars printed along an envelope's edge; ZIP+4 extended it to nine digits in 1983, and two more digits of delivery-point detail followed in 1990, letting machines sort letters down to the walk order of a carrier's route. In 2006 came the Intelligent Mail barcode, four bar heights instead of two, carrying nearly three times the data, routing and tracking in one symbol; from 2013 large mailers had to use it to qualify for automation postage rates.[31] The envelope became, in effect, a self-sorting object.

The plane. Airlines met the barcode at the baggage belt. Eastern Air Lines was first, in the early 1980s, sorting bags with circular bull's-eye codes whose key idea outlasted the geometry: a license plate number, a unique string per bag that the sorting system could look up. As baggage-security requirements tightened after 1988, IATA's baggage working group standardized the concept industry-wide: a ten-digit license plate, a leading digit for handling flags, the issuing airline's three-digit code, and a six-digit serial, printed in Interleaved 2 of 5 precisely because that code could still be produced by the mechanical numbering wheels of older tag printers.[32] Boarding passes took the same journey, from magnetic stripes to PDF417 and Aztec codes, the matrix symbols that fit a ticket's margin and a phone's screen.[7]

The library. Long before retail data mining had a name, libraries ran circulation on barcodes: a Codabar label in every book and on every borrower card turned lending into scanning, shelving audits into machine-readable records, and unrecorded loans into exceptions the system could flag. Codabar's 1971 birth at Monarch Marking Systems found here one of its most durable homes.[7]

The blood bank. And in the one inventory where a wrong item can be fatal, blood banking adopted machine-readable labels decades before regulators required them, using Codabar structures on every unit so that donation, testing, storage and transfusion could be checked against each other at every step; the FDA's 2004 rule then made machine-readable blood labeling mandatory nationwide.[7,27] The pattern repeats across all four worlds: an object that must be found, matched or trusted is given a number, the number is given stripes, and the stripe becomes the checkpoint. The item announces itself; the system verifies. Store, truck, ward, letter, bag, book, blood bag: one grammar, many dialects, everywhere the same beep.

CHAPTER 25

The Factory Floor

Manufacturing pushed the barcode beyond the identification of finished goods. The factory's problem is traceability: knowing not just what a thing is, but which one it is, what went into it, and what happened to it at every station. That is a deeper demand than retail's license plate, and meeting it dragged the industry from stripes to squares, from paper labels to marks etched into metal, and from scanning at the checkout to scanning at every step of making.

The roots, fittingly, are Japanese. Toyota's postwar kanban system ran production on physical cards that told each workstation what to make and what to fetch, and when Toyota's suppliers looked to automate the card, the result, as the QR chapter told, was DENSO's 1994 matrix code: enough characters for part, lot and process data, readable at line speed, tolerant of oil and damage, unlicensed so anyone could use it.[14,36] The QR code is thus best understood as the kanban card grown electronic, and its factory manners, finder patterns for instant orientation, error correction up to roughly thirty percent, explain its design.[36]

Western industry standardized the same instinct through its trade bodies. The automotive sector, which had given the laser scanner its first industrial job at General Motors in 1971, built common shipping-label and parts-marking standards through its industry associations, so that a brake line's label reads the same to every plant it passes through.[7] Defense procurement spread the practice through purchasing rules, as the LOGMARS chapter described: from 1982, tens of thousands of suppliers shipped Code 39 labels because the Pentagon's standard required them, and the practice diffused outward into civilian industry.[21] Electronics pushed the marking technology hardest: circuit boards and components too small or too valuable for stickers carry Data Matrix codes applied by laser etching, dot peen or inkjet directly onto the part, read by machine-vision systems like those of Cognex, a company whose entire business, $914.5 million of revenue in 2024, is teaching machines to see such marks and much else.[33,35]

The sum of these practices is the modern concept of traceability, which the barcode made ordinary long before regulators demanded it: the ability to ask any unit where it was born, what it absorbed, and where it went, and get an answer in seconds. A recall can use a batch identifier, a warranty system can use a serial number, and a counterfeit investigation can follow recorded movements. Barcodes can capture those identifiers; the linked records determine how much can be traced.[22,35]

PART VIII

The People and the Companies

The barcode is a commons, but commons need toolmakers. A handful of companies, most of them unglamorous and one of them born in a basement over a coin-counting machine, turned the reading and printing of stripes into an industry.

CHAPTER 26

The Builders

The barcode industry has no household names, and it has made its founders wealthy anyway. Its history reads as a genealogy of specialists, each owning one layer of the stack: symbols, scanners, printers, vision systems, labels. A few careers and companies carry most of the story.

David Collins built the industry's through-line: KarTrak at Sylvania, then Computer Identics in 1968, the first company founded purely on barcodes, which put laser scanning to work in car plants and gave the world Code 128.[5,7] **Jerome Swartz**, a physicist, co-founded Symbol Technologies and spent decades shrinking the scanner itself: Symbol shipped the first truly successful handheld laser scanner in 1982, patented the self-scanning concept decades before supermarkets adopted it, and under Ynjiun Wang's research leadership created PDF417, the stacked code of a thousand boarding passes.[7,23] **Dr. David Allais** at Intermec authored Interleaved 2 of 5 and Code 39, two enduring industrial symbologies.[7] **George Laurer** at IBM drew the UPC and EAN grammars; **Masahiro Hara** at DENSO drew the QR. The inventors' chapter of this industry is unusually well documented because it is unusually young: many lived to see their inventions used at industrial scale, and several received their honors late, Woodland among them, inducted with Silver into the National Inventors Hall of Fame.[3,10]

The scanner makers consolidated around the checkout. Spectra-Physics built the first slot scanners with NCR's registers; the business passed to PSC in 1996; NCR itself, Ohio-born, dominated the register side from the Troy installation onward.[8,16] **The printer makers** consolidated around the label: Sato of Japan shipped the first thermal transfer printer in 1980, and Zebra Technologies, founded on a thermal printing idea, grew into a major manufacturer, reporting $4.98 billion in net sales for fiscal 2024 and $5.40 billion for fiscal 2025, across printers, scanners, mobile computers and the software that ties them together.[7,17,18,41] **The vision makers** serve the factory: Cognex, reporting $914.5 million in 2024 revenue, sells the cameras and software that read etched codes on production lines and verify print quality at speed.[33] Datalogic in Italy, Honeywell's scanning businesses in the United States, and a long tail of label converters, verifier makers and integrators fill out the map; many of the pioneering independents were eventually absorbed into these larger houses, a normal consolidation story for a maturing tool trade.[25]

One company deserves mention for staying at the layer underneath them all: GS1's member organizations, funded by their two million company members, keep the register that gives every scanner and printer in this chapter something meaningful to read and print.[11,22] The toolmakers sell the beep; the commons sells the meaning. The industry works because neither could exist without the other.

CHAPTER 27

The Economics of a Beep

What does a scan cost, and what does it buy? The question has a fifty-year answer, and the shape of that answer explains why the barcode conquered the world slowly and then all at once.

In 1974 a scan was expensive. The hardware ran to roughly $10,000 per checkout lane, before the store computer, the software and the staff time, and the savings were promises in consultants' binders: McKinsey had projected $1.4 billion in hard savings for the American grocery industry, but only past adoption thresholds nobody had yet crossed.[2,16] The economics improved on three curves at once. Hardware fell with the semiconductor curve: the integrated circuit that IBM's Bob Evans had pulled from his pocket in 1973 to promise decoding power at every lane did what such chips do, and by the early 1980s scanners were smaller, sturdier and far cheaper, with reading good enough to bank real labor savings.[2,16] Software rose to meet it, turning raw scans into replenishment and pricing systems. And the network effect did the rest: every newly marked product raised the value of every installed scanner, and every new scanner raised the value of marking, until the chicken-and-egg trap ran in reverse as a virtuous circle.[2]

Today's unit economics invert 1974's. A printed barcode costs effectively nothing, a fraction of a cent of ink inside artwork already being printed; the number behind it costs a registration fee spread over a company's catalog; a camera-equipped phone can read common codes without a separate dedicated scanner. Dedicated industrial readers still have costs justified by speed, durability and integration. Against costs that have fallen to noise, the benefits compound at scale: the labor of manual entry abolished, inventory records that stay honest, recall precision, and the demand signal that lets supply chains run lean. GS1's headline count, over ten billion scans a day across a billion-plus products and two million companies, is what a technology looks like when its unit cost has fallen below every threshold of hesitation.[10,11]

The toolmaking side of those economics is a real, measurable industry: roughly $69.8 billion of 2024 global revenue by Grand View Research's estimate for automatic identification and data capture as a whole, with Zebra alone at nearly five billion and machine-vision specialists like Cognex near one.[17,18,25,33] But the stranger and larger truth is the barcode's ratio of infrastructure to value: a commons maintained by modest fees and a tool trade worth tens of billions underwrites the inventory accuracy of essentially the entire world trading system. Economists struggle to measure the productivity of such general-purpose systems precisely, and this book will not invent a number. It is enough to note that when scanning stops, at a store whose system has failed, in a warehouse whose labels have degraded, commerce can fall back to slower manual work, and automated flows may stop until the missing information is recovered. The beep is cheap because everything without it is dear.

PART IX

Bottlenecks

The barcode's limits are the price of its virtues: a mark that costs nothing can be ruined by almost anything, and a code built to say one short sentence cannot tell a long story. The industry lives inside these constraints and engineers around them daily.

CHAPTER 28

Bad Bars

The barcode's most persistent enemy is not a rival technology but a bad print job. A symbol is a precision instrument drawn with the crudest of tools, flexographic presses on corrugated board, inkjets on curved cans, thermal ribbons on scuffed labels, and every failure of the press becomes a failure at the scanner, hundreds of miles and several companies away. The industry's whole quality discipline exists to manage this one problem: bars must be the right widths, in the right contrast, with clean edges, flanked by their quiet zones, or the beep does not happen.[35,38]

The failure modes have names and causes. Ink spread widens bars and narrows spaces until the decoder's arithmetic no longer resolves them; voids and spots do the reverse. Low contrast, black bars on colored board, pale ribbons, washes the signal toward the noise. A truncated symbol, printed short to save space, deprives the scanner's beam of dwell time. And the quiet zone violation, a logo, a border or a price creeping into the mandatory blank margin, remains among the commonest reasons a perfectly good symbol refuses to scan. Each fault is small; multiplied across a supply chain, each becomes chargebacks, manual keying, mis-sorted freight and queues.[35,38]

The countermeasure is measurement, and it is institutionalized. International standards define how to grade a printed symbol, sampling it along scan lines and scoring contrast, edge determination, modulation and dimensional accuracy into a letter grade; the verification instruments described earlier apply those standards at the press, and major retailers enforce quality by contract, fining suppliers whose codes fail at their docks. The GS1 General Specifications prescribe the printing rules, symbol sizes, magnifications, placements, that keep the whole system interoperable.[35,38] This is the barcode's quiet maturity: a technology whose failures are so well catalogued that they can be insured against by specification.

KarTrak's ghost haunts this chapter, properly. The railroad system died of dirty labels and unowned maintenance, an 80 percent read rate that meant the cars most in need of tracking were the ones the system missed.[6] Modern commerce learned the lesson institutionally: label quality is someone's measured job, print is verified at source, and the read rate, not the reader, is the system's real product. When a checkout beeps ten billion times a day, it is because an invisible discipline of widths and margins held, everywhere at once.[10]

A successful scan is not a quality certificate

Try a label with one reader and it may beep. That proves only that this reader, at that distance and under that light, recovered this message. Verification asks whether the printed symbol has enough margin to work across the equipment and conditions it will encounter. GS1's two-dimensional verification guideline makes the distinction concrete: record the sample and its associated data, verify the symbol, perform additional tests, issue a report and retain the result. This is a production-control workflow, not a cashier's acceptance test.[38]

For a matrix symbol the measured parameters include contrast, modulation, damage to the fixed locating patterns, axial and grid non-uniformity, decoding and unused error correction. The overall grade is constrained by the weakest parameter. A symbol with strong contrast but a damaged finder pattern cannot borrow credit from its good ink. Nor is a bare grade enough: the report needs the measuring aperture and illumination, because the measurement is inseparable from the conditions under which it was made.[38]

The dimensions are application-specific. In the guideline, GS1 DataMatrix requires a quiet zone at least one module wide on each side; GS1 QR Code requires four. Those values should not be transplanted indiscriminately to another symbology. The practical lesson is to use the specification for the chosen symbol and its intended job, then test the actual printed package, not merely the clean digital artwork. Printing, label placement and the scanner's optical environment all intervene between the design file and the beep.[38]

CHAPTER 29

The Limits of the Line

For all its triumphs, the linear barcode was designed in 1973 to say one short sentence, and its limits all follow from that sentence. GS1's own case for moving beyond it begins with the same fact DENSO confronted in 1991: the compact retail stripes carry an identifier rather than a full product record. Some industrial linear codes can carry more, including attributes, but their physical length grows with the message.[13,14] In an age that wants expiry dates, batch numbers, origins and recall data at the scan, the stripes are a key in search of more locks than they can open.

The physical limits are just as plain. A barcode must be seen to be read: line of sight, correct orientation, undamaged print. That is why a conveyor scanner needs the label facing it, why a torn pallet plate stalls a dock, and why radio-frequency identification, which reads through cardboard at a distance, keeps being proposed as the successor, a story the next chapter takes up. The stripes also carry no intelligence: the mark cannot say when it was printed, cannot change, cannot respond. Everything dynamic must live in the database, so the usefulness of a decoded number depends on the records available to the application. Optical decoding itself requires no internet connection: a disconnected reader can still return the encoded digits. Losing a remote database can prevent a lookup, while a system holding the needed records locally can still use the number. The mark, the lookup and the network are different layers, not one mechanism.[35]

The social limits surfaced first and have never entirely left. The 1970s fights over item pricing and purchase tracking were early skirmishes in a long argument about what scan data knows about people; loyalty programs and digital receipts have since made the linkage between items and individuals routine, and the privacy questions have migrated from the checkout to the cloud, where this book leaves them with a note that they began, like so much else, at the beep.[2] Security cuts the other way: a barcode is trivially copyable, a photocopy scans as well as the original, so the stripes can authenticate nothing by themselves, a limit that matters in ticketing and pharmaceuticals. A serial number allows a system to distinguish individual instances, but a copied serial number remains copyable. A square symbol alone adds neither a digital signature nor a trusted chain of custody; authentication needs controls outside the printed pattern.

Even the numbering has limits, though they are managed rather than felt. Prefixes are finite; company prefixes that are abandoned must be handled with care so that yesterday's manufacturer number does not collide with tomorrow's product. GS1's register exists largely to prevent such collisions, and its governance of reuse and capacity is the unglamorous work that keeps a fifty-year-old numbering plan from running out of road.[22] Limits, though, are not failures. Every constraint in this chapter is the shadow of a design choice that made the barcode cheap, open and universal, and the industry's answer has never been to abandon the line but to build beside it: first stacked codes, then matrices, and now, deliberately and on a schedule, the transition the final part of this book describes.

PART X

What Comes Next

The stripes are not being killed; they are being promoted. The next barcode is expected to do everything the old one did, and then carry the product's whole story in the same mark. The transition has a name and a date.

CHAPTER 30

Sunrise 2027

Standards bodies almost never set dates, so when GS1 set one, the industry listened. The program is called Sunrise 2027: an ambition, in GS1's words, that by the end of 2027, retail point-of-sale systems around the world should be able to read and process two-dimensional barcodes, QR codes and GS1 DataMatrix, alongside the traditional stripes, and extract from them the same trade-item number the UPC has carried since 1974, plus whatever else the brand chooses to pack in.[12,22] The traditional barcode is not being withdrawn; the checkout is being taught a second language.

The case for the move is the limit case from the previous chapter, stated positively. A 2D code can hold batch and serial numbers, dates and origins in the symbol itself; linked through the GS1 Digital Link standard, the same square can open the web, connecting a scan to ingredients, allergens, sustainability data, instructions and recalls, one mark serving the checkout lane, the regulator, the supply chain and the consumer's phone at once.[12,22] GS1 reports endorsements for the transition from more than twenty-five global companies, among them Alibaba, Carrefour, L'Oréal and Procter & Gamble, and the scanning-equipment industry has publicly lined up behind the migration, as it must: the 2027 date is above all a deadline for scanners, not for symbols.[13,34]

GS1 US's own guidance to industry is deliberately unheroic, a crawl-walk-run path. Crawl: brands add a 2D code beside the stripes, built on the Digital Link standard and carrying the same product number, while retailers install imagers capable of reading it. Walk: the 2D codes begin carrying the operational extras, dates and variants, and appear on retailers' own private-label goods. Run: the symbol becomes a consumer channel in its own right.[12] The sequencing is the barcode's oldest lesson reapplied: the chicken-and-egg trap of 1974 is escaped by making every step worth taking on its own, so that no one has to move first on faith alone.

What will the shelf of 2030 look like if the program holds? The UPC will still be there, because billions of packages and fifty years of habit do not reprint on a deadline, and GS1 has promised dual-marking coexistence rather than replacement. A square is a plausible choice for many products needing more data, but its adoption will depend on the application and on the readers and systems in use. The student of this book will recognize the pattern: the stripes solved identification; the squares are solving information. The first took twenty-five years from patent to beep. The second is being attempted in about five, on the strength of everything the first one taught.[12,13]

The upgrade beneath the square

GS1's implementation guideline makes the 2027 ambition more precise than the slogan. The minimum goal is to read and process the GTIN from both linear and two-dimensional barcodes at retail point of sale. That requires software changes and may require new equipment; even possession of an imaging scanner does not by itself establish readiness. Recognising the square, extracting its identifier, and making use of an expiry date are

separate capabilities.[39]

The data can also arrive in different grammars. GS1 DataMatrix uses GS1 element strings, while QR Code and Data Matrix can use GS1 Digital Link URI syntax. A scanner or its software must hand the till data in a form the till understands, not simply return an unfamiliar web address. GS1 describes translation from Digital Link URI syntax into element-string syntax as one way to avoid changing an older host system. The front-end reader and the back-end application must be tested as a pair.[39]

Dual marking introduces another operational problem: two symbols must not become two sales. Placement, scanner handling of multiple codes, and consistent identifiers across both marks are part of the migration, not afterthoughts. GS1's guidance calls for linear codes to coexist during the transition and treats the change as voluntary. This is less a contest between stripes and squares than a coordinated upgrade to artwork, printers, readers, data rules and checkout software. A factory can print the new mark long before a retailer can safely use everything it says.[39]

CHAPTER 31

Beyond the Beep

Every decade since 1974 has produced a technology predicted to replace the barcode, and the predictions are worth reviewing because their failures map the barcode's real moats: cost, openness and habit.

The most serious challenger is radio-frequency identification. An RFID tag answers a radio query from meters away, needs no line of sight, can be read in bulk inside a sealed carton, and can carry a serial number unique not just to a product but to one individual item. In 2003 the challenge looked decisive: Wal-Mart, whose barcode mandates had settled the question in the 1980s, announced that its top one hundred suppliers would ship pallets and cases carrying Electronic Product Code RFID tags from January 2005, and trade coverage projected nearly a billion tags flowing into the system.[29,30] Two decades later the honest scorecard is split. RFID won specific territories, apparel inventory above all, where item-level radio reads transformed stock accuracy, plus toll tags, access cards, library systems and baggage pilots. It did not take the checkout or the carton. The reasons are the barcode's virtues inverted: a tag costs real money where ink costs nothing, radio physics argues with liquids and metals, and a printed stripe never detunes. For the cheapest job in commerce, naming a thing at a counter, nothing has ever underbid the barcode.[29]

The newest challenger does not ask objects to carry anything at all. Camera-based checkout, watching what shoppers take with ceiling sensors and machine vision, removes the beep entirely, and where it works it feels like the future arriving. But notice what it keeps: the product master data, the per-item inventory discipline, the scan-logic of a store that knows its shelf, all descend directly from the barcode era, and the systems still lean on barcodes for receiving, shelf labels and the long tail of exceptions. Computer vision is best read not as the barcode's replacement but as its most ambitious descendant, automating the act of looking that the scanner first taught the store to value.[24]

What comes next, then, is least dramatically the likeliest: the barcode's own evolution. The 2D transition of Sunrise 2027 folds the web into the mark; digital watermarking research presses data into package artwork itself; regulators from Brussels outward are building product-passport regimes that will demand machine-readable identity at exactly the barcode's layer of the stack.[12,22] The student of industrial history learns to bet on the incumbent that keeps absorbing its challengers. The barcode has absorbed the laser, the camera, the database, the internet and the smartphone. It was drawn in sand by a man stretching Morse code into lines, and the lines turned out to be one of the most extensible ideas ever printed. Whatever marks the packages of 2074, the odds are good that somewhere in the lineage sits a quiet zone, a guard bar, and a check digit that still adds up.[1,9]

EPILOGUE

The Humble Stripes

This library studies items by following them from invention through science, industry and dependence, and the barcode submits to the method with unusual grace, because it is unusual in one respect: it is an invention almost nobody wanted, at first, and almost everybody now uses, constantly, without thought.

Its invention was curiosity in the purest form this series records: not a struggle narrative but a wandering one, a student who overheard a question, a walk on a beach, fingers dragged idly through sand.[1] Its science came from elsewhere and arrived exactly when needed, a light brighter than the sun built by men who did not foresee the supermarket.[1] Its industry was conjured by cooperation, competitors at a hotel by an airport agreeing that everyone would gain more from one shared mark than from seven private ones.[2] Its growth ran on the humblest of engines, a registration fee and a printed stripe, until it became, by scan count, among the most used artifacts on earth.[10,11] And its future is being negotiated in the open, on a published schedule, by the same kind of committee that gave it life.[12]

Human dependence on the barcode is now of the infrastructural kind: total, quiet and revealed only by interruption. Food arrives because cases announce themselves; medicine is safer because doses check themselves; a parcel's journey is a public diary because depots read its plate. The material thinker's exercise from the prologue, asking of any object who made it and through what pipelines, has, in the barcode's case, a recursive answer: the barcode is the tool the asking is done with. It is how the pipeline knows itself.

Woodland lived to ninety-one, and late in life he watched the little drawing from the beach get celebrated on its fiftieth anniversary as one of the machines that made the modern economy.[1,10,22] There is a fitting completeness in that. Morse code gave the world its first long-distance dots and dashes; stretched into lines, the same idea gave the world's objects a voice; and the voice, once heard, could not be un-heard. The queue at the checkout still moves to the rhythm set in Troy, Ohio, at 8:01 on a June morning in 1974: beep, beep, beep, ten billion times a day and counting.[9,10]

APPENDIX A

A Chronology of the Barcode

1934	Kermode, Young and Sparks patent a light-read bar-pattern card sorting concept in Youngstown, Ohio.[7]
1948	A grocery chain president asks Drexel's dean for an automatic checkout; Bernard Silver overhears; Joseph Woodland takes up the problem.[1,3]
1949	January: Woodland draws lines, then a bull's-eye, in Miami Beach sand. October 20: Woodland and Silver file their patent.[1,4]
1952	October 7: U.S. Patent 2,612,994 granted.[4]
1959-61	David Collins proposes railcar tracking at Sylvania; KarTrak tested on the Boston & Maine from 1961.[5,6]
1960	Theodore Maiman demonstrates the laser.[1]
1962	Woodland and Silver sell the patent to Philco for $15,000; Philco later sells to RCA. Silver dies in 1963.[3,26]
1967	KarTrak becomes the mandatory North American railcar standard; abandoned around 1977.[6]
1968	Collins founds Computer Identics, the first barcode-only company.[5,7]
1970	August: the grocery industry's Ad Hoc Committee first meets at O'Hare; McKinsey facilitates.[2]
1971	Codabar (Monarch); General Motors installs the first industrial laser scanner; AIM founded; first handheld wands.[7]
1972	Interleaved 2 of 5 (Allais, Intermec); July 3: RCA's bull's-eye goes live at Kroger Kenwood Plaza, Cincinnati.[1,7]
1973	March 30: Symbol Committee chooses IBM's linear code; April: the UPC is announced.[1,15]
1974	June 26, 8:01 a.m.: first UPC scan, Wrigley's gum, Marsh Supermarket, Troy, Ohio. Code 39 (Allais and Stevens). UCC appointed administrator.[7,9,22]
1976	Business Week eulogizes “The Supermarket Scanner That Failed”; six states pass item-pricing laws; December: thirteen-digit EAN symbol approved.[2,15,23]
1977	Twelve countries found the EAN association in Brussels.[22]
1980	Sato ships the first thermal transfer barcode printer.[7]
1981	Code 128 (Computer Identics); DoD adopts Code 39 as LOGMARS; first CCD scanner.[7,21]

1982	Symbol ships the first successful handheld laser scanner; POSTNET barcodes begin sorting U.S. mail; some 50,000 defense suppliers must label in Code 39.[7,21,31]
1983-87	Wal-Mart scans at POS (1983), scans shelves with handhelds (1984), completes its private satellite network (1987); by about 1986, 70% of U.S. supermarkets scan.[16,24]
1991-95	PDF417 (Wang, Symbol); MaxiCode (UPS, 1992); Aztec Code (Longacre and Hussey, 1995).[7]
1994	DENSO's Masahiro Hara team creates the QR code; DENSO WAVE publishes the spec and waives patent rights.[14,36]
2000	QR code becomes ISO/IEC 18004.[36]
2004-06	FDA bar code rule for drugs and blood (2004; compliance by 2006).[27,28]
2005	UCC and EAN merge to form GS1; UPC-EAN mutual compatibility formalized.[22,23]
2010	Poon et al. (NEJM) show bar-code medication administration cuts non-timing errors 41%.[19]
2013	FDA Unique Device Identification final rule.[20]
2017	The BBC names the GS1 barcode one of the 50 things that made the modern economy.[22]
2024	Fiftieth “Scanniversary”: over 1 billion products, 10 billion+ scans a day, 116 GS1 member organizations.[10,22]
2027	Sunrise 2027: GS1's target for 2D-capable checkouts worldwide (ambition, not deadline for stripes).[12,22]

APPENDIX B

The Symbology Shelf

The principal barcode languages of commerce, industry and transport, side by side. Dates are of invention or first publication; uses are characteristic, not exclusive.[7,21,31,35,36]

Symbology	Year	Type	Character set	Characteristic uses
UPC-A / UPC-E	1973	Linear, continuous	12 / 8 digits	Retail point of sale (Americas)
EAN-13 / EAN-8	1976	Linear, continuous	13 / 8 digits	Retail point of sale (worldwide)
Codabar	1971	Linear, discrete	Digits + symbols	Libraries, blood banks, airbills
Interleaved 2 of 5	1972	Linear, continuous	Digits (paired)	Cartons (ITF-14), airline baggage plates
Code 39	1974	Linear, discrete	43 characters, alphanumeric	Industry, defense (LOGMARS), automotive
Code 128	1981	Linear, continuous	Full 128 ASCII	Shipping labels, GS1-128 logistics
POSTNET / IMb	1982 / 2006	Height-modulated	Routing + tracking data	Mail sorting and tracking
GS1 DataBar	2000s	Linear, stacked	GTIN + attributes	Fresh foods, small items, coupons
PDF417	1991	Stacked 2D	~1 KB data	Boarding passes, ID cards, manifests
MaxiCode	1992	Matrix 2D	Fixed-size	Parcel sortation at conveyor speed
Data Matrix	1990s	Matrix 2D	Up to 2,335 bytes	Electronics, instruments, GS1 healthcare
Aztec Code	1995	Matrix 2D	Up to 3,067 bytes	Transport tickets, mobile boarding passes
QR Code	1994	Matrix 2D	Up to 7,089 digits; kanji	Factories, then everything: payments, links, tickets

APPENDIX C

Glossary

Application identifier (AI). A numeric prefix in GS1 data strings that says what the following digits mean: batch, date, weight, serial.

Check digit. A computed final digit that lets a scanner verify the others; the UPC's modulo-ten scheme catches most single misreads.

Continuous / discrete. Whether a symbology packs characters edge to edge or pads each with a gap; continuous codes are denser, discrete ones more forgiving.

GTIN. Global Trade Item Number, the GS1 key carried by retail barcodes.

Guard bars. The fixed patterns at a symbol's start, center and end that give the decoder its reference rhythm.

Linear / 1D. Codes read along a single line, in relative widths of bars and spaces.

Module. The narrowest element of a symbol; all other widths are multiples of it.

Quiet zone. The mandatory blank margin flanking a symbol; printing inside it is a leading cause of scan failure.

SSCC. Serial Shipping Container Code, the GS1 license plate for pallets and shipping units.

Symbology. A barcode language: the rules mapping characters to bar-and-space or cell patterns.

Verifier. A measuring instrument that grades printed symbols against international quality standards.

A Note on Sources

Superscript numbers throughout this book point to the Source Companion that accompanies it, which lists every source consulted, what was actually read in each case, and the specific claims each reading supports. Figures drawn from forecasts are labelled as forecasts where they appear. Historical details that survive only in a single telling are attributed to that telling in the text. The author and publisher thank the archivists of the ID History community, whose oral histories with the UPC's founders underpin much of the best secondary literature on this subject.