BOOKS & ARTS

On the origin of technology

An overdue theory of how machines and tools evolve downplays human creativity, argues **Jon Agar**.

Every rivet of a jet engine is the outcome of a development process.

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Technological change, implies economist and complexity theorist W. Brian Arthur, is a lot like climbing a mountain. You could never do it in a single bound. You break the journey into parts by walking the foothills, aiming for a base camp and ascending a sheer face with ropes and pitons before reaching the summit. Each stage needs further consideration. Do you place your foot on that rock or go through the mud? Each movement harnesses some natural phenomenon. Walking uses the friction between land and sole. Climbing exploits the solidity of rock and steel, the tensile strength of polypropylene yarn and the physical laws of pulleys. Combining many solutions, you achieve your purpose of standing at the top to enjoy the view.

To invent a jet engine, say, you might start with the idea of an explosive mix of fuel and oxygen that exploits the physics of action and reaction as an alternative to propellers that fail at high altitudes. But that goal must be achieved in stages using existing technologies — compressors, fuel systems, containers, turbines — each of which is the outcome of its own development process, down to the smallest rivet.

Arthur's theory, outlined in his engaging and provocative new book *The Nature of Technology,* builds on three principles. First, all technologies are made up of pre-existing components, so technological change involves assembling new combinations of old and refined technologies — Arthur calls this process 'combinatorial evolution'. Second, each component is itself a technology, meaning that technologies have a hierarchical and recursive nature. Finally, he writes, "all technologies harness or exploit some effect or phenomenon" and fulfil a human purpose. Arthur distinguishes between individual technologies (for example, a sink); between bodies of related technologies that he calls domains (such as all plumbing systems); and the "collective of technology", meaning everything, including the kitchen sink. Because each level is a nested assemblage, Arthur treats them similarly in his theory.

The Nature of Technology: What It Is and How It Evolves
by W. Brian Arthur
Free Press/Allen Lane: 2009.
256 pp. $27.00/£22.00

His model of invention as combination and change as accumulation is not new; he nods to the 1920s pioneers of this idea, William Fielding Ogburn and S. Colum Gilfillan. The notion that technology evolves is older still, going back at least to Charles Darwin's contemporaries, such as the author Samuel Butler and the archaeologist Augustus Pitt Rivers. Arthur correctly records that historians of science have been some of the best guides to the logic of technology. Thomas P. Hughes, for example, offers a model of technological change similar to Arthur's to explain the growth of systems in his book *Networks of Power* (Johns Hopkins University Press; 1983). But Hughes gives more room for human organizations and individuals, considering an invention to be useless without the social system that supports it.

Arthur's theory captures many well-known features of technological change. These include 'lock-in', in which an early choice between technologies becomes difficult to undo because it is more profitable to refine existing components than develop new ones; and 'clustering', in which certain geographical regions become hot spots of innovation by hosting those with crucial know-how. The theory also answers interesting questions, explaining that technology is modular because nested assemblages are easier to improve; and that it is related to but different from science because it manipulates new effects generated by the skills base of research. As technology increasingly harnesses natural phenomena that are far from everyday experience, so it relies on science even more. Thus, technology can feel unnatural, yet "in its deepest essence it is natural".

Arthur's argument will gain notoriety because of the analogy between biological and technological evolution. He is right to distinguish his combinatorial evolution from Darwinian evolution. Imagining combinatorial evolution in living organisms, he notes, would be like putting together "an organ that had proved particularly useful in lemurs, say, and another organ from iguanas, and another one from macaque monkeys … in combination with others to create a new creature". Combination in nature can happen, such as in the ancient incorporation of bacteria to form mitochondria in the eukaryotic cell, but not routinely. Yet Arthur cannot resist a few one-liners that will bait critics, such as "Conceptually at least, biology is becoming technology. And physically, technology is becoming biology."

In its favour, Arthur's theory does not appeal to mysterious entities such as creativity. Ernest Lawrence's 1929 invention of the first cyclotron is as mundane as fixing a bicycle when viewed as the assembly of pre-existing technologies. But, by focusing on logic, *The Nature of Technology* downplays human achievement. Arthur does conclude that the collective of technology builds itself "with the agency of human inventors", although merely as a "coral reef builds itself from itself from the activities of small organisms".

This is the US west-coast entrepreneur's philosophy of technology as fluid combinations, forever reconfigurable in the interests of profit. Arthur wants us to think that technology has always been this way, and that it is natural. Portraying something new and man-made as permanent and natural is one of the oldest and most effective strategies to depoliticize a subject. ■

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