

4 | The Panda's Thumb of Technology

THE BRIEF STORY of Jephthah and his daughter (Judg. 11:30–40) is, to my mind and heart, the saddest of all biblical tragedies. Jephthah makes an intemperate vow, yet all must abide by its consequences. He promises that if God grant him victory in a forthcoming battle, he will sacrifice by fire the first living thing that passes through his gate to greet him upon his return. Expecting (I suppose) a dog or a goat, he returns victorious to find his daughter, and only child, waiting to meet him “with timbrels and with dances.”

Handel's last oratorio, *Jephtha*, treats this tale with great power (although his librettist couldn't bear the weight of the original and gave the story a happy ending, with angelic intervention to spare Jephthah's daughter at the price of her lifelong chastity). At the end of Part 2, while all still think that the terrible vow must be fulfilled, the chorus sings one of Handel's wonderful “philosophical” choruses. It begins with a frank account of the tragic circumstance:

How dark, O Lord, are thy decrees! . . .
No certain bliss, no solid peace,
We mortals know on earth below.

Yet the last two lines, in a curious about-face, proclaim (with magnificent musical solidity as well):

Yet on this maxim still obey:
WHATEVER IS, IS RIGHT

This odd reversal, from frank acknowledgment to unreasonable acceptance, reflects one of the greatest biases (“hopes” I like to call them) that human thought imposes upon a world indifferent to our suffering. Humans are pattern-seeking animals. We must find cause and meaning in all events (quite apart from the probable reality that the universe both doesn’t care much about us and often operates in a random manner). I call this bias “adaptationism”—the notion that everything must fit, must have a purpose, and in the strongest version, must be for the best.

The final line of Handel’s chorus is, of course, a quote from Alexander Pope, the last statement of the first epistle of his *Essay on Man*, published twenty years before Handel’s oratorio. Pope’s text contains (in heroic couplets to boot) the most striking paean I know to the bias of adaptationism. In my favorite lines, Pope chastises those people who may be unsatisfied with the senses that nature bestowed upon us. We may wish for more acute vision, hearing, or smell, but consider the consequences.

If nature thunder’d in his op’ning ears
 And stunn’d him with the music of the spheres
 How would he wish that Heav’n had left him still
 The whisp’ring zephyr, and the purling rill!

And my favorite couplet, on olfaction:

Or, quick effluvia darting thro’ the brain,
 Die of a rose in aromatic pain.

What we have is best for us—whatever is, is right.

By 1859, most educated people were prepared to accept evolution as the reason behind similarities and differences among organisms—thus accounting for Darwin’s rapid conquest of the intellectual world. But they were decidedly not ready to acknowledge the radical implications of Darwin’s proposed mechanism of change, natural selection, thus explaining the brouhaha that the *Origin of Species* provoked—and still elicits (at least before our courts and school boards).

Darwin’s world is full of “terrible truths,” two in particular. First, when things do fit and make sense (good design of organisms, harmony of ecosystems), they did not arise because the

laws of nature entail such order as a primary effect. They are, rather, only epiphenomena, side consequences of the basic causal process at work in natural populations—the purely “selfish” struggle among organisms for personal reproductive success. Second, the complex and curious pathways of history guarantee that most organisms and ecosystems cannot be designed optimally. Indeed, to make an even stronger statement, imperfections are the primary proofs that evolution has occurred, since optimal designs erase all signposts of history.

This principle of imperfection has been a major theme of my essays for several years. I call it the panda principle to honor my favorite example, the panda's false thumb. Pandas are the herbivorous descendants of carnivorous bears. Their true anatomical thumbs were, long ago during ancestral days of meat eating, irrevocably committed to the limited motion appropriate for this mode of life and universally evolved by mammalian Carnivora. When adaptation to a diet of bamboo required more flexibility in manipulation, pandas could not redesign their thumbs but had to make do with a makeshift substitute—an enlarged radial sesamoid bone of the wrist, the panda's false thumb. The sesamoid thumb is a clumsy, suboptimal structure, but it works. Pathways of history (commitment of the true thumb to other roles during an irreversible past) impose such jury-rigged solutions upon all creatures. History inheres in the imperfections of living organisms—and thus we know that modern creatures had a different past, converted by evolution to their current state.

We can accept this argument for organisms (we know, after all, about our own appendixes and aching backs). But is the panda principle more pervasive? Is it a general statement about all historical systems? Will it apply, for example, to the products of technology? We might deem this principle irrelevant to the manufactured objects of human ingenuity—and for good reason. After all, constraints of genealogy do not apply to steel, glass, and plastic. The panda cannot shuck its digits (and can only build its future upon an inherited ground plan), but we can abandon gas lamps for electricity and horse carriages for motor cars. Consider, for example, the difference between organic architecture and human buildings. Complex organic structures cannot be re-evolved following their loss; no snake will redevelop front legs. But the apostles of post-modern architecture, in reaction to the

sterility of so many glass-box buildings of the international style, have juggled together all the classical forms of history in a cascading effort to rediscover the virtues of ornamentation. Thus, Philip Johnson could place a broken pediment atop a New York skyscraper and raise a medieval castle of plate glass in downtown Pittsburgh. Organisms cannot recruit the virtues of their lost pasts.

Yet I am not so sure that technology is exempt from the panda principle of history, for I am now sitting face to face with the best example of its application. Indeed, I am in most intimate (and striking) contact with this object—the typewriter keyboard.

I could type before I could write. My father was a court stenographer, and my mother is a typist. I learned proper eight-finger touch-typing when I was about nine years old and still endowed with small hands and weak, tiny pinky fingers. I was thus, from the first, in a particularly good position to appreciate the irrationality of placement for letters on the standard keyboard—called QWERTY by all aficionados in honor of the first six letters on the top letter row.

Clearly, QWERTY makes no sense (beyond the whiz and joy of typing QWERTY itself). More than 70 percent of English words can be typed with the letters DHIATENSOR, and these should be on the most accessible second, or home, row—as they were in a failed competitor to QWERTY introduced as early as 1893. But in QWERTY, the most common English letter, E, requires a reach to the top row, as do the vowels U, I, and O (with O struck by the weak fourth finger), while A remains in the home row but must be typed with the weakest finger of all (at least for the dexterous majority of right-handers)—the left pinky. (How I struggled with this as a boy. I just couldn't depress that key. I once tried to type the Declaration of Independence and ended up with: th t ll men re cre ted equ l.)

As a dramatic illustration of this irrationality, consider the accompanying photograph, the keyboard of an ancient Smith-Corona upright, identical with the one (my dad's original) that I use to type these essays (a magnificent machine—no breakdown in twenty years and a fluidity of motion unmatched by any manual typewriter since). After more than half a century of use, some of the most commonly struck keys have been worn right through the surface into the soft pad below (they weren't solid plastic in those

days). Note that E, A, and S are worn in this way—but note also that all three are either not in the home row or are struck with the weak fourth and pinky fingers in QWERTY.

This claim is not just a conjecture based on idiosyncratic personal experience. Evidence clearly shows that QWERTY is drastically suboptimal. Competitors have abounded since the early days of typewriting, but none has supplanted or even dented the universal dominance of QWERTY for English typewriters. The best-known alternative, DSK, for Dvorak Simplified Keyboard, was introduced in 1932. Since then, virtually all records for speed typing have been held by DSK, not QWERTY, typists. During the 1940s, the U.S. Navy, ever mindful of efficiency, found that the increased speed of DSK would amortize the cost of retraining typists within ten days of full employment. (Mr. Dvorak was not Anton of the *New World Symphony*, but August, a professor of education at the University of Washington, who died disappointed in 1975. Dvorak was a disciple of Frank B. Gilbreth, pioneer of time and motion studies in industrial management.)

Since I have a special interest in typewriters (my affection for them dates to childhood days of splendor in the grass and glory in the flower), I have wanted to write such an essay for years. But I never had the data I needed until Paul A. David, Coe Professor of American Economic History at Stanford University, kindly sent me his fascinating article, "Understanding the Economics of QWERTY: The Necessity of History" (in *Economic History and the Modern Economist*, edited by W. N. Parker, New York, Basil Blackwell Inc., 1986, pp. 30–49). Virtually all the nonidiosyncratic data in this essay come from David's work, and I thank him for this opportunity to satiate an old desire.

The puzzle of QWERTY's dominance resides in two separate questions: Why did QWERTY ever arise in the first place? And why has QWERTY survived in the face of superior competitors?

My answers to these questions will invoke analogies to principles of evolutionary theory. Let me, then, state some ground rules for such a questionable enterprise. I am convinced that comparisons between biological evolution and human cultural or technological change have done vastly more harm than good—and examples abound of this most common of all intellectual traps. Biological evolution is a bad analogue for cultural change



A classic upright typewriter of World War I vintage. Brother to the machine that I use to write these essays.



Notice the patterns of wear for most frequently used keys, as illustrated by breakage through the surface after so many years of striking. In QWERTY, all the most common keys are either not in the home row, or are hit by weak fingers in the home row—thus illustrating the suboptimality of this standard arrangement.



A keyboard for a typewriter made in the 1880's, illustrating one of the many competing non-QWERTY arrangements so common at the time.

because the two systems are so different for three major reasons that could hardly be more fundamental.

First, cultural evolution can be faster by orders of magnitude than biological change at its maximal Darwinian rate—and questions of timing are of the essence in evolutionary arguments. Second, cultural evolution is direct and Lamarckian in form: The achievements of one generation are passed by education and publication directly to descendants, thus producing the great potential speed of cultural change. Biological evolution is indirect and Darwinian, as favorable traits do not descend to the next generation unless, by good fortune, they arise as products of genetic change. Third, the basic topologies of biological and cultural change are completely different. Biological evolution is a system of constant divergence without subsequent joining of branches. Lineages, once distinct, are separate forever. In human history, transmission across lineages is, perhaps, the major source of cultural change. Europeans learned about corn and potatoes from Native Americans and gave them smallpox in return.

So, when I compare the panda's thumb with a typewriter keyboard, I am not attempting to derive or explain technological change by biological principles. Rather, I ask if both systems might not record common, deeper principles of organization. Biological evolution is powered by natural selection, cultural evolution by a different set of principles that I understand but dimly. But both are systems of historical change. More general principles of structure must underlie all systems that proceed through history (perhaps I now only show my own bias for intelligibility in our complex world)—and I rather suspect that the panda principle of imperfection might reside among them.

My main point, in other words, is not that typewriters are like biological evolution (for such an argument would fall right into the nonsense of false analogy), but that both keyboards and the panda's thumb, as products of history, must be subject to some regularities governing the nature of temporal connections. As scientists, we must believe that general principles underlie structurally related systems that proceed by different overt rules. The proper unity lies not in false applications of these overt rules (like natural selection) to alien domains (like technological change), but in seeking the more general rules of structure and change themselves.

The Origin of QWERTY: True randomness has limited power to intrude itself into the forms of organisms. Small and unimportant changes, unrelated to the working integrity of a complex creature, may drift in and out of populations by a process akin to throwing dice. But intricate structures, involving the coordination of many separate parts, must arise for an active reason—since the bounds of mathematical probability for fortuitous association are soon exceeded as the number of working parts grows.

But if complex structures must arise for a reason, history may soon overtake the original purpose—and what was once a sensible solution becomes an oddity or imperfection in the altered context of a new future. Thus, the panda's true thumb permanently lost its ability to manipulate objects when carnivorous ancestors found a better use for this digit in the limited motions appropriate for creatures that run and claw. This altered thumb

then becomes a constraint imposed by past history upon the panda's ability to adapt in an optimal way to its new context of herbivory. The panda's thumb, in short, becomes an emblem of its different past, a sign of history.

Similarly, QWERTY had an eminently sensible rationale in the early technology of typewriting but soon became a constraint upon faster typing as advances in construction erased the reason for QWERTY's origin. The key (pardon the pun) to QWERTY's origin lies in another historical vestige easily visible on the second row of letters. Note the sequence: DFGHJKL—a good stretch of the alphabet in order, with the vowels E and I removed. The original concept must have simply arrayed the letters in alphabetical order. Why were the two most common letters of this sequence removed from the most accessible home row? And why were other letters dispersed to odd positions?

Those who remember the foibles of manual typewriters (or, if as hidebound as yours truly, still use them) know that excessive speed or unevenness of stroke may cause two or more keys to jam near the striking point. You also know that if you don't reach in and pull the keys apart, any subsequent stroke will type a repetition of the key leading the jam—as any key subsequently struck will hit the back of the jammed keys and drive them closer to the striking point.

These problems were magnified in the crude technology of early machines—and too much speed became a hazard rather than a blessing, as key jams canceled the benefits of celerity. Thus, in the great human traditions of tinkering and pragmatism, keys were moved around to find a proper balance between speed and jamming. In other words—and here comes the epitome of the tale in a phrase—QWERTY arose in order to slow down the maximal speed of typing and prevent jamming of keys. Common letters were either allotted to weak fingers or dispersed to positions requiring a long stretch from the home row.

This basic story has gotten around, thanks to short takes in *Time* and other popular magazines, but the details are enlightening, and few people have the story straight. I have asked nine typists who knew this outline of QWERTY's origin and all (plus me for an even ten) had the same misconception. The old machines that imposed QWERTY were, we thought, of modern de-

sign—with keys in front typing a visible line on paper rolled around a platen. This leads to a minor puzzle: Key jams may be a pain in the butt, but you see them right away and can easily reach in and pull them apart. So why QWERTY?

As David points out, the prototype of QWERTY, a machine invented by C. L. Sholes in the 1860s, was quite different in form from modern typewriters. It had a flat paper carriage and did not roll paper right around the platen. Keys struck the paper invisibly from beneath, not patently from the front as in all modern typewriters. You could not view what you were typing unless you stopped to raise the carriage and inspect your product. Keys jammed frequently, but you could not see (and often did not feel) the aggregation. Thus, you might type a whole page of deathless prose and emerge only with a long string of E's.

Sholes filed for a patent in 1867 and spent the next six years in trial-and-error efforts to improve his machine. QWERTY emerged from this period of tinkering and compromise. As another added wrinkle (and fine illustration of history's odd quirks), R joined the top row as a last-minute entry, and for a somewhat capricious motive according to one common tale (perhaps apocryphal)—for salesmen could then impress potential buyers by smooth and rapid production of the brand name TYPE WRITER, all on one row. (Although I wonder how many sales were lost when TYPE EEEEEEE appeared after a jam!)

The Survival of QWERTY: We can all accept this story of QWERTY's origin, but why did it persist after the introduction of the modern platen roller and front-stroke key? (The first typewriter with a fully visible printing point was introduced in 1890.) In fact, the situation is even more puzzling. I thought that alternatives to keystroke typing only became available with the IBM electric ball, but none other than Thomas Edison filed a patent for an electric print-wheel machine as early as 1872, and L. S. Crandall marketed a writing machine without typebars in 1879. (Crandall arranged his type on a cylindrical sleeve and made the sleeve revolve to the required letter before striking the printing point.)

The 1880s were boom years for the fledgling typewriter industry, a period when a hundred flowers bloomed and a hundred

schools of thought contended. Alternatives to QWERTY were touted by several companies, and both the variety of printing designs (several without typebars) and the improvement of key-stroke typewriters completely removed the original rationale for QWERTY. Yet during the 1890s, more and more companies made the switch to QWERTY, which became an industry standard by the early years of our century. And QWERTY has held on stubbornly, through the introduction of the IBM Selectric and the Hollerith punch card machine to that ultimate example of its nonnecessity, the microcomputer terminal.

To understand the survival (and domination to this day) of drastically suboptimal QWERTY, we must recognize two other commonplaces of history, as applicable to life in geological time as to technology over decades—contingency and incumbency. We call a historical event—the rise of mammals or the dominance of QWERTY—contingent when it occurs as the chancy result of a long string of unpredictable antecedents, rather than as a necessary outcome of nature's laws. Such contingent events often depend crucially upon choices from a distant past that seemed tiny and trivial at the time. Minor perturbations early in the game can nudge a process into a new pathway, with cascading consequences that produce an outcome vastly different from any alternative.

Incumbency also reinforces the stability of a pathway once the little quirks of early flexibility push a sequence into a firm channel. Suboptimal politicians often prevail nearly forever once they gain office and grab the reins of privilege, patronage, and visibility. Mammals waited 100 million years to become the dominant animals on land and only got a chance because dinosaurs succumbed during a mass extinction. If every typist in the world stopped using QWERTY tomorrow and began to learn Dvorak, we would all be winners, but who will bell the cat or start the ball rolling? (Choose your cliché, for they all record this evident truth.) Stasis is the norm for complex systems; change, when provoked at all, is usually rapid and episodic.

QWERTY's fortunate and improbable ascent to incumbency occurred by a concatenation of circumstances, each indecisive in itself, but all probably necessary for the eventual outcome. Remington had marketed the Sholes machine with its QWERTY key-

board, but this early tie with a major firm did not secure QWERTY's victory. Competition was tough, and no lead meant much with such small numbers in an expanding market. David estimates that only 5,000 or so QWERTY machines existed at the beginning of the 1880s.

The push to incumbency was complex and multifaceted, dependent more upon the software of teachers and promoters than upon the hardware of improving machines. Most early typists used idiosyncratic hunt-and-peck, few-fingered methods. In 1882, Ms. Longley, founder of the Shorthand and Typewriter Institute in Cincinnati, developed and began to teach the eight-finger typing that professionals use today. She happened to teach with a QWERTY keyboard, although many competing arrangements would have served her purposes as well. She also published a popular do-it-yourself pamphlet. At the same time, Remington began to set up schools for typewriting using (of course) its QWERTY standard. The QWERTY ball was rolling but this head start did not guarantee a place at the summit. Many other schools taught rival methods on different machines and might have gained an edge.

Then a crucial event in 1888 probably added the decisive increment to QWERTY's small advantage. Longley was challenged to prove the superiority of her eight-finger method by Louis Taub, another Cincinnati typing teacher, who worked with four fingers on a rival non-QWERTY keyboard with six rows, no shift action, and (therefore) separate keys for upper- and lowercase letters. As her champion, Longley engaged Frank E. McGurrin, an experienced QWERTY typist who had given himself a decisive advantage that, apparently, no one had utilized before. He had memorized the QWERTY keyboard and could therefore operate his machine as all competent typists do today—by what we now call touch-typing. McGurrin trounced Taub in a well-advertised and well-reported public competition.

In public perception, and (more important) in the eyes of those who ran typing schools and published typing manuals, QWERTY had proved its superiority. But no such victory had really occurred. The tie of McGurrin to QWERTY was fortuitous and a good break for Longley and for Remington. We shall never know why McGurrin won, but reasons quite independent of QWERTY cry

out for recognition: touch-typing over hunt-and-peck, eight fingers over four fingers, the three-row letter board with a shift key versus the six-row board with two separate keys for each letter. An array of competitions that would have tested QWERTY were never held—QWERTY versus other arrangements of letters with both contestants using eight-finger touch-typing on a three-row keyboard, or McGurrin's method of eight-finger touch-typing on a non-QWERTY three-row keyboard versus Taub's procedure to see whether the QWERTY arrangement (as I doubt) or McGurrin's method (as I suspect) had secured his success.

In any case, the QWERTY steamroller now gained crucial momentum and prevailed early in our century. As touch-typing by QWERTY became the norm in America's typing schools, rival manufacturers (especially in a rapidly expanding market) could adapt their machines more easily than people could change their habits—and the industry settled upon the wrong standard.

If Sholes had not gained his tie to Remington, if the first typist who decided to memorize a keyboard had used a non-QWERTY design, if McGurrin had a bellyache or drank too much the night before, if Longley had not been so zealous, if a hundred other perfectly possible things had happened, then I might be typing this essay with more speed and much greater economy of finger motion.

But why fret over lost optimality. History always works this way. If Montcalm had won a battle on the Plains of Abraham, perhaps I would be typing *en français*. If a portion of the African jungles had not dried to savannas, I might still be an ape up a tree. If some comets had not struck the earth (if they did) some 60 million years ago, dinosaurs might still rule the land, and all mammals would be rat-sized creatures scurrying about in the dark corners of their world. If *Pikaia*, the only chordate of the Burgess Shale, had not survived the great sorting out of body plans after the Cambrian explosion, mammals might not exist at all. If multicellular creatures had never evolved after five-sixths of life's history had yielded nothing more complicated than an algal mat, the sun might explode a few billion years hence with no multicellular witness to the earth's destruction.

Compared with these weighty possibilities, my indenture to QWERTY seems a small price indeed for the rewards of history.

For if history were not so maddeningly quirky, we would not be here to enjoy it. Streamlined optimality contains no seeds for change. We need our odd little world, where QWERTY rules and the quick brown fox jumps over the lazy dog.*

Postscript

Since typing falls into the category of things that many, if not most of us, can do (like walking and chewing gum simultaneously) this essay elicited more commentary than most of my more obscure ramblings.

Some queried the central premises and logic. An interesting letter from Folsom Prison made a valid point in the tough humor of such institutions. (I receive many letters from prisoners and am always delighted by such reminders that, at least for many people, the quest for knowledge never abates, even in most uncongenial temporary domiciles):

Some of us were left with a nagging question: If the hunt 'n peck method prevailed until around 1882, how could Sholes or his cohorts have "relegated common letters to weak fingers" when there were no weak fingers, just hunt 'n peck type fingers? At least none of the hunt 'n peck typing clerks or cops around here use the weak fingers. If you could find the time to answer this it would really be appreciated and could serve to reduce the likelihood of increased violence at Folsom between opposing QWERTY origin factions.

My correspondent is quite right, and I misspoke (I also trust that recent tension at Folsom had sources other than the great typewriter wars—yes, I did answer the letter promptly). Fortu-

*I must close with a pedantic footnote, lest nonaficionados be utterly perplexed by this ending. This quirky juxtaposition of uncongenial carnivores is said to be the shortest English sentence that contains all twenty-six letters. It is, as such, *de rigueur* in all manuals that teach typing.

nately, my hypothesis is secure against my own carelessness—for Sholes needed simply to separate frequently struck keys to avoid jamming. The finger used to strike mattered little (I also rather suspect that many people were experimenting with many-fingered typing before the full four-fingered methods became canonical).

But the vast bulk of correspondence, more than 80 percent, took issue with my throwaway and tangential last line—thanks to our long-standing and happy fascination with words and word games. I gave the conventional typist's sentence as being the shortest phrase using all letters:

The quick brown fox jumps over the lazy dog.

I have since learned that sentences containing all letters of the alphabet are called “pangrams,” and that the quest for the shortest represents at least a minor industry, with much effort spent, and opposing factions with strong passions. Many readers suggested, as a well-known alternative with three fewer letters (32 versus 35),

Pack my box with five dozen liquor jugs.

Zoological enthusiasts and prohibitionists then retort that the fox-dog classic can still tie by dropping the first article and becoming only slightly less grammatical:

Quick brown fox jumps over the lazy dog.

But Ted Leather wins this limited derby for shortest sensible pangram with the 31-stroke

Jackdaws love my big sphinx of quartz.

We now enter the world of arcana. Can shorter pangrams be made? Can the ultimate 26-letter sentence be constructed? This quest has so far stymied all wordsmiths. Using common words only, we can get down to 28 (but only by the slightly dishonorable route of using proper names):

Waltz, nymph, for quick jigs vex Bud.

And to 27, with some archaic orthography:

Frowzy things plumb vex'd Jack Q.

But for the ultimate of 26, we either use initials in abundance (which doesn't seem quite fair),

J. Q. Schwartz flung V. D. Pike my box,

or we avoid names and initials, but employ such unfamiliar and marginally admissable words that an equal feeling of dissatisfaction arises,

Zing! Vext cwm fly jabs Kurd qoph.

A *cwm* is a mountain hollow in Wales, while *qoph*, the nineteenth letter of the Hebrew alphabet, has been drawn (and has attracted the ire of an immigrant fly) by a member of an Iranian minority. Sounds awfully improbable.

My favorite proposal for a 26-letter pangram requires an entire story for comprehension (thanks to Dan Lufkin of Hood College):

During World War I, Lawrence's Arab Legion was operating on the southern flank of the Ottoman Empire. Hampered by artillery fire from across a river, Lawrence asked for a volunteer to cross the river at night and locate the enemy guns. An Egyptian soldier stepped forward. The man was assigned to Lawrence's headquarters [G.H.Q. for "general headquarters"—this becomes important later] and had a reputation for bringing bad luck. But Lawrence decided to send him. The mission was successful and the soldier appeared, at dawn the next morning, at a remote sentry post near the river, dripping wet, shivering, and clad in nothing but his underwear and native regimental headgear. The sentry wired to Lawrence for instructions, and he replied:

Warm plucky G.H.Q. jinx, fez to B.V.D.'s.

A free copy of this and all my subsequent books to anyone who can construct a 26-letter pangram with common words only and no proper names.