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Little Things Can Mean a Lot

Many a writer on technology has been struck, in a moment of pause between sentences or an hour of distraction between paragraphs, by the extraordinariness of ordinary things. The push-button telephone, the electronic calculator, the computer on which words such as these are processed are among the more sophisticated things we use, and they can awe into silence those of us who are not electrical engineers. On the other hand, such low-tech objects as pins, thumbtacks, and paper clips are frequently and verbosely praised for their functionality and beauty of line, but are seldom the subject of study, unless it is for the sake of learning how to market something that people use much but consider little. The most common of objects are certainly not generally thought to hold lessons for technological process, prowess, or progress.

But if there are general principles that govern the evolution of technology and artifacts, then the principles must apply equally to the common and to the grand. And how much easier it may be to understand how technology works if we can pursue it in the context of something that is less intimidating than a system that takes teams of engineers years to develop. The individual complexity of supercomputers and skyscrapers, nuclear-power plants and space shuttles, distracts us from the common basic elements of technological development that underlie all things—the great and the small, the seemingly simple and the clearly complex. The individual designer and engineer involved in the creation of large systems is often lost in numerous management shuffles, and the story of the end product is frequently that of a major production with an anonymous if professional cast of thousands, no single one of whom is commonly

known to be *the* designer or *the* engineer. But, although the often amateur actors in the little-theater pieces surrounding the design and development of many of our simple objects may also be anonymous as far as myriad consumers are concerned, the plot is usually much easier to follow.

Ironically, the largest and publicly most anonymous engineering structures and systems—like bridges, skyscrapers, airplanes, and power plants—are frequently produced by companies named after people. Thus we have the Burns and Roes, the Brown and Roots, the Bechtels, and the countless regional and local founder-named construction companies that ultimately shape so much of our public space and convey a sense of civic pride and achievement. We have the airplanes called Curtiss-Wrights and McDonnell-Douglases, namesakes of inventors and innovators whose pioneering has, directly or indirectly, given us the space shuttles, superjets, and even corporate jets of today. And we have the Westinghouses and the Edisons that have provided us with the electric-power stations and distribution networks that make modern life so comfortable and convenient. We have the Fords, Chryslers, Mercedes-Benzes, Rolls-Royces, and other automobiles invoking with their grilles-cum-headstones the names of long-gone entrepreneurs. Even the giant corporations called General Electric, General Motors, and General Dynamics can invoke the sense of a leader of manufacturing troops more than evoke the culmination of a concatenation of once individual and private companies.

The names commonly associated with some of the most familiar and cherished products on our desks, on the other hand, are obscure if they are known at all. Items like pins and paper clips certainly do not carry nameplates or medallions memorializing their makers. If we do examine the box that paper clips come in, it tells us our clips were made by Acco or Noesting, which hardly sound like the names of inventors or even people. Many a desk stapler reads Bostitch. Is that someone's name, or what? Modest products tend to have at best a pseudonymity that gives little hint of their inventor, but the brand name of a product and that of the company that makes it often do hold clues as to how the product evolved, and thus can give tremendous insight into the evolution of things. And the stories of their names often parallel those of the products that were developed to solve problems with, if not the downright failure of, pre-existing products.

On a package of Post-it notes, those little yellow slips of paper that stick to everything from irate correspondence to refrigerator doors, we can find the "Scotch" trademark and a bold "3M," which older thingophiles and trivia buffs may recall was once known as the Minnesota Mining and Manufacturing Company. How did such a seemingly self-explanatory and no-nonsense-sounding company get involved with little sticky notepads? Besides, isn't Minnesota peopled by Scandinavians rather than Scots?

In 1902 five businessmen from Two Harbors, Minnesota, formed the Minnesota Mining and Manufacturing Company to quarry what they thought was a local find of corundum, a mineral just short of diamond in hardness and thus a valuable abrasive for grinding-wheel manufacturers. The mineral proved inferior for that application, however, and so in 1905 the fledgling company turned to making sandpaper in Duluth. Difficult years followed, with new financing staving off bankruptcy, but true success in selling sandpaper could come only with a product at least as good as the other guy's.

In 1916 the company's sales manager insisted that a laboratory be formed to carry out experiments and tests to ensure quality control so that salesmen would not be embarrassed by faulty products. The laboratory in time made possible the research and development necessary to produce new and improved items in response to problems experienced by sandpaper users. Whereas a manufacturer's salesmen might say that, after quality control, the raison d'être for a company's laboratory was to respond to customers' needs for new products, engineers might see a laboratory more as a troubleshooting workshop in which to deal with the horror stories of product failures and the general tales of irritating shortcomings brought home by the salesmen. In the course of troubleshooting, new products would naturally evolve to deal with objections to existing products.

In the making of sandpaper, an abrasive material is bonded to a paper backing, and the quality of the product depends not only on the quality of the principal raw materials of grit and paper, but also on how uniformly and securely they can be combined. Hence, to manufacture sandpaper it was necessary to develop an expertise in coating paper with adhesive. Unfortunately, even with good glue, the paper used in early sandpaper fell apart when wet, and so using sandpaper was necessarily a very dry and dusty operation. But in the growing automobile industry, where in the 1920s a considerable amount of sanding was needed to finish the paint on auto bodies, the dust was causing lead poisoning among workers. Making waterproof sandpaper would allow wet sanding, which in turn would cut down on dust, and thus be a great improvement. To remove the failings of existing sandpaper, the Minnesota Mining and Manufacturing Company developed a waterproof paper that one of its young lab technicians, Richard Drew, was asked to take to some St. Paul auto shops, where it might be tested. In doing so, he became aware of another problem.

The new two-tone style of painting automobiles was popular in 1925, but it presented considerable problems for auto manufacturers and body shops alike. In order to get a clean, sharp edge when applying a second paint color, the first had to be masked, of course, and this required that newspaper or butcher paper be fastened to the car body. If shop-brewed glue was used, it would sometimes stick so well that it had to be scraped off, more often than not pulling paint with it. Surgical adhesive tape was sometimes employed, but its cloth backing tended to absorb solvents from the newly sprayed paint and cause the masking materials to stick to the paint they were intended to protect. Clearly, existing means of masking had serious flaws. One day, when he was dropping off a batch of waterproof sandpaper, Drew overheard some body-shop workers cursing two-tone painting. The young technician, who had studied engineering through correspondence-school courses, promised he would make something to solve the problem.

As in the majority of design problems, Drew's objectives were most clearly expressed principally in negative terms: he wished to have a kind of tape whose adhesive would not stick very readily. This not only would allow the tape to be formed in rolls from which it could easily and cleanly be removed, but also should have enabled it to be removed easily from a freshly painted auto body. Stating the problem and finding the right combination of adhesive and paper are two different things, however. The first could have come in a flash at a body shop. The latter took two years of experimenting with oils, resins, and the like, not to mention papers to which they could be applied. After many negative results and suggestions that the problem should be dropped, Drew tried some crepe paper left over from unrelated experiments and found that its crinkled surface proved to be an ideal backing. Samples of the new product were taken by the company's chief chemist to Detroit auto manufacturers, and he returned to Minnesota with orders for three carloads of Drew's masking tape.

According to company lore, the tape came to be called Scotch because on an early batch of two-inch-wide tape the adhesive was applied only to the edges, presumably since this was thought to be sufficient and even perhaps desirable for masking applications. One edge of the tape would hold the paper, the other would adhere to the auto body, and the dry middle would not stick to anything. However, with so little adhesive, the heavy paper pulled the tape off the auto body, and a frustrated painter is said to have told a salesman, "Take this tape back to your stingy Scotch bosses and tell them to put more adhesive on it." Though some company old-timers have labeled the story apocryphal, others give it credence by recalling that the incident "helped spark the inspiration for the name" of the line of pressure-sensitive adhesive tapes that now carry the tartan trademark, presumably not because the manufacturer is stingy with adhesive but, rather, because consumers can use the tape to make economical repairs on so many household items.

Cellophane was another new product in the late 1920s, and its being transparent and waterproof made it ideal for packaging everything from bakery goods to chewing gum. It was even natural to want to package masking tape in cellophane, and so someone in St. Paul was experimenting with it. At the same time, Drew was working on another problem, trying to remove his tape's shortcoming of not being waterproof and thus not being applicable in very moist environments. He got the idea of coating cellophane with his adhesive, which would certainly be a promising new tape to make clear packaging watertight. But sticking an adhesive that works wonderfully on crepe paper onto cellophane is easier said than done, and using existing machinery to manufacture quantities of a new product made of a new material usually involves considerable experimentation and development. In the case of Scotch cellophane tape, Drew's initial attempt to make it waterproof failed to come up to expectations: "It lacked proper balance of adhesiveness, cohesiveness, elasticity and stretchiness. Furthermore, it had to perform in temperatures of 0 to 110 degrees F in humidity of 2 to 95 percent." Not surprisingly, at first it did not, and so presented some well-defined problems to be solved.

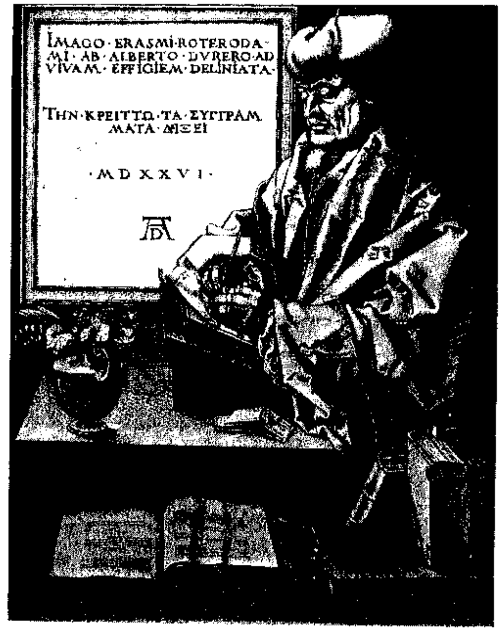
After a year of work, Drew did solve the problems, at least to a satisfactory degree for the time, and shiny-backed cellophane tape was *the* transparent tape for many years. It was used for all sorts of mending and attaching jobs, and its yellowing with age, its curling up and coming off with time, and the notorious stubbornness with which it hid its end and tore diagonally off the roll were accepted by users as just the way the tape was—nothing better was available. But inventors and tinkerers like Drew saw each shortcoming as a challenge for improvement, in part because they and their bosses knew that competitors did also. Difficulties in getting Scotch tape off the roll, for example, prompted the development of a dispenser with a built-in serrated edge to cut off a piece squarely and leave a neat edge handy for the next use. (This provides an excellent example of how the need to dispense a product properly and conveniently can give rise to a highly specialized infrastructure.)

As changes in the tape were made, new and improved versions were offered to users who wondered how they had ever gotten along with the old tape. Indeed, the company's own description of the latest version of its product can be read not only as praise for Scotch Magic Transparent Tape but also as an indictment of cellophane tape: "It unwinds easily. You can write on it. You can machine-copy through it. It's water repellent. And, unlike the earlier tape, it won't yellow or ooze adhesive with age." This list of implicit and explicit faults of the "earlier tape" sure makes it sound disgusting and inadequate, but in its day it was the cat's meow. Our expectations for a technology rise with its advancement.

The company that began by making an adequate sandpaper may not have foreseen the nature of its products many years hence, but the accumulation of experience in attaching adhesives of one kind or another to paper and other backings, and a receptivity to new applications of that expertise—and others accumulated along the way—enabled the Minnesota Mining and Manufacturing Company eventually to make tens of thousands of products. Since the old name no longer fully described the diverse output of the giant manufacturer, it came to be known more and more by the abbreviation "3M," and in a recent annual report to the stockholders the full name appears only in the accounting statement.

The characteristic of 3M that enabled it to attain such diversity in its product line is a policy of what has generally come to be called "intrapreneurship." The basic idea is to allow employees of large corporations to behave within the company as they would as individual entrepreneurs in the outside world. A model intrapreneur is Art Fry, a chemical engineer who in 1974 was working in product development at 3M during the week and singing in his church choir on Sundays. He was accustomed to marking the pages in his hymnal with scraps of paper, so that he could quickly locate the songs during the two services at which he sang. The procedure worked fine for the first service, but often by the second one some of the loose scraps of paper had fallen out of their places. Fry, not having noticed this, was sometimes at a loss for words. Now, loose scraps of paper have long been used for bookmarks—some are clearly visible in the foreground of Albrecht Dürer's famous etching of the great humanist Erasmus—and one can safely say that many a bookmark had lost its place in the four and a half centuries between that etching's date of 1526 and the time when Fry reflected on the failure of bookmarks to do all that might be expected of them.

Fry remembered a curious adhesive—a strong and yet easily removed "unglue"—that Spencer Silver, another 3M researcher, had come upon several years earlier in the course of developing very strong and very tacky adhesives. Although it was not suited to solving his immediate problem, Silver felt the unusual adhesive might have some commercial value, and so he demonstrated it to various colleagues, including Fry. At the time, no one had come up with a use for it, and so the formula for the weak adhesive was filed away—until the Monday morning when Fry came to work with the idea of making sticky bookmarks that could also be removed without damaging the book. His initial attempts left some adhesive on the pages, and Fry has surmised that "some of the hymnal pages I tested my first notes on are probably still stuck together." But since it is 3M's policy (and that of other enlightened companies) to allow its engineers to spend a certain percentage of their work time on projects of their own choosing, a practice known as "bootlegging," Fry was able to gain access to the necessary machinery and materials and to spend nearly a year and a half experimenting and refining his idea for sticky—but not-too-sticky—slips of paper that could be used for "temporarily permanent" bookmarks and notes. While Fry wanted bookmarks to stick gently to his pages, he did not want their projecting ends to stick to each other, and so adhesive was applied at one end only. This also served well for repositionable memos and removable notes: with adhesive all over their backs, these would have been as hard to peek under and remove as labels.



Albrecht Dürer's *Portrait of Erasmus,* prominently dated 1526, shows that the great Dutch Renaissance humanist employed scraps of paper as bookmarks. Though they were sure to mark his place as long as the book was latched shut, some bookmarks may have slipped between pages or fallen out as the book was used. About 450 years passed before the use of loose scraps of paper frustrated someone enough to motivate him to persist in inventing a more tenacious paper bookmark, which in turn led to the now familiar Post-it notes.

When Fry thought the stick-and-remove notes were ready, he took samples to the company's marketing people, "who had to accept the idea as being commercially viable and meeting a market need" before any substantial amount of the company's own time or money was to be invested in the product. There was a general lack of enthusiasm for something that would have to sell at a premium price compared with the scratch paper it was intended to replace. (Its removable-note function was believed to hold greater commercial potential than its sticky-bookmark function.) Fry was committed to his brainchild, however, and he finally convinced an office-supply division of 3M to test-market the product, which "met an unperceived need." Early results were not at all promising, but in those cases where samples were distributed, customers became hooked. Though no prior need for the little sticky notes had been articulated, once they were in the hands of office workers all sorts of uses were found, and suddenly people couldn't do without the things. Post-it notes were generally available by mid-1980 and are now ubiquitous, even coming in long, narrow styles to accommodate the vertical writing of Japanese. It might be argued that they have reduced the recycling of scrap paper as scratch paper and bookmarks, but the removable notes do have the conservatory potential of eliminating the use of unsightly and damaging tape and staples for posting notes and announcements in public places.

Years ago, when I would meet my dean walking across campus to the Engineering School, as we approached the building he would invariably remove the numerous announcements of meetings, parties, and kittens for adoption that had been taped or tacked to the door since his last entrance. He carefully peeled off the tape that made posting notices so easy but maintaining an attractive entrance to a school so difficult. The dean explained on more than one occasion how the tape could become difficult to remove if it stayed up over several days and nights, and how it had ruined some freshly painted walls, which had had to be patched and repainted. The dean was not opposed to notices, but to the damage that their attachment did to the main entrance to his school. How he might have loved Post-it notes and dreamed of them in poster sizes.

Post-it notes provide but one example of a technological artifact that has evolved from a perceived failure of existing artifacts to function without frustrating. Again, it is not that form follows function but, rather, that the form of one thing follows from the failure of another thing to function as we would like. Whether it be bookmarks that fail to stay in place or taped-on notes that fail to leave a once-nice surface clean and intact, their failure and perceived failure is what leads to the true evolution of artifacts. That the perception of failure may take centuries to develop, as in the case of loose bookmarks, does not reduce the importance of the principle in shaping our world.

Scrolls were once the standard medium for recording and pre-

serving the written matter of everything from politics to scholarship, and a single scroll was called in Latin a *volumen*, from the verb "to roll." The length of such a volume was limited literally by how long a piece of papyrus could be rolled up or onto the rods that marked its ends. Papyrus was made by laying crosswise slices of the pith of the papyrus plant and pounding or pressing them together until they formed sheets, which in turn could be pasted together end to end to form the long and narrow continuous sheets needed for scrolls. The papyrus sheets were rolled rather than folded up, because the material cracked easily and thus could not for practical purposes be folded over on itself.

If the written word were still preserved on scrolls, going from one end of a long manuscript to another could involve considerable rolling and unrolling. One way of removing this inconvenience of scrolls, while at the same time eliminating the need to form sheets of writing material into long strips, is to form or fold the sheets into leaves of uniform size that can be bound together in some way along one edge. Parchment and vellum, which were formed from the skin of newborn lambs, kids, and calves, could be folded without cracking, and so volumes no longer had to be stored on rolls. With the introduction of paper and the printing press, books multiplied and their binding came to be done more and more efficiently with needle and thread in the folds.

The needle is among the oldest of artifacts, and its usefulness is without question. Yet in certain applications it has severe shortcomings. The infrastructural thimble answers to the problem of pushing a needle through a tough piece of material before the needle itself pierces the finger. And the clever diamond-shaped loop of fine spring wire is a godsend to those of us whose squinting eye can never seem to focus on the more squinting one we are trying to thread. But the needle has also led to the development of many other twentieth-century artifacts that we may hardly recognize as related.

Needles can be thought of as headless pins with a single eye meant to pass readily through anything from the hem of a veil to the hide of a camel, leaving behind only a thread of a clue to their presence. When fully sewn into a garment, a piece of thread can be thought of as a continuous and flexible ghost of a needle, but with no bulging eye to find our most sensitive spot and no point to pierce our skin. Needle and thread not only fashioned the clothes of our ancestors but also gathered printed leaves of paper into signatures and these into volumes; though in this latter application the thread may have been invisible to the reader, it certainly left its mark on the book.

The classic shape of a book's spine derived from the fact that the folds of paper that formed it were thickened by the passes of thread that they contained. To keep a bound book from having a spine much thicker than its other edges, and thus from having the undesirable shape of a wedge that would make stacking and shelving books much less convenient than it is, the sewn spine was rounded and fanned out before binding, so that the threads did not sit directly on top of one another. The boards that formed the hard front and back of the book added enough thickness to rise above the thickest part of the spine, and the hinge of cloth that connected them followed the rounded shape of its contents. The characteristic shapes of books were clearly captured by Dürer in his *Portrait of Erasmus,* with the front edge of their pages fitting the curve of their spines because the paper was trimmed before the spine was formed.

Though today's books may appear to retain the curved look in their spines, it is really just a rounding of the stiffened binding cloth. The book proper has a squarish shape, with a flat front edge as well as a flat spine. This change in form came about because the traditional procedure of sewing books in signatures was time-consuming and costly, and thus failed to be as economical as alternative procedures. The typical book is now "perfect-bound," which means that its sheets are folded in signatures as before but not sewn. Rather, the signatures are gathered and stacked, and trimmed all around to a boxlike shape. Containing no thread in its folds, the stack of paper does not bulge at the spine, and so does not have to be rounded. Instead, it is ground to a rough finish, the better to receive an adhesive similar to the stuff that holds pads of paper together. This procedure was first used in binding cheap paperbacks and has now been almost universally adapted to even the most expensive hardcovers, to the dismay of many an author, reader, and bibliophile. In spite of its name, perfect binding has great failings, not the least of which is that a book so bound is often badly misshapen after a single reading. The modern bookshelf is thus characterized not by a neat ripple of round-ended volumes but by a jagged surface of creased spines. When seen on end, once-read perfect-bound books are sadly skewed reminders of how form follows fortune. Even if this may be to the myopic delight of manufacturers, it can certainly be to the dismay of those who have a sense of form.

In the late nineteenth century, magazines came to be bound by what amounted to sewing with a piece of wire, which could serve as both needle and thread, and a single-wire stitch was certainly much stronger and self-contained than one of cotton. Furthermore, a short piece of bent wire could pierce and hold together more separate sheets of paper, and eventually small booklets and magazines could be made in a single signature with a single stitching operation, known as "saddle stitching." Toward the end of the century, wire stitchers were common in the printing-and-bookbinding industry. Although they were cumbersome machines and took some time to adjust for different thicknesses of work, this was not an unacceptable disadvantage in producing large printings. But for smaller jobs the setup time could be prohibitive, and so a stitching machine that could be adjusted with a slight turn of a screw would lower considerably the cost of printing small runs of small booklets.

Such a machine was built in 1896 by Thomas Briggs, an inventor who lived in the Boston suburb of Arlington. He called his company the Boston Wire Stitcher Company, after the machine it manufactured, and the firm rapidly outgrew its two early homes. In 1904 it settled in a large new factory in East Greenwich, Rhode Island, where the company's descendant flourishes today. Briggs's original machine worked on a conventional principle, which was to feed wire from a head parallel to the seam being stitched, cut off the proper length, bend it into a U-shape, and then drive it into the work and clasp it into what was called a stitch. Because of the size of the feeding head, stitches could not be made closer than twelve inches apart in a single operation. This meant that to bind a small pamphlet took at least two separate stitching operations. In East Greenwich, Briggs developed a machine that fed the wire perpendicular to the seam, cut off a piece, and then turned it before bending it and stitching it into the work. This meant that stitches could be made as close as two inches apart in a single operation, and so binding could proceed at least twice as fast as before.

What made wire-stitching machines so complicated and hence expensive was the mechanism to cut off, turn, and bend the short pieces of wire. To overcome this disadvantage, machines were developed that used individual pieces of wire preformed into a shape that could be driven directly into material being stitched together. The individual pieces were called staples, after the U-shaped pieces of wire with sharp ends that were driven into wooden doors, walls, and posts to secure hooks, hasps, wire, and the like. Although rudimentary stapling machines date from as early as 1877, the first ones had to be fed by hand a staple at a time, and thus were very slow-operating indeed. In 1894 a stapler was introduced that employed a supply chamber into which a line of loose staples could be loaded, but it was a very delicate procedure, for the loose staples had to be pushed off a wooden core onto which they were packed, an operation that had to be done slowly and carefully lest jamming occur. These shortcomings were removed by wrapping a supply of staples in paper around a tin core, thus holding them in place until used; the stapling machine could cut a fresh staple out each time the line was advanced. The driving-and-clinching operation itself was relatively simple and straightforward, principally requiring brute force to push staples through the work and turn them on a sturdy anvil on the back side. Thus, stapling machines could be made inexpensive enough for the smallest printshops and binderies to buy and use, and these were indeed the earliest markets for the new devices.

The first of Briggs's pamphlet-and-magazine staplers were large, freestanding, and foot-operated. They certainly would have been overkill for fastening just a few papers together in an office, and so simple straight pins or the newer wire paper clips continued to be used for that. Hence the Boston Wire Stitcher Company saw business offices as a ready market for a light-duty stapler, and in 1914 offered a desk model priced accordingly. However, the first desk staplers employed loose or paper-wrapped staples, were relatively complicated in their construction, and were prone to jamming. It was not until 1923, at the height of office-efficiency movements, that a simplified desk stapler was introduced and "the use of staples for attaching related papers received its first big push." Soon the company introduced staples glued together in a strip, "which eliminated the disadvantages of handling, loading and feeding which had plagued users of loose staples," and this unpatented idea spread quickly among the growing competition. As stapling machines grew in importance for the Boston Wire Stitcher Company, which had long since moved out of Boston, a distinctive trade name was sought. From the already shorthand name of Boston Stitcher came the contraction Bostitch (pronounced "Boss-titch"), which was registered as a trademark for the stapler line. This name became so prominent that in 1948 the company's name was changed to Bostitch, Inc.

By the early 1930s, desk staplers were smooth-operating little ma-

chines indeed, and changes were generally restricted to cosmetic streamlining in keeping with the times. But the new models also incorporated an easier method of loading and could be used as a tacker as well. Thus, the light desk staple, which had the origins of its name, at least, in the U-shaped, double-pointed tacks that for so long had attached hooks to doors and barbed wire to fence posts, was being employed (not always to the benefit of the surfaces so attacked) to fasten signs and notices to bulletin boards, telephone poles, and school walls and doors. This was but one of the hundreds of variations of fasteners made by just one company, whose house history confirms that "new models are always under development, sometimes to do a job that has not been done before, sometimes to do better or faster a job that is already being done." It is especially out of such comparatives that variations in the form of staplers and all technological artifacts evolve.