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SMALLER

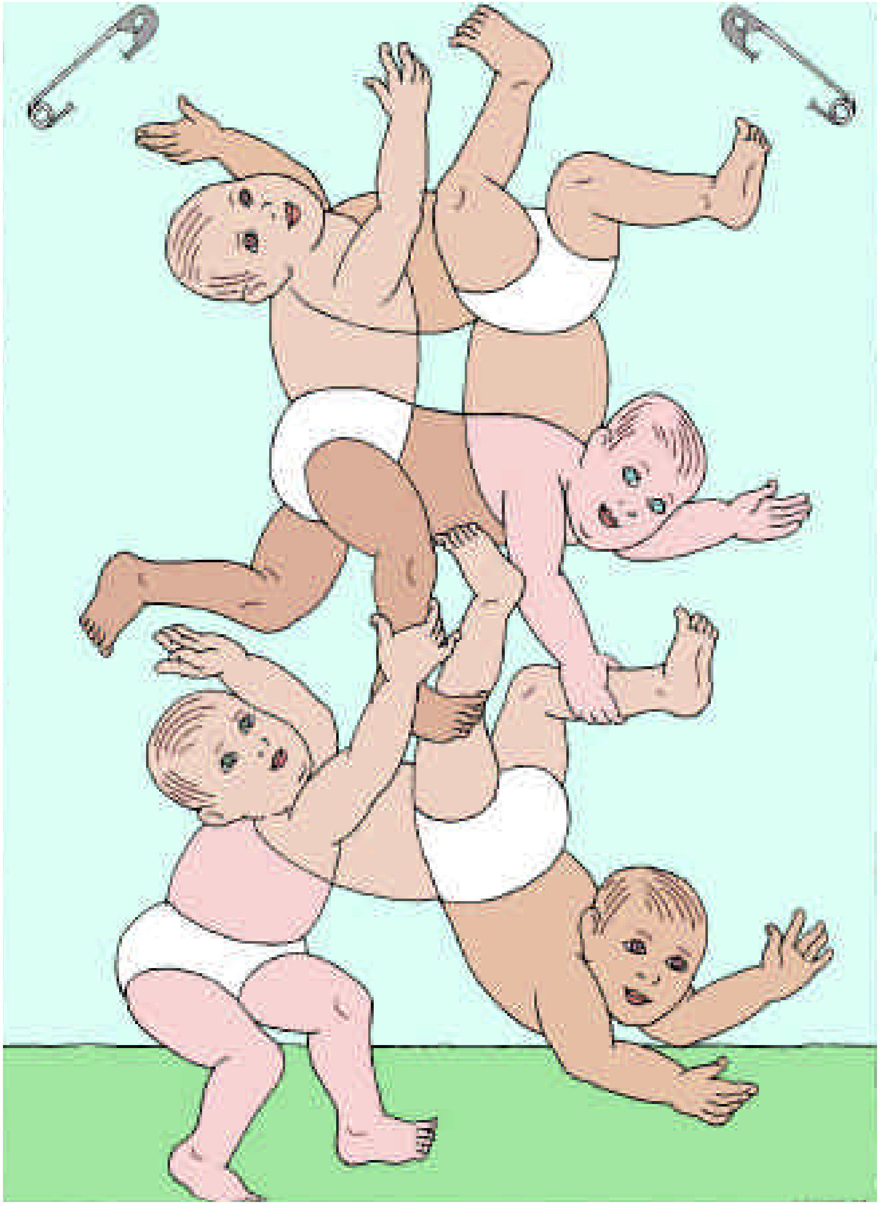
The disposable diaper and the meaning of progress.

BY MALCOLM GLADWELL

The best way to explore the mystery of the Huggies Ultratrim disposable diaper is to unfold it and then cut it in half, widthwise, across what is known as the diaper's chassis. At Kimberly-Clark's Lakeview plant, in Neenah, Wisconsin, where virtually all the Huggies in the Midwest are made, there is a quality-control specialist who does this all day long, culling diapers from the production line, pinning them up against a lightboard, and carefully dismembering them with a pair of scissors. There is someone else who does a "visual cull," randomly picking out Huggies and turning them over to check for flaws. But a surface examination tells you little. A diaper is not like a computer that makes satisfying burbling noises from time to time, hinting at great inner complexity. It feels like papery underwear wrapped around a thin roll of Cottonelle. But peel away the soft fabric on the top side of the diaper, the liner, which receives what those in the trade delicately refer to as the "insult." You'll find a layer of what's called polyfilm, which is thinner than a strip of Scotch tape. This layer is one of the reasons the garment stays dry: it has pores that are large enough to let air flow in, so the diaper can breathe, but small enough to keep water from flowing out, so the diaper doesn't leak.

Or run your hands along that liner. It feels like cloth. In fact, the people at Kimberly-Clark make the liner out of a special form of plastic, a polyresin. But they don't melt the plastic into a sheet, as one would for a plastic bag. They spin the resin into individual fibres, and then use the fibres to create a kind of microscopic funnel, channelling the insult toward the long, thick rectangular pad that runs down the center of the chassis, known as the absorbent core. A typical insult arrives at a rate of seven millilitres a second, and might total seventy millilitres of fluid. The liner can clear that insult in less than twenty seconds. The core can hold three or more of those insults, with a chance of leakage in the single digits. The baby's skin will remain almost perfectly dry, and that is critical, because prolonged contact between the baby and the insult (in particular, ammonium hydroxide, a breakdown product of urine) is what causes diaper rash. And all this will be accomplished by a throwaway garment measuring, in the newborn size, just seven by thirteen inches. This is the mystery of the modern disposable diaper: how does something so small do so much?

Thirty-seven years ago, the Silicon Valley pioneer Gordon Moore made a famous prediction. The number of transistors that engineers could fit onto a microchip, he said, would double every two years. It seemed like a foolhardy claim: it was not clear that you could keep making transistors smaller and smaller indefinitely. It also wasn't clear that it would make sense to do so. Most of the time when we make things smaller, after all, we pay a price. A smaller car is cheaper and more fuel-efficient, and easier to park and maneuver, but it will never be as safe as a larger car. In the nineteen-fifties and sixties, the transistor radio was all the rage; it could fit inside your pocket and run on a handful of batteries. But, because it was so small, the sound was terrible, and virtually all the other mini-electronics turn out to be similarly imperfect. Tiny cell phones are hard to dial. Tiny televisions are hard to watch. In making an object smaller, we typically compromise its performance. The remarkable thing about chips, though, was that there was no drawback: if you could fit more and more transistors onto a microchip, then instead of using ten or twenty or a hundred microchips for a task you could use just one. This meant, in turn, that you could fit microchips in all kinds of places (such



Diapers are like microchips in that they got better as they got smaller.

SEYMOUR CHWAST

as cellular phones and laptops) that you couldn't before, and, because you were using one chip and not a hundred, computer power could be had at a fraction of the price, and because chips were now everywhere and in such demand they became even cheaper to make—and so on and so on. Moore's Law, as it came to be called, describes that rare case in which there is no trade-off between size and performance. Microchips are what might be termed a perfect innovation.

In the past twenty years, diapers have got smaller and smaller, too. In the early eighties, they were three times bulkier than they are now, thicker and substantially wider in the crotch. But in the mid-eighties Huggies and Procter & Gamble's Pampers were reduced in bulk by fifty per cent; in the mid-nineties they shrank by a third or so; and in the next few years they may shrink still more. It seems reasonable that there should have been a downside to this, just as there was to the shrinking of cars and radios: how could you reduce the amount of padding in a diaper and not, in some way, compromise its ability to handle an insult? Yet, as diapers got smaller, they got better, and that fact elevates the diaper above nearly all the thousands of other products on the supermarket shelf.

Kimberly-Clark's Lakeview plant is a huge facility, just down the freeway from Green Bay. Inside, it is as immaculate as a hospital operating room. The walls and floors have been scrubbed white. The stainless-steel machinery gleams. The employees are dressed in dark-blue pants, starched light-blue button-down shirts, and tissue-paper caps. There are rows of machines in the plant, each costing more than fifteen million dollars—a dizzying combination of conveyor belts and whirling gears and chutes stretching as long as a city block and creating such a din that everyone on the factory floor wears headsets and communicates by radio. Computers monitor a million data points along the way, insuring that each of those components is precisely cut and attached according to principles and processes and materials protected, on the Huggies Ultratrim alone, by hundreds of patents. At the end of the line, the Huggies come gliding out of the machine, stacked upright, one after another in an endless row, looking like exquisitely formed slices of white bread in a toast rack. For years, because of Moore's Law, we have considered the microchip the embodiment of the technological age. But if the diaper is also a perfect innovation, doesn't it deserve a place beside the chip?

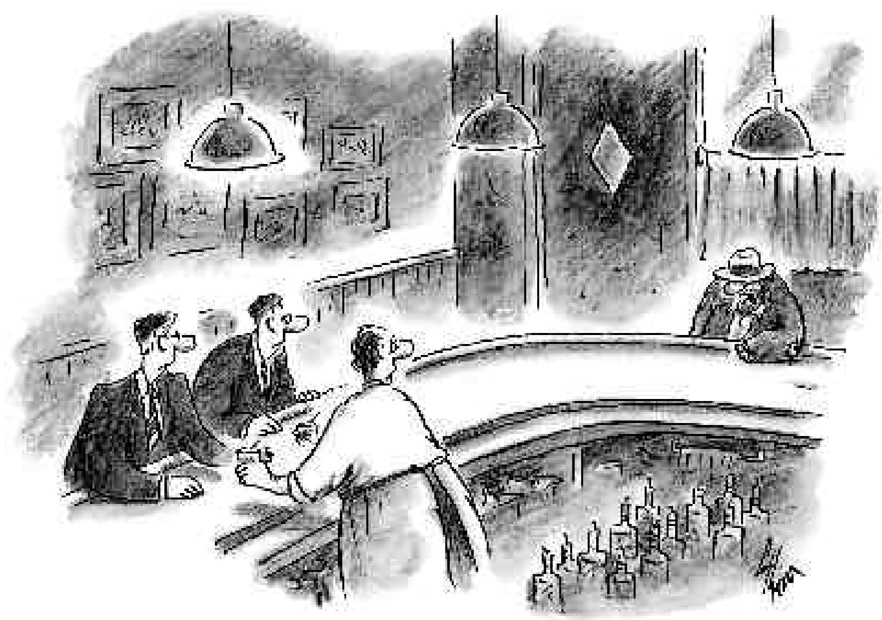
The modern disposable diaper was invented twice, first by Victor Mills and then by Carlyle Harmon and Billy Gene Harper. Mills worked for Procter & Gamble, and he was a legend. Ivory soap used to be made in an expensive and time-consuming batch-by-batch method. Mills figured out a simpler, continuous process. Duncan Hines cake mixes used to have a problem blending flour, sugar, and shortening in a consistent mixture. Mills introduced the machines used for milling soap, which ground the ingredients much more finely than before, and the result was New, Improved Duncan Hines cake mix. Ever wonder why Pringles, unlike other potato chips, are all exactly the same shape? Because they are made like soap: the potato is ground into a slurry, then pressed, baked, and wrapped—and that was Victor Mills's idea, too.

In 1957, Procter & Gamble bought the Charmin Paper Company, of Green Bay, Wisconsin, and Mills was told to think of new products for the paper business. Since he was a grandfather—and had always hated washing diapers—he thought of a disposable diaper. "One of the early researchers told me that among the first things they did was go out to a toy store and buy one of those Betsy Wetsy-type dolls, where you put water in the mouth and it comes out the other end," Ed Rider, the head of the archives department at Procter & Gamble, says. "They brought it back to the lab, hooked up its legs on a treadmill to make it walk, and tested diapers on it." The end result was Pampers, which were launched in Peoria, in 1961. The diaper had a simple rectangular shape. Its liner, which lay against the baby's skin, was made of rayon. The outside material was plastic. In between were multiple layers of crêped tissue. The diaper was attached with pins and featured what was known as a Z fold, meaning that the edges of the inner side were pleated, to provide a better fit around the legs.

In 1968, Kimberly-Clark brought out Kimbies, which took the rectangular diaper and shaped it to more closely fit a baby's body. In 1976, Procter & Gamble brought out Luvs, which elasticized the leg openings to prevent leakage. But diapers still adhered to the basic Millsian notion of an absorbent core made out of paper—and that was a problem. When paper gets wet, the fluid soaks right through, which makes diaper rash worse. And if you put any kind of pressure on paper—if you squeeze it, or sit on it—it will surrender some of the water it has absorbed, which creates further difficulties, because a baby, in the usual course of squirming and crawling and walking, might place as much as five kilopascals of pressure on the absorbent core of a diaper. Diaper-makers tried to address this shortcoming by moving from crêped tissue to what they called fluff, which was basically finely shredded cellulose. Then they began to compensate for paper's failing by adding more and more of it, until diapers became huge. But they now had Moore's Law in reverse: in order to get better, they had to get bigger—and bigger still wasn't very good.

Carlyle Harmon worked for Johnson & Johnson and Billy Gene Harper worked for Dow Chemical, and they had a solution. In 1966, each filed separate but virtually identical patent applications, proposing that the best way to solve the diaper puzzle was with a peculiar polymer that came in the form of little pepperlike flakes and had the remarkable ability to absorb up to three hundred times its weight in water.

In the Dow patent, Harper and his team described how they sprinkled two grams of the superabsorbent polymer between two twenty-inch-square sheets of nylon broadcloth, and then quilted the nylon layers together. The makeshift diaper was "thereafter put into use in personal management of a baby of approximately 6 months age." After four hours, the diaper was removed. It now weighed a hundred and twenty



"Excuse me, but it's important to get those drinks to those who need them the most."

grams, meaning the flakes had soaked up sixty times their weight in urine.

Harper and Harmon argued that it was quite unnecessary to solve the paper problem by stuffing the core of the diaper with thicker and thicker rolls of shredded pulp. Just a handful of superabsorbent polymer would do the job. Thus was the modern diaper born. Since the mid-eighties, Kimberly-Clark and Procter & Gamble have made diapers the Harper and Harmon way, pulling out paper and replacing it with superabsorbent polymer. The old, paper-filled diaper could hold, at most, two hundred and seventy-five millilitres of fluid, or a little more than a cup. Today, a diaper full of superabsorbent polymer can handle as much as five hundred millilitres, almost twice that. The chief characteristic of the Mills diaper was its simplicity: the insult fell directly into the core. But the presence of the polymer has made the diaper far more complex. It takes longer for the polymer than it does paper to fully absorb an insult, for instance. So another component was added, the acquisition layer, between the liner and the core. The acquisition layer acts like blotting paper, holding the insult while the core slowly does its work, and distributing the fluid over its full length.

Diaper researchers sometimes perform what is called a re-wet test, where they pour a hundred millilitres of fluid onto the surface of a diaper and then apply a piece of filter paper to the diaper liner with five kilopascals of pressure—the average load a baby would apply to a diaper during ordinary use. In a contemporary superabsorbent diaper, like a Huggies or a Pampers, the filter paper will come away untouched after one insult. After two insults, there might be 0.1 millilitres of fluid on the paper. After three insults, the diaper will surrender, at most, only two millilitres of moisture—which is to say that, with the aid of superabsorbents, a pair of Huggies or Pampers can effortlessly hold, even under pressure, a baby's entire night's work.

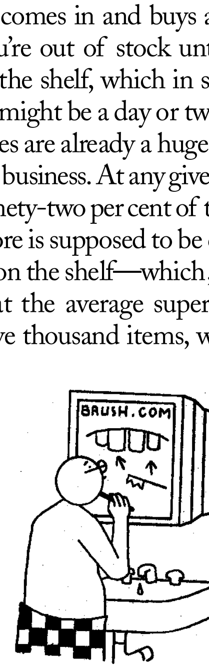
The heir to the legacy of Billy Gene Harper at Dow Chemical is Fredric Buchholz, who works in Midland, Michigan, a small town two hours northwest of Detroit, where Dow has its headquarters. His laboratory is in the middle of the sprawling chemical works, a mile or two away from corporate headquarters, in a low, unassuming brick building. "We still don't understand perfectly how these polymers work," Buchholz said on a recent fall afternoon. What we do know, he said, is that superabsorbent polymers appear, on a microscopic level, to be like a tightly bundled fisherman's net. In the presence of water, that net doesn't break apart into thousands of pieces and dissolve, like sugar. Rather, it just unravels, the way a net would open up if you shook it out, and as it does the water gets stuck in the webbing. That ability to hold huge amounts of water, he said, could make superabsorbent polymers useful in fire fighting or irrigation, because slightly gelled water is more likely to stay where it's needed. There are superabsorbents mixed in with the sealant on the walls of the Chunnel between England and France, so if water leaks in the polymer will absorb the water and plug the hole.

Right now, one of the major challenges facing diaper technology, Buchholz said, is that urine is salty, and salt impairs the unravelling of the netting: superabsorbents can handle only a tenth as much salt water as fresh water. "One idea is to remove the salt from urine. Maybe you could have a purifying screen," he said. If the molecular structure of the superabsorbent were optimized, he went on, its absorptive capacity could increase by another five hundred per cent. "Superabsorbents could go from absorbing three hundred times their weight to absorbing fifteen hundred times their weight. We could have just one perfect particle of superabsorbent in a diaper. If you are going to dream, why not make the diaper as thin as a pair of underwear?"

Buchholz was in his laboratory, and he held up a small plastic cup filled with a few tablespoons of superabsorbent flakes, each not much larger than a grain of salt. "It's just a granular material, totally nontoxic," he said. "This is about two grams." He walked over to the sink and filled a large beaker with tap water, and poured the contents of the beaker into the jar of superabsorbent. At first, nothing happened. The amounts were so disproportionate that it looked as if the water would simply engulf the flakes. But, slowly and steadily, the water began to thicken. "Look," Buchholz said. "It's becoming soupy." Sure enough, little beads of gel were forming. Nothing else was happening: there was no gas given off, no burbling or sizzling as the chemical process took place. The superabsorbent polymer was simply swallowing up the water, and within minutes the contents of the cup had thickened into what looked like slightly lumpy, spongy pudding. Buchholz picked up the jar and tilted it, to show that nothing at all was coming out. He pushed and prodded the mass with his finger. The water had disappeared. To soak up that much liquid, the Victor Mills diaper would have needed a thick bundle of paper towelling. Buchholz had used a few tablespoons of superabsorbent flakes. Superabsorbent was not merely better; it was *smaller*.

Why does it matter that the diaper got so small? It seems a trivial thing, chiefly a matter of convenience to the parent taking a bag of diapers home from the supermarket. But it turns out that size matters a great deal. There's a reason that there are now "new, improved concentrated" versions of laundry detergent, and that some cereals now come in smaller boxes. Smallness is one of those changes that send ripples through the whole economy. The old disposable diapers, for example, created a transportation problem. Tractor-trailers are prohibited by law from weighing more than eighty thousand pounds when loaded. That's why a truck carrying something heavy and compact like bottled water or Campbell's soup is "full," when the truck itself is still half empty. But the diaper of the eighties was what is known as a "high cube" item. It was bulky and not very heavy, meaning that a diaper truck was full before it reached its weight limit. By cutting the size of a diaper in half, companies could fit twice as many diapers on a truck, and cut transportation expenses in half. They could also cut the amount of warehouse space and labor they needed in half. And companies could begin to rethink their manufacturing operations. "Distribution costs used to force you to have plants in lots of places," Dudley Lehman, who heads the Kimberly-Clark diaper business, says. "As that becomes less and less of an issue, you say, 'Do I really need all my plants?' In the United States, it used to take eight. Now it takes five." (Kimberly-Clark didn't close any plants. But other manufacturers did, and here, perhaps, is a partial explanation for the great wave of corporate restructuring that swept across America in the late eighties and early nineties: firms could downsize their workforce because they had downsized their products.) And, because using five plants to make diapers is more efficient than using eight, it became possible to improve diapers without raising diaper prices—which is important, because the sheer number of diapers parents have to buy makes it a price-sensitive product. Until recently, diapers were fastened with little pieces of tape, and if the person changing the diapers got lotion or powder on her fingers the tape wouldn't work. A hook-and-loop, Velcro-like fastener doesn't have this problem. But it was years before the hook-and-loop fastener was incorporated into the diaper chassis: until over-all manufacturing costs were reduced, it was just too expensive.

Most important, though, is how size affects the way diapers are sold. The shelves along the aisles of a supermarket are divided into increments of four feet, and the space devoted to a given product category is almost always a multiple of that. Diapers, for example, might be presented as a twenty-foot set. But when diapers were at their bulkiest the space reserved for them was never enough. "You could only get a limited number on the shelf," says Sue Klug, the president of Catalina Marketing Solutions and a former executive for Albertson's and Safeway. "Say you only had six bags. Someone comes in and buys a few, and then someone else comes in and buys a few more. Now you're out of stock until someone reworks the shelf, which in some supermarkets might be a day or two." Out-of-stock rates are already a huge problem in the retail business. At any given time, only about ninety-two per cent of the products that a store is supposed to be carrying are actually on the shelf—which, if you consider that the average supermarket has thirty-five thousand items, works out to



"Remember, son, it's never too early to start saving for retirement."

twenty-eight hundred products that are simply not there. (For a highly efficient retailer like Wal-Mart, in-stock rates might be as high as ninety-nine per cent; for a struggling firm, they might be in the low eighties.) But, for a fast-moving, bulky item like diapers, the problem of restocking was much worse. Supermarkets could have allocated more shelf space to diapers, of course, but diapers aren't a particularly profitable category for retailers—profit margins are about half what they are for the grocery department. So retailers would much rather give more shelf space to a growing and lucrative category like bottled water. "It's all a trade-off," Klug says. "If you expand diapers four feet, you've got to give up four feet of something else." The only way diaper-makers could insure that their products would actually be on the shelves was to make the products smaller, so they could fit twelve bags into the space of six. And if you can fit twelve bags on a shelf, you can introduce different kinds of diapers. You can add pull-ups and premium diapers and low-cost private-label diapers, all of which give parents more options.

"We cut the cost of trucking in half," says Ralph Drayer, who was in charge of logistics for Procter & Gamble for many years and now runs his own supply-chain consultancy in Cincinnati. "We cut the cost of storage in half. We cut handling in half, and we cut the cost of the store shelf in half, which is probably the most expensive space in the whole chain." Everything in the diaper world, from plant closings and trucking routes to product improvements and consumer choice and convenience, turns, in the end, on the fact that Harmon and Harper's absorbent core was smaller than Victor Mills's.

The shame of it, though, is that Harmon and Harper have never been properly celebrated for their accomplishment. Victor Mills is the famous one. When he died, he was given a *Times* obituary, in which he was called "the father of disposable diapers." When Carlyle Harmon died, seven months earlier, he got four hundred words in Utah's *Deseret News*, stressing his contributions to the Mormon Church. We tend to credit those who create an idea, not those who perfect it, forgetting that it is often only in the perfection of an idea that true progress occurs. Putting sixty-four transistors on a chip allowed people to dream of the future. Putting four million transistors on a chip actually gave them the future. The diaper is no different. The paper diaper changed parenting. But a diaper that could hold four insults without leakage, keep a baby's skin dry, clear an insult in twenty seconds flat, and would nearly always be in stock, even if you arrived at the supermarket at eight o'clock in the evening—and that would keep getting better at all those things, year in and year out—was another thing altogether. This was more than a good idea. This was something like perfection. ♦