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The Optimization Problem

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In 1875, two Royal Navy ships sailed for the North Pole with the fleet's antiscorbutic ration aboard, and the expedition came home a year early because scurvy had torn through its spring sledging parties out on the ice. The juice was in the barrels. The barrels wore the right name. A century of naval medicine said the fleet was protected, and the disease that citrus had beaten in 1795 came up out of the past as though the cure had never existed.

To understand what was in those barrels, go back eighty years. For three centuries scurvy had constrained long voyages and emptied whole fleets, a slow and gruesome disease with nothing aboard that could interrupt it. The suspicion that citrus could was old; the proof and the policy arrived in 1795, when the Admiralty put lemon juice into the daily ration and scurvy all but vanished from the service. The cure acted with a speed the age called miraculous. Nobody knew why it worked, and for sixty years nobody needed to know. The operational reading was simple and true: citrus prevents scurvy.

Around 1860 the Navy changed fruit. The reasoning deserves respect, because it was optimization performed carefully on the best model available. The science of the day identified acidity as the operative property of the cure, and West Indian limes were more acidic than the Sicilian lemons the Navy had been buying, and they grew inside the empire rather than in a foreign supply chain. On every measure the Admiralty could see, the substitution improved the ration: sharper fruit, surer supply. Nobody proposed tolerating a weaker cure for convenience. The decision-makers believed they were strengthening the relevant property while strengthening everything around it, and in time the change even gave the world its name for British sailors: limey, after the new fruit, the one that was quietly failing them.

The medicine was never the acid. The substance that did the work was unnamed, unmeasured, and unsuspected, and a lime starts with a fraction of the quantity a lemon has. And the fruit was one of several conditions moving at once. Juice for the fleet waited in settling tanks and passed through copper piping, and copper is chemically active: in a vat of juice it catalyzes the destruction of the antiscorbutic substance far faster than air alone. Around fruit and manufacture alike, the service itself was changing, steam reshaping voyages and provisioning across the same decades. Each change was locally reasonable, none was coordinated with the others, and all of them interacted through a property that appeared in no ledger. The floor was re-laid one board at a time while every label in the storehouse was left exactly where it was.

The fleet noticed none of it, and the reason is the most treacherous gear in the machine. The changing conditions of ordinary service, shorter passages, more ports, readier fresh food, were reducing the severity of the nutritional test in the same years the ration was quietly weakening. Every healthy year arrived as confirmation. The juice was aboard, the men were well, the barrel said antiscorbutic. The test was getting easier at exactly the rate the answer was getting worse.

Then the Nares expedition restored the old conditions, months on the ice with no fresh anything, and the eighteenth century returned with them. What happened next is the part worth studying, because the system responded the way a healthy system should. It checked. Parliament opened an inquiry; the Admiralty convened a committee. The check was honest, and the check was wrong. It compared orders to records and records to records, found that the sledge parties had gone out without their lime juice, and faulted the omission and the captain who allowed it. Nobody could assay the juice for the property that mattered, because no such assay yet existed anywhere in the world. And neither body recognized that the fruit had been changed fifteen years earlier; the substitution was unrecoverable through the records the inquiry used. The records agreed with each other, their agreement was genuine, and it certified nothing about the property under examination.

The verdict produced the saddest turn in the story. The Navy retained the ration and lost its faith in citrus. Scurvy with lime juice aboard, the service press reasoned, proved the old cure had been a delusion all along, and into the vacancy came new theories of the disease. Expeditions of the following decades went onto the ice defended by doctrine instead of a cure. Having checked honestly and concluded wrongly, the institution corrected the one component of the entire system that had never failed: its confidence in the fruit.

The real correction came from outside the fleet and from a laboratory chasing a different disease. In 1907, two researchers in Oslo produced scurvy in guinea pigs, the first animal model anyone had, and for the first time the cure could be measured instead of trusted. When the bioassays were run in the following decade, fresh lime juice tested at about a quarter of the antiscorbutic strength of fresh lemon juice, and the preserved lime juice the Navy had actually been issuing tested at little to none. By 1932 the nameless substance had a name, vitamin C, and once it had a name, that class of substitution lost its cover. Change the fruit now, change the piping, shorten the voyage, and each change can be evaluated against the property that does the work. The science made the old cure safe to change.

Now step out of the story and look at its structure.

The 1860 decision succeeded on its own terms. Acidity went up, supply grew surer, and the change destroyed the term that mattered. The failure was sharper than irrelevance: the proxy moved opposite to the outcome it represented. A measured quantity can do worse than drift away from the thing it protects. It can improve while the protected outcome collapses, and from that point forward, every clean reading of the proxy becomes an argument against reopening the question.

Beneath the proxy failure is a more general condition. Institutions inherit practices that work for reasons nobody wrote down, because the reason never needed defending. The operative property of a working practice is often precisely the part that was never represented, since representation is expensive and the practice was already working. A century of success establishes that such a practice can survive the conditions that have tested it. It establishes nothing about which of its represented variables are safe to improve, because optimization operates on the representation, and whatever the representation omits is handed to luck.

The defense available in 1860 required no prediction of the eventual failure mode. Nobody needed to foresee Nares, or steam, or copper chemistry, or to suspect a vitamin that would go unnamed for another seventy years. The decision needed only to leave its own reasoning behind in a form a later reader could find: we formerly issued Sicilian lemon; we now issue West Indian lime; we believe acidity is the operative property; here is why we expect the substitution to preserve the effect. A record of that grade gives reality a future vote. When 1875 delivered contradictory evidence, an inquiry that could reach the 1860 wager could have asked the productive question, whether the assumption had survived contact with the world. Instead the wager was unrecoverable through the records the inquiry used, and the only question those records could answer was compliance. So compliance was the question the inquiry asked. Institutions ask the questions their trace can answer.

A hundred and sixty years later, the pattern has a new engine. Take any inherited practice and put it through modern optimization, machine learning over the process, automated procurement, consolidated suppliers, restructured logistics, and the tooling changes the fruit, the vessel, the piping, and the route within the same short span. The changes arrive radially, from every direction at once, each one defensible on the properties the model represents. The practices most exposed may well be the oldest, whose operative properties were solved so long ago and so thoroughly that nobody alive can say what they are, and whose low-technology fixes are the least documented, because a fix that works is a fix nobody defends in writing.

And the modern case can lose the one mercy the Navy had. In 1860 the easing of the test was a coincidence: changing service conditions happened to soften the verification environment while the ration degraded, and the two curves crossing was bad luck. Modern systems can go one step further, because the optimizer and the verifier can share a substrate. The tooling that rewrites a process can also generate the reports that certify it, and where it does, the test eases in step with the change by construction. The Victorian Navy had to be unlucky. A modern institution can build the unluck in.

None of this indicts the fruit. The lime was blameless, a perfectly respectable lime with exactly the antiscorbutic properties reality assigned it. The fairest charge against the Admiralty is also the sharpest one: nobody could have preserved what nobody yet knew, and somebody could have preserved what the Navy changed. The failure belonged to a representation that did not preserve the difference between the two fruits and had no place at all for the thing that cured. For fifteen years the barrels wore the right name and the fleet passed every test the calm sea administered.

The readings were clean. The cure was already gone.