A COMPANION TO AMERICAN TECHNOLOGY

Edited by
Carroll Pursell

Blackwell Publishing
A Companion to American Technology
This series provides essential and authoritative overviews of the scholarship that has shaped our present understanding of the American past. Edited by eminent historians, each volume tackles one of the major periods or themes of American history, with individual topics authored by key scholars who have spent considerable time in research on the questions and controversies that have sparked debate in their field of interest. The volumes are accessible for the non-specialist, while also engaging scholars seeking a reference to the historiography or future concerns.

**Published**
- A Companion to the American Revolution
  *Edited by Jack P. Greene and J.R. Pole*
- A Companion to 19th-Century America
  *Edited by William L. Barney*
- A Companion to the American South
  *Edited by John B. Boles*
- A Companion to American Indian History
  *Edited by Philip J. Deloria and Neal Salisbury*
- A Companion to American Women’s History
  *Edited by Nancy Hewitt*
- A Companion to Post-1945 America
  *Edited by Jean-Christophe Agnew and Roy Rosenzweig*
- A Companion to the Vietnam War
  *Edited by Marilyn Young and Robert Buzzanco*
- A Companion to Colonial America
  *Edited by Daniel Vickers*
- A Companion to 20th-Century America
  *Edited by Stephen J. Whitfield*
- A Companion to the American West
  *Edited by William Deverell*
- A Companion to American Foreign Relations
  *Edited by Robert Schulzinger*
- A Companion to the Civil War and Reconstruction
  *Edited by Lacy K. Ford*
- A Companion to American Technology
  *Edited by Carroll Pursell*
- A Companion to African-American History
  *Edited by Alton Hornsby*
- A Companion to American Immigration
  *Edited by Reed Ueda*
- A Companion to American Cultural History
  *Edited by Karen Halttunen*

**In preparation**
- A Companion to California History
  *Edited by William Deverell and David Igler*
- A Companion to American Military History
  *Edited by James Bradford*
- A Companion to American Urban History
  *Edited by David Quigley*
- A Companion to the History of Los Angeles
  *Edited by William Deverell and Greg Hise*
- A Companion to American Environmental History
  *Edited by Douglas Sackman*
- A Companion to the History of American Science
  *Edited by Mark Largent*
A COMPANION TO AMERICAN TECHNOLOGY

Edited by
Carroll Pursell
Contents

Notes on Contributors vii

Introduction 1
Carroll Pursell

PART I BEGINNINGS
1 Technology in Colonial North America 9
   Robert B. Gordon
2 The American Industrial Revolution 31
   James C. Williams

PART II SITES OF PRODUCTION
3 The Technology of Production 55
   Carroll Pursell
4 Technology and Agriculture in Twentieth-Century America 69
   Deborah Fitzgerald
5 House and Home 83
   Gail Cooper
6 The City and Technology 97
   Joel A. Tarr
7 Technology and the Environment 113
   Betsy Mendelsohn
8 Government and Technology 132
   Carroll Pursell
9 Medicine and Technology 156
   James M. Edmonson

PART III SITES OF CONTEST
10 The North American “Body–Machine” Complex 179
    Chris Hables Gray
11 Gender and Technology  
*Rebecca Herzig*  
12 Labor and Technology  
*Arwen P. Mohun*

**PART IV**  **TECHNOLOGICAL SYSTEMS**

13 The Automotive Transportation System: Cars and Highways in Twentieth-Century America  
*Bruce E. Seely*  
14 Airplanes  
*Roger E. Bilstein*  
15 Technology in Space  
*Roger D. Launius*  
16 Nuclear Technology  
*M. Joshua Silverman*  
17 Television  
*Douglas Gomery*  
18 Computers and the Internet: Braiding Irony, Paradox, and Possibility  
*Jeffrey R. Yost*

**PART V**  **PRODUCING AND READING TECHNOLOGICAL CULTURE**

19 The Profession of Engineering in America  
*Bruce Sinclair*  
20 Popular Culture and Technology in the Twentieth Century  
*Molly W. Berger*  
21 Art and Technology  
*Henry Adams*  
22 Critics of Technology  
*David E. Nye*

Index  
453
Notes on Contributors

**Henry Adams** was recently singled out by *Art News* as one of the foremost experts in the American field. Dr Adams has produced over two hundred publications, including scholarly and popular articles, books, catalogues, and exhibitions catalogues. His major books and exhibition catalogues include *John La Farge* (1987), *Thomas Hart Benton: An American Original* (1989), *Thomas Hart Benton: Drawing from Life* (1990), *Albert Bloch: The American Blue Rider* (1997), and *Viktor Schreckengost and 20th-Century Design* (2000). In 1989, in partnership with filmmaker Ken Burns, he produced a documentary on Thomas Hart Benton, which was broadcast nationally on PBS to an audience of 20 million. He currently serves as Professor of American Art at Case Western Reserve University.

**Molly W. Berger** is an Instructor of History in the Department of History at Case Western Reserve University. She also serves as Assistant Dean in the College of Arts and Sciences. Dr Berger is currently writing *The Modern Hotel in America, 1829–1929*, a cultural history about nineteenth-century American urban luxury hotels that explores ideas about technology, democracy, and urban growth. The book is forthcoming from Johns Hopkins University Press.

**Roger E. Bilstein** is Professor of History, Emeritus, University of Houston-Clear Lake, where he was a Charter Faculty Member at the time of its establishment in 1974 as an upper-division, suburban campus for juniors, seniors, and graduate students. He is the co-author/editor or sole author of nine books and monographs, including *Flight in America: From the Wrights to the Astronauts* (3rd edition, 2000) and *Enterprise of Flight: The American Aviation and Aerospace Industry* (2nd edition, 2001). The official NASA history *Stages to Space: A Technological History of the Apollo/Saturn Launch Vehicles* (1980), received the history award for 1979 from the American Institute of Aeronautics and Astronautics and was released in a second edition by the University of Florida Press in 2003. His latest book is *Testing Aircraft, Exploring Space: An Illustrated History of NACA and NASA* (2003). He is also the author of several dozen articles and book chapters.

**Gail Cooper** is an Associate Professor in the history department at Lehigh University. She is the author of *Air-conditioning America* (1998). In addition, she served as historical consultant for the exhibit *Keep Cool!* at the National Building Museum in Washington, DC. She is particularly interested in the history of manufacturing, and has written on the connections between gender and technology.

**James M. Edmonson** is Chief Curator of the Dittrick Medical History Center and Museum of Case Western Reserve University, and is Adjunct Associate Professor in the Department of History. A graduate of the College of Wooster, he received an MA and PhD in the history of technology at the University of Delaware. While at Delaware he was a Hagley Fellow and a Fulbright-Hays Fellow in Paris, France, and his dissertation, *From mécanicien to ingénieur: Technical Education and the Machine Building Industry in Nineteenth-Century France* (1986) received the Sypherd Prize for outstanding dissertation in the humanities. Since becoming Chief Curator at the Dittrick he has written on medical museology, surgical instrumentation, endoscopy, and medical patents. His publications include *Nineteenth...*

Deborah Fitzgerald is Professor of the history of technology in the Program in Science, Technology and Society at MIT. Her work includes the book The Business of Breeding: Hybrid Corn in Illinois, 1890–1940 (1990), and “Every Farm a Factory”: The Industrial Ideal in American Agriculture (2003), which won the Theodore Saloutos Prize for the best book in agricultural history in 2003 from the Agricultural History Society. She has published essays and articles on dairying in agriculture, the Rockefeller Foundation’s agricultural experiences, and the modernization of agricultural practice and thinking. Fitzgerald is an advisory editor for Technology and Culture. She is currently president of the Agricultural History Society, and has served on the Executive Council, the Secretary search committee, and the Dexter Prize committee for the Society for the History of Technology. She has been awarded two National Science Foundation Fellowships. With Harriet Ritvo, Fitzgerald received a Sawyer Seminar Grant from the Mellon Foundation to run a seminar “Modern Times, Rural Places,” at MIT in 2001–2004. She is currently working on the industrialization of food in America.

Douglas Gomery teaches media history at the University of Maryland and is Resident Scholar of the Library of American Broadcasting. His Who Owns the Media? won the Picard Award in 2002. He has published 11 more books, and over 1,000 articles in journals, magazines, and reference works.


Chris Hables Gray is an Associate Professor of the Cultural Studies of Science and Technology and of Computer Science at the University of Great Falls in Montana. He is the author of numerous articles and Postmodern War (1997), Cyborg Citizen (2001) and Peace, War, and Computers (New York: Routledge, 2005) and edited The Cyborg Handbook (1995) and Technohistory (1996). He is also Core Faculty of the Graduate College of the Union Institute and University and is a professor at Goddard College. A former NASA and Eisenhower fellow, he is currently writing on information theory, anarchism, and art.

Rebecca Herzig teaches courses on the history and sociology of science, technology, and medicine in the Program in Women and Gender Studies at Bates College. She is the author of two forthcoming books: Suffering for Science: Will, Reason, and Sacrifice in Nineteenth-Century America and, with Evelynn Hammonds and Abigail Bass, The Nature of Difference: A Reader on Science, Race, and Gender.

Roger D. Launius is Chair of the Division of Space History at the Smithsonian Institution’s National Air and Space Museum in Washington, DC. Between 1990 and 2002 he served as chief historian of the National Aeronautics and Space Administration. He has written or edited more than twenty books on aerospace history, including Space Stations: Base Camps to the Stars (2003), which received the AIAA’s history manuscript prize, Flight: A Celebration of 100 Years in Art and Literature edited with Anne Collins Goodyear, Anthony M. Springer, and Bertram Ulrich (2003), Taking Off: A Century of Manned Flight edited with Jonathan
Betsy Mendelsohn studies how law, science and technology have interacted to shape environmental quality in the United States. She is finishing a book about how Chicago managed surface water to meet its needs for clean water, drainage, sewerage, navigation, and secure property boundaries. Her next book describes how science and law interacted to resolve environmental conflicts during the period 1850–1940. She earned her history PhD from University of Chicago as a US Environmental Protection Agency graduate fellow. She is the co-chair of Envirotech, a special interest group of the Society for the History of Technology, and is a postdoctoral fellow in the history of environment and technology at the University of Virginia’s School of Engineering and Applied Science, Department of Science, Technology and Society.

M. Joshua Silverman is a Program Manager for the US Department of Energy’s Office of Environment, Safety and Health. He manages a federal program addressing the health legacy of American nuclear weapons production. His research focuses on changing risk management and environmental safety practices in American nuclear weapons production.

Bruce Sinclair is a Senior Fellow at the Dibner Institute at MIT. He taught for a number of years at the University of Toronto, where he was director of the Institute for the History and Philosophy of Science and Technology, and then moved to the Georgia Institute of Technology, when he was appointed Melvin Kranzberg Professor of the History of Technology. Long active in the Society for the History of Technology, he won its Dexter Prize, served as its president, and was awarded its da Vinci Medal.

Joel A. Tarr is the Richard S. Caliguiri Professor of History and Policy at Carnegie Mellon University. His main research interests are in the history of urban environmental pollution and urban technological systems. Most recently, he is the author of The Search for the Ultimate Sink: Urban Pollution in Historical Perspective (1996) and the editor of Devastation...
and Renewal: An Environmental History of Pittsburgh and Its Region (2004). He has served as president of both the Urban History Association and the Public Works Historical Society.

James C. Williams is Professor Emeritus of History at de Anza College, was formerly the Treasurer of the Society for the History of Technology and is currently Vice President of the International Committee for the History of Technology. He is the author of Energy and the Making of Modern California (1997).

Jeffrey R. Yost is the Associate Director of the Charles Babbage Institute, University of Minnesota. He served as the principal investigator on a recently completed National Science Foundation sponsored project, “Building a Future for Software History,” was co-principal investigator on the NSF-sponsored “Computer as a Scientific Instrument,” published a book on the history of scientific computing, A Bibliographic Guide to Scientific Computing, 1945–1975 (2002), and is currently completing a book on the history of strategic management and technological change in the computer industry. He serves as the editor of the scholarly journal Iterations: An Interdisciplinary Journal of Software History, and has published a number of articles on the business, technical, and cultural and intellectual history of computing, software, and networking.
Introduction

CARROLL PURSELL

Americans live lives saturated with technology. They are certainly not unique in that, but this is no reason not to accept responsibility for attempting to discover how that happened, what shape it takes, and what it means. This Companion is designed to give us a place to start on that voyage of self-discovery.

First let us deal with the problem of definition. Those of us who study technology for a living are often challenged to define what that is. In fact, no single definition has been imposed upon the authors because, in my opinion at least, no single definition is possible. This is not because defining technology is difficult – indeed, the problem is the opposite: it is all too easy. Such chestnuts as “applied science” or “the tools with which we make things” spring to mind, but are immediately seen as too partial to serve.

As Leo Marx has famously pointed out, the word itself is of fairly recent origin. For most of American history such phrases as the mechanical, the practical or industrial arts stood for the stock of tools we used and the knowledge of how to use them. Technology, as both a word and a concept, replaced these older terms, in Marx’s estimation, sometime between the two world wars. During the period roughly from 1880 to 1920, he claims, both the character and representation of “technology” changed dramatically, eliding the accustomed identification of the older terms with real and specific tools and processes.

These tools and processes were displaced by great systems of power and production, in railroads and chemical, electrical and other industries, which were “large-scale, complex, hierarchical, centralized.”1 A telling case in point is the contrasting ways in which the Ford company represented its automobiles to the public. At the 1915 Pan-Pacific Exposition in San Francisco, Ford set up an actual assembly line so that viewers could see for themselves the miraculous way in which the Model T was produced. A quarter century later, at the New York World’s Fair of 1939–40, the emphasis had shifted from the artifact and how it was made to the image of the happy, fulfilled lifestyle which could be yours if you bought a Ford.

The cutting loose of the representation from the things themselves also marked an ideological shift from the Enlightenment notion of first defining the good life or the just society through rational argument and political debate, and then using particular tools to help create those ideals, to a modern urge to define that good life and just society in terms of technological progress. In other words, this new floating signifier technology became the end and not the means of our lives. All this is a powerful
reminder that what words we use, and what we mean by them, is critical to our political and social, as well as personal being.

A problem closely related to that of definition is the way in which I have chosen to organize this book as shown in the Table of Contents. Beginnings seems straightforward enough. Most of the chapters that follow concentrate on the twentieth century but Americans had technology long before then of course. Indeed, the idea that we somehow live in a “technological age” whereas previous generations did not is not only nonsense but profoundly ahistorical. One can argue in fact that since our use of technology is one of the major ways of separating us from other animals, humankind has always lived in a technological age. In discussing the Technology of Colonial North America, Robert Gordon begins with that of the indigenous Americans, moves through that of the Spanish settlers, before focusing on the more familiar stories of Northern European activities. For the 1800s, James Williams chronicles the changes of the “Long Century,” encompassing the Industrial Revolution in America and its spread across the continent, setting the stage for the so-called Second Industrial Revolution of the twentieth century.

Sites of Production seems somewhat less straightforward. Factories and farms; yes of course. Cities and the environment are where we expect to find factories and farms so they may be accepted as well. The home is more often thought of as a site of consumption than of production, though, of course, a great deal of consumption (of coal, steel, fertilizers, pesticides, petroleum and so forth) goes on in factories and on farms. How though do we justify government and medicine as topics of production? These last two tip us off that sites of production are also sites of contest.

The essay on Manufacturing Technology covers the familiar subjects of Armory Practice and Mass Production, but also shows the ways in which the latter influenced the way in which ships and houses came to be made. As Deborah Fitzgerald’s essay on Agriculture reveals, the ideal of the “Factory Farm” provided both a roadmap for agricultural change and a model of what the modern farm should look like. Gail Cooper’s essay on House and Home chronicles the way in which houses are networked into systems of utility, and the gradual integration of appliances into the home. The “house,” in other words, has become a part of technological systems from electrical grids to electric toasters. Cities are “home” to millions of people and, according to Joel Tarr, are shaped and serviced in much the same way as Cooper’s homes. From walking cities to “edge” cities, technology has played a critical role in the way urban geography and urban life have been formed, not always by design.

In writing on the Environment, Betsy Mendelsohn includes under that term both wilderness and urban neighborhood air quality. Our own particular “environments” are ones in which we necessarily consume not only food but air and sensory perceptions. Work environments, whether the factory floor or the office cubicle, are places where we both consume and produce. Governments at all levels play a critical part in production: setting the rules, defining the playing field, offering incentives or disincentives. The most passionate libertarian walks the streets, flies in and out of airports, lives under the shadow of the law. In a democracy, governments are the chosen instruments with which we produce the conditions of our lives. As James
Edmonson points out, medical technology at the very least reproduces good health and well-being. The “mechanical fix,” he asserts, tends to be preferred to preventative medicine.

The Body, according to Chris Hables Gray, is “one of the main sites of technological innovation in America.” Whether or not that should be so, of course, is hotly debated. Technology moves the body about (cars, for example), decorates them, reshapes them, and makes them perform more to our liking. Tattoos, birth control pills, cloning, and penal implants can all cause an argument and, in some cases, perhaps sway an election. Even the very notion of gender, or at least its malleability, is controversial. Rebecca Herzig notes that so basic a technology as the water closet (more commonly called a toilet in the US) is gendered in ways that most people accept without thinking unless the line at the “ladies” room is impossibly long. It is one of those technological spaces which compel us to make the “right” decision about our own gender identification or risk not only the wrath of our colleagues but the majesty of the law. And finally, Arwen Mohun analyses the ways in which class is shaped by and determines technological choices. Matters of skill or unskill, for example, are deflected by notions of class and the extent and form of technological alienation are closely tied to class. It is ironic that in a country where everyone considers themselves “middle class,” historians have concentrated more on the relationship between machines and the working class than any other.

Sites of Contest itself becomes clear as a subheading only when we see the topics that have been subsumed under it. The body and gender are both, most scholars would argue, socially constructed and labor is, as always, very much about class which too is socially constructed. Originally an essay on race and technology was planned, but finally proved impossible to include. Race, too, we now understand is socially constructed. What most scholars mean by that term, I think, is that race, class, gender and the body (and other things as well, like sexuality and ethnicity) are categories that, while more or less agreed upon by societies in any particular time and place, lack the kind of essentialist quality that is so often attributed to them. All of these are contingent as well as contested, but they are also sites where meaning is produced.

Technological Systems seems to put us back on a more solid footing – we are talking about things, and in the case of this book the very most obvious, ubiquitous, and iconic things at that. Although not an American invention, the automobile is intimately connected not only to the nation’s economy but to its very self-conception. As Bruce Seely shows, the car along with the highway is an American totem of great power. Despite excited predictions that the airplane would replace the car as a mode of personal travel, Roger Bilstein shows that commercial and military applications quickly took precedent in aviation development. Rockets and space flight, on the other hand, grew largely out of the circumstances of America’s international rivalries, according to Roger Launius. M. Joshua Silverman emphasizes the dual nature of the promise and practice of nuclear technology: energy and medical treatments, for example, on the one hand, but toxic wastes and weapons of mass destruction, on the other. Douglas Gomery describes how television took a half century to materialize, but then became a major factor in the way Americans spend their time and understand their
world. Along with the car and television, the computer has a ubiquitous and totalizing influence on American life. Jeffrey Yost emphasizes the “ironic” nature of the complexities of the computer’s development.

*Producing and Reading Technological Culture* seems almost as unproblematic but hides a few complexities. It would be wrong, I think, to read it as meaning that engineers produce the culture and painters, let us say, or novelists, do the interpreting. Engineers stand ready and willing to interpret our technological culture (they do it all the time in fact), and cultural production is the very purpose of Hollywood and academic departments of humanities, of High Art and Popular Art.

Bruce Sinclair traces the practice and the public understanding of engineers from the many heroes of the early twentieth century to the “nerds” and “geeks” of a century later. Dilbert is a sympathetic and competent engineer, but more anti-hero than hero; more “everyman” than elite. Molly Berger looks closely at the ways in which our popular culture figures both engineers and technology in general. She finds that while many “popular” expressions of culture would appear to express a bottom-up picture of technology, they are often commodities produced by particular people for particular purposes. The High Art of paintings, sculptures, photographs and the like, links the complications of defining technology with the equally slippery definitions of “art.” Henry Adams, in his essay, calls for a new art history which places art in not just a social context, but one of technological development as well. And finally, David Nye discusses the tradition of questioning our technology even as we elaborate it. Since the late eighteenth century, he shows – that is from the dawn of the industrial age – there have been individuals and groups which have asked the hard political, social, and moral questions of technology as a whole as well as its various components.

In fact none of these categories will withstand too close an inspection. It is an article of faith among historians that everything including the word “technology” and everything signified by it is contingent and contested. *Contingent* because, as historians, we insist that things change through time and the understanding of any one historical moment is not frozen in time but was something else before and became something else as time moved on. Not only did the means of travel change with the coming of the automobile, but the very idea and meaning of travel as well. It was one thing to be an “engineer” in the early nineteenth century, but quite another at the end of the twentieth. What it took to be manly – a concept long associated with the possession and use of technologies – in one period did not prove adequate in another.

All this is also *contested* because at any one time there were competing measures of masculinity and while one is usually hegemonic at any point in time, it is never universally accepted. The definition of the word *technology*, as we have seen, is still contested: it will not be obvious to everyone that *the body* deserves a place in a book such as this or that wearing glasses makes us cyborgs. One very important contest being fought out in our own time is whether the factory model of farming is either efficient or constructive of the kind of society in which we want to live. (And the Good Society, of course, is a concept that has always been fought over and redefined – while, it should be pointed out, the role of particular technologies in furthering or eroding one’s own idea of the Good Society is an important part of that debate.)
The history of technology, as a self-conscious academic field, is hardly a half-century old. It came together during the post-Sputnik years when rapid technological change was devoutly desired to keep the Americans ahead of the Soviet Union. Both the economy and defense seemed to be based on Americans’ ability to invent, engineer, and impose their technologies on themselves, their allies, and the nations of Africa and Asia, newly emerging from the often violent decay of the great European empires. Understanding what Americans had done right in the past seemed useful to shaping sound policies for the future.

A second critical context of the emergence of this new field was that it tended to take place in engineering schools. As a profession, engineers had always suffered from a belief that they were not sufficiently appreciated; that the American public at large, while basking in a technological modernity, did not recognize where and from whom this all came about. Not surprisingly many early historians of technology had some engineering background, either through training or practice. This meant that such scholars had a close and insiders’ knowledge of the machines and tools they wrote about, but it also meant that they were sometimes inclined by training, practice, and employment to have a basically uncritical view of what it all meant. Progress was the measure of civilization, and technology was the engine of that progress.

Being centered in engineering colleges also meant that women were not often found in their ranks. Both the subject (“toys for boys”) and the engineering departments which provided the employment for these scholars were not welcoming to women. This was importantly true also of the larger historical profession, and of academia as a whole, but the history of technology seemed particularly masculine. All this constituted a serious limitation on who would be likely to take up the subject, but also worked to limit what subjects were taken up at all.

Over the past half century, however, many of these limitations have been swept aside and new scholars as well as new topics have become a part of the shared enterprise of understanding the history of technology. This book is a snapshot in time of what we now know, and in what we are interested.

NOTES

PART I

BEGINNINGS
CHAPTER ONE

Technology in Colonial North America

ROBERT B. GORDON

Technology, in the definition favored by those who study its history, encompasses the skills and tools people need to make and do things. It is, and has been since earliest human experience, a part of everyone’s life. Knowledge gained through experience, experiment, and in recent times the application of natural science, has expanded opportunities for the use of techniques to achieve aspirations and express cultural values. Because of the distinctly different choices people worldwide have made in the techniques they have used in their everyday lives and enterprises, technology is a record of cultural choice.

European immigrants to North America gradually adapted the techniques of their homelands to their new environment to provide themselves with food and shelter, and to earn a place for themselves in the North Atlantic trade networks that would allow them to prosper. The natural resources available in North America and the choices colonists made about the technologies they would use to exploit these resources defined regional cultural patterns that persisted far beyond the colonial period.

History

Native Americans' Technology

The immigrants from Asia who populated North America thousands of years before Europeans arrived developed specialized techniques for hunting the continent’s varied and abundant wildlife, their primary source of food and an important source of materials for clothing. These Native Americans used agriculture largely to supplement the food they got from hunting and fishing. Those who lived near waterways developed sophisticated skills as builders of small boats. None built roads, or used wheeled vehicles. They relied on human or animal power for all purposes, even to propel their watercraft.

Although Native Americans in the southwest opened turquoise mines as early as AD 900 to supply demand from their Mexican cousins, they made only sparse use of North America’s abundant mineral resources, such as the copper found in northern Michigan. Unlike the native settlers of South America, those in the northern continent never smelted metal from ore. In their early contacts with Europeans, they supplied French adventurers with animal pelts, and taught British colonists on the
east coast food-production skills vital to their survival. Native Americans quickly learned the use of firearms through their contacts with Europeans, and soon developed the mechanical skills to make repair parts for their gunlocks.

Native Americans’ low population density, further reduced by new diseases, combined with their limited use of the continent’s natural resources left North America open for colonists to apply European technologies on a scale unimaginable in their home countries. Europeans brought dramatically different systems of land tenure and management to the New World, and commenced road building, pyrotechnology (metallurgy, glassmaking), and the application of inanimate power (principally from falling water). By the end of the colonial period they had applied technology to achieve a material culture comparable in quality to that of all but the richest Europeans, and had initiated the rapid industrialization that would transform the entire continent in the nineteenth century.

European Background

Sixteenth-century Europe saw the rise of industrial capitalism and the belief that people had both a right and duty to fully exploit natural resources wherever they might be found. Vannoccio Biringuccio explained in his *Pirotechnica* published in 1540 “I say and conclude that the gifts of such copious blessings conceded by heaven should not be left to our descendents in future centuries...we should denounce [those who fail to exploit minerals] and severely reprove them in the same terms that farmers would deserve if, when the fruits of the earth are ripe, instead of gathering them, they should leave them to rot and waste in the fields...” Spanish adventurers diligently applied this concept of exploitation in Central and South America. French, British, Portuguese, and others applied it in their North Atlantic fisheries, and to the fur and timber resources of the adjacent land.

Although the Spanish and Dutch were the first Europeans to settle in North America, and Germans, French, Swedes, and others followed. Immigrants from Britain predominated in all but the extreme southeast, the distant southwest, and Quebec. The early sixteenth century saw the start of rapid population growth in Britain that would double the country’s population by the end of the seventeenth century. Rapid growth overtaxed Britain’s ability to house and employ everyone. Prices rose, landlords enclosed commons, increased agricultural productivity released men for industrial work if they could find it, while the gentry invested in manufactures. The crown, always in need of new revenue, fostered commercial expansion, principally through international trade. The mercantile concept, with its emphasis on a favorable balance of trade for the mother country, turned investors’ interest to the Atlantic Coast of North America. Here the British could apply European techniques of fishing, mining, and metallurgy to resources far more abundant than any they knew at home. When they ventured to North America, they had centuries of experience with the application of waterpower to tasks such as grinding grain and blowing furnaces (but, curiously, not to sawing wood). They had learned and surpassed Spanish deep-water
shipbuilding and navigation, and continental ordnance. Their agriculture emphasized husbandry without extreme specialization.

The Puritans who migrated to New England in the early seventeenth century held beliefs different from the values held in Spain and Italy, as expressed by Birringuccio. They endowed work with religious and social purpose as well as material gain. They believed in stewardship and a duty to improve one’s holdings, and insisted that the common good must take precedence over personal gain.

The Sixteenth Century

The Spanish, already established in Mexico, settled in St Augustine, Florida, in 1565 and in Santa Fe, New Mexico, in 1609. Spanish technology had its greatest influence in the southwest and the extreme southeast in the seventeenth century. The French, established along the Gulf Coast, had applied European military technology in the forts they built in Florida, such as Fort Caroline, erected in 1564. Since the French built with timber, their fortifications lacked the permanence of later Spanish stonework forts and do not survive for our inspection.

The lure of gold attracted British as well as Spanish adventurers to the New World. Martin Frobisher returned from a voyage to find the Northwest Passage in 1540 with a dark, glittering rock from Baffin Island. London adventurers chose to believe the claim by Italian alchemist Agnello that Frobisher’s rock was gold ore rather than the assays of others that showed no precious metal content. On two subsequent expeditions Frobisher’s men mined 1,500 tons of worthless rock, and failed to plant the colony that Queen Elizabeth wanted established in America. Instead of gold, it was the more prosaic fisheries of the northwest Atlantic and the fur-bearing animals trapped on the adjacent land that earned profits for sixteenth-century European adventurers in the New World.

The Seventeenth Century

The Spanish spread settlements through the southwest, establishing Santa Fe in 1609, and extending them into Texas and California in the eighteenth century. Documentation of Spanish technology in the southwest remains sparse. Excavation of a pueblo near Albuquerque has uncovered evidence of copper smelting carried on before the Pueblo Revolt of 1680 in which all the Spanish colonists were killed or expelled. The Spanish technological presence in the southeast is still on display in fortifications they built for the defense of Florida. Work on the four-bastion Castillo de San Marcos, designed by Ignacio Daza for the defense of Saint Augustine, began in 1672. The Castillo’s walls of coquina stone finished with stucco had a surrounding ditch crossed by a drawbridge defended by a portcullis. Characteristic Spanish features were the bartizans (lookout towers) placed on the salient of each bastion, and the prominent place given to the fort’s chapel.

French military architects adapted the European four-bastion form to local circumstances and materials in numerous fortifications built around the American east and
south coasts. The French constructed Fort Pentagoet (1635) in Maine of earth and stone. On the Gulf Coast in Mississippi they used squared timber for Fort Maurepas (1699). In the eighteenth century, the Spanish did little further fortification; however, the British competed with the French in fort-building at strategic locations on the coast and on the inland waterways.

Northern Europeans who ventured to Newfoundland and Labrador early in the sixteenth century preserved fish in camps along the coast by drying and salting, and found a ready market for their product in the Catholic countries of Europe. Two companies of British merchant adventurers, organized in 1606, sponsored colonies in Maine and Virginia. The colonists at Sagadahoc, Maine, were to exploit the fish and fur trades. They failed to appreciate the difficulties of winter survival without thorough preparation, and their enterprise lasted only a year. The settlement in Virginia fared only slightly better. Here the colonists, who were expected to establish industries that would produce goods such as glass and iron for export, did not grow enough food for themselves, or establish constructive relations with the Native Americans. Their industrial enterprises failed to achieve either adequate quality or quantity to be economically viable. Virginia eventually became a stable colony after 1614, when the colonists discovered the profits to be made by exporting tobacco to Britain.

Unlike the adventurers sent to Virginia, the settlers in the Massachusetts colonies included merchants and men with experience in manufacturing as well as ministers and members of the gentry. While they had strong feelings about cleansing the British church from Roman Catholic influence, they also represented the new British mercantile economy. New England offered them the chance to put their mercantile ideas to the test. Accordingly, the Massachusetts Bay Company recruited artisans with the skills needed to process the material resources of North America: sawyers, carpenters, smiths, millwrights, and the like. Although the founders of the early colonies brought ideas of common ownership with them, they soon discovered these principles were inimical with the need to produce food for sustenance and products for export. Massachusetts began the sale of private land in 1627. An unforeseen consequence was that the availability of land encouraged artisans to give up their trades to enter farming on their own accounts. Towns soon had to recruit, and offer subsidies to induce smiths, millers, and other artisans to settle and provide their essential services.

Decreased immigration in the early 1640s created a balance of payments problem in New England. The Massachusetts Bay colony offered land grants, tax abatements, exemptions from militia duty, and 21-year monopolies to entrepreneurs who would undertake new industries or shipbuilding. It sent John Winthrop, Jr, to Britain to raise capital and hire artisans for a modern, integrated ironworks that would produce metal for export. However, the proprietors of these early industrial ventures faced numerous difficulties, including insufficient capital, inadequate skills and experience, and poorly developed market mechanisms. Agriculture offered the best comparative advantage, distantly followed by industries that could make use of the continent’s abundant natural resources. Imported goods, often of superior quality, could be had for less than those made in the colonies. Successful exporting called for the services of
skilled agents abroad. Proprietors’ difficulties in coping with these problems soon led most of the subsidized enterprises into financial failure.

From 1650 onward New England merchants, joined later by entrepreneurs in the middle colonies, profited by exporting barrel staves, timber, and other wood products, fish; and provisions to the southern colonies and the West Indies. Planters in the West Indies soon depended entirely on the North American colonies for flour, rice, corn, peas, salt fish, cattle, shingles, staves for sugar casks, and lumber delivered by American-made ships. Colonial merchants organized supply networks for production in inland communities through creation of markets and, in some cases, direct investment in production facilities such as sawmills. Thus, even remote communities were removed from the need for self-sufficiency and incorporated into organizations that applied technology to specialized production by the end of the seventeenth century. Additionally, entrepreneurs in New England and the middle-Atlantic colonies found economic opportunity in processing raw sugar imported from the West Indies. They began distilling rum in the 1650s. Over the following decades Boston, Newport, New York, and Philadelphia developed numerous distilleries. Rum exports made a large contribution to the colonial balance of trade.

The New England colonists started hunting the world’s largest mammals when they captured whales along the coast. To export their whale oil, fish, and furs, they began building oceangoing ships that could also enter their own coastal trade and for trade with the West Indies. War-induced demand opened the opportunity of selling ships in Europe after 1680. Shipbuilding had important backward linkages since shipwrights needed timber, iron fastenings, sailcloth, and cordage that colonial makers could produce. Shipyard demand stimulated colonial industries that had previously failed due to lack of local markets and the difficulties of successful export trade.

The Eighteenth Century

The economies of the southern colonies thrived through concentration on monoculture: tobacco in Virginia and rice in South Carolina. Trade with the West Indies and military expenditures for the Seven Years War stimulated the economies of New England and the middle-Atlantic colonies through the mid-eighteenth century. As the middle colonies added industrial-scale food processing and ironmaking, their artisans expanded their use of mechanical arts and pyrotechnology. New Englanders diversified industrial production of goods for export. Despite periods of economic slackness, non-farm, artisanal and industrial work occupied an increasing proportion of people’s time outside the southern colonies as the century advanced.

Trade with the West Indies and Europe required a network of support services. New England merchants such as the Brown family in Rhode Island commissioned shipwrights to build vessels for their own use and for sale in Europe. By 1750, New Hampshire yards were producing 20–30 ships a year. Shipwrights in turn required timber, cordage, iron, pitch, and sailcloth produced by local industries. Merchants stimulated industry by accepting these products in payment of loans. Whale oil and
potash made by frontier farmers became major colonial exports from New England to Britain by mid-century.

Farm sizes decreased after 1730 as farm families in New England and the middle colonies invested in equipment such as wool cards and looms, and put more time into home industries such as weaving, shoemaking, and broom-making. Towns tended to specialize in particular products. Specialization implied dependence on markets for the exchange of goods and services. By 1750 New England farmers routinely traveled to other towns to reach markets for their products. A sample of some 200 trips made by farmers in central Massachusetts showed that in 1750–75 the most frequent trips were about 20 miles, and ranged from 5 to 175 miles. The distribution remained the same for 1775–90. Local merchants encouraged home industry with the putting-out system, which also increased the division of labor. These entrepreneurs might purchase wool to distribute to homes for spinning or weaving, or precut shoe parts for home sewing into finished shoes. Later they collected and paid for the finished products.

Growing affluence stimulated consumer demand for the services of cabinetmakers, tinsmiths, and silversmiths. Connecticut had 13 silversmiths before 1750; the number soon rose to 125. By 1768 makers in Lynn were turning out 80,000 pairs of shoes per year. Colonial iron production so impacted the British economy that the mother country passed the Iron Act in 1750. It encouraged export of the pig and bar iron that British manufacturers wanted and required colonial governors to suppress any new enterprises that attempted to make finished iron products. In the southern colonies no communities achieved comparable production of manufactured goods, and even individual artisans found limited opportunities, partly because of the dispersion of population on plantations. Wealthy southerners bought imported goods or traded with the northern colonies.

By 1785 southern New England and the middle-Atlantic states were ready to enlarge manufacturing of textile, wood, and metal products in factories with power-driven machinery, thereby initiating the industrialization that would gather momentum in the early republic, and by the mid-nineteenth century give the northern states an enormous economic advantage over the still-agricultural south. One stimulant to industrialization was the network of regional, integrated produce markets in place within a few years of the Revolution that delivered agricultural products to the towns and cities where factories would be established. Farm productivity had so increased that farmers had surplus funds to invest. They, along with merchants, put the new savings into the growth opportunities of the day: textile mills; turnpike roads; and the mechanized production of tools and household products.

**Colonial Artisans and Industries**

Technology entered everyone’s home life in the colonies of British North America, and most people used some agricultural implements regardless of whatever else they did. Artisans who had forsaken full-time farming typically specialized in particular crafts and techniques. Some, such as metalsmiths, could work alone, or part time, in
their own shops with or without partners, or at home. At the other extreme, glassblowing and ironmaking required team efforts with a physical plant that would ordinarily be beyond the means of individuals. The list of some of the colonial industries in Table 1.1 shows the range of work undertaken by colonial artisans.

**Metalsmiths**

The increase in colonial wealth by the mid-seventeenth century opened opportunities for artisans supplying luxury goods, primarily to the urban wealthy, but also to reasonably prosperous town and country dwellers. Boston had one silversmith for every 240 inhabitants in 1690. Metalsmiths made gold, silver, pewter, or brass goods. An advanced smith might undertake assaying or refining, but most worked
with imported or recycled metal, often supplied by the customer. Success depended first on having the requisite skill in metal forming, casting, joining, and engraving. Technical skill alone did not suffice, however. A smith needed business acumen, and had to build a reputation with a network of customers. Reputation in the community was particularly important for gold and silversmiths since customers entrusted them with precious metals for fabrication.

A skilled smith in colonial America could achieve a position of social equality with leading merchants and statesmen in society. Jeremiah Drummer, the son of one of the largest landowners in Massachusetts established himself as a silversmith in late seventeenth-century Boston without loss of social standing. Customers expected him to keep up with the latest fashions, and to remake their silverware accordingly. The large collections of colonial silverware now in museums give us an unusually good record of these artisans’ skills and the tastes of their customers. Smiths in the larger towns, such as Boston, introduced division of labor with particular smiths specializing in specific branches of the trade, such as casting or engraving. Work would then pass through several shops on its way to completion.

**Gunsmith**

The colonial gunsmith catered to the needs of men in all classes of colonial society since nearly everyone at one time or another participated in hunting, the militia, and the occasional military adventure away from home. The gunsmith worked with iron, steel, wood, brass, and sometimes silver. He might have a water-powered hammer or grindstone, but most worked entirely with hand-operated tools as they carried out tasks ranging from heavy forging, through heat-treating delicate springs, to shaping the complex curves of gunstocks. The decorative brass and silver inlay work on the frontiersman’s rifle could equal the work of the best urban artisans.

Since colonists found their European firearms ill-suited to American conditions once they moved inland from the immediate coastal areas, gunsmiths everywhere modified European designs to suit the needs of their customers. However, Huguenot artisans, joined later by Germans and Swiss, working near Lancaster, Pennsylvania, in the eighteenth century carried this process of adaptation a huge step forward when they developed the long, precision, handsomely proportioned and decorated weapon now popularly known as the Kentucky rifle. William Penn had granted land near Lancaster to Huguenot refugees arriving from Europe from 1710 onward. Here the Ferree and LeFevre families each produced a line of distinguished gunsmiths. They created a uniquely American technology beginning in the 1720s with rifles that gave their owners an accurate, light, and easily reloaded rifle particularly suited to the needs of frontiersmen. The long, slim, fully stocked barrel sweeping into a gracefully curving, richly decorated curly maple butt have made surviving Kentucky rifles highly prized by collectors and art galleries today.

It took a Pennsylvania gunsmith working with an apprentice about a week to make a good, plain rifle, two days on the stock and the rest on the metal parts and assembly. He shaped a flat iron plate into a tube and welded the seam to make the barrel. After
reaming and straightening, he cut the rifling in the bore with the aid of a machine he made himself. Finally, he browned the outside of the barrel to give it a pleasing finish. Most Pennsylvania gunsmiths made their own locks by forging and filing the individual parts. Often the springs were cut out of an old sword or bayonet, shaped by filing, and then hardened to the requisite temper.

For stocking material the gunsmith selected maple grown on a mountainside since trees on thin, rocky soils had a closer grain and better curl than those from lowland soil. He used planes, chisels, and rasps to shape the stock. This work was unlike cabinetmaking because every surface of the gunstock was curved. He let brass or silver decorative work into the stock. Oil rubbed into the wood gave it a smooth, mellow finish. Owners highly prized the finished product. A gunsmith’s trade grew with his reputation for the quality of his work.

The Kentucky rifle proved enormously successful in the Appalachian frontier county. The mountain riflemen soon acquired a reputation for prowess in hunting and Indian fighting known throughout the colonies. At the opening of war in 1775, Washington and his fellow officers called on Pennsylvanian rifle companies to demonstrate the prowess of the Continental Army facing the British in Boston. They failed to realize that a technology perfectly adapted to one particular need is not necessarily useful in another setting, or the need to devise tactics that exploit the advantages of a particular technology in warfare. The riflemen made a great show of precision shooting until the British sentries learned not to expose themselves, and thereafter could accomplish little in the siege warfare underway at Boston. Later, in fighting inside Quebec City, the riflemen’s long weapons proved a positive disadvantage and led to most being captured. By the summer of 1777, American commanders better understood how to use this unique weapon. At the battles of Freeman’s Farm and Bemis Heights, Daniel Morgan’s riflemen acted as light infantry and, firing from concealed positions, caused havoc in the ordered ranks of British soldiers.

*Millwrights and Millers*

New England and the middle-Atlantic colonies had excellent water power resources. The abundance of small water privileges that could be developed with modest capital allowed colonists to erect power-driven mills near their communities. Most had grist and saw mills; many also had fulling, snuff, and oil mills. The seaport cities, however, lacked waterpower sites. Hence, breweries in Philadelphia had to use horse gins to grind their malt and New Haven citizens trekked two miles to the falls of the Mill River north of town to get their grain ground.

Colonists made water-powered mills one of the principal adaptations of mechanical technology to the natural resources of North America. Wherever settlers moved into new land, they made erection of a gristmill their first-community enterprise. As soon as possible, they added a sawmill so they could side and floor their buildings with sawn planks. Sawing could be a part-time occupation for farmers in the winter and early spring, when streams were in spate and there was little to do in the fields. The Dutch had a sawmill operating in New Amsterdam by 1623, and New Englanders
had them by 1634. Within a decade, mills in Massachusetts, New Hampshire, Maine, and the Connecticut River valley were turning out sawn products for domestic use and export.

The millwright who erected a gristmill needed practical knowledge of hydraulics, waterwheel construction, and gearing for a power train. Millstones had to be procured from distant quarries (the best were imported). The miller had to know how to align the stones and set the spacing between them so that they cut rather than mashed the grain. From time to time he had to dress the stones by re-cutting the grooves that gripped the grain as the stones rotated. All these were skilled tasks. Watching a miller and his machinery at work introduced children to mechanical and hydraulic technology in a way that would contribute to the development of Yankee ingenuity.

Grist millsers developed a mercantile function as well as a technological one. Since they were paid in kind and had grain to place on the market, they began trading, which led them to act as merchants and as agents for farmers. A concentration of grist, fulling, paper, saw, and snuff mills along the Brandywine formed the basis of the economy of Wilmington, Delaware. In this way, millers contributed both to the diffusion of technological sophistication and to the development of domestic and overseas marketing networks.

Glassblower

The Virginia Company had a glassworks underway at Jamestown by 1609. It intended to utilize the abundant American wood fuel and sand resources to supplement the then inadequate production of British glassworks for the home market, but achieved only marginal success. Other seventeenth-century glassmaking attempts at Salem, Massachusetts (1639–43), New York City (c. 1645), and Philadelphia (c. 1683) also achieved little. Successful colonial glassmaking began with Caspar and Richard Wistar’s glassworks in Salem County, New Jersey (1739–77); it produced window glass and bottles until the Revolution. The Bayard works in New York, Stiegel in Pennsylvania, and the Germantown works in Quincy, Massachusetts, joined in producing utilitarian products for the domestic market in the eighteenth century.

No one managed to mechanize any of the glassblowers’ work until the 1830s, when artisans first used full-size bottle molds. The colonial blower gathered molten glass on the end of a blowpipe and, while it remained hot enough to flow under air pressure applied by his lungs and rotation of the pipe, shaped it into a bottle. In the crown method used to make window glass the blower collapsed the molten glass bubble into a thin disk from which other artisans subsequently cut the glass panes. The center “bullseyes” could be used for small windows through which one did not need to see. The combined need for lung power, strength to twirl the heavy iron blowpipe weighted at the end with hot glass, manipulative dexterity, and judgment of temperature made glassblowing a physically demanding, highly skilled, specialized occupation.