1 Introduction: Thinking about Technology

Humans have always used technology, so a history of humanity would be incomplete without understanding the role it has played in our collective story. To understand technology in society, we need a definition of technology. This is not a simple task, since thinkers have been debating its effect on society since the time of the ancient Greeks. Technology should not be confused with tools, devices or machines. Physical objects, whether a stone axe or a supercomputer, are created in a specific human context and are part of a system of human knowledge. With a working definition, we can look at several of the most important issues that scholars have raised about the interaction of technology and society, particularly the problem of technological determinism, the general conditions that contribute to invention and the potential problems of technology in society.

To be human is to use technology. Everything we do, from telling stories around a campfire to examining the farthest reaches of the universe, is done using technology. The web of technology that makes human life possible is so pervasive that we are often only aware of it when it breaks down or suddenly changes. It is so closely tied to human existence that we identify groups of people by their access to technology, comparing "industrialized" countries to "developing" countries. We even classify vast periods of human history on the basis of technology such as the Neolithic period or "New Stone Age," followed by the "Bronze Age."

Some scholars have described technology as the ability to make tools, while others see it as a kind of framework that surrounds us. This book argues that technology does not exist on its own as something separate from people and the societies we create. At a fundamental level, we are our technology. In other words, a history of technology is

a history of the development of human society and, as such, this book places in the foreground the social context of technology. This does not mean that tools are unimportant. No history of technology can ignore the history of invention, but inventions, no matter how marvelous, are always created within the context of the society of the inventor. Historically, the success or failure of a particular tool or device was determined not simply by the quality or utility of the invention itself, but by a range of social factors such as the degree to which society is open to change or the social status of the inventor. Since no history of technology could encompass the vast range of inventions and their use, I have selected examples that illustrate this integral relationship of technology and society and that were key to transforming human history.

Technology: A Definition

The main difficulty with defining the term "technology" is that its common use is vague and implies value. In everyday use the term means the created physical objects around us, and there is a strong sense that new technology is better than existing technology. We often present objects as the technology, whether it is in an advertisement for the latest tablet computer, or the newest "technology of hair care" shampoo. There also seems to be a special category of "high technology." In advertising, "high tech" is always the most advanced – and the implication is that it is the best technology. This suggests there is a hierarchy, with low technology (usually old or requiring manual operation) at the bottom and high technology (usually electronic and increasingly autonomous) at the top.

The problem with using common meanings for complex terms is that they can cloud our understanding of what is really happening. Technology is not the object itself. An airplane or a spoon is only an artifact or a product of human construction and craft, and is thus the physical component of technology, but it is not the technology itself. It is only when the artifact is used that it becomes something more than a collection of matter.

A more precise definition of technology is that it is the *system* by which we attempt to solve real-world problems. In other words, technology presents the complex web of knowledge, social connections and behavior that makes it possible for us to solve real-world problems. Most of the time technology includes a material object that we use to interact with the environment, but not all technologies require a physical artifact. To understand why technology must be a system, consider an incandescent light bulb. The light bulb is a simple object with no moving parts and consisting of glass, a bit of metal and some ceramics. As a physical object, it could have been built by the ancient Egyptians, but it was not invented until the late nineteenth century when the controlled production of electricity became possible. The light bulb in your home cannot be used

for its designed purpose without access to an electrical network that includes the generating plant, the delivery system and the people who create and maintain the network. Although a person with moderate knowledge of glassmaking, smelting and ceramics could make a single working light bulb, the incandescent bulb is really a manufactured object, and as such is part of a vast manufacturing chain that links mines, refineries, transportation, factories and retail operations together. The light bulb, humble in creation and simple in construction, is in fact part of one of the most extensive and complex systems every devised. To use a light bulb is to take part in the vast system needed to make the light bulb possible. Without the access to the system, the bulb is an artifact or a manufactured object, not the technology itself.

The distinction between technology and artifact is important because it is possible to have a technology that does not require physical objects or produces no artifacts. For example, education is one of the greatest technologies we have ever created, but it does not produce a material end product the way that we produce automobiles or sewing machines. These "invisible technologies" include language, education and forms of governance and extend to such things as national governments, corporations and sports governing bodies.

Some artifacts seem to be self-contained and their purpose self-evident. A knife, whether it is a stone tool from the Paleolithic era or a surgical steel blade manufactured today, seems like it should be understood as a cutting tool. Yet even the simplest objects had to be invented and their use taught to new generations. A modern surgical steel scalpel would be instantly recognized by a Babylonian surgeon accustomed to bronze cutting tools, but a heart regulating pacemaker would be a mystery and completely unusable, even if it could be transported back in time. In a thought experiment, we could bring a Babylonian surgeon to the present and train him to use a pacemaker, but this would mean that our ancient surgeon would become part of the web of knowledge in which the pacemaker was embedded. The pacemaker fits within the context of our current society with all its education, infrastructure and intellectual concepts. Our current medical technology includes the knife and the pacemaker, but the Babylonian surgeon's world included the knife, but not anything electrical.

It is important to remember that the reverse is also true. To really understand the world of the Babylonian surgeon, we must learn about the network and social context that made his technology possible. Thus, the Babylonian knife and the modern scalpel both function as cutting devices because our society shares with the Babylonians the concept of surgery, but to understand what the knife means and how it was used by the ancient surgeon, we need to understand the education and social circumstances of the surgeon, not just note the existence of a type of knife. Both societies had real-world problems and created a device that would solve those problems. Assuming that our knowledge is automatically superior to or subsumes the knowledge of people of the past can lead us to undervalue our ancestors and misinterpret history.

The Concept of Invention

Whether a knife is made of bronze or high carbon steel, a knife is only a knife if the user understands the object as part of a larger category of things that can cut. The concept of cutting must already exist in the mind of the person taking the action. To create such a plan requires the ability to identify a problem, conceive of a desired end point and take action to reach the desired conclusion. When the path from problem to solution does not already exist, we call the act of creating a new path "invention." Like technology, most inventions involve the creation of artifacts, but not all inventions are physical.

The story of invention has been one of the most enduring and popular forms of history. We have created entire museums dedicated to important inventions such as automobiles, aircraft, weapons of war, ceramics and shoes. Our interest has spanned the ages. In ancient China, Sima Qian (c. 145–90 BCE) wrote about many of the great inventions in his *Historical Record*. Hero of Alexandria (c. 10–70 CE) wrote about his inventions, including a type of steam engine called the *aeolipile*. His work was rediscovered by Islamic scholars around 1000 CE and then by Europeans during the Renaissance and in both cases contributed to periods of new creativity. The *Encyclopédie* (1765–72) published by Denis Diderot (1713–84), was one of the greatest documents of the Age of Enlightenment, and contained some of the most detailed descriptions of tools and machines ever published. Today almost every important invention has its own book. Even something as humble as the screw was examined by Witold Rybczynski in his book *One Good Turn: A Natural History of the Screwdriver and the Screw* (2000).

Part of the reason that inventions get so much attention is that there is a link between the tools a society has and the power of that society. Thus, our interest in the history of invention extends far beyond a fascination with the devices themselves and becomes a study of the course of human history, particularly the dramatic moments such as the clash of nations, the rise and fall of industries and other dramatic turning points.

Although devices can be looked at without direct reference to the creators of those devices, historians have also been fascinated by inventors. The stories of inventors are often a significant part of history, particularly when some new thing (a cannon, a radio, a supposedly unsinkable ship) can be pointed to as "changing the course of history." People like Archimedes, Li Jun, Johann Gutenberg or Thomas Edison become icons, often woven into national identity and serving as role models. This is particularly true of inventors who faced opposition or deprivation in the course of creating world-changing devices. Stories such as Archimedes running naked through the market shouting "Eureka!," Johann Gutenberg forced to sell his press and dying in poverty, John Harrison (inventor of the first reliable marine chronometer) denied the prize money for his invention for many years, have fascinated people for generations. These stories are often presented as morality lessons teaching us things like the value of

curiosity and persistence, that individuals can make a difference, especially if they are resolute, or that geniuses are often unappreciated in their own time. In the case of many of the greatest inventions, the power to change the course of history was unexpected, adding to the romance of the story.

Although this book will look at many inventors and their inventions, there is a difference between a history of human invention and a history of technology. A history of invention treats tools and devices as separate from the world in which they are created and often attempts to trace a kind of family tree of development. It portrays inventors as heroic figures (who may also be misunderstood or tragic) who exist outside the norms of society. This is not to say that there weren't great inventors, but rather that the act of invention is not what creates a new technology. Successful invention requires the adoption of the new technology and that requires a collaboration of intellectual insight, technical utility and social acceptance. It is important to remember that there are many examples of inventions that were not adopted even though they were at some technical level better than their competition, and conversely, inventions that were far less useful than what already existed and yet were adopted. There were also periods when societies resisted adopting any major new invention, and others that have become known as periods of great inventiveness.

Progressivism and Presentism

The belief that there is a kind of arrow of development from primitive to highly developed is called "progressivism." A related belief called "presentism" is the idea that the past existed only to produce us in the present, and that the past can be judged by the standards and knowledge of the present. Historians try to avoid these two "isms," but it can be a particularly difficult job for historians of technology. In consumer culture, especially as it has developed in the industrialized world, there is constant pressure to produce new and "improved" models, partly because it is the job of engineers and designers to create new things, and partly to entice consumers to continue to purchase products. Thus, any historical examination of consumer goods strongly suggests that there *is* a hierarchy of product quality from rudimentary devices produced in the past to the improved versions available today, and toward the glorious and almost magical products on the drawing boards of scientists and engineers for the future. The transition from crystal radios to radios with vacuum tube technology to black and white television, to color television, to digital high-definition LED flat screen televisions with stereo surround sound seems like a perfect example of the improvement of technology. Although people frequently complain about the decline of the quality of consumer goods and the disappearance of craft skill, for the most part the material goods of the present are superior to those produced in the past in terms of reliability, price and availability.

Although we can argue for a kind of progressivism in technology, it would be wrong to see human history being based on an ideology of progressivism. The conception of constant material progress as a component of society is an ideology found primarily in modern Western culture (meaning Europe and European-settled regions including North America, South America, New Zealand and Australia). Through most of human history, the objective of societies was to create stability, because stability meant survival. The tool kits of our ancestors were finely tuned to match the local environment, helping us harvest the food and other resources we needed, but in turn those tools were based on what was available in the location where we lived. One of the major characteristics of modern Western society was the establishment of long-distance trading that allowed the exploitation of resources globally and thus broke the intimate connection between people and their local environment. Although the power of Western culture created the first truly global economy, it was not the first time that cultural expansion was made possible by technological power. The rise of various empires such as those found in Egypt, India and China were based in part on technological developments and long-distance trade. The initial spread of Islam around the globe was another historical period that had a strong technological aspect. Yet in all the earlier cases, a period of invention was followed by a period when invention declined or was actively resisted. Too much change brought about by technology created a social reaction to restore stability.

This examination of the history of technology ends with a focus on Western society because currently the West has produced the greatest abundance of tools, machines and infrastructure. Western powers came to dominate international relations in the last 500 years in large part because technology gave them an advantage over other groups of people. Yet as the technologies pioneered in Western countries became globalized, the advantages have narrowed or disappeared. There is thus a distinction in this book between "Western society" used to refer to the geographic collection of European-based societies and the historical period of Western expansion and colonialism and "industrial society" that includes the West but also other countries that have created significant manufacturing economies such as Japan, Korea, Turkey, China and South Africa.

The rise to power of Western society makes it easy to conflate the idea of technological power with cultural superiority, but this is just another version of chauvinism and no different than claiming that cultures can be ranked by skin color, language or religion. What makes the problem of technology and culture more complicated is that from a historical point of view, and in terms of physical condition, we as people *are* better off than our ancestors. Although the benefits are not uniform, and the disparity between rich and poor cannot be overlooked, it is nonetheless the case that people in the industrialized world (not just the West) are the longest-lived, strongest, smartest,

healthiest people in human history.[1] This is not to say that industrial society is without problems (there are many), but rather to point out that the effect of technology can be looked at from different perspectives.

People who object to the idea of technological society often suggest that while people in the industrial world may be better off in a material sense, all this technology has not made us better people. As for being better people, it is difficult to measure whether we are better or worse in a moral sense, but by other measures we seem to be doing very well. We are safer than people in the past as overall levels of violence (outside of actual wars) have steadily declined, the concept of human rights has developed in parallel with the growth of industrialization, and our ability to empathize and offer aid to people around the world has grown with our ability to communicate and travel. Philosophical ideals such as universal suffrage, human rights, public education and democracy have become a reality in parallel with the rise of industrialization. Technology made it possible, and perhaps even a necessity, to care about people beyond the family or the tribe.

It is likely that you have read the above statement with a growing sense of suspicion. Few people when presented with an argument extolling the virtues of technology can avoid thinking of counterexamples to balance the optimism of progressivism. Hasn't our technology also given us the power to destroy all human life on the planet with weapons of mass destruction, and did we not fight the two biggest wars in history where killing was "industrialized"? Our industries and lifestyle are wrecking the environment, depleting the ozone and producing climate change. While we have a powerful medical system, we are also producing new health problems such as obesity and a plague of diabetes, environmental sensitivity and cancer. Some people have even argued that we have enslaved ourselves to the demands of machines, from our Pavlovian response to ringing telephones to our dependence on the complex systems of energy, communication and industry that keep contemporary society going. There is a subculture of survivalists and preppers who are preparing for what they believe is the imminent collapse of industrial society. Popular culture is full of stories about dark futures where monsters of our own creation lurk, from Mary Shelley's *Frankenstein: Or the Modern Prometheus*, the first great morality tale about the dangers of modern technology, to *Gattaca* and the *Terminator* movies.

These reactions to technology are also the product of technology.

This is exactly the challenge that historians face: How do you present the history of technology without falling into the trap of presentism and progressivism, or taking the opposite position and becoming completely anti-technology?

The first answer is that historians try to see all parts of human history as valuable in their own right. We ask about what issues were important to the people of the time and how the people of the past acted to address those issues. This helps historians link the past with the present without making it seem that the past was just getting the world ready for us.

The second strategy is to understand that the level of total complexity in human society remains relatively constant. We falsely believe we live in a more complex society than people in the past because we live in a world filled with complex devices, see things that are happening around the world, and have access to massive quantities of information. While we expend a great deal of time learning how to live in a world filled with devices, from coffee makers to laptop computers, people in the past filled their lives just as fully with the skills of hunting, farming and dealing with the people and spirits that filled the world. Consider television as a form of entertainment. Producing a television program is an incredibly complicated activity, but watching one requires little or no effort except sitting and staring at the screen. For our ancestors, home entertainment required things like a knowledge of how to play an instrument, remembering lyrics, poems and stories, learning the rules for games, and participating in religious and ceremonial rites. All those activities depended on the active participation of the people involved, not just passive observation.

Another aspect of the complexity of the past has to do with memory. People in the past remembered far more than people in literate societies who have transferred memory to paper or digital form. From important events to poetry and music, human memory was just about the only means of recording available to people who did not read or write. It was not uncommon in pre-literate times for people to memorize hundreds and even thousands of lines of poetry, dozens of stories, or the lyrics to a song after hearing it only once. Today such memory work is seen as a special talent or requiring the kind of serious effort a stage actor uses to memorize a part.

In addition to the idea that social complexity is not analogous to the complexity of our tools, we do well to remember that technology is never trapped in amber. We mix tools, systems and approaches to problem solving from across time and from many places. If you open the toolbox of a carpenter today you might find a hammer, a ruler, a spirit level, a screwdriver and a power drill with a lithium ion battery. In one little box we have tools that span at least 5,000 years of technological history and devices created in a variety of different places and cultures. This tangling of technology chronologically and geographically has been looked at by David Egerton, particularly in his *The Shock of the Old: Technology and Global History since 1900* (2007). He argues that technology can appear, disappear and then re-emerge as well as undergoing transformation when it is transferred from one place to another. This allows "old" technology to be mixed with "new" technology as people use a variety to approaches to solve problems.

A final point about the complexity of human life comes from Neil Postman, who pointed out that information is not knowledge. We tend to discount the knowledge of our ancestors because we assume that we know more about the world today than people in the past knew. What this really means is that we have more information about the world and it tends to be more accurate because we have developed precise

measuring devices, have access to vast information systems, and use scientific principles like experimentation to gain that information. What people in the past lacked in terms of access to information, they more than made up for with local knowledge. They knew their world, and more, they knew their place in it. Rather than seeing the world in terms of data, they saw things as a series of relationships, often connected to religious or spiritual worlds beyond the immediate physical world. For historians, it is important to be cautious about assuming that our access to information means superior knowledge. A perfect example of this is the completely false idea that people in the past thought the Earth was flat. The majority of scholars from the Babylonians to the scholars of the late Middle Ages thought the world was a sphere. Sailors around the world knew the world was a sphere. Christopher Columbus did not set sail to prove that the world was a sphere, but to find a new route to Asia. The question for geographers of the past was not the shape of the Earth, but its size and whether people lived in other parts of it. If we impose ignorance on our ancestors, our understanding of our own history will be flawed.

Technology in Society versus Technological Determinism

Societies exist because they are able to exploit their environment to gain the resources necessary for survival. The only way to exploit the environment is by using technology, so societies cannot exist separately from their technology. As the range of tools and number of people has increased over time, the relationship between technology and the people who use it has become more complicated. Since social rules both perpetuate and constrain technology, there is always a tension between the need to use technology and the need to follow the rules about the use of technology. This tension is particularly evident when new tools or methods are introduced that change the relationships of the people within the society and the people and their technologies.

In contrast to this interactive view of technology in society is the unidirectional model of technological determinism. At the most basic level, technological determinism seems perfectly reasonable. For example, humans have dreamt of flying since the dawn of time, but we could not actually undertake controlled flight (not just floating or gliding) until we had developed the internal combustion engine to the point where it could provide the power to propel an airplane. It would then seem perfectly logical to say that human flight was dependent on the availability of the technology of the internal combustion engine. It follows that the modern aviation industry, from fighter jets to package tours to exotic destinations, was only made possible by the existence of a specific technology.

One of the earliest applications of technological determinism to explain history was by Karl Marx. His most famous assertion about the relationship between devices and

social organization was in *The Poverty of Philosophy* where he said "The handmill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist." By explicitly linking a certain tool with the structure of society, Marx was pointing out that history depended upon the material conditions experienced by people.

This idea has often been repeated, although Marx's ideas about technology were more directly concerned with the means and control of production than with the equipment being used. In 1967, the historian Robert L. Heilbroner addressed the concept of technological determinism by asking the question "Do Machines Make History?" in an important article of the same name (Heilbroner 1967). His answer was almost as complex as the issue itself, but concluded in part that the degree of effect of technology on society depends on the state of the society at the time of the introduction of the technology. Thus, the greatest degree of technological determination occurred when capitalism was least restrained: "Technological determinism is thus peculiarly of a certain historical epoch … in which the forces of technical change have been unleashed, but when the agencies for the control or guidance of technology are still rudimentary."

When we think of technological determinism in terms of what we can do in the physical world, it seems perfectly reasonable. If we apply the theory of technological determinism to how we behave, or how we interact with each other, it fails.

One of the most profound applications of the concept of technological determinism has been the idea that the rise of modern mass democracy was dependent on the development of mass communications, specifically the invention of movable type printing by Johann Gutenberg around 1450. The reasoning for this conclusion hinges on the idea that, to create a democracy, the people must be aware of the issues and be able to discuss, plan and report on actions. Candidates must be able to communicate with the electorate. Without the ability to communicate with a significant portion of the population, no such coordination would be possible. Prior to mass printing, democracy could only function in groups small enough for the voters to attend meetings or have personal knowledge of the issues and candidates because that was the only way to get the information necessary to participate. Thus, democracy could work in a limited way in a city-state like Athens, but not for a large country.

In the determinist story, mass printing solved the communications problem, and candidates no longer had to personally interact with voters to gain their support. It also created higher levels of literacy, increased the speed at which ideas could be communicated, and raised the expectation of the people in regards to their ability to participate. It is certainly true that the modern democratic states only came into existence after Gutenberg's printing press had been spread across Europe and into the Americas.

There is a flaw in this argument. If there was strict technological determinism, it should follow that printing leads inevitably to democracy, but of course this is not the case. Some of the most powerful totalitarian regimes came into being *after* printing was