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The Cat and the Bullet: A Ballistic Fable

This is the tale of a ball-bearing that moved at high speed through the thigh of a cat. Some years ago, I had spent the morning digging through boxes of wartime science records when I came across several contract proposals from the Princeton Biology Department that detailed an investigation of the mechanism of wound formation—of wound ballistics—by using as targets anaesthetized cats, dogs, monkeys, and even, it was proposed, human cadavers. I have never objected to the grim investigations war necessitates. My mental journeys have taken me across many of the battlefields of wartime science from the invention of the machine gun to the atomic bombings of Hiroshima and Nagasaki. But this discovery moved me deeply and I have found myself wondering why it did so. So what follows is my tale, too.

THE STORY: CMR-395

By the latter third of the 19th Century, Western industrialized nations had learned how to mass-produce wounds in great abundance; what they had yet to develop was the science of wounds, wound ballistics as it came to be called, or the standardization of their production. The British Army Medical Service had a great collection of wounds, accumulated during WWI and housed for study at the Royal College of Surgeons but lost to a bombing raid during the next war.[1] In the United States, the science of wounds had been similarly initiated after WWI by the joint efforts of the Army's Ordnance and Medical Departments, but "unfortunately, the work was stopped in 1934."[2] By 1943, however, wounds were again being produced in large numbers.

As the Pacific island campaigns were heating up, a civilian physicist from the Aberdeen Proving Ground contacted the chairman of the National Research Council's Division of Medical Sciences about initiating research "designed to test the effectiveness of U.S. weapons."[3] The first of numerous conferences on wound ballistics was convened and, in short order, endorsed an experimental study at Princeton University, a major site for research on projectiles and explosions with close ties to ballisticians at Aberdeen.

By the middle of October 1943, OSRD's Committee for Medical Research, which worked closely with the NRC's medical committees, approved contract CMR-395 with the physiologist E. Newton Harvey and the anatomist Elmer Butler, the chairman of Princeton's Biology Department, for a quantitative study of the mechanism of wound formation that would allow them to predict missile masses, shapes, and velocities most favorable for injury and incapacitation. Over the next several years, the Wound Ballistics Research Group spent $150,000 and grew quite large, employing some dozen workers and expanding to include John Fulton's animal experimentation laboratories at Yale University. At the end of the war, the study was transferred first to the Army Surgeon General and then to the Medical Division at Edgewood Arsenal. Seventeen years later in 1962, when the Army published a massive volume on wound ballistics, the Princeton study still formed its experimental basis.[4]

Quite a lot had been learned about wound formation in the previous fifty years, but several puzzles perturbed analysts. In particular, high-velocity missiles produced injuries so massive that, when they first appeared on European battlefields, they provoked recriminations about the use of explosive bullets.[5] Such bullets had the mysterious capacity to break bones and destroy muscle and nerve function at some distance from the wound track. In order to solve these high-velocity puzzles and to "place wound ballistics on a sound quantitative basis," the WBRG created a laboratory for the standardized production of "wound events."

The laboratory housed a .30 caliber smoothbore gun that could be mounted either vertically or horizontally and directed at a variety of targets some ten feet away: water, gelatin blocks, plasticene dough, or animals tied to a wooden backstop. The gun was loaded with a rifle cartridge tipped with a wooden sabot designed to cradle the desired missile—in most cases, steel ball-bearings ranging in diameter from one to three-sixteenth inches. Arranged around the target as needed, were high-speed movie cameras and instruments for producing spark shadowgrams, microsecond x-radiographs, and pressure pulses by means of embedded piezoelectric crystals.

By war's end, the group was able to narrate a standard wounding that went something like this: Fired from the gun, an eighth-inch bearing crossed the lab in a hurry. Striking the surface of the cat's thigh at 3000 ft/sec with an energy of about 3.7×10^8 ergs, the bearing produced shockwaves radiating out from the point of impact with a period of about three microseconds and maximum pressures of 170 lbs/sq in, causing the leg to ring like a bell—if one had the ears to hear it. Penetrating the skin, the bearing passed through the leg in about fifty microseconds, pulping tissue before it and spraying debris out entrance and exit holes. A key observation: losing some 85% of its energy in its passage, the bearing left in its wake an explosively expanding cavity that tore muscle fibers, stretched nerves, and fractured bones at some distance from its path. This temporary cavity also pulsated, although with a much slower rhythm of about three milliseconds, before collapsing into a permanent track. The puzzling behavior of high-velocity bullets was not due to wind pushed by the bullet, the initial shock, or local heating, but by this transient, energetic cavity whose maximum size was $1 \times 10^{-7} cm^3$ for each erg lost in transit.

Over the course of its study, the Wound Ballistics Research Group fired bearings into water, dough, and gelatin, and through the legs, abdomens, and heads of assorted animals—building the quantitative foundations of the modern science of wound ballistics.

COMING TO TERMS

A picnic table used to sit on the lawn near the front entrance to the Suitland center. Thinking to take a break, I had come outside into the sun and found Stanley Goldberg, a friend and fellow historian of science, already sitting at the table.

"Hey, Stan! I have this great title for a paper: 'The Mathematics of Death and Destruction,'" and I told him about the discovered documents.

"You should write about it!" he said simply.

"I don't think I can. Clever title, but writing it up wouldn't be much fun!"

I didn't take Stan's advice. This wasn't the sort of material I liked writing about. Indeed, it was too much like the very first subject I stumbled across as a graduate student when I realized that John Jacob Abel, Johns Hopkins' first physiologist and my topic-to-be, had become preoccupied with scraping cadavers in order to study the chemical basis of pigmentation. Wound ballistics? No thanks! Wartime laboratories I could enjoy, but I would stick to the dreams and devices I knew best and found most interesting, pursuing safer questions—I thought at the time—such as how laboratories embodied culture. Despite some nagging of conscience, I moved on, and forgot.

Stan has since died, and I have found myself remembering that encounter and the topic. Reluctantly, I've come to the realization that I need to write about it—partly for Stan, whom I greatly admired, and partly for myself as a child of the Cold War who grew up on SAC bases with B-52s falling out of the sky and midnight evacuations to test our preparations for avoiding annihilation. Wounds are not a happy subject, but as Sir Alfred Keogh, the Director-General of the British Army's Medical Service, said about the British wound collection in 1917: "Such specimens are original documents, they constitute an original and reliable source of knowledge for all time."[6] Maybe I can learn something about myself and my times by bringing these wounds out of the archival shadows into the sun. And by trying to read them.

READING WOUNDS

But how? To begin with, by asking some basic questions. What was in it for the parties involved? What larger significance might wound ballistics have had? What sort of texts are these wounds? And to how many readings might they lend themselves? One shouldn't forget the obvious, of course: that natural philosophical attempts to link wound and weapon go back quite a long time, beyond the wars of the last century, back at least to the notorious "weapon salve" of the Middle Ages. Why should we be surprised that, in 1943, Army ordnance men and medicos should seek help to continue study of such things—both to anticipate the nature of battlefield casualties, and thus better care for the wounded, and to design more effective weapons? Nevertheless, the activities of the Wound Ballistics Research Group were a special moment in a long history of killing and maiming.

Reading #1. A New Institutional Partnership

From an organizational point of view, the Princeton study was hardly exceptional. Indeed, CMR-395 was a garden-variety example of civilian science mobilized for war. Aside from these particularly gory goings-on, WBRG's activities could have been any of the other 2300 experimental studies funded by Vannevar Bush's Office of Scientific Research and Development. It was state-funded, mission-oriented, cooperatively-managed, and interdisciplinary—bringing together anatomy, physiology, physics, and the ballistics expertise of NDRC's Division 2 and the Army's Aberdeen Proving Ground. It introduced civilian scientists to research-minded military men. New relationships and purposes often shifted traditional balances of power both within and among universities as new disciplinary alliances vied with old and schools sought to hitch their futures to a new era of federal largess that wartime mobilization foreshadowed. In short, the shooting room was only the Manhattan Project writ small, an instance of that unprecedented wartime partnership between the university and the state that would transform American science after the war.

Reading #2. The Dynamics of Disciplines

From an organizational point of view, wound ballistics can be understood as an exercise in creative management. From another point, however, it appears a case of disciplinary dynamics and intellectual opportunism. The driving force behind the Princeton study was probably not the Army but Yale's John Fulton, who had been agitating for a research program on the anti-personnel effectiveness of U.S. fragmentation missiles since 1940.[7] And Fulton was a man of large ambition. In 1930, he had taken over the Department of Physiology with the hope of making Yale "a world center of neurophysiological research." To that end, between 1938 and 1943, he wrote an early textbook of general neurophysiology and launched two new journals—the *Journal of Neurophysiology* in 1938 and the *Journal of Neurosurgery* in 1943. He also established at Yale a world-class primate colony for animal experimentation, a facility that included twelve animal rooms, three operating rooms, and a room for autopsies where by 1944 4000 operations on more than 3000 animals had been performed. In 1943, most of these animals were being used for war research.

For Fulton, as for George Ellery Hale in an earlier generation, war was a great opportunity to advance the discipline and good for the future fortunes of the department. The discovery of fibrin foam had been announced in the *Journal of Neurosurgery* and "it was a source of considerable gratification to the editors last spring," he noted in his diary, "to have cables for the new homeostatic agent ... from the Anzio Beachhead and later from points in the South Pacific." Fulton was deeply appreciative of the benefits of such attention: "owing to our good fortune in having had a number of war contracts of high priority assigned to the laboratory, we have maintained our staff largely intact; indeed we have a stronger staff than at any time in the history of the Department." He also hoped to use the resources generated by war to take advantage of what he anticipated would be a large increase in demand for graduate instruction in neurophysiology after the war.

In short, Fulton found the war—and wound ballistics—a happy opportunity to promote animal experimentation and to exercise his scientific skills in the service of his country, reaping the benefits for himself, his department, and his discipline.

Reading #3. The Laboratory as a Workplace for the Production of Truth

One can also take the long view. From this vantage what seems most striking about wound ballistics is the laboratory itself: a distinctive and highly-evolved site for the production of knowledge and the display of power. In a historical sense, the shooting room exquisitely combines two purposes that have driven the development of the laboratory since it emerged as the crucial theater for the practice of natural philosophy in the seventeenth century.

In the first, the laboratory is conceived as a workplace for the manufacture of natural knowledge through the use of philosophical machinery. Not logic but instruments point the way to sound knowledge of nature. Boyle taught us that in his detailed narratives of air-pump experiments, and over the next three centuries the machinery of the laboratory has become increasingly complex. In such a place, nature is quantitatively reimagined, boundaries are erased between the animate and inanimate, and the body reconstituted as a scientific object.[8] In such a place, surrounded by oscilloscopes, high-speed cameras, and micro-second x-ray equipment, water, plasticene dough, and living flesh are interconvertible, as the Wound Ballistics Research Group sought to define the "standard wound."[9] In such a place, what difference is there between Harold Edgerton's famous stroboscopic photographs of bullets and bulbs and the Princeton shadowgrams of bearings and cats?

The second purpose embodied by the laboratory derives from Francis Bacon. Drawing on legal and inquisitorial experience as the King's spy-master and chief judicial officer, Bacon's approach to nature was inquisitorial. He once explained himself by revising the ancient fable of the god Proteus. Menelaus had been stranded on his way home from the Trojan Wars and was befriended by the god's daughter. If the King could manage to capture and restrain her father—who was reputed to be an extraordinary prophet and revealer of secrets—then Proteus could be forced, the daughter confessed, to reveal knowledge the

King desired, despite the god's efforts to deceive and escape. Nature, Bacon argued, was the face of matter unconstrained. Only by "the method of binding, torturing, or detaining" could the philosopher force a reluctant nature to reveal its secrets.[10]

More clearly than most examples of wartime research, the wound laboratory illustrates these two themes. In a chamber devoted to the needs of the nation and sanctioned by science, Princeton's inquisitors put their animal subjects to the test, extracted truth, and manufactured useful numbers.

Reading #4. The Trajectory of Ballistic Civilization

My last reading is surely an obvious one. At just about the moment when experimenters begin firing bearings into cats, mathematicians at Aberdeen Proving Ground were struggling with the mathematics of gunnery while across the ocean a German general wept for joy as he watched the first successful V-2 streak upwards into the stratosphere.[11] Less familiar than its internal and external cousins, wound ballistics is nonetheless ballistics and represents an important phase in the long history of a discipline central to the rise of the West. Indeed, the contributors to the Army's wound ballistics volume compactly summarized this history: "clubs, stones, sling, bow to propel an arrow, gunpowder, rifle, smokeless powder, TNT and related propellants, airplane, rockets and rocket-propelled bombs, and the atomic bomb. From this brief résumé of the progressive development of the missile as an antipersonnel agent, it is natural to inquire just how that missile produces a casualty."[12] When the WBRG finally derived the retardation equation

$$R = dV/dt = -aV^2$$

where V is velocity and a is the retardation coefficient, 0.09cm^{-1} for water and 0.14cm^{-1} for cat thigh (living), they were merely extending the mathematics of projectile motion from better-known, less dense media like air to the lesser-known, denser medium of flesh.

The art and science of ballistics have been a Western obsession since at least the time of the Renaissance artist-engineers. Once in a letter to the Duke of Milan, Leonardo meticulously enumerated his ballistic proficiencies before adding, almost as an afterthought, his talent for sculpture. Galileo moved projectile motion—of little interest to Aristotle—to the heart of the New Science, and Newton's linkage between planetary motion and falling bodies was aptly illustrated in 1728 with a neat sketch of a mountain-top cannon firing a ball into orbit. Jules Verne's "From the Earth to the Moon," translated into English in 1874 with the title "The Baltimore Gun Club," tells the story of out-of-work American artillerists, aimless, disgruntled, and unhappy since the end of the Civil War, who restore meaning to their lives by building the world's largest gun to fire a bullet at the moon. As Verne's astronauts ride their projectile into the moon what should they exclaim as they near their target but "Does not this plain look like an immense battlefield?"

From the gunpowder revolution of the fourteenth century to the Army's atomic Howitzer to the Apollo moon missions, the West has grown strong by learning, better than any civilization in history, how to throw things around—at one another, at other peoples, and at the world. And then by making a science of targets. That defining skill has provided our central scientific problems and paradigms, influenced our images of nature, powered our global expansion, and shaped our historical identity. At the beginning of Thomas Pynchon's *Gravity's Rainbow*, London is being bombarded by the German rocket. Roger, the Army statistician, is struggling to explain to his girlfriend Jessica the satisfying certainties of ballistic destruction when seen from "the angel's-eye view, over the map of England." Jessica, who's having an understandably difficult time trying to reconcile Poisson curves and random death, asks "Why is your equation only for angels, Roger?… Couldn't there be an equation for us too, something to help us find a safer place?"[13]

LABORATORY MECHANICS

So. Is this the end of the story? That depends on whether the tale is mine alone. The attempt to frame accounts for the Princeton project has convinced me that my reluctance has roots deeper than grim and gory details. My deepest fear rests, I think, in the suspicion that the "wound event" might be more than just CMR-395. That it might be a deep structure of sorts. A paradigm. A habit of mind, maybe. And more pervasive than we might like to think. After all, there are plenty of examples better known. What were the bombings of Hiroshima and Nagasaki—the first experimental cities—and the Atomic Bomb Casualty Commission survivor studies written about by Susan Lindee but wound ballistics? Or the AEC's use of the innocent and uninformed during the Nevada bomb tests and written up by Carol Gallagher but wound ballistics? And most unsettling of all, what is Herman Kahn's 1960 On Thermonuclear War, a closely reasoned and dispassionate analysis of death, destruction, and the prospects for national survival after a nuclear attack, but an exercise in wound ballistics?

I know of historians that such a notion wouldn't surprise. Especially those who argue that efficient, highly mechanized, scientifically planned acts of violence are no accident. They write about the assembly-line slaughterhouse,[14] the industrialization of war,[15] and the rational efficiency of the Nazis' Final Solution.[16] And they consider these to be not exceptional failures, but characteristic expressions of modernization in areas normally closed to view.[17] Wound ballistics in this frame is only another instance of the advance of a civilizing reason in which wars and scientific slaughter coexist with religion, "beautiful art, and exquisite music."[18]

Is wound ballistics a symptom of modernity? Probably. But the story of the cat and the bearing is also more than that. It's a fable about ballistic culture. About peoples who, much too nonchalantly, have become habituated to the infliction of harm in good conscience—inhabiting a world in which sometimes one's the gun, sometimes the bullet. And sometimes, like the Princeton cats or Erhard Schön's Sixteenth-Century manikins, is pressed against the frames and tied to the backstops of our modern age. Might being a target, in fact, be good for us? There are those who think so. Maybe, in some way, we all do. In 1964, a few years after

Herman Kahn's analysis of doomsday, Robert Heinlein published *Farnham's Freehold*. As the story begins, Hubert Farnham and friends are discussing the meaning of life and the future of man while hunkered down in an underground bomb shelter being shaken by thermonuclear explosions. "Barbara," Farnham tells a young guest, "I'm not as sad over what has happened as you are. It might be good for us. I don't mean us six; I mean our country."

She looked startled. "How?"

"Well—It's hard to take the long view when you are crouching in a shelter and wondering how long you can hold out. But—Barbara, I've worried for years about our country. It seems to me that we have been breeding slaves—and I believe in freedom. This war may have turned the tide. This may be the first war in history which kills the stupid rather than the bright and able. . . ."

"How do you figure that, Hugh?"

"Well, wars have always been hardest on the best young men. This time the boys in service are as safe or safer than civilians. And of civilians those who used their heads and made preparations stand a far better chance. Not every case, but on the average, and that will improve the breed. When it's over, things will be tough, and that will improve the breed still more."[19]

Is it possible to escape Farnham's morally offensive post-apocalypse and answer Jessica's question at the same time? I doubt it. At least without taking refuge in religion or non-Western science. Ballistics, as science and metaphor, has become too important in too many ways, too much a part of that modern civilization that grew from the ashes of the Middle Ages and has made us what we are. Sorry, Stan! I wish my story had a better ending.

NOTES

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[1]Major James C. Beyer, "Preface" to *Wound Ballistics* (Washington, DC: Office of the Surgeon General, Department of the Army, 1962), xi.

[2]George Callender to Dr J. S. Lockwood, 9-20-44, letter attached to CMR395, contract extension proposal, 8-25-44, National Archives RG227, Office of Scientific Research and Development [OSRD], Admin. Office, Contract Records, Box 196, folder on Princeton University. In fact, substantial earlier work had been done in the U.S.; see for the best brief review Ronald F. Bellamy and Russ Zajtchuk, "The Evolution of Wound Ballistics: A Brief History," *Conventional Warfare: Ballistic, Blast, and Burn Injuries*, ed. Ronald F. Bellamy and Russ Zajtchuk (Washington DC: Walter Reed Army Institute of Research, 1991), Ch. 3. This is part of the series on combat casualty care published by the Department of the Army, Office of the Surgeon General. I'd like to thank Professor Robert Joy, MD, FACP, for this reference and for help generally with the history of wound ballistics.

[3]Beyer, xii.

[4]Material for this and the following paragraphs is taken from the original contract proposal for CMR-395 and its various extension proposals; Yale's CMR-549 proposal; Beyer's *Wound Ballistics*, esp. Major Ralph French and General George Callender, "Ballistic Characteristics of Wounding Agents," and E. Newton Harvey, J. H. McMillen, Elmer G. Butler, and William O. Puckett, "Mechanism of Wounding."

[5]Beyer, 144. For information on the Swiss surgeon Theodor Kocher, recognized as the founder of wound ballistics as an experimental science, see Martin L. Fackler and Paul Dougherty, "Theodor Kocher and the Scientific Foundation of Wound Ballistics," 172 *Gynecology and Obstetrics* (1991): 153-160.

[6]Beyer, ix.

[7]Fulton Diaries, volume XIX, entry for 9-25-43, John F. Fulton Papers, the Sterling Library, Yale University.

[8]See Steven Shapin, "The Body of Knowledge," in Steven Shapin and Christopher Lawrence, eds., *Science Incarnate: Historical Embodiments of Natural Knowledge* (Chicago: University of Chicago Press, 1998). Susan M. Lindee has become especially interested in wound ballistics and the "constructed" body; see "What is the Body of a Soldier? Cold War Testimonies," a talk delivered at Johns Hopkins, 2/7-8/2003, personal copy; see also her earlier "Atonement: Understanding the No-Treatment Policy of the Atomic Bomb Casualty Commission," *Bulletin of the History of Medicine* 68 (1994): 454-490.

[9]The phrase is Harold Lamport's in Yale's subcontract proposal CMR-549.

[10]Francis Bacon, "Proteus, or Matter," in *Bacon's Essays* (Chicago: The Henneberry Company, 1883 [?]), 285-288.

[11]For the German general, see Walter Dornberger, *V-2: The Nazi Rocket Weapon* (New York: Ballentine Books, 1954), 21.

[12]French and Callendar, 93.

[13]Thomas Pynchon, *Gravity's Rainbow* (New York: Penguin Books, 1995), 54.

[14]S. Giedion, *Mechanization Takes Command: A Contribution of Anonymous History* (New York: W.W. Norton & Company, 1948 [1969 edition]), 240-246.

[15]Daniel Pick, *War Machine: The Rationalization of Slaughter in the Modern Age* (New Haven: Yale University Press, 1993).

[16]Zygmant Bauman, *Modernity and the Holocaust* (New York: Cornell University Press, 1989).

[17]Bauman, 8-9.

[18]Richard Rubenstein, *The Cunning of History (*New York: Harper & Row, 1978), 92.

[19]Robert Heinlein, *Farnham's Freehold* (New York: Baen, 1964), 33.