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**Bicycle Balls:**

**A Lesson in High-Tech Productivity**

**from 1911**

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**Any questions?**

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At about 10:35 on the morning of December 17, 1903, Orville Wright made the first sustained powered flight in aircraft heavier than air. The decision that took him aloft was a process that had begun twenty-five years earlier, when Orville was seven years old and his brother, Wilbur, eleven. In 1878, the boys’ father, Milton Wright, a bishop in the United Brethren Church who held strong beliefs, including a belief in the value of educational toys, gave Wilbur and Orville a present. It was a toy helicopter designed by an early French aeronautical experimenter named Alphonse Pénaud. In 1912, during testimony in one of a number of patent suits he and his brother continually became involved in, Orville described the toy as “actuated by a rubber spring which would [drive a four-bladed rotor and] lift itself into the air.” Orville explained that “Our interest [in flight] began when we were children,” when “Father brought home to us [this] small toy.” It so fascinated him and Wilbur that “We built a number of copies of this toy, which flew successfully.” The boys took action and “built the toy on a much larger scale,” but “it failed to work so well.”

 The Wright boys had hoped to build an aircraft sufficiently large and powerful to enable them to fly, but they never did it, not as children, anyway, And when they did grow to adulthood, they went into a different line of work altogether, opening up a bicycle shop in their hometown of Dayton, Ohio. From dreams of powered heavier-than-air human flight to running an Ohio bike shop may seem like a real come-down. Literally.

 But not so fast. At the end of the nineteenth century, bicycles were at the cutting edge of transportation technology. Moreover, seemingly everybody wanted in on it. There was a turn-of-the-century bicycle boom, which led inventors and manufacturers to develop new technologies that quickly moved the bicycle from the “penny farthing” high-wheelers to highly efficient machines. During the last decade of the nineteenth century, one-third or more of all new patent applications at the U.S Patent Office were related to bicycles. Both design and materials advanced. Wood originally dominated but steel soon caught on and even the most advanced metal of the late nineteenth century, aluminum, was used to save weight and gain speed. While automobiles, which emerged at the very end of the 1800s, were called horseless carriages, the very first example was actually a tricycle on which a small steam engine was mounted.

 So, the two brothers in their Dayton shop were storekeepers, mechanics, makers, and high technologists. No wonder they got into airplanes. Flying machines, after all, were not so much a quantum leap as they were a logical step up from the cutting-edge bikes the Wrights purveyed. Think about it. Designing, building, and riding a two-wheel bicycle involves speed, balance, and control, which makes the technology about the closest you can get to flying without actually leaving the ground. The Wrights opened their Wright Cycle Exchange in 1892. Simultaneously, they continued to pursue flight. About 1890, they religiously followed news reports about the exploits of Otto Lilienthal, a German experimenter with gliders. In 1896, they read the news that Lilienthal had been killed in the crash of one of his gliders. Far from being discouraged, Wilbur later recalled, “The brief notice of his death … aroused a passive interest which had existed from my childhood.” Wilbur and Orville Wright started thinking seriously and practically about manned flight, and in 1899, they read a book on ornithology that included a “Dissertation on Aeronautics.” Orville later explained that he and his brother concluded that there was nothing “about a bird that could not be built on a larger scale and used by man. If the bird’s wings would sustain it in the air without the use of any muscular effort, we did not see why man could not be sustained by the same means.” Just three years later, they were flying gliders—as pilots—having solved the problem that had killed Lilienthal: inability to control the flight. At Kitty Hawk, North Carolina, on October 23, Orville glided for 26 seconds over 622.5 feet. So, they figured it was time to build a gas motor, put a propeller on it, and attach the assembly to the glider.

On a blustery Kitty Hawk morning, December 14, 1903, they flipped a coin decide who would fly first. Wilbur won, but he stalled the machine on takeoff, and it fell to earth barely sixty feet beyond the end of the rail that had been rigged for launching it. Repairs took the rest of the day and the next. The craft was ready by December 16, but the wind was all wrong. At last, on December 17, Wilbur agreed it was Orville’s turn. He covered 120 feet in 12 seconds—in the first powered and manned flight by a heavier-than-air craft. They kept at that day. And by the fourth and final launch, Wilbur Wright flew 852 feet in 59 seconds, a 1,022 percent advance in the very first day of human flight.

They did not stop making bicycles. In fact, making them had drawn on their skills in metalwork, lightweight design, chain drives, and, most basic of all, the use of ball bearing. They understood the demand for what were called “bicycle balls.” These ball bearings, either loose or packed into rings, were essential to the bicycles they built as well as those they serviced and repaired. They even sold bicycle balls separately to bicycle do-it-yourselfers. The things flew off the shelf. And this demand was national, even global. At the turn of the nineteenth century, people couldn’t get enough bicycle balls.

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In 1856, Frederick Winslow Taylor was born in Germantown, Pennsylvania, the son of Franklin Taylor, a wealthy lawyer, and Emily Winslow, descended from Edward Winslow, one of the fifteen original *Mayflower* Pilgrims. A blue blood presumably destined to a blue-blood white-collar life, young Frederick set out to be a lawyer but found that reading lawbooks with his severely astigmatic eyes gave him unbearable headaches. So, Harvard diploma and all, the blue blood went blue-collar, finding work as a patternmaker and machinist at a Philadelphia pump company. He rose quickly and by the 1880s was a foreman at the Midvale Steel Works in Nicetown, Pennsylvania.

Despite his eye problems, Taylor had a vision. And he saw plenty. The Industrial Revolution had become a Machine Revolution, but Taylor saw that despite the growing mechanization at the Midvale plant, the rate of production was still largely dependent on the pace and methods set not by the least skilled human workers but the most skilled. The idiosyncrasy of the craftsman, Taylor concluded, actually retarded the rate of production, especially partially mechanized production. To optimize productivity, Taylor reasoned, managers, not workers, must take control of all processes, prescribing each method employed and movement made so as to coordinate everyone’s labor. The managers were to set the pace. In this dance, only the lockstep would be tolerated.

Not that Taylor believed the managers were naturally omniscient. No, he argued, managers must base their instructions on the meticulous observation and analysis of each manufacturing step—down to each movement made by each worker. Rigorous collation of these observations would then allow the managers to determine the best method for getting each job done. In 1911, he took everything he knew about optimizing productivity and distilled it into a book, *Principles of Scientific Management.*

For Taylor, there were four main pillars of scientific management:

1. Develop the science of every task in whatever processes your business required. If, for example, it was bricklaying, create, based on close observation and measurement, strict rules for each motion of each worker involved in the laying of bricks. Along with this, perfect and standardize the tools and working conditions of the trade. Both the rules promulgated and the tools used had to be the products of experiments closely observed, with results precisely measured. Most important, the experimentation, analysis, conclusions drawn, and procedures, rules, and tool design created had to be the work of managers, not the laborers or craftspeople. Workers had to adhere to the rules and use the tools.

2. Select the best workers and give them the best training, all based on the requirements of the rules that had been scientifically arrived at. Starting with workers of high potential *for the task at hand*, train them to be first-class bricklayers, retaining and rewarding those who embrace the methods management prescribes and eliminating those who either cannot or will not adopt the methods that scientific observation has proved best..

3. Provide managers who continuously observe, train, teach, and help the first-class bricklayer to perfectly and efficiently execute the science of bricklaying. A crucial dimension of this third pillar is that the first-class workers must be rewarded, typically be a substantial *daily* bonus for working fast and producing work of high quality—and doing these things as instructed.

4. Understand that, in a business operated on scientific principles of management, work and responsibility are divided very nearly equally between the worker and the management. Scientific managers do their work essentially side-by-side with the workers, helping them, encouraging them, and facilitating their success on daily basis.

 In a forthcoming paper, we will discuss the contemporary equivalent of Taylor’s scientific management with emphasis on creating the “science” of essential processes—and not so much manual processes, which was Taylor’s focus, but what the economist and management theorist Peter Drucker called “knowledge work.” For the rest of this paper, however, I want to pursue Taylor’s application of scientific management to what he called the “scientific selection of the workman,” substituting today the far more appropriately gender-neutral term, “worker.”

 This is where bicycle balls come in. “When the bicycle craze was at its height some years ago,” Taylor wrote in 1911, “several million small balls made of hardened steel were used annually in bicycle bearings.”

 What was happening at the time is familiar in our own era. A breakthrough in high technology—the modern bicycle, of the kind the Wright Brothers themselves were building—created a sudden booming demand not just for the bicycles themselves but for their essential components. Think of the modern demand created by computers, smartphones, and smart technology in general for advanced chip components. The businesses that get the edge on both innovation and competitive production were the winners at the turn of nineteenth century even as they are in these first decades of the twenty-first century.

 Ball bearings are ubiquitous in and essential to any rotational mechanism. During World War II, the U.S. Army Air Forces risked—indeed, spent—the lives of more than 600 airmen and suffered the loss of more than 350 four-engine heavy bombers in two raids on Nazi ball-bearing plants in Schweinfurt, Germany (August 17 and October 14, 1943). Disrupt ball-bearing production, it was thought, and the Allies would bring the German military to literally grinding halt.[[1]](#endnote-1) The availability of ball bearings are an existential issue in modern civilization.

 It turns out that ball bearings are not easy to make, and the diminutive ball bearings required to allow a bicycle axle to turn with a minimum of friction and wobble. Taylor counted twenty or more operations involves in making the bearings, perhaps the most important of which was “inspecting them after final polishing so as to remove all fire-cracked or otherwise imperfect balls before boxing.” He was “given the task of systematizing the largest bicycle ball factory in this country.” The workers devoted to the inspection task were 120 or more “girls,” most of whom had been doing the work for ten or more years and were “old bands … skilled at their jobs.”

Taylor admitted that it was impossible “to change rapidly from the old independence of individual day work to scientific cooperation,” but he was determined to do as much as he could as quickly as possible. As always, he began by observing, evaluating, and measuring. He found that the girls—they were correctly called “inspectors”—worked 10.5 hours per day, with a half-day on Saturday. As he explains:

Their work consisted briefly in placing a row of small polished steel balls on the back of the left hand, in the crease between two of the fingers pressed together, and while they were rolled over and over, they were minutely examined in a strong light, and with the aid of a magnet held in the right hand, the defective balls were picked out and thrown into especial boxes. Four kinds of defects were looked for-dented, soft, scratched, and fire-cracked—and they were mostly so minute as to be invisible to an eye not especially trained to this work. It required the closest attention and concentration, so that the nervous tension of the inspectors was considerable, in spite of the fact that they were comfortably seated and were not physically tired.

 It was immediately apparent to Taylor that “a very considerable part of the ten and one-half hours during which the girls were supposed to work was really spent in idleness because the working period was too long.” His first step, therefore, was to shorten the working hours, with the objective of ensuring that the inspectors could “‘work while they work’” and ‘play while they play,’ and not mix the two.”

Taylor enlisted the foreman, a veteran of many years, “to interview one after another … the better inspectors and the more influential girls and persuade them that they could do just as much work in ten hours each day as they had been doing in ten and one-half hours.” Though the day would be shortened by a half-hour, they would be paid the same wage as they had been paid for 10.5 hours. Although the inspectors whom the foreman had interviewed agreed, Taylor made the mistake of putting the proposal to a vote. All voted against any change. After a few months of this, Taylor experimentally shortened the day in steps” 10 hours, 9.5., 9, and 8.5. The daily pay remained unchanged, and (as Taylor knew it would) production increased rather than diminished.

Taylor brought in experts to evaluate the “personal coefficient” of the inspectors. This value was learned by “suddenly bringing some object, the letter A or B for instance, within the range of vision of the subject, who, the instant he recognizes the letter has to do some definite thing, such as to press a particular electric button. The time which elapses from the instant the letter comes in view until the subject presses the button is accurately recorded by a delicate scientific instrument.” People who possess unusually quick powers of perception accompanied by quick responsive action have a low personal coefficient. Those who have slow perception and slow action have a high personal coefficient. Taylor was looking for bicycle ball inspectors with a low personal coefficient, and he therefore culled out inspectors who had a high personal coefficient. He noted that “many of the most intelligent, hardest working, and most trustworthy girls” had to be removed as inspectors but, where possible, because of their other qualities, were reassigned.

Taylor introduced other changes. He observed that pay is pegged to the quantity of work done, quality tends to deteriorate. Since quality was the very essence of the work of the inspectors, he needed to introduce into the structure and process of their task a way to “make it impossible for them to slight their work without being, found out.” He introduced what he called “over-inspection.” Each day, he gave to four of the most reliable inspectors a lot of bicycle balls that had been inspected the day before by one of the “regular” inspectors. As a further check, one of the lots the four over-inspectors examined was inspected by the chief inspector, a veteran of the work, who had amply demonstrated her “especial accuracy and integrity.” Finally, every two or three days, a lot of bicycle balls was prepared by the foreman. He counted out a number of perfect specimens, to which he added a recorded number of balls with defects of various kind. This lot was given to inspectors as well as over-inspectors but not identified as a prepared lot. The number defective balls was counted and compared to the number the foreman had recorded.

These steps took time and person-hours, but the slightest imperfection in a ball bearing could not be tolerated. Over time, evaluation of the inspection, over-inspection, and final check confirmed that quality was not deteriorating. With quality—the primary objective of inspection—assured, Taylor went on to develop the means of increasing output.

The first step in improving daily output was to keep an accurate daily record of both quantity and quality of production. Numbers left no room for guesses or for the exercise of any foreman’s biases or preconceived perceptions. Using the record, foremen incentivized the best work by increasing the wages of inspectors who turned out a large quantity and good quality. At the same time, the pay of those who did less than optimal work might be reduced. Those who proved, by the numbers, slow or careless, were fired.

While evaluation of inspectors by the numbers—quantity of high-quality work produced—was ongoing, Taylor used time and motion studies to minutely examine how each inspector used her time. Armed with stop-watches and record blanks, he and his assistants compiled the data by which they could determine how fast each kind of inspection could and should be done and then to precisely establish the conditions under which each inspector would their quickest and best work—without pushing so hard that inspectors would become fatigued.

The study revealed that the inspectors spent much of their time either in semi-idleness, conversation while half-working, and even simply doing nothing. Even after the workday had been shortened from 10.5 to 8.5 hours, it was found that after about 1.5 hours of continuous work, they showed signs of restlessness. Clearly, they needed a rest. Taylor introduced a ten- minute break every hour and fifteen minutes—two in the morning and two in the afternoon. Inspectors were *required* to take these recesses and were encouraged to get up, leave their seats, walk around, talk, and so on. When it was time to work, they were deliberately seated far apart, so that they could not (conveniently) talk to one another. The shorter workday, with brief but regular and enforced breaks, enabled the inspectors to work steadily, with care, efficiency, and integrity. In exchange, Taylor laid out a system of high wages to go along with maximum output and best quality. The combination made for a low cost of labor.

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Frederic Winslow Taylor’s most famous scientific management breakthrough came early in his career when Bethlehem Steel hired him to make the 600 men the company employed to shovel iron ore into its open-hearth furnaces more efficient shovelers. Shoveling was considered a pretty primitive task. No matter, Taylor believed it could be improved by scientific management. He started with the most basic assumption in shoveling, namely that there must be an optimum shovel load by which a shoveler will do his best day’s work. Foremen and shovelers alike had opinions on how big or small this load was. Instead of listening to the opinions, Taylor identified the best shovelers among the 600 at Bethlehem and observed and recorded their performance with different measured shovel loads, ranging from 10 pounds to 40. He discovered that shovels holding exactly 21 pounds resulted in the most productive shoveling among the top shovelers. Next, he experimented with different kinds of shovels—spades, flat shovels, rounded shovels, shovels with longer or short handles, shovels with a hand grip perpendicular to the handle, and so on. He moved on from gathering shovel data to getting data on shoveling techniques. Again, he observed and recorded until he formulated an exact prescription for optimal shoveling in terms of load, shovel type, and shoveling technique.

 Applying scientific management to bicycle balls were a big step beyond shoveling. Shoveling requires neither great precision nor concentration. In contrast, producing perfect ball bearings for high-tech machinery—including bicycles—is a different matter altogether. It is all about detail. Where shoveling is a matter of muscle modified by dexterity, inspecting tiny steel balls for defects so minute as to evade the naked eye calls for the keenest degree of mental concentration.

 Some find it hard to believe that knowledge workers have anything to learn from manual laborers. If these doubters are correct, then knowledge workers have little to learn from Taylor. But the fact that Taylor’s approach improved productivity in shoveling iron ore and minutely inspecting bicycle balls tells us that scientific management can readily make the leap from manual labor to knowledge work. As neither shovelers nor bicycle ball inspectors nor the people who managed both knew very much about processes and mechanics of the activities in which they were engaged, so even in the most accomplished knowledge workers give very little thought to how they do what they do. They don’t define processes for thinking.

 Taylor realized and taught that every productive activity consists of discrete tasks and thus may be broken down into these tasks, even as the tasks themselves can be reduced to a series of motions. Observe, record, and experiment how each movement contributes to each task and each task contributes to a process or product, and you can improve productivity on highly granular level. Why not, then, apply Taylor’s basic principles to knowledge work?

**•** Break down problems into tasks. **Breakdown the tasks into their constituent mental movements or** micro-tasks.

**•Measure long each micro-task takes.**

**•Aim to reduce the number of micro-tasks required to perform a task. Conduct experiments to measure the impact of the reductions you make.**

**• Aim to reduce the number tasks in a process. Again, experiment to measure the impact of the reductions you make.**

**Keep experimenting to find the one best way of thinking through a problem.** Don’t settle for good enough processes. Strive for the optimum. Once the optimal approach has been determined, train on it, evangelize on it, standardize it.

 The imperative *Think!* is not difficult to act upon. I mean, when somebody tells you to think, the fact it that you’re already thinking. We all are. We do it all the time. We can’t help it. The hard part comes when we are required to think about something specific. Bicycle ball inspectors are supposed to be thinking about identifying defective bicycle balls and to this every single second they are inspecting this product. But Taylor, who watched and time them, found that they spent a great deal of time doing other things. Oh, doubtless they were thinking, but they weren’t thinking about bicycle ball defects. In the end, he found ways to hire inspectors more suited to their jobs, and to increase productivity not by lengthening the workday, but by shortening it—*and* shortening it some more by inserting multiple breaks. The result of reduced time at the bench was the opposite of reduced output. The shorter day and the mandatory breaks increased both production and quality.

 Doing knowledge work requires thought. Begin by thinking about how you view productivity and how you organize your work, your mental tasks and micro-tasks. So-called Taylorism applied in five basic areas:

1. Sequencing

2. Goals

3. Measurement

4. Method

5. Optimization

When it came to sequencing, Taylor found that the conventional approach was to put technology first, machines first. He concluded—by observation and analysis—that this was a mistake, suboptimal. Instead, he put process first. Formulate a process and act in accordance with it.

As for goals, most businesses were looking to gain a more-or-less permanent competitive advantage by making a handful of big changes. Taylor advocated for many small changes, continuous incremental change.

Knowledge workers, like manual laborers, understand the importance of measurement. Before tackling a problem, even the brightest knowledge workers are anxious to get a rough idea of the task or problem before them. Taylor tried never to guess. He measured with as precise an instrument as he could obtain or make for himself.

In deciding on a method for moving forward in a task, the conventional approach is to follow a “best practice” or “rule of thumb.” Taylor employed the scientific method to determine experimentally the “laws” or “principles” governing the task at hand.

And what about optimization? The usual approach is to aim for *good enough* in most things. Taylor was convinced that, for any task or process, one best way existed.

The belief that there is one best way to do something is not to be confused with merely learning knowledge. That is important, of course. We need to learn about the wheel so that we don’t waste time reinventing it—except when reinvention is necessary. In World War I, a relatively young Winston Churchill was looking for a way to transform the static warfare of the trenches into mobile warfare. He discovered that, in battlefield networked with trenches, the wheel had to be reinvented as the tank tread. *Learn* knowledge when you can, but *create* knowledge when you must. Managers, Taylor knew, sought to increase production by lengthening the workday. That was common knowledge! Taylor showed how to increase productivity by making the workday shorter. In so doing, he created knew knowledge.

And then he shared the knowledge, both the learned and the created, shared it throughout the business, so that everyone began to standardize on the one best way. Because his innovations were based on observed fact and experimental trial, they were not rules of thumb or best practices. They were simply natural laws discovered as natural laws have been discovered maybe since René Descartes, Francis Bacon, and Isaac Newton: by the scientific method—observation, measurement, and confirmation, refutation, and improvement via experimentation. Try it.

1. Martin Caidin, *Black Thursday* (New York: Ballantine, 1981). [↑](#endnote-ref-1)