prolific Henry Bessemer, "knows no bounds or finality." Thus the process of technological evolution is a never-ending one, and a study of artifact after artifact reveals that it is the successive identification and elimination of faults found in any given thing at any given time that forms and re-forms its form.

From: Henry Petroski. 1992. The Evolution of Useful Things. New York: Vintage.

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From Pins to Paper Clips

Whatever its intended function, an object's form alone often suggests new and more imaginative forms, as the stick did the fork and the shell the spoon. It is no less the case with manufactured things, and few artifacts have been more formed, de-formed, and re-formed than the common paper clip, as a survey once made clear. Attribution of the study and its follow-ups has become as confused as the origins of the object itself, credit going variously to, among others, Lloyd's of London, "relentlessly inquisitive Germans" at a Munich manufacturing firm, and Howard Sufrin, heir to the Pittsburgh family business that made Steel City Gem Paper Clips. According to Sufrin, who claims to have conducted the original study in 1958, three of every ten paper clips were lost, and only one in ten was ever used to hold papers together. Other uses included toothpicks; fingernail and ear cleaners; makeshift fasteners for nylons, bras, and blouses; tie clasps; chips in card games; markers in children's games; decorative chains; and weapons.

I recall the last purpose as the only one to which my classmates and I put paper clips in the early 1950s: We flexed and twisted them apart and used the sharply pointed halves as ammunition for the rubber bands stretched between thumb and index finger. More than one teacher kept the whole class after school when no one would admit to launching the U-shaped missile that had just whizzed past her ear and struck the blackboard—or ricocheted off the ceiling and rung off the waste basket in the corner of the room. We would listen to the familiar lecture on how eyes had been put out by the sharp points of paper clips made into vile projectiles, but we continued to employ these urban slingshots, for none of us had ever actually witnessed a serious injury. The incorrigibles in the class would conduct wars across the back rows, and every time a paper clip pinged

off the window the whole class would hold its breath, hoping the teacher would not hear the sound.

Paper clips have also served as objects of more inwardly directed aggression by providing something for the fingers to twist grotesquely out of shape during phone calls, interviews, and meetings. This tactile form of doodling may consume only a fraction of the twenty billion paper clips produced each year, but it underscores the almost limitless functions to which a single form can lead. However paper clips have come to be used or misused, they evolved to their present form only slowly, and at times as circuitously as their wire can be bent. Where to begin the story of something so common in its form and yet so complex in its associations can be as arbitrary and difficult as picking a particular paper clip from a box of a hundred. Just as the clips can get all tangled together, with one pulling others in its wake, so picking up the story of the artifact itself out of the box of cultural and social history inevitably produces a tangle of tales wound around tales.

Paper was developed in first-century China and in time moved westward. By the thirteenth century, making paper from the pulp of linen rags was established in Europe, and the generally available medium on which to write replaced parchment and vellum for all but the most ceremonial and special of documents. In addition to the need for bound volumes of fixed size that were the essentially unchanging records of vital statistics, thought, and achievement, there arose, with the rise of bureaucracy and commerce, increasing amounts of occasional paperwork whose contents did not demand or require rugged or permanent binding. Indeed, it would have been a bother, an expense, and an exercise in pretentiousness to bind two pieces of business paper together as elaborately as were the leaves of books.

Related pages that were not attached often failed to remain together, however. One early way of attaching loose sheets required only a penknife—always close at hand to point quills—and a length of string, a strip of cloth, or a piece of ribbon. Two small parallel slits would be made in the pages to be fastened together with whatever was threaded through the slits, and the ends could be sealed with wax to the paper to ensure that no substitutions were made. In general, the quality of the tie marked the importance of the document, and even today one can find contemporary records fastened in such a manner: I have received from Eastern Europe university

Pin making, shown here in an eighteenth-century print from Diderot's *L'Encyclopédie,* was a classic example of division of labor. The pin, like the needle, was highly evolved long before its manufacture became mechanized.

transcripts whose pages were gathered with exquisite ribbons elaborately tied. But I have also received from underdeveloped countries multipage documents or unofficial copies of records fastened together by another old method—a straight pin.

Pins were fashioned out of iron and bone by the Sumerians as long ago as 3000 B.C., and were used to hold clothes together. The manufacture of pins was industrialized long before it was mechanized, and the manual process was illustrated in Denis Diderot's monumental *L'Encyclopédie,* completed in 1772. In a famous passage near the opening of *Wealth of Nations,* Adam Smith described how a pin was made to demonstrate the advantages of a division of labor: "One man draws the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds the top for receiving the head. . . ." William Cowper rendered the same process in verse—"One fuses metal o'er the fire; / A second draws it into wire"—thus showing that there is more than one way to make a point.

Wire could be drawn at the rate of sixty feet per minute, but only slightly more than one pin a second could be cut by a practiced worker. This would yield about four thousand pins per hour. The bottleneck in the manufacture of pins occurred when they were attached to cards or papers; the women who worked at that cottage

industry accomplished the task at the rate of perhaps fifteen hundred per day. Adam Smith observed that, averaged over all the specialists that divided the labor (and as many as seventeen different people might work on each single pin), about forty-eight hundred pins per day per worker was the output. He speculated that without a division of labor, the output of a single person making each pin from start to finish might be as great as twenty but perhaps as small as a single pin per day.

The efficiency of the division of labor in making pins was a major impediment to mechanizing the industry. But, just as there were many ways in which to divide the hand labor that produced pins, so there would be many ways in which to put together belts and pulleys, cams and gears, shears and hammers, claws and files, to make a pin mechanically. As Steven Lubar, who has written on the cultural as well as the technological influences on design in the pin industry, has warned us, "we must not be misled into thinking that [a pin] machine has the form it has because of some deterministic factors, that physical law requires that pin machines look and operate" alike. One machine was invented and patented as early as 1814 in America, and a more practical one was patented in 1824 in England by an American engineer then living there. But the most successful of the early pin-making machines took its form from the "mechanical scheming" of an erstwhile physician who had watched the process of hand pin-making by the inmates of the New York Alms House, where he was resident.

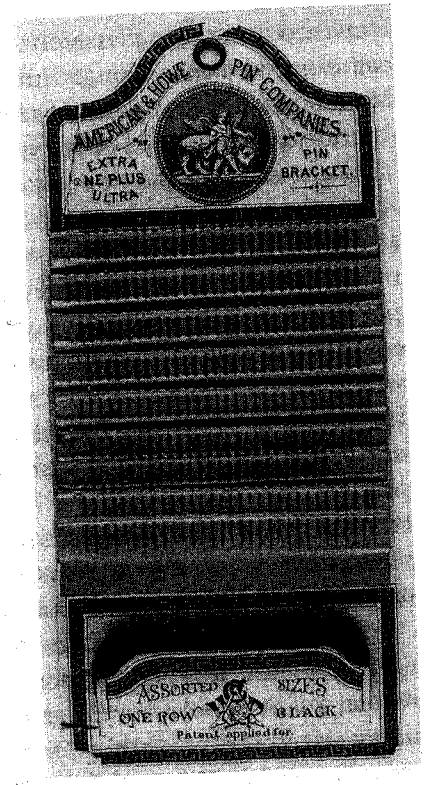
John Ireland Howe, who was no relation to the inventor of the sewing machine, was born in Ridgefield, Connecticut, in 1793 and began to practice medicine in New York City in 1815. An inventive urge drove him to apply his knowledge of chemistry to produce a practical rubber compound, and after receiving a patent in 1829 he gave up his medical practice to manufacture rubber goods. But when the venture did not succeed, he began to experiment, with an eye toward developing machinery that would replace the many human hands that he had observed making pins in the almshouse. However, he was limited by his lack of mechanical experience and so sought the help of Robert Hoe, a designer and manufacturer of printing presses. It was in Hoe's shop in 1832 that Howe came up with a working model of a machine for making pins in one operation, and it was patented. Although early attempts to sell the imperfect machine were unsuccessful, leading him into considerable debt,

Howe continued successively to remove faults in early models and came up with increasingly improved machines. In 1835 the Howe Manufacturing Company was founded and it soon had five machines operating, with pins being made in both England and America.

At one stage in the development of his business, Howe had three machines, producing seventy-two thousand pins per day, but it took as many as sixty pin stickers to package the output. Thus the true mechanization of the industry required the mechanization of the pin-sticking operation. Eventually Howe and some employees of his company designed a machine to crimp paper into ridges through which the pins could be stuck, and this proved to be a great success. It was a far cry from the situation in the Middle Ages, when pins had become so scarce that a British law allowed pin makers to sell their product only on certain days. "Pin money" was set aside to purchase the dear necessities, but, with mass production and the consequent sharp decline in price, "pin money" came to mean pocket money or "a pittance sufficient to purchase only pins."

The sale of pins on cards came about for several reasons. In the early nineteenth century, people had been used to handmade pins whose quality could vary significantly from piece to piece, some being straighter than others, some having better points than others, some heads being uncomfortably large and others painfully small when holding together (and close to the body) the parts of one's dress. Even after mechanization, by displaying very clearly the head and point of every pin on a card, the manufacturer could demonstrate the uniformly "extra ne plus ultra" quality of the product, and the customer could easily verify that a full count of pins was being bought. Carded pins also were conveniently and safely stored and yet could be at the ready to be picked up when a seamstress might need one in a hurry. A "paper of pins" was a godsend, and to this day pins and needles are packaged in a similar way, even though the advances in mechanization have made the quality of pins very high and reliable.

As the availability of high-quality pins increased and their price dropped, they became available in bulk to the commercial establishments that had grown up with the Industrial Revolution. Although the pins sold to businesses as "bank pins" and to home seamstresses as "toilet pins" (named after the dressing table, not the washroom) were identical in their manufacture, differences in packaging distinguished their price. Bank pins were sold loose in half-pound lots,



Although mechanization was producing highly uniform pins by the middle of the nineteenth century, they continued to be packaged so that the customer could see that there was a full count and that all the heads and points were properly formed. The carding or papering of pins had long been a bottleneck in their production, and the output of the first mechanized pin factories was limited by how fast pins could be put up in such packages.

whereas toilet pins continued to be sold threaded in neat rows through pieces of paper or cardstock, often imprinted with the company's name and claims about the quality of the pins. A card of pins might also contain assorted sizes and types, such as "one row black" for use with darker garments. Commercial purchasers did not require such variety and did not have to be sold on the quality or economy of items that made it possible to attach papers together securely yet quickly for processing. Banknotes could be temporarily attached to invoices for proper crediting and accounting, and then removed, leaving only a couple of tiny pinholes—a distinct advantage over slits large enough for ribbons.

A single bank pin would naturally have been more difficult to pick out of a pile or tray of others, and so they also came to be packaged not on flat cards but in ways that suggested a full pincushion ready for the picking. Some such arrangements are really rolls of long strips of paper, not unlike scrolls, to which a single line of pins is

attached sideways, and they are still sold as "pyramids" of pins that can sit at the ready on a clerk's desk, and thus are sometimes called "desk pins." The difficulty of picking up pins from a pile in a desk drawer or tray also led to the evolution of a different form of pin—the "T" pin—which has a large head formed by bending the pin wire sideways and then back upon itself in a tight curve to form a T-shaped head. A current catalogue offering these pins, "used primarily in brokerage houses for securities," really documents the failings of the straight pin that "T" pins overcome: "These pins have handles which speed pick-up, insertion, and withdrawal, will not slip through paper."

By the end of the nineteenth century, pin-making machinery had improved to such a point that a half-pound box of bank pins could be had for forty cents, whereas a much smaller quantity of carded or papered pins for home use sold for about seventy-five cents. Many early pins were made of brass, which is a soft metal and hence not so desirable as steel. Mass production could not keep steel from rusting, however, and so the better pins began to be plated with nickel, but even this metal started to break down and flake off in extremes of humidity, causing rust marks to soil whatever was pinned together.

This shortcoming of steel pins was not especially inconvenient for homemaking uses, where pins were often used only temporarily while sewing or wearing garments, and homeworkers could take care not to leave pins in anything that would be put away for a while. (Pins that did develop rust could be cleaned by pushing them back and forth in a sack of emery grit, which was often sewn into the form of a strawberry.) However, it was necessary in business applications to have piles and files of papers that remained pinned together over long periods of time, and it was impractical to have to worry about them or clean the pins of rust. Another disadvantage of using pins to attach business papers together was the unsightly holes, often ringed with rust, that remained. This was an especially bothersome problem when papers were attached, detached, and reattached time after time over the course of years. The pinned corners began to become rather ragged, and so alternatives that corrected this flaw were sought.

To obviate the undesirable use of pins to attach papers together, inventors as early as the middle of the nineteenth century developed what were called "paper fasteners" and "paper clips," though