BOOK REVIEWS

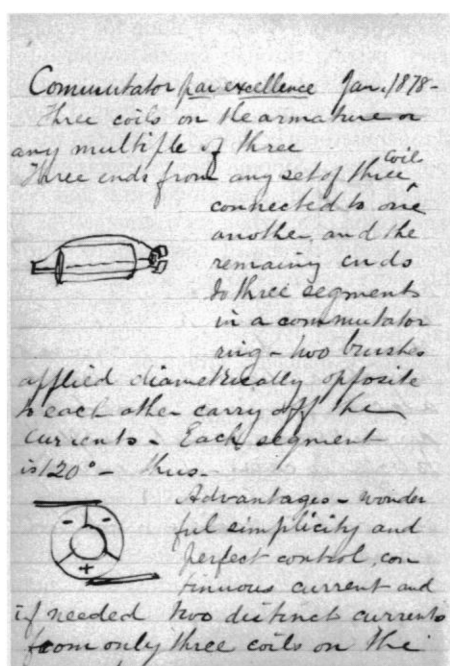
An American Success

Innovation as a Social Process. Elihu Thomson and the Rise of General Electric, 1870–1900. W. BERNARD CARLSON. Cambridge University Press, New York, 1992. xxii, 377 pp., illus. $44.50. Studies in Economic History and Policy.

With the end of the Cold War, few issues seem more pertinent than how economic organizations and institutions influence the ability of nations to generate innovations and distribute them to individuals. Yet at the same time, few seem more perplexing. Just when Americans might unabashedly celebrate victory in the Cold War, a triumph justly attributable to the stunning superiority of the United States over the centrally directed Soviet Union in providing for the material and psychological desires of its citizenry, many find themselves dwelling instead on a challenge from Japan, a nation widely perceived as pursuing a state-coordinated industrial policy. A gap between ideology and reality adds to the confusion. Those most inclined to celebrate typically interpret the end of the Cold War as vindication of the free-market doctrines of Adam Smith. But the United States that waged the Cold War, though rooted in those doctrines, had long since passed from Smith's world of small producers into one characterized by corporate organizations and an administrative state.

In this fine new study of the inventor Elihu Thomson, W. Bernard Carlson shows how historians can help us get our bearings. Together with Thomas Edison and George Westinghouse, Thomson was one of a triumvirate of inventor-entrepreneurs whose names became virtually synonymous with a remarkably successful innovation of the late 19th century: the rapid emergence of electric light and power in America. Each of these men began his career as a relatively independent, self-sufficient tinkerer and investigator operating in an environment much like that envisioned by Smith. Each ended up with his name attached to one of the three dominant firms in a highly structured, oligopolistic industry. Carlson follows Thomson on that odyssey and in the process demonstrates conclusively that a full account of innovation in electric power must take both worlds into consideration.

Drawing upon the pioneering work of his mentor Thomas Hughes and other recent students of invention, Carlson suggests that we think of Thomson and others like him as problem-solvers. In their approach to problems, such people exhibit distinctive tendencies, or what Hughes has termed an identifiable "style." We can with benefit examine those problem-solving techniques, in much the same way we might study the work of a scientist or other intellectual. Carlson devotes much of the early chapters of his book to precisely that task. But to understand the process of innovation we must also pay attention to how individuals such as Thomson come to work on the particular problems they do (for there is never a shortage of problems), and we must also examine how their solutions diffuse through society (for there is seldom only one available solution, and in any event there is nothing automatic about its selection). Since in the American context the marketplace has always served as the primary forum for generating problems and selecting solutions, Carlson finds that to comprehend innovation we must pay particular attention to the ways problem-solvers connect to the market. Inevitably, this leads him to the corporation.

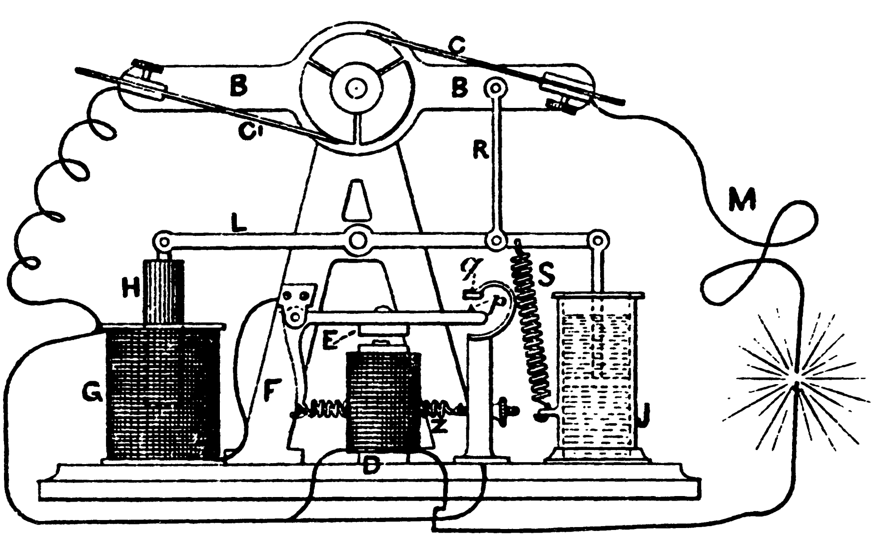


Entry in Elihu Thomson's "Dynamo Electric Machines" notebook describing his three-coil armature winding, January 1878. [From *Innovation as a Social Process*; Thomson Papers, American Philosophical Society, Philadelphia]

Carlson's account focuses on two nodes. The first is post–Civil-War–era Philadelphia, where Thomson came of age. Born into a working-class family, Thomson attended the city's famous Central High School, a public institution with tough entrance requirements and rigorous academic standards. He excelled as a student and developed a close relationship with his mentor, Edwin J. Houston, whom he served for a time as a laboratory instructor. Through Houston, the diligent and eager young Thomson gained access to the segment of Philadelphia's elite that shared a general interest in what was then called "natural philosophy." This circle included doctors, lawyers, bankers, merchants, manufacturers, educators, and artisans, all loosely interconnected through webs of personal friendships, business transactions, and educational background. With the aid of a thriving technical press and lectures and other events sponsored by institutions such as the Franklin Institute and the American Philosophical Society, these men learned from one another and kept abreast of ideas and developments from throughout America and Europe. Together they formed an extraordinarily fluid community, one that blurred divisions among commerce, craft, and science, just as the concept of natural philosophy embraced ideas that would later fall into the separate disciplines of physics, chemistry, biology, and engineering.

Thomson found this world endlessly fascinating. He took special pleasure in the thrill that came from sharing a new observation or from exhibiting a familiar phenomenon produced in a novel way. Thomson developed an extraordinary ability to master new devices and tinker with them in ways that helped illustrate scientific principles. This skill served him well in his teaching and also secured him a reputation in the broader community, for whom he regularly staged public demonstrations. In the grandest and best-publicized example, he and Houston after traveling to Europe on research conducted a systematic investigation of electrical generators for the Franklin Institute, in an effort to ascertain the relationship between mechanical friction and power loss.

Thomson pursued these activities out of intellectual interest, but in the process he came to possess information and attributes of significant commercial value. His study of generators, for instance, put him in a position to design more economical models and helped him grow familiar with various systems of arc lighting, which at the time provided the largest market for generators. With Houston's



Elihu Thomson's current regulator for dynamo electric machines as illustrated in U.S. Patent No. 238,315 (1 March 1881) to Thomson and Edwin J. Houston. "(G) electromagnet for moving brushes, (D) electromagnet for increasing sensitivity of regulator, (J) dashpot for dampening the motion of (L), the arm that moves brushes (C, C')." [From *Innovation as a Social Process*]

encouragement and assistance, moreover, Thomson began patenting many of the modifications he made to existing devices in the course of his research and teaching. For Thomson, the patent system functioned as a quick means of publication. A patent simultaneously publicized his contributions to knowledge and certified his claim to novelty or discovery. Much as modern researchers might hone their abilities to write articles containing the "least publishable unit," Thomson grew adept at recognizing just when he had done enough to obtain a patent.

Not long after completing their study of generators, Thomson and Houston decided they could without much difficulty produce a competitive arc lighting system of their own. Again, Houston took the initiative. He located financing and supervised the requisite patent applications. Thomson agreed to provide essential technical expertise and supervise installation of a pilot facility. He would give up all other employment and work full-time for the new firm, soon known as the Thomson-Houston Company. Thomson thus became, as Carlson writes in his conclusion, perhaps "the first corporate engineer." It was a role he would occupy for the rest of his life.

Right away, Thomson exhibited a combination of technical abilities and selflessness that made him extraordinarily useful to his financial backers. He and Houston had pursued an alternating-current lighting system because it held greater intellectual fascination for them. But when the financiers suggested that Thomson switch to direct current, which they considered more promising commercially, he acquiesced without apparent objection. Many other inventors might have balked at giving up their personal creation. Thomas Edison, an advocate of direct current, ultimately fell into dispute with his supporters over precisely the same issue. Thomson proved more flexible. He sought the pleasure that came from the process of discovery, and he knew he could derive it from working on any number of technologies. Interestingly, Thomson's attachment to the values of science made it easier for him to function in the corporate world.

Despite yeoman efforts by Thomson, the lighting company limped along for several years, passing through several ownerships before finally landing in the hands of a group of shoe manufacturers from Lynn, Massachusetts, who hoped to broaden their community's economic base. Thomson relocated to the shoe-making center and began working for what soon emerged as a dramatically revamped corporation. With this move, we pass to the second node of Carlson's study and encounter a new central character, Charles A. Coffin, the extraordinary manager who took charge of Thomson-Houston.

Coffin was by inclination and experience a master marketer. In the shoe industry, he had rousted his complacent competitors by introducing the element of fashion and design into an environment that had grown obsessed with the pursuit of economies in production. When Coffin turned to his new endeavor, he found a promising market immobilized by uncertainty. Many people wanted electric light and power, but it required major investments, and a myriad of inventors and small firms presented consumers with a confusing array of options that raised concerns about patent liabilities and rapid obsolescence. Coffin devised a strategy that in effect cleared the way for centralized purchasing decisions. Using his agents in the field, he helped organize groups of prospective consumers into nascent utility companies. Coffin then arranged financing for the venturous utility managers and supplied them with Thomson-Houston equipment, which they usually paid for in utility stock. This technique drew many utilities into positions of dependency, in which they purchased all their equipment from Thomson-Houston and passed much of the income earned from selling light and power back to the supplier as well.

Where did Thomson fit in this scheme? In order to lure customers and retain them in exclusive supply contracts, Coffin needed to offer a comprehensive line of products that possessed sufficient novelty to allay fears about patents. He understood that consumers, who often had little expertise in the new technology, would gladly place themselves in the hands of a single supplier so long as they did not feel they were giving up access to any significant developments. Thomson, with his experience in generating patentable modifications of existing technology and his willingness to respond rapidly to virtually any request, offered a technical style that nicely complemented Coffin's needs. During the first few years of their association, Thomson took out more patents than during any comparable period of his life.

Over time, however, Thomson's significance to the firm diminished steadily. As it secured a position in the marketplace, Thomson-Houston found it could safely wait for others to introduce new technology, then acquire through merger any that proved successful. Coffin pursued this strategy with increasing frequency during the 1880s, and as he did so Thomson-Houston came to acquire a stable of inventors. Moreover, as its volume of business grew, the center of technical innovation within Thomson-Houston shifted toward its manufacturing operations, where mechanics modified products and altered production techniques in order to achieve economies of scale.

These trends came to a head in the late 1880s, when J. P. Morgan and other investment bankers who were supporting the industry orchestrated the merger of Thomson-Houston with one of its two principal competitors, the Edison electrical interests. Historians have sometimes interpreted this merger as a joining of Edison's direct-current technology with Thomson's expertise in alternating current. Carlson's authoritative account suggests that the move had much more to do with concerns that competition would waste capital. Morgan wanted Coffin free to extend his ordering strategies without disruption. If not for the personal stubbornness of George Westinghouse, Carlson suggests, Morgan might well have placed all three of the giant electrical manufacturers under Coffin's control.

During this long, critical stretch of the narrative, Thomson drops entirely out of the story. When he reappears, with the merger complete and Coffin in charge of a single organization that would soon be known simply as General Electric, his role had clearly diminished further. GE soon moved its corporate offices and most of its operations to Schenectady, but Thomson stayed behind in Lynn. The new organizational chart showed him as one of several managers who supervised groups of product engineers, all of whom reported ultimately to the person who previously had supervised the manufacturing works at Thomson-Houston. Thomson soon even lost his place as the most "scientific" member of GE's staff to Charles Steinmetz. While Thomson increasingly focused his energies outside GE, most notably in his activities with the newly formed American Institute of Electrical Engineers, Steinmetz cultivated an integral position within the firm by providing calculations for its engineers who were busily installing electric power systems in the field.

Americans came to enjoy the benefits of those power systems more rapidly than any other people of the time, and American firms garnered more than their share of profits in the international market for electric power. By paying attention not only to the inventors but to the organizational context in which they functioned, Carlson has shown us why. In the process, he has produced a book rich with insights into the process of innovation.

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Dining Respectably

Cannibalism. Ecology and Evolution among Diverse Taxa. MARK A. ELGAR and BERNARD J. CRESPI, Eds. Oxford University Press, New York, 1992. viii, 361 pp., illus. $75.

In the 1960s and '70s, refinements of natural selection theory led most biologists to realize that phenotypic traits, including behavior patterns, evolve because of net benefit to the individual's inclusive fitness. One consequence of this paradigm shift away from classical "group selection" (the view that traits evolve mainly for the good of the population or species) was that sporadically reported cases of vile or unsavory behaviors performed by animals (such as rape, slavery, infanticide, mate-desertion, and cannibalism) could not simply be assumed to be pathological or aberrant any more. Even actions such as these might have evolved if they typically conferred reproductive advantages on their practitioners. One could no longer seek comfort in the meager records (many such behaviors are inherently rare and hard to witness) or dismiss them airily as mere byproducts of captivity.

Modern selection theory thus provided two key legitimizations for topics like cannibalism. First, the few extant anecdotes could be retrofitted with plausible and testable functions, salvaging the topic as scientific. Second, workers were inspired to search systematically for additional examples and twists. This led to exponential growth on several fronts. Ecological predictions began to emerge, specifying the contexts in which these behaviors should be found. Eventually, reviews began to appear. The current volume can be viewed, therefore, as the formal rite of passage for the fascinating topic of cannibalism as a very respectable area in evolutionary biology.

Fifteen review chapters by 17 scientists make it abundantly clear that there is nothing particularly astonishing or freakish about the ingestion of conspecific tissue. Such habits have evolved repeatedly as a solution to various problems, often (but not always) involving food shortages. On the other hand, cannibalism is not for everyone: it has special costs. Conspecifics are far more likely than alternative prey types to carry the parasites to which the diner is vulnerable. Then too, there are at least three categories of conspecifics (genetic kin, potential mates, and flock-mates) that are often more valuable to an individual as living entities than as meals. Finally, some conspecifics are more easily killed and eaten than others.

A predictive framework emerges: *ceteris paribus*, cannibalism should be expected in food-poor contexts, preferably involving helpless unrelated neonates, perhaps of the cannibal's own gender. The exceptions are many and often the most edifying cases. For example, cannibalism of close genetic relatives is quite common in various insects where mothers produce extra eggs whose sole function is to nourish siblings (chapters by Crespi and Kukuk). Sometimes these "trophic eggs" are not viable (unfertilized); otherwise siblings have a developmental race that determines who becomes the diner and who the dinner. From the parental perspective, producing extra offspring that will serve as future meals for others can be a means of converting available and efficiently harvested nutrients into a stable form (eggs) that will not spoil before being ingested by the first-hatching progeny.

At first glance, consuming a viable full sib (which carries copies of half of the cannibal's own alleles) seems maladaptive. Many factors can tip the balance. For example, the sacrificed brood mate may have had a vanishingly small chance of reaching reproductive maturity. In one Swedish land snail, Bruno Baur reports that average egg survivorship is so low (fewer than 1% ever become juveniles) and benefits for eating a conspecific egg so high (the cannibal's shell diameter enlarges 25% in three days if it consumes just one egg, a feat of growth that otherwise takes 21 days) that the cannibal's likelihood of reaching adulthood is increased by about 40%. For this species the balance sheet suggests that relatedness to the victim is immaterial. Full sib, half sib, or alien, an egg is more valuable as a food item. This helps explain why these snails show no discrimination by degree of kinship.

Similarly, Martha Crump notes that desert tadpoles are often under great pressure to escape quickly from an evaporating natal pool; rich meals of animal protein can make the difference. In several amphibians spectacular developmental polymorphisms arise, wherein some individuals acquire bizarre cannibal structures (among them a greatly enlarged head, hypertrophied mouthparts) and others remain omnivorous. If the pool vanishes, fast-growing cannibal-morph individuals are more likely to have metamorphosed; otherwise, the larger lipid reserves of the (uneaten) omnivores apparently confer compensating advantages through larger adult body size.

For various fishes, the solo parent tending a fertilized egg mass cannot leave to forage, so it sustains itself by eating some of its own brood (chapters by G. Fitzgerald, F. Whoriskey, and C. Sargent). This "filial cannibalism" satisfies parental needs while greatly benefitting all siblings not consumed (they receive continuous guarding). If the parent finds itself holding a clutch that is "too small," below some threshold, it may achieve higher reproductive success by eating all current eggs (recouping part of a bad investment) and starting anew with a larger family. Similar loss-cutting measures are described for birds, mammals, and plants in other chapters.

Sexual cannibalism has evolved in some insects, spiders, and their allies, when mating females consume courting males. Mark Elgar draws a distinction between taxa where the cannibalism occurs before the mating act itself (a uniquely effective form of female mate rejection) and those practicing it afterward. Postmating cannibalism accommodates the tantalizing possibility that males are suicidal collaborators, willingly providing paternal investment not unlike the fatal conversion of body tissue to eggs by semelparous female salmon. In the spider *Argiope aemura*, the male inseminates the female once, inverts himself to facilitate her initial feeding on his abdomen, moves away briefly