HISTORY OF APPLIED SCIENCE & TECHNOLOGY

History of Applied Science & Technology

An Open Textbook

Danielle Skjelver, David Arnold, Hans Peter Broedel, Sharon Bailey Glasco, Bonnie Kim, Sheryl Dahm Broedel

Jennie Brosnan, Shalon van Tine, Benjamin Guyer, Martin Odler, Sarah Jeong, Tashia Dare, Antoine Leveque, Bonnie Kim, Friedel Weinert, Stephanie Guerin-Yodice, Solange Ashby, Richard McGaha, Matthew Marsh, Karen Garvin, Hans Peter Broedel, Danielle Skjelver, David Arnold, and Sharon Glasco

The Digital Press @ UND

Grand Forks, ND

CONTENTS

PART XI. COVER & BOOK DESIGN

PART XII. SECTION EDITORS

COPYRIGHT

This textbook was partially funded by a generous grant from the University System of North Dakota.

ACKNOWLEDGEMENTS

This project is made possible by grants from both the North Dakota University System and the University of North Dakota. Deneen Marynik of the History Department at the University of North Dakota (UND) provided administrative support for the grant. Stephanie Walker, Dean of the UND Libraries, assisted with grant applications.

Without the support of Damon Freeman, Director of the History and African American Studies Programs at University of Maryland Global Campus (UMGC), this textbook would simply not have been possible. He generously allowed the executive editor to devote time and focus to this textbook. *History of Applied Science & Technology: An Open Access Textbook* would never have gotten off the ground were it not for that very real support.

The idea for this open educational resource grew out of a course at UMGC, HIST 125: Technological Transformations. Analysis of technology, primarily in Europe and the United States, and how people have shaped and been shaped by technology forms the core of this course. However, it is also something of a course in epistemological history, an exploration and analysis of shifts in ways of understanding and engaging with the natural world. This textbook has attempted to draw on the strengths of HIST 125 while seizing opportunities to bring a global approach to bear.

William Caraher of The Digital Press @ UND has provided guidance in open access publishing. It is not an overstatement to credit Caraher with the launching of this project. Without his relentless optimism and encouragement to try the seemingly impossible, this project would never have gotten beyond the "Someone should really do something about the lack of high quality open access teaching materials for undergraduate courses" stage.

We would like to thank Linda Ruggles, who came out of retirement as a collegiate professor at University of Maryland Global Campus, to serve as interim executive editor for a year.

We thank Karen Garvin, who is a contributor as well as the copyeditor and layout artist.

We also thank Kevin Tengesdahl of Blue Pine Designs, who designed and created our cover.

In the early days of the project, Sheryl Dahm Broedel of UND and Hugh McGuire, Apurva Ashok, Liz Mays, and Zoe Wake Hyde of the Rebus Foundation provided support in the form of recruiting, template design, and regular meetings.

INTRODUCTION

FOR STUDENTS

The first of its kind, *History of Applied Science & Technology: An Open Access Textbook* aims to provide a high quality, peer-reviewed, open access textbook to meet the needs of History of Science and Technology courses at centers of higher education around the world. This textbook is innovative in 3 ways.

> Global in Perspective and Authorship – This textbook begins the process of decentering the History of Applied Science and Technology from its traditional focus on Europe. Because this project is collaborative in nature, many writers with many perspectives from all over the world enable us to showcase the importance of cross-cultural exchange as we strive to avoid culturally biased value judgements.
>
> Living – This textbook is ever expanding. 2021 saw print publication of contributions that had been accepted to that point. Because we know there are gaps, we will continue this project as a living, growing digital venture.
>
> Open Access – We use the the CC-BY license. The only requirement for use is attribution. Our textbook, in whole or in part, can be shared as many times and in as many ways as possible. It can be copied into other files and edited. The only requirement is that the contributors are acknowledged for their work.

CONCEPTUAL TOOLS

Students will better understand the content presented here if they have a grasp of the basic conceptual tools that our authors have used. Below are the editors' definitions of these concepts.

> **What is History?**
> History is an argument about how to interpret evidence left behind from the past. Many people tend to think of history as the past itself. It is not. There is no finding the past as it truly was; that is impossible. So historians use the evidence from the past to try to understand what happened in the past. They often disagree about how to interpret this evidence, which is why any good bookstore will have several books on the same topic.
>
> **What is Technology?**
> Technology is the manipulation of matter for human needs. Technology more broadly includes those aspects of human culture that are predominantly utilitarian in nature, whether machines or processes. It can include writing, for example. Some would go so far as to include algorithms as technology.

What is Applied Science, and how is it different from what we call Science?
Science is the systematic study, description, and explanation of the natural world. Science, particularly until roughly the middle of the 19th century, was a matter of understanding how the universe worked – simply for the sake of knowledge. We call this pure science. When scientific knowledge, such as, say the table of elements, is applied to technology as in the case of enhancing engine power or the strength and flexibility of metals, this is called applied science.

What is Periodiziation?
To mark major societal and cultural changes, historians break the past into periods. These tend to be Western in nature. While we envision a global History of Applied Science and Technology, these terms are widely accepted and used around the world. As a result, you will see them in this textbook from time to time. Periodization is rough and overlapping. Historians do not all agree on beginning and end dates.

The abbreviation ca. refers to circa, meaning around or roughly. The terms BCE and CE below refer to Before Common Era (before year 1 CE) and Common Era (year 1 CE through today).

- Ancient – before ca. 700 BCE
- Classical – ca. 700 BCE – 200 CE
- Late Antique – ca. 200 CE – 700 CE
- Medieval – ca. 700 CE – ca. 1500 CE
- Early Modern – ca. 1500 CE – 1800 CE
- Modern – ca. 1800 CE – present

What are Progress and Advancement?
The Oxford English Dictionary (OED) defines progress as "Progression or advancement through a process, a sequence of events, a period of time, etc.; movement towards an outcome or conclusion."

When applied to human events, this definition of progress assumes that human beings are on a trajectory toward some imagined future. Generally this future is imagined through a Eurocentric value system, which measures all civilizations according to an external ideal.

Technological innovation is not universally understood as progress or advancement. Some technologies are as destructive as they are constructive; others alienate humans from their natural environment in ways that can be destructive to human and animal health.

We have therefore avoided the problematic terms progress and advancement.

What is Society?
The OED defines society as "The state or condition of living in company with other people; the system of customs and organization adopted by a group of people for harmonious coexistence or mutual benefit."

In general, this textbook uses this definition. Society and its structures or systems may not always work toward harmonious coexistence and mutual benefit, but this is generally the stated aim of societies.

What is Culture?
There are many definitions of culture. For the purposes of this textbook, culture is the sum of a community's learned experiences as expressed through its practices, beliefs, and norms.

What is Worldview?
This textbook uses the OED definition or worldview, which is "a set of fundamental beliefs, values, etc., determining or constituting a comprehensive outlook on the world; a perspective on life."

How Do Applied Science and Technology Affect Worldview, Culture, and Society?
There is considerable debate about this question. Do applied science and technology shape human worldview, culture, and society, or do human worldview, culture, and society shape technology?

Our answer is yes. Applied science and technology both shape and are shaped by worldview, culture, and society. You will see in these pages significant transformative impact of technological and epistemological changes on worldview and human behavior as they relate to every day life and global choices.

The term neo-materialism might be helpful. This textbook is informed by historian Timothy James LeCain's approach to neo-materialism, which is a view that culture "is not an abstract phenomena solely confined to the human brain, but is instead intimately connected to the material world from which it emerges."[1] This approach to the history of applied science and technology places material objects center stage with human beings, and explores how human interaction with the material world and the material world's impact on the human experience interact.

DOING HISTORY

We believe that students best learn history by doing history, and our method reflects this commitment. We want students to understand how historians make sense of the past, why and how historians use argument to understand the past, and we aim to help students achieve this understanding by working with primary sources.

Each chapter has or will have a Doing History section. These sections offer students the opportunity to see how historians ask different questions based on the lens through which they are looking at a particular problem: gender, economic, social history, etc. Each Doing History inset contains 1 or 2 exemplary primary sources to illustrate how historians go about drawing conclusions related to their research questions.

You will notice that there are chronological and subject-matter gaps in the print version. The living, digital version is intended to remedy that. You will find it here.

History of Applied Science & Technology
https://press.rebus.community/historyoftech/

FOR INSTRUCTORS & COURSE DESIGNERS

This textbook is designed for maximum flexibility in the 21st century classroom. Faculty may adopt this work in whole, or as is more commonly done so far, adopt specific sections to address specific questions. You may remix these pieces. You might have students rework them and add to them for your own foci in particular courses. You might use elements of the textbook to create interactive presentations or drills. The only obligation is attribution to our authors for the original contribution to any use that students and faculty might make of these pieces.

In our vetting of scholars and their proposed contributions, we have allowed the focus to stretch in order serve the interests of our writers who often wanted to contribute in tangential ways. So you will find some pieces that may not fit the applied science and technology definition, but all articles address epistemological changes.

ORIGIN

This project emerged from a need for a high quality, peer reviewed open access textbook in a University of Maryland Global Campus (UMGC) course entitled *Technological Transformations.* For the last decade, this course had had the highest enrollment of any History course at UMGC.

Open Education Resources (OERs) offer a freely accessible foundation for college courses, with the ability to be tailored each instructor's needs. To clarify, for instructors with the authority to select their own materials for their own individual courses, there is a vast quantity of free history resources available online. Many of them are outstanding, such as the Fordham University Sourcebook, the Stanford Encyclopedia of Philosophy, and the rich troves available at Black Past and the Library of Congress to name just a few. However, these are not truly open because of their copyright restrictions. While they serve individual classrooms quite well, they cannot be used for all sections of a course where administrative policies dictate that all faculty use the same readings. The fair use clause permits limited use of copyrighted materials in individual classrooms. It does not permit mass use by hundreds of students in several sections.

The University of Maryland Global Campus (UMGC) has taken a significant leap in moving entirely to OERs for all courses. UMGC's bold trial by fire illuminates strengths and weaknesses in OER implementation, something from which faculty and administrations at colleges and universities across the country can benefit. For example, we can see the strengths of OERs in the many mathematics, physics, chemistry, economics, etc., OA textbooks and even a US History OA textbook all offered through Rice University's OpenStax.com.

With the exception of two peer-reviewed OA US History textbooks in the Open Access ecosystem, such resources are few and far between in the humanities, and often where they do exist, they lack peer review, and advertising detracts from and clutters the material.

UMGC, which, with over 90,000 students, could be the largest single consumer of OERs in the world. Through a collaborative effort with editors from the University of North Dakota and UMGC and writers from higher education institutions around the world, we have seized the opportunity to fill a specific need for History of Science & Technology instructors and to add to the OER ecosystem as a whole. The OER ecosystem is rapidly maturing and outstripping the traditional, closed resource ecosystem. Now is the time to be part of this process, to leverage what already exists and to expand the resources available.

As more and more schools move toward OERs, scholars will create better and better resources for their own classrooms, which ideally they will share with the world. One would expect that with the current momentum in OER production, there will soon be World Civilization and Western Civilization Open Access textbooks competing with one another for classroom use. This is good. Instructors and departments will have some choice. We anticipate that a History of Science & Technology textbook will emerge later, given the greater enrollment in courses like World and Western Civilization. While others are focusing on these courses – as we hope they are – we have seized the opportunity to meet the need for History of Science & Technology.

PUBLICATION PROCESS

All pieces in the print publication and all pieces published in the digital version of the textbook not bearing **Guest Author* in the title have been through the following process:

- Content editing by a member of the editorial board or ad hoc editor (See Ad Hoc Editors)
- Peer Review with two reviewers
- Final content approval by editorial board
- Copyediting

Digital pieces with **Guest Author* in the title have been through the following process:

- Content editing by executive editor or ad hoc editor
- Peer Review with one reviewer
- Copyediting by executive editor

POTENTIAL CONTRIBUTORS

As mentioned above, in the digital medium this is a living textbook. We are actively seeking contributions. If you have a master's degree or higher and are interested in writing for this project, please email dskjelver (at) gmail dot com.

Danielle Mead Skjelver, Ph.D.
Executive Editor
July 20th, 2021
Bozeman, Montana, USA

[1] Timothy James LeCain, "The Matter of History: How Things Create the Past," *LeCain: Exploring the New Material Humanism*. http://www.timothyjameslecain.com/the-matter-of-history/

For a more fulsome exploration of LeCain's theory of neo-materialism, see Timothy James LeCain, *The Matter of History: How Things Create the Past* (New York: Cambridge University Press, 2017), 8-20, 38-63.

ADOPTIONS

As this textbook grows in content, we anticipate growth in adoptions. Please let us know if you are using portions or all of this work. We are also interested in feedback you may have, or any interest you may have in contributing a chapter.

Send an email to oahistoryoftech @ gmail.com .

This textbook has been adopted in History of Science at the University of North Dakota and in two courses at the University of Maryland Global Campus: Technological Transformations and Technology & Culture.

PREHISTORY

SHALON VAN TINE

To understand how cultures and technologies have evolved over time, historians rely on written records that explain people, transactions, events, and traditions. However, this approach is limited as systems of writing were invented less than six thousand years ago. Since the earliest human tools date back to at least 2.6 million years ago, historians differentiate between history and prehistory, which is the study of human history before written records. Without written records, historians work with anthropologists, archeologists, paleontologists, geologists, botanists, paleobiologists (who examine fossilized remains of dead biological life), and linguists to help make sense of the prehistoric world.[1] By studying fossil remains, tools, dwellings, and other cultural artifacts, these specialists are able to construct a vivid picture of life for prehistoric humans. The study of prehistory covers all aspects of human culture from the Paleolithic Period to the birth of civilizations during the Neolithic Period.

Paleolithic Period—circa 2.4 million years ago to 8,000 BCE

The development of technology corresponds to the evolution of humankind. Compared to the timeline of the universe, humans have only existed for an extremely short time. The universe came into existence around 13.6 billion years ago with the Big Bang.[2] The Earth formed about 4.6 billion years ago, and dinosaurs ruled the Earth around 200 million years ago.[3] After the extinction of the dinosaurs, some smaller mammals evolved into primates, which are animals that include monkeys, apes, and humans.[4] It was only about 2.4 million years ago that primates evolved into a new branch that would lead to the modern human.

The Paleolithic Period, also called the "Old Stone Age," marks the era when hominids, or the earliest humans, began walking upright, which was around three million years ago.[5] One of the first of these was *Australopithecus*, who had a slightly larger brain than earlier primates and was *bipedal*, meaning it walked on two feet (fig. 1).[6]

Figure 1: A skull of *Australopithecus Afarensis*. Photograph by Tiia Monto. Naturmuseum Augsburg, Germany (public domain).

Being able to walk on two feet was a necessary condition for the development of technology since bipedalism frees the use of the hands to create tools. Coexisting with *Australopithecus* was *Homo habilis*, also known as the "handy man." *Homo habilis* created the first human tool: simple choppers, or sharp-edged stones, which were used as cutting tools to crush bones or hack roots (fig. 2).[7]

Figure 2: A simple chopper, which was commonly used by *Homo habilis*. Photograph by Didier Descouens. Muséum de Toulouse, France (public domain).

While humans are not the only animals that utilize tools, it seems that humans may be the only ones to create new tools from previously-made tools.[8] This process of toolmaking indicates a major shift in human evolution—one that marked human mastery over the environment and allowed for all subsequent human advances in technology to spring forth.

After *Homo habilis* came *Homo erectus*, who was larger in size and had a bigger brain than *Homo habilis*.[9] *Homo erectus* emerged in the evolutionary record around 1.8 million years ago and became one of the first human ancestors to migrate outside of Africa, spreading to the temperate and subtropical zones in Afro-Eurasia.[10] *Homo erectus* achieved an important technological development: the mastery of fire. The technology of fire allowed *Homo erectus* to extend human activity into dark places such as caves and to stay warm in colder areas.[11] Fire could also be used to cook food, making the food easier to digest.[12] Additionally, *Homo erectus* refined the hand axe, which improved the ability to hunt.[13]

About a half million years ago, these species splintered into different branches. *Homo neanderthalensis* was one of the first to demonstrate human rituals of caring for the sick and burying the dead (fig. 3).[14]

Figure 3: A Neanderthal burial. Photograph by Carol Tomylees. Natural History Museum, London (public domain).

Homo neanderthalensis also developed a verbal language, a trait shared with *Homo sapiens*, the modern human species. Even though *Homo neanderthalensis* became extinct around 40,000 years ago, both *Homo neanderthalensis* and *Homo sapiens* developed the capacity to share symbolic information in a way that was more complex than other animals.[15] While some animals, such as bonobos and capuchin monkeys, may understand some basic symbolic information, humans are the only animals known to demonstrate more complex symbolic understanding, such as dancing, creating art, and using verbal language.[16] Scholars are unsure exactly how spoken language evolved, but the emergence of language reflected cognitive development in early humans.[17] Language enabled Paleolithic humans to create culture, or knowledge and ideas that are passed down from one generation to the next.[18]

A key aspect of *Homo sapiens* culture was not only the creation and use of tools, but also the design of social rituals that accompanied the reality of death. An example of this development is found in Paleolithic burial sites. Paleolithic burials show skeletons wearing beads and resting in a prearranged position, signifying that early humans understood death on a conceptual or abstract level.[19] Paleolithic art in the form of figurines, cave paintings, personal adornment, and early forms of music and dance demonstrate that humans were able to communicate dense religious ideas in a creative way.[20] By producing a wide variety of cultural objects, such as stone tools, hunting weapons, sewn clothing, shelters, and lunar calendars, *Homo sapiens* changed the way humans reacted to their environment in a way never before seen. These conditions set the stage for more complex societies and technologies that were yet to come.

Paleolithic Technology

Paleolithic humans were nomadic, surviving by hunting and gathering their food.[21] They were organized in small bands of people, typically consisting of members who were all closely related.[22] The technology used in hunter-gatherer societies primarily functioned to increase their food supply and protect them from the elements. Women were responsible for gathering edible seeds, plants, and eggs, while men were responsible for mainly hunting animals.[23] Paleolithic humans used wood, stone, or animal bones, teeth, and antlers to create early tools for use as digging and scraping implements, hand axes, spears, fishing hooks, choppers, and animal traps.[24] These early tools helped humans collect the food supply necessary for survival.

In addition to food-related skills, Paleolithic humans developed tools used for everyday activities. One example of this was the use of lunar notation systems, which date back to the Upper Paleolithic period.[25] Lunar notations tracked the cycles of the moon, helping Paleolithic humans follow animal migrations for hunting. Hunting large animals was a grueling task that often required many men following herds for weeks at a time. To aid with this difficulty, lunar cycles were carved onto bone or antler and carried along for the journey.[26] These notation systems may also have been used in religious ceremonies or fertility rituals.[27]

Other skills may have included making shelters, clothing, and art. Because Paleolithic people were nomadic, they did not settle down in one place to establish permanent settlements. The most well-known examples of shelters are caves; however, thatched huts have also been found in prehistoric campsites, suggesting that Paleolithic humans built temporary shelters outside of the standard cave dwellings.[28] These huts often used large animal bones as a base and had a hearth and a hole in the roof where smoke from a fire could be released. Additionally, they contained grass and fur bedding on the floors, which provided an extra level of comfort and warmth.[29]

Sewn clothing made of animal skins was another step forward in prehistoric technology by both *Homo neanderthalensis* and *Homo sapiens*.[30] In order to create clothing, Paleolithic humans used animal skins for leather and cloth and sewed them together with sharpened needles formed from bone, antler, or stone. A common animal type used for clothing in North America and East Asia was the reindeer, which provided both a sturdy hide and antlers that could be used for creating needles and awls (fig. 4).[31]

Figure 4: Paleolithic bone needle, circa 17,000 BCE. Photograph by Didier Descouens. Haute-Garonne, France (public domain).

Additionally, Paleolithic humans wore jewelry adornment in the form of twigs, beads, and pendants.[32] Beads require drilling holes into hard material, and because of this, one of the earliest rotary devices to be developed was the bow drill, a device used for starting fires and later for spinning textiles.[33]

In addition to tools developed for survival during the Paleolithic era, humans expanded their technological development to include artistic creations. In the nineteenth century, archaeologists discovered images that were painted or carved on the walls of caves around the globe. Some of these artistic endeavors extend back at least 40,000 years ago outside Europe, with some of the earliest art found in Indonesia.[34] Cave art was created by applying burnt coal and mineral pigments to the cave walls. Images ranged from basic symbols, such as handprints, to more complex images, such as bison, reindeer, elk, zebras, horses, lions, panthers, and mammoths (fig. 5).[35]

Figure 5: Paleolithic cave painting, circa 28,000–10,000 BCE. Photograph by John McLinden. Lascaux Caves, France (public domain).

While these images could have been used as calendars for hunting cycles, historians assume that they could have also served as a ceremonial or an artistic function. These cave drawings were often accompanied by carved figurines, usually in the form of animals or women with exaggerated features (fig. 6).[36]

Figure 6: *Venus of Willendorf*, circa 28,000 BCE. Photograph by Artúr Herczeg. Vienna Museum of Natural History, Austria (public domain).

Since these figurines emphasized female reproductive organs, historians hypothesize that these figurines may have been used in fertility rituals.

The Paleolithic marks the era when humans distinguished themselves by creating technology. Technology allowed humans to create cultural patterns and traditions that would later lead to settlement and the development of civilizations. The Paleolithic period ended around 10,000 BCE, which marked a new era called the Mesolithic. In the Mesolithic era, the Earth grew warmer and the Ice Age ended.[37] The mammoths died out along with many reindeer that remained in colder areas. Some humans followed the reindeer north, but others developed new methods for survival.

Around 8000 BCE, many hunter-gatherers began to inhabit areas and grow food. The process was gradual and occurred at different rates around the globe. Humans may have started experimenting with farming, or perhaps drier climates allowed them to stay in one place. This change evolved humans into the last major era in prehistory, the Neolithic.

Neolithic Period—8000 BCE to 3000 BCE

The Neolithic era, also called the "New Stone Age," is the time when humans shifted from hunter-gatherer societies toward human settlements, allowing for the development of agriculture and animal domestication. This shift arose independently in various places around the globe and may have been facilitated by the Earth's changing climate, which pressured human communities to exploit their available resources more intensively.[38] While the spread of agriculture seems fast in comparison to other prehistoric developments, the process was gradual and varied depending on the area. Domesticated plants began showing up around 9000 BCE: millet and small seeded grasses in north China, rice in south China, wheat in the Fertile Crescent, potatoes and beans in South America, and maize (corn) in Mesoamerica.[39] Domesticated animals also began to appear: dogs in both Europe and Asia, cats in Africa, and pigs, goats, sheep, and cattle in the Fertile Crescent.[40]

Because these changes permanently transformed the way humans interact with their environment, historians have labeled this shift the Agricultural Revolution (also called the Neolithic Revolution). The Agricultural Revolution set the stage for an agrarian world, a state of human existence that lasted until the Industrial Revolution of the eighteenth century. Because humans could now grow and store their own food, there was no longer the need to travel from one place to the next. Instead, Neolithic humans could settle in one area, grow their population, improve technology, and eventually develop large-scale societies. In essence, the Agricultural Revolution facilitated the rise of civilizations around the world.

Neolithic Technology

The Agricultural Revolution allowed Neolithic humans to grow and store food, which meant that they no longer needed to follow the hunting patterns of animals for survival. Historians are not sure what factors prompted humans to experiment with plants, but the results can be seen in a variety of agricultural technologies that developed during this time. Gathering food was replaced with gardening and plow agriculture, and irrigation was implemented to water crops. Early Neolithic peoples cleared land using hoes, digging sticks, axes, and adzes, a tool similar to an ax but with an arced blade (fig. 7).[41]

Figure 7: Adze, circa 1900 BCE. Metropolitan Museum of Art, New York (public domain).

As plants were harvested, a collection of tools was needed to collect, thresh, and grind grain. The sickle was developed to harvest cereal grains, and the rotary quern, a hand mill for grinding grain, was invented to grind the grain into flour.[42] Early ceramic pottery was made by hand, dried in kilns, and used to both cook and store food (fig. 8).[43]

Figure 8: Pot from Iran, Neolithic period. Metropolitan Museum of Art, New York (public domain).

Another important aspect of the Agricultural Revolution was the domestication of animals. By selectively breeding animals to be manageable in terms of size and temperament, Neolithic humans could utilize animals in a variety of ways. First, domesticated animals provided good sources of meat and milk. Animal foods are rich sources of proteins, vitamins, and fats, improving nutrition and leading to larger human populations. Second, domesticated animals provided fibers (such as wool and hair) and leather. Animal fibers could be spun into textiles or rope, and animal hides could be used for clothing, blankets, shelters, harnesses, drums, and other uses. Additionally, other animal parts, such as teeth, bones, and horns, could be used to create tools, jewelry, and weapons. Third, domesticated animals provided labor. Oxen and horses were harnessed and put to work in the fields. Where early farming techniques had to be done by hand, the introduction of the ox-plow, a tool used to prep the soil for the planting of seeds, allowed that task to be completed by draft animals instead.[44] Oxen were domesticated as early as 7000 BCE in Africa, and farmers began to use horses around 3500 BCE in Central Asia. In addition to farm labor, dogs were used to herd sheep and cattle, and horses and camels were used for long-distance travel. As one of the earliest domesticated animals (beginning as early as 12,000 BCE), dogs have proven indispensable to humans in Europe, Asia, and the Americas for their ability to aid in herding and hunting.[45] The downside to domesticated animals, however, is that as people lived in closer proximity to animals and other humans, waste disposal became more difficult, and the diseases endemic in animal populations to were able to make the jump to humans.[46]

The effects of the Agricultural Revolution were not limited to cultivation, but extended to many interconnected aspects of Neolithic society. Since agriculture allowed humans to settle down in one area, they needed more permanent structures in which to live. Settlement led to new types of architecture. Some of the earliest structures found in the archeological record are mud huts. Located in various parts of Southwest Asia, mud huts were made of mud bricks and plaster, an amalgam of lime with sand and water that is spread on walls and ceilings and creates a smooth surface when dried.[47] These huts were painted with images of Neolithic life, giving archaeologists and historians a view into early Neolithic societies.

In addition to mud huts, archeologists have discovered the existence of Neolithic stilt houses, which are houses raised on piles above water, serving as a protection against rodents and flooding. Pit-houses, shelters that are partly dug into the ground and covered by a thatched roof, were used for both housing and food storage.[48] Over time, Neolithic settlements grew in size, and homes were built with lumber and stone.[49] Eventually, farming villages would develop around these permanent structures, and their use expanded to ceremonial and governmental functions.

As Neolithic societies increased, complex tombs and ritual structures were constructed. While funeral practices existed in the Paleolithic era, these traditions would become more elaborate as populations grew. Collective tombs, such as long barrows, held many bodies in an accessible place, likely so that bones could be utilized in ancestral worship (fig. 9).[50]

Figure 9: Stoney Littleton Long Barrow, circa 3500 BCE. Photograph by Mike Peel. Somerset, England (public domain).

Those with higher social status were buried in chamber tombs, which were built with rock or wood and often contained material possessions or the remains of attendants.[51]

The most striking of the Neolithic tombs are the megaliths. Megaliths are upright stone slabs with a horizontal capstone slab on top that were used to mark graves and to serve as a ceremonial space.[52] One of the oldest examples of this kind of structure is Göbekli Tepe, which dates back to 9000 BCE. Historians believe this site was used as a religious temple.[53] Another remarkable example of a megalith is Stonehenge, located in southwest England (fig. 10).

Figure 10: Stonehenge, circa 3100–1500 BCE.Wiltshire, England (public domain).

Stonehenge was constructed in different phases between 3100 BCE and 1500 BCE, and its construction required the labor of at least 10,000 people.[54] Excavations to date reveal cremated remains of more than fifty people, making it the largest known Neolithic burial site. Historians debate how Stonehenge was constructed, but most theories rest on the notion that large stones were dragged across the ground on tracks made of timber, rope, and perhaps even glacier ice. The stones were likely lifted with wooden A-frames and rope. For the people of the Salisbury Plain of what is England today, Stonehenge functioned as a ceremonial center and astronomical observatory.[55] The monument tracks the movements of the sun and the moon, demonstrating a basic understanding of the connections between astronomical events and seasonal changes.

As Neolithic villages grew in population and size, they began to create surpluses of food and other goods. These excesses allfowed trade with neighboring villages. Trade created the need to record and track economic information more effectively, and also influenced how these societies divided their labor. These changes led to the birth of civilizations, which are societies with complex social, political, and economic organizational structures, generally with defined borders and systems of writing and government. The earliest civilization was Sumer, located in Mesopotamia (modern-day Iraq).[56] Sumer was established as early as 5500 BCE, and other civilizations developed independently around the globe: Egypt around 3500 BCE, Crete around 2500 BCE, the Indus Valley around 2300 BCE, and northern China around 2200 BCE.[57] These ancient civilizations would create writing, metallurgy, laws, and warfare, taking human endeavors out of the context of prehistory and into the realm of recorded history.

[1] Gloria Fiero, *The Humanistic Tradition: Prehistory to the Early Modern World* (New York: McGraw Hill Education, 2015), 2.

[2] Stephen Morillo, *Frameworks of World History: Networks, Hierarchies, Culture* (New York: Oxford University Press, 2014), 8.

[3] Morillo, *Frameworks of World History.*

[4] Morillo, *Frameworks of World History.*

[5] James McClellan and Harold Dorn, *Science and Technology in World History: An Introduction* (Baltimore: The Johns Hopkins University Press, 2006), 6.

[6] McClellan and Dorn, *Science and Technology*, 7.

[7] Morillo, *Frameworks of World History*, 10.

[8] McClellan and Dorn, *Science and Technology*, 8.

[9] Morillo, *Frameworks of World History*, 11.

[10] Morillo, *Frameworks of World History.*

[11] McClellan and Dorn, *Science and Technology*, 9.

[12] McClellan and Dorn, Science and Technology, 9.

[13] Matt Kaplan, "Stone Tools Shed Light on Early Human Migrations," *Nature*, August 31, 2011.

[14] Emma Pomeroy et al., "New Neanderthal Remains Associated with the 'Flower Burial' at Shanidar Cave," *Antiquity* 94, 373 (2020): 12–14.

[15] Steven Mithen, *The Singing Neanderthals: The Origins of Music, Language, Mind, and Body* (Cambridge: Harvard University Press, 2007), 105.

[16] Peter Ulric Tse, "Symbolic Thought and the Evolution of Human Morality," in *The Evolution of Morality: Adaptations and Innateness*, ed. Walter Sinnott-Armstrong and Christian B. Miller, vol. 1 of Moral Psychology (Cambridge: MIT Press, 2008), 269.

[17] Morillo, *Frameworks of World History*, 14.

[18] Morillo, *Frameworks of World History*, 14.

[19] Morillo, *Frameworks of World History*, 14. 18.

[20] Fiero, *The Humanistic Tradition*, 3.

[21] Morillo, *Frameworks of World History*, 22.

[22] Morillo, *Frameworks of World History.*

[23] Robert J. Wenke and Deborah I. Olszewski, *Patterns in Prehistory: Humankind's First Three Million Years* (New York: Oxford University Press, 2007), 113.

[24] Wenke and Olszewski, *Patterns in Prehistory*, 126.

[25] Alexander Marshack, "Lunar Notation on Upper Paleolithic Remains," *Science* 146, no. 3645 (1964): 744.

[26] Marshack, "Lunar Notation on Upper Paleolithic Remains," 6.

[27] McClellan and Dorn, *Science and Technology*, 14.

[28] Dani Nadel, "Stone Age Hut in Israel Yields World's Oldest Evidence of Bedding," *Proceedings of the National Academy of Sciences* 101, no. 17 (2004): 6822.

[29] Nadel, "Stone Age Hut in Israel Yields World's Oldest Evidence of Bedding," 6823.

[30] Wenke and Olszewski, *Patterns in Prehistory*, 138.

[31] Wenke and Olszewski, *Patterns in Prehistory*, 175.

[32] Bryan Bunch and Alexander Hellemans, *The History of Science and Technology* (New York: Houghton Mifflin Company, 2004), 14–15.

[33] Bunch and Hellemans, *The History of Science and Technology.*

[34] Fiero, *The Humanistic Tradition*, 4.

[35] Fiero, *The Humanistic Tradition*, 4.

[36] Fiero, *The Humanistic Tradition*, 5.

[37] Wenke and Olszewski, *Patterns in Prehistory*, 240.

[38] McClellan and Dorn, *Science and Technology*, 17.

[39] Wenke and Olszewski, *Patterns in Prehistory*, 229.

[40] Wenke and Olszewski, *Patterns in Prehistory*, 229.

[41] McClellan and Dorn, *Science and Technology*, 18.

[42] Bunch and Hellemans, *History of Science and Technology*, 55.

[43] Wenke and Olszewski, *Patterns in Prehistory*, 60.

[44] Graeme Barker, *The Agricultural Revolution in Prehistory: Why Did Foragers Become Farmers?* (New York: Oxford University Press, 2009), 69–88.

[45] David Grimm, "Dogs May Have Been Domesticated More Than Once," *Science* 352, no. 6290 (2016): 1153.

[46] Morillo, *Frameworks of World History*, 49.

[47] Fiero, *The Humanistic Tradition*, 6.

[48] Bunch and Hellemans, *History of Science and Technology*, 20.

[49] Wenke and Olszewski, *Patterns in Prehistory*, 294.

[50] Wenke and Olszewski, *Patterns in Prehistory*, 295.

[51] Wenke and Olszewski, *Patterns in Prehistory*, 295.

[52] Fiero, *The Humanistic Tradition*, 8.

[53] Andrew Curry, "Göbekli Tepe: The World's First Temple?" *Smithsonian Magazine*, November 2008.

[54] McClellan and Dorn, *Science and Technology*, 24.

[55] McClellan and Dorn, *Science and Technology*, 27.

[56] Fiero, *The Humanistic Tradition*, 9.

[57] Fiero, *The Humanistic Tradition*, 9.

Further Reading

Primary Sources:

Adze. Artifact. Metropolitan Museum of Art, New York.

Bone needle. Photograph by Didier Descouens. Haute-Garonne, France.

Cave painting. Photograph by John McLinden. Lascaux Caves, France.

Neanderthal burial. Photograph by Carol Tomylees. Natural History Museum, London.

Pot. Artifact. Metropolitan Museum of Art, New York.

Simple chopper. Photograph by Didier Descouens. Muséum de Toulouse, France.

Skull of *Australopithecus Afarensis*. Photograph by Tiia Monto. Naturmuseum Augsburg, Germany.

Stonehenge. Monument. Wiltshire, England.

Stoney Littleton Long Barrow. Photograph by Mike Peel. Somerset, England.

Venus of Willendorf. Photograph by Artúr Herczeg. Vienna Museum of Natural History, Austria.

Secondary Sources:

Barker, Graeme. *The Agricultural Revolution in Prehistory: Why Did Foragers Become Farmers?* New York: Oxford University Press, 2009.

Bunch, Bryan, and Alexander Hellemans. *The History of Science and Technology*. New York: Houghton Mifflin Company, 2004.

Curry, Andrew. "Göbekli Tepe: The World's First Temple?," *Smithsonian Magazine*, November 2008.

Fiero, Gloria. *The Humanistic Tradition: Prehistory to the Early Modern World*. New York: McGraw Hill Education, 2015.

Grimm, David. "Dogs May Have Been Domesticated More Than Once." *Science* 352, no. 6290 (2016): 1153–54.

Kaplan, Matt. "Stone Tools Shed Light on Early Human Migrations." *Nature*, August 31, 2011.

McClellan, James, and Harold Dorn. *Science and Technology in World History: An Introduction*. Baltimore: The Johns Hopkins University Press, 2006.

Marshack, Alexander. "Lunar Notation on Upper Paleolithic Remains." *Science* 146, no. 3645 (1964): 743–45.

Mithen, Steven. *The Singing Neanderthals: The Origins of Music, Language, Mind, and Body*. Cambridge: Harvard University Press, 2007.

Morillo, Stephen. *Frameworks of World History: Networks, Hierarchies, Culture*. New York: Oxford University Press, 2014.

Nadel, Dani. "Stone Age Hut in Israel Yields World's Oldest Evidence of Bedding." *Proceedings of the National Academy of Sciences* 101, no. 17 (2004): 6822–26.

Pomeroy, Emma, et al. "New Neanderthal Remains Associated with the 'Flower Burial' at Shanidar Cave." *Antiquity* 94, 373 (2020): 11–26.

Tse, Peter Ulric. "Symbolic Thought and the Evolution of Human Morality." In *The Evolution of Morality: Adaptations and Innateness*, edited by Walter Sinnott-Armstrong and Christian B. Miller, vol. 1 of *Moral Psychology*. Cambridge: MIT Press, 2008.

Wenke, Robert J., and Deborah I. Olszewski. *Patterns in Prehistory: Humankind's First Three Million Years*. New York: Oxford University Press, 2007.

PART I

CHAPTER 1 - ANCIENT MESOPOTAMIA AND THE FERTILE CRESCENT (PREHISTORY - CA 1750 BCE)

Figure 16. Sargon of Akkad. Google Images. CC-BY.

CHAPTER 1 - LEARNING OBJECTIVES

STEPHANIE GUERIN-YODICE

When you finish this chapter, you should be able to:

1. identify tools that were instrumental in advancing human societies in the Paleolithic and Neolithic periods
2. understand how technology advanced nomadic peoples from hunter-gatherers to emerging agricultural communities
3. identify how technology was applied to everyday life and how it developed into a material culture
4. analyze how technological advances transformed Mesopotamia from an agricultural society to city-states and then to advanced civilizations
5. gain knowledge pertaining to the technological dissemination of ideas throughout the Fertile Crescent

CHAPTER 1 - METHODS USED TO UNDERSTAND EVENTS OF THE PAST

STEPHANIE GUERIN-YODICE

What type of methods are used to understand the events of the past?

What historians and scientists know about the ancient world comes from the evidence that remains:

- **Anthropologists** apply biological, cultural, and material aspects of migratory communities by studying the push-pull factors that influenced migratory patterns during the Neolithic Period.
- **Biological anthropologists** take a big-picture approach, using physical matter to infer the evolution of the human body and how it changed over time.
- **Cultural anthropologists** take a more humanistic approach by considering individuals as products of the society they lived in and thinking about how their experiences shaped both individuals and society.
- **Archeologists** look at the material culture through the use of tools, the written word, pottery, soil samples, found objects, and human remains.
- **Geologists** apply physics, chemistry, and biology to study how the earth's surface changes.
- **Paleoclimatology** studies the geophysical changes in raw resources brought about by climate change.
- **Epigraphy** is the study of writing on a hard surface and it is a key tool in understanding events in the ancient world.

CHAPTER 1 - INTRODUCTION AND THESIS

STEPHANIE GUERIN-YODICE

Throughout the course of history, the human condition has prevailed because of people's ability to adapt to changing environments. As early as the Paleolithic Period (Old Stone), evidence shows that stones were used as primitive tools by hunter-gatherers. Without permanent dwellings as places to store their goods, people cast aside these tools after hunting or after using them to provide food, shelter, and clothing. Over the span of centuries, primitive technology advanced from disposable tools to more permanent tools that combined items found in nature such as bone and wood. As societies advanced, the period of Old Stone technology evolved into the Neolithic Period (New Stone), which continued to shift the use of stone technology away from hunting and gathering and toward agricultural societies.

The Neolithic Period denotes a technology transition that helped to further advance the human experience through cultural and intellectual diffusion. The success of those emerging cultures and societies depended on were people were located, the type of natural resources that were available, and how the society could adapt and advance technologically. If the adaptation of these items proved effective, knowledge was disseminated, assimilated, and adapted from generation to generation, changing the fundamental structure of society through technological innovations.

CHAPTER 1 - FROM THE PALEOLITHIC TO THE NEOLITHIC PERIOD

STEPHANIE GUERIN-YODICE

The term "Paleolithic" essentially describes nomadic people or hunter-gatherers, whose primary food source involved the direct procurement of edible plants and animals from the wild: foraging and hunting without significant recourse to the domestication of either. Based on available resources, people traded when and where they could and carried few possessions. Unlike in the modern world, they did not need to take out the trash, mow the lawn, or pay their cell phone bills. Sounds liberating, but through the span of the Paleolithic Period the objective was human (and often individual) survival. From the time of hunter-gatherers, people lived in small clan-based communities, roaming the land to search for food. Traditionally men followed large animals in a hunt and women gathered food from the seasonal variation of plants in the valleys and on the plains. Natural structures, such as caves and temporary dwellings made from wood and animal hides, served as resting places where the clan could seek refuge from the harsh elements, using fire to keep warm and to cook their food. When tools were utilized, they served rudimentary functions and then were cast aside because people did not have pockets, purses, or backpacks back then. Nomadic people may not have been advanced technologically, but they were profoundly influenced by their environment and understood how to survive in a mysterious and unpredictable world.

Figure 1. Click here: How Stone Age Humans Made Hand Axes. Encyclopedia Britannica.

What is technology and why it is so important to the advancement of civilizations?

Technology can be defined as using natural resources for tools that contribute to advances in knowledge, a process, purpose, invention and/or industry that advance people and civilizations. Through humans' ability to adapt to their environment, and because ideas were assimilated through interactions, technology could advance in a way that aided in the survival of humans. Technological adaptations then led to cognitive changes in human communication, with the world and its environment bringing about a material culture. As technology evolved, so did the purpose and intent of resources, so that over time these technological innovations were fine-tuned and applied to everyday life, making it easier for people to build boats, crush wheat, cook food, and hunt animals. Basically, live better and longer lives!

The impetus for technological change during the Paleolithic period was the climate changes brought about by the Ice Age, which profoundly impacted the developing culture of humans during the early to middle Paleolithic Period. With the geostructural changes brought about by the formation and subsequent recession of ice sheets cycling over millions of years, the nomadic tribes adapted to the changing topography of the earth's surface and shifted their migratory patterns according to available food sources.[1] Through this experience, a distinct culture based on epistemological reasoning allowed for the evolutionary prosperity of man to continue. Where the early Paleolithic period is marked by the use of simple tools to achieve a desired result, the middle of the Paleolithic period showed that humans continued to respond to environmental changes, where their technology and learned behavior was readapted to meet new challenges. Research shows that toward the end of the Paleolithic Period, increased temperatures thawed the Scandinavian and Siberian ice sheets, causing water to rapidly flow into the Caucasus Mountains, where the rivers swelled and traveled north into the Black Sea and Caspian Sea. As the seas swelled, the water found its way into the lakes and rivers flowing from the Anatolia region into the Tigris River and Euphrates River. This caused human migratory patterns to change and shift toward the northern regions.[2]

Why did nomads become sedentary? Due to the shifting environment, nomads were forced to redefine their existence and adopt a more sedentary lifestyle. They observed the climate changes, the activity of the riverbeds and studied the plants and animals around them, all the while passing information down from generation to generation. As humans adopted to their changing environment they also advanced technology to improve their existence. Nonspecific tools became more complex, requiring a higher degree of specialization that lead to semi-sedentary communities. Humans discovered that they could plant and harvest crops and that did not have to keep moving around. Once a localized food source is established it is harder to go back to hunting and gathering because people needed to stay localized to harvest and replant. Either way, a transformative event occurred when semi-nomadic and sedentary societies developed into agricultural communities. This evolutionary process, transitioning from hunter-gathers to sedentary agricultural communities, transformed human interactions as the idea of harnessing resources to benefit people's day-to-day interactions became paramount to sustaining clan-based populations. Whatever the reason, these nomads began to settle down, to stop roaming the lands, and stop following the herds, historians can deduce that their existence was threatened by natural disasters, human encroachment, food scarcity, infestation of insects, blight, diseases, and overpopulation. Historically the end of the Ice Age marked the end of the Paleolithic Period and the beginning of the Neolithic Period.

[1]. Guy Gugliotta, "The Great Human Migration," *Smithsonian*, July 2008.

[2]. David Biello, "What Thawed the Last Ice Age?, *Scientific American*, April 4, 2012.

CHAPTER 1 - FROM THE NEOLITHIC PERIOD TO THE AGRICULTURAL REVOLUTION

STEPHANIE GUERIN-YODICE

Like the Paleolithic Period, the Neolithic Period is also divided by an early, middle, and late timeframe. The early part of the Neolithic Period reflects hunting, gathering, and primitive use of stone tools; the "esolithic" (in the middle of the time period) marks the more sophisticated use of stone tools for agriculture; and the "eneolithic" (toward the end of the period) denotes further advancement toward domestication; a surplus of food; and technology adapted toward farming, irrigation, and defense techniques. Still, the Neolithic Era is less about a chronological demarcation and more about the human behavior and interaction as people moved from clan-based communities into societies and civilizations by way of technological advances.

Neolithic consists of two separate words, *neos*, meaning new, and *lithos*, meaning stone. Historians denote this period in history because the stones used for tools during the Paleolithic Period (Old Stone) advanced from edges or points used to serve basic purposes into stone tools meant for specific functions, such as arrows, fishhooks, and spears; sharp tools used to hollow out logs that would became canoes and shelter; and lighter harpoons made from bones and antlers. During the Neolithic Period, humans transitioned from nomadic hunter-gatherers to semi-sedentary and sedentary societies and the advancement of the farming technology called the Agricultural Revolution. Additionally, this period in history also represents the cultural, intellectual, and social evolution of humans. The "revolution" was not spontaneous, but it denotes a fundamental change in how the people of the ancient world lived. They started to build semipermanent dwellings, tame animals, and essentially domesticate both plants and animals. This domestication meant that humans adapted plants and animals so they could be cultivated by humans and used for labor or food. This in turn freed humans from hunting and gathering and allowed people to control the production of food, rather than being at the mercy of whatever was available from their environment.

Sounds like a good idea?

Most people lived in simple agricultural villages of about 100 to 200 people, but others took the settlement process further and developed large and complex city-states in the Sumer region. Together, these people talked, tried to figure out how to best use the resources available to them, and created houses and storage facilities, cleared fields, divided territories, and appointed societal roles for people in the community. Eventually, an advanced state of trading emerged due to specialized labor and a surplus of plants and animals, which was initially not a money economy but a bartering system.

CHAPTER 1 - A CASE STUDY: TECHNOLOGY IN TRANSITION

STEPHANIE GUERIN-YODICE

Figure 2. Map of Çatalhöyük and Konya Region. Google Images. CC-BY.

Agricultural villages are not civilizations, yet agriculture is necessary for the survival of a civilization. The rise of civilizations developed independently through the ancient world, each with a unique culture linked to its geographical region and the resources provided by nature. Obsidian glass proves to be a transitional element which transformed societies and launched civilizations. Unlike a stone picked up off the ground, obsidian glass comes from a volcano. It provided the small agricultural town of Çatalhöyük with a technological resource that helped humans to establish trade as far west as the Levant and south along the Tigris River and Euphrates River to the Persian Gulf.

In 1959, a team of British archeologists discovered the remains of a Neolithic town (7500 BCE to 5700 BCE) nestled in the Konya plain of Anatolia (present-day Turkey). What they discovered was a very well preserved Neolithic town that represented technology in transition. The people of Çatalhöyük settled in a geographically desirable area that proved to be well protected by forests and included a plateau, plains, waterways, and a stable source of water from the mountains.

Figure 3. Click here: Landscape with Volcano Eruption. Çatalhöyük, Turkey, 6150 BCE. Science News, 2014.

It is assumed that this location developed into an agricultural community that successfully acquired a food surplus, which would then lead to population growth and well-established trade routes.[1] The evidence uncovered by subsequent archeological digs revealed a mix of seminomadic and permanently established communities that used technology to advance their society, thus establishing communities that were rich in culture, resources, and specialized labor. Excavation of the site revealed permanent dwellings, complete with worship centers, shared sleeping quarters, and artifacts that testify to a level of human advancement. Inside one of the dwellings archeologists discovered a painting. After restorative efforts were made, it revealed an image of the town and a volcano in the distance. This discovery helped archeologists to identify the area where obsidian glass was collected and also gave historians insight into how the Çatalhöyük people participated in advanced trade networks. Historians are unclear as to how the people of Çatalhöyük acquired the volcanic glass from Cappadocia, which lay 160 miles northeast of the primitive agricultural settlement, but what is evident is the value this resource provided to the technological advancement of civilizations.[2]

> "It has long been argued that this [obsidian] was an extremely valuable resource to Çatalhöyük, not only with regard to its functional capabilities and daily household use, but also in terms of the community's (alleged) role in its long-distance exchange and its symbolic properties."[3]
>
> – Stanford University department of Geological and Environmental Science

[1] Andrew Cherratt, "The Obsidian Trade in the Near East, 14,000 to 6500 BC." *ArchAtlas 4.1* (2005). Accessed June 12, 2017. http://www.archatlas.org/ObsidianRoutes/ObsidianRoutes.php

[2]. "Stanford Obsidian Research Team," Stanford University, https://earthsci.stanford.edu/research/mahood/geoarc_people_sort.htm.

[3]. SORT.

CHAPTER 1 - MESOPOTAMIA AND THE FERTILE CRESCENT

STEPHANIE GUERIN-YODICE

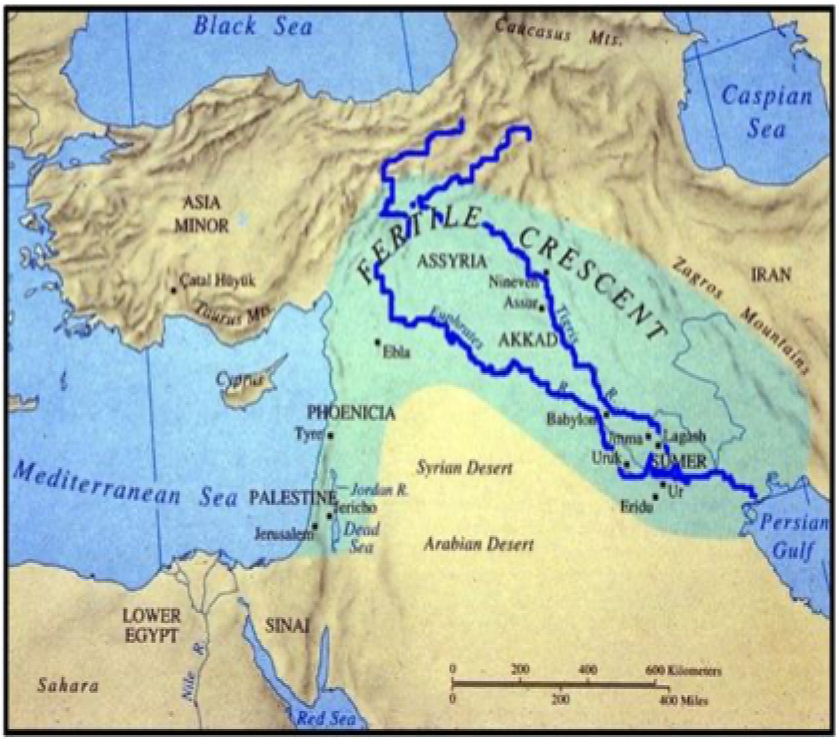


Figure 4. Map of Ancient Mesopotamia. Google Images. CC-BY.

Beginning about 10,000 BCE, nomadic clans began to migrate out of the Taurus, Caucasus, and Zagros Mountains regions and funneled into the mouth of the Tigris and Euphrates Rivers. These two rivers serve a unique purpose to the development of agricultural societies. Historians have deduced that human migration was due to environmental issues. Paleoclimatology scientists believe global warming caused the glaciers and icecaps from the Taurus, Caucasus, and Zagros Mountains to melt. Some researchers believe that clans were pushed from the upper region of Anatolia down into the mouth of the Mesopotamian rivers as floodwaters raised the sea level along the surrounding basins. Other scientists have found evidence that suggests the sea level rose steadily over a long period of time, encroaching on the seminomadic communities and eventually forcing them to relocate.[1]

Mesopotamia in Greek means "between the rivers," and it did possess two wonderful rivers, called the Tigris and Euphrates. The region spans more than 10,000 square miles and the farthest point between the two rivers is about 150 miles across; the closest point is around 20 miles across. In the early period of settlement along the Tigris and Euphrates Rivers, the soil beds were rich with silt, which provided the necessary nutrients to establish agricultural communities, thus giving the region the name the Fertile Crescent. When the water level rose between April and June, the plains were flooded with enriching silt deposits that made the soil viable for agriculture.

Sumer Region

Figure 5. Map of Sumer Region. Google Images. CC-BY.

For over a thousand years, the peoples from the north and surrounding regions continued to migrate down the path of the rivers and settle in the lower portion of the Tigris and Euphrates Rivers. In this geographically advantageous area, they were able to successfully transfer and adapt crop techniques, and eventually develop self-sustaining agricultural communities. Humans' ability to adapt and learn from the past proved to be effective in selecting the settlement area of Sumer**.** They learned how to survive through observing their surroundings, utilizing the local resources, and working toward common interests. Eventually the transmission of technology helped societies evolve from agricultural communities to advanced civilizations. In the region of Sumer, political, cultural, and religious life became the synergy for close-knit communities, and the cities of Kish, Lagash, Ur, Umma, and Uruk emerged as powerful independent states.

[1]. "Paleoclimatology Data," National Centers for Environmental Information, https://www.ncdc.noaa.gov/data-access/paleoclimatology-data.

STEPHANIE GUERIN-YODICE

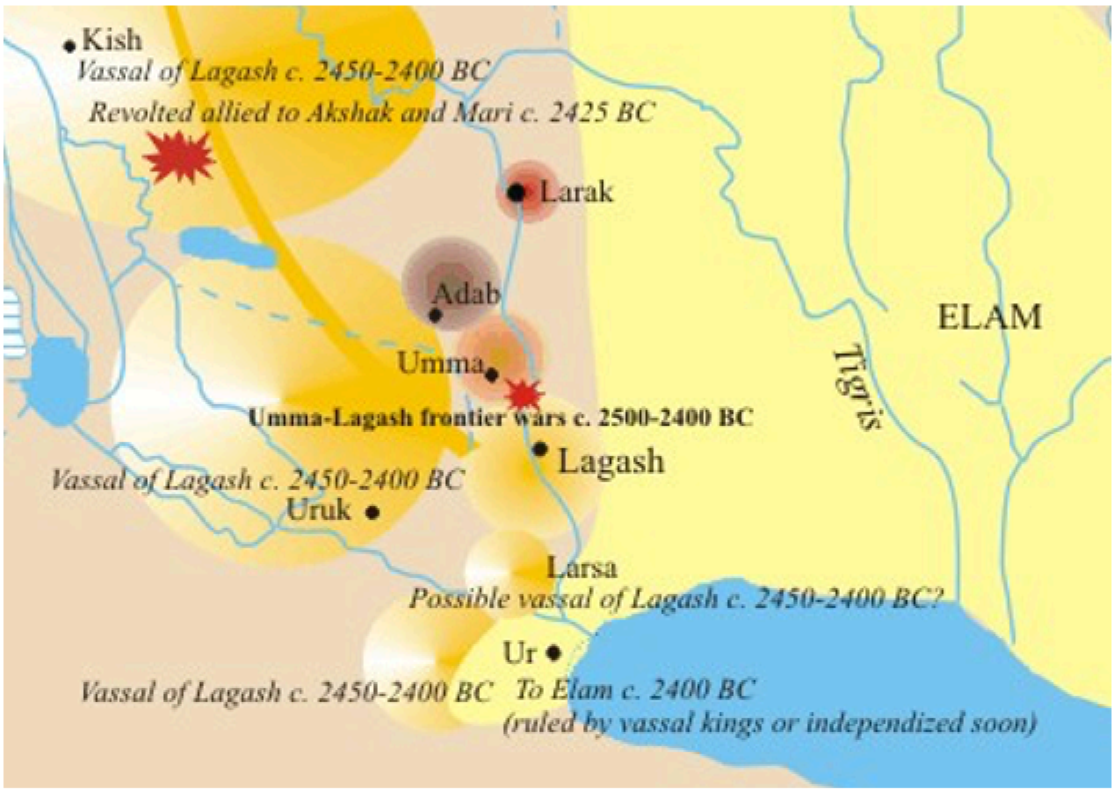


Figure 6. Map showing the struggle for power, 2500–2400 BCE. Google Images. CC-BY.

There is evidence that the first conflict over waterways occurred in 2500 BCE between the rulers of Lagash and Umma. Lagash was one of the original established agricultural communities along the Tigris River. Over time, the kings of Lagash (circa 2500–2270 BCE) expanded beyond the walls of the city-state to eventually conquer most of the Sumer region. It was customary for Sumerian kings of the First Dynasty to reduce conquered city-states to tributary states. In this system, authority was primarily decentralized and the rulers within Lagash's vassal territory maintained substantial autonomy. When the king of Umma, a city-state approximately 35 miles north of Lagash, threatened Lagash's land and water resources, a series of reappropriations were made in an attempt to settle the border dispute. [1] Epigraphic scientists have translated multiple inscriptions outlining Umma's transgressions, the interstate conflict with Lagash, and the course of action the kings of Lagash took to reclaim their lands.

The primary source titled *Inscription from Umma and Lagash* (See Doing History) demonstrates the importance placed on access to waterways: land and canal maintenance was paramount to the

Figure 7. "Stele of Conflict" between Umma and Lagash. Google Images. CC-BY.

success and failure of early city-states. Essentially, without access to water the people of Sumeria could not sustain their agricultural base and the survival of the community was at risk. Furthermore, as the region attracted more settlers along the riverbeds, the agricultural communities grew in population. Because of the severe flood and drought seasons, however, the shared water source either experienced over salination and silt and/or flooded the agricultural plains. The conflict would have occurred because communities at the lower end of the rivers would have had to deal with oversalination and silt buildup from the irrigation systems of communities at the upper end of the rivers, a lower water supply, or the devastating consequences of flood waters that increased in volume and debris. These issues propelled humans to solve issues surrounding the use of river water and irrigation techniques.

See **Doing History** at the end of the chapter on *Inscription from Umma and Lagash*

[1]. George A. Barton, "Inscription of Entemena #7," in *The Royal Inscriptions of Sumer and Akkad* (New Haven, CT: Yale University, 1929), 61, 63, 65.

CHAPTER 1 - TECHNOLOGY OF MESOPOTAMIA: IRRIGATION

STEPHANIE GUERIN-YODICE

Advanced techniques in irrigation became distinct to the region of Sumer. The Tigris and Euphrates Rivers provided an adequate water source for societies to thrive, but the region's topographical features also posed issues. During the warmer season, when the region experienced low rainfall levels, the ice which formed in the upper region of Anatolia began to melt, causing water levels to rise. By the time the water flowed down into the Sumer region, large amounts of silt had accumulated within the flat and poorly drained riverbed of Kish, Lagash, Ur, Umma, and Uruk. Furthermore, the issue was exacerbated by the Euphrates River, which was at a higher elevation than the Tigris and often overflowed into the settlements on the Tigris side of the territory. During the early history of Sumer, these regional conditions led to issues with over salination, silt, flood, and drought among the city-states.[1]

Shaduf: A long pole rested on a V shaped piece of wood or a large rock. A bucket was tied to one end of the pole with a counterweighted on the other. The fulcrum created the leverage needed to move water from one place to another with relative ease and efficiency.

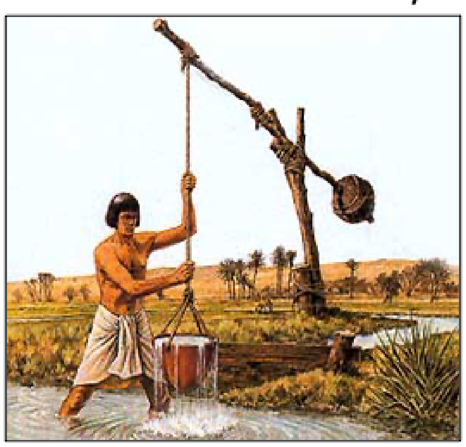


Figure 8. Example of how Sumerians used the shaduf. Google Images. CC-BY.

Despite these challenges, irrigation techniques unique to the Sumer region were responsible for the formation of the city-state and urban development. The first few settlements of Kish, Lagash, Ur, Umma, and Uruk established a foothold along the two rivers and benefited from a single irrigation system that supplied their settlements with adequate water flow. However, it was not a perfect scenario because in late winter and spring the glaciers and icecaps from the Taurus, Caucasus, and Zagros Mountains flooded the two rivers with devastating amounts of silt, sediment, and debris, causing the river patterns to change from year to year. Additionally, when the rivers were receding, the region experienced extreme droughts that eroded the nutrients in the soil and produced a hard clay that was not conducive to agriculture.[2] Responding to the need for a predictable water source that these conditions created, the settlements developed artificial irritation techniques. Overtime, subsequent settlements developed along riverbeds, and these also employed single-use irrigation systems by hoisting water in buckets over levees and canals.

[1] D. Brendan Nagle, *The Ancient World: A Social and Cultural History* (New Jersey: Pearson Education, 2010), 1- 66.

[2]. Maria Kielmas, "Ancient Sumerian Levees and Canals," Sciencing.com, March 10, 2018, https://sciencing.com/ancient-sumerian-levees-canals-16874.html

CHAPTER 1 - TECHNOLOGY OF MESOPOTAMIA: LEVEES AND CANALS

STEPHANIE GUERIN-YODICE

Water flow produces natural levees and canals within riverbeds, but subsequent flooding can also change the direction of rivers, washing out the riverbanks and changing agricultural access to the surrounding plains. Using technological innovations, the early settlers of Sumeria built levees along the riverbank with baked-mud bricks and bitumen to prevent erosion during the high flood seasons. When the water levels were high, holes were made in the levees for water to flow out and irrigate the crops. During the dry season, advanced cultivation tools called *shadufs* were used to collect water in the low-lying area of the river and bring it to the agricultural plains. Subsequently, when the levee walls failed, Sumerians dug artificial channels to redirect the water. Artificial irrigation techniques were further mechanized with levers and pulleys, which also allowed for the magnification of human and animal force.[1]

[1] Richard Cowen, "Chapter 17: Ancient Irrigation." *Exploring the Earth.* Accessed January 7, 2018. http://mygeologypage.ucdavis.edu/cowen/~gel115/index.html

CHAPTER 1 - TECHNOLOGY OF MESOPOTAMIA: DAMS AND SLUICE GATES

STEPHANIE GUERIN-YODICE

The technology needed to employ artificial irrigation techniques is only effective if there is a constant water source. Other agricultural innovations used in Sumer were dams and sluice gates. On higher ground, diversion dams were built over secondary waterways to restrict the flow of water and allow it to accumulate in large quantities. These reservoirs supplied the canals and plains with water during droughts and slowed the flow of water during flood seasons. Many of the canals and dams along the Tigris and Euphrates Rivers were also controlled by sluice gates which regulated the direction, rate, and flow of water.[1]

Figure 9. Click here: Image of Dams and Sluice Gates. University of Toronto Atlas of the Ancient Near East, c. 3000-300 BCE.

[1] Richard Cowen, "Chapter 17: Ancient Irrigation." *Exploring the Earth.* Accessed January 7, 2018. http://mygeologypage.ucdavis.edu/cowen/~gel115/index.html

CHAPTER 1 - TECHNOLOGY OF MESOPOTAMIA: THE WRITTEN WORD

STEPHANIE GUERIN-YODICE

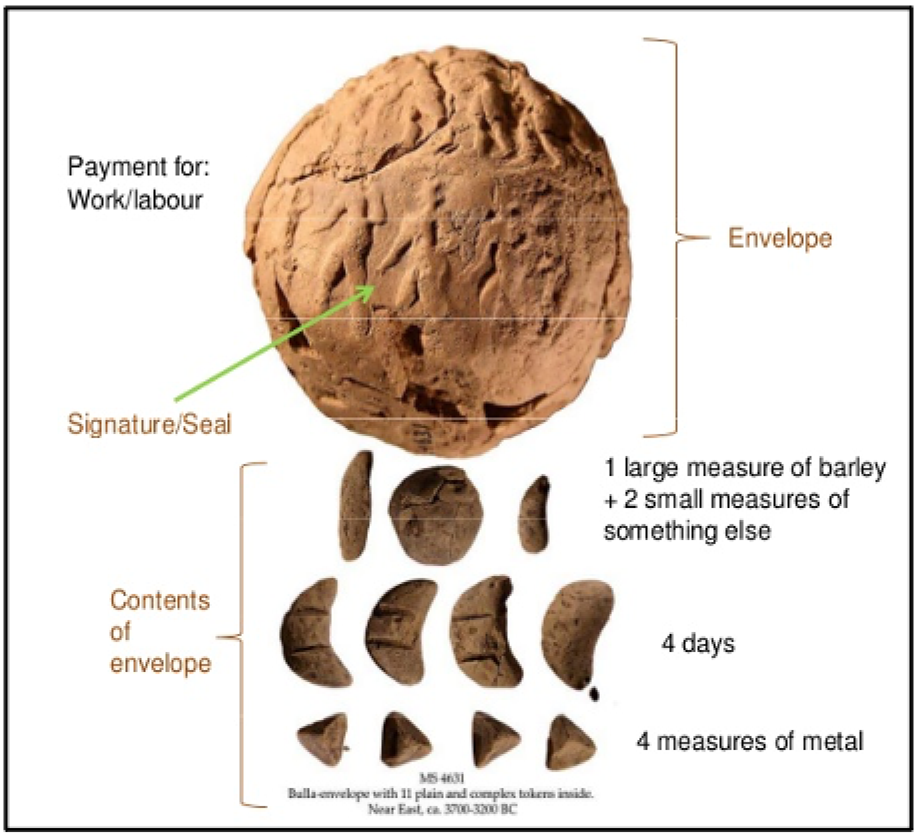


Figure 10. Sumerian counting tokens. Google Images. CC-BY.

Another technological innovation unique to the people of Mesopotamia is written communications. The importance of irrigation and access to waterways highlighted in the case study on the kings of Lagash and Umma demonstrates how important communication and documentation was to the ancient Sumerians. It makes sense then, that this region is also responsible for originating communication through shapes, signs, symbols, and eventually, letters. The earliest evidence of written communication, called *cuneiform*, dates back to 7500 BCE and was found in the form of tokens or seals that served as legal documents, identification, or a form of recordkeeping. These small forms of oddly shaped clay were originally a way to record agricultural and pastoral exchanges that were traded, stored, or sold.[1] Together, the shape of the token and the stylized markings on it convey a pictorial resemblance to the physical object. Much like we use wallets and change purses today, the tokens were stored in larger hollowed-out balls of clay called *bulla*, which held the items in an "envelope" to represent a sealed contract. Subsequently, trade routes expanded beyond the Sumerian region and there was need for more complex forms of communication. The technological process of the written word advanced toward cuneiform. Cuneiform combines word-concepts (pictograms) with phonics to create monosyllabic words that represent the image and action being described.

Figure 11. Cylinder seal. Google Images. CC-BY.

The small cylinder seal in Figure 11 dates back to 5000 BCE and represents another form of written communication that is specific to the Mesopotamian region. Fashioned primarily out of stone, these seals became popular because they could be easily carried on a rope or pinned to a garment, making them less cumbersome then the *bulla* or stone tablets. Made from local stone such as hematite, lapis lazuli, and even obsidian, the objects were made by a *burgul* or sealcutter who carved a small cylinder from the stone and drilled a hole lengthwise through the middle.[2] Images were carved on the stone so that when it was rolled across wet clay an impression of the writing or design was created.

Cylinder seals were commonly used by anyone involved in business dealings, but they served a more extensive purpose than just recordkeeping. The seals usually bore an individual's identification and occupation. When the seal was rolled on to a wet clay surface, its image served as a calling card or signature for proof of payment, much like a business card or signature on a credit-card receipt is used today. In addition to personal rank and standing, cylinder seals held decorative motifs that reflected the style and culture of Mesopotamia. Each seal was fashioned out of locally quarried stone with designs that were indicative of the region and the period in which it was created. As a result, archeologists and historians utilize cylinder seals to learn more about the daily lives of people who lived throughout the ancient Mesopotamian region. The images tell of everything from epic tales, religious rituals, objects found in nature, and everyday domestic life to administrative hierarchies, making them both functional and culturally reflective.

As the written word evolved into an alphabetic language, the use of clay tablets remained the primary form of documentation through the Mesopotamian region, and was used for literature, administration, commemoration, recordkeeping, and business transactions. It was not until the time of the Phoenicians, residents of a coastal city-state in the Levant region that monopolized maritime trade across the Mediterranean Sea, that a more simplified alphabetic language replaced the Sumerian alphabet. The Phoenician alphabet, made up of a combination of Egyptian hieroglyphics and cuneiform, spread as the city-state engaged in maritime trade throughout the region.

For example, in looking at fig. 12, the first image is a pictograph of an object that is used to represent the generic term for grain (translated into bread). By 3200 BCE, different types of grain, such as wheat, oats, and barley needed specialized identification called ideogram, which can be seen in the second image.

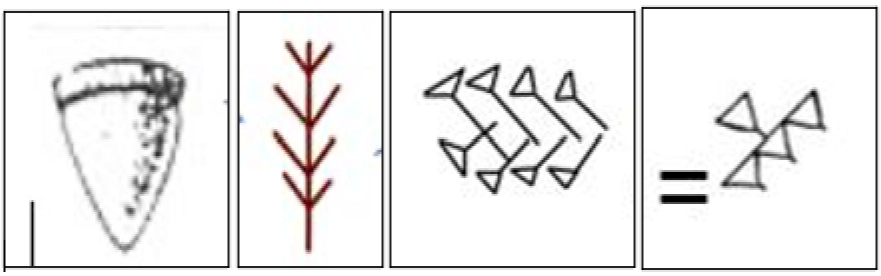


Figure 12. Transformation of Barley. Google Images. CC-BY.

While the pictogram and ideogram for barley is easily identifiable in the first two images, by 3000 BCE the image for barley becomes more stylized as techniques in writing advanced toward signs for syllables and vowels called logographic. Not only is the image of barley more stylized but it is turned on its side and depicts not just a singular "grain" but the amount of barley per volume. Moving to the last and final image of barley, the written word became more complex as it transitioned to include both barley on a Cuneiform table that represents a transaction or record but the sound for barley, called a logograph. The last image represents the transitions from the of barley into a phonogram and phonetic sound that represents the spoken and written language that we have today.

Written forms of communication were not solely linked to the Mesopotamian region, but one element of writing that can be attributed to the Sumerian people was their practice of recording transactions. Countless clay tablets and cylinder seals served as documentation of transactions such as land grants, storage facilities, marriage, territorial borders, receipts, wills, and contracts. Steles in the shape of obelisks, cones, large standing slabs of stone, and votive offerings served as monuments of devotion toward commemoration, gravesites, boundaries, divination, and law codes. Recordkeeping pushed the people of ancient Mesopotamia in other directions as well.

[1] "Writing," *British Museum.* Accessed November 14, 2017. http://www.mesopotamia.co.uk/writing/story/sto_set.html

[2] Gale World History in Context, "Cylinder Seals," *Gale World History in Context*. Accessed February 7, 2018. http://ic.galegroup.com/ic/whic/ReferenceDetailsPage/ReferenceDetailsWindow?displayGroupName=Reference&zid=89322a709a5a518024288feed497bb92&p=WHI

CHAPTER 1 - TECHNOLOGY OF MESOPOTAMIA: SPECIALIZATION OF LABOR

STEPHANIE GUERIN-YODICE

As Sumerians developed city-states and defined the borders of kingship towns, agriculture and industry increased to the point of specialization. Specialization occurs in an advanced agricultural society when staple crops experience high yields and grain stores can adequately feed the community, thus freeing people up to develop trades in specific areas: either in commodities, services, or luxury goods. Using obsidian glass as an example, we can trace the development of a commodity to a luxury item through travel and trade networks. Obsidian glass from the upper Anatolian region was a hot commodity to regions that did not have volcanic activity. Communities local to this resource had an advantage in the trading industry because many other regions wanted to obtain the valuable glass that was cut from the hardened volcanic lava. A trader would most likely gather up a local commodity, such as stored grain from Lagash, and travel north beyond Kanya, to Çatalhöyük, in the hopes of trading one commodity for another. Along the way, a bartering system allowed the trader to distribute grain or other valuable commodities in exchange for food and lodging until reaching the foothills of Hasan Dağ.[1] From there, grain could be traded for the obsidian glass, which became available through either mining or local trade networks. Once the trader returned home, the glass was distributed through either a marketplace or personal transactions. Depending on the need or intended use for the glass, an artist could use it in jewelry, a builder could use it to carve intricate details, or a physician could use it to perform surgeries. The journey to obtain the obsidian could take up to three months, so before the trader left, a promissory note was made by imprinting the symbol of grain plus the amount taken with another register, identifying the amount of obsidian glass the trader would exchange for the grain.

The Life of a Scribe: The term *dubsar* refers to an ancient Mesopotamian scribe, but in modern terminology the people who wrote, recorded, and transcribed the written word would be called linguists, historiographers, artists, revisionists, instructors, and reporters. In fact, the role of a scribe in the ancient world was highly respected and not easily obtained. Traditionally, ancient societies were structured so that children took up the trade of their parents. Boys continued to farm their fathers' fields, and girls were expected to raise children or take up the artisan craft of their mothers.

Education was not extended to everyone, and the training needed to become a scribe was long and rigorous. Young boys with social status and financial means could be sent to *bit tuppi*, or a "tablet house" school. There they were taught the style and structure of impressing wedge-shaped markings into clay by first copying short proverbs and simple textual passages. Next, students began the arduous task of transcribing lists consisting of signs, symbols, vocabulary, grammar, and sounds, followed by extensive training in linguistic translation, the number system, lexical text, and the role of a scribe within the community. Once schooling was complete, scribes were employed for a multitude of reasons: by the government, business owners, the royal court of a king, or even their friends and

Figure 13. Scribes. Google Images. CC-BY.

neighbors, but the highest role for a scribe was to become a priest, which during ancient times meant a person highly valued in society and not just held authority in religious matters but also held political importance . The scribes and scholars of ancient Mesopotamia played a seminal role in transmitting knowledge and disseminating ideas.

Mathematics: There are more than 2,000 tablets that demonstrate the sophisticated mathematical minds of the people in ancient Mesopotamia. Concrete math came first, with tokens representing numbers of items, but eventually the equivalent was written in cuneiform to accompany the words that described the items. Approximately 1,613 tablets reveal that by 2000 BCE a numeric system existed for representing weights, measures, addition, subtraction, and division. This decimal system was based on a sexagesimal system, which used 60 as a base, and a value system separated by columns, that functioned much in the same way that the decimal point does today.[2] All that number crunching led the Sumerians to begin crude speculations about the nature of numbers. Processes involving numbers and simple math turned to more complex and abstract formulas (see fig. 14). In this manual for quadratic problem-solving, two dozen of the calculations were applied toward building projects and land surveys.

Astrology: All this record-keeping and administration required much more than the ability to calculate and record day-to-day transactions. State-building demanded an efficient system for measuring long periods of time. Similarly, agriculture required more than irrigation techniques, so the Sumerians invented calendars. Through careful observation of celestial patterns, they divided a year into 12 months according to the cycles of the moon. This interest in measuring long periods of time led the Sumerians to develop a complicated knowledge of astronomy. The zodiac was another invention used to measure yearly time. However, adjustments needed to be made since a lunar month is 29 days and 12+ hours, which does not exactly correlate with a solar year, which is 365 and a quarter days (actually 365 days, 5 hours, 48 minutes, and 47.8 seconds). To deal with this mathematical inaccuracy, around 2500 BCE an intercalary day was inserted every four years, creating a “leap year” that brought the seasons back to normal.[3]

In a modern society people can use their electronic devices to access weather forecasts, but the people of ancient Mesopotamia looked to the sky to understand their physical environment. Mathematic

Figure 14. Sumer Mathematics.
Google Images.

innovations helped them to chart and map the daily movement of the planets and stars, which allowed them to track the passage of time with a 12-month calendar and a pattern of changing seasons, all of which is still used today. Astrological observation could also predict the best seasons for sowing and reaping crops. The constellations also became important to those early societies, as they were central to folklore and mythmaking. Where modern scientists and astronomers have advanced technology to evaluate the depth of our sky above, people of the ancient world relied on epistemological and metaphysical knowledge.[4]

Through knowledge passed down for generations, the pattern of the solar system was observed, calculated, and recorded because ancient civilizations believed that everything happened for a reason. If people could understand the movement of the sky, they thought that they could interpret their future. In modern times we understand that thunder is created by atmospheric conditions but imagine experiencing thunder and lightning while living in 3000 BCE. This was a very scary and unpredictable phenomenon to which no rational understanding could be applied. When they were unable to explain the reason for thunder and lightning, early societies turned to metaphysics. Other everyday events and rare occurrences also took on a deeply religious meaning for the same reason.

Figure 15. Sumerian star chart. Google Images. CC-BY.

For instance, the movement of the stars and planets assumed names, had personalities, and demanded rituals of worship. The people of ancient Mesopotamia believed their gods and goddesses were personified in the planets and that their movements conveyed their wishes. The gods and goddesses became zodiac signs and were associated with the months of the year. What we call the planet Venus was then called Ishtar, after the goddess of love, war, and fertility. Mercury was Nubu, god of wisdom, and Mars was Nergal, the god of pestilence. Nergal imbued feelings of death and destruction and was associated with the sun that scorched the earth of vegetation. Nerghal would conquer Tammuz, the god of food, so a funeral was held for Tammuz when he died each year when the season changed from summer to fall. [5]

[1] Geologists have identified the glass from this volcano was widely traded throughout the Middle Eastern Region. See Cherratt.

[2]. "Cuneiform Mathematics," *A Library of Knowledge of the Cuneiform Digital Library: Science & Technology, May 5, 2017*. Accessed February 7, 2018. http://cdli.ox.ac.uk/wiki/doku.php?id=history_of_science

[3]. "Astral Sciences," *A Library of Knowledge of the Cuneiform Digital Library: Science & Technology, May 5, 2017*. Accessed February 7, 2018. http://cdli.ox.ac.uk/wiki/doku.php?id=babylonian_astronomy

[4] "Astral Sciences," *A Library of Knowledge of the Cuneiform Digital Library: Science & Technology, May 5, 2017*. Accessed February 7, 2018, http://cdli.ox.ac.uk/wiki/doku.php?id=babylonian_astronomy

[5]. Massoume Price, "Astrology and Astronomy in Iran and Ancient Mesopotamia," *Iranian Chamber Society,* December 2001. http://www.iranchamber.com/calendar/articles/astrology_astronomy_iran_mesopotamia.php.

CHAPTER 1 - TECHNOLOGY AND EMPIRE BUILDING: SARGON I OF AKKAD

STEPHANIE GUERIN-YODICE

Sargon I of Akkad: circa 2334 to 2284 BCE

Figure 16. Sargon of Akkad. Google Images. CC-BY.

Since the early conflict between the kings of Umma and Lagash, issues over territorial boundaries and resources continued to monopolize state-building. Territory and resources were both key to the advancement of civilizations in ancient Mesopotamia. Sometime around 2300 BCE, the Sumerian region experienced a usurpation from the north. Sargon, a king from Kish, seized the lower portion of Sumer through a series of wars. He conquered one city-state after another to form a new region called Akkad. Sargon became king of Akkad and systematically brought every city-state within his newly conquered territory under one empire. Sargon realized that implementing bureaucratic systems would be necessary to the survival of his empire. The once independent city-states were now forced to deploy their resources and labor force in the interest of nation-building and the securing the empire. Trade routes were widened and maintained to provide safe passage for traders and travelers. A system of communication with garrison outposts ensured the dissemination of political decrees. Sargon standardized currency throughout the empire by codifying a system of weights and measures. Taxes were collected from every city-state and used to organize a hierarchical bureaucracy. It was under Sargon's reign that scribes were employed to record his achievements, maintain palace administration records, dispatch government correspondence, oversee the collection and allocation of taxes, and amass a body of literature that reveals the religious and cultural customs of people during the 150 year reign of Sargon and his successors.

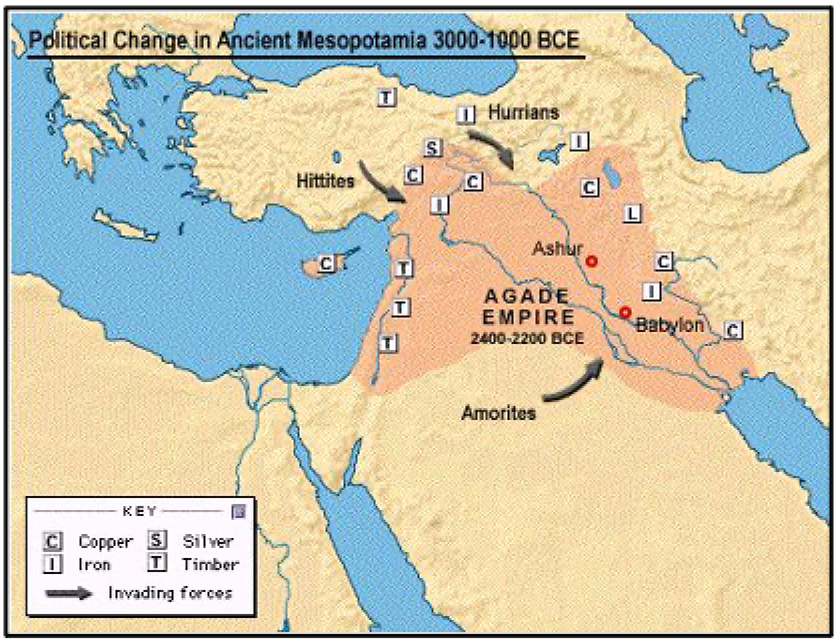


Figure 17. Map of Sargon's Resources. Google Images. CC-BY.

The success of Sargon's state-building can also be attributed to his willingness to embrace technological diffusion. By Sargon's time, the Stone Age had become the Bronze Age (circa 4000 to 1200 BCE) and smelting techniques had revolutionized military weaponry. Sargon procured key mining locations that fueled his commercial and military expeditions. Through these technological advances, Sargon developed and funded a professional army that was responsible for his military success. Prior to this, men were expected to defend their city-state in times of need but they were not paid. Sargon's fighting force was made up of infantry who were protected by copper helmets and equipped with a copper-tipped spear. Sargon reorganized their phalanx formations, issued pikes and axes, and armed the front men with shields. He also brought back the bow and arrow, organizing large formations of archers whose barrage of arrows killed men and animals well before the hand-to-hand combat began.

Sargon's legacy remains clear in the evidence he left. Copious records indicate his talent as a bureaucratic administrator and an economic and military strategist, as well as his vision toward unifying a territory for the benefit of empire-building. After Sargon's death, a series of rulers continued to reign for approximately 100 years, until a series of conflicts consumed the Akkadian

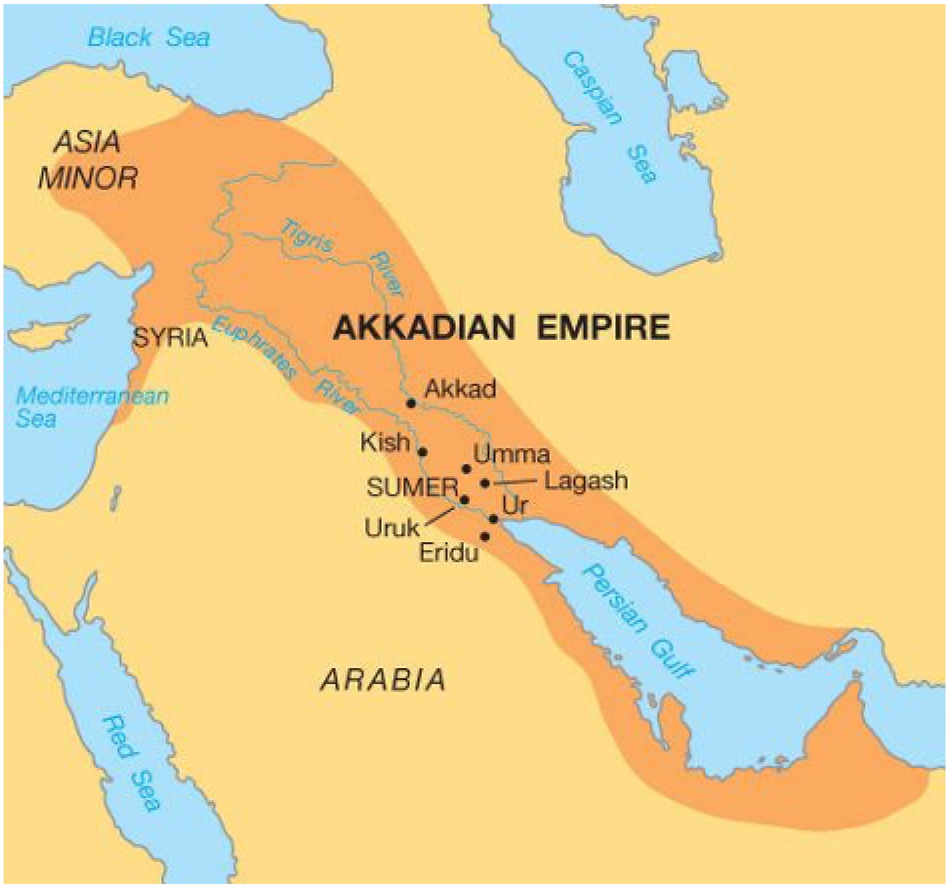


Figure 18. Map of Akkadian Empire. Google Images. CC-BY.

Empire, thrusting the Mesopotamian region into turmoil for centuries. For a short period of time, power was reconcentrated back in the region of Sumer under the Third Dynasty of Ur (2047–1750 BCE), where successful nation-building still relied on the same set of factors: resources, labor force, political structure, and authority. The kings of Ur attempted to consolidate and centralize their authority by building a protective wall around their territory. Still, they were constantly attacked by surrounding tribes, and ultimately the Elamites broke through and sacked the city, ending the era of the Third Dynasty of Ur.

CHAPTER 1 - TECHNOLOGY AND EMPIRE BUILDING: KING HAMMURABI OF BABYLON

STEPHANIE GUERIN-YODICE

King Hammurabi of Babylon: circa 1795 to 1750 BCE

Figure 19. Hammurabi. Google Images. CC-BY.

Hammurabi was the sixth king of the Amorite Dynasty (2400 BCE to 1595 BCE). He established the city of Babylon as the capital during his reign. Like rulers before him, he slowly encroached on the surrounding regions through war and force, but he is also notable for his use of diplomacy. Hammurabi judiciously elevated Marduk, the god of fertility and the original god of thunderstorms, as the chief deity of Babylon. Marduk came to be synonymous with the god Ashur, who was chief deity in the Mesopotamian pantheon of gods and goddesses up until Hammurabi's reign. By establishing a new deity, Hammurabi was also able to issue a set of laws in which he claimed to come from the divine word of Marduk himself.

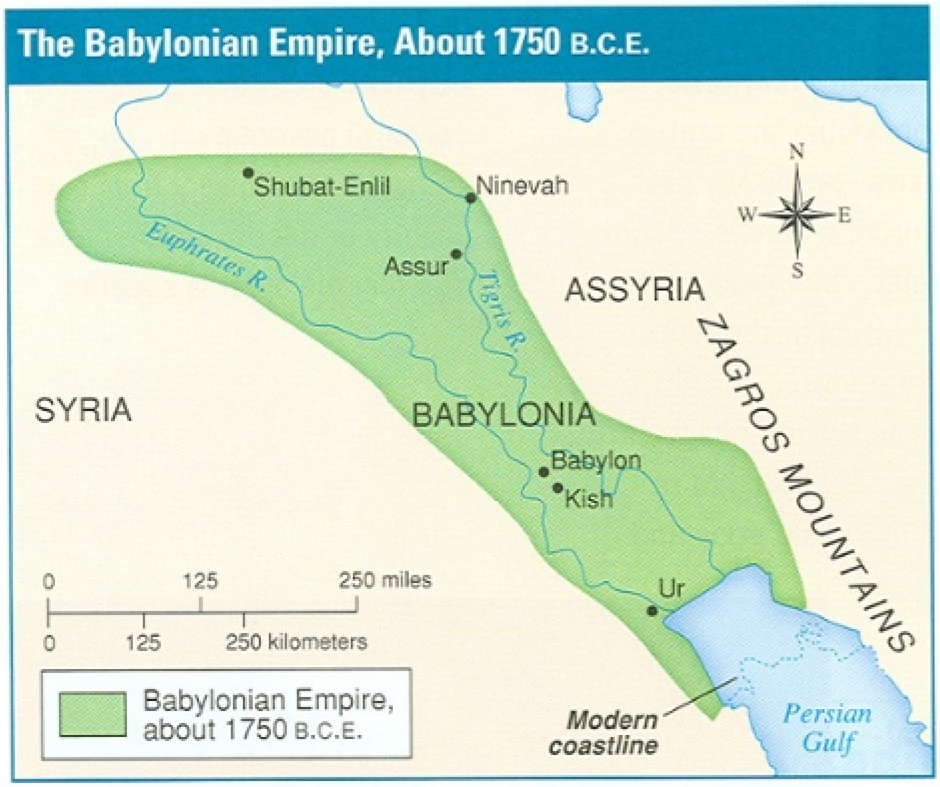


Figure 20. Babylonian Empire. Google Images. CC-BY.

In 1901, archeologists discovered a large basalt stele, 7.4 feet tall and covered in cuneiform writing. At the top of the stele, Hammurabi is standing in front of the seated Marduk, engaged in what appears to be a conversation, and below the two figures, epigraphists were able to decipher almost 300 laws. Hammurabi's innovative code of law indicates the transitional nature of his society because he standardized a set of rules that laid the foundation for advanced forms of governance. Hammurabi erected a stele or tablet within each city-state to regulate the daily lives of its occupants and make people aware of the punishments that would be exacted if the rules were broken.

Hammurabi took Sargon's consolidation a step further by unifying a set of laws that each city-state within the Babylonian territory had to follow and setting in stone the action to be taken if the laws were broken.[1] Additionally, Hammurabi's cunning use of Marduk's authority as chief god allowed him to depict himself as a benevolent, divine authority. He also ensured that he was not himself directly responsible for enforcing punishment if the laws were broken, as they were really dictated by Marduk. From this centralized code of law, historians and cultural anthropologists have gained insight into the daily lives of people in ancient Mesopotamia and the challenges their societies faced.

While the registers display the same set of laws, punishments were different for property owners, freed men, and slaves. Laying the foundation for modern judicial reasoning, Hammurabi's laws addressed issues such as property, theft, trade, contracts, resources, and family matters. They also demonstrated Hammurabi's vision for a collectivized community of people who were forced to share responsibility: not just for their own actions, but for the actions of others. One law, for instance, highlights the importance of truth, "If any one bring an accusation of any crime before the elders, and does not prove what he has charged, he shall, if it be a capital offense charged, be put to death."[2]

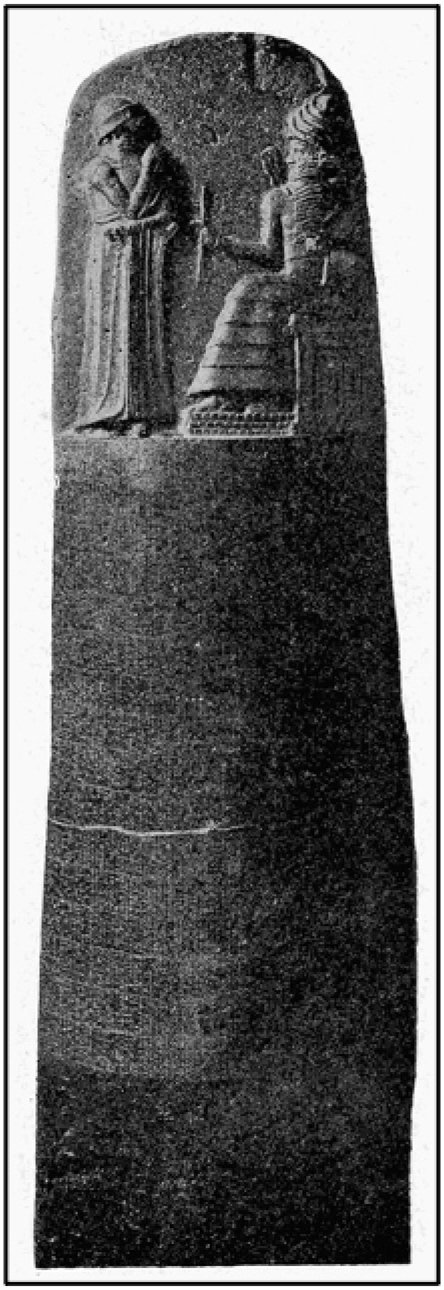


Figure 21. Stele showing the Code of Hammurabi. Google Images. CC-BY.

Another law regarding theft also demonstrates that punishments were determined by an individual's social class: "If any one steal cattle or sheep, or an ass, or a pig or a goat, if it belong to a god or to the court, the thief shall pay thirtyfold therefor; if they belonged to a freed man of the king he shall pay tenfold; if the thief has nothing with which to pay he shall be put to death." [3]

Concerning slaves, the law stated, "If anyone find runaway male or female slaves in the open country and bring them to their masters, the master of the slaves shall pay him two shekels of silver… If he hold the slaves in his house, and they are caught there, he shall be put to death… If the slave that he caught run away from him, then shall he swear to the owners of the slave, and he is free of all blame."[4] These law codes and many others demonstrate the need to enforce order among the people, but the punishment was administered based on social class distinctions.

Hammurabi's code of law represents an amalgamation of technology and epistemological knowledge that fused traditional behavior, religious authority, and political conformity into a body of law that predates the Old Testament. Introducing the principle of *lex talionis* (an eye for an eye) into the process of nation-building, Hammurabi managed to solidify his position as one of the great leaders of ancient Mesopotamia. Swift and clear punishment proved to be an efficient means of regulating the behavior of the masses, allowing Hammurabi to control more important elements of state-building, such as bureaucratic efficiency, territorial expansion, and economic prosperity.

[1] In the 3rd Dynasty of Ur the King Ur-Nammu constructed a basic set of laws that were the precursor to Hammurabi's Codes. See A Library of Knowledge of the Cuneiform Digital Library: http://cdli.ox.ac.uk/wiki/doku.php?id=laws_ur_nammu

[2]. "Ancient History Sourcebook: Code of Hammurabi, c. 1780 BCE, " Internet History Sourcebooks, https://sourcebooks.fordham.edu/ancient/hamcode.asp#horne.

[3]. Code of Hammurabi.

[4]. Code of Hammurabi.

CHAPTER 1 - CONCLUSION

STEPHANIE GUERIN-YODICE

In the Mesopotamian region, nomadic tribes from the north and easterly regions followed migratory patterns that traversed the Taurus and Zagros Mountains, before settling along the water way between the Tigris and Euphrates Rivers. These tribes brought with them generations of technological innovations that became paramount to the advancement of civilizations.

Over time, nomadic tribes went from hunting and gathering to a semi-sedentary lifestyle where they relied on newly adapted technology to assist in food production. With more effective tools, the hunt became easier and the life expectancy of the hunter increased. Predicting the behavior and cycle of vegetation allowed humans to produce more stable food sources. Small communities started to organize around the successful production of local food sources through the domestication of plants and animals.

This change lead to a more sedentary lifestyle, with temporary dwellings at first, followed eventually by successful agricultural settlements. As these societies grew, they developed new technology, established permanent dwellings and city-states, and became the center of advanced civilizations. Humans' ability to adapt to the changing world around them facilitated the transformative impact of technological innovations, thus advancing the human experience in ancient Mesopotamia.

CHAPTER 1 - DOING HISTORY: A CASE STUDY

STEPHANIE GUERIN-YODICE

In the **A Case Study** section, you saw an image of the inscription from Ummah and Lagash. Below is the inscription in modern English. Read the inscription, keeping the Case Study section in mind.

As you read this primary source consider the following:

- how access to waterways was paramount to the survival of a city-state
- emphasis placed on the wrath of the gods and the importance of honoring written laws
- how the ruler(s) of Lagash took matters into their own hands and destroyed the ruler and city-state of Umma because its people refused to adhere to the law set in place

What do you think is the authors' purpose? What are they achieving with this inscription?

Inscription from Umma and Lagash

Under the authority of Enlil, appointed god of the lands who established borders, agricultural fields, and made war over territorial infractions: erected a stele upon the disputed territories between Lagash and Umma.

In retaliation: *"Ush, ruler of Umma, formed a plan to seize it. That stele he broke in pieces, into the plain of Lagash he advanced."*

After war was made upon the people of Umma, the king of Lagash redefined the borders by placing steles along the canal and erecting a temple in the name of Enlil.

The Umma king retaliated in kind, *"Urlumma, ruler of Umma drained the boundary canal of Ningirsu, the boundary canal of Nina; those steles he threw into the fire, he broke [them] in pieces; he destroyed the sanctuaries, the dwellings of the gods, the protecting shrines, the buildings that had been made."*

Another war resulted in King Urlumma's death. Power was reasserted through Ili, appointed by King Lagash as vassal ruler over the city-state of Umma, but he, too, does not respect the boundaries laid out by the Lagash king. *"Ili, took the ruler of Umma into his hand. He drained the boundary canal of Ningirsu, a great protecting structure of Ningirsu, unto the bank of the Tigris above from the banks of Girsu. He took the grain of Lagash, a storehouse of 3600 gur* (year)*. Entemena, ruler of Lagash declared hostilities on Ili, whom for a vassal he had set up. Ili, ruler of Umma, wickedly flooded the diked and irrigated field; he commanded that the boundary canal of Ningirsu; the boundary canal of Nina be ruined…."*

Once again, the king of Lagash waged war and with the blessing of Enlil he *"restored their canal to its place according to the righteous word of Enlil, according to the righteous word of Nina, their canal which he had constructed from the river Tigris to the great river, the protecting structure, its foundation he had made of stone …."*[1]

---

[1] Barton, "Inscription of Entemena #7," 61, 63, 65.

PART II

CHAPTER 2 - THE INDUS RIVER VALLEY CIVILIZATION AND THE VEDIC AGE OF INDIA (CA. 3000 BCE - 700 BCE)

Excavated ruins of Mohenjo-Daro. Photo by Usman Ghani; CC BY-SA 3.0 license. https://en.wikipedia.org/wiki/File:Other_side_of_Moenjodaro_by_Usman_Ghani.jpg.

CHAPTER 2 - CHANGING HISTORY: THE DISCOVERY OF THE INDUS / HARAPPAN CIVILIZATION

MATTHEW MARSH

Prior to the 1924 publication of a British newspaper article announcing the excavations at Mohenjo-Daro, the earliest confirmed date in Indian history was 326 BCE, with the arrival of Alexander III of Macedon (Alexander the Great, 336–323 BCE) in the Indian northwest. During the late nineteenth and early twentieth centuries, historical analysis of the Vedas, the sacred texts of the Indo-Aryan and Vedic peoples of India, pushed the presumed beginnings of India back to about 1500 BCE. However, there was no indication in any of the historical texts of ancient India that suggested the existence of a pre-Vedic civilization in India. Accordingly, the discovery of Mohenjo-Daro and Harappa in the early 1920s set off a shockwave that forced the complete rewriting of the early history of India (fig. 1). As R. C. Majumdar, an eminent Indian historian of the twentieth century, stated:

The discovery of this civilization has almost revolutionized our conception of Indian history. At a single stroke the antiquity of Indian civilization has been pushed back to 3000 B.C., if not earlier still, and India now ranks along with Sumer, Akkad, Babylon, Egypt, and Assyria as a pioneer of human civilization.[1]

Figure 1. Excavated ruins of Mohenjo-Daro. In the foreground is the Great Bath and the granary mound can be seen in the background. Photo by Saqib Qayyum; CC BY-SA 3.0 license. https://commons.wikimedia.org/wiki/File:Mohenjo-daro.jpg.

The Indus Valley Civilization, also sometimes known as the Harappan Civilization after the first archaeological site discovered there, became the fourth and most recently discovered of the ancient centers of civilization with the publication of the Mohenjo-Daro excavations in 1924. All knowledge of the Indus Valley Civilization had been forgotten until 1921, when Daya Ram Sahni, an Indian archaeologist working for the British government, began excavating the archaeological site of Harappa in the Punjab (northern India). A year later, the Indian historian R. D. Banerjee discovered the site of Mohenjo-Daro in the Sindh (now southeast Pakistan). Through their respective excavations, both Sahni and Banerjee unearthed critical new architectural and material evidence indicating a developed urban culture. Later, under the successive supervision of British archaeologists John Marshall, and then Mortimer Wheeler, large-scale archaeological excavations were carried out at Mohenjo-Daro and Harappa prior to the independence of India and Pakistan from Britain in 1947. Following independence, excavations by Indian, Pakistani, and international archaeologists continued, and they identified nearly 2800 sites related to the Indus Valley Civilization.[2]

[1]. R. C. Majumdar, *Ancient India* (New Delhi: Motilal Banarsidass Publishers, 1952), 18–19.

[2]. K. Antonova, G. Bongard-Levin, and G. Kotovsky, *A History of India*, vol. 1 (Moscow: Progress Publishers, 1979); P. N. Chopra, B. N. Puri, M. N. Das, and A. C. Pradhan, *A Comprehensive History of Ancient India* (New Delhi: Sterling Publishers, 2003) 8–9; A. K. Dani and B. K. Thapar, "The Indus Civilization," in *History of Civilizations of Central Asia, Vol. I: The Dawn of Civilization: Earliest Times to 700 B.C.* (Paris: UNESCO Publishing, 1992), 279–307; Rao Bahadur K. N. Dikshit, "Archaeological Explorations and Excavations," in *The History and Culture of the Indian People Vol. I: The Vedic Age,* 8th ed., ed. R. C. Majumdar (Mumbai: Bharatiya Vidya Bhavan, 2015.) 70–72; Rao Bahadur K. N. Dikshit, *Prehistoric Civilization of the Indus Valley*, Sir William Meyer Lectures, 1935 (Madras: University of Madras, 1939), 3–11; Irfan Habib, *A People's History of India, Vol. 2: The Indus Civilization*, 9th ed. (New Delhi: Tulika Books, 2015), 13; D. N. Jha, *Early India: A Concise History* (New Delhi: Manohar Publishers, 2004), 29; D. N. Jha, *Ancient India in Historical Outline,* rev. and enlarged ed. (New Delhi: Manohar Publishers, 1998), 30; Jagat Pati Joshi, *Harappan Architecture and Civil Engineering* (New Delhi: Rupa and Co., 2008), 2–6; J. L. Mehta and Sarita Mehta, *History of Ancient India: From the Earliest Times to 1206 A.D.* (New Delhi: Lotus Press Publishers, 2008), 89–92; Gregory L. Possehl, "Revolution in the Urban Revolution: The Emergence of Indus Urbanization," In *Annual Review of Anthropology* 19 (1990): 26–82; A. D. Pusalker, "The Indus Valley Civilization" in *The History and Culture of the Indian People Vol. I: The Vedic Age,* 8th ed. ed. R. C. Majumdar (Mumbai: Bharatiya Vidya Bhavan, 2015), 172; and R. S. Sharma, *India's Ancient Past* (New Delhi: Oxford University Press, 2005), 74–76.

MATTHEW MARSH

Dating back to approximately 3500 BCE in its earliest phase, the timeframe for the mature phase of the Indus Valley Civilization ranges from approximately 2700 BCE to 1900 BCE, making it contemporary with the Early Dynastic II-III, Akkadian, and Ur III periods of Mesopotamian Civilization. Perhaps the largest of the ancient centers of civilization, the Indus Valley Civilization covered an area of more than 800,000 square miles, which is comparable to a land area the size of Alaska and Texas combined (fig. 2).

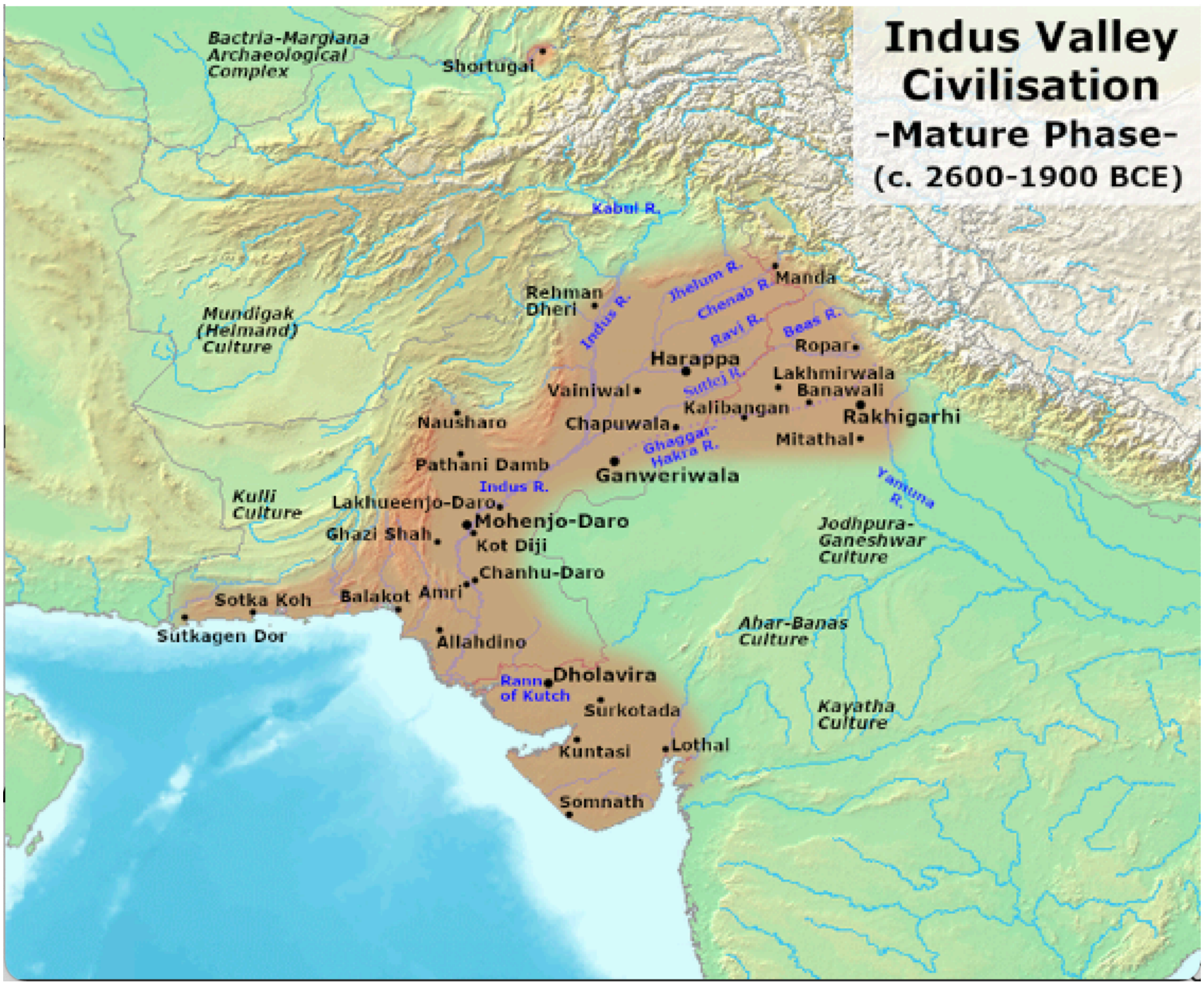


Figure 2. Indus Valley Civilization, Mature Phase (2600-1900 BCE); CC BY-SA 3.0 license.

https://commons.wikimedia.org/wiki/
File:Indus_Valley_Civilization,_Mature_Phase_%282600-1900_BCE%29.png

As its name suggests, the Indus Valley Civilization was an urban civilization of the plains, based around the Indus river and its tributaries, whose economic foundations were based upon agriculture, production of goods, and trade. Much like the Nile River in Egypt, the Indus River provided the fertile soil necessary to grow crops through the annual flooding of the river. However, the defining characteristic of the Indus Valley Civilization was its cities. Unlike the cities of Mesopotamia, Egypt, or ancient China, which developed and grew organically, those of the Indus Valley Civilization are distinguished by a uniform system of town planning. Indus cities are laid out on a grid system, with roads cutting across each other at right angles, creating large city blocks. The larger cities, such as Harappa and Mohenjo-Daro, have a citadel or acropolis that was possibly occupied by members of the ruling class.[1] A detailed political history of the Indus Valley Civilization is at this time impossible to chart, since we have not yet deciphered the Indus writing system. It is a historical irony that even though the Indus Valley Civilization was a literate one, we are entirely dependent on archaeological remains for insight into its history.

[1]. Antonova et al., *History of Ancient India*, 16–19; Chopra et al., *Comprehensive History*, 8–13; Dani and Thapar, "The Indus Civilization," 271–75; Habib, *The Indus Civilization*, 13–16, 22–24; Jha, *Early India*, 28–31; Jha, *Ancient India*, 30–32; Mehta and Mehta, *History of Ancient India*, 90–92; Pusalker, "The Indus Valley Civilization," 195–96; and Sharma, *India's Ancient Past,* 75–76.

CHAPTER 2 - TOOLS OF AGRICULTURE IN THE INDUS CIVILIZATION

MATTHEW MARSH

The Indus region today receives less rainfall than it did in ancient times, so it is not as fertile as it was during the period of the Indus Valley Civilization. Greater rainfall, coupled with the annual flooding of the Indus River, gave the region enormous fertility. The archaeological remains of protective walls, made of burnt bricks, indicate that floods were an annual event, giving the population of the Indus Valley Civilization the nutrient-rich soil needed for farming. [1] The primary crops cultivated by the Indus Valley Civilization were several types of wheat and barley. Inhabitants followed what is today known as *rabi* cultivation, in which seeds are sowed in the flood plains during November. Then, before the spring floods arrived in April, farmers harvested their crops of wheat and barley. The Indus Valley Civilization also began cultivating several other cereal grains as well, bringing varieties of millets into production at a number of sites. The types of crops being produced varied according to the particular environment of an Indus city.[2]

In addition to these main staple crops, the Indus Valley Civilization also grew cotton, dates, jujube, grape, and melons. Cotton was used for weaving, while the other crops supplemented the primary diet of the Indus people. Development of the plow in the early period of the Indus Civilization encouraged widespread agricultural cultivation, while the domestication of the zebu cattle provided oxen to pull the plow in the field. After the growing season, the Indus inhabitants primarily used stone sickles to harvest their crops due to the expense of copper or bronze implements.[3] Once harvested, the crops were stored in large granaries, examples of which were found in Mohenjo-Daro and Harappa. Based on similar situations in Mesopotamia, historians believe that grain may have been received as taxes in kind and stored to be used as payment of wages. [4]

Figure 3. Miniature Votive Images or Toy Models of Indus Valley Oxen, Cart and Driver, and Other Livestock ca. 2500 BCE, Photograph by Trish Mayo, CC-BY 2.5. https://commons.wikimedia.org/wiki/File:Harappan_small_figures.jpg.

The Indus Valley Civilization also domesticated a large number of animals that were used to support agricultural production. Oxen drew the carts and plow of the Indus farmers, while cows provided milk (fig. 3). Both types of livestock served as the major source of meat for the people of the Indus Valley Civilization. While oxen were the primary beasts of burden for the Indus, asses and Bactrian two-humped camels were also bred and used for the same purpose. Water buffaloes, goats, sheep, and pigs were domesticated as well.[5]

[1]. Habib, *The Indus Civilization*, 27–28; Jha, *Early India*, 33–35; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 81–85; and Sharma, *India's Ancient Past*, 77–79.

[2]. Dani and Thapar, "The Indus Civilization," 274–75; Habib, *The Indus Civilization*, 24–25; Jha, *Early India*, 33–34; Jha, *Ancient India*, 34–35; Mehta and Mehta, *History of Ancient India*, 98–100;

Abdul Sabahuddin and Rajshree Shukla, *History of Ancient Indian Economy* (New Delhi: Global Vision Publishing House, 2010), 79–81; and Sharma, *India's Ancient Past*, 77–78.

[3]. Habib, *The Indus Civilization*, 24-27; Jha, *Early India*, 33–34; Jha, *Ancient India*, 34–35; Mehta and Mehta, *History of Ancient India*, 98-100; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 73-77; Sharma, *India's Ancient Past*, 77–78.

[4]. Habib, *The Indus Civilization*, 27–30; Jha, *Early India*, 33–34; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 73–78; and Sharma, *India's Ancient Past,* 77–79.

[5]. Chopra et al., *Comprehensive History*, 14; Dani and Thapar, "The Indus Civilization," 275–76; Habib, *The Indus Civilization*, 45; Jha, *Early India*, 33–34; Joshi, *Harappan Architecture,* 108–10; Mehta and Mehta, *History of Ancient India*, 107–09; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 98; and Sharma, *India's Ancient Past*, 78.

CHAPTER 2 - TOOLS OF MANUFACTURE AND TRADE IN THE INDUS CIVILIZATION

MATTHEW MARSH

The Indus Valley Civilization was a Bronze Age polity and numerous examples of bronze artifacts have been discovered at several of the main Indus sites. Examples of these artifacts include bronze images, tools, utensils, and several types of weapons. Interestingly, bronze tools are not as numerous in the Indus Valley Civilization as in Mesopotamia because neither copper nor tin, the two metals used to create the alloy of bronze, were easily obtainable. In terms of day-to-day technology, this suggests that the people of the Indus Civilization used both bronze and stone tools, implements, and weapons across multiple crafts areas, and does not seem to have been an elite status symbol. Reinforcing this lack of elite status is that, throughout the Indus Valley region, archaeologists have discovered numerous kits used by bronze smiths for the manufacture of bronze goods. The presence of these kits suggest that, even if bronze was not as common as other metals, bronze smiths constituted an important part of Indus society.[1]

The Indus Civilization also developed a standardized system of weights and measures, which was then dispersed throughout the region (fig. 4). One of the clearest examples of these standards can be found in building construction. Due to a lack of stone at a number of sites on the plains surrounding the Indus River, several of the largest Indus cities, Mohenjo-Daro and Harappa, were built using bricks. These bricks, which were either dried mud or kiln-baked, were made using a standard ratio of 1:2:4, regardless of their actual size.[2]

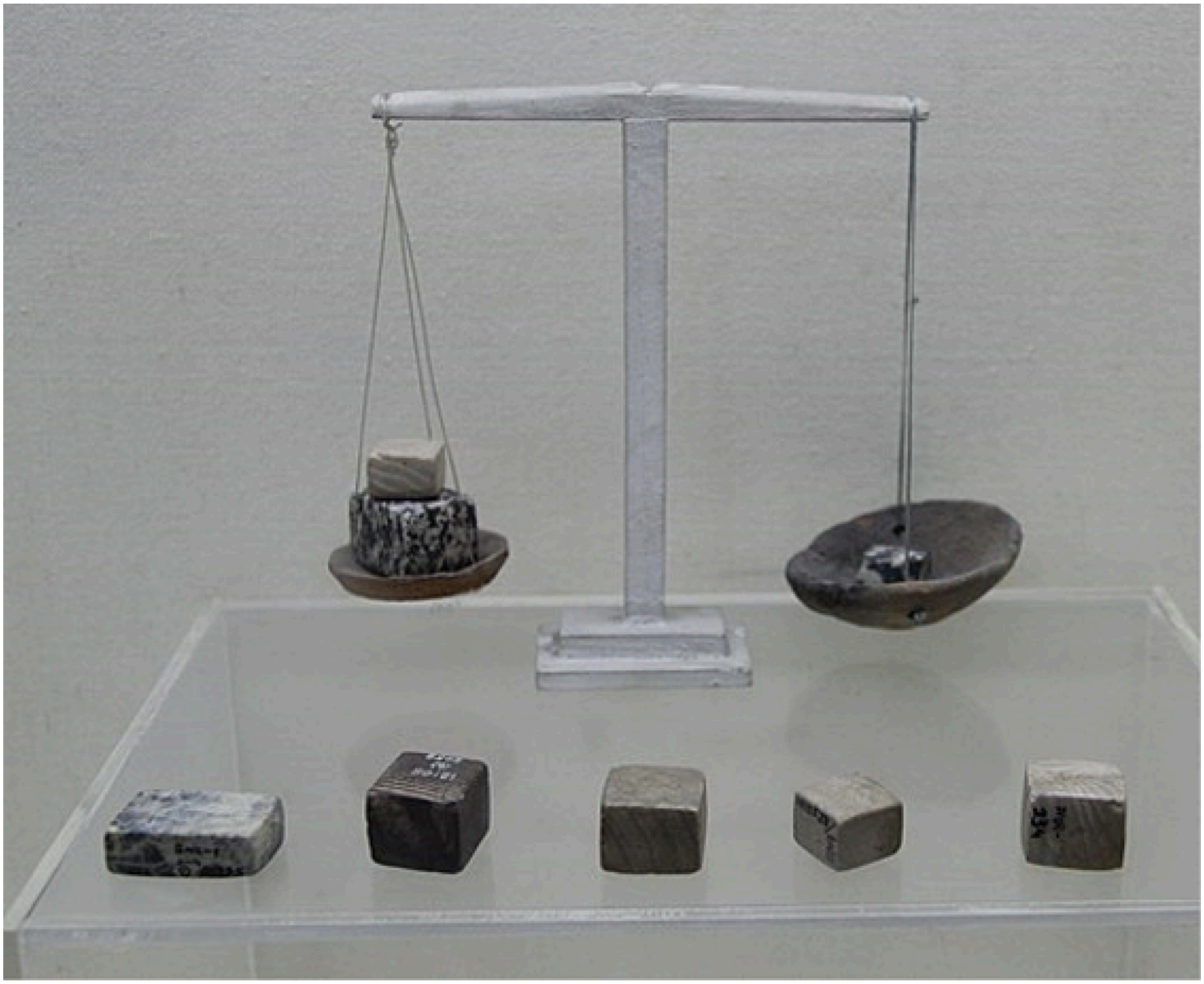


Figure 4. Harappan (Indus Valley) balance and weights. Civilization Gallery, India National Museum, New Delhi. Photo by Gary Lee Todd; CC0 1.0 license. https://commons.wikimedia.org/wiki/File:Harappan_(Indus_Valley)_Balance_%26_Weights.jpg.

In addition to the manufacture of bronze goods, other types of craft technologies developed during the Indus Civilization. The technologies used to create pottery were well developed during this period, and the potters represented a visible artisanal group. Indus pottery was produced in large quantities using the potter's wheel, and it was generally thick-walled, plain, and lightly decorated. Potters cast utilitarian household items, such as cookware, storage jars, dishes, and water pipes for house drains. The widespread use of these items was, presumably, what prompted the spread of Indus pottery wherever their civilization was established.[3] Outside of pottery, archaeological evidence of textile production during the Indus period can be seen in the existence of numerous examples of terracotta spindle whorls, which were used for hand spinning thread, and a piece of woven cloth recovered from Mohenjo-Daro. Like many craft technologies during the Bronze Age, the production of both thread and cloth would have been completed in the home rather than in a factory or warehouse.[4]

Finally, one of the most striking scientific developments of the Indus Civilization was its complex sanitation system, which could be found in all Indus cities. Every household, large or small, had terracotta pipes that flushed used water into the city drains, which ran alongside the streets. These drains were covered with bricks, or stone slabs, and the drains ran to a central soak pit within the city. The clear importance of sanitation is one of the unique attributes of the Indus Civilization, which was not found in any of the other ancient centers of civilization. It would not be until the Roman era, thousands of years later, before a comparable sanitation system was developed again.[5]

The Indus Civilization, like Mesopotamia, supported itself primarily through farming. However, trade was conducted locally and internationally by Indus traders, using water transportation and ox-drawn wagons to transport finished goods or food for raw materials. The discovery of several Indus seals, small square amulets featuring Indus script, in Sumerian gravesites provide evidence of contact between the Indus and Sumerian Civilizations of Mesopotamia. Some two dozen Indus seals have been found in cities such as Susa, Ur, Nippur, and Kish, while Mesopotamian literature describes instances of trade conducted between merchants of Ur and those from foreign countries. Sargon of Akkad (circa 2350 BCE) is said to have taken pride in the fact that the ships of Dilmun (Bahrain), Magan (Makran), and Meluha (India) traded in his capital city of Akkad.[6]

[1]. Antonova et al., *History of Ancient India*, 22; Dani and Thapar, "The Indus Civilization," 289; Habib, *The Indus Civilization*, 28–30; Mehta and Mehta, *History of Ancient India*, 101–04; Pusalker, "The Indus Valley Civilization," 182, 188; Sharma, *India's Ancient Past,* 75–76.

[2]. Chopra et al., *Comprehensive History*, 12–13, 18; Habib, *The Indus Civilization*, 34–37; Mehta and Mehta, *History of Ancient India*, 101–02; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 98.

[3]. Dani and Thapar, "The Indus Civilization," 290; Habib, *The Indus Civilization*, 32–34; Jha, *Early India*, 35–36; Mehta and Mehta, *History of Ancient India*, 103–04; Pusalker, "The Indus Valley Civilization," 185–86; and Sharma, *India's Ancient Past*, 84–85.

[4]. Antonova et al., *History of Ancient India*, 21–22; Habib, *The Indus Civilization*, 34; Mehta and Mehta, *History of Ancient India*, 99, 103; Pusalker, "The Indus Valley Civilization," 185; and Sharma, *India's Ancient Past*, 79–80.

[5]. Antonova et al., *History of Ancient India*, 22–23; Chopra et al., *Comprehensive History*, 12–13; Dani and Thapar, "The Indus Civilization," 278; Habib, *The Indus Civilization*, 38–43; Joshi, *Harappan Architecture,* 90–107; Mehta and Mehta, *History of Ancient India*, 95–97; Pusalker, "The Indus Valley Civilization," 172–75; and Sharma, *India's Ancient Past*, 77.

[6]. Antonova et al., *History of Ancient India*, 22–23; Chopra et al., *Comprehensive History*, 18–19; Dani and Thapar, "The Indus Civilization," 290; Habib, *The Indus Civilization*, 45–50; Jha, *Early India*, 37; Jha, *Ancient India*, 37–38; Mehta and Mehta, *History of Ancient India*, 101–02; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 118–23; and Sharma, *India's Ancient Past*, 80.

CHAPTER 2 - WRITING IN THE INDUS CIVILIZATION

MATTHEW MARSH

The Indus Civilization also invented a form of writing, much like the people of Sumer and Egypt. At present, nearly 4,000 specimens of Indus script have been found, which are primarily engraved on seals, and there is evidence of 375 to 400 signs, generally written from right to left (fig. 5).

Figure 5. Indus script recovered from Khirsara, Indus Valley Civilization. Anil K. Pokharia et al., "Altered Cropping Pattern and Cultural Continuation with Declined Prosperity Following Abrupt and Extreme Arid Event at ~4,200 yrs BP: Evidence from an Indus Archaeological Site Khirsara, Gujarat, Western India," PLOS One, October 6, 2017, https://doi.org/10.1371/journal.pone.0185684; CC BY 4.0 license. https://commons.wikimedia.org/wiki/File:Indus_script_recovered_from_Khirsara,_Indus_Valley_Civilization.jpg.

However, despite the existence of numerous examples of Indus script, scholars have been unable to translate it into a modern language. This is due to the absence of a bilingual or trilingual inscription, such as the Rosetta Stone or the Behistun Inscription, which would allow historians and linguists to compare two or three different examples of writing. In addition, scholars have yet to find an Indus inscription with a sufficient number of recurring symbols to ensure a proper translation. However, this has not stopped numerous scholars around the world from attempting to translate the extant writing using a varied number of techniques—all of which have been questioned for their accuracy. Needless to say, the inability to decipher the Indus script has been a major hindrance in the comprehensive reconstruction of Indus society.[1]

[1]. Antonova et al *History of Ancient India*. 26-27; Chopra et al., *Comprehensive History*, 20–21; Dani and Thapar, "The Indus Civilization," 290–91; Habib, *The Indus Civilization*, 67–71; Mehta and Mehta,

History of Ancient India, 106–07; Pusalker, "The Indus Valley Civilization," 193–95; and Sharma, *India's Ancient Past,* 83–84.

CHAPTER 2 - END OF THE INDUS VALLEY CIVILIZATION

MATTHEW MARSH

Unlike the civilizations of Mesopotamia, Egypt, or China, the Indus Valley Civilization disappeared from history, leaving few traces of its existence. For reasons that are still unclear, between 1900 BCE—1700 BCE the Indus Valley Civilization went into decline, as its urban centers began to decay and were ultimately abandoned. The remaining outliers of the Indus Valley Civilization reverted to a pre-urban settlement type. The reasons cited by historians for its disappearance are numerous, often controversial, and, ultimately, inconclusive. What is clear is that by 1700 BCE the main cities of the Indus civilization (Harappa, Mohenjo-Daro, and Ganweriwala) were abandoned, and several smaller settlements saw severe depopulation. Alongside this sharp decline in urban population was a marked decrease in long-distance trade, a drop in the production of luxury items, and a general shift in population to the east.

There have been numerous theories as to the proximate cause of the decline of the Indus Civilization.

One of the earliest fully expounded theories was that of Mortimer Wheeler, who hypothesized that circa 1500 BCE, the Indo-Aryan tribes launched an armed invasion and destroyed the Indus Civilization. Due to his use of circumstantial evidence, and the fact that there is no evidence supporting the arrival of the Indo-Aryan tribes during the time of the Indus Civilization, Wheeler's theory was discredited by the 1980s.

However, his theory still appears in some popular works on the Indus Civilization. Other explanations for the demise of the civilization include geological disruption of the Indus River, climatic change, and the loss of trade.

Regardless of the reason, by 1700 BCE the Indus Valley Civilization had vanished and, as the second millennium BCE drew to a close, a new people began slowly moving into the Indian subcontinent.[1]

[1]. Antonova et al., *History of Ancient India,* 27–29; Chopra et al., *Comprehensive History*, 21–22; Habib, *The Indus Civilization*, 62–66; Jha, *Early India*, 39–41; Mehta and Mehta, *History of Ancient India*, 110–15; Gregory L. Possehl, "The Transformation of the Indus Civilization," *Journal of World Prehistory* 11, no. 4 (1997): 425–72; Sharma, *India's Ancient Past*, 85–89; and R. E. M. Wheeler, "Sociological Aspects of the Harappa Civilization," *Ancient India* 3 (1946): 74–78.

CHAPTER 2 - VEDIC CIVILIZATION

MATTHEW MARSH

Around 1500 BCE a new ethnolinguistic group, the Indo-Aryans, began migrating into India from Central Asia. This migration was not a massive invasion but instead consisted of several waves of Indo-Aryan tribes moving into the Indian subcontinent. The earliest of these waves began with the arrival of a group called the Rig Vedic people, who appeared in India between 1500 BCE and 1400 BCE, the beginning of what is known as the Vedic period of Indian history. Due to a number of factors, such as the environment, native resistance, and inter-tribal fighting, the Indo-Aryan settlement of India moved slowly over the course of centuries. It would take nearly a thousand years for the various Indo-Aryan tribes to take control of northwestern and northern India.[1]

Much of our information about Indo-Aryan and Vedic society comes from the Vedas, the sacred literature of the Indo-Aryan and Vedic peoples. The Vedas are the mass compilation of literature gathered over a period of centuries. There are four main collections of the literature that provide historians with information on the Vedic civilization: the *Rigveda*, the *Atharvaveda*, the *Samaveda*, and the *Yajurveda*. The oldest of the Vedas is the *Rigveda*, which dates to approximately 1000 BCE, and it provides historians with information on the earliest form of Vedic society in India. It is important to note that, unlike the earlier Indus Civilization, at least initially the Indo-Aryans were semi-nomadic pastoralists. In the *Rigveda*, Indo-Aryans appear not as builders of cities, but as destroyers. As the Indo-Aryans subjugated the native tribes this would cause Indian civilization to shift from an urban setting to a rural one. However, apart from the use of horses and chariots, the Indo-Aryans possessed no other advanced technology. While India reverted to a rural civilization, in several ways continuity existed between the Indus and Vedic civilizations, particularly in agricultural and tool industries. Technologies that disappeared from India included much of the construction systems found in the Indus Civilization, the regulated system of weights and measures, and the major sanitation systems.[2]

[1]. Antonova et al., *History of Ancient India*, 31–36; Chopra et al., *Comprehensive History*, 23–25; Irfan Habib and Vijay Kumar Thakur, *A People's History of India, Vol. 3: The Vedic Age,* 7th ed. (New Delhi: Tulika Books, 2014), 3–6; Jha, *Ancient India,* 43–45; and Sharma, *India's Ancient Past,* 106–08.

[2]. Antonova et al., *History of Ancient India*, 36–38; Chopra et al., *Comprehensive History*, 26–29; Habib and Thakur, *The Vedic Age*, 7–8; Jha, *Ancient India,* 46–48; Majumdar, *Ancient India,* 32–42; and Sharma, *India's Ancient Past,* 109–10.

CHAPTER 2 - AGRICULTURE IN THE VEDIC CIVILIZATION

MATTHEW MARSH

In its earliest stages, Vedic civilization was semi-nomadic, particularly between 1500 BCE—1000 BCE, and relied on a mix of agriculture and pastoral economy to survive. During this period, the primary agricultural crops continued to be wheat varieties and barley. The basic plow and other farming implements, primarily flint or stone tools rather than bronze, that had been used by Indus farmers would continue to be used by the Vedic farmers. The only addition to the types of domesticated animals raised was the horse, which would take the place of oxen in the transportation of goods. In line with a semi-nomadic civilization, cattle played a major role in Vedic society and were the chief form of wealth for Indo-Aryan tribes.[1]

In the later Vedic period, after about 1000 BCE, historians see the nomadism of the early Aryan migrants shifting into a more settled lifestyle. As later waves of Indo-Aryan tribes migrated into India the main area of settlement shifted from northwestern India to the Ganges River Valley. While cattle were still an important part of Vedic life, a semi-nomadic lifestyle could not meet the needs of a growing population. The result was that, as Vedic society grew larger, it began the transition from a semi-nomadic life into a settled existence. As agriculture became more important families began settling into permanent habitation. In addition to the traditional staple crops of wheat and barley, rice is mentioned for the first time, beginning its slow spread into India.[2]

[1]. Antonova et al., *History of Ancient India*, 36–38; V. M. Apte, "Chapter XIX: Social and Economic Conditions," in *The History and Culture of the Indian People, Vol. I: The Vedic Age,* 8th ed., ed. R. C. Majumdar (Mumbai: Bharatiya Vidya Bhavan, 2015), 398–99; Chopra et al., *Comprehensive History*, 26–29; Habib and Thakur, *The Vedic Age*, 6–8; Jha, *Ancient India,* 46–47; Mehta and Mehta, *History of Ancient India*, 185–86; and Sharma, *India's Ancient Past*, 109–10.

[2]. Antonova et al., *History of Ancient India*, 36–38; V. M. Apte, "Chapter XXVII: Social and Economic Conditions," in *The History and Culture of the Indian People, Vol. I: The Vedic Age*, 8th ed., ed. R. C. Majumdar (Mumbai: Bharatiya Vidya Bhavan, 2015), 529–30; Chopra et al., *Comprehensive History*, 32–33; Habib and Thakur, *The Vedic Age*, 40–48; Jha, *Ancient India,* 52–55; Mehta and Mehta, *History of Ancient India*, 185–86; and Sharma, *India's Ancient Past*, 117–19, 120.

CHAPTER 2 - CRAFTS AND TRADE IN THE VEDIC CIVILIZATION

MATTHEW MARSH

As later Vedic society began the transition into an agricultural economy, there was an expansion of crafts and trades. Some of these crafts and trades were linked to existing technologies, such as weaving, jewelry making, or pottery, while others were linked to the expanding metals industries. At the beginning of this period, smiths and smelters would have worked primarily in copper because iron production was still in its infancy. As the population increased, weaving would become practiced on a wider scale than before, although much of the work was still done by women. Other industries, such as pottery, leatherworking, and carpentry, were connected to the construction of buildings. While large towns were not yet a part of Vedic India, a transition to a settled way of life led to the growth of a number of villages in Vedic India that drove the expansion of industry.[1]

The largest technological advance that appears in Vedic India is the arrival or discovery of iron working. Meteoric iron had been available in the ancient world for several thousand years but was used primarily for jewelry or ornaments. What had not yet been developed was the process of steeling the surface of iron, which was critical to strengthening the metal and enabling it to hold an edge.[2] In this process iron is heated to high temperatures (smelted) until impurities in the metal float to the top and can be skimmed off. Then, certain amounts of carbon are introduced to the surface of the iron through a controlled blast of air from the bellows. After heating and hammering the iron, the blacksmith will then quench (cool it with water) to temper it, giving it the hardness and elasticity that makes steel so effective as a tool or weapon.[3] Beginning around 1200 BCE—1000 BCE, as smiths began to discover the process of steeling iron, its use began to spread through the Near East. Based on archaeological evidence, historians have estimated that iron use reached the northwestern regions of India around 1000 BCE and the Ganges region by approximately 800 BCE—700 BCE. As the use of iron spread, it began to replace not only bronze weapons, but also stone or wooden agricultural implements. Steeled iron was harder, more durable, and able to hold a sharper edge than bronze, and its introduction into society would have long-lasting effects.[4]

[1]. Apte, "Chapter XXVII: Social and Economic Conditions," 530–31; Chopra et al., *Comprehensive History*, 33; Habib and Thakur, *The Vedic Age*, 48–51; Jha, *Ancient India,* 54–55; Mehta and Mehta, *History of Ancient India*, 120; Sabahuddin and Shukla, *History of Ancient Indian Economy*, 166–71; Sharma, *India's Ancient Past*, 120–22.

[2]. Habib and Thakur, *The Vedic Age,* 85–86.

[3]. Habib and Thakur, *The Vedic Age,* 86–87; telephone conversation with H. A. Marsh, Jr., analytical chemist, October 1, 2014.

[4]. Habib and Thakur, *The Vedic Age*, 86–87; Sharma, *India's Ancient Past*, 119–20; Krishna Mohan

Shrimali, *A People's History of India, Vol. 4: The Age of Iron and the Religious Revolution*, 5th ed. (New Delhi: Tulika Books, 2013), 2–9.

PART III

CHAPTER 3 - THE ANCIENT WORLD (BEFORE 500 BCE) – FARMERS TO PHARAOHS

CHAPTER 3 - ANCIENT EGYPTIAN METALLURGY

MARTIN ODLER

Metallurgy is the science of separating metals from their ores, and it developed quite recently, considering the length of human history. Ancient Egyptians were neither the inventors of metallurgy, nor the most innovative in its development.[1] Yet metals, especially gold, had a very important place in their culture, and they produced some of the best-known ancient metal objects from that metal, such as the golden mask of King Tutankhamun. From the point of view of historians and archaeologists, Egypt's importance lies in the incredible detail in which the evidence of the past was preserved in the arid climate of ancient Egypt. What was destroyed elsewhere was, in Egypt, preserved or recorded in its art.

Ancient Egypt fascinates both the general public and scholars. The study of ancient Egyptian metallurgy is a developing field, but although hundreds of analyses of the chemical composition and technology of ancient Egyptian metal objects have been done, there is no synthesis of the knowledge amassed so far.[2] The evidence available to modern archaeologists is largely determined by preselection by the past culture—in this case ancient Egyptians—by conscious and unconscious rules that were applied to the creation and production of sources. For ancient Egypt, we have data that show how much evidence is present and how other pieces of evidence are missing from the sources.

The main metals used in ancient Egypt were copper, gold, silver, and iron. Copper and gold were more abundant, while silver was relatively rare, and iron emerged very late in Egyptian history (only in the first millennium BCE, although meteoritic iron was already in use as early as the fourth millennium BCE).[3] Sources of the copper ore were found in the Egyptian Eastern Desert and Sinai, and were exploited by mining and military expeditions, as this was not the core territory of ancient Egyptians. Co-occurrence of gold and copper ore, found in quartz veins that contained both metals, was the decisive factor in the earliest explorations. Ancient Egyptian prospectors were very successful in reading the natural characteristics of rocks and discovering new sources of ore. There is hardly any modern site with ore near the surface that was not already known in antiquity. Gold was mined from the quartz veins, and ore had to be crushed. In the case of copper, Egyptians knew how to extract copper from the oxide and sulphide ores, repeatedly smelting the ore to get ever purer metal. Sources of iron ore were not very rich in Egypt, but those in Nubia, further to the south, were richer.[4] Egyptians relied on broad exchange networks, reaching both south, north, and northeast of Egypt, although these trade connections were harmed when competing neighboring states stopped the influx of the materials. More scientific analyses are needed to reconstruct these exchange networks and study their changes through time.

Metal objects have been used for the greater part of Egyptian history by the elite and for the elite. The occurrence of metals in Egypt is rather late compared to other Eastern Mediterranean cultures. Small copper objects appeared for the first time in the Badarian culture, in Upper Egypt, during the second half of the fourth millennium BCE. A wider application of copper objects can be found about five hundred years later, with the appearance of copper tools for craftsmen, copper and gold jewellery, and metal vessels. Later items included cosmetic objects, such as mirrors, razors, and tweezers. Many popular works state that early Egyptians, including the Old Kingdom and Middle Kingdom pyramid builders, used only tools made of pure copper, but that is not true: they were using arsenic copper as the main practical alloy, which was typical for the whole ancient Near East in the Early Bronze Age. Sometimes arsenic and copper occur naturally together in one ore but in other cases they were mixed intentionally. The addition of arsenic to copper causes the resulting alloy to be harder and gives it properties similar to those of tin bronze, such as hardness and ductility.[5] And already in the Early Dynastic Period, Egyptians certainly used tin bronze (an alloy of copper with c. 10% tin). Archaeologists know this because the oldest definitively dated tin bronze objects, a spouted jar and wash basin, were found in the tomb of King Khasekhemwy, which was built and furnished at the end of the Second Dynasty (*c.* 2775–2650 BCE).

Old Kingdom (Fourth to Sixth Dynasties, c. 2600–2180 BCE) evidence from the era of the pyramid builders shows in great detail how that culture decided what they would preserve and how. Had it not been for the custom of depositing copper model tools in the burial equipment, we would have almost nothing preserved from the metal tools used in that era because full-sized tools were recycled, both in that period and later. Iconographic sources indicate the use of other metal artifacts that were not preserved from the Old Kingdom, such as metal weapons. Scattered finds from Old Kingdom settlements provide artifacts which were not included in the burial equipment (or only very rarely), nor included in the iconography, such as sewing needles.[6]

Ancient Egyptians were rather conservative in their recourse to technological solutions. They used V-shaped wooden hafts and used leather thongs to attach metal blades to tools (fig. 1) even though they knew about the more practical technological solution of the socket eye for tool and weapon blades (fig. 2).

Figure 1: Metal adze blade attached to a wooden haft by leather thongs. Egypt, New Kingdom, Deir el-Bahari. Metropolitan Museum of Art, New York (public domain).

Figure 2: So-called duck-bill axe with a socket hole for insertion of a wooden haft. The socket is marked by an oval shape. Egypt, Second Intermediate Period. Metropolitan Museum of Art, New York (public domain).

Scholars know that Egyptians were aware of such technology because they depicted captured foreign soldiers with weapons of a different construction. Later, in the Second Intermediate Period (sixteenth to fifteenth century BCE), part of north Egypt was ruled by foreigners, called Hyksos, who used socket eyes on their axe blades.

Ancient Egyptians accepted innovative approaches, but only when necessary. The technology of their tools and weapons did not change much, and they held to their traditional solutions, which worked well enough. Full-size tools and model tools used similar concepts (figs. 3 and 4).

Figure 3: Foundation deposit of a temple with model tools. Deir el-Bahari, temple of Queen Hatshepsut. Metropolitan Museum of Art, New York (public domain).

Figure 4: New Kingdom battle axe with a new blade shape, but with the traditional attachment to the blade. Asasif. Metropolitan Museum of Art, New York (public domain).

But Egyptians did adopt new types of weapons, such as swords and horse-drawn chariots, when it became inevitable that they would have to fight the foreign Hyksos troops.[7] Also, they adopted tin bronze very slowly. There are sites where tin bronze objects were used along with those made of arsenical copper.[8] Only from the New Kingdom and its Eighteenth Dynasty (fourteenth century BCE) do we have definitive evidence of the use of tin bronze on a large scale.[9]

Most Egyptians worked in agriculture and used stone-flint sickle blades (fig. 5) and other tools made from stone, wood, and bone.

Figure 5: Wooden sickle with inserted flint blades. Egypt, Lisht. Metropolitan Museum of Art, New York (public domain).

The iron agricultural tools were used on a larger scale only since the Ptolemaic Period, when a foreign Macedonian dynasty ruled over Egypt and iron was more accessible, because in nature iron ores are more widespread than ores of other metals. Only then was there a mass dissemination of metal objects in Egypt, tin bronze still being used for cast objects. Later, in Roman Egypt, this division continued, with iron tools and weapons being used massively, while bronze and brass (the latter being an alloy of copper and zinc) was used for a wide range of cast objects. It is interesting to note that both Greek and Roman authors had no doubts attributing the building of the pyramids to Egyptians, which by that time were already ancient. Wild theories, disregarding our knowledge of the ancient Egyptian technology, including metallurgy, are of much later date.

The question of cultural conservativism, apparent in the case of ancient Egypt, is characteristic for many human societies: if the solution works for the society, there is no pressing need to change it. This can be observed in the case of electric cars versus gasoline-powered cars, and more generally in the use of fossil fuels versus renewable energy sources. The school of thought researching the "success" of technologies in societies is called SCOT—social construction of technology.[10]

It was true in the past that many ancient Egyptian treasures were accessible only in Egypt or in world museums. However, in the last decade a number of credible online resources allow access to hundreds of ancient Egyptian objects just by entering the word "Egypt" in a collection search, including the oldest working Egyptological website, courtesy of the Fitzwilliam Museum; the online collections of the Metropolitan Museum of Art in New York; the Museum of Fine Arts in Boston; the British Museum in London; and the Petrie Museum of Egyptian Archaeology, University College, London.

Complete documentation for excavating the famous tomb of Tutankhamun is also online at the Griffith Institute of the University of Oxford. However, online and open-access resources about ancient Egyptian metallurgy are rather scarce, and there is also misleading information in popular works. One important and credible online resource is a lavishly illustrated catalog, *"Gifts for the Gods: Images from Egyptian Temples,"* on ancient Egyptian metal statues.[11]

[1]. Current synthesis on the knowledge of early metallurgy is presented in *Archaeometallurgy in Global Perspective: Methods and Syntheses*, ed. Benjamin W. Roberts and Christopher P. Thornton (New York: Springer, 2014).

[2]. A good introduction in English is Jack Ogden,"Metals," in *Ancient Egyptian Materials and Technology*, ed. Paul T. Nicholson and Ian Shaw (Cambridge: Cambridge University Press, 2009), 148–76.

[3]. See Thilo Rehren et al.,"5,000 Years Old Egyptian Iron Beads Made from Hammered Meteoritic Iron, " *Journal of Archaeological Science* 40, no. 12 (2013): 4785–92; and Diane Johnson, Joyce Tyldesley, Tristan Lowe, Philip J. Withers, and Monica M. Grady, "Analysis of a Prehistoric Egyptian Iron Bead with Implications for the Use and Perception of Meteorite Iron in Ancient Egypt," *Meteoritics and Planetary Science* 48, no. 6 (2013): 997–1006.

[4]. Rosemarie Klemm and Dietrich Klemm, *Gold and Gold Mining in Ancient Egypt and Nubia: Geoarchaeology of the Ancient Gold Mining Sites in the Egyptian and Sudanese Eastern Deserts* (New York: Springer, 2012).

[5]. Heather Lechtman, "Arsenic Bronze: Dirty Copper or Chosen Alloy? A View from the Americas," *Journal of Field Archaeology* 23, no. 4 (Winter 1996): 477–514.

[6]. For further detail, see Martin Odler, *Old Kingdom Copper Tools and Model Tools*, Archaeopress Egyptology no. 14 (Oxford: Archaeopress, 2016).

[7]. See John Coleman Darnell and Colleen Manassa, *Tutankhamun's Armies: Battle and Conquest during Ancient Egypt's Late 18th Dynasty* (Hoboken: John Wiley & Sons, 2007); and André J. Veldmeijer and Salima Ikram, eds., *Chasing Chariots: Proceedings of the First International Chariot Conference (Cairo 2012)* (Leiden: Sidestone Press, 2013).

[8]. Graham Philip, *Tell El-Dab'a XV: Metalwork and Metalworking Evidence of the Late Middle Kingdom and the Second Intermediate Period* (Vienna: Österreichischen Akademie der Wissenschaften, 2006).

[9]. Some analyses of Eighteenth Dynasty Amarna objects have been published in Zofia Stos-Gale, Noel Gale, and Judy Houghton,"The Origins of Egyptian Copper: Lead-Isotope Analysis of Metals from El-Amarna," in *Egypt, the Aegean and the Levant: Interconnections in the Second Millenium BC*, ed. W. Vivian Davies and Louise Schofield (London: British Museum, 1995), pp. 127–35.

[10]. Wiebe E. Bijker, Thomas P. Hughes, Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge MA: MIT Press, 1987).

[11]. Marsha Hill and Deborah Schorsch, eds., *Gifts for the Gods: Images from Egyptian Temples* (New York: Metropolitan Museum of Art, 2007).

CHAPTER 3 - ANCIENT EGYPTIAN MEDICINE

TASHIA DARE

Introduction

When studying the history of medicine, names such as the Greek physicians Hippocrates (circa 460–circa 375 BCE) and Galen (129 CE–circa 216 CE) immediately come to mind. Modern medicine is indebted to the ancient Greeks, but it is equally important to study the development of medicine in the ancient Near East before the Hellenistic period. As this section will demonstrate, we are just as indebted to the ancient Egyptians as we are to the Greeks.

Medicine in ancient Egypt incorporated both conventional (rational) medicine and religious practices. Religion played a major role in ancient Egyptian daily life. There was an overlap between the priesthood and healers in addition to the frequent employment of incantations, amulets, and imagery related to deities such as Horus and Seth.[1] The Egyptians' religious life and views helped shape their understanding of the human body, how it functions, and how to heal it.

Ancient Egyptians recognized health and illness as expressions of an individual's relationship with the world, which comprised people, animals, spirits, and gods.[2] Although they saw a distinction between the mundane/mortal and the supernatural/divine, they saw these worlds as frequently interacting with one another. *Maat* (order, balance, justice) was an integral part of this, governing people's actions and approaches to healing illnesses and injuries (fig. 1).

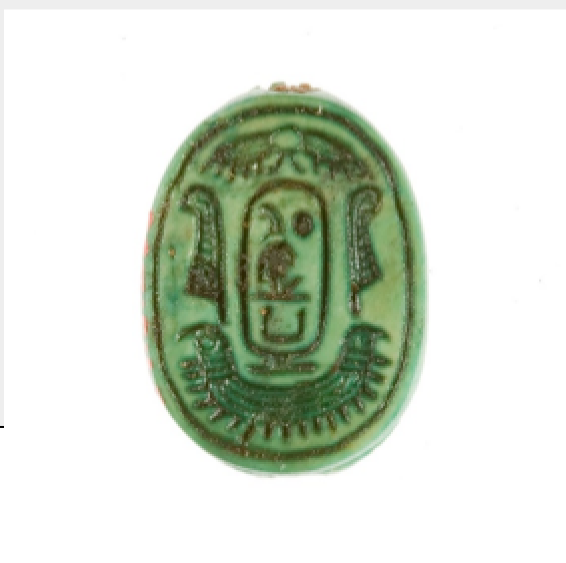


Figure 1. Scarab inscribed for Maatkare (Hatshepsut), New Kingdom, Eighteenth Dynasty (1479–1458 BCE). In the center of the base of the scarab in the cartouche is Hatshepsut's throne name, Maatkare (Hatshepsut was queen and later pharaoh during the Eighteenth Dynasty). Maatkare generally translates as "Maat is the life force of Re (the sun god)." On either side of the cartouche are feathers representing the goddess Maat (truth). Above the cartouche is a winged sun disk and below is a broad collar with falcon terminals. Steatite (glazed), 1.8 × 1.3 cm (11/16 × 1/2 in.). New York Metropolitan Art Museum, Rogers Fund, 1927, 27.3.230.

One's good health meant that *maat* was balanced, while illness, injuries, and other issues indicated that *maat* was not in order. Health depended on this balance just like Egypt depended on the Nile River to maintain life.[3] Purity preserved *maat* and thus the body guided views on the relationship between the mortal world and the divine. Being pure was particularly important when one was coming into contact with the divine, including priests. To not be so could anger the gods.[4] The *swnw* (conventionally pronounced as "sewnew"), *wab* priest, and *sau* were healers who focused either on the divine or mortal aspects of an illness or injury.[5] They turned to the religious idea that illness was a message from divine entities with access to *heka* (magic power). Symptoms were a result of a disturbance of *maat,* which could be repaired by *heka,* supplication, spells, and ritual.[6]

Much of what we know about ancient Egyptian medicine comes from human remains, visual representation as seen in tombs and temples, among other places, and through written texts. The beginning of organized medical care and the development of Egyptian medical science may be credited to Imhotep, during the reign of Pharaoh Djoser of the Third Dynasty (circa 2686–2613, Old Kingdom). Clemens of Alexandria (150–215 CE) noted that this knowledge may have existed much earlier with Athothis of the First Dynasty (circa 3100–2890); (son of Menes, the first pharaoh and who united Upper and Lower Egypt) and who may have authored a volume on anatomy.[7]

The Corpus of Medical Papyri

Much of what we know about ancient Egyptian medicine has been preserved through several medical papyri. Many of the surviving papyri have been found in tombs. Before the discovery of these papyri, much of what we knew was through the writings of individuals like Hippocrates, Homer, Herodotus, Pliny the Elder, and Diodorus.[8] Although the papyri are in various states of preservation, they give us valuable insight into the ancient Egyptians' knowledge of human anatomy and physiology, ways of diagnosing disease and injuries, and how to treat medical issues using both rational medicine and magico-religious (a belief in supernatural beings) elements. Presently, there are at least eleven known medical texts (in chronological order): the Kahun, Ramesseum, Edwin Smith, Ebers, Berlin, Hearst, London, Chester Beatty, Carlsberg, Brooklyn, and the London-Leiden Papyrus (fig. 2).[9]

Table 2.1 The most important medical papyri

TITLE	LOCATION	APPROXIMATE DATE OF COPY	CONTENTS
Edwin Smith	New York	1550 BC	surgical, mainly trauma
Ebers	Leipzig	1500 BC	general, mainly medical
Kahun (gynaecology)	University College, London	1820 BC	gynaecological
Hearst*	California	1450 BC	general medical
Chester Beatty VI*	BM 10686	1200 BC	rectal diseases
Berlin*	Berlin	1200 BC	general medical
London*	BM 10059	1300 BC	mainly magical
Carlsberg VIII	Copenhagen	1300 BC	gynaecological
Ramesseum III, IV, V*	Oxford	1700 BC	gynaecological, ophthalmic and paediatric
London and Leiden	BM 10072 and Leiden	AD 250	general medical and magical
Crocodilopolis	Vienna	AD 150	general
Brooklyn snake*	Brooklyn	300 BC	snake bite

*No English translation is available.
BM British Museum

Figure 2. List of significant ancient Egyptian medical papyri. From John F. Nunn, *Ancient Egyptian Medicine* (Norman: University of Oklahoma Press, 1996).

All of these papyri were composed in hieratic except Ramesseum V, which is in cursive hieroglyphs, much like the Kahun veterinary text. Later papyri were composed mainly in demotic, which was the dominant script.[10] Hieratic and cursive hieroglyphs were used at the same time and within a medical setting. Thus, they may have been understood by most physicians. Hieratic is a cursive form of Egyptian hieroglyphs that could be written quickly on papyri for administrative and literary purposes, while cursive hieroglyphs were used mainly in religious texts (including the Book of the Dead). Demotic was primarily used for administrative purposes but over time also came to be used for literary, science, and religious documents.[11] There is no clear reason why the Ramesseum V and the Kahun texts were written in a different script than the other texts. There is reason to believe that we only have a fraction of medical papyri that existed, as some papyri quote or allude to unknown texts.[12]

Some papyri appear to have been handbooks for physicians, while others have outlines from lectures, record instructions including lecture notes, or were clinical notebooks owned by students.[13] Many simply provide remedies for diseases, listing numerous drugs available but without including much other information. These drugs are likely to have been from local plants, minerals, and animals, but some may also have been imported, such as lapis lazuli from Afghanistan.[14] A few of the papyri that incorporate magic explain their origins in order to establish authority and authenticity, in certain cases stating that they were found at the foot of a statue of a god.[15] Although many of the texts have been successfully translated, there is still much that is unknown. Some of the vocabulary only occurs in the medical texts, while other words are well known in nonmedical settings but have specific unknown meanings in the medical context.[16]

The Edwin Smith and Ebers Papyri are the most well-known and informative of all the medical papyri, giving a structured method of approaching patient diagnosis and treatment. Both were purchased in 1862 by the American Edwin Smith, who lived in Luxor, Egypt, from 1858–1876 (the Ebers Papyrus was later purchased by Georg Ebers in 1872). They may have come from the same tomb, that of a physician buried in the Theban necropolis on the west bank of the Nile.[17] The Edwin Smith Papyrus dates to circa 1600 BCE (late Middle Kingdom), with most of the language being in Middle Egyptian. It is generally agreed, however, that the original dates to the Old Kingdom (ca. 2600–2500 BCE). This papyrus stands out for its content and approach to medicine, and is often referred to as the surgical papyrus. It focuses on forty-eight cases of mostly traumatic injuries and treatments of the head, face, neck, upper part of the thorax, spine, and arm.[18] It follows empirical understanding, is an instruction book rather than simply a compilation of remedies, and only has one spell. Each medical case follows the same pattern, beginning with the title "knowledge gained from practical experience: examination, diagnosis and prognosis, and treatment."[19] Physical manipulations, sutures, and bandages are the primary means of treatment of injuries that were likely caused by various types of weapons.[20]

Over time, the Edwin Smith Papyrus became one of the standard reference texts on treating trauma in ancient Egypt and the glosses that were added to fill in omissions attest to its continual utilization.[21] If the Edwin Smith Papyrus is as old as some scholars believe, it contains the earliest known examination of the pulse and details the parallel roles of the physician, the priest of Sekhmet, and magicians. Some scholars propose that the papyrus contains the first description of the circulation of blood. If this is true it means that there was some understanding of this long before the Greek Democritus' own description in his treatise *On Nutrition*.[22] After Smith's death the papyrus was donated to the New York Historical Society and in 1920 the papyrus was given to Egyptologist James Henry Breasted for translation. After a lengthy period of study and analysis, Breasted translated the papyrus. In 1930, he published a historic two-volume edition containing the English translation, with medical notes prepared by physician Arno Luckhardt and an hieroglyphic transcription of the original scroll.

The Ebers Papyrus (circa 1550 BCE) is the longest medical text and is in very good condition (fig. 3).

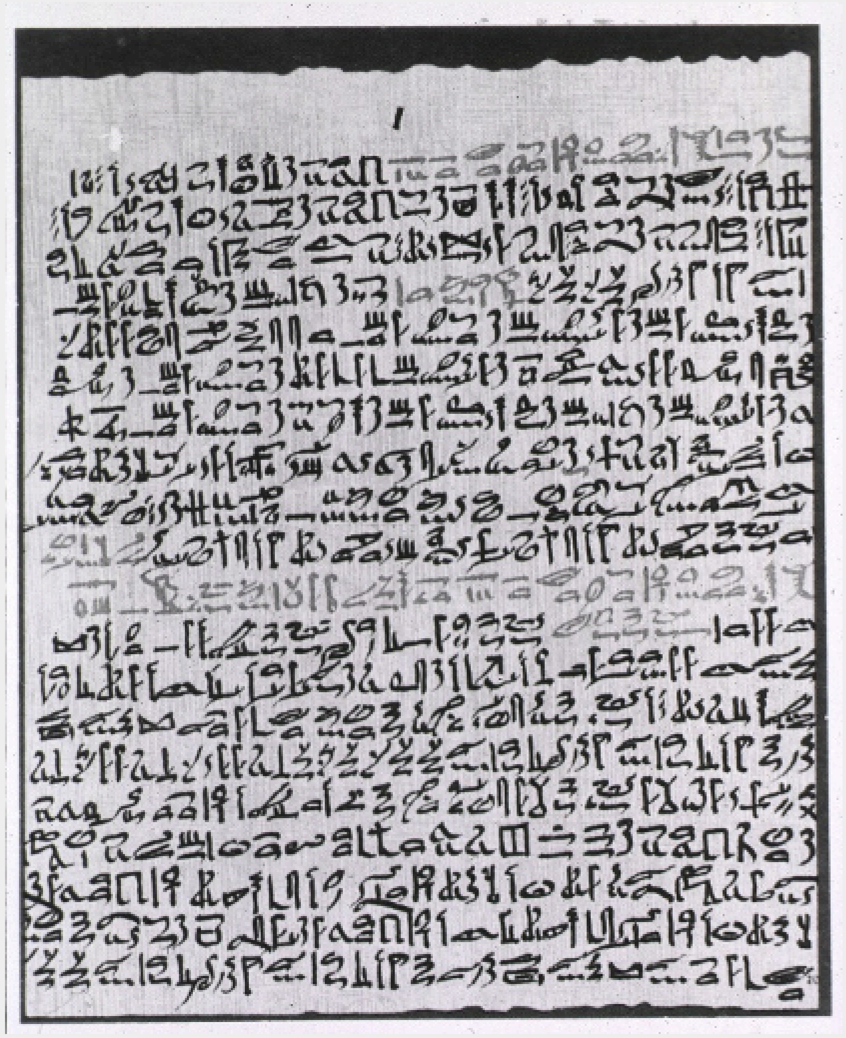


Figure 3. A section from the Ebers Papyrus (circa 1550 BCE). From the National Library of Medicine at the U.S. National Institute of Health, http://resource.nlm.nih.gov/101436767.

This text is a compilation of original medical texts haphazardly ordered, which makes deciphering references to ailments and treatments difficult, but it nonetheless presents us with a breadth of information. Paragraph 856a notes that the original text was "'found amongst writings of ancient times in chests of writing material under the feet of Anubis, in Letopolis, in the time of the majesty of the king of Upper and Lower Egypt Den' (First Dynasty)."[23] This gave the text added ancient authority in its own time (the Berlin Papyrus makes the same statement), as the god Anubis possessed medical knowledge and was patron of embalmers. Unlike the Edwin Smith Papyrus, diseases or symptoms are often assumed, so only a treatment or remedy is listed. Medical issues addressed in this text include those related to the stomach (15 diseases); the anus; the skin (18 diseases); a significant section focuses on the eye (29 diseases); and 21 treatments are provided for cough.[24] There is also a notable section called *The Book of Vessels*, which focuses on the *metu*. The *metu* is generally identified as the blood vessels, ducts, tendons, muscles, and possibly the nerves, although it is uncertain how well the ancient Egyptians understood the nervous system. The *metu* may transport blood, air, mucus, semen, urine, and disease, acting as canals for substances to flow through. The pulse was taken regularly to make sure the *metu* vessels were open.[25] The end of the text is more surgical in nature and is our primary source on surgery outside of trauma, listing about 700 drugs and 800 formulas.[26] There are several spells in the text and there are parallels with the Hearst, Berlin, and London papyri.[27]

Another noteworthy medical text is the Kahun gynecological papyrus. This papyrus was found by Flinders Petrie in 1889 in the Fayum area. It dates to circa 1850–1825 BCE, during Amenemhat III's reign, and is written in hieratic, although the accompanying veterinary text is in hieroglyphic script, which is usually reserved for religious texts. It is in very poor condition, but nonetheless gives us insight into ancient Egyptian's notions of gynecological issues, including contraception and pregnancy testing. The information does not relate to current gynecological understanding and there is nothing about obstetrics or midwives. Along with this text, there are substantial sections of the Berlin, Carlsberg, Ebers, London, and Ramesseum papyri that address gynecological concerns.[28]

In addition to writing medical knowledge on papyri, physicians also wrote on ostraca, which are potsherds or flakes of mostly white limestone. Due to the material used, ostraca last longer than papyri. Known medical ostraca date from the Amarna Period (Eighteenth Dynasty) to the Roman occupation (30 BCE–395 CE).[29] Medical ostraca were likely used to transmit knowledge and collect treatments in texts. Frequently, medical treatments were listed one after another on these. In general, ostraca were easy to carry and were disposable. As a result, there are probably many medical ostraca missing. Unfortunately, we do not know who specifically used ostraca, whether all physicians did or only physicians of certain levels.

The Medical Profession

While the pharaoh was seen as the supreme healer, his powers were delegated to physicians, priests of Sekhmet and Serqet, and magicians who played critical roles in the process of diagnosing and treating injuries and diseases. Often these roles were intertwined with one other, with some individuals having one or more of these positions. Physicians came from various social classes and the title of physician was held in high regard.

Swnw is usually the ancient Egyptian term translated as doctor or physician (fig. 4).

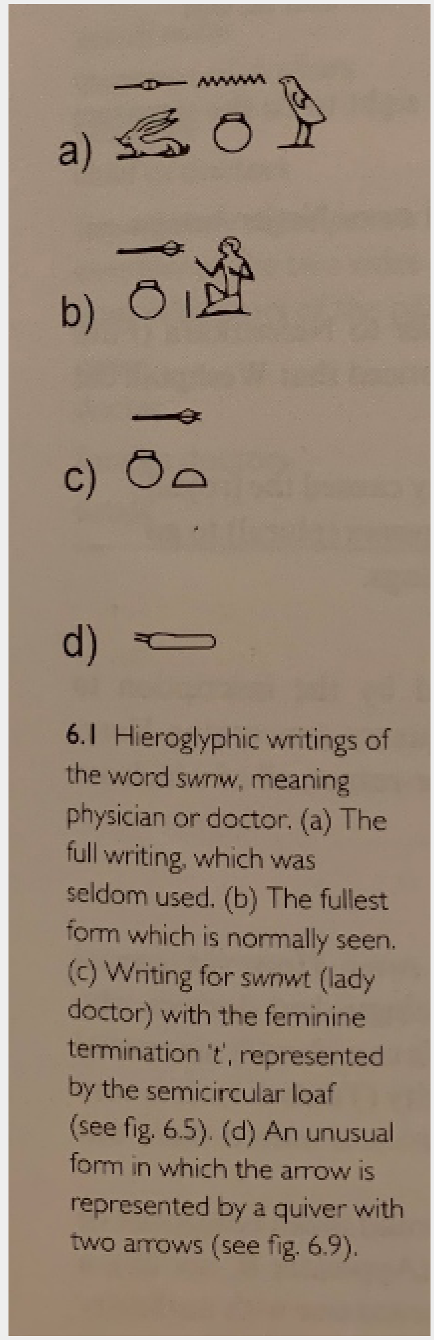


Figure 4. Ancient Egyptian hieroglyphic variations of the word *swnw*. From John F. Nunn, *Ancient Egyptian Medicine* (Norman: University of Oklahoma Press, 1996).

This title appears 150 times in tomb biographies, graffiti, stelae, and papyri dating from the Fourth Dynasty (2649–2513 BC) to the Twenty-seventh Dynasty (525–404 BCE). This is linguistically similar to the Egyptian word for pain (*swny.t*) and for affliction (*swn*).[30] One of the identifying features of the *swnw* in the medical papyri is the phrase "placing the hand."[31] This may have been a way of diagnosing and/or was similar to "the laying on of hands" as we say today as a means of healing.[32] After the Twenty-seventh Dynasty, when Egypt came under Persian rule, *swnw* came to mean both doctor and embalmer.[33] Furthermore, during the Ptolemaic Period, *swnw* could mean embalmer as well.[34] Previously, during the Pharaonic period, there may have been limited interactions between physicians and embalmers. Egyptologist Kent Weeks recommends that a more accurate translation of *swnw* should be "one who treats the ailments of the upper classes," which reflects the idea that most *swnw* had connections with the royal court rather than treating ordinary people.[35]

Wab (pure) priests and *sau* (magicians) were additional healers who used similar healing techniques as *swnw*. *Wab* priests and *sau* are mentioned in the Edwin Smith and Ebers papyri as placing their hand over a patient, demonstrating their participation in healing traumatic injuries and internal ailments. The title *wab* can refer to even the most novice temple personnel. In the medical context, the title is usually, "*wab* priest of Sekhmet." The lioness goddess Sekhmet was both a destructive and healing force. *Sau* is often translated as magician, but some scholars suggest that a better translation is "protector" or "amulet-man," although the latter may not be completely accurate either as it implies that the *sau* only worked with amulets, which is not the case. *Sau* is often used in connection with Serqet, the scorpion goddess. Like Sekhmet, this goddess also embodied destructive and healing aspects.[36]

The Court physician formed the apex of the medical field.[37] In the Old Kingdom, nearly half of the known doctors and dentists had royal connections. After the Old Kingdom the number of known doctors with a royal connection becomes much fewer. Several *swnw* also had a priestly title, such as *wab* priest of Sekhmet, *hem netjer* (servant of god), or *wab nesu* (royal priest). Additionally, some *swnw* were appointed to estates of gods, including that of Amun and Ptah, as well as the "Place of Truth" (the necropolis). [38] Selected physicians were sent to treat miners, workmen, or soldiers, or else were temple physicians, who were at the lowest level of the social ladder and made house visits.[39] Physicians often associated themselves with deities who related to their specialties.[40]

Physician Titles

While most physicians had the title *swnw*, there were other known related titles, including *kherep swnw*, meaning the most exalted "controller or administrator of doctors." *Hery swnw* and *imy-r* mean "one with authority over doctors" and "overseer," respectively, while *sehedj* or *shd swnw* is translated as "inspector." The senior physician was referred to as "Overseer of the House of Health" or "Chief of the House of Secrets," and *smsw swnw* meant the "eldest of doctors."[1] The most widely held special title was *wr swnw*, meaning "great one" or "chief" physician. Sometimes titles were followed by the geographic limitation of authority, such as Upper or Lower Egypt or both. Many physicians served pharaoh, often having the title *swnw per aa*, meaning "doctor of the Great House or palace."

Documents suggest that, much like in modern medicine, ancient Egyptian doctors had specialties.[41] For example, Herodotus famously recorded in his travels to Egypt in about 450 BCE that "medicine is practiced among them on a plan of separation; each physician treats a single disorder, and no more: thus, the country swarms with medical practitioners, some undertaking to cure diseases of the eye, others of the head, others again of the teeth, others of the intestines, and some of those which are not local."[42] This sentiment is supported by qualifying words relating to body parts following *swnw*, which have been found on several stelae.[43] In addition, a number of doctors noted that they were also scribes, and some doctors were also dentists. It has been argued that *swnw* was primarily a physician while surgeons may have been referred to as "great ones of the body" and were mainly *wab* priests of Sekhmet.[44]

Physicians received years of training at the Peri-Ankh, or "House of Life," which was either within or attached to a temple and also served as a scriptorium and library where master copies of papyri were likely held.[45] Medicine was a specialty within scribal education.[46] Surgeons received special rudimentary training. It was a science and known as early as 4000 BCE, although the first record of surgical procedures was as early as 2500 BCE.[47] In addition, it appears, based on the papyri, that all physicians were expected to have basic knowledge of all types of medication available.[48] There is indication that medical wisdom was passed down through families, as found on stelae concerning Khay and Huy as well as being documented in the Ebers Papyrus in an obscure passage.[49]

Like other parts of the ancient Near East, such as Mesopotamia, Egypt's political structure meant that the medical field was well organized, although there was no medical licensure system.[50] Physicians were required to follow strict rules of treatment. One reason for this was that it was deemed that there was nothing to improve upon the existing wisdom of older eras. Physicians were advised to use only the authoritative texts and methods so that their actions would be beyond question.[51] Later, Aristotle wrote that physicians were "warned by the state not to alter a course of treatment until at least four days have passed, or else be subject to legal penalties."[52] For example, if the physician deviated within those four days he risked the penalty of death if the patient died.

Based on the evidence we have, about 150 physicians are attested to from the Old Kingdom to the Late Period.[53] A few notable physicians are Djer; Imhotep; Amenhotep, son of Hapu; Netjer-hotep; Hesy-ra; Pesehet; Mereuka; Ankh; Ir-en-akhty; Gua and Seni; Renef-seneb; Hery-shef-nakht; Wedja-hor-resnet; Iry; and Pentu. Imhotep ("he who comes in peace") is perhaps the most well-known (fig. 5).

Figure 5. Statuette of Imhotep, donated by Padisu, Late Period-Ptolemaic Period (circa 664–30 BCE). Cupreous (copper-containing) metal, 17.9 cm × 5.4 cm × 12.9 cm (7 1/16 × 2 1/8 × 5 1/16 in.). New York Metropolitan Museum of Art, Theodore M. Davis Collection, Bequest of Theodore M. Davis, 1915, 30.8.94.

He was the royal chamberlain of Pharaoh Djoser of the Third Dynasty and was architect of the Step Pyramid in addition to being a priest, astrologer, and sage. Possibly by the Nineteenth Dynasty (circa 1295–1186 BCE, New Kingdom) and certainly by the Twenty-seventh Dynasty (circa 525–404 BCE, Persian Dynasty), Imhotep was deified as the "son of Ptah," later replacing Thoth as the chief god of healing.[54] He was the only non-royal to be deified.[55] Miniature statues of Imhotep were sometimes worn as amulets to protect against disease.[56] During the Ptolemaic Period Imhotep was often identified with Asklepios, the ancient Greek god of medicine, but it is not apparent if Imhotep ever held the title *swnw*.[57]

Hesy-ra, a contemporary of Imhotep, is considered the first documented doctor in the world (circa 2650 BCE), working during Djoser's reign. He held several titles, including *wer ibeh swnw*, "chief of dentists and doctors."[58] According to a stela found in Akhet-hotep's Fifth or Sixth Dynasty tomb (circa 2494–2181 BCE, Old Kingdom), Pesehet is possibly the first female physician, or at least the first female overseer, of doctors. She held the titles *imy-r swnwt*, which could be read "[female] overseer of the female doctors," and *imy-r hem-ka*, "overseer of the funerary priest."[59] While she held the title of overseer, this does not necessarily mean she was a doctor herself. Pesehet remains the only attested female physician in ancient Egypt.[60] Hery-shef-nakht of the Twelfth Dynasty (circa 1985–1795 BCE, Middle Kingdom) uniquely held triple qualification as *wer swnw*, *wab* priest of Sekhmet, and overseer of magicians. These titles were recorded in the Ebers Papyrus. He also held the important title *wer swnw n nesu*, chief of the king's physicians.[61] Iri, a Sixth Dynasty physician, was referred to as the Keeper of the Royal Rectum and "one understanding the internal liquids" and was possibly the pharaoh's enema expert.[62]

Ancient Egyptian physicians were well known in neighboring countries. They were regularly requested by the Hittite court.[63] For example, Rameses II was asked to send a physician to the Hittite court "to prepare herbs for Karunta, King of the land of Tarhuntas," according to an Akkadian text about Pariamakhu.[64] Egyptian doctors were sent to dislodge a possessing demon, to heal the Hittite king's eye, and "to provide the king's vassals 'with all sorts of prescriptions.'"[65] Rameses II also wrote, "They will bring to you all the very good remedies which are here in Egypt, and which I allowed in friendly fashion to go to you in order to help you."[66] Another request was made in which Neb-amen, a New Kingdom physician, received gifts for assisting a Syrian prince. Homer's *Odyssey* also references ancient Egyptian medicine, and Herodotus remarked that before the Persian invasion, King Cyrus sent items to Pharaoh Ahmose II (Amasis) "for the services of the best ophthalmologist in Egypt."[67] Foreign physicians were also allowed to practice medicine in Egypt, as indicated by four Babylonian physicians in New Kingdom records.[68] The Greeks expressed admiration for Egyptian medicine, specifically the effectiveness of their drugs.[69] In turn, there is evidence that Egyptian physicians adopted medical concepts from contact with peoples in the Levant, most notably during the Eighteenth Dynasty and the Ramesside Period (Nineteenth Dynasty). For example, the Nineteenth Dynasty London Medical Papyrus incorporates seven incantations in two different languages; six are in Northwest Semitic dialects and written in syllabic Egyptian script, while one is in the Cretan language, using syllabic Egyptian script. These prescriptions were accepted into Egyptian medical practice as legitimate remedies rather than being marginalized. Another example is a Cretan spell against an "Asiatic disease" using an Egyptian methodology from the Eighteenth Dynasty Hearst Medical Papyrus to treat the ailment.[70]

Ailments, Injuries, and Treatments

Snake and scorpion bites, eye diseases, and gastrointestinal issues were among the most frequently treated ailments. Pneumonia and silicosis (inhaling dust particles), parasitic diseases, typhoid, dysentery, smallpox, and diarrhea were other common ailments.[71] Although they believed that people were born healthy, ancient Egyptians believed that their well-being was endangered by both earthly and supernatural forces, such as through intestinal putrefaction or malignant deities entering through bodily openings and consuming vital parts of the interior of the body. Supernatural origins of disease "could function as a form of punishment from the gods, a reminder of one's social obligation or an outright attack by a malicious or capricious entity."[72] Particularly unpleasant remedies sometimes were prescribed that were intended to rid the body of a malignant spirit.[73] Good health was linked with living correctly, which included being at peace with the gods and spirits, as well as the deceased.[74] It was thought that illness was due to an imbalance that could subsequently be brought back to equilibrium through prayers, spells, and rituals.

It is clear from the Edwin Smith and Ebers papyri that the ancient Egyptians had a rudimentary understanding of the cardiovascular system, seeing this as a network of vessels (*metu*) coming from the heart and going through the body to the organs and other body parts. The heart was the center of the system, where "the *metu* delivered and received."[75] This system involved the movement throughout the body of air, water, blood, and bodily waste, termed as *wekhedu*. *Wekhedu* was a distinct focus of the ancient Egyptians.[76] The accumulation of bodily waste sometimes appeared as pus in wounds or blisters as *wekhedu* worked through the blood system. Physicians sought to treat this by keeping wounds clean and bandaged with honey and copper salts. Physicians advocated purging one's body and using enemas and emetics in order to keep *wekhedu* from accumulating. Enemas had a divine origin as ancient Egyptians believed that Thoth invented them.[77]

It is evident from the Edwin Smith Papyrus that the brain was the location "of the nervous control of the body" and that paralysis could be because of a brain injury.[78] The ancient Egyptians had an extensive knowledge about the skull, brain, jaw, and face, in particular. This was due in part to traumatic injuries that often occurred from industrial accidents, warfare, or animal bites.[79] Fractures were frequent injuries. Consequently, the Egyptians had an extensive set of words describing various types of fractures, including more complicated ones.[80]

In terms of treatment, it was often stated in the Edwin Smith and Ebers papyri that the doctor would either treat, "contend with," or not treat.[81] The options were based on the level of the physician's confidence that the injury was treatable. If a patient could not be treated, he or she was still given care and kept comfortable until death.[82]

Views on the sources and nature of diseases ranged widely and medical classifications were made based on symptoms rather than diseases. Traumatic injuries had an obvious origin and therefore a sure means of diagnosis and treatment with some predictable outcome.

This includes the belief that objects could be infused with a life-force or spirit, allowing the object to act against an individual, thus was the cause of the injury because the object readjusted *maat*.[83] Conversely, internal issues, such as heart disease and lung ailments, had unpredictable outcomes as the source of illness was not always apparent. In these cases, reliance on incantations, spells, and amulets was common, sometimes in combination with drugs. If it was believed that there was a supernatural origin of the disease, such as a malign deity, the supernatural (benign deities) would be relied upon to cure the ailment. Many deities were invoked to prevent or cure diseases or attacks by dangerous animals.[84] Incantations often took the form of directly addressing the disease or disease-demon. Incantations or prayers were also meant to reinforce the effectiveness of remedies and often were related to specific diseases and drugs.[85] They were infused with *heka*, which involved the component of speech.[86] Egyptians thought that the "divine creative word and magical energy" could turn ideas into reality and therefore negate or turn away negative forces.[87] Often, spells or incantations had a “sympathetic” role; therefore, they would have been pragmatic and rational to the ancient physician.[88]

Amulets were also worn as a means of addressing health care. Many amulets resembled living creatures (human or animal) or specific body parts, with the intent of the wearer assimilating the desired characteristic, such as strength or sharp eyesight. A number of people also wore amulets to protect against harm, such as animal bites.[89] It was thought that the material the amulet was made of and the shape of it provided protection and healing for the wearer. Even substances that came in contact with amulets were considered to have a healing effect.[90] Amulets have been used by many people across the centuries and cultures. People still wear them today, believing that certain objects, whether they are of natural material or human-made, have power from a greater force, from a religious connection, or through the way the object was created. A rabbit’s foot or other good-luck charms are such examples.

Prescriptions made from animals, minerals, and vegetable substances were a regular means of treating various types of illnesses and injuries. The ancient Egyptian pharmacopeia was quite rich, although many of the terms have not yet been translated.[91] The efficacy of various drugs was not always evident, since multiple drugs were often utilized simultaneously, with several elements involved, while other times drugs were used in tandem with magic. Water, alcohol (beer and wine), oil, honey, and milk were part of preparing various types of prescriptions (fig. 6).[92]

Figure 6. Pharmaceutical jar, Saite Period, Twenty-sixth Dynasty (570–526 BCE). The inscription lists the contents of the jar as “Special ointment of the Manager of the Red-Crown Enclaves and Chief Physician, Harkhebi.” The man who owned the jar likely lived in the town of Buto in the Nile Delta. The “Red-Crown Enclaves” was an ancient area in Buto. Travertine (Egyptian alabaster), 47 × 34 cm (18 1/2 × 13 3/8 in.). New York Metropolitan Art Museum, Rogers Fund, 1942, 42.2.2.

Drugs were administered in five ways: orally, rectally, vaginally, by external application, and by fumigation. They were given in the form of cakes, suppositories, enemas, mouth rinses, tablets, drops, ointments, or special baths.[93] Often prescriptions would be made based on the patient’s age and weight.[94] Physicians also recited incantations while preparing or administering prescriptions.[95]

Drugs made from animals include honey, milk, excrement, blood, urine, placenta, bile, animal fat, meat, and liver and other internal organs. Honey was an especially beneficial element for its antibacterial and antifungal properties, as well as being a flavorful additive to other drugs (fig. 7).

Figure 7. Fragment of a jar with a label identifying the contents as honey. The script is in hieratic, which is written right to left. The sign at the beginning of the second line represents a bee, the symbol used for the word "honey." New Kingdom, Eighteenth Dynasty (1390–1352 BCE). Pottery and ink, 8.5 x 15.3 × 0.7 cm (3 3/8 × 6 × 1/4 in.). New York Metropolitan Art Museum, Rogers Fund, 1917, 17.10.12.

Honey was used both internally, including helping with cough, and externally, for various types of wounds.[96] This is the case today as well. Honey is still used to help reduce coughs and sooth sore throats. It is also beneficial in healing wounds, including burns and leg ulcers, because of its antibacterial and anti-inflammatory properties. For this reason, it may also help with skin grafts.[97] Milk was mainly used to make it easier to swallow other ingredients, although it was sometimes used as an enema or applied to skin, eyes, or ears.[98] Like honey, it also helped with respiratory ailments and throat irritations. Animal fat was utilized to make a greasy ointment, but also to convey the meaningful animal characteristics, such as strength.[99] For certain wounds, applying a bandage with fresh meat on the first day was general practice. In subsequent days, bandages with honey and oil or resin would be applied, which helped the healing process.

Some mineral-based drugs that were used include natron, common salt, malachite, lapis lazuli, imru, and gypsum. Natron was particularly beneficial in drawing out fluid and reducing swelling and was often applied with bandages. Malachite was the base for green eye paint and was often used for treating eye diseases, which were widespread due to flies, dust, and sand. Malachite is a natural antibacterial and was used in cases to treat burns or inflammation. However, it is unclear if the ancient Egyptians recognized this property or if they were more influenced by the decorative elements of the mineral.

The ancient Egyptians took advantage of the plants and herbs available to them, including onions, mint, lettuce, barley, acacia, dates, willow, dill, aloe vera, frankincense, garlic, mustard seeds, and linseed, among others. Aloe vera is one plant we still use to help soothe sunburns and other skin ailments. We also mint or peppermint today to help with stomach issues. Unfortunately, there is difficulty in positively identifying some of the plant species that were used. Reasons for this are that the disease for which the remedy was created cannot be translated or is otherwise unknown; in a few cases it is unknown which part of the plant was added, or we may not know the fullness of the pharmacological effect of the plant. Some plants may now be extinct or have disappeared from the Nile Valley, which also hinders researchers in determining the plant species that were used.[100]

Cannabis was known by the ancient Egyptians, including using hemp to make rope. It infrequently appears in the medical papyri and was administered by mouth, rectum, vagina, fumigation, on bandaged skin, and applied to the eyes. It is unknown if the Egyptians understood the effects of the plant on the nervous system.[101] Alcohol was likely the customary means of alleviating pain, just as it has been used in the centuries since.

Nearly a quarter of the listed prescriptions in the Ebers Papyrus were for gastrointestinal issues. As previously commented, the bowels were a specific focus for the ancient Egyptians at all levels of society, as they believed that a certain toxin (*wekhedu*) originated there, which could then spread to the rest of the body and cause aging, disease, and death.[102] They practiced purging themselves on a regular basis in order to keep their bodies healthy (Herodotus noted that this occurred for three days each month).[103] Castor oil, senna, and colocynth were often consumed for this process, while earth almonds and tiger nuts were also regularly eaten. Wormwood and pomegranate were effective in treating intestinal parasites.

There currently is not much documentation of surgery beyond simple procedures including removing tumors, closing wounds, or treating traumatic injuries such as fractures. There are only a few examples of human remains that show that the ancient Egyptians knew of trephination to relieve swelling of the brain.[104] Wounds were often either closed with linen sutures, as observed in seven cases in the Edwin Smith Papyrus, or bandaged with linen.[105] Surgery deep inside the body was generally not practiced because of the lack of an anesthetic.[106] Some surgical instruments referenced in the medical papyri are lancets, tweezers, drills, hook-like instruments, retractors, and dental tools (fig. 8).

Figure 8. Image of medical instruments chiseled on the inner part of the northern section of the outer enclosure wall of the temple of Kom Ombo (Roman era). Kom Ombo is north of Aswan in southern Egypt. From John F. Nunn, *Ancient Egyptian Medicine* (Norman: University of Oklahoma Press, 1996).

Bronze was initially widely implemented but later copper was the preferred metal.

Snakes were much dreaded in ancient Egypt. While the Edwin Smith Papyrus does not address how snake bites were treated and the Ebers Papyrus only minimally addresses this, the Brooklyn Museum Papyri focuses on this subject. The extant copy of the text dates to circa 6th-4th century BCE, although the original may date as early as the Old Kingdom.[107] The papyri identify at least twenty-one snakes and one chameleon. It also provides a brief description of the effects of the different types of snake bites, along with the prognosis. Care included local treatment of the bite, drugs (mainly herbal), and incantations. Many of these treatments intended to address pain and swelling as opposed to preventing the general absorption of the venom. There are several suggestions of applying bandages, which would have helped with applying localized drugs. Onion was one of the primary ingredients for treating bites, which was often part of a compound with salt and sweet beer, and at times was utilized along with incantations. Emetics were also prescribed, as the theory was to expel the venom through vomiting. The kherep priests of Serqet were the main healers in preventing and treating snake bites as well as scorpion stings.[108]

Ancient Egypt's Influence on Greek Medicine

Not long after Alexander the Great invaded Egypt in 332 BCE, the famous Alexandrian medical school was established, which had a great impact during the Ptolemaic, Roman, and Coptic periods. Many Greek physicians studied there, including Herophilus and Galen. Pliny the Elder, the Roman naturalist, asserted that the art of medicine may have been invented by the Egyptians.[109] Scholars have long debated the extent to which the Egyptians may have influenced ancient Greek medicine.

The following is what some scholars claim as being among the contributions. The Greek physician Herophilus, who studied in Alexandria, adopted the technique of pulse-taking as developed by the Egyptians. In addition, the practice of mummification allowed for anatomical dissection, which was otherwise taboo in ancient Greece. The Pre-Alexandrian Hippocratic Corpus illustrates parallels with Egyptian ideas and practices, such as birth prognoses adapted from pregnancy texts found in the Kahun, Carlsberg, and Berlin papyri, as well as disorders of the womb.[110] Some of the Greek gynecological, and possibly surgical, techniques may also be attributed to ancient Egyptians.[111] A few Egyptian terms were also adopted into Greek, such as that for migraine.[112] The four humors in Greek thinking may have also first come from Egypt.[113]

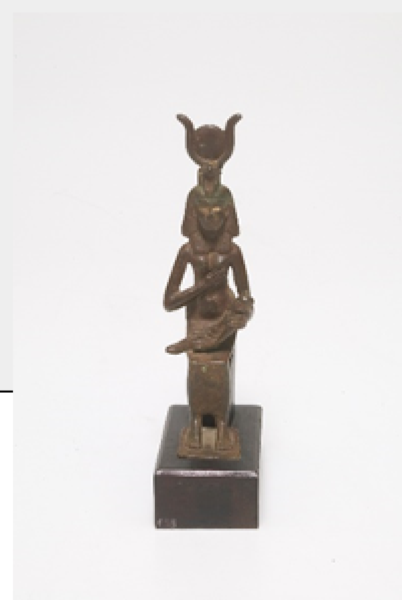
In addition, we know that the Greeks imitated and further developed the practice of empirical examination of patients, including diagnosis and prognosis.[114] The practice of incubation (sleeping in a sacred area with the purpose of experiencing divine dreams or healing) may also have originated with the Egyptians.[115] There is textual evidence that this practice existed at Deir el-Medina during the New Kingdom, circa 1200 BCE, and that temples at Sais and Heliopolis were well-known medical centers in the Middle Kingdom, circa 1900 BCE.[116]

One of the most noteworthy ancient Egyptian contributions to Greek, and later Roman, medicine is pharmaceuticals. The symbol for prescription, Rx, is Latin for "recipe," meaning "take," and may have originated from the Eye of Horus (fig. 9), which was an especially significant component of ancient Egyptian medicine, as it was believed that it had power to heal and protect.

Figure 9. Stamp seal in the shape of Wedjat-Eye (Eye of Horus), New Kingdom, Eighteenth Dynasty (1400–1390 BCE). Steatite (glazed), 1.7 × 1.1 × 0.6 cm (11/16 × 7/16 × 1/4 in.). New York Metropolitan Art Museum, gift of Helen Miller Gould, 1910, 10.130.208.

It also served to measure prescriptions, as the mathematical proportions of the eye were used to determine the amount of ingredients in medicines. The eye was divided into six parts related to the six senses: touch, taste, thought, hearing, sight, and smell.[117] In addition, many drugs and vegetable substances termed "Egyptian" played a prominent role in Greek and Roman medicine, as found in Greek medical works such as the Hippocratic Corpus and in the works of Herophilos, Dioscurides, Galen, and Pliny. The *Odyssey* also refers to Helen of Troy dispensing a drug to soothe her guest, where it is said to have been a gift from an Egyptian woman, and she praises Egyptian physicians as being "knowledgeable beyond all humans."[118] Pharmaceutical contributions include natron, aloe, chicory, alum, beans, castor oil, comfrey, pomegranate, saffron, and other oils and perfumes. The most popular was natron, as it is a naturally occurring soda that is used for cleansing purposes. The administration of drugs was also influenced by the Egyptians. Greek physicians at the Alexandrian medical school were the first to quantify specific ingredients in remedies, mimicking the precision of the Egyptians. One markedly influential prescription ingredient was the "milk of a woman who has borne a male child," which was "sympathetically evoking the curative milk of Isis after the birth and injury of [her son] Horus" (fig. 10).

Figure 10. Isis and the infant Horus, circa 300 BCE, Ptolemaic Kingdom (332 BCE–30 CE). Bronze and wood, 16.51 cm (6.5 in.). Spencer Museum of Art, University of Kansas, gift of Dr. Franklin D. Murphy, 1956.0029.



This element can be found several times in Egyptian texts and later was recommended in the Hippocratic Corpus, by Pliny and Dioscorides, in Coptic medicine, and in British herbals from the twelfth through seventeenth centuries. Castor oil was another prescribed drug that is still used today.[119] Conversely, in later

Egyptian medical papyri new drugs appear, and while they are transcribed in Egyptian, they originated from someplace else.[120]

Chronological table

PREDYNASTIC PERIOD		
Badarian	c. 5000–4000 BC	
Naqada I	c. 4000–3600	
Naqada II	c. 3600–3100	
EARLY DYNASTIC PERIOD		
1st Dynasty	c. 3100–2890	Djer supposedly a physician (according to Manetho)
2nd Dynasty	c. 2890–2686	Breasted's date for original of Edwin Smith papyrus
OLD KINGDOM		Imhotep, Hesy-ra (first known *swnw*)
3rd Dynasty	c. 2686–2613	
4th Dynasty	c. 2613–2494	
5th Dynasty	c. 2494–2345	Peseshet (*swnwt*)
6th Dynasty	c. 2345–2181	Mereruka, Ankh (*swnw*); Ankh-ma-hor
FIRST INTERMEDIATE PERIOD		
7th/8th Dynasties	c. 2181–2125	
9th/10th Dynasties	c. 2160–2025	Ir-en-akhty (*swnw*)
11th Dynasty (early)	c. 2125–2040	
MIDDLE KINGDOM		
11th Dynasty (late)	c. 2040–1985	Gua, Seni (*swnw*)
12th Dynasty	c. 1985–1795	Ref-seneb (*swnw*), Hery-shef-nakht (*swnw*); Kahun papyrus
SECOND INTERMEDIATE PERIOD		
13th–17th Dynasties	c. 1795–1550	Ramesseum papyri
NEW KINGDOM		
18th Dynasty	c. 1550–1295	Ebers and Edwin Smith papyri
19th Dynasty	c. 1295–1186	Hearst, London and Carlsberg papyri
20th Dynasty	c. 1186–1069	Chester Beatty and Berlin papyri
THIRD INTERMEDIATE PERIOD		
21st–25th Dynasties	c. 1069–656	
LATE PERIOD		
26th Dynasty (Saite)	664–525	
27th Dynasty (Persian)	525–404	Wedja-hor-resnet (*swnw*) Herodotus in Egypt Hippocrates in Cos
28th Dynasty	404–399	
29th Dynasty	399–380	
30th Dynasty	380–343	
Persian reconquest	343–332	
GRAECO-ROMAN PERIOD		
Macedonian	332–305	
Ptolemaic	305–30	Alexandrian museion; Herophilus; Erasistratus; Brooklyn papyrus on snake bite (may be 30th Dynasty); Diodorus Siculus in Egypt
Roman	30 BC–AD 323	Galen in Alexandria Crocodilopolis papyrus
BYZANTINE PERIOD	AD 323–642	
ARAB CONQUEST	AD 642	

The Third Dynasty is sometimes assigned to the Early Dynastic Period.
There is no agreement on the limits of the First Intermediate Period. It is often limited to the Ninth and Tenth Dynasties.

Chronology of ancient Egyptian dynasties, notable physicians, and medical papyri. From John F. Nunn, *Ancient Egyptian Medicine* (Norman: University of Oklahoma Press, 1996).

Bibliography

Aboelsoud, N. H. "Herbal Medicine in Ancient Egypt." *Journal of Medicinal Plants Research* 4, no. 2 (2010): 82–86.

Allen, James P. "The Art of Medicine in Ancient Egypt." In *The Art of Medicine in Ancient Egypt.* New York: The Metropolitan Museum of Art, 2005, 9–12.

Carrick, Paul. *Medical Ethics in the Ancient World*. Washington: Georgetown University Press, 2001.

Escolano-Poveda, Marina. "Demotic: Opening New Windows into the Understanding of Egyptian History and Culture." ARCE, American Research Center in Egypt. October 20, 2020. https://www.arce.org/resource/demotic-opening-new-windows-understanding-egyptian-history-and-culture#:~:text=The%20term%20%E2%80%9CDemotic%E2%80%9D%20refers%20to,language%20of%20the%20

Gross, Charles. "From Imhotep to Hubel and Wiesel: The Story of Visual Cortex." In *Brain, Vision, Memory: Tales in the History of Neuroscience*. Cambridge, MA: MIT Press, 1998, 1–90.

Horstmanshoff, H. F. J., and Marten Stol, eds. *Magic and Rationality in Ancient Near Eastern and Graeco-Roman Medicine*. Leiden: Brill, 2004.

Longrigg, James. *Greek Rational Medicine: Philosophy and Medicine from Alcmaeon to the Alexandrians*. London: Routledge, 1993.

Meo, Sultan Ayoub, Saleh Ahmad Al-Asiri, Abdul Latief Mahesar, and Mohammad Javed Ansari. "Role of Honey in Modern Medicine." *Saudi Journal of Biological Sciences* 24 no. 5 (2017): 975–78.

Mininberg, David T. "The Legacy of Ancient Egyptian Medicine." In *The Art of Medicine in Ancient Egypt*. New York: The Metropolitan Museum of Art, 2005, 9–12.

Nicolaides, Angelo. "Assessing Medical Practice and Surgical Technology in the Egyptian Pharaonic Era." *Medical Technology SA* 27, no. 1 (2013): 19–25.

Nunn, John F. *Ancient Egyptian Medicine*. Norman: University of Oklahoma Press, 1996.

Porter, Roy. *The Greatest Benefit to Mankind: A Medical History of Humanity*. New York: W.W. Norton Co., 1997.

Ritner, Robert K. "Innovations and Adaptations in Ancient Egyptian Medicine." *Journal of Near Eastern Studies* 59, no. 2 (2000): 107–17.

Saber, Aly. "Ancient Egyptian Surgical Heritage." *Journal of Investigative Surgery* 23, no. 6 (2010): 327–34.

Saunders. J. B. de C. M. *The Transitions from Ancient Egyptian to Greek Medicine.* Lawrence, KS: University of Kansas Press, 1963.

“Snakebite Papyrus.” Brooklyn Museum. https://www.brooklynmuseum.org/opencollection/objects/124173.

Sullivan, Richard. “A Brief Journey into Medical Care and Disease in Ancient Egypt.” *Journal of the Royal Society of Medicine* 88, no. 7 (1995): 141–45.

Zucconi, Laura M. “Medicine and Religion in Ancient Egypt.” *Religion Compass* 1, no. 1 (2007): 26–37.

Suggested Further Reading

Ghalioungui, Paul. *The House of Life: Magic and Science in Ancient Egypt*. 2nd ed. Amsterdam: B.M. Israël, 1973.

Ghalioungui, Paul. *The Physicians of Pharaonic Egypt*. Cairo: Al-Ahram Center for Scientific Translations, 1983.

Grapow, Herman, and Hildegard von Deines. *Grundriss der Medizin der Alten Ägypter*. Berlin: Akademie-Verlag, 1954.

Halioua, Bruno, and Bernard Ziskind. *Medicine in the Days of the Pharaohs*. Trans. M.B. DeBevoise. Cambridge, MA: The Belknap Press of Harvard University Press, 2005.

Jonckheere, Frans. *Les Médicines de l’Egypte Pharaonique: Essai de Prosopographie*. Brussels: Éditions de la Fondation Éqyptologique, 1958.

Laskaris, Julie. *The Art Is Long: On the Sacred Disease and the Scientific Tradition*. Leiden: Brill, 2002.

Lefebvre, Gustave. *Essai sur la Médecine Égyptienne de l’Époque Pharaonique*. Paris: Presses

Universitaires de France, 1956.

Majno, Guido. *The Healing Hand: Man and Wound in the Ancient World*. Cambridge, MA: Harvard University Press, 1975.

Manniche, Lise. *An Ancient Egyptian Herbal.* Austin: University of Texas Press, 1989.

Saba, Magdi M., Hector O. Ventura, Mohamed Saleh, and Mandeep R. Mehra. “Ancient Egyptian Medicine and the Concept of Heart Failure.” *Journal of Cardiac Failure* 12, no. 6 (2006): 416–21.

Westendorf, Wolfhart. *Handbuch der altägyptischen Medizin*. Leiden: Brill, 1999.

[1]. Laura M. Zucconi, “Medicine and Religion in Ancient Egypt,” *Religion Compass* 1, no. 1 (2007): 26.

[2]. Zucconi, “Medicine and Religion,” 27.

[3]. Zucconi, “Medicine and Religion,” 28.

[4]. Zucconi, “Medicine and Religion,” 28.

5. John F. Nunn, *Ancient Egyptian Medicine* (Norman, OK: University of Oklahoma Press, 1996), 115.

[6]. Zucconi, “Medicine and Religion,” 36; and Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W.W. Norton Co., 1997), 49.

[7]. Richard Sullivan, “A Brief Journey into Medical Care and Disease in Ancient Egypt,” *Journal of the Royal Society of Medicine* 88, no. 7 (1995): 141–42.

[8]. Angelo Nicolaides, “Assessing Medical Practice and Surgical Technology in the Egyptian Pharaonic Era,” *Medical Technology SA* 27, no. 1 (2013): 19.

[9]. Zucconi, “Medicine and Religion,” 26.

[10]. Nunn, *Ancient Egyptian Medicine,* 23, 24, 39.

[11]. Marina Escolano-Poveda, “Demotic: Opening New Windows into the Understanding of Egyptian History and Culture,” ARCE, American Research Center in Egypt, October 20, 2020, https://www.arce.org/resource/demotic-opening-new-windows-understanding-egyptian-history-and-culture#:~:text=The%20term%20%E2%80%9CDemotic%E2%80%9D%20refers%20to,language%20of%20the%20

[12]. Nunn, *Ancient Egyptian Medicine,* 24; and Robert K. Ritner, “Innovations and Adaptations in Ancient Egyptian Medicine,” *Journal of Near Eastern Studies* 59, no. 2 (2000): 108.

[13]. Rosalie David in H. F. J. Horstmanshoff and Marten Stol, eds., *Magic and Rationality in Ancient Near Eastern and Graeco-Roman Medicine* (Leiden: Brill, 2004), 140.

[14]. Nunn, *Ancient Egyptian Medicine,* 138.

[15]. Nunn, *Ancient Egyptian Medicine,* 104.

[16]. Nunn, *Ancient Egyptian Medicine*, 25, 68.

[17]. Nunn, *Ancient Egyptian Medicine,* 30.

[18]. James P. Allen, “The Art of Medicine in Ancient Egypt,” in *The Art of Medicine in Ancient Egypt* (New York: Metropolitan Museum of Art, 2005), 11.

[19]. Nunn, *Ancient Egyptian Medicine*, 26–30; and Allen, “The Art of Medicine in Ancient Egypt,” 9.

[20]. Zucconi, “Medicine and Religion,” 27; and Allen, “The Art of Medicine in Ancient Egypt,” 9.

[21]. Nunn, *Ancient Egyptian Medicine,* 26–30.

[22]. Sullivan, “A Brief Journey,” 141.

[23]. Nunn, *Ancient Egyptian Medicine,* 31, 38; and J. B. de C. M. Saunders, *The Transitions from Ancient Egyptian to Greek Medicine* (Lawrence, KS: University of Kansas Press, 1963).

[24]. Porter, *The Greatest Benefit*, 48.

[25]. Zucconi, "Medicine and Religion," 28.

[26]. Porter, *The Greatest Benefit,* 48.

[27]. The majority of the information in this paragraph comes from Nunn, *Ancient Egyptian Medicine,* 30–34.

[28]. All Information in this paragraph comes from Nunn, *Ancient Egyptian Medicine,* 34–35.

[29]. Nunn, *Ancient Egyptian Medicine,* 41.

[30]. Zucconi, "Medicine and Religion," 35.

[31]. Nunn, *Ancient Egyptian Medicine,* 115.

[32]. Nunn, *Ancient Egyptian Medicine,* 115.

[33]. Nunn, *Ancient Egyptian Medicine,* 115, 134.

[34]. Nunn, *Ancient Egyptian Medicine,* 44.

[35]. Robert Arnott in H. F. J. Horstmanshoff and Marten Stol, eds., *Magic and Rationality in Ancient Near Eastern and Graeco-Roman Medicine* (Leiden: Brill, 2004), 156n7.

[36]. Information in this paragraph from Zucconi, "Medicine and Religion," 34.

[37]. Porter, *The Greatest Benefit,* 49.

[38]. The majority of the information in this paragraph comes from Nunn, *Ancient Egyptian Medicine,* 116–118, 120.

[39]. Nicolaides, "Assessing Medical Practice," 21.

[40]. Sullivan, "A Brief Journey," 142.

[41]. Nunn, *Ancient Egyptian Medicine,* 11.

[42]. Paul Carrick, *Medical Ethics in the Ancient World* (Washington: Georgetown University Press, 2001), 15. Porter also cites a similar quote; see *The Greatest Benefit,* 49.

[43]. Nunn, *Ancient Egyptian Medicine,* 119.

[44]. Nicolaides, "Assessing Medical Practice," 20; and Nunn, *Ancient Egyptian Medicine,* 119.

[45]. Nicolaides, "Assessing Medical Practice," 21; and David, *Magic and Rationality,* 138.

[46]. David T. Mininberg, "The Legacy of Ancient Egyptian Medicine," in *The Art of Medicine in Ancient Egypt* (New York: Metropolitan Museum of Art, 2005), 13.

[47]. Nicolaides, "Assessing Medical Practice," 19, 22.

[48]. Nicolaides, "Assessing Medical Practice," 21.

[49]. Nunn, *Ancient Egyptian Medicine,* 130–131.

[50]. Porter, *The Greatest Benefit,* 50.

[51]. Nicolaides, "Assessing Medical Practice," 21.

[52]. Carrick, *Medical Ethics,* 72.

[53]. Ritner, "Innovations and Adaptations," 116.

[54]. Nunn, *Ancient Egyptian Medicine,* 122; and Nicolaides, "Assessing Medical Practice," 20.

[55]. Nicolaides, "Assessing Medical Practice," 20.

[56]. Charles Gross, "From Imhotep to Hubel and Wiesel: The Story of Visual Cortex," in *Brain, Vision, Memory: Tales in the History of Neuroscience* (Cambridge, MA: MIT Press, 1998), 5.

[57]. Nunn, *Ancient Egyptian Medicine,* 122; and Allen, "The Art of Medicine," 12.

[58]. Nunn, *Ancient Egyptian Medicine,* 124.

[59]. Nunn, *Ancient Egyptian Medicine,* 124.

[60]. Ritner, "Innovations and Adaptations," 117; and Porter, *The Greatest Benefit,* 49.

[61]. Nunn, *Ancient Egyptian Medicine,* 128.

[62]. Porter, *The Greatest Benefit,* 49; and Nicolaides, "Assessing Medical Practice," 21.

[63]. Ritner, "Innovations and Adaptations," 111; and Arnott, *Magic and Rationality,* 169.

[64]. Nunn, *Ancient Egyptian Medicine*, 131.

[65]. Ritner, "Innovations and Adaptations," 112.

[66]. Ritner, "Innovations and Adaptations," 112.

[67]. Nunn, *Ancient Egyptian Medicine,* 132; and James Longrigg, *Greek Rational Medicine: Philosophy and Medicine from Alcmaeon to the Alexandrians* (London: Routledge, 1993), 228n2.

[68]. Most information in this paragraph comes from Nunn, *Ancient Egyptian Medicine,* 131–32.

[69]. Carrick, *Medical Ethics,* 15.

[70]. Ritner, "Innovations and Adaptations," 111.

[71]. Nicolaides, "Assessing Medical Practice," 20.

[72]. Zucconi, "Medicine and Religion," 20.

[73]. David, *Magic and Rationality,* 141.

[74]. Porter, *The Greatest Benefit,* 49.

[75]. Nicolaides, "Assessing Medical Practice," 21.

[76]. Ritner, "Innovations and Adaptations," 114.

[77]. Porter, *The Greatest Benefit,* 49.

[78]. David, *Magic and Rationality,* 144.

[79]. Nunn, *Ancient Egyptian Medicine,* 50.

[80]. Nunn, *Ancient Egyptian Medicine,* 57.

[81]. Nunn, *Ancient Egyptian Medicine,* 114.

[82]. Carrick, *Medical Ethics,* 74.

[83]. Zucconi, "Medicine and Religion," 30.

[84]. Nunn, *Ancient Egyptian Medicine,* 96.

[85]. Nunn, *Ancient Egyptian Medicine,* 105.

[86]. Zucconi, "Medicine and Religion," 32.

[87]. David, *Magic and Rationality,* 134.

[88]. Ritner, "Innovations and Adaptations," 113.

[89]. Nunn, *Ancient Egyptian Medicine,* 110.

[90]. Allen, "The Art of Medicine," 10.

[91]. Nunn, *Ancient Egyptian Medicine,* 144.

[92]. Nunn, *Ancient Egyptian Medicine,* 139–40.

[93]. Nicolaides, "Assessing Medical Practice," 21.

[94]. Nicolaides, "Assessing Medical Practice," 22; and N. H. Aboelsoud, "Herbal Medicine in Ancient Egypt," *Journal of Medicinal Plants Research* 4, no. 2 (2010): 84.

[95]. Aboelsoud, “Herbal Medicine in Ancient Egypt,” 82.

[96]. Nunn, *Ancient Egyptian Medicine,* 148.

[97]. Sultan Ayoub Meo, Saleh Ahmad Al-Asiri, Abdul Latief Mahesar, and Mohammad Javed Ansari, “Role of Honey in Modern Medicine,” *Saudi Journal of Biological Sciences* 24 no. 5 (2017): 977.

[98]. Nunn, *Ancient Egyptian Medicine,* 148.

[99]. Nunn, *Ancient Egyptian Medicine,* 149–50.

[100]. Nunn, *Ancient Egyptian Medicine,* 151.

[101]. Nunn, *Ancient Egyptian Medicine,* 156.

[102]. Nunn, *Ancient Egyptian Medicine,* 158.

[103]. Porter, *The Greatest Benefit,* 50.

[104]. Nunn, *Ancient Egyptian Medicine,* 169.

[105]. Nunn, *Ancient Egyptian Medicine,* 171 and 173; and Mininberg, “The Legacy of Ancient Egyptian Medicine,” 14.

[106]. Nicolaides, “Assessing Medical Practice,” 22.

[107]. Nunn, *Ancient Egyptian Medicine,* 183; and “Snakebite Papyrus,” Brooklyn Museum, https://www.brooklynmuseum.org/opencollection/objects/124173.

[108]. All information in this paragraph is from Nunn, *Ancient Egyptian Medicine,* 188–89, 99–100.

[109]. Longrigg, *Greek Rational Medicine,* 229n17.

[110]. Longrigg, *Greek Rational Medicine,* 11.

[111]. Longrigg, *Greek Rational Medicine,* 10.

[112]. Most information in this paragraph is from Ritner, “Innovations and Adaptations,” 115–16.

[113]. Carrick, *Medical Ethics*, 15–16.

[114]. Carrick, *Medical Ethics,* 15.

[115]. Longrigg, *Greek Rational Medicine,* 10.

[116]. David, *Magic and Rationality,* 143.

[117]. Aly Saber, “Ancient Egyptian Surgical Heritage,” *Journal of Investigative Surgery* 23, no. 6 (2010): 333.

[118]. Longrigg, *Greek Rational Medicine,* 10; and Arnott, *Magic and Rationality,* 183.

[119]. Much of the information in this paragraph, including the quote about milk, is from Ritner, “Innovations and Adaptations,” 116.

[120]. David, *Magic and Rationality,* 145.

CHAPTER 3 - SAHELIAN AFRICA AND THE CENTRAL AFRICAN IRONSMITHS

SOLANGE ASHBY

Figure 1. Stela of Meroitic King Tanyideamani, Walters Art Museum, Baltimore. CC-0.

Kush (Sudan) 2300 BCE—300 CE

Nok (Nigeria) 1500 BCE—500 CE

Axum (Ethiopia) first century BCE—700 CE

Early history contains many examples of technological advancements made by African peoples, including engraving (fig. 1), writing (figs. 2 and 3), animal husbandry, and the development of agriculture, ceramic technology, and metallurgy. These and developments in urban planning, architecture, woodworking, and glass bead technology are noteworthy examples of technology that were developed into unique forms on the African continent, not to mention the elaboration of music, dance, and hair braiding, which was unknown elsewhere.

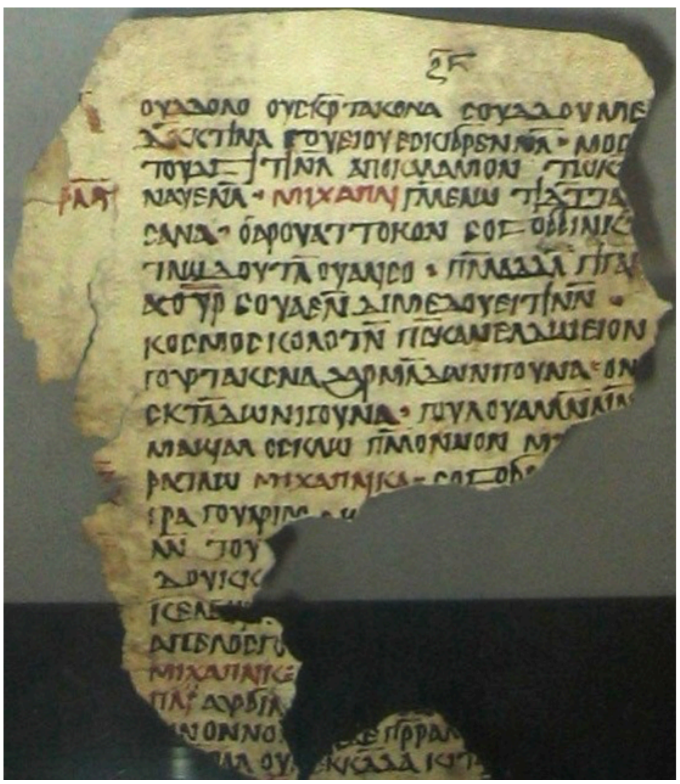
Writing

Figure 2. Ethiopian Ge'ez script. This example records the text of Genesis 29: 11–16. Wikimedia Commons. Public Domain.

Two vastly different systems of writing, hieroglyphs and cuneiform, appeared in Egypt and Sumer, respectively, around 3200 BCE.[1] The earliest alphabet developed from hieroglyphs (proto-Sinaitic, which evolved into Phoenician), which is the ancestor of most forms of writing currently in use.[2] Egyptian hieroglyphs were developed to tally and record grain donations to temples and label funerary offerings that were buried with the earliest kings. In the second century BCE, Meroitic scholars developed two scripts, a hieroglyphic script that was derived from the Egyptian hieroglyphic repertoire, and a cursive (alphasyllabary) based on the Demotic script (fig. 1). Alphasyllabaries are scripts in which a consonant and a vowel are indicated together by one character.

In the case of the Meroitic script, the vowel is always "a" unless otherwise indicated. In Ethiopic, a base consonant is modified into seven different forms to indicate which vowel follows the consonant. Ge'ez, the Ethiopic script invented in the fourth century CE (fig. 2), was also an alphasyllabary. Its consonants were based on the Old South Arabian script, which was modified to indicate vowels.

The Old Nubian script, invented around the fifth century CE (fig. 3), used the Greek alphabet with the addition of Egyptian Coptic and Meroitic letters for sounds that were not present in the Greek language. These are just a few of the numerous scripts invented in Africa.



Old Nubian script. Text from the Book of Archangel Michael found at Qasr Ibrim in Lower Nubia. Wikimedia Commons CC-BY SA 3.0.

Agriculture

The invention of agriculture was not unique to the Fertile Crescent. In fact, the independent creation of indigenous agricultural practices occurred in as many as twelve areas of the world. In Africa, for instance, availability of wild grains in the Sahara was greatly enhanced by the dramatic increase in rainfall and the northward movement of seasonal rains during the Holocene Wet Period (9500–5000 BCE). Climate change prompted an agricultural revolution in Africa, which was host to the development of crop cultivation in four separate regions.[3] The West African Ounjoungou culture of Niger-Congo speaking peoples began harvesting the wild grain *fonio* as early as 9500 BCE, which eventually led to cultivation of this grain by 8000 BCE. Similarly, Nilo-Saharan speaking people in East Africa began to harvest sorghum as early as 8500 BCE and then began cultivating it by 7000 BCE. In the period from 7000–3500 BCE, melons, and gourds such as calabashes were added to the agricultural repertoire.

Ceramics

Pottery is one of the oldest human inventions. Neolithic ceramic remains have been found in many cultures around the world.[4] Two independent types of ceramic technology that were used to boil grains for human consumption were developed in different parts of Africa: in West Africa the Ounjougou culture began producing ceramics around 9500 BCE[5], and in East Africa, the North Sudanic Nilo-Saharan people began making their own pottery by 8500 BCE.[6] The late Kushite kingdom of Meroe (descendants of the Nilo-Saharan speaking population) produced master potters who created vessels of unrivaled beauty for use in the domestic, ritual, and funerary spheres, where the tradition of pouring libation in drink offering to gods or spirits (found in many African cultures) was of paramount importance.

Many scholars attribute the invention of ceramic technology (fig. 4) in Africa to women, who were primarily responsible for food preparation. This may explain why ceramic pots in many cultures are decorated to represent female bodies.[7] Both independent inventions of ceramic technology in Africa predate the use of ceramics in the Middle East (6500 BCE) by thousands of years.

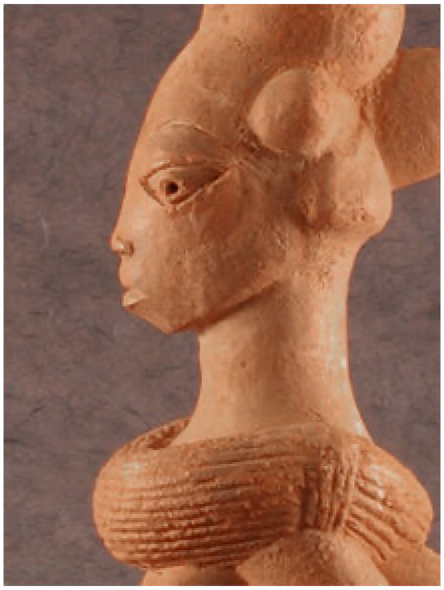


Figure 4. Nok Terracotta Figurine.
Wikimedia Commons. CC-SA 3.0

Powerful life-sized terracotta figures—some dating back as early as 500 BCE—were discovered in Nok, Ife, and the Chad basin (See Figure 5).[8] Scholars have suggested that the striking terracotta figures of Middle Africa may have been created by women for use in their society's ritual sphere, to be set up in shrines or as funerary statues to be included in burials.[9]

Figure 5. Map of Nok Cultural Influence.
Wikimedia Commons. Public Domain.

Nok artisans were also iron workers and the terracotta sculptures were often found in proximity to smelting sites. Perhaps this is a case of male-female complementarity: women formed the amazing terracotta figures, while men produced stunning iron artifacts. The early excavator of these objects "postulated the terracottas were objects of worship to aid blacksmithing and smelting."[10]

> In looking more closely at technology, the role of women in its history must be acknowledged more emphatically. Pottery production is 'among the most longstanding of human technical achievements' although little has been written about the history of its development and the organization of its production. A history of pottery production in Africa or in other parts of the world is a history in which women have played a central role.[11]

Animal Husbandry

The earliest domestication of cattle took place in Africa. Wild cattle, indigenous to the Mediterranean steppe area in the northern Sahara, moved southward during the Holocene period (9500 BCE), where the North Sudanic peoples of East Africa quickly shifted from cattle tending to cattle domestication. This necessitated herding cattle to the Nile during the long dry season before year-round surface water became available throughout the Sahara sometime after 8000 BCE.[12] Donkeys were first domesticated by two groups of early Cushitic-speaking people in the Red Sea Hills (east of the Nile), and the Ethiopian highlands in the sixth millennium BCE. Here I use the term Cushite to denote an Afro-Asiatic language group spoken in the highlands of Ethiopia, not the Kushite people of Nubia in Sudan and Egypt. By the fourth millennium the use of the donkey as a beast of burden had spread to the Ancient Near East.[13]

Weaving

Figure 6. Ancient Egyptian Spindle Whorl. National Museums Liverpool.

Archaeological evidence of spindle whorls of baked clay confirms the invention of weaving by Africans living along the Middle Nile Valley circa 5000 BCE as a result of the domestication of cotton. The development of cotton weaving technology by Nilo-Saharan speakers along the Nile occurred earlier than anywhere else in the world except India, where this technology developed around the same period.[14] As early as the fourth millennium BCE, the invention of a broadloom allowed for the weaving of raffia palm fibers into fabric that would later become a commodity of long-distance trade in West and Central Africa.[15]

Metallurgy

In at least two different regions of Africa, the technology to mine, smelt, and work copper was practiced. Copper-working technology was introduced into Egypt from the eastern Mediterranean in the second half of the fourth millennium but was also developed independently in the Aïr Mountains of northern Niger by around 2500 BCE.

Anatolia (modern Turkey) is often touted as the site where iron-working technology originated, around 1500 BCE, diffusing from there into Egypt, Europe, and the Middle East. However, new archaeological discoveries seem to indicate the beginnings of iron production in central Africa (today's Central African Republic) as early as 2000–1800 BCE.[16] Furthermore, in the last millennium BCE, African iron smiths developed smelting furnaces capable of producing temperatures high enough to produce steel directly during the smelting process. This technology was not used in China until 1100 CE, and it was not until the mid-nineteenth century when this technology, which would come to be known as the Bessemer process, began to be employed in Europe.[17] North and South American slave societies benefited from the technical knowledge of the Africans they enslaved. Ornate iron work can be seen in the antebellum homes of the southern United States. Perhaps as archaeological research in Africa develops, the continent will be found to be the origin of many other technologies.

Conclusion

Both the development of agriculture and writing allowed complex civilizations to emerge by increasing food resources, which in turn allowed for population growth and the founding of cities. The development of a centralized state to collect and protect the food wealth created by agriculture, increased the need for a bureaucracy to manage it. Writing allowed rulers to calculate grain production and record temple donations, distribute food rations to temple employees, and to collect and record taxes. The development of agriculture and writing went hand in hand with development of complex societies in some areas of Africa, while other African regions saw the creation of complex societies that eschewed writing and practiced pastoralism. The earliest Kushite state, Kerma (2600–1600 BCE), is an example of a non-literate, highly complex ancient African state.

To date, few studies on the development of technology in Africa have examined the topic through the transformative early achievements of the African people. African societies focused more on technologies relating to economic and social life rather than the development of military technology. Complicating matters further, the vast majority of existing literature has focused on Western technologies that enabled European colonial incursions on the continent. Born of this history is a tendency to attribute the highly esteemed term "civilization" to those socially stratified and militarily dominant societies.

While African societies contributed greatly to technological developments that changed human culture from gatherer-hunters to settled, complex civilizations, the pursuit of technology in the forms of weapons of war—or as a means of economic exploitation—may have been an interest but was not a driving focus of African civilizations. The focus on "technology" is itself inherently Eurocentric when used as a metric to judge the historical development of human civilizations. Christopher Ehret expresses this well:

> Those societies designated as "civilizations" are treated as if they were the centers of almost all innovation and of all the really important developments. They tend to be viewed, fallaciously, as culturally more complicated, artistically more accomplished, and technologically more advanced than "noncivilizations." The fact that many key technological innovations in human history began, and much great art was produced, in other, less stratified, nonurban societies is glossed over. […] We miss the many human accomplishments of lasting importance that originated in other places entirely. How peculiar, anyway, that today, in an era of democratic thinking given to the idea of

democracy for all people, we should continue in our history books to esteem so highly societies in which wealth and political power were monopolized by the few.[18]

Endnotes

[1]. Elise V. Macarthur, "The Conception and Development of the Egyptian Writing System," in *Visible Language: Inventions of Writing in the Ancient Middle East and Beyond,* ed. Christopher Woods (Chicago: University of Chicago, 2010), 121.

[2]. Joseph Lam, "The Invention and Development of the Alphabet," in *Visible Language: Inventions of Writing in the Ancient Middle East and Beyond,* ed. Christopher Woods (Chicago: University of Chicago, 2010), 189–90.

[3]. Christopher Ehret, *The Civilizations of Africa: A History to 1800* (Charlottesville: University of Virginia Press, 2016), 96.

[4]. Czech Republic (29,000–25,000 BCE); Jiangxi, China (18,000 BCE); Jōmon, Japan (10,500 BCE); the Russian Far East (14,000 BCE); Africa (9,400 BCE); South America (9,000–7,000 BCE); and the Middle East (7,000–6,000 BCE).

[5]. Ehret, *Civilizations of Africa*, 57.

[6]. Harriet Hafsaas, *Cattle Pastoralists in a Multicultural Setting: The C-Group People in Lower Nubia 2500–1500 BCE* (Bergen, Norway: University of Norway, 2006), 77.

[7]. Hafsaas, *Cattle Pastoralists in a Multicultural Setting,* 76; Ehret, *Civilizations of Africa,* 57; Randi Haaland, "Emergence of Sedentism: New Ways of Living, New Ways of Symbolizing," *Antiquity* 71, no. 272 (1997): 378–79, https://doi.org/10.1017/S0003598X00084982.

[8]. Ehret, *Civilizations of Africa,* 225.

[9]. Marla C. Berns, "Art, History, and Gender: Women and Clay in West Africa," *African Archaeological Review* 11 (1993): 129–48, https://www.jstor.org/stable/25130562.

[10]. Bernard Fagg, *Nok Terracottas,* 1st ed. (Lagos: Ethnographica for the National Museum, 1977), 23n16.

[11]. Berns, "Women and Clay in West Africa," 143.

[12]. Ehret, *Civilizations of Africa,* 72.

[13]. Ehret, Civilizations of Africa, 83.

[14]. Ehret, *Civilizations of Africa,*75.

[15]. Ehret, *Civilizations of Africa*, 62.

[16]. Ehret, *Civilizations of Africa,* 14, 150–1. [Danielle, these two were footnotes, which might be why the numbering was off. I've converted them to endnotes and they should be in the correct order.]

[17]. Ehret, *Civilizations of Africa*, 151.

[18]. Ehret, *Civilizations of Africa,* 6.

CHAPTER 3 - COPTIC TEXTILES

TASHIA DARE

What is Coptic?

The modern term "Copt" derives from a corruption of the ancient Greek *aigyptos* via Arabic *qibt*, meaning "Egyptian." This is a reference to native Egyptians as opposed to Greek and Roman settlers. The Coptic period (or Byzantine period) began with the division of the Roman Empire in 395 CE and lasted until 641 CE when the Byzantine Empire was defeated through the Arab conquest.[1] This era belongs to the late Roman or Byzantine Empire through the Arab conquest under the Umayyad, Abbasid, and Fatimid caliphates.[2] During this time Coptic, the Egyptian language that was written using both the Greek alphabet and Demotic (a common form of Egyptian writing), was the lingua franca.

Copt also references the native Egyptian Christian population. Christianity arrived in Egypt during the first century CE, and by the fourth century the region was largely Christianized. After the Arab conquest, and despite periods of persecution by Muslims, Copts were viewed as the intellectual elite and held important positions. However, due to heavy taxation of non-Muslims, many Coptic Christians converted to Islam. In subsequent centuries many more Egyptians became Muslim, resulting in only 10 percent of today's Egyptian population calling themselves Coptic.

Additionally, the term describes an artistic movement that developed as early as the late third century CE and continued until the twelfth century, when the arts and crafts of Egyptian Christians were no longer produced because the artists were by then largely copying Byzantine and Islamic art.[3] Artistically, the term encompasses both pagan art as well as early and medieval Egyptian Christian art. Iconography found in Coptic textiles includes the ancient Egyptian ankh (for the sign of the cross); Greco-Roman motifs such as nereids, gods and goddesses, putti, dancers, animals, and vegetation; Christian images of Biblical figures, saints, and other depictions of the Church; Persian/Sassanian motifs of birds and other animals, rosettes, and trees; and Islamic non-figural designs and inscriptions.

The majority of the textiles we have today were found in Middle Egypt, primarily in Antinoöpolis/Antinoë (modern Sheikh Abada); Panopolis (modern Akhmim); and the Fayum area. These, along with Alexandria, were textile production centers. Many textiles were found in Christian burials. The dry conditions of Egypt helped preserve these delicate fabrics, which were initially made from linen, but later were made from wool, cotton, and eventually—and more rarely—silk.[4] Mummification ceased beginning in the fourth century CE. The general practice was to place a body on wooden planks or on earth rather than in a coffin. Shrouds were kept in place with narrow bandages, imitating earlier mummies. Each shroud covered different parts of the body. The number of wrappings on a body demonstrated the status of the individual. Bodies could be wrapped in tunics, mantles, and furnishing textiles, such as curtains. Furthermore, many had cushions underneath the head, which were often covered with decorated fabrics. The textile wrappings allowed moisture from the body to be gradually drawn out. Wall hangings have also been found in many graves, having previously been kept as heirlooms for years.[5]

Coptic Weaving

Glossary of Weaving Terms

Most Coptic textiles were produced in plain (also known as tabby weave) and tapestry weave techniques using simple looms that were often very wide. Tapestry weave decorations were commonly woven into a basic linen fabric or sometimes sewn onto the linen. This type of weaving allowed the weaver to achieve greater detail than with other techniques, such as highlighting geometric lines or body features of humans and animals and creating variations of outlines. The preservation of selvage in some fragments indicates that the textile was sewn onto linen rather than woven directly into the fabric.

Although tapestry and plain weave were the most common forms of producing textiles, loop weave and sprang, among others, were also employed. Another decorative weave technique was the "flying shuttle." For this method, thin weft threads, usually light in color, were added during weaving to provide contrast through fine internal lines or patterned details.[6] This technique appears to be unique to Coptic textiles.

Linen has a long history in Egypt, but outside of Egypt wool was the most important clothing material because it was easier to produce, provided more insulation, and accepted dyes more readily. It was only after the Greeks conquered Egypt in the fourth century BCE and selected flocks of sheep were introduced that wool gained acceptance in Egypt. However, linen remained the dominant fabric, and until Christianity was introduced wool was forbidden to be used in burials. Consequently, mummies buried during the Roman period were wrapped solely in linen.[7] By later periods, flax, from which linen is produced, was still widely grown in Egypt, but it remained a specialized crop, which made it more expensive than local coarse wool.

The earliest known examples of Coptic clothing are from circa 300 CE. At the time that Christianity was rapidly spreading in Egypt, clothing for both men and women of different classes began to be more decorative after centuries of having largely been plain. Beginning in the third century, limited areas of patterning were added, which eventually developed into pictorial designs. Sleeveless tunics were replaced with sleeved tunics that included decorative vertical double bands. *Clavi*, or shoulder stripes, which were initially full-length, now stopped at the waist and had decorative finials (fig. 1).

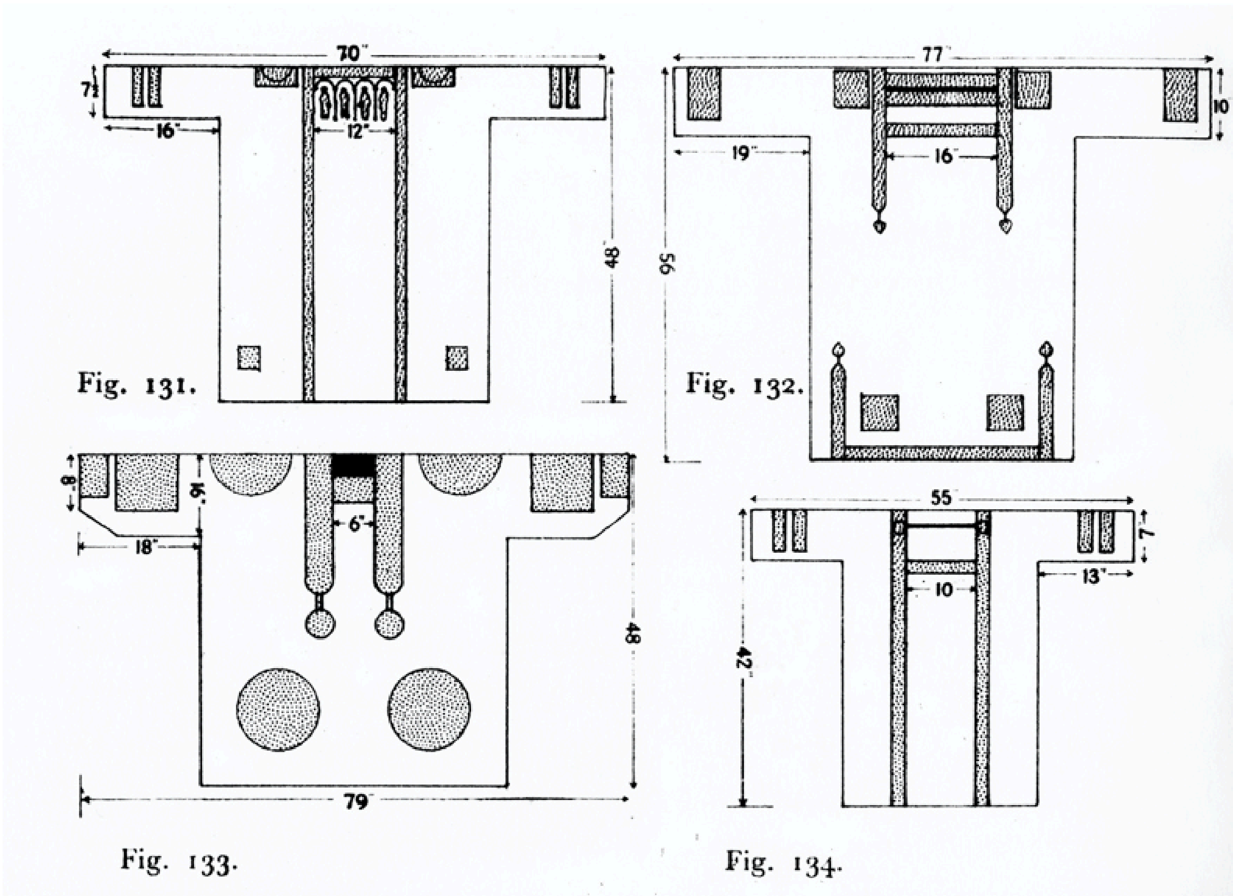


Figure 1: Diagrams of ornamented tunics. Originally in M. Houston, *Ancient Greek, Roman and Byzantine Costume and Decoration* (London: A&C Black Publishers, Ltd., 1931). Reproduced in Thelma K. Thomas, "Coptic Byzantine Textiles Found in Egypt: Corpora, Collections, and Scholarly Perspectives," in *Egypt in the Byzantine World, 300–700*, edited by Roger S. Bagnall (Cambridge: Cambridge University Press, 2007), 151 . Permission Cambridge University Press.

Over time, ornaments were enlarged and true tapestry weave became progressively significant. Designs were borrowed from traditional tapestry furnishings and became more representational even though they were still mainly monochromatic. Human figures were increasingly consistently depicted within a pictorial scene.[8]

By the sixth century, stylization became prominent and was characteristic of later Coptic textiles. Short, stocky human figures with enlarged eyes are the most notable stylized form. This stylization is due to three possible factors: simplification due to repetition of conventional designs, a reflection of a change in aesthetic tastes, and the growing desire for more elaborate weaves through integration of traditional technique with advanced weaves and repetitive designs.[9]

Persia briefly occupied Egypt in the seventh century and it was then that a Persian/Sassanian influence on Coptic textiles emerged. This notably appears in the form of various motifs, including birds, rosettes, and trees, as well as the outlining of motifs (fig. 2).

Figure 2. Coptic textile fragment with braided cord surround, circa ninth century CE; wool and linen. Spencer Museum of Art, University of Kansas, William Bridges Thayer Memorial, 1928.0129. a,b.

This fragment is representative of Sassanian art. The winged tree in the center is typically Sassanian, as is the symmetry of the birds nesting in the branches and the quadrupeds at the foot of the tree. While the date of this textile is later than the Sassanian dynasty (third to seventh century CE), the artistic style and motifs did not vanish. This is also true of Greco-Roman motifs that continued to be used well into the early Christian era. Later, Islamic styles and motifs would overlap with earlier styles and motifs.

In addition to traditional Coptic tunics and shawls, there were also Persian fitted garments, including outer coats, that had long slender sleeves, were sewn to follow the contour of the torso, and opened down the front.[10] Fitted leggings also went with the outer coat.

Although there were entire silk garments and panels of silk appliquéd onto clothing, silk weaving was generally underdeveloped in Egypt, likely because of the continued significance of the linen industry. Egyptian linen continued to be exported and was highly valued by the Arabs. For finer linen textiles, tapestry bands were woven in, but with colored silk instead of wool.[11] Early Fatimid and Abbasid (tenth through early eleventh centuries) textiles were relatively plain compared to later Fatimid textiles of the late eleventh through twelfth centuries, which had multiple bands of complex decoration. This may reflect the changes in representational art in the early Arab period. During this early period, decoration was typically limited to *tiraz* (Persian for "embroidery" and for the current ruler or caliph) inscriptions in Kufic lettering. The last definable examples of Coptic textiles are characterized by the use of inscriptions by Christian weavers who were imitating Arabic artists.[12] After this, Coptic textiles and dress become nearly indistinguishable from those of their Arab rulers.

Coptic Dyes

Our knowledge of dyes in Coptic textiles comes, in part, from historical sources. These include two late third/early fourth century CE Egyptian papyri written in Greek concerning dyeing methods. *Papyrus X Leidensis* includes eleven recipes on dyeing wool, while *Papyrus Graecus Holmiensis* has seventy instructions on dyeing wool.[13] While colored linens are not common, since linen is resistant to dyeing, wool and cotton easily accept and retain color. Colors were produced from a variety of natural dyestuffs. Blues were achieved using indigo or woad (a yellow cabbage-like plant indigenous to Southeast Europe and Central Asia); yellows from saffron, pomegranate, safflower, or weld (originally from the Mediterranean and West Asia); reds from madder root (Southeast Europe, Southwest Asia, and the Mediterranean), henna, lac-dye (India and Southeast Asia), the kermes insect, or the Polish cochineal insect (Eastern Europe); browns from barks, gall, or various fruits; and purples from orchil (extracted from lichen) or the glands of certain snails. Greens were created by double dyeing weld and woad, while oranges were produced by double dyeing madder and weld.[14] Deeper shades were achieved by double dyeing. Unfortunately, some colors, such as the purples and yellows, have now faded to a dull brown.

When Coptic textiles were first produced, dyeing wool and silk was an established technique. One of the most important colors was "true" purple, which was extracted from sea snails. True purple ranged from red-purple to blue-purple, with red-purple having the most important social status since clothing with this color was associated with kingship. In the archaeological record, the darker blue-purple is most commonly found, and often in smaller quantities, on *clavi* or other ornaments against an undyed background. However, even the blue-purple was too expensive for many individuals and imitations were created, primarily from a combination of madder with woad. A Greek list of colors composed in 327 CE has a recipe for an inexpensive version of purple made from madder and the costly Tyrian purple, as well as orchil.[15]

By 600 CE true purple fell out of use because it was a color more suited for wool and did not work well with silk. Nonetheless, the color was so important that the madder-woad imitation served as the primary color and the combination of purple-undyed textiles remained a favorite even after the Arab conquest. By the sixth century, red became an acceptable alternative background for clothing decorations. Through Sassanian influence new color combinations were developed, including several simple bright colors brought together, while purple was replaced with variations of blue. In addition, with the increased usage of silk a new group of animal dyes were employed. Here, insects were utilized, specifically the Armenian cochineal from Turkey, which produced a pinkish red, and the Indian lac, which generated a bright red.[16]

Social Implications

In the first centuries CE, Egypt was a land of multiplicity with Greeks, Romans, and Arabs having conquered the area. With this multiplicity came various religious beliefs, as seen in Coptic textiles. Most textiles are either neutral, in that they depict vegetation or geometric patterns (this is particularly the case with early monochromatic textiles) or else have pagan imagery from the Hellenistic-Roman period, which extended well beyond the collapse of the Roman Empire. There are several instances of overt Christian images, but this is not as prevalent as pagan or neutral images. Moreover, while some textiles have pagan images, these images may be interpreted as Christian. The Spencer Museum of Art at the University of Kansas, for example, has a textile fragment of a decorative roundel possibly from a tunic or curtain that depicts an unidentified male figure in the upper register (horizontal band) in the center seated on a throne (fig. 3). He is surrounded by a nimbus (halo) and is holding a scepter. This figure may represent Jesus or a saintly figure. However, the other figures surrounding him, as well as the figures in the third register (winged putti carrying offerings), are not clearly Christian, nor are the geometric designs in the second register. Consequently, this textile could be interpreted as either Christian and/or pagan.

Figure 3. Coptic textile fragment, circa sixth to eighth century CE; linen and wool. Spencer Museum of Art, University of Kansas, William Bridges Thayer Memorial, 1928.0018.

Like other early Christians, Coptic Christians adopted many pagan motifs as their own, in turn Christianizing them. This was commonplace in part because the Hellenistic-Roman style and motifs immediately preceded the Coptic period and overlapped with it. This is seen in the Coptic textiles, particularly in the third and fourth centuries, but even as the style changed to be more abstract, reflecting Byzantine art, for the most part classical motifs stayed the same. This was also the case for other parts of the ancient Near East, such as in Syria, where textiles with classical motifs and styles were found at Dura-Europos, Palmyra, and Halabiyeh (Zenobia).[17]

The effects of multiplicity on Coptic art in general, as well as the textiles specifically, recall the influence of multiplicity seen in mummy portraits, which were found primarily in the Fayum region. These portraits were produced between 30 CE and as late as the mid-fourth century CE (fig. 4).

Figure 4. Portrait of a Woman, Egyptian (Antinoöpolis), Roman Period (130–161 CE). Encaustic on wood panel with gilt stucco, 17 l/2x 6 3/4 inches (44.5 x 17.1 cm). The Nelson-Atkins Museum of Art, Kansas City, Missouri. Purchase: William Rockhill Nelson Trust, 37-40. Photo courtesy Nelson-Atkins Media Services / Jamison Miller.

The Hellenistic and Roman Egyptians made a concerted effort to exhibit not only their social status, but also their religious and ethnic affiliation. For visitors to the home during a person's lifetime, and for future generations who would see a portrait on that person's mummy, it was important to include features that indicated who the deceased had been in society. This was especially true regarding ethnicity. When the Greeks first arrived in Egypt, many married locals. In the process, Greeks, and subsequently Romans, adopted Egyptian religious practices and beliefs. In turn, the Greeks brought their skills as artists and their educational system. The mummy portraits reflect these changes in the Egyptian landscape. There was a sense of multiple belonging, if not by blood, then by cultural and religious ties.

While for the Copts this multiple belonging is more organic, there is still a realization and, at least to some degree, acceptance of their cultural connections with the classical past that long remained in the region. After the Arab invasion, this idea continued. As previously mentioned, Arabic/Islamic motifs and color schemes entered Coptic art and textiles, almost melding both worlds together.

Art represented on textiles was a means for Copts to express their sense of multiple belonging. Two roundels from the Spencer Museum of Art demonstrate this sense of belonging and multiplicity well (figs. 5 and 6). They show a change in style from Hellenistic-Roman to indigenous, but the iconography is pagan, remnant of the classical period, or perhaps is pagan that has been transformed to represent Christian beliefs.

Finally, it is important to note that, from at least the period of the Persians (525–404 BCE) through the Roman Empire to the Islamic Conquest, Egypt was one of the first known multi-cultural civilizations. This was in large part because of Egypt's proximity to Africa, Asia, and Europe. Egypt is at the confluence of these three continents and all that they bring with them.

Figure 5. Coptic textile fragment, circa sixth to eighth century CE; wool and linen. Spencer Museum of Art, University of Kansas, William Bridges Thayer Memorial, 1928.0126.

These two ancient roundels were cut from larger textiles and may have been sewn together in the modern period to sell to tourists. The center roundel has two winged putti (nude young males) and two wingless putti. The central figure, possibly a young female, is holding a blue bird. The two figures above are holding a bowl of fruit, which is a symbol of plenty. The two-winged figures are presenting offerings, which is typical of putti. Between the putti are quadrupeds. The outer roundel shows Sassanian Persian horsemen, wearing short tunics and leggings, fighting lions. The Sassanians (also referred to as Sassanids, third to seventh century CE) were in Egypt between the sixth and seventh centuries CE, having originated in Persia.

Figure 6. Coptic textile fragment, circa sixth to eighth century CE; wool and linen. Spencer Museum of Art, University of Kansas, William Bridges Thayer Memorial, 1928.0126 (detail of inner roundel; photo taken by Tashia Dare).

Loom: Tool used to stretch warp threads in equal tension while weaving; often includes heddle rods, lashes, and pedals.

Loop Weave (short and long): Added weft threads that protrude from the surface of the fabric; used as decoration.

Plain Weave (also known as tabby weave or cloth weave): One of the simplest weaves. One weft thread is woven under and over alternate warp threads and the next weft thread is woven over and under alternate warp threads. Each warp and weft thread is visible.

Selvage: The finished edge of a textile that is parallel to the warp and is often of a heavier weave than the body of the textile.

Sprang: Threads stretched across a frame and twisted and interlaced.

Tapestry weave: A weave that has more wefts than warps with the warp being nearly invisible; in patterns, the wefts are woven back and forth as needed.

Warp: Threads stretched across a loom between the warp and cloth beams that forms the groundwork of a fabric. Warp threads run lengthwise.

Weft: Threads run widthwise across a textile, passing over and under the warp threads.

Bibliography

Baginski, Alisa, and Amalia Tidhar. “Glossary.” In *Textiles from Egypt, 4th–13th Centuries C.E.*, 24–33. Jerusalem: L. A. Mayer Memorial Institute for Islamic Art, 1980.

Granger-Taylor, Hero. “Coptic Textiles in the Detroit Institute of Arts.” *Bulletin of the Detroit Institute of Arts* 79, no. 1/2 (2005): 46–59. http://www.jstor.org/stable/41505003.

Hunt, Lucy-Anne, Hero Granger-Taylor, and Dominic Montserrat. “Coptic Art.” Oxford Art Online. Grove Art Online. (2003). http://www.oxfordartonline.com/groveart/view/10.1093/gao/9781884446054.001.0001/oao-9781884446054-e-7000019365.

Hofmann-de Keijer, Regina. “Dyestuffs in Coptic Textiles.” In *Verletzliche Beute: Spätantike und frühislamische Textilien aus Ägypten* (*Fragile Remnants: Egyptian Textiles of Late Antiquity and Early Islam*), edited by Peter Noever, 26–36. Vienna: Hatje Cantz, 2005.

Thomas, Thelma K. “Coptic Byzantine Textiles Found in Egypt: Corpora, Collections, and Scholarly Perspectives.” In *Egypt in the Byzantine World, 300–700*, edited by Roger S. Bagnall, 137–62. Cambridge: Cambridge University Press, 2007.

Van Strydonck, Mark, Antoine De Moor, and Dominique Bénazeth. “14C Dating Compared to Art Historical Dating of Roman and Coptic Textiles from Egypt.” *Radiocarbon* 46, no. 1 (2004): 231–44.

Völker, Angela. “Late Antique and Early Islamic Textiles.” In *Verletzliche Beute: Spätantike und frühislamische Textilien aus Ägypten* (*Fragile Remnants: Egyptian Textiles of Late Antiquity and Early Islam*), edited by Peter Noever, 8–19. Vienna: Hatje Cantz, 2005.

Further Reading

Carroll, Diane Lee. *Looms and Textiles of the Copts: First Millennium Egyptian Textiles in the Carl Austin Reitz Collection of the California Academy of Science.* (Memoirs of the California Academy of Sciences). Seattle: University of Washington Press, 1988.

Hoskins, Nancy Arthur. *The Coptic Tapestry Albums and the Archaeologist of Antinoé, Albert Gayet*. Seattle: University of Washington Press, 2004.

Lewis, Suzanne. *Early Coptic Textiles. Stanford Art Gallery. Stanford University. May 4 to May 25, 1969.* Stanford: Stanford University Department of Art, 1969.

Maguire, Eunice Dauterman. *Weavings from Roman, Byzantine and Islamic Egypt: The Rich Life and the Dance*. Champaign, IL: Krannert Art Museum and Kinkead Pavilion, 1999.

Rutschowscaya, Marie-Hélène. *Coptic Fabrics*. Paris: Adam Biro, 1990.

Trilling, James. *The Roman Heritage. Textiles from Egypt and the Eastern Mediterranean 300 to 600 AD*. Washington, DC: Textile Museum, 1982.

[1]. Mark Van Strydonck, Antoine De Moor, and Dominique Bénazeth, "14C Dating Compared to Art Historical Dating of Roman and Coptic Textiles from Egypt," *Radiocarbon* 46, no. 1 (2004): 231.

[2]. Hero Granger-Taylor, "Coptic Textiles in the Detroit Institute of Arts," *Bulletin of the Detroit Institute of Arts* 79, no. 1/2 (2005): 48, http://www.jstor.org/stable/41505003.

[3]. Lucy-Anne Hunt, Hero Granger-Taylor, and Dominic Montserrat, "Coptic Art," Oxford Art Online, Grove Art Online, 2003, https://doi.org/10.1093/gao/9781884446054.article.T019365.

[4]. Granger-Taylor, "Textiles," 48.

[5]. Granger-Taylor, "Coptic Textiles," 48.

[6]. Angela Völker, "Late Antique and Early Islamic Textiles," in *Verletzliche Beute:Spätantike und frühislamische Textilien aus Ägypten (Fragile Remnants: Egyptian Textiles of Late Antiquity and Early Islam)*, ed. Peter Noever (Vienna: Hatje Cantz, 2005), 17; Alisa Baginski and Amalia Tidhar, "Glossary," in *Textiles from Egypt, 4th–13th Centuries C.E.* (Jerusalem: L.A. Mayer Memorial Institute for Islamic Art, 1980), 26.

[7]. Granger-Taylor, “Coptic Textiles,” 48.

[8]. Granger-Taylor, “Coptic Textiles,” 49–50.

[9]. Granger-Taylor, “Coptic Textiles,” 51.

[10]. Thelma K. Thomas, “Coptic Byzantine Textiles Found in Egypt: Corpora, Collections, and Scholarly Perspectives,” in *Egypt in the Byzantine World, 300–700*, ed. Roger S. Bagnall (Cambridge: Cambridge University Press, 2007), 150–51.

[11]. Granger-Taylor, “Coptic Textiles,” 53.

[12]. Granger-Taylor, “Coptic Textiles,” 53.

[13]. Regina Hofmann-de Keijer, “Dyestuffs in Coptic Textiles,” in *Verletzliche Beute: Spätantike und frühislamische Textilien aus Ägypten (Fragile Remnants: Egyptian Textiles of Late Antiquity and Early Islam)*, ed. Peter Noever (Vienna: Hatje Cantz, 2005), 27.

[14]. Hofmann-de Keijer, “Dyestuffs in Coptic Textiles,” 31.

[15]. Hofmann-de Keijer, “Dyestuffs in Coptic Textiles,” 27.

[16]. Information in this paragraph is indebted to Granger-Taylor, “Coptic Textiles,” 55–56.

[17]. Thomas, “Coptic Byzantine Textiles,” 154.

CHAPTER 3 - COPTIC TEXTILES TERMS

TASHIA DARE

Loom: Tool used to stretch warp threads in equal tension while weaving; often includes heddle rods, lashes, and pedals.

Loop Weave (short and long): Added weft threads that protrude from the surface of the fabric; used as decoration.

Plain Weave (also known as tabby weave or cloth weave): One of the simplest weaves. One weft thread is woven under and over alternate warp threads and the next weft thread is woven over and under alternate warp threads. Each warp and weft thread is visible.

Selvage: The finished edge of a textile that is parallel to the warp and is often of a heavier weave than the body of the textile.

Sprang: Threads stretched across a frame and twisted and interlaced.

Tapestry weave: A weave that has more wefts than warps with the warp being nearly invisible; in patterns, the wefts are woven back and forth as needed.

Warp: Threads stretched across a loom between the warp and cloth beams that forms the groundwork of a fabric. Warp threads run lengthwise.

Weft: Threads run widthwise across a textile, passing over and under the warp threads.

CHAPTER 3 - DOING HISTORY: MATERIAL CULTURE

TASHIA DARE

Material culture is about the social relationship between people and things. It is not only about how humans have shaped objects, but also about how objects have shaped humans. When studying material culture there are several questions that archaeologists, anthropologists, historians, art historians, and others seek answers to. Many of the questions are concerned with social dynamics and power structures, wealth and status, religion, politics, symbolism, priorities and interests, tradition, creativity, and ingenuity. These questions focus on identity formation, relationships, experiences, and how these are communicated. They are also concerned with trade and local and long-distance economies. It is about social interactions among different populations and the adoption and adaption of methods and techniques of producing objects. The questions are also about what was meaningful to individuals and groups of people in a particular time and/or space. What did someone think about when they incorporated a specific image, symbol, and/or text on an object? What was their understanding of certain symbols or images? How did they understand what came before them and how do we see them adapt that to their own time and purpose?

Some questions are reflective of us today and what has been passed down over generations. What are people interested in studying and collecting and why? Where objects are located today, such as in museums or private collections, and how they are displayed says much about our views today as well as where we have come from. It speaks to how we have come to understand certain histories and how we categorize or classify material culture, people, and geography. Our perspectives change over time based on the information we learn and our own societal viewpoints. What was classified as one thing in the past may continue to be passed down to us in that manner, but many people today question the underpinnings behind those classifications.

The questions below focus on objects, but many of them may also be applied to built structures that could be considered material culture, such as temples, churches, and other places of worship; houses; historical buildings; and historical or archaeological sites.

1. Who made the object? Was the piece commissioned by an individual, a group, or an institution for a specific reason, or did the creator make the object for their own purpose?
2. What material is the object made of? How were the colors created? What is the quality of craftsmanship? What was available to the creator and what was their training?
3. What is on the object? What iconography (range or type of images) or text is there and why?
4. When was the object created? What was happening at the time of production?
5. Why was the object made? What purpose did it have? Was it for rituals, practical daily use, or for another purpose? Was there any symbolic meaning given to the object? How did it function?
6. Was the object created in one place and moved to another location, whether local or long

distance (for example, an amphora produced in Rome but shipped to Asia Minor or Roman Britain)? What does this say about social, cultural, and economic trade; the rise and fall of empires and colonies; imperialism; creativity; ingenuity; adaption; and nature and climate change?

7. Where was the object placed within its original setting? Was it in a home, in or on the exterior of a place of worship or another type of building? How was the object supposed to be seen, such as overhead or at eye level? What was the purpose by the creator and/or patron of placing something at that vantage point? Inside a building the same questions can be asked, as well as others. How was the object placed in relation to other objects? Is it in isolation or in a group? Was it placed in a niche or on an altar or was it hanging on a wall or ceiling? How did the creator and/or patron want people to interact with the object(s)?
8. Where was the object found? Was it found in its original context or was it found in another location such as in a museum, in a personal collection, or elsewhere?
9. When an object is described as art, and art is an early form of technology, we must ask what makes this object art. Was the object considered "art" when it was first created or do we classify it today as art rather than as it originally was intended? Does it have both artistic and practical qualities? How is the object displayed to the public?

For example, there are ancient Greek stelae or urns on display in art museums. While these have artistic qualities, their original function was as a grave marker or as a storage vessel. The same is true for ancient Egyptian sarcophagi. The decorations on these are often intended to help the deceased through the afterlife and to identify the individual. In this case, the decorations both have practical implications for the deceased but are also artistic.

10. Concerning the above questions, who has the authority to name or classify material culture at any given time? The creator, the patron, scholars, or another entity? Why that particular person or persons? What is the reason or goal of making such a classification?

Figure 1. Portrait of the Boy Eutyches, 100–150 CE, Roman Period (30 BCE–323 CE). Encaustic on wood and paint, 38 cm (14 15/16 in.) × 19 cm (7 1/2 in.). New York Metropolitan Museum of Art. Gift of Edward S. Harkness, 1918, 18.9.2.

In the Roman world portraiture played a significant role as a mode of recording individual appearance and social standing. The portrait genre is an enduring legacy of the Romans that continues to be employed today.[1] From the early first century CE to the third century CE, hundreds of funerary portraits (commonly referred to as mummy portraits) were created for Graeco-Roman elites living in Egypt. These portraits serve not only as a way to memorialize the deceased, but they also record important personal and social identities of the those depicted. They demonstrate the family, religious, cultural, and professional ties of a multicultural and multiethnic Egypt during the Roman Empire (27 BCE–323 CE). The portraits display the interrelations of the Hellenistic (Greek), Roman, and Egyptian worlds.

Prior to the Roman era the Greeks governed Egypt from approximately 332 BCE–27 BCE. One of Alexander the Great's generals, Ptolemy I, took over Egypt, founding the Ptolemaic Dynasty that ended with the death of the famous Cleopatra VII in 30 BCE. The early settlers in the Greek region of the Fayum Oasis were given land, and many throughout Egypt married native Egyptians.[2] In 27 BCE the Roman Emperor Augustus gained control of Egypt. Greek-speaking residents likely saw themselves as both Greek and Egyptian. It was common in the Roman East to have dual or plural identities, to retain both local identification and pride as well as to take part in metropolitan culture in the Greek regions of the Roman Empire.[3] Roman authorities put the descendants of the early Greek settlers in charge of towns and villages of the Fayum, giving them privileged status and a poll-tax rate reduction.[4] When the Ptolemies and Romans arrived in Egypt they brought with them their language, cultural practices, clothing and hairstyles, and artistic techniques. In turn, they adopted aspects of ancient Egyptian religious beliefs and burial practices. This included the adoption of some Egyptian gods and goddess, notably Osiris and Isis (many Greek and Roman temples were dedicated to Isis). Additionally, like ancient Egyptians before them, many of the elite were mummified and wrapped in linen and then placed in a sarcophagus decorated with Egyptian hieroglyphs and a portrait covering the deceased's face. Early Roman-Egyptian portraits are particularly lifelike, utilizing Roman verism or naturalism, and are exemplars in Greek painting techniques, while later portraits and funerary masks are less personalized. It is important to note that these portraits are some of the only surviving works of Greek painting. Wet and humid conditions in Greece did not allow much for the preservation of ancient Greek paintings, unlike in Egypt, where the arid environment preserved most organic material.

The funerary portrait of the boy Eutyches is a beautiful example of a Roman-Egyptian funerary portrait (sometimes referred to as a panel) (fig. 1). We can apply many of the questions listed above to this portrait. To begin, who made this portrait? At this point, scholars do not know. Throughout much of the ancient Near East artists usually did not sign their names. Since this portrait is of a child, we can imagine that his parents or at least his father may have commissioned the portrait, although there may have been another individual who commissioned the panel, as noted below. While some scholars suggest that this type of portraiture was commissioned during the lifetime of the individual, in this case it was likely commissioned shortly after the child's death.

Second is the question of how the portrait was created, what materials were used, and the quality of craftsmanship. While many portraits were painted in tempera, most were produced with encaustic on wood or on linen shrouds. In tempera, the pigments are mixed with a water-soluble agent, usually an animal glue. In encaustic, the pigments are mixed with hot or cold beeswax and other ingredients such as resin, egg, or linseed oil. Brushes and hard tools were used to execute the portrait. Sometimes only a brush was used throughout, while in others we see the use of a brush before a hard tool was utilized to blend colors and to add "wound" marks that create texture and depth.[5] Eutyches's portrait was created with encaustic directly applied to wood without a distemper ground (a type of whitewash), as evidenced at the top and bottom of the portrait where there is no paint (linen wrappings would have hidden these bare areas).[6] We can see the brushstrokes and the use of a hard tool, especially in Eutyches's neck and clothes, as well as in the background. The craftsmanship of this portrait is of exceptionally high quality, a symbol of both the painter's skill as well as the status of the person or persons who commissioned or paid for the panel. The style of painting, which originated in Classical Greece in the fifth and fourth centuries BCE, the shadowing, the modeling of his face, and other features are Greek in nature, while the use of naturalism in depicting the child's face is Roman.[7] Furthermore, the artist depicts Eutyches's fleshy face as a golden brown. Having tanned skin was an important social aspect for Greek males.

Next is the question of what is on the object, the iconography and/or text, and why. The depiction of Eutyches's clothes indicates a Roman affiliation. He wears a white Roman tunic with a narrow purple *clavus* (a vertical stripe) over the right shoulder and a mantle draped over the left shoulder.[8] Typically, the *clavi* (plural of *clavus*) in Rome indicated social rank, but in Egypt it may have demonstrated the individual's general sense of affiliation with Roman customs.[9] In black or dark purple ink along the neckline of Eutyches's garment is a Greek inscription. Greek was one of the primary languages in the ancient Mediterranean. Additionally, it is not uncommon to see Greek inscriptions on funerary portraits, which includes the name of the deceased and a short epitaph. These can often be found around the neck area. Other times the identity of the portrayed may appear on the sarcophagus itself, just as ancient Egyptians had previously done with their deceased. Scholars debate over aspects of the inscription on Eutyches's portrait. What is clear is the boy's name, "Eutyches, freedman of Kasanios." What is in question is the rest of the inscription, which either says "son of Herakleides Evandros" or "Herakleides, son of Evandros." It is also uncertain whether the "I signed" at the end of the inscription indicates the act of manumission (freeing a slave) or is the painter's signature.[10] It is very uncommon for painters to sign their name on a funerary portrait. In addition, the verb used here is different than what is typically used by artists signing their work.[11] The combination of Eutyches's Roman clothes and the Greek inscription demonstrate his and possibly his parents' (or his father's) plural identity in Egypt.

One of the most important questions is when an object was created. This helps scholars to better understand the object they are studying and to place that object in a wider context. For funerary portraits, dating is often based on clothing, hairstyles, and/or women's jewelry. It also is dependent on the context of where the mummified human remains were found. If they were found within their original location, scholars can date an object based on other objects found with the mummified human remains. This is possible because even in remote parts of the Roman Empire people generally attempted to follow imperial fashion and certain aspects of daily life, such as Latin handwriting and tableware, which were fairly consistent across the empire. In the case of the portraits, many individuals may have been engaged in the local administration on behalf of the empire, which explains the desire to dress like those living in Rome. We also see this in portraits in Syria and Libya of the same time period as the Roman-Egyptian portraits.[12] A great example of dating based on features depicted in the portrait is that of a panel of a young woman wearing a blue mantle (fig. 2). Scholars date this portrait to Emperor Nero's reign (54–68 CE) based on the woman's hairstyle, which is modelled after Nero's mother, Agrippina. Eutyches's portrait dates to 100–150 CE, during Trajan, Hadrian, or Antoninus Pius' reigns. Scholars date this portrait based on his clothing, the orderliness of his hair, and by the high quality of the portraiture.[13]

Another important question is why an object was created and what its purpose was. As previously noted, Roman-Egyptian funerary portraits were created to record an individual's personal and social identities. Scholars debate whether the funerary portraits were produced during the lifetime of the individual depicted or posthumously. If they were created during the lifetime of the individual, then the image would have been placed within the person's home, likely hanging on a wall as a reminder to any viewer of the cultural and social status of the person. It is much like what people have done over the centuries who have had their portraits painted or their picture taken. Upon death, the Roman-Egyptian portraits would have been cut in the upper corners to fit over the face of the mummified body within a sarcophagus and inserted into linen wrappings. Portraits may have been processed (*ekphora*) along with the body through the hometown or village of the deceased before being taken to embalmers to be mummified.[14] The *ekphora* was a Greek rite. It was custom to keep mummies of loved ones in the home or in a chapel for quite a length of time, which also allowed family members and others to view the portrait and remember that person. The Roman practice of the Cult of the Ancestor was significant throughout the empire and was related to the above custom. On the other hand, some portraits were painted at the time of death, notably those of children. In the case of Eutyches, his death may have been unexpected and thus his parents (or his father) or Kasanios, who freed Eutyches, commissioned the portrait after his death as a means of memorializing him and his place within society.[15] Slavery in ancient Rome was different than we understand slavery today. Individuals could be freed by their owners or buy their own freedom. We do not know what the situation was for Eutyches. If his parents, or specifically his father, commissioned the portrait, that may also be a sign of his parents' or his father's status in Egypt at the time and indicate the socio-economic situation Eutyches would have grown up in and what he would have been expected to be as an adult. However, if Kasanios commissioned the portrait, that demonstrates his position in local society and may also indicate his love for Eutyches, almost as if he was his own son.

The provenance, or origin, of this portrait is unknown. One source suggests that it may originate from the Philadelphia area because the name Kasanios was popular in the area during the second century CE.[16] Philadelphia is in the Fayum Oasis region. The Fayum is where many funerary portraits were found, although several others have been found in Middle Egypt and as far north as near Alexandria. Another source suggests the portrait is from Antinoöpolis, which is in Middle Egypt, although this is in question.[17] Regardless, the portrait would likely have been produced locally rather than having been made in a distant city. The materials used to create the portrait would also likely have been available locally.

Today, many funerary portraits are in museums, specifically art museums, either on display or in storage. The majority of portraits were discovered by archaeologists in the late nineteenth to early twentieth centuries, although several were found much earlier and more recently. Some portraits were found with their mummified human remains and were preserved intact, while others had been previously detached from the mummified human remains, such as that of Eutyches. In some cases, the mummified human remains to which the portrait was attached either were not preserved or were discarded completely, as the portrait was viewed as being more valuable. While today we view the portraits as works of art, we also must remember that these portraits in their time had very real implications for the individuals portrayed and for their families. They were created to record a person's personal, social, cultural, and religious identities and were a reminder to anyone seeing the portrait, whether in the home where it was hung on the wall or before burial, who this person is and was. Furthermore, in death, the portraits serve to immortalize and memorialize the individual. Consequently, the people depicted in these portraits must be viewed by us with respect, as any human being deserves. For us today, these portraits are beautiful works of art that give us a glimpse into the lives of those living in Egypt and in the Roman empire nearly 2,000 years ago.

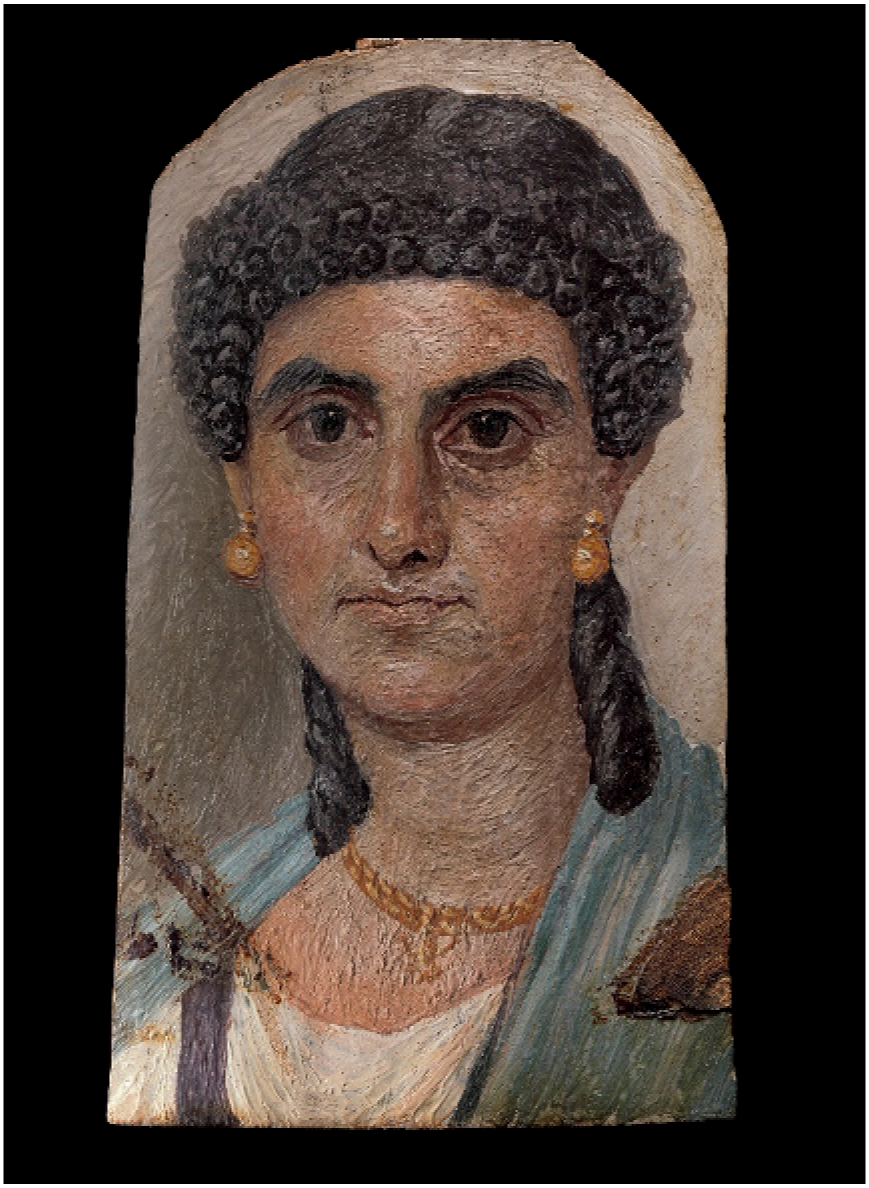


Figure 2. Panel painting of a woman in a blue mantle, 54–68 CE, Roman Period (30 BCE–323 CE). Encaustic on wood, 38 cm (14 15/16 in.) × 22.3 cm (8 3/4 in.). New York Metropolitan Art Museum. Director's Fund, 2013, 2013.438.

Bibliography

Doxiadis, Euphrosyne. *The Mysterious Fayum Portraits: Faces from Ancient Egypt*. New York: Harry N. Abrams, Inc., 1995.

Campbell, Thomas P. *The Metropolitan Museum of Art Guide*. New Haven, CT: Yale University Press, 2012.

"Portrait of the Boy Eutyches." Metropolitan Art Museum. https://www.metmuseum.org/art/collection/search/547951?searchField=All&sortBy=Relevance&where=Egypt&ft=mummy+portrait&offset=0&
and Susan Walker and Morris Bierbrier, with Paul Roberts and John Taylor. *Ancient Faces: Mummy Portraits from Roman Egypt*. London: British Museum Press, 1997.

Further Reading:

Bierbrier, Morris L. *Portraits and Masks: Burial Customs in Roman Egypt*. London: British Museum Press, 1997.

Borg, Barbara E., and G. W. Most. "The Face of the Elite (Complexities of Cultural Identity Illustrated by Mummy Portraits from Graeco-Roman Egypt)." *Arion: A Journal of Humanities and Classics* 8, no. 1 (2000): 63–96.

Geoffroy-Schneiter, Bérénice. *Fayum Portraits*. New York: Assouline, 2004.

Montserrat, Dominic. *Sex and Society in Graeco-Roman Egypt*. London: Kegan Paul International, 1996.

Montserrat, Dominic. "*Your Name Will Reach the Hall of the Western Mountains*": Some Aspects of Mummy Portrait Inscriptions." *Archaeological Research in Roman Egypt: The Proceedings of the Seventeenth Classical Colloquium of the Department of Greek and Roman Antiquities, British Museum, held on 1–4 December 1993*. Journal of Roman Archaeology Supplementary Series Number 19, ed. Donald M. Bailey, 177–86. Ann Arbor, MI: Thomson-Shore, 1996.

Riggs, Christina. "Facing the Dead: Recent Research on the Funerary Art of Ptolemaic and Roman Egypt." *American Journal of Archaeology* 106, no. 1 (2002): 85–101.

Thompson, David L. *Mummy Portraits in the J. Paul Getty Museum*. Malibu, CA: J. Paul Getty Museum, 1982.

[1]. Susan Walker and Morris Bierbrier, with Paul Roberts and John Taylor, *Ancient Faces: Mummy Portraits from Roman Egypt* (London: British Museum Press, 1997), 14.

[2]. Walker and Bierbrier, *Ancient Faces,* 15.

[3]. Walker and Bierbrier, *Ancient Faces,* 20.

[4]. Walker and Bierbrier, *Ancient Faces,* 15.

[5]. Walker and Bierbrier, *Ancient Faces,* 22.

[6]. Euphrosyne Doxiadis, *The Mysterious Fayum Portraits: Faces from Ancient Egypt* (New York: Harry N. Abrams, Inc., 1995), 33.

[7]. "Portrait of the Boy Eutyches," Metropolitan Art Museum,

https://www.metmuseum.org/art/collection/search/
547951?searchField=All&sortBy=Relevance&where=Egypt&ft=mummy+portrait&offset=0&

[8]. “Portrait of the Boy Eutyches.”

[9]. Walker and Bierbrier, *Ancient Faces,* 16.

[10]. “Portrait of the Boy Eutyches.”

[11]. Walker and Bierbrier, *Ancient Faces,* 116.

[12]. Walker and Bierbrier, *Ancient Faces,* 14.

[13]. Walker and Bierbrier, *Ancient Faces,* 116.

[14]. Walker and Bierbrier, *Ancient Faces,* 15.

[15]. Thomas P. Campbell, *The Metropolitan Museum of Art Guide* (New Haven, CT: Yale University Press, 2012), 59.

[16]. Doxiadis, *The Mysterious Fayum Portraits*, 33.

[17]. Walker and Bierbrier, *Ancient Faces,* 116.

PART IV

CHAPTER 5 - THE MEDIEVAL PERIOD (500 TO 1400 CE) – EUROPE

The Medieval Period (500 to 1400 CE) – Europe

An early fifteenth-century astronomical clock from the town square in Prague. A mechanical skeleton representing death strikes the hours, which provides a nice insight into medieval sensibilities.

CHAPTER 5 - LEARNING OBJECTIVES

HANS PETER BROEDEL

1. When you finish this chapter you should be able to explain how medieval science and technology were an expression of medieval culture and world view.
2. As part of this explanation, you should also be able to identify particular aspects of technology that reflected the concerns of different elements of medieval society.
3. Similarly, you should be able to explain how medieval science (natural philosophy) served the purposes of scholars and the church.
4. You will also understand that technologies and science do not exist in isolation but in close relationships.
5. Finally, you should appreciate the European middle ages were not some scientific and technological "Dark Age," but an era of innovation and creativity.

CHAPTER 5 - INTRODUCTION AND THESIS

HANS PETER BROEDEL

We are accustomed to think of the middle ages, that roughly thousand-year span between the Fall of the Roman Empire in the West and the dawning of the modern world around 1500 CE, as a period of ignorance and benighted superstition. This is largely because the term "middle ages" was invented by very smart, but very conceited, Renaissance scholars who liked to contrast their own considerable achievements with what they saw as the intellectual wasteland that preceded them. This bit of slander also suited the purposes of reforming Protestants who used the alleged darkness of the medieval centuries as evidence of the stifling influence of the Catholic Church. Yet, as we shall see, such an attitude is mostly wrong and completely unfair: **medieval people made great contributions to the development of European science and technology without which the future achievements of the moderns would have been impossible.**

Sometimes medieval contributions are difficult to understand because they do not look like what we expect or are accustomed to. When we study the middle ages, however, we need to remember that neither science nor technology progresses just because "that's what it does," but because change brings benefits to certain sufficiently important members of society. A warrior aristocracy dominated medieval Europe for whom the capacity for violence provided not only the means to power, but also its very justification. For this reason, technologies that enhanced force and that maximized the ability of a relatively small number of men to project violence as efficiently, safely, and widely as possible, were embraced and encouraged. Castles, steel swords and armor, heavy warhorses, Viking ships: these iconic images define the middle ages in our imaginations, but they were also extremely effective and functional expressions of medieval technological goals.

Other medieval technologies responded to the needs of society more broadly. Agricultural innovations, many imported from Asia, spread rapidly because they were profitable: higher crop yields meant better, longer lives for peasants and more rents for lords. The use of waterpower for mills and other industrial technologies came rapidly where it was profitable, and slowly or not at all where it was not. The development of clocks, bookkeeping, and new techniques of manufacture met the quite different needs of growing urban communities. Finally , an increasing dependence on writing served the needs of a broad constituency, including urban guilds, governments, and, of course, the church.

In a quite similar way, medieval natural philosophy (or we could say "medieval science" since it endeavored to better understand and describe the natural world) reflected the values, goals, and worldview of its most important stakeholder, the Church. Because the natural world, God's creation, was a direct expression of his thought and will, to better understand it led to a better understanding of God. The natural world was perceived as a kind of text, a "book of nature," which could and should be examined and studied in ways much like scripture. Naturally, for this reason medieval science was required to conform to basic Christian teachings, yet because the Church was also steeped in classical and Latin traditions, the Greco-Roman inheritance provided a second basis for understanding the natural world. How these two traditions coexisted, adapted, and merged determined in large part the direction of medieval science.

CHAPTER 5 - HISTORICAL SKETCH OF THE MIDDLE AGES

HANS PETER BROEDEL

The middle ages lasted a very long time, during which far too many important things happened to summarize here, but a quick sketch of the period may be useful. Historians usually divide the middle ages the way they divide almost everything else, into three parts: the early, the high (saying the "middle – middle ages" sounds silly), and the late.

The early middle ages (c. 500 – c. 1000) are usually said to begin when German warlords started carving new kingdoms out of the old Roman Empire. This is the era often termed the "Dark Ages," and, truthfully, much of Roman culture was indeed lost. Population fell sharply, though this was more the result of a horrendous plague than barbarian massacres.1 Most cities either disappeared entirely or shrank down to the size of villages. Schools vanished, and almost no one outside of the clergy was able to read or write. The authority of kings suffered from a combination of scarce resources, most of which were funneled into their nearly constant wars, too powerful subordinates, and inadequate administrative institutions. This meant that they did not have sufficient wealth to project their authority. There were exceptions, of course, and the most important was the reign of Charlemagne (768-814), who, through inheritance and conquests, managed to forge an Empire comprising most of what is today France, Italy, Germany, and the Low Countries (the modern Netherlands and Belgium) Charlemagne's empire did not long endure, however, collapsing under the weight of foreign invasion, constant civil war, endemic local violence, and the tragic incompetence of his successors. But despite this litany of unfortunate events, in many respects conditions began to improve toward the middle of this period, as population finally began to grow again, and economic activity and crop yields increased.

With the year 1000 the high middle ages begin, and the pace of improvement picked up speed.2 Increasingly dense local trade networks allowed people to specialize in doing whatever was most profitable, because they could use their surplus to buy those goods that they did not produce themselves. Local trade encouraged more adventurous merchants to travel farther afield in search of goods in high demand back home. The weather improved; food was more plentiful; and life expectancy, although still very low by modern standards, went up as a result. All things considered, if you didn't mind being a serf—a sort of semi-free tenant farmer whose labor supported everyone else—it was a good time to be a peasant. Improved personal security came hand in hand with better economic conditions, as did the growing power kings and princes. After years of being invaded by just about everyone, European rulers now decided it was their turn and launched aggressive campaigns to conquer territory in the Iberian peninsula, around the Baltic, and even as far away as the Eastern Mediterranean. In sum, all those deeds and images that we associate with the word "medieval"—mighty castles, soaring cathedrals, tournaments, crusades—all were made possible by the economic expansion of the high middle ages.

But all good things must come to an end, and the glory days of medieval Europe ended with almost-shocking speed. By start of the late middle ages, around 1300, the weather was turning colder and failing harvests led to severe, but localized famines. Pope Clement V (r. 1305 -1314) decided to quit Rome for the more genteel environs of Southern France, and sparked a spiritual crisis that lasted over a hundred years (1309 – 1417). England and France became embroiled in an endlessly protracted and enormously damaging series of conflicts, known collectively as the Hundred Years War (1337 – 1453) and, predictably, other states could not resist joining the fray, all of which had disastrous consequences for any peasants who got caught in the way. Finally, and most devastatingly of all, in 1347 the Plague arrived back in Europe. [as part of the most terrible pandemic that the human race has ever endured. Europe lost between one third and one half of its population; globally, deaths may have exceeded 100 million people out of a total human population of half a billion.3 These crises profoundly altered medieval social and economic life, but they also paved the way for the dramatic changes of the fifteenth century that mark the conventional beginnings of the modern era.

1 See William Rosen, *Justinian's Flea: The First Great Plague and the End of the Roman Empire* (New York: Viking Penguin, 2007), 264-265 and *passim.*

2 See R.I. Moore, *The First European Revolution, c. 970 – 1215* (Oxford: Blackwell, 2000) for an accessible summary of this argument;

3 Anthony N. Penna and Jennifer S. Rivers, *Natural Disasters in a Global Environment* (Chichester, UK: Wiley-Blackwell, 2013), 197.

CHAPTER 5 - THE TOOLS OF AGRICULTURE

HANS PETER BROEDEL

During the late Roman Empire, agricultural production had been focused largely on the great estates of powerful aristocrats. Known as *latifundia*, these plantations were typically specialized, producing whatever might generate the highest profits for their owners, but they were also not very productive. Roman agriculture was "extensive," meaning that it required relatively little labor or other resources, and relied on sheer size to compensate for low yields. Slaves or impoverished tenant farmers worked these farms, with little investment in their success or failure. With the collapse of Roman administration in Europe, however, and the arrival of new German landlords in the early Middle Ages, this system was gradually replaced with smallholdings – self-sufficient family farms. These employed intensive agriculture in which labor, fertilizer, and other techniques enhanced productivity. This, along with the fact that many of these farmers were now free and therefore more personally invested in how well their farms did or did not do, made farmers receptive to agricultural innovation, and early medieval peasants embraced technologies that had either been unknown to the Romans or previously underutilized.1

The so-called heavy plow provides an excellent and important example of this process. Roman farmers used a lightweight scratch plow called an ard ; this was basically just a pointed stick that was drawn through the soil to create a shallow, narrow furrow for planting. This worked well enough in the light, dry, sandy soils of the Mediterranean, but much less well in the dense, wet, clay soils common in Northern Europe.

This copy of a medieval manuscript illustration shows a peasant using a very modest version of the heavy plow. Larger plows would be equipped with wheels and would require twice as many oxen and a substantial crew. Medieval fields were characteristically very long and narrow because peasants wanted to plow the longest furrows possible before they were required to turn the plow around, a cumbersome process.

In contrast, the heavy plow was both massive and complicated; its simplest version consisted of a sharp coulter to cut into the soil and a trailing iron ploughshare and wooden moldboard. This plow dug a deep furrow and turned over the soil, burying weeds, enhancing fertilization and improving drainage.2 Exactly where the components of this plow originated is hard to say, but the fully developed European heavy wheeled plow was almost certainly the work of European farmers, who were experimenting with different plow configurations at least as early as the seventh century. A relevant and lasting consequence of Charlemagne's empire was that new ideas and techniques passed easily from place to place, and by the year 1000, the heavy plow in various forms had become common throughout Europe.3

As is so often the case, one technological change begets others. Because the new plow was extremely heavy, it required a team of as many as eight oxen to draw it. When added to the already considerable cost of the plow, this meant that economics encouraged or even required peasants to work together and pool their resources in order to plow the fields efficiently. On one hand, this increased productivity because animal power was replacing human labor; on the other hand, however, it also encouraged lords to impose a common set of obligations on all of their tenants, free and serf alike, that demanded they work together for their master's benefit .4 This was a crucial step in the development of what is called "the manorial economy," in which a manor's lord exercised almost complete legal, economic, and social control over those who farmed the land. In some respects the manor resembled the old Roman *latifundium*, in that aristocrats exploited the labor of their peasants, both serf and free, who were required to devote two or three days of each week to farming their lord's personal fields in addition to paying rent and a bothersome assortment of special fines and dues. At the same time, though, lords tried to ensure that their peasants derived at least some benefit from their efforts, which was not only nice but also good business. Manorial farming evolved to be extremely resource intensive; it required substantial investments in specialized labor, equipment, fertilizer and drainage. The willing cooperation of the peasants was therefore essential to having a productive farm.

Thus, a good harvest benefited everyone on the manor, which encouraged further innovation. Horses gradually replaced oxen as the draft animal of choice because horses could plow more land more quickly. (This change also depended on an improved horse collar, imported from China, that permitted the animal to breath easily while pulling a heavy load, while horseshoes, another invention new to the European middle ages, further improved equine efficiency as they (or horseshoes) reduced hoof breakage.5) European farmers embraced a new suite of crops better suited to their climate and growing conditions than the old Roman staples of spelt and barley, including oats and rye in addition to wheat, and to take advantage of the different planting seasons of these crops, they also adopted a three field system of crop rotation: one third of the land was sown with wheat in the autumn; one third was planted in the spring; and one third was allowed to lie fallow, while being fertilized by grazing animals. By growing different crops at different times, farmers could minimize the risks of bad weather, pests, and disease.6 Taken all together, these innovations constituted a kind of "technological complex" involving tools, techniques, suites of crops, and modes of life, all in complex interrelation.7 No single person was responsible, nor was this a sudden technological "breakthrough" or revolution; rather, this was an incremental transformation in agriculture, made possible mainly by the work of simple farmers using their accumulated agricultural knowledge, along with new and existing tools and techniques, to maximize their productivity.

1 For this transition, see Jean-Pierre Devroey, "The Economy," in Rosamund McKitterick, ed., *The Early Middle Ages* (Oxford: Oxford University Press, 2001), 97-129).

2 This is an argument first brought to prominence by Marc Bloch in 1931, but then popularized by Lynn White in *Medieval Technology and Social Change* (London: Oxford University Press, 1962), 39-78; Thomas Barnebeck Anderson, Peter Sandholt Jenson and Christian Volmar Skosvsgaard, "The Heavy Plow and the Agricultural Revolution in Medieval Europe," *Journal of Development Economics* 118 (2016): 133-149, tend to validate White's economic and demographic claims, but see George Comet, "Technology and Agricultural Expansion in the Middle Ages: The Example of France North of the Loire," in *Medieval Farming and Technology: The Impact of Agricultural Change in Northwest Europe*, Grenville Astill and John Langdon, eds. (Leiden: Brill, 1997), 11-39.

3 Thomas Glick, Seven J. Livesey, Faith Wallis, eds., *Medieval Science, Technology, and Medicine: An Encyclopedia* (NY: Routledge, 2005), 269-70; Anderson et al, 135-136.

4 Devroey, 119-120.

5 Georges Raepsaet, "The Development of Farming Implements Between the Seine and the Rhine From the Second to the Twelfth Century," in Astill and Langdon, 41-68; although the horse collar is much beloved in these sorts of accounts, Raepsaet argues that it was actually not very important at all; rather, it was a combination of collar with other elements of horse furniture "collar, shafts, girths, followed by the swingletree – which constitute a remarkable innovation…," 56.

6 Comet, 29. Comet argues that this was the chief benefit of this system and that the three field method did not, in itself, substantially improve yields.

7 Christopher Dyer, "Medieval Farming and Technology," in Astill and Langdon, 293-312; 294.

CHAPTER 5 - THE TOOLS OF WAR

HANS PETER BROEDEL

With only a handful of exceptions, such as in the cities of the Northern Italian Renaissance, warrior aristocrats dominated medieval society. Their social position depended in theory and in practice on their capacity to inflict violence effectively,

- in competition with their fellow aristocrats
- in the service of their lords in war and feud
- and to quell the aspirations of their social inferiors.

Their values, their mode of life, and their technology reflect this intimate association between nobility and violence.

KNIGHTS

The paradigmatic medieval warrior was the armored knight: a man trained since childhood to fight in armor on horseback. His principal weapons were the lance and sword. Skirmishing with bows or other missiles he viewed with contempt, for only in close hand-to-hand combat could he display his prowess, that murderous combination of courage, strength and skill that his culture most prized. His body was encased in armor: first, in mail of interwoven forged metal rings; then, after around 1300, in plates of high-grade steel. His training, mount, and equipment represented a massive investment of economic and social capital that could not be lightly thrown away, so every possible effort was made to preserve his life despite the inherent dangers of his occupation. The knight was a man superbly integrated into his own characteristic technological complex, a lethal synthesis of armor, weapons, horse, and martial skills. How this complex emerged, however, is the subject of an interesting debate.

Back in 1962, an outstanding historian of technology, Lynn White Jr., published a series of essays in famous book, *Medieval Technology and Social Change*. In it, he argued that medieval society had evolved in response to a series of technological innovations in war, agriculture, and industry. Among professional historians, White's arguments have been mostly discredited, mainly because we tend to privilege the role of culture in history and resist what can be seen as determinism. Nonetheless, White's arguments remain powerful, and retain many supporters.1 White contended that when the stirrup was introduced to Europe sometime in the eighth century, it provided horsemen a fighting platform sufficiently stable for the development of the first true shock cavalry —mounted knights. White believed that Charlemagne's grandfather, Charles Martel, had realized what was going on and fielded an army of these new and improved warriors who would become the basis for future Carolingian power. To pay for them—and they were expensive—he granted them land pried from the Church under the condition that they maintain their horses and weapons, and come to fight whenever the army was mustered. And thus, for White, feudalism was born. On the surface, this is a persuasive argument; but, unfortunately, it seems most likely wrong. First of all, the dates do not work out as White expected; second, he seems to have very much overstated the importance of stirrups to effective cavalry.2 Rather, it seems likely that Charlemagne himself began to place an increased emphasis upon cavalry, whose mobility was a great benefit within a sprawling empire, and who were ideally suited to the "rapid response" and "search and destroy" missions his policies demanded.3 When his empire and royal authority began to collapse after his death, aristocratic warrior horsemen came to dominate the local landscape, achieving the social dominance they would enjoy until the end of the middle ages.

To do this, however, required one further element: castles.

CASTLES

The origins of the iconic medieval structure—the castle—are obscure, but by the time of Charlemagne, rural fortresses of wood and earth played an essential role in local defense.4 As royal power eroded in the ninth and tenth centuries, kings ceased being responsible for building and maintaining these structures, and they passed entirely into the hands of local noble families, who were given the task of defending and governing the surrounding territory as part of their feudal obligations.5 This was a development with far reaching consequences, for these early castles also gave local noble families the power to resist higher authority. Capturing even a castle of wood and earth, if stoutly defended, required a major effort which, given their limited resources, early medieval kings could ill afford. For this reason, royal power diminished each time a castle passed out of royal control and into the hands of an aristocratic family

These castles also provided secure bases from which even small numbers of mounted knights could dominate the countryside for miles around. Noble families with knights and castles were in a position to extort submission from their less powerful neighbors. Thus, the hapless monks at Conques wrote that their neighbor, Count Raymond, built a castle adjacent to their land despite their protests. Raymond declared baldly that he was going "to subjugate by violence and submit to his lordship those who neglected to render their due submission to him."6 The efficiency of the knight and castle technological complex was such that it gave a military advantage to those who had it over those who did not. For this reason, Norman mastery of these interrelated technologies was a crucial component in their conquest first of England (c. 1066) and then Ireland and Wales.7

Early medieval castles were simple affairs, consisting most often of a central mound of earth surrounded by a broad ditch. Within the ditch was a wooden wall or palisade, and on top of the mound a wooden tower or blockhouse. This type of castle is often described as "motte-and-bailey" (the motte is the mound and fortress, while the bailey is the walled off area within the ditch), but there were many variations on this basic design.8

Wood and earth castles can, or course, be burned and leveled, and they suffer the effects of neglect rapidly, and for these reasons by the 11th-C., the wealthiest and most powerful aristocrats were instead building castles of stone. Over time, castles designs became progressively more elaborate. Crusaders adopted many of the principles of sophisticated Byzantine military architecture and applied them to their own castle construction, and brought back what they learned to Europe. So effective were these structures that conquering territory supplied with castles and resolute defenders became all but impossible.

The Normans (that is, "the North Men") represented here on the famous Bayeux Tapestry, were the descendants of Scandinavian Vikings and their families, who settled in Northern France. They readily adopted the religion, language, customs, and technologies, while retaining the ferocity of their forebears. This, along with their mastery of knight and castle technology, enabled Normans to conquer vast territories in Europe, including Sicily and most of Southern Italy in addition to the conquests in the British Isle, and overseas during the crusades.

A modern reconstruction of the motte – the mound and tower – of a motte and bailey castle.

Not that medieval warlords did not routinely make the effort, and nowhere, perhaps, is the openness and flexibility of the medieval mind toward technological innovation on greater display than at the castle walls. Armies experimented with siege towers and various kinds of battering rams. Miners dug tunnels under castle walls to undermine them (which is why castles were often built on solid rock or at least surrounded with a moat). Engineers built huge stone throwing machines to batter down castle walls. The best of these was the trebuchet, a device that like so many medieval innovations originated in China, but was redesigned in Europe to deal with high castle walls.

A trebuchet is basically a giant lever: a long tapering beam pivots on an offset fulcrum. A sling was attached to the long end of the beam; a massive weight, often of many tons, hung from the short broad end. Men used ropes to lower the long end to the ground, hoisting the weight into the air. A boulder, weighing between 100 and 300 lbs. was then loaded in the sling, and then when the weight fell the

Caerlaverock Castle, a thirteenth century Scottish castle that shows the increasing sophistication of medieval military architecture in the high middle ages.

Modern reconstructions of medieval trebuchets.

sling arm flew up releasing the stone that could fly some 300 yards. The English king Edward I used a battery of giant trebuchets to destroy the walls of several Scottish castles.9 Nonetheless, walls usually did not come down so easily, and when all was said and done, the only sure fire way to capture a castle was to starve its defenders into submission, an undertaking that could sometimes take years.

The knight and castle ruled medieval battlefields for many years, but towards the end of the high middle ages, starting around 1300, they received a new and worrisome challenge. Not only in the towns of Italy and Flanders, but across large swaths of Europe as in England and the Swiss Alps, the society of common folk was losing its dependence upon local lords, and its culture was becoming more self-reliant and better prepared to accept military discipline. Previously, while peasants identified themselves as serfs, as a kind of human property, they had no incentive to go out, fight, and be killed on behalf of their masters, and for this reason were generally considered a liability on the battlefield. Now, however, foot soldiers, were starting to win victories over their noble antagonists. This shift in military power provides a good example of why historians do not usually look to technological change alone as the cause of major cultural events. For what was changing was not so much technology, since all the weapons that foot soldiers were using had been around for quite a while, but rather the culture of the foot soldiers themselves, which now enabled and encouraged them to embrace tactical and technological change. Soldiers from the ranks of commoners could not afford the horses and equipment of knights, and so sought out military technologies that would magnify their strengths and offset their weaknesses: pikes, massive two-handed pole arms, and highly effective missile weapons, the crossbow and longbow. 10

1 For a balanced summary of the (almost) current state of White's theses, see Alex Roland, "Once More Into the Stirrups: Lynn White Jr., *Medieval Technology and Social Change*," *Technology and Culture* 44.3 (2003): 574-585.

2 See Stephen Morillo, "The "Age of Cavalry" Revisited," in L. Andrew Villalon and Donald J. Kagay, eds., *The Circle of War in the Middle Ages: Essays on Medieval Military and Naval History* (Boydell, 1999): 45-58.

3 Bernard S. Bachrach, "Charlemagne's Cavalry: Myth and Reality," *Military Affairs* 47.4 (1983): 181-187.

4 Kelly DeVries and Robert Douglas Smith, *Medieval Military Technology*, 2nd ed. (Toronto: University of Toronto Press, 2012), 197-198.

5 Ibid., 206.

6 From the *Vita Geraldi,* quoted in T.N. Bisson, "The Feudal Revolution," *Past and Present* 142 (1994): 6-42; 16. The argument presented in this chapter is derived in large part from Bisson's, but see also the ensuing debate: Dominique Barthélemy and Stephen D. White, "The Feudal Revolution," *Past and Present* 152 (1996): 196-223; Timothy Reuter and Chris Wickham, "The Feudal Revolution," *Past and Present* 155 (1997): 177-208; and finally Bisson's response, "The Feudal Revolution: Reply," *Past and Present* 155 (1997): 208-225.

7 DeVries and Smith, 213-217.

8 For a discussion of the evolution of castle construction and design, see DeVries and Smith, 212-259.

9 Ibid., 128; for siege equipment generally, see Ibid., 165-181, and for trebuchets and artillery, 115-136.

10 This argument is from John Stone, "Technology, Society, and the Infantry Revolution of the Fourteenth Century," *The Journal of Military History* 68.2 (2004): 361-380.

CHAPTER 5 - TECHNOLOGIES OF TOWNS AND TRADE

HANS PETER BROEDEL

Together with generally good weather and the rapid clearing of arable land, the new modes of farming improved crop yields, leading to rising population. During the high middle ages, Europe's population doubled, from about 37 million to 74 million, with much of this increase concentrated in the North and West: modern Britain, France, the Netherlands, and Germany.1 The most productive medieval manors were the most specialized; they farmed the most productive crops most intensively. These manors, however, had to trade for everything they could not supply themselves, and required markets in which to sell their surplus. They needed towns. For this reason, although there were only 29 towns with more than 5000 inhabitants in Europe before 1000 CE, by 1200 there were 127.2 Towns generated wealth: they produced cloth, tools, glass and metal ware, furniture, and luxury goods; they provided markets for the sale of grain, fruit, and animals; and they housed butchers, brewers, and specialists of many kinds.

Townsfolk needed very different sorts of technologies than did rural farmers, and they eagerly adopted tools of all sorts when they became available. This happened more frequently than in the early middle ages because the growth of towns and trade in Europe was part of a more general rise in population, agricultural yields and trade that extended all the way from Sung China to West Africa.3 As Europeans became increasingly engaged in this emerging global economy, they gained access to a host of technologies developed in other cultures, and proved adept at adapting them to their own particular needs. One development particularly important for the future was the effort to replace the work of humans and animals with alternative sources of power, a trend particularly noticeable in the spread of mills. Mills are technically machines for grinding or cutting, but when we talk of medieval mills we usually are talking more generally about machines that convert the work of humans, animals, wind or water into rotary power, most commonly to grind grain, but also for many other purposes. Most medieval rivers and streams boasted at least a few mills, and in some places they were extremely common. They were built for the usual reason: they were profitable. In return for an admittedly significant capital investment, mill owners could exploit a resource that was basically free instead of relying on power sources that had to be fed, or, worse, paid. Manor lords were particularly fond of watermills, because lords were able to require their tenants to pay to use them; peasants caught illicitly grinding their own grain at home were liable to pay heavy fines.4

Watermills, of course, had been in use for centuries, but growing wealth encouraged their spread; and more remarkable were the simultaneous efforts to use waterpower in other industries. A key enabling invention was the cam, an irregularly shaped wheel or cylinder that, when mounted on a shaft, can convert rotary to linear motion and vice versa. Cam shafts were known and used in the East and in the ancient world, but whether Europeans inherited them from the Romans or encountered them in Asia is unknown, but by the year 1000, Europeans were adapting them to existing mill technology to power hammers that forged iron and pounded wool into cloth. Soon they were also adapted to make paper, saw wood and stone, and tan animal hides.5 Adam Robert Lucas, a historian specializing medieval technology, determined that medieval mills were employed in the production of at least seventeen different products, ranging from malted grain to metal to opium.6

Like heavy plows and horse collars, however, it should be noted that watermills are similarly just one part of interrelated "technological complex." To build an efficient overshot watermill requires a number of related skills: water must be channeled into a millpond, and then released through sluice gates into a downward running millrace so that the water pours over the top of a waterwheel providing rotary power.

An overshot water wheel.

Europeans first developed the necessary hydrological expertise while draining swamps and marshes to gain arable land. For this reason, the best hydraulic engineers were probably the Dutch. Ironically, however, the Netherlands are not only notoriously boggy, they are also famously flat, and suitable streams for mill building were few and far between. A solution to this lack of waterpower appeared by the early twelfth century, when someone had the idea to use the wind as an alternative source of power. Like watermills, windmills had been used for centuries throughout the world, but the European windmill again adapted existing technologies to local conditions in unique ways. The European windmill was extremely large, with massive vertically mounted sails, and was mounted on a post or pivoting cap, that permitted the apparatus to rotate into the prevailing wind. The first windmills were used to grind grain, but they were soon adapted to pump water and drain bogs. By the end of the middle ages, windmills were in use all across Northern Europe to drain marshes and to mill paper, grind corn, turn saw blades and so forth.7

All of this activity can create a false impression of a "medieval industrial revolution."8 The reality, however, was much more complex. Although in some places Europeans embraced new technologies and deployed them in innovative and sometimes spectacular ways, most did not or did so only seldom. The problem was that to deploy mill technologies on a large scale profitably required an unusual set of conditions: mills were expensive, so abundant capital was required, as was the presence of specialists to build, operate, and maintain the mills. Once built, mills needed plenty of raw materials—grain, , wood, stone, or whatever—to process, and they needed markets in which their products could be sold profitably. And, of course, they required ready and reliable supplies of wind and water. These conditions were found in a few French river valleys, in Northern Italy, and parts of the Low Countries, but seldom elsewhere. As Lucas remarks, the evidence indicates "those regions of medieval Europe that were engaged in industrial milling appear to have been geographical pockets of technological innovation within a broader environment of technological incrementalism."9 This should not be seen as an insult to medieval Europeans, but as a reminder that we should be careful when thinking about historical change in terms of revolutions and breakthroughs: changes indeed are sometimes "revolutionary," but far more often they are gradual and incremental.

A second technology with major implications for the future involved time keeping and, curiously enough, its story begins, like watermills, with hydraulic engineering. Humans, of course, have been interested in keeping track of time for all sorts of reasons for just about as long as modern humans have been around, but medieval clergy were particularly fixated on this problem. First, the Christian calendar was unusually complex because to calculate the annual date of Easter, you had to reconcile the Lunar Hebrew calendar with the Solar Julian. This was a source of endless controversy, and is so complicated that it has never been resolved to everyone's satisfaction, which is why even today Eastern and Western Christians celebrate Easter on different days. Second, the duties of Benedictine monks were regulated according to the hours of the day, which were announced by the ringing of a bell (our English word "clock" comes from the Latin, *clocca*, meaning "bell"). For these reasons the clergy were keenly interested in keeping time. Sun dials were a possibility, but were not much use on cloudy days and tracking time by just keeping an eye on the sun suffered from the same problem. Hence, at least by the tenth century, some monasteries were using water clocks to keep track of the hours of the day.10

Water clocks, also known as clepsydra (water-thief), had been used since antiquity, and medieval Europeans had access to the fine description of their operation in the *De architectura* (*On Architecture*) of the Roman military engineer, Marcus Vitruvius (fl. 25 BCE).11 In this clock, water flowed at a controlled rate from a water source into a tank. As the water rose, it lifted a float, and this motion could be used to turn the dial of a clock face or release weights to ring bells. The Abbasid Caliph in Baghdad, Harun al-Rashid, had sent a very elaborate and elegant clepsydra as a gift to Charlemagne, complete with twelve mechanical horsemen that would ride out on the hour.12 We can imagine that the Frankish king was duly impressed, but simpler versions of these early alarm clocks seem to have been fairly common monastic conveniences.13 Yet water clocks had obvious disadvantages as well: they were inaccurate and fiddly; in the summer, the water in their tanks evaporated, and in the winter, it would freeze.

Yet the first mechanical clock was almost certainly not invented merely to tell time but rather to do something far more complicated, to model the motion of the stars and planets. This is not as strange as it might appear in this age of digital time, for all traditional analog clocks are just devices which model the path of the sun as it moves across the sky.14 Since antiquity, however, astronomers and horological engineers ("horology" is the study of time) had been inventing devices to model more complex celestial relationships. Islamic scholars were particularly good at this because of the complexity of their lunar calendar, and their need to determine latitudes to find the direction of Mecca, and the time for morning prayers. For similar reasons, European clergy were interested in heavenly motion and eagerly learned everything they could from Muslim texts and exemplars. The astrolabe, a device used to determine the position of stars and planets and to work out time and latitude, was almost certainly introduced to medieval Europe from Muslim Spain.15

As in many similar cases, however, Europeans applied this inherited expertise to their own problems in new ways, and just as the camshaft enabled them to devise new uses for mills, the escapement proved the essential technological component of the mechanical clock.

A late fourteenth-century French astrolabe. To use the device, you would sight a star in the sky along the straight edge, measure its angle above the horizon, and then locate the star on the "rete" (the moving dial above the face). Engraved on the base plate are concentric circles denoting azimuth and altitude, forming a stereoscopic projection of the sky. When you rotate the "rete" dial until the star lines up with its position in the sky, you can read the time from a scale on the rim of the device.

An escapement is a gear that restricts the rotation of another gear or shaft so that it moves only in certain well defined increments; sometimes a pendulum regulates the speed of rotation, but there are a number of alternatives. In all cases, it meant that hanging weights suspended from a cord wound about a shaft could be used to drive mechanical clocks, as could a coiled spring. Who invented the first escapement is a mystery, but records of clocks probably using them begin to appear in Europe around the close of the thirteenth century.

Then in the fourteenth, an English monk, Richard of Wallingford, wrote a detailed description of his extremely complex astronomical clock: not only did his clock tell time, but also modeled the motion of the sun and moon, it predicted solar and lunar eclipses, and calculated the times of high and low tides.16

This was a legitimate marvel of engineering, requiring extremely complex calculations to be performed mechanically through the timed intersection of meticulously crafted gears. It also illustrates how sometimes in history a very complicated invention precedes a simpler one. For,

The Abbot Richard of Wallingford is shown here proudly presenting his astronomical clock to his monastery.

although astronomical clocks were of great value and interest to the church and its scholars, much simpler mechanical clocks, primarily used just to tell time, sprang up in European towns and cities almost immediately.

An early fifteenth-century astronomical clock from the town square in Prague. A mechanical skeleton representing death strikes the hours, which provides a nice insight into medieval sensibilities.

Already by the mid-fourteenth century, the hours were being counted on a Paduan city clock from noon and midnight, as we do now.[17]

The regular chiming of bells permitted, or perhaps better, required that people use time to regulate their lives. Now for the first time you could meet for lunch at one o'clock and reasonably expect your associates to be on time. Now the workday would run to ten or twelve equal hours, regardless of the time of year. More importantly, perhaps, the spread of clocks made time public and secular, and not under the control of the church. In later years, this understanding of secular time would play a pivotal role in the development of science, business, and urban society.

1 Moore, 30; Kay Slocum, *Medieval Civilization* (Belmont, CA: Thomas Wadsworth, 2005), 136.

2 Moore, 31.

3 William Thompson, *The Emergence of the Global Political Economy* (London: Routledge, 2000).

4Jean Gimpel, *The Medieval Machine: The Industrial Revolution of the Middle Ages* (New York: Penguin Books, 1977), 12-15.

5 Frances Gies and Joseph Gies, *Cathedral, Forge, and Water-Wheel: Technology and Invention in the Middle Ages* (New York: Harper Collins, 1994), 115-117; Arnold Pacey, *The Maze of Ingenuity: Ideas and Idealism in the Development of Technology* , 2nd ed. (Cambridge MA: MIT Press, 1992), 12.

6 Adam Robert Lucas, "Industrial Milling in the Ancient and Medieval Worlds: A Survey of the Evidence for an Industrial Revolution in Medieval Europe," *Technology and Culture* 46.1 (2005): 1-30; 14.

7 Dyer, 299; Michael Pye, *The Edge of the World: A Cultural History of the North Sea and the Transformation of Europe* (New York: Pegasus Books, 2015), 258-260.

8 Lynn White, *Medieval Technology and Social Change* (London: 1968), 89; Gimpel expresses this argument even more forcefully: *The Medieval Machine: The Industrial Revolution of the Middle Ages.*

9 Lucas, 29.

10 This and subsequent paragraphs are deeply indebted to John North's terrific book, *God's Clockmaker: Richard of Wallingford and the Invention of Time* (London: Continuum, 2005).

11 North, 151.

12 E.A. Truitt, *Medieval Robots: Mechanism, Magic, Nature, and Art* (Philadelphia: University of Pennsylvania Press, 2015), 21.

13 North, 148.

14 Pacey, 35-43.

15 James Hannam, *The Genesis of Science: How the Christian Middle Ages Launched the Scientific Revolution* (Washington D.C.: Regnery, 2011), 21.

16 North, 201-218.

17 Gimpel, 164.

18 An idea explored in Jacques Le Goff, "Merchant's Time and Church's Time," in *Time, Work, and Culture in the Middle Ages*, Arthur Goldhammer, trans. (Chicago: University of Chicago Press, 1982), 29-42.

CHAPTER 5 - THE RISE OF UNIVERSITIES AND THE DISCOVERY OF ARISTOTLE

HANS PETER BROEDEL

The Church reform of the high middle ages was a movement of the highest significance to European culture and society. From its beginnings as an effort to free monasteries from secular interference, the movement eventually led to a major restructuring of the relations between the institutional Church and the laity, the general population. The effects of reform and its underpinning ideology can be seen in the growth of papal power, the rise of new religious orders, increasing concern with heresy, and the crusades. For us, here, however, of particular importance was a newfound emphasis upon clerical education and a corresponding search for intellectually satisfying and rational bases for Christian doctrine. Without these parallel developments within the Church, the achievements of early modern science would probably have been impossible.

Some modicum of education had always been required of Christian clergy, of course, and through the early middle ages monasteries and cathedral schools had preserved the basics of the classical Roman curriculum. This consisted of a sequence of two courses of study. The first, **the trivium**, was based around language, and included the study of grammar, logic, and rhetoric. The second, **the quadrivium**, focused on mathematics – arithmetic, geometry, music, and astronomy.1 Together, these comprise the liberal arts, which the Romans thought all free men (*liberi*) should master. With the reform movement, however, educational requirements became more uniform and more exacting. Even parish priests were now expected to read and speak competent Latin and to compose sermons regularly. Priests in large urban churches also had to have some understanding of biblical exegesis to ensure that their sermons were properly orthodox and to counter a rising tide of heresy. To meet these needs, as well as to supply a growing demand for academically trained professionals in government, business, and urban society, new forms of schools arose, and, of these. by far the most important was the *studium generale*, the university.2

Curiously, the very first European university was an exception, for it was founded in Bologna by laymen who wanted to study Roman law. Bologna was unusual in this as well: the students ran the school. This makes perfect sense because they were the ones paying tuition: in order to safeguard their investment, they formed a kind of corporation, a students' guild, which hired faculty, set the curriculum, and ensured that academic standards were maintained.3 Faculty who were late to class or droned on too long could be fined or fired.4 Thankfully for generations of professors, though, everywhere else it was a different story, and the faculty, with support from the Church and local governments, ran the show. In all cases, however, medieval universities took the form of guilds, collective associations of teachers and students who banded together to protect their rights and privileges, set standards, and resist unwelcome interference. Thus European universities were from the outset exceptional in that they were largely autonomous but united by a common language (Latin) and a common intellectual heritage. Their curricula, too, was uniform. Everywhere students began with the study of the Arts—the trivium and quadrivium—before moving on to more advanced subjects such as medicine, law, and theology. After sufficient study, a student who had already become a Master of Arts, might achieve his doctorate, his ***licentia ubique docendi*** (his license to teach anywhere) and join the faculty at some other institution. The universal acceptance of this credential meant that new ideas travelled quickly between schools, while promoting a uniform academic culture.5

The big, new ideas of high medieval academia were Aristotle's. The Romans seem never to have bothered to translate his work into Latin, for the simple reason that if a Roman were to be interested, he would certainly already know Greek.6 For this reason, Aristotle remained almost completely unknown to medieval European scholars until Latin translations from Arabic versions of his texts began to filter across the border from Spain in the twelfth century. 7 Aristotle's thought transformed the medieval intellectual world. His was a comprehensive philosophical system of enormous persuasive and explanatory power: through a combination of **logic**, **empiricism**, and **basic principles**, his system was capable of explaining almost anything. Even better, because Aristotle explained the workings of the cosmos without reference to supernatural power ("philosophical naturalism"), his thought, for the most part, did not contradict Church teachings. There were a few exceptions—Aristotle denied the immortality of the soul, for example—but since, as a pagan, he was not expected to be an authority in theological matters, these errors could be ignored. Indeed, it did not take long for Christian scholars to realize that Aristotle's philosophy could provide insight into all aspects of the natural world, even those that impinged upon religion.

For Aristotle, the goal of philosophy was explanation, which meant that natural philosophy entailed the search for the causes of natural phenomena. Aristotle believed that **inherent purpose** determined the essential characteristics of all natural things. For this reason, his philosophy is often called "teleological," or purpose oriented, from Greek *telos*, meaning "end," or "purpose." For example, Aristotle would argue that cats have claws because they are predators, and need to be able to catch and grasp their prey—that's what claws are for. Determining a phenomenon's cause, however, could often be much more complicated and require careful observation, rigorous logic, and the appropriate application of the principles that provided the essential framework from which the Aristotelian universe depended. This Aristotelian cosmos was composed of matter; indeed, it was filled to the brim with it; it was a plenum (a spaced filled with matter, as opposed to a vacuum) in which true emptiness was impossible. All things were composed of varying proportions of the four basic material substances: earth, air, water, and fire. (As this arrangement makes perfectly clear, Aristotle knew that the earth was a globe, as did most everyone else in the ancient world, and medieval scholars knew this too; so let's put to rest the old fib that prior to Columbus everyone thought the world was flat.)

Within the cosmos, these were arranged hierarchically, with earthy matter in the very center, surrounded by a watery sphere, then a sphere of air, and finally one of fire. All matter sought to find its appropriate sphere, which is why fire always goes upward, but stones fall downward. If something floats on water, it means simply that its substance contains more aerial and fiery matter than earth. Beyond the sphere of fire were the celestial spheres of the seven planets—the Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn—and beyond them was the sphere of the fixed stars. These celestial spheres were basically unknowable to humans, and so their composition and the physical laws that determined their motion were subjects for speculation, but not for science.8

Here in the terrestrial realm, however, the substance of a thing determined its essential nature, and

The classical universe from a sixteenth-century cosmographical treatise. At the center is the earth and spheres of water, air, and fire, then the transparent crystalline spheres of the seven planets and the fixed stars.

not its appearance, size, form and so forth. These, in Aristotelian terms, were "accidents," which were external traits that differentiated particular individual things from others, but that did not pertain to their essence. So, for example, a pencil might be yellow or green, sharp or dull, long or short, but these characteristics have no bearing on its essential "pencil-ness."

For medieval scholars, this way of understanding the physical universe was the key to solving a famous riddle: it was then a doctrine of the Church, as it remains for modern Catholics, that during the Mass, the Host, which is the consecrated bread, is miraculously transformed into the literal body of Christ prior to being consumed by the faithful. But if this is true, a cynic might ask, why does the bread still look and taste just like bread?

Aristotle's matter theory provided the answer: the substance of the bread was transformed into the very substance of Christ, while its accidents, its externals, remained those of bread. After a certain amount of debate, this process, called "transubstantiation," was accepted as the necessary way to understand the Eucharist or communion.9 This was just one of the ways—although perhaps the most important—that Aristotelian philosophy was turned to the service of the medieval Church. Similarly, theologians used Aristotle's rules of logical deduction and physical science to prove the existence of God, to explain the divine paradox of the trinity, and to provide a rational explanation of how Christ could be both wholly human and at the same time completely divine .

In this way, Aristotelian natural philosophy became an essential bulwark of Church doctrine in addition to offering a comprehensive philosophical framework through which to understand the natural world. Little wonder, then, that Aristotle became an integral part of the new universities' arts curriculum, despite the fact that many within the Church remained suspicious of the Philosopher's skepticism and pagan background. The problem was how to make Aristotle compatible with medieval Christianity without fatally damaging the intricately interwoven strands of his thought. This became the essential project of medieval academia, which we commonly refer to as "scholasticism": an attempt to explicate a thoroughly rational Christianity and an acceptably Christian Aristotle, and join the two together.10 This was the all-consuming project and crowning achievement of Thomas Aquinas (1225 – 1274), the greatest medieval theologian and philosopher, whose masterpiece, the *Summa Theologiae*, created just the necessary "amalgam" to reconcile Aristotelian natural philosophy with the truth of divine revelation, using metaphysics as the necessary bridge between the two.11

1 Michael Shank, "Schools and Universities in Medieval Latin Science," in David Lindberg and Michael Shank, eds., *The Cambridge History of Science*, vol. 2, *Medieval Science* (NY: Cambridge UP, 2013): 207-239; 210.

2 For the origins of medieval universities, see Shank, 207-239.

3 Ibid, 214-215.

4 Kay Slocum, *Medieval Civilization* (Belmont, CA: Thomson Wadsworth, 2005), 376.

5 Shank, 229-233.

6 Ibid., 210.

7 Edward Grant, "Reflections of a Troglodyte Historian of Science," *Osiris* 27.1 (2012): 133-155; 136-137.

8 Edward Grant, "Cosmology," in David Lindberg and Michael Shank, eds., *The Cambridge History of Science*, vol. 2, *Medieval Science* (NY: Cambridge UP, 2013): 436-455.

9 Stephen Gaukroger, *The Emergence of a Scientific Culture: Science and the Shaping of Modernity, 1210-1685* (Oxford: Oxford University Press, 2006), 65.

10 David Lindberg, "Science and the Medieval Church," in David Lindberg and Michael Shank, eds., *The Cambridge History of Science*, vol. 2, *Medieval Science* (NY: Cambridge UP, 2013): 268-287; 279.

12 Gaukroger, 80.

CHAPTER 5 - MEDIEVAL SCIENCE

HANS PETER BROEDEL

This clerical embrace of Aristotle had a number of interesting consequences relevant to the development of medieval science. First, Aristotle believed that all knowledge originated in sense experience, which was a major departure from the epistemology (way of knowing) of St. Augustine and the earlier middle ages. High medieval churchmen certainly did not deny that direct revelation from God was possible, but insisted that it was unusual, and so the best way to understand God was to understand what we could perceive directly, that is, the natural world. As the theologian, Hugh of St. Victor put it in the twelfth century, "The whole of the sensible world is like a kind of book written by the finger of God… and each particular creature is somewhat like a figure, not invented by human decision, but instituted by the divine will to manifest the invisible things of God's wisdom."1 The work of natural philosophy , then, was to decode the book of nature, so to speak, in order to reveal the hidden hand of God. This led medieval scholars to study animals and plants, stars and planets, water, fire, and all manner of natural phenomenon. Further, although understanding God was the ultimate goal, his creation was assumed to follow rules that did not require His constant intervention, and so, like Aristotle, they described nature in what we would call "natural" terms. Miracles could, of course, still happen, but that was the provenance of theologians; natural philosophy dealt with nature, not with God directly.

In this way, medieval scholars were encouraged to explore the natural world, to build upon the work of their classical predecessors, but at the same time to acknowledge that the wonder of nature was a testament to the glory of God. Although they worked within an Aristotelian cosmos, and accepted as complete truth the great Philosopher's (Aristotle's) basic assumptions, they also recognized that their own work surpassed that of the ancients, both in its Christianity and in its capacity to build upon the achievements of the past. Bernard of Chartres, a twelfth-century philosopher and theologian, put it neatly when he observed that the scholars of his day were like "dwarves on the shoulders of giants and thus we see more and farther than they did."2 This meant that when necessary they were even prepared to try to correct the great Philosopher's mistakes.

Aristotle explained most things quite well, but his rules of motion were an exception. Aristotle dictated that inanimate objects move naturally to their proper sphere, but, otherwise, they only move if they are pushed by something else. This makes sense at first: if I want to move a piano, I'm going to have to push it, and once I stop, so will the piano. But what about an arrow? The motive force of the bow is removed when the arrow leaves the string, but the arrow clearly continues to move. Aristotle's answer, like the rest of his physics, is extremely complicated, but he argues in effect that the force of the bow not only moves the arrow but the air around it, and that the air continues to push the arrow proportionally to the force that initially sets it in motion. This seems pretty ridiculous on its face, but medieval scholars had a serious vested interest in maintaining the integrity of the Aristotelian cosmos, and so they began to investigate motion diligently. One of main ways that their approached differed from the Aristotle's was that they tried to describe motion mathematically. For Aristotle, this was a huge mistake, because numbers were completely abstract concepts that exist only in the mind, not in nature. To describe nature in such "unnatural" terms was invalid. Similarly, Aristotle would have rejected what would later come to be called "experiments," because they artificially constrained nature to behave in unnatural ways. Rather, the Aristotelian scientist observed nature passively, recording what it did, not what it was made to do.

Yet, in an attempt to salvage his cosmos, medieval natural philosophers rejected Aristotle's methodological criticism, and tried to figure out exactly how projectiles move. They failed, unsurprisingly, because they could not abandon the basic principles of the Aristotelian cosmos, but their failures nonetheless foreshadowed the mathematical modeling that was such an essential part of the new science of the sixteenth and seventeenth centuries.3 In the early fourteenth century, a series of remarkable scholastic physicists at Oxford's Merton College, sometimes dubbed the Merton Calculators, tried to solve to the problems of motion using only mathematics and what we might call "thought experiments." Many of their results, in retrospect, proved quite wrong, but they did show conclusively that mathematics could be used to model natural phenomena, and eventually expounded what we now call "the mean speed theorem" (that a moving body undergoing continuous acceleration will travel a distance in a given time exactly equal to that of a body moving at a constant speed equal to the mean speed of the accelerating body).

Equally significant, the community of medieval scholars built on this work. So, a few years after the Merton Calculators, Nichole Oresme (d. 1382), bishop of Orleans, developed a geometric proof of the Merton theorem that provides us with one of the very eariiest examples of the use of a graph to model a mathematical function.4 (A purely mathematical proof of the theorem would await the development of the calculus.) Oresme, by the way, was also notable for proposing that the earth revolved. He remained committed to the notion that the earth was at the center of the cosmos, but argued that it was more economical to suggest that the earth turned while the surrounding heavens stood still. He systematically replied to various counterarguments, including suggesting that the reason that an arrow shot straight upwards comes straight back down, instead of being offset by the motion of a revolving earth, was that the arrow, like the air surrounding it, was spinning at exactly the rate of the earth to begin with.5

1 Hugh of St. Victor, *De tribus diebus* (migne 1844-1905, 122, 176.814 B-C). trans. Peter Harrison, in Harrison, "Hermeneutics and Natural Knowledge among the Reformers," in Jitse M. van der Meer, and Scott Mandelbrote, *Nature and Scripture in the Abrahamic Religions: Up to 1700* (Leiden, Brill, 2009) 346.

2 Cited in Shank, 216.

3 This argument and its particulars are taken from James Hannam, *The Genesis of Science* (London: Icon Books, 2009), 166-187.

4 Eriola Kruja, Joe Marks, Ann Blair, Richard Waters, "A Short Note on the History of Graph Drawing," in P. Mutzel, M. Jünger, S. Leipert, eds., *Graph Drawing, Lecture Notes in Computer Science*, vol. 2265 (Berlin: Springer Verlag, 2002): 1-15.

5 Hannam, 183.

CHAPTER 5 - CONCLUSION: LIGHT AND STONE

HANS PETER BROEDEL

By way of conclusion, I would like to offer you a final example of the close interdependence of medieval science, technology and religion: the Cathedral.

Cathedrals are my favorite memorial of medieval Europe—soaring high into the air, their huge vaults seemingly almost weightless upon thin stone pillars, glowing with the radiant light of countless panes of brilliantly colored glass: cathedrals are(wonder incarnate, and one of humanity's enduring artistic masterpieces .

To build these architectural marvels required enormous skill and enormous resources, but build them they did. In France alone, during the high middle ages medieval people constructed more than eighty cathedrals and hundreds of large stone churches in the new "Gothic" style.1 These depended upon three technological innovations.2

- The first, the rib vault, probably arose in Islamic Spain through incremental improvements upon the Roman barrel vault, but where the vault ribs (the arches that support the roof and ceiling) in the old style ran parallel to one another, in a rib vault they run diagonally, crisscrossing, making the structure stronger while at the same time permitting thinner ribs and supporting pillars. (insert a link)
- The second was the pointed arch and also an Islamic invention. In all arches, the force of supported weight is projected both vertically downward and horizontally outwards, but it is the outward push that poses the greatest problem because without the help of the ground the walls and pillars must support the weight of the vault Pointed arches direct a much greater proportion of force vertically, so they can be taller and slimmer, and yet stronger. (insert a link)
- The final innovation was the flying buttress, perhaps adapted from buttresses used in the walls of fortresses. The flying buttress was an external brace that supported the pillars upon which the arches of the vault rested. This meant that the walls between the pillars supported almost no load at all and could be quite thin, or even replaced entirely with windows of glass. (insert a link)

These technologies enabled the Gothic cathedral's construction, but do not explain why they were built in the first place. For that, we need to understand the meaning of light in the middle ages.

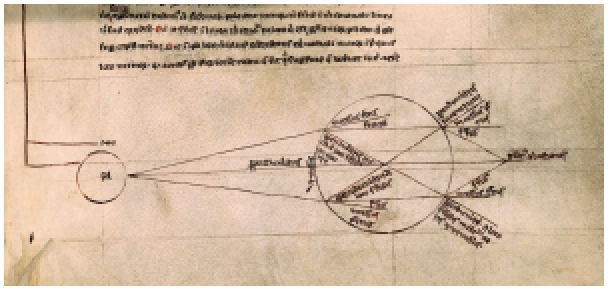
Light has long been a metaphor for the divine, as, for example, it appears in the writing of St. Augustine and John the Evangelist (see John 1.5). Yet due to the influence of a late antique theologian, now known to scholars by the tongue-twisting name of Dionysius the Pseudo-Areopagite, light was much more than a metaphor to medieval scholars. Dionysius argued that physical light was a visible

The chancel at the basilica of Saint-Denis in France that illustrates both the cross-ribbed vaulting and pointed arches characteristic of Gothic churches.

expression of God, a reflection of that divine light that bound the cosmos together and joined it with the being of God.3 To medieval theologians, steeped in Aristotle, this was an appealing notion, because it meant that their earthly senses were capable of experiencing the divine, not through some singular miracle or revelation, but through a natural and integral part of God's creation. This inspired them to subject light to detailed scientific study.

Robert Grosseteste (1170-1253), the bishop of Lincoln, studied Arabic optical science, and carried out his own research on refraction and reflection. He knew that curved lenses could make objects appear larger or smaller, and suggested that they could be used to make a magnifying glass.4 Indeed, reading glasses are first found in Italy in the 1280s, and their invention may very well be indebted to Grosseteste's work . Yet the bishop was not simply curious about light: he also composed a Latin translation of Dionysius, and wrote about light as "a divine essence," and "an emanation from God."5 Grosseteste's most famous student, the English Franciscan Roger Bacon (d. 1294) continued his master's work, studying the refractive properties of water, the anatomy of the eye, and Islamic optical science, which his writing made available to the Latin world for the first time.

The origin of Gothic architecture lies in this same understanding of light. When the abbot Suger began to supervise the reconstruction of the ancient Church of Saint-Denis in the mid-twelfth century, he embraced the new architectural style explicitly in order to fill his church with light, so that through great windows of colored glass worshippers could be joined with God. For Suger, the light of the great windows illuminated the hearts of those within just as the words of scripture illuminated their souls.6 It is no accident, then, that medieval churches were also home to illuminated Bibles, their pages painstakingly covered with finely hammered gold so that they literally glowed with the reflected light of God.



A drawing from Roger Bacon's Greater Work (Opus Maius) that illustrates the refraction of light through a pillar of water.

The light reflecting from the gold leaf adorning this illustration of Christ in Majesty should give you a good idea of how medieval "illumination" gets its name.

These ideas and their expression in Gothic churches and stained glass took the medieval world by storm and were repeated many times. Just as one example, several hundred years later, toward the end of the high middle ages, another French bishop, William Durandus, wrote that, "The glass windows in a church are Holy Scriptures, which expel the wind and the rain, that is, all things hurtful, but transmit the light of the True Sun, that is, God, into the hearts of the faithful."7

So here we see how some of the most important developments in medieval science, religion, and art are all expressions of a common cultural imperative—to better know God—and a common worldview in which light was God's visible expression. This example gives us an opportunity to reflect that neither science nor technology exists in a vacuum: To understand either science or technology, one must grasp its cultural dimensions along the bare facts. This in turn allows us to observe that technology should not be viewed as purely utilitarian—it is not all about building a better toaster — but responds to the cultural imperatives of the societies in which it is embedded. Similarly, science should not be judged simply by how well we think it models the natural world; it should be appreciated for how it integrates nature and human culture, how it "makes sense" of natural phenomena within the framework of a particular world view. From this perspective, we can see that medieval Christianity should not be viewed as somehow antagonistic toward science or technology, and that neither should medieval science and technology be denigrated as being backwards or stagnating. Far from it: medieval people were remarkably adaptable and innovative when innovation was compatible with their culture. They embraced mechanization and labor saving technologies, the development of universities and new centers of learning, as well as the tenets of Aristotelian naturalism — all of which laid the groundwork for the new light and learning of the modern age.

1 Moore, 37.

2 Hannam, 98-99; Pacey, 5-8.

3 Carol Anne Jones, "Shine Forth Upon Us in Thine Own True Glory," in *The Institute for Sacred Architecture* 14 (2008). Accessed 5/22/2017: www.sacredarchitecture.org/articles/shine_forth_upon_us_in_thine_own_true_glory

4 Gimpel, 185.

5 Gaukroger, 97; Ian Howard, Brian Rogers, *Perceiving in Depth: Volume 1 Basic Mechanisms* (Oxford UP, 2012), 26.

6 This is an argument from Erwin Panofsky, *Renaissance and Renascences in Western Art* (Stockholm: Almquist and Wiksells, 1960), p. 187

7 William Durandus, *Rationale divinorum officiorum*, 1.1.24; cited in Fred S. Kleiner, *Gardner's Art Through the Ages: A Global History* (Wadsworth, 2015), 384.

CHAPTER 5 - DOING HISTORY: MEDIEVAL EUROPEAN TEXTS

HANS PETER BROEDEL

Bestiaries, books about animals, often lavishly illustrated, were among the most popular of medieval texts. The following extract about the mole is from an anonymous thirteenth-century example, largely copied from earlier very similar treatises.

> "The mole is so called because it is condemned to perpetual darkness because of its blindness. It has no eyes, and always digs the earth and turns it over and eats the roots. The mole… is the image of pagan idols, blind, deaf and dumb; or even their worshippers, wandering in the eternal darkness of ignorance and folly… The mole is also the symbol of heretics or false Christians who, like the eyeless mole which digs in the earth, heaping up the soil and eating the roots beneath the crops, lack the true light of knowledge and devote themselves to earthly deeds…" (*Bestiary,* Bodley M.S. 764.)1

Compare with this description of the mole from roughly the same period in Albertus Magnus' work, *De Animalibus* (*About Animals*). Albert was a famous Aristotelian scholar and theologian who taught at the Universities of Paris and Cologne.

> "[The mole] is a small animal that belongs to the class of rodents and is sometimes called "earth mouse" or "blind mouse." It has very short legs and sharp claws, with five digits on its forefeet and four on its hind feet. Black in color, it has soft fur which is short in length but densely distributed. In place of eyes it has tiny bare spots bereft of hair. It feeds on grubs, but I have also watched it eating frogs and toads. In fact, I once saw a mole which, from its underground burrow, captured a large toad… The mole also consumes earthworms… It depends a great deal on its sense of hearing and can detect the movement of worms through the soil at some distance. However, this may be less a function of its auditory acuity than it is the transmission of sound through the displaced earth. By way of illustration, if one constructs a long tunnel underground, one can hear with great clarity the spoken voice of another person, even though he is situated far away at the other end of the tunnel…" (Albert the Great, *De Animalibus,* 22.143) 2

From these extracts, how would you characterize the purposes of each author? What are they trying to provide their readers?

What does each author think are the mole's most important characteristics?

How does the mole's blindness influence the authors' accounts of the creature? (The European mole is not, in fact, blind, but has tiny eyes buried under its skin. Albert went so far as to dissect a mole looking for them, and found tiny "bead-like structures" in its head containing fluid, but could not identify them as eyes.) 3

Where does each author get his information? How important to each author is the accuracy of his account?

How do you think the bestiary author might have altered his description of the mole if he had read Albert's? Would Albert's claim that moles mainly ate worms and grubs have mattered to the bestiary author?

1 Richard Barber ed. and trans., *Bestiary: Being an English Version of the Bodleian Library, Oxford M.S. Bodley 764* (Woodbridge, UK: Boydell Press, 1999), 110-111.

2 Albert the Great, *Man and the Beasts: De Animalibus (Books 22-26)*, trans. James J. Scanlan (Binghamton, NY: Medieval and Renaissance Texts and Studies, 1987), 179-180.

3 Scanlan, 24.

CHAPTER 5 - PRIMARY SOURCES

HANS PETER BROEDEL

1. **The Utrecht Psalter**

http://www.utrechtpsalter.nl/#highlights

This is an illustration from an Anglo-Saxon copy of the Utrecht Psalter, an illustrated book of Psalms, probably originally from Francia and dating to the ninth century (the details are easier to see in the color copy than the line drawn original). The illustration depicts Psalm 64: on the right the psalmist stands under the Lord amid the forces of righteousness; on the left is the army of darkness. As Lynn White first pointed out, the interesting thing is that while the iniquitous are sharpening their swords the traditional way, using a whetstone, the righteous have invested in the very latest technology. In fact, this is the first known illustration of a rotary grindstone, being turned, what is more, by that most useful of inventions, the hand crank. This illustration is particularly useful to historians because it demonstrates that contrary to what you may sometimes hear, the medieval Church was perfectly capable of aligning virtue with technological progress.

2. **Roger Bacon: "On the Hidden Workings of Nature and Art and the Emptiness of Magic."** This is an extract from a long letter that Bacon wrote to William of Paris, who seems to have asked him

to discuss the possibility of doing marvelous things through magic. Bacon responded that magic was empty and evil, but that one could do truly wonderful things through technology.

"I will now enumerate the marvelous results of art and nature which will make all kinds of magic appear trivial and unworthy. Instruments for navigation can be made which will do away with the necessity of rowers, so that great vessels, both in rivers and on the sea, shall be borne about with only a single man to guide them and with greater speed than if they were full of men. And carriages can be constructed to move without animals to draw them, and with incredible velocity. Machines for flying can be made in which a man sits and turns an ingenious device by which skillfully contrived wings are made to strike the air in the manner of a flying bird. Then arrangements can be devised, compact in themselves, for raising and lowering weights indefinitely great. . . . Bridges can be constructed ingeniously so as to span rivers without any supports." (From James Harvey Robinson, *Readings in European History*, vol. 1 (Boston: Ginn and Company, 1904), 461)

3. Jacques de Vitry, "Description of University Students." Jacques de Vitry (d. 1240) was a French bishop who traveled widely before settling down and attending to his very successful ecclesiastical career. Among his many works of history he included this not-very-flattering description of the students at the University of Paris.

"Almost all the students at Paris, foreigners and natives, did absolutely nothing except learn or hear something new. Some studied merely to acquire knowledge, which is curiosity; others to acquire fame, which is vanity; still others for the sake of gain, which is cupidity and the vice of simony. Very few studied for their own edification or that of others. They wrangled and disputed not merely about the various factions and subjects of discussions; but the differences between the countries also caused dissensions, hatreds and virulent animosities among them, and they impudently uttered all kinds of affronts and insults against one another. They affirmed that the English were drunkards and had tails ; that the sons of France were proud, effeminate and carefully adorned like women. They said that the Germans were furious and obscene at their feasts ; the Normans, vain and boastful ; the Poitevins, traitors and always adventurers. The Burgundians they considered vulgar and stupid. The Bretons were reported to be fickle and changeable and were often reproached for the death of Arthur. The Lombards were called avaricious, wicked and cowardly; the Romans, seditious, turbulent and slanderous ; the Sicilians, tyrannical, brigands and ravishers ; the Flemings, fickle, prodigal, gluttonous, yielding as butter, and slothful. After such insults as these in words they often came to blows…" (From James Harvey Robinson, *Readings in European History*, vol. 1 (Boston: Ginn and Company, 1904), 455-54.)

PART V

CHAPTER 8 - THE EARLY MODERN PERIOD (1500-1600) – EUROPE – PHASE I: BREAKTHROUGHS IN SCIENTIFIC THOUGHT & TECHNOLOGICAL APPLICATION

CHAPTER 8 - CANNON AND FORTRESSES IN EARLY MODERN EUROPE

RICHARD MCGAHA

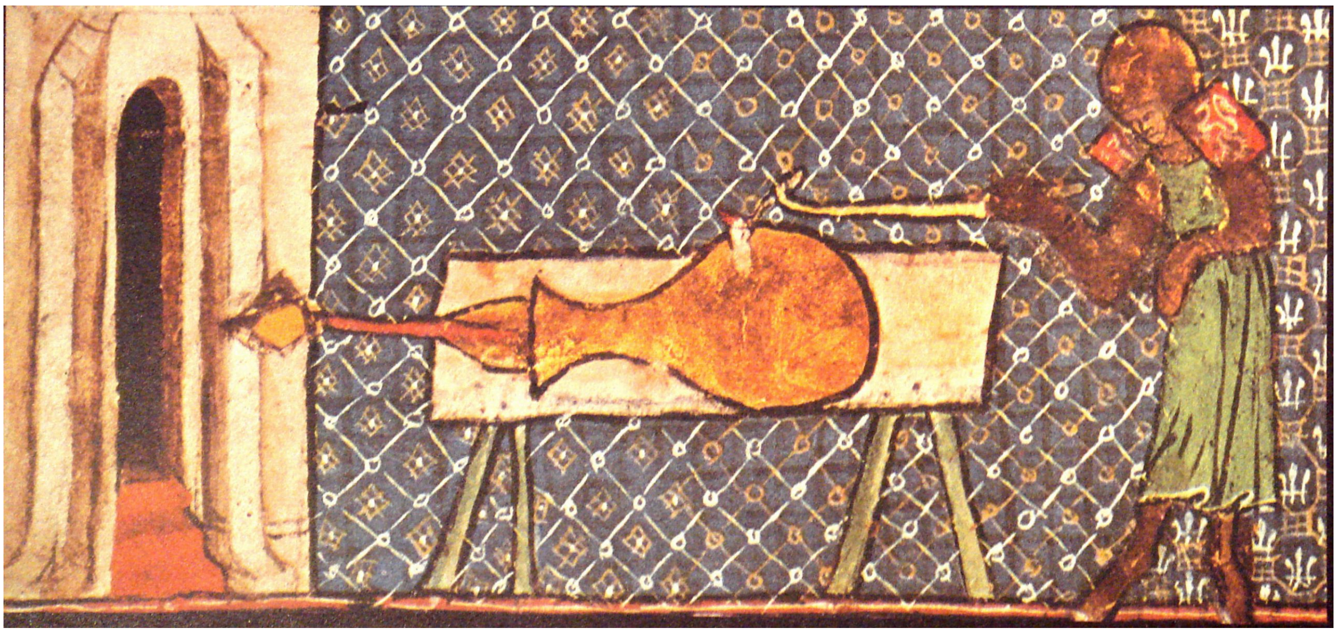


Figure 1. Early Cannon from Walter de Milemete's De Nobilitatibus Sapientii Et Prudentiis Regum Manuscript, 1326. Wikimedia Commons.

By the fourteenth century Europe was on the cusp of a revolution in warfare, one that would have a profound impact on war and the state. The utilization of gunpowder as a military weapon along with the invention of the gun would profoundly alter Europe. The English philosopher Francis Bacon (1561–1626) ranked gunpowder weapons alongside printing and the compass as the three critical discoveries of humankind.[1]

The first unequivocal description of a cannon is a Florentine document dating to 1326 authorizing the manufacture of brass cannon and iron cannonballs. Cannon technology spread quickly across Europe, first being used on the battlefield in 1340.[2]

While early cannon were ineffective tactically, they were effective psychologically. (See fig. 2) At the Battle of Crècy in 1346 the English king Edward III (1312–1377) "struck terror into the French Army with five or six pieces of cannon, it being the first time they had seen such thunderous machines."[3] While cannon may have been ineffective on the battlefield they did prove their worth in siege operations. Sieges had been an important part of warfare from ancient times. An effective fortification could keep an enemy occupied until either the castle or keep fell or the enemy had to retreat because winter was approaching. Sieges in the ancient and medieval world were incredibly time-consuming.[4] At the siege of Harfleur in 1415 Henry V (1386–1422) used twelve cannon to force the town to surrender. The defenders told him that "he schuld make his gunneres to sese, for it was to [t]hem intollerabil."[5]

Figure 2. Cannon at the Siege of Orleans from *Les Vigiles de Charles VII,* manuscrit de Martial d'Auvergne, ca. 1484. Wikimedia Commons.

Early cannon were incredibly heavy and could only be transported easily by sea or on rivers. It was only with difficulty that cannon could be transported overland given the poor road conditions in Europe. Some cannon were cast on the spot of sieges with workshops, men and materials transported to the site. A good example is the siege of Constantinople in 1453, where Sultan Mehmed II (1432–1481) had cannon cast on site for use against the city.[6] Casting cannon on site was incredibly expensive as it required the building of workshops and forges to cast the cannon. It also required the movement of raw materials to the battlefield which required the creation of a logistical train.

Early cannon suffered from several limitations. First, metallurgy was not refined enough to make an iron cannon solid enough to withstand the pressure of exploding gunpowder. Firing a cannon could be hazardous to the operator with the very real risk of the cannon exploding. Some smaller and mid-size iron cannon were wrapped in leather straps so that if the barrel ruptured, the pieces would not fly off and kill or injure the gunners. Larger cannon were cast in bronze. While bronze was stronger than iron, it was also three times more expensive, although the benefits justified the expense.

Second, early gunpowder was not powerful enough to show the true potential of cannon. It was not until the 1420s that "corned powder" was developed. It had larger granules which meant it was faster burning, 30 percent more powerful and resistant to moisture.[7] Early cannon also fired arrows or stones that had been chiseled down to fit the barrel of the cannon. This required access to a ready supply of stone to use as cannonballs which were generally transported to the siege site. The introduction of standard iron cannonballs in the fifteenth century alleviated this concern. Iron cannonballs combined with corned powder and improved metallurgy were more effective at penetrating fortress walls than stone cannonballs.[8] By the end of the fifteenth century cannon had become powerful enough and mobile enough to cause European warfare to change in the early modern period.

Fortresses

Figure 3. Magnus Manske, *Muiden Castle*. (CC BY-SA 2.0)

The standard castle in the medieval period was made of high stone walls with towers on the four corners surrounded by a moat which was basically a water-filled ditch. (See fig. 3) Indeed, in the Middle Ages, this was the standard design of castles, which was more than adequate for the age. The moat prevented an attacker from digging and undermining the integrity of the wall. Stone was resistant to most weapons of the age, including trebuchet which were basically catapults designed to hurl stones over walls. The height of the walls gave several advantages to a defender. First, the defender could throw down objects at attackers. Second, an attacker had to either build assault towers to roll up to the wall or put up ladders to allow their men to scale the walls. Assaulting a medieval castle was a costly and time-consuming effort. Cannon made those castle designs obsolete almost overnight and turned the advantage back to the attacker.[9]

The impetus for this change happened in the constantly warring Italian peninsula during the late fifteenth century. Charles VIII of France (1470–1498) invaded Italy in 1494 with an army of 18,000 men and forty siege guns. As the military historian Geoffrey Parker points out, "even contemporaries realized that this marked a new departure in warfare."[10] The Italian city-states scrambled to find a way to counter this potent new threat. Their solution was a fortress that became known as the *trace italienne*. (See fig. 4) Instead of building higher walls the walls were instead lowered and made thicker. Since this made them vulnerable to a surprise attack, flanking fire was needed, and as a result the bastion was developed. The bastion was an angled quadrilateral that jutted out from the main wall of a fortification, which allowed defenders to see every part of the wall and eliminated the blind spots that straight walls and round turrets contained. Bastions also provided mutually supporting fields of fire that caught attackers in a deadly crossfire. Over time, artillery was put on bastions to keep enemy siege guns as far away as possible. A ditch or moat was put around the wall to make it more difficult to undermine the wall. These star-shaped forts allowed a fortress to control up to fifty square miles (eighty square kilometers) of territory.[11]

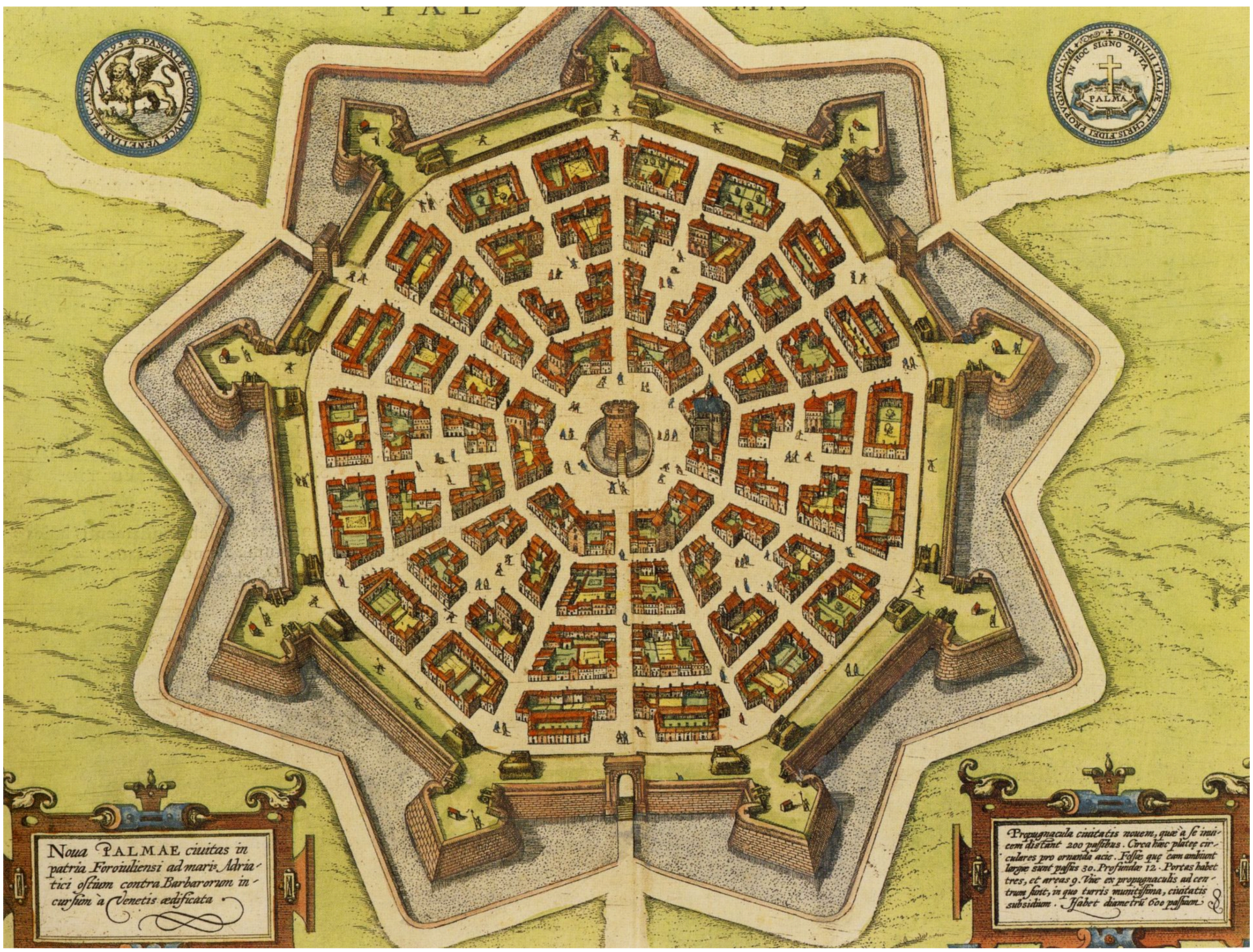


Figure 4. Palmanova *Trace Italienne* Fortress ca 1600 from Civitates Orbis Terrarum. https://commons.wikimedia.org/wiki/File:Palmanova1600.jpg Wikimedia Commons.

The cost of these new fortresses was staggering. Smaller city-states and cash- strapped monarchs struggled to pay for these fortresses and ensure their continued survival. Constructing and garrisoning fortresses became the state's single biggest expense. For example, in the early sixteenth century the Papal States planned a series of eighteen *trace italienne* style fortresses to protect Rome. The plan was scrapped when it was discovered that the cost of a single fortress was 44,000 ducats—the modern equivalent of 6.6 million dollars. To show how much that was, Venice, easily one of the most powerful city-states on the Italian peninsula had an annual income of 1,150,000 ducats. Siena, another powerful city-state was annexed by Florence when it could not afford to complete the fortifications it had started to build.[12]

In such an environment the state, such as it was in the fifteenth and sixteenth centuries, was the only body capable of building and financing *trace italienne* style fortresses in the numbers needed to protect their territory. By promising protection to local lords in exchange for subservience, the early modern nation-states were able to collect taxes to finance their military needs. This led to the creation of a bureaucracy to manage the size of the newly emerging "fiscal-military state."[13] The consolidation of power and resultant monopoly on violence led to the creation of the modern nation-state. In the words of historian Charles Tilly, "war made the state, and the state made war."[14] It should be noted that this is not a universally held view and the idea of a technologically driven "military revolution" has drawn some criticism. As historian Steven Gunn points out, there are "those who think war hindered or perverted processes of state formation based on the rule of law, the realization of an ideal model of sovereignty, or the construction of social coalitions based on religious or moral interests."[15]

The Israeli political scientist Azar Gat and English historian Jeremy Black have argued that the "military revolution" was preceded by political change instead of the reverse. Gat argues that the increase in army size and cost is illusory when compared to the rise in European population during the early modern period. Even Louis XVI's (1754–1793) massive army of 500,000 was only about 2.5 percent of the total French population which is estimated to have been 20 million. Black argues that only a modern nation-state could have "formed the political pre-condition for military growth." [16]

In some ways the arguments described above are a chicken-or-egg conundrum. The emergence of firearms and *trace italienne* style fortresses in the fifteenth century would bring a period of warfare to Europe that would continue almost unabated until 1815. Cannon added a new element ushering in the development of new types of fortresses as well as the creation of governmental bureaucracies to support the armies formed during this period.

[1]. Geoffrey Parker, *The Military Revolution: Military Innovation and the Rise of the West 1500-1800* 2nd ed. (Cambridge: Cambridge University Press, 1996), 160.

[2]. Ian V. Hogg, *A History of Artillery* (London, Hamlyn Publishers, 1974), 14–15.

[3]. Hogg, *A History of Artillery.*

[4]. Kelly DeVries and Robert Douglas Smith, *Medieval Military Technology*, 2nd ed. (Toronto: University of Toronto Press, 2012), 165–67.

[5]. Clifford J. Rogers, "The Military Revolutions of the Hundred Years War," in Clifford J. Rogers, ed.,

The Military Revolution Debate: Readings on the Military Transformation of Early Modern Europe (Boulder, CO,: Westview Press, 1995), 65–66.

[6]. Parker, *The Military Revolution*, 7; and Roger Crowley, *1453: The Holy War for Constantinople and the Clash of Islam and the West* (New York: Hachette Books, 2006), 90–92.

[7]. For a good discussion of early cannon and technology see Hogg, *A History of Artillery*, particularly chapters one and two; and Crowley, 87–88.

[8]. Simon Pepper and Nicholas Adams, *Firearms and Fortifications: Military Architecture and Siege Warfare in Sixteenth Century Siena* (Chicago: University of Chicago Press, 1986), 8.

[9]. See Parker, *The Military Revolution*, particularly chapter one.

[10]. Parker, *The Military Revolution*, 9; and Michael Mallett, "Diplomacy and War in Later Fifteenth Century Italy," *Proceedings of the British Academy*, 67 (1982), 270.

[11]. J. R. Hale, "The Early Development of the Bastion: An Italian Chronology, c. 1450–c. 1534," in John Hale, Roger Highfield and Beryl Smalley, eds., *Europe in the Late Middle Ages* (London: Faber & Faber, 1965), 466–94 and Parker, *The Military Revolution*, 11.

[12]. Parker, *The Military Revolution*, 12, 39; and Roger Crowley, *City of Fortune: How Venice Ruled the Seas* (New York: Random House, 2013), ch. 16.

[13]. This was a state whose only function was national defense and who devoted all of its resources to the military. See especially the argument of Jan Glete in *War and the State in Early Modern Europe: Spain, the Dutch Republic and Sweden as Fiscal-Military States* (London: Routledge, 2001).

[14]. This is the thesis of Charles Tilly's, *Coercion, Capital and European States, AD 990–1992* (London: Wiley-Blackwell, 1992).

[15]. Steven Gunn, "War and the Emergence of the State: Western Europe, 1350-1600," in Frank Tallett and D.J.B. Trim eds, *European Warfare, 1350-1750* (Cambridge: Cambridge University Press, 2010), 50.

[16]. For Gat's argument see Azar Gat, *War in Human Civilization* (Oxford: Oxford University Press, 2006), 466–71 and 474–76. The quote is from Geoffrey Parker, "In Defense of the Military Revolution," in Rogers, *The Military Revolution Debate*, 340. Black's argument can be found most prominently in "A Military Revolution? A 1660-1792 Perspective," in Rogers, *The Military Revolution Debate*, ch 4. Wayne E. Lee also has a valuable discussion of the critiques of the military revolution in Wayne E. Lee *Waging War: Conflict, Culture and Innovation in World History* (Oxford: Oxford University Press, 2016), 244–47.

PART VI

CHAPTER 9 - THE EARLY MODERN PERIOD (1600-1750) – EUROPE – PHASE 2: THE NEW SCIENCE OF THE SEVENTEENTH CENTURY & THE ENLIGHTENMENT

CHAPTER 9 - VARIABILITY OF THE HUMAN SPECIES BEFORE 1750

ANTOINE LEVEQUE

The current definition of the term "species" only started to emerge in Europe during the historical period that Western scholars call the Enlightenment. Before 1750, Christian theology asserted that God had created *all* species in an immutable fashion.[1] In pre-modern times, European learned discourses were dominated by the political perspectives of the Christian Church.[2] Species were therefore conceived as "essences" but, after World War II, when the genus *homo* started to be established from the standpoint of comparative anatomy in a non-racialist paradigm,[3] the term species then started to be simply understood as biological: a succession of individuals.[4] Before the Enlightenment, Western European scholars did not consider individual bodily differences as something important to their theological science. This is not to say that ancient Greco-Roman science or pre-Enlightenment science considered the body as unimportant. However, the body of non-Western Europeans was often imagined rather than studied anthropologically.

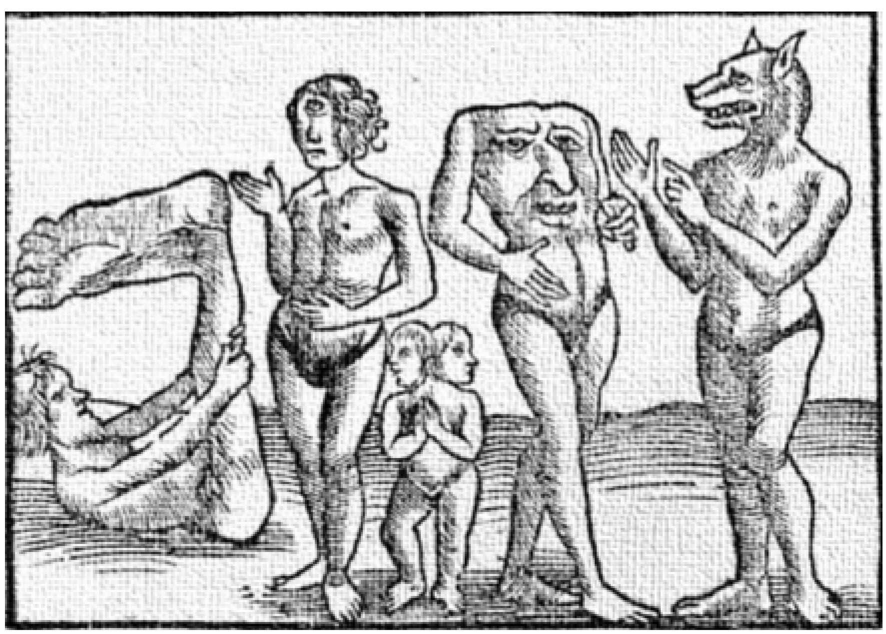


Figure 1. An image traditionally found in medieval books. This depiction of diversity is borrowed from the natural history of an authoritative Roman author named Gaius Plinius Secundus (CE 23–79), known as Pliny the Elder.' This is a phantasmagorical rendering of far-away people before Western Europeans mastered oceangoing ships and gunpowder technology. (Image in the public domain.)

For instance, language and religious faith were more important to Western European scholars than traits such as skin color or hair type. The most important point is that Western European theologians considered the members of our species as beings possessed of an immortal soul. Following ancient theories such as that of Aristotle, they deemed this soul to be naturally rational. However, a conversion to Christianity though the religious rite of baptism was indispensable in order for people to be considered human beings.[5]

As the Christian Church became an epistemic and political institution from the 5th century CE onward, a specific doctrine about mankind crystallized in European learned discourses and scholarly circles. The Church's theorists argued that the label *homo* (the Latin for "man"), which was used in pre-Christian science, was to be applied to any living form endowed with the ability to reason and the ability to speak.[6] If one could utter words, learn a language, and speak in an intelligible manner, Western European science considered that person possessed the character that was considered as the distinctive *sign* of species membership. However, before the introduction of transcontinental navigation technology, people living overseas and far away from Europe did not speak the same languages as the Europeans, who came to exploit natural resources, trade, colonize, and convert locals to Christianity.

The aggressive behavior of European merchants made cultural exchanges and good diplomatic relationships between people difficult. This was especially true where financial capitalization was the prime aim of the then emerging Western European nation states, which launched the overseas travel expeditions.

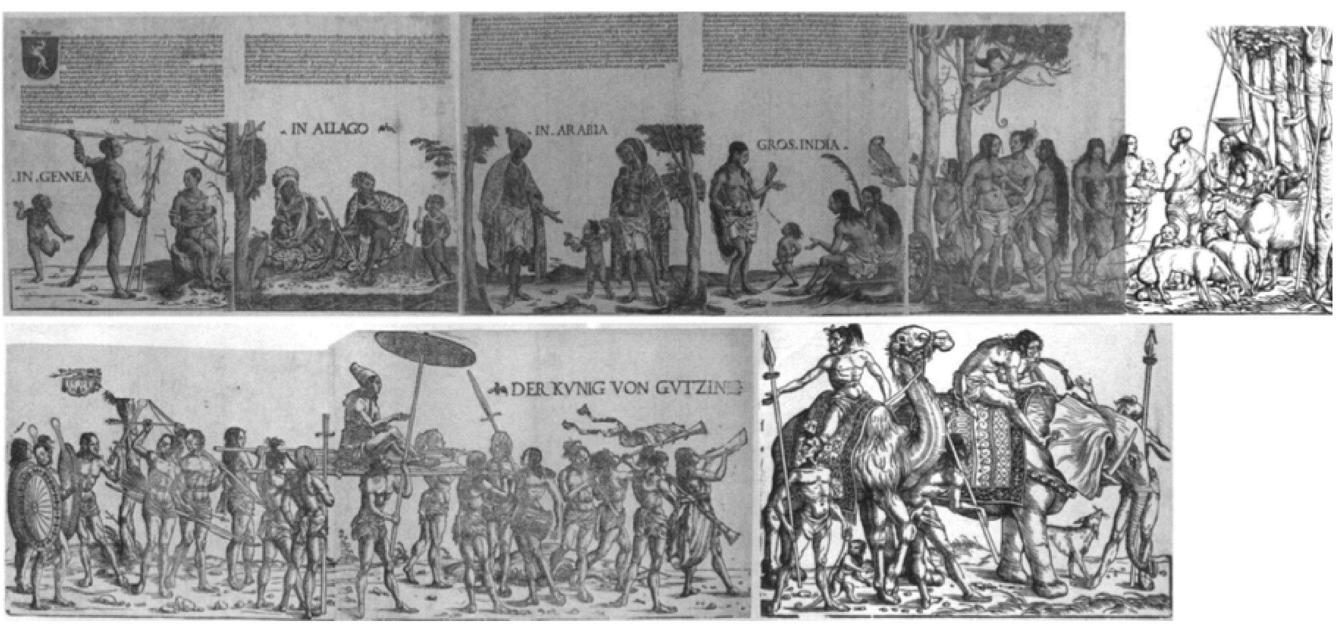


Figure 2. This 1493 wood engraving was printed after a powerful Augsburg merchant family launched the first commercial enterprise to continents far away from Western Europe. It depicts the people encountered by Europeans and relativizes the subjects to the European viewer by using iconographic

models that were familiar in Europe. From Stephanie Leitch, "Burgkmair's *Peoples of Africa and India* (1508) and the Origins of Ethnography in Print," *Art Bulletin* 91, no. 2 (June 2009): 135, https://doi.org/10.1080/00043079.2009.10786162. (Image in the public domain.)

Because of their technological means and the nature of their purpose, Europeans rarely felt compelled to recognize the linguistic and rational abilities of the people they came into contact with.[7] Colonization was mostly conducted for financial profit and only missionaries were tasked with transforming and integrating conquered individuals into the mother countries. In time, and with the development of African-based slavery, the validity of the classical criteria for establishing species membership would itself be doubted: that is when the geographical concept of race started to be used in science. This development only happened from the late 17th century onward.[8] From then on, learned discourses would increasingly focus on the variability of physical characters peculiar to the different groups making up our species. However, this focus was virtually absent in Western European scholarship of the medieval and early modern period.

In the fifth and sixth centuries CE, the Catholic theologian Augustine of Hippo (354–430) had produced a synthesis conflating ancient Greco-Latin theories about our genus, on the one hand, and the revealed truths contained in the Bible, on the other. His discourse was used as a foundation for the Church's doctrine, which relied on the book of Genesis to state that all the members of our kind were descendants of Adam and Eve, who are the male and female mythical figures contained in the Bible.[9] Theologians of the Catholic Church devised a strict criterion to distinguish between humans and nonhumans. Thus, their religious and political entity could grow maximally, up to the point of extending virtually to the confines of the habitable Earth.[10] Except for a few marginal authors, European scholars of the early modern period considered mankind to be one genus. Jesus of Nazareth had proscribed ethnic divisions in his teachings, which were relayed by his disciples in what Christians call the New Testament. This text was a central point of reference for the Church, both as a political institution and as an institution of knowledge. Individuals belonging to the category human possessed an ability to understand the intent of God, the supposed author of nature according to Christian theological science.[11] This criterion allowed Western Europeans to establish a distinction between mankind and the animal kingdom. However, it also required that people converted to the Christian faith. This ability was identified as an endowment specifically given by God to one species, which had been entrusted with a mission: that of accomplishing the Christian god's will on Earth.

As Western European nation-states emerged in the late Middle Ages, scholars looked more freely toward natural science to theorize about the human soul and this altered the structure of theological discourses. The Protestant Reformation introduced an epistemic shift that allowed anatomical study to develop independently of the Church's canonical and authoritative theologians.[12] All souls had equally been created by God according to pre-modern Western European science.[13] However, the body became a new topic of inquiry with the political rise of bourgeois identity. An important shift happened when astrology and other environmental and geographical influences started to become part of theology.[14] Alongside the holy Christian scripture, natural science now gave scholars a new perspective. They could produce theories about the human soul and how its faculties varied according to climate and other environmental influences, such as diet and intellectual or physical exercise.

When Europeans colonized the world from the 15th century onward, they generally justified their endeavor as being the Christian fulfilment of a divine mission. However, pre-Christian theories from antiquity also started to be incorporated into early modern learned discourses about the variety of customs, languages, and physical traits among the Earth's people.[15] Since all humans descended from Adam and Eve according to the Christian doxa, it was difficult to explain how far-away regions that were not mentioned in the Bible had been peopled. The legal right and justification of conquest was at stake when those questions were debated among scholars.[16] However, the peculiar physical characteristics of the world's different peoples was not something of importance in science during the early modern period.

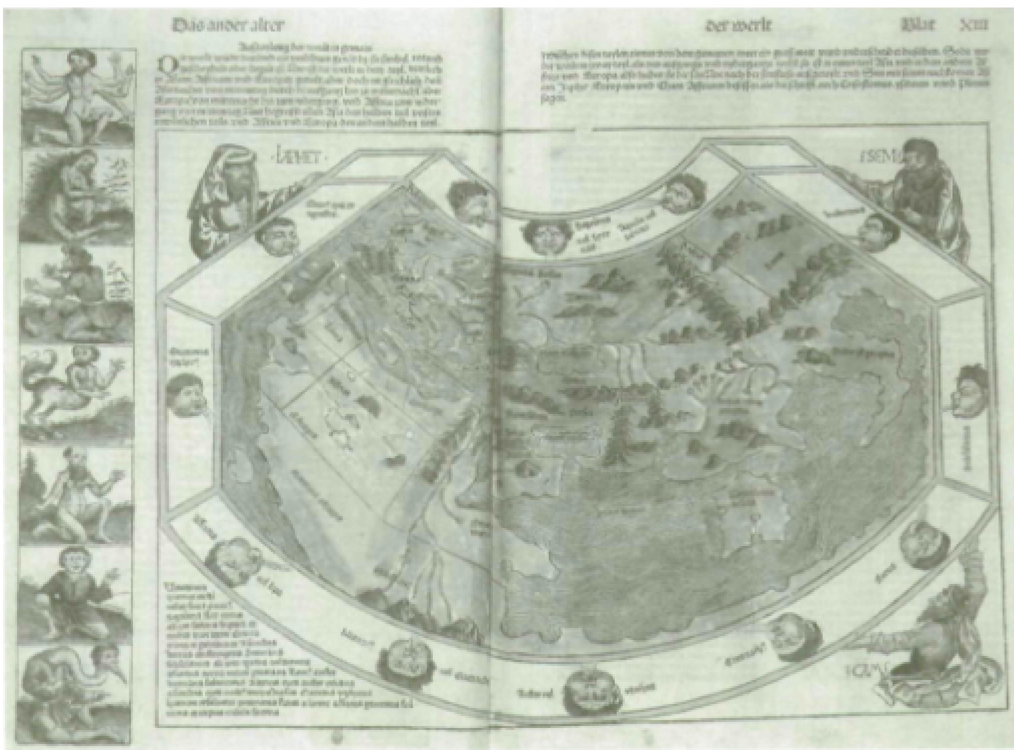


Figure 3. Hans Pleydenwurff and Michael Wolgemut, "Map of the World, in *Nuremberg Chronicle*, 1493 (artwork in the public domain). A new strategy is at play here: pre-Christian phantasmagorical representations of diversity are on the left margin. The Earth is divided among Sem, Japhet and Cain, the three sons of Noah, the mythical figure who peopled the earth after a putative universal flood, according to the story told in the book of Genesis, which is contained in the Bible.

Before 1750, the taxonomy of people was based on religious faith, which accounted for the divide between political entities.[17] The essentialization of differences between people of European, Asian, and African descent originated more in folk knowledge than in scholarly discourses.[18] For science, all indigenous people could and should be transformed both physically and morally through missionary work. With few exceptions, Western European thinkers before 1750 held a conception of all people as fundamentally the same. When the pope mandated colonizing European monarchies to convert the recently discovered peoples of the world,[19] missionaries believed that all people were in possession of a savable soul.[20] This theory justified proselytism and conquest, but not segregation, as would be the case when the geographical concept of race spread in the language of science from the mid-eighteenth century onward.

[1]. Folk taxonomies and definitions of the species concept shall not concern us here. For this subject, see Scott Atran, "Origin of the Species and Genus Concepts: An Anthropological Perspective," *Journal of the History of Biology* 20, no. 2 (Summer 1987): 195–279, http://www.jstor.org/stable/4331011; and Scott Atran, "The Early History of the Species Concept: An Anthropological Reading," in *Histoire du concept d'espèce dans les sciences de la vie*(Paris: Singer-Polignac, 1987), 1–36.

[2]. When this term is capitalized, it refers to the political and epistemic Christian institution, not to the building.

[3]. B. A. Wood, "The History of the Genus *Homo*," *Human Evolution* 15, nos. 1–2 (2000): 39–49, https://doi.org/10.1007/BF02436233.

[4]. Ernst Mayr, *The Growth of Biological Thought* (Harvard: Harvard University Press, 1982), p. 261.

[5]. Anthony Pagden, *The Fall of Natural Man: The American Indian and the Origins of Comparative Ethnology* (Cambridge: Cambridge University Press, 1986), 103.

[6]. Some contemporary theorists of feminism have argued that pre-modern learned discourses linked the sexual diversity of body between men and women to a natural difference in intellectual ability. Furthermore, they have argued that this type of learned discrimination among genders formed the theoretical matrix on which scientific racism was built after 1750. See Elsa Dorlin, *La matrice de la race: généalogie sexuelle et coloniale de la nation française* (Paris : La Découverte, 2014). If they are correct, then the Latin ”homo” did not refer to man *and* woman, but only to men. See also Londa Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (Boston: Beacon Press, 1993).

[7]. The technological superiority of Europeans consisted, for instance, of the oceangoing ship and the canon. James E. McClellan III and Harold Dorn, *Science and Technology in World History: An Introduction*, 3rd ed. (Baltimore: John Hopkins University Press, 2015), 220.

[8]. The concept of race came from the vocabulary of animal and plant breeders. It was used for the first time to speak about the human species to refer to the royal dynasties of French kings. The French nobility then used it from the sixteenth and seventeenth century onward to secure their political privileges over the common people, after gunpowder had changed the feudal political system and large monarchies started to centralize political power. See Pierre H. Boulle, "Francois Bernier and the Origins of the Modern Concept of Race," in *The Color of Liberty, Histories of Race in France*, ed. Sue Peabody and Tyler Stovall, 2nd printing (Durham, NC: Duke University Press, 2006), 11–27, 20.

[9]. David N. Livingstone, *Adam's Ancestors: Race, Religion, and the Politics of Human Origins* (Baltimore: John Hopkins University Press, 2008).

[10]. The etymological root for the term "catholic" is the ancient Greek term *katholikos*, which means "universal." However, this term was only used early in the history of the Church, before it became popular again after the Protestant Reformation of Martin Luther and John Calvin. Augustine of Hippo

used it to refer to those Christians who had the "true faith" and who complied with the Church's political and spiritual ambitions.

[11]. John Block Friedman, *The Monstrous Races in Medieval Art and Thought* (Syracuse: Syracuse University Press, 2000).

[12]. The structure of medieval knowledge was based on the study of a given number of texts. European scholars were trained through the learning and discussion of those texts, which were called *auctoritates*. See Steven J. Livesey, "Scholasticism," in *Medieval Science, Technology, and Medicine: An Encyclopedia*, ed. Thomas Glick, Steven J. Livesey, and Faith Wallis (New York: Routledge, 2005), 453–55.

[13]. For Augustine and all major official Catholic discourses up until the 13th century, all human souls were fundamentally and essentially equal. The relationship between the three faculties of the soul— memory, intellect, and will—were then understood according to the relationship between the elements of the Holy Trinity. "*Haec tria, une vita, una mens, una essentia*." See Augustine, lib. 10, cap. 11), in W. J. Mountain, ed. *De Trinitate*, Corpus Christianorum series latina, vol. 50 and 50a (Turnhout, Belgium: Brepols, 1968).

[14]. Edward Grand, *Studies in Medieval Science and Natural Philosophy,* chap. 13 (London: Variorum, 1981), 211–44; Clarence J. Glacken, *Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley: University of California Press, 1967); and Marian J. Tooley, "Bodin and the Medieval Theory of Climate," *Speculum* 28, no. 1 (January 1953): 64–83.

[15]. In the early sixteenth century, right after the start of the Spanish and Portuguese colonization of the Americas, new scholarly texts emerged among the *auctoritates*. For instance, a new passage by Aristotle on "natural slavery" entered the corpus of authoritative of texts in 1519. Hugh Thomas, *Rivers of Gold: The Rise of the Spanish Empire, from Columbus to Magellan* (New York: Random House, 2005), 297-98. Anthony Pagden, *The Fall of Natural Man*; and Lewis Hanke, *Aristotle and the American Indians*: *A Study of Race Prejudice in the Modern World* (London: Hollis and Carter, 1959).

[16]. For instance, scholars belonging to particular European monarchies would sometimes not hesitate to claim that the people they wanted to colonize overseas were remote descendants of their own nation. See M. L. Kuntz, *Guillaume Postel: Prophet of the Restitution of All Things. His Life and Thought* (The Hague: Kluwer, Martinus Nijhoff, 1981); Toy-Fung Tun, "Of Adam's Rib. Cannibalism and the Construction of Otherness through Natural Law," in *Theorizing Legal Personhood in Late Medieval England*, ed. Andreea D. Boboc (Leiden: Brill, 2015), 218–43; and Giuliano Gliozzi, *Adam et le Nouveau Monde. La naissance de l'anthropologie comme idéologie coloniale: des généalogies bibliques aux théories raciales (1500–1700)* (Nîmes: Théétète éditions, 2000).

[17]. Ivan Hannaford, *Race: The History of an Idea in the West* (Baltimore: John Hopkins University Press, 1996); 148–49.

[18]. Lay and unofficial interpretations of the biblical story about Noah's three sons were produced during the Middle Ages about the peopling of the world and the diversity of customs and physical traits among the world's peoples. See Benjamin Braude, "The Sons of Noah and the Construction of Ethnic and Geographical Identities in the Medieval and Early Modern Periods," *William and Mary Quarterly* 54, no. 1, Constructing Race (January, 1997): 103–42.

[19]. In this regard, two events are worth mentioning. First, the Treaty of Tordesillas, which was signed between the pope, the king of Spain, and the king of Portugal, on June 7, 1494. Under the pope's benediction, it divided the newly discovered world between Spain and Portugal, under the expression condition that the newly conquered people would be Christianized. The second event was the Valladolid controversy, at the end of which the Church decided that Amerindians were creatures naturally endowed with the ability to understand the plan of the Christian god. See Stephanie B. Martens, *The Americas in Early Modern Political Theory States of Nature and Aboriginality* (New York: Palgrave Macmillan, 2016).

[20]. Justin Smith, *Nature, Human Nature, and Human Difference: Race in Early Modern Philosophy*, ch. 3 (Princeton: Princeton University Press, 2015), pp. 70–91.

CHAPTER 9 - THE ORIGINS OF ETHNOLOGY AND ANTHROPOLOGY (1750–1900)

ANTOINE LEVEQUE

In the second half of the eighteenth century, European naturalists started to see the physical diversity of people around the globe differently. More than was previously the case, evolving epistemologies tended to consign a much broader range of accounts, and especially traveler's tales, to the realm of "fable." Such was, for instance, the case of accounts telling of giants living in Patagonia or of people with tails. In the 1750s, two naturalists had an impact on the development of theories pertaining to the variability of the human species. Swedish taxonomist Karl Linnaeus (1707–1778) coined the term *homo sapiens* and, in light of comparative anatomy, was the first to include humankind into the order of primates. He divided mankind into five groups: American, European, Asian, African, and one labelled as "deformed by climate or art." French zoologist, botanist, and philosopher Louis Leclerc de Buffon (1707–1788) initiated the natural history of man and disseminated a radically new meaning for the concept of species.[1]

In time, the project of first subclassifying human types and then discovering the reasons accounting for intraspecific variability would upset pre-Enlightenment theories about the station of humankind within the natural order. In 1859, British naturalist Charles Darwin (1809–1882) published *On the Origin of Species* and French biologist Paul Broca (1824–1880) established the world's first anthropological society. This year may be used to mark the date of final exclusion of a concept known as the Great Chain of Being from scientific literature.[2] According to this concept, nature was God's creation and he had placed the human *form* atop all other lifeforms by giving it a common form, or "essence," residing in the ability to reflect divine intellect.

As ethnology and anthropology became institutional sciences, this worldview, which considered the specificity of the human form as an intentional act of God, would be overturned.[3] The world's first ethnological society was founded in Paris in the 1830s under the patronage of François d'Orléans, Prince of Joinville (1818–1900), who was a hero in the colonial war that France waged in North Africa.[4] Ethnology was then defined as the scientific study of human races and the concept of race[5] crystalized as a paradigm in this discipline.[6] The Ethnological Society of Paris was founded by William F. Edwards (1777–1842), whose family owned slaves in Jamaica when the British crown abolished slavery.[7] The world's leading practitioner of anthropology in the second half of the nineteenth century, Paul Broca, credited Edwards for having first stated the scientific objective of his newly institutionalized discipline.[8]

In the second half of the eighteenth century, scholars focusing on the natural history of man often used the concept of *variety* instead of the concept of race to conduct their research.[9] Yet European explorers and colonialists were still in the process of finishing their survey of the world and of the people inhabiting it as European nations started to administer large-scale colonial empires. This is when the concept of *race* started to become central in scientific circles. The period ranging from 1750 to 1900 was marked by a profound change of ideas pertaining to the trading of African slaves, whom European colonists had been using as free labor to maximize financial profits.[10] The scientific study of physical differences became a way to legitimize differences pertaining to the legal status of people who had European ancestry and people who did not.

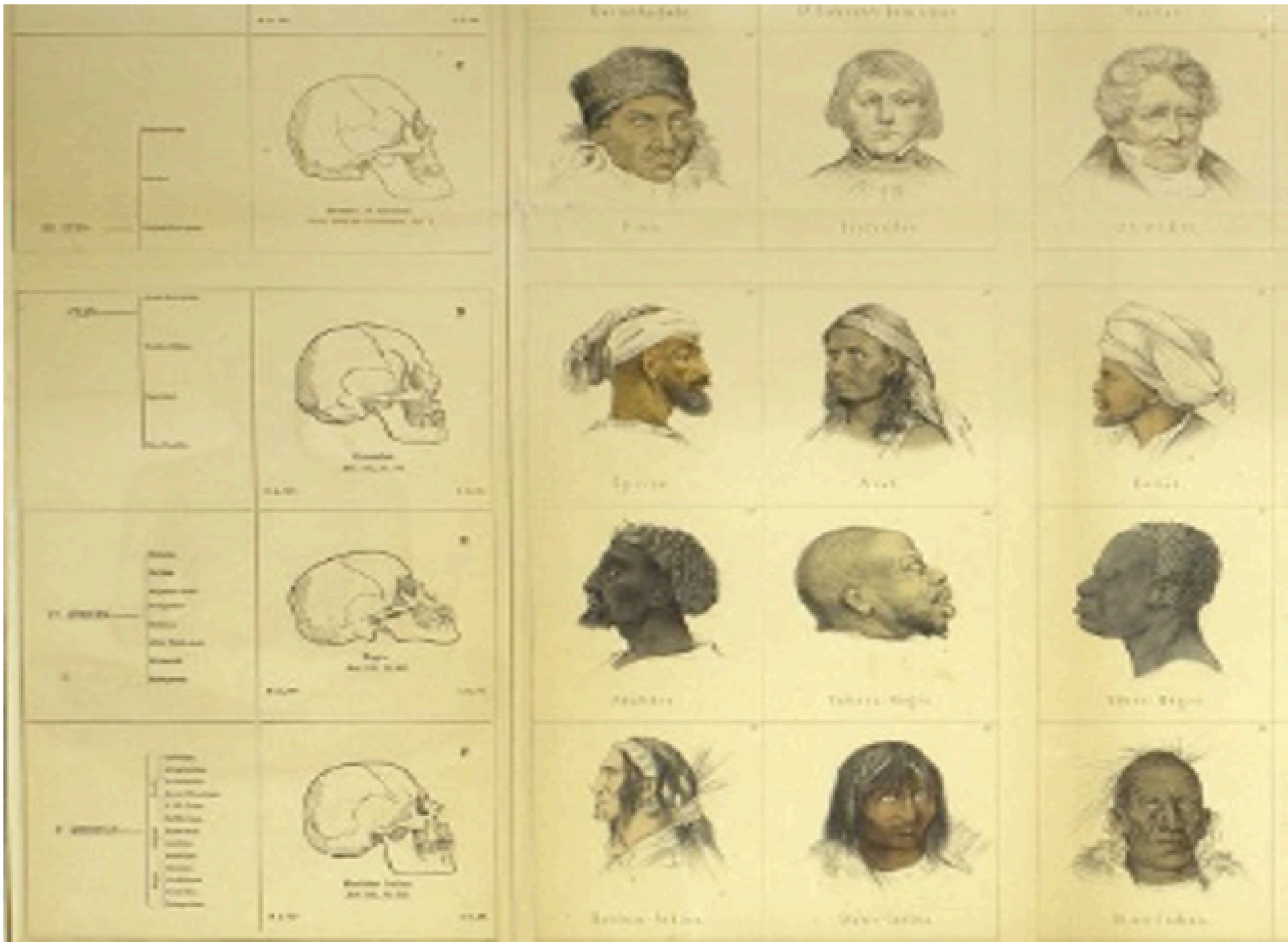


Figure 1. Specimens of human races. Illustration by Peter Kramer, "Ethnographic Tableau: Specimens of Various Races of Mankind" in J. C. Nott. and George R. Gliddon, *Indigenous Races of the Earth; or, New Chapters of Ethnological Inquiry* (Philadelphia: J. B. Lippincott & Co., 1857).

Johannes F. Blumenbach (1752–1840) coined the term "Caucasian" and started a seminal study of human skulls, which he deemed representative of each human variety. Using this work, later generations of craniologists would produce theories in which the cranial structures of individual people were typified according to each race. Yet there has never been complete agreement among ethnologists and anthropologists about the exact number of human races or about the precise criteria to distinguish one race from the next. However, throughout the nineteenth century, European naturalists interested in the natural history of man were divided into two camps: those embracing a monogenetic theory of human variability and those embracing a polygenetic one.

In the 1820s, the polygenetic theory, which stated that there were originally different and permanent types, races, or species within mankind, became prevalent in France.[11] This perspective was highly unorthodox because it contradicted the revealed truth of the Bible, which stated that all of mankind descended from a single pair of humans, Adam and Eve. Theories upholding the unity of the human species were called "monogenetic," but did not uphold a more egalitarian view of the races' intellectual abilities than "polygenetic" theories. Indeed, nineteenth-century ethnologists and anthropologists recognized the existence of natural differences with regard to the intellectual abilities of the human races they distinguished taxonomically. In the late eighteenth century, European physiologists started to correlate the study of racial types with physiological investigations about the intellect, increasingly consensually considered as the *function* of an organ. They thought that racial differences entailed specific cranial structures and thus specific mental abilities. Anthropology considered itself useful as a science to ground political decisions because it revealed the physiological specificity of people and thus the function that was best suited to them.

In the second part of the nineteenth century, anthropology was not only the science in charge of researching the taxonomical lines between human races, it also tried to decipher the connection between bone structure and behavior.[12] Physical anthropology applied not only to human races but also to differences between the sexes and political 'classes'.[13] It was a way to use the natural sciences in order to justify political inequalities. Between 1830 and 1870, ethnology and anthropology were founded as institutional disciplines in all the countries of Western Europe and in the United States of America. As sciences, they sought to establish the nature of the cause-and-effect relationship between the biological makeup of the human races and their historical development. The use of comparative anatomy for taxonomical purposes had started in the late eighteenth century, and, at this time, authors could still classify great apes among humans.[14]

The classification of bones according to their sizes was seemingly neutral and objective: it allowed ethnology and anthropology to gain the repute of being able to solve conflicts of interest impartially. People of different geographical ancestry coexisted in the colonies established by Europeans, and the scientific status of ethnology gave the white race a powerful rhetorical tool to argue that nonwhites were physiologically unfit for political life. For instance, the physician Josiah Nott (1804–1873), based in Mobile, Alabama, fought to preserve the legal right of whites to own African slaves: he was eager to spread the findings of French and British ethnological science in the United States.[15] Paul Broca measured 180,000 human skulls in an attempt to establish racial classifications and made discoveries pertaining to the localization of brain functions. However, his work did not create a precedent for the discipline that is called anthropology today. Nowadays, anthropology is typically defined as "the study of people, *culture* and society through all time and everywhere around the world."[16]

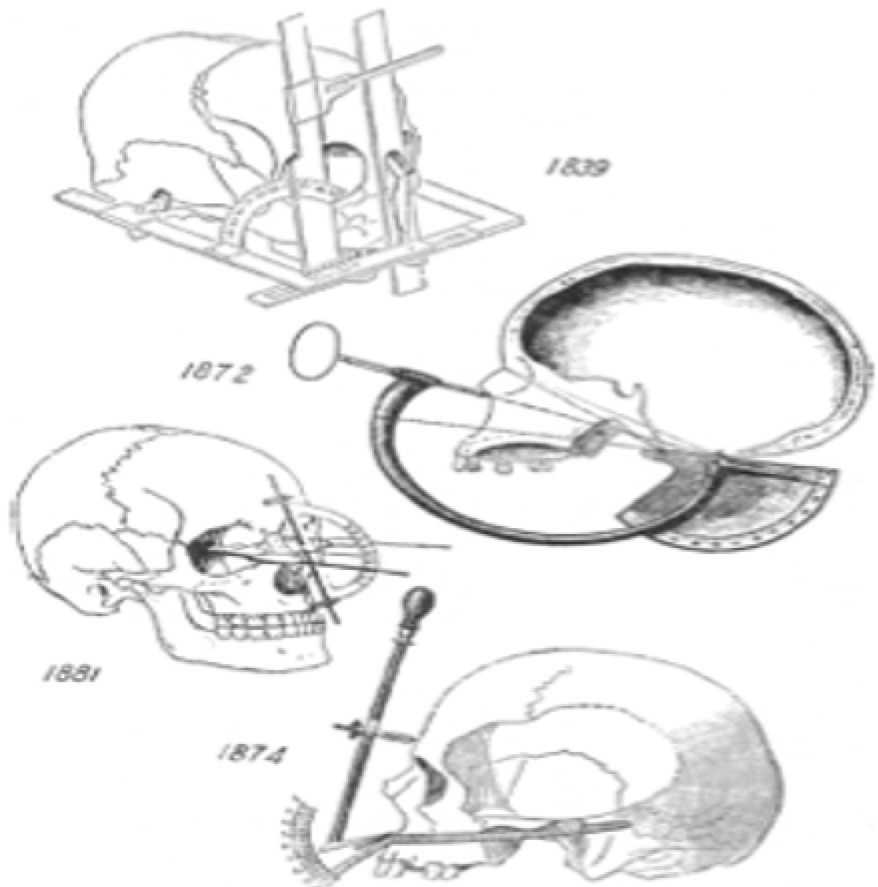


Figure 2. Anthropological instruments used for measuring human skulls. Lucile E. Hoyme, "Physical Anthropology and Its Instruments: An Historical Study," in *Southwestern Journal of Anthropology* 9, no. 4 (Winter 1953): 416.

[1]. Ernst Mayr, *The Growth of Biological Thought* (Harvard: Harvard University Press, 1982), 260–63.

[2]. This notion had been continuously prevalent in the discourse of European scholars since Greco-Roman antiquity and through the Middle Ages, as well as during the Enlightenment and modern period. Michael Ruse, *Monad to Man: The Concept of Progress in Evolutionary Biology* (Harvard: Harvard University Press, 1996), 21–23.

[3]. Jennifer Michael Hecht, *The End of the Soul: Scientific Modernity, Atheism, and Anthropology in France* (New York: Columbia University Press, 2005).

[4]. M. Alfred Nettement, *Histoire de la conquête d'Alger: écrite sur des documents inédits et authentiques*(Paris: J. Lecoffre, 1870), 207-08.

[5]. The term "race" has a long history in the Romance languages: it started to be used in the vocabulary of animal and plant breeders in the 15th century, before French royal and noble families started to use it in the sixteenth and seventeenth century. Historians generally agree that the

contemporary meaning of the term was first used in a scientific theory in 1684. This date marks the first occurrence in science of the idea that there is a natural division among people according to their geographical ancestry. The new use of the term conveyed the notion that physical differences are worth correlating with people's geographical ancestry. However, scientific interest for this topic remained marginal until the 1780s. See Siep Stuurman, "François Bernier and the Invention of Racial Classification," *History Workshop Journal* 50, no. 1, (2000): 1–21, https://doi.org/10.1093/hwj/2000.50.1.

[6]. Robert Rondinelli, "An Historical Review of Racial Studies in Physical Anthropology from a Kuhnian Perspective, " *Steward Anthropological Society Journal* 6, no. 1 (Fall 1974): 49–69, 56.

[7]. Frank Spencer, ed., *History of Physical Anthropology: An Encyclopedia*, vol. 2 (New-York: Garland Publishing, 1997), 357–59.

[8]. Claude Blanckaert, *De la race à l'évolution*, *Paul Broca et l'anthropologie française* (Paris: Harmattan, 2009).

[9]. Nancy Stepan, *The Idea of Race in Science: Great Britain, 1800–1960* (Hamden, CT: Archon Books, 1982).

[10]. In 1750, this commercial practice had reached its apex, but it was definitively abolished in England, France, and the United States by the time that the nineteenth century came to a close. Pierre Boulle, "In Defense of Slavery: Origins of a Racist Ideology in France," in *History from Below*, *Studies in Popular Protest and Popular Ideology*, Frederick Krantz, ed. (Oxford: B. Blackwell, 1988), 220–24.

[11]. Martin S. Staum, *Labelling People: French Scholars on Race, Society, and Empire, 1815–1848* (New York : McGill-Queen's University Press, 2003).

[12]. John W. Stocking, Jr., *Bones, Bodies, Behavior: Essays on Biological Anthropology*, History of Anthropology, vol. 5 (Madison: Wisconsin University Press, 1988).

[13]. Londa L. Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (Boston: Beacon Press, 1993).

[14]. James Burnet, *Lord Monboddo, Orangutans and the Origins of Human Nature* (Bristol: Thoemmes Press, 2000).

[15]. Josiah Clark Nott, *Two Lectures on the Natural History of the Caucasian and Negro Races* (New York: Barlett and Welford, 1849), 7–8.

[16]. James H. Birx, *Encyclopedia of Anthropology*, vol. 1 (Thousand Oaks, CA: SAGE, 2005), 142. (Italics added.)

CHAPTER 9 - ENCYCLOPEDIAS: BOTANY AND BOOKS - LINNAEUS AND DIDEROT

SARAH JEONG

The first description of the natural world in the West can be traced to Aristotle, who placed man at the pinnacle of God's creation, and later was revitalized in medieval Christian Europe as the concept of natural theology, which justified the application of religion to the discovery and description of new flora and fauna during voyages to the New World.[1] The medieval philosophy of the Great Chain of Being of the continuous, hierarchical gradation of species from simpler forms to more complex human beings influenced many Enlightenment thinkers, including Georges-Louis Leclerc, Comte de Buffon (1707–1788) and Denis Diderot (1713–1784).[2]

Before Swedish naturalist Carolus Linnaeus (1707–1778) published his taxonomic botanical nomenclature system, Buffon, who was based in Paris, was the prominent Enlightenment botanist. Linnaeus's classification of species as being of equal rank (including *Homo sapiens*) was a paradigm shift from the hierarchical existential order of the traditional, commonly held concept of the Great Chain of Being. When Linnaeus shared his work with Dutch naturalists, among those who accepted his work was Jan Frederik Gronovius (1690–1762), who facilitated the publication of Linnaeus's *Fundamenta Botanica* (*Foundations of Botany*) in Holland in 1735, which based plant nomenclature on the number, form, and order of the stamens and pistils. As an author of a series of books, Linnaeus created a framework for the first objective system to catalog every plant and animal by genera and species, establishing a binomial nomenclature of flora and fauna. Linnaeus published the first edition of *Systema Naturae* (*System of Nature*) in 1735 after completing his doctoral thesis. In this work, Linnaeus proposed a new system of classification order of kingdoms, which included plants, animals, and minerals.[3] Specifically, Linnaeus organized new nested categories of equal status, and every species known at the time was placed within a genus, order, class, and kingdom.

Another concurrent historical development in France was the writing, editing, and publication of Diderot's *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers* (*Encyclopaedia, or Classified Dictionary of Sciences, Arts, and Trades*). Published over a period from 1751 to 1772, it is a landmark work of secular, polemical Enlightenment thought that criticized Linnaeus's classification system with articles written by naturalist Louis-Jean-Marie Daubenton (1716–1800), who was a collaborator for Buffon's *Histoire naturelle* (*Natural History*, 1749), and who argued that the natural diversity of life comprises individuals with granular characteristics such that no classification was the best system.[4] Initially, the publisher Le Breton hired their first editor, Jean-Paul de Gua de Malves (1713–1785), a mathematician, to improve upon Ephraim Chambers's (1680–1740) *Cyclopaedia* (1728) as a model, which was accepted by the traditional regime. Jean-Paul de Gua de Malves recruited fellow mathematician Jean le Rond d'Alembert (1717–1783) as his assistant, who later assumed the coeditorship after de Malves' resignation, with Denis Diderot as editor-in-chief and one of the contributors to the *Encyclopédie.*[5] Diderot differentiated the *Encyclopédie* from Chambers's *Cyclopaedia* through modernizing the universal map of knowledge by decentralizing theology and reordering reason and natural history at the core.[6] Extensive cross-references heralded open-ended, scholarly conversations in this new general encyclopedia.[7] The naming of the title *Encyclopaedia* established the term "encyclopedia" in the lexicon as a compendium of human knowledge.[8]

> Figure 1. Click here: Title page of Denis Diderot's *Encyclopédie, first edition*. Wake Forest University, Z. Smith Reynolds Library Special Collections, CC-BY-NC-SA 2.0 license.

The first volume of the *Encyclopédie* was published in 1751, and contrary to popular assumption, the contributors, also known as encyclopedists, were not like-minded thinkers from a common occupation or ideology. The eclectic authorship is among the most fascinating aspects of the *Encyclopédie.* This multivolume encyclopedia contains articles authored by more than a hundred contributors, including the scientific writings of Paul-Henri Thiry, Baron d'Holbach (1723–1789); Gabriel-François Venel (1723–1775); and Anne Robert Jacques Turgot, Baron de l'Aulne (1727–1781), who later inspired Antoine Lavoisier's (1743–1794) chemistry discoveries in the eighteenth century. Diderot and d'Alembert used a tree metaphor to connect their perspective of mapped knowledge under the heading "Memory, Reason, and Imagination" instead of using an alphabetized list of articles. In the *Encyclopédie*, one of the fundamental components of encyclopedic knowledge is the discipline of natural history. The editors categorized approximately 4,500 of the encyclopedia's more than 70,000 articles under natural history.[9] Diderot was influenced by Buffon's works on natural history, which were cited in the *Encyclopédie.*

Diderot and Buffon together criticized Linnaeus's artificial system of botanical binomial nomenclature. Buffon's traditional adherence to the Great Chain of Being of grouping animals in relation of their utility to God's perfect creation of a rational man, which ranked domesticated animals above wild animals, attempted to raise skepticism of Linnaeus's classification, which systematically grouped animals by feet, teeth, and mammary glands.[10] Buffon asserted in his forty-four-volume *Histoire naturelle* that descriptions of nature could only be complete or incomplete. Although natural history is covered in the beginning of Diderot's *Encyclopédie* under "Initial Discourse," it echoes Buffon's notion that life was comprised of unique individual plants and animals in relation to man. Therefore, Diderot implicitly decried Linnaeus's artificial classification system on the basis of an incomplete description of reproductive parts of plants.[11]

> Figure 2. Click here: Tree of Life. This fold-out frontispiece is from the first *Table Analytique* volume of the *Encyclopédie, first edition*. Wake Forest University, Z. Smith Reynolds Library Special Collections, CC BY-NC-SA 2.0 license.

A significant part of volume six is devoted to natural history, with drawings of fossils, plants, insects, and mammals.[12] D'Alembert resigned as an editor in 1758 but finished his mathematics articles, leaving Diderot as the sole editor. Due to royal censorship of the *Encyclopédie*, the last printing of the remaining volumes was finished by a Swiss publisher, Samuel Falche.[13] Hence, Diderot became an advocate for censorship reform, which ultimately paved the way for the intellectual freedom of the press from royal and ecclesiastical control as defined during the French Revolution.[14]

Linnaeus was one of the first naturalists to adopt the serial publication of his books, and binomial nomenclature was consistently utilized after the publication of *Species Plantarum.*[15] Despite Buffon's influence on Diderot and Parisian botanists, Linnaeus had a following in British circles, who translated his Latin texts into English and also established the Linnean Society of London, which has preserved the archive of Linnaeus's manuscripts; his personal library collection; the first edition of *Species Plantarum* (*Species of Plants*, 1753);, the tenth edition of *Systema Naturae* (*System of Nature*, 1758); and *Philosophia Botanica* (*Botanical Philosophy*, 1751), which classified major taxonomic groups from higher plants to mosses and is considered to be the foundation of all Linnaeus's works.[16] Despite counterpoint views by Buffon's popular *Histoire naturelle*, which were supported by other French naturalists and Diderot, it was not until French revolutionaries established Linnaeus's systematic natural history approach that it became the precedent for the modern taxonomic classification system after his death in 1778.[17] The work's prospective impact on the future development of natural history is evident: the first edition of *Species Plantarum (1753)* includes the development of botanical nomenclature and the tenth edition of *Systema Naturae* (1758) builds the foundation of zoological nomenclature that are Linnaeus' taxonomic accomplishments in systematic biology. Although Diderot's *Encyclopédie* was relatively expensive, numerous copies were sold across Europe. This work represented secular humanistic tomes, which were not entitled to the inner circle of clergy and royal aristocrats, but were aimed for the public intellectual sphere.

Figure 3. Click here: *Species Plantarum* [*Species of Plants*] from the Biodiversity Heritage Library (Public domain)

Bibliography

Blom, Philipp. "A Dangerous Man in the Pantheon." *Public Domain Review*, October 2, 2013, Accessed July 3, 2018. https://publicdomainreview.org/2013/10/02/a-dangerous-man-in-the-pantheon/.

Farber, Paul Lawrence. *Finding Order in Nature: The Naturalist Tradition from Linnaeus to E.O. Wilson*. Johns Hopkins Introductory Studies in the History of Science. Baltimore: Johns Hopkins University Press, 2000.

Hodacs, Hanna, Kenneth Nyberg, and Stéphane van Damme, eds. *Linnaeus, Natural History and the Circulation of Knowledge*. Oxford University Studies in the Enlightenment, Oxford: Voltaire Foundation, 2018.

Gordon, Douglas Huntly, and Norman L. Torrey. *The Censoring of Diderot's Encyclopédie and the Re-Established Text*. New York: AMS Press, 1966.

Kafker, Frank A., ed. *Notable Encyclopedias of the Late Eighteenth Century: Eleven Successors of the Encyclopédie*. Studies on Voltaire and the Eighteenth Century 315. Oxford: Voltaire Foundation, 1994.

Kafker, Frank A., and Serena L. Kafker. *The Encyclopedists as Individuals: A Biographical Dictionary of the Authors of the Encyclopédie*. Studies on Voltaire and the Eighteenth Century, volume 257. Oxford: Voltaire Foundation, 1988.

Koerner, Lisbet. *Linnaeus: Nature and Nation*. Cambridge, MA: Harvard University Press, 1999.

Llana, James. "Natural History and the '*Encyclopédie*.'" *Journal of the History of Biology* 33, no. 1 (2000): 1–25, https://doi.org/10.1023/A:1004736103768.

Morton, A. G. *History of Botanical Science: An Account of the Development of Botany from Ancient Times to the Present Day*. London: Academic Press, 1981.

"The Encyclopedia of Diderot & d'Alembert Collaborative Translation Project." https://quod.lib.umich.edu/d/did/.

Tortarolo, Edoardo. *The Invention of Free Press: Writers and Censorship in Eighteenth Century Europe*. International Archives of the History of Ideas 219. Dordrecht, Netherlands: Springer, 2016.

"Welcome to the Linnean Collections." http://linnean-online.org/.

Werner, Stephen. *Blueprint: A Study of Diderot and the Encyclopédie Plates*. Birmingham, AL: Summa Publications, 1993.

Whyte, Ryan. "Exhibiting Enlightenment: Chardin as Tapissier." *Eighteenth-Century Studies* 46, no. 4 (Summer 2013): 531–54.

Wilkins, John S. *Species: A History of the Idea*. Berkeley: University of California Press, 2009.

Withers, Charles W. J. "Encyclopaedism, Modernism and the Classification of Geographical Knowledge." *Transactions of the Institute of British Geographers* 21, no. 1 (1996): 275–98. https://doi.org/10.2307/622937.

[1]. James Llana, "Natural History and the *Encyclopédie*," *Journal of the History of Biology* 33, no. 1 (March 1, 2000): 1–25, https://doi.org/10.1023/A:1004736103768.

[2]. John S. Wilkins, *Species: A History of the Idea* (Berkeley: University of California Press, 2009).

[3]. Paul Lawrence Farber, *Finding Order in Nature: The Naturalist Tradition from Linnaeus to E.O. Wilson*, Johns Hopkins Introductory Studies in the History of Science (Baltimore: Johns Hopkins University Press, 2000).

[4]. Llana, "Natural History and the *Encyclopédie*."

[5]. "The Encyclopedia of Diderot & d'Alembert Collaborative Translation Project," https://quod.lib.umich.edu/d/did/. ; Frank A. Kafker and Serena L. Kafker, *The Encyclopedists as Individuals: A Biographical Dictionary of the Authors of the Encyclopédie*, vol. 257, Studies on Voltaire and the Eighteenth Century (Oxford: Voltaire Foundation, 1988).

[6]. Charles W. J. Withers, "Encyclopaedism, Modernism and the Classification of Geographical Knowledge," *Transactions of the Institute of British Geographers* 21, no. 1 (1996): 275–98, https://doi.org/10.2307/622937.

[7]. Withers, "Encyclopaedism, Modernism and the Classification of Geographical Knowledge."

[8]. Frank A. Kafker, ed., *Notable Encyclopedias of the Late Eighteenth Century: Eleven Successors of the Encyclopédie,* Studies on Voltaire and the Eighteenth Century 315 (Oxford: Voltaire Foundation, 1994).

[9]. Llana, "Natural History and the *Encyclopédie*,." 1–25.

[10]. Ryan Whyte, "Exhibiting Enlightenment: Chardin as Tapissier," *Eighteenth-Century Studies* 46, no. 4 (Summer 2013): 531–54; Wilkins, *Species*.

[11]. Llana, "Natural History and the *Encyclopédie*."

[12]. Stephen Werner, *Blueprint: A Study of Diderot and the Encyclopédie Plates* (Birmingham, AL: Summa Publications, 1993).

[13]. Douglas Huntly Gordon and Norman L. Torrey, *The Censoring of Diderot's Encyclopedie and the Re-Established Text* (New York: AMS Press, 1966).

[14]. Edoardo Tortarolo, *The Invention of Free Press: Writers and Censorship in Eighteenth Century Europe*, International Archives of the History of Ideas 219 (Dordrecht, Netherlands: Springer, 2016).

[15]. Hanna Hodacs, Kenneth Nyberg, and Stéphane van Damme, eds., *Linnaeus, Natural History and the Circulation of Knowledge,* Oxford University Studies in the Enlightenment (Oxford: Voltaire Foundation, 2018); A. G. Morton, *History of Botanical Science: An Account of the Development of Botany from Ancient Times to the Present Day* (London: Academic Press, 1981).

[16]. Morton, *History of Botanical Science*; "Welcome to the Linnean Collections," http://linnean-online.org/.

[17]. Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge, MA: Harvard University Press, 1999).

PART VII

CHAPTER 12 - THE NEW SCIENTIFIC REVOLUTION - THE LONG 19TH CENTURY

CHAPTER 12 - ADA LOVELACE

KAREN GARVIN

Ada King, Countess of Lovelace (1815–1852), was an English mathematician who collaborated with the mathematician Charles Babbage (1791–1871), the inventor of the mechanical analytical engine. Although Babbage's intent was to use the machine for arithmetic calculations, Ada realized that by using numbers to represent more than just quantities the analytical engine could become a computing machine instead of a mere computational device. Her analysis led to her being credited with inventing the first computer program.

Ada Lovelace was born Augusta Ada Byron (1815–1852), on December 10, 1815, in Piccadilly Terrace, Middlesex, now part of the city of London.[1] Her parents were the poet Lord George Gordon Byron (1788–1824) and Lady Byron, Anne Isabella Milbanke (1792–1860), who was nicknamed Annabella.

A few weeks after Ada's birth, her mother separated from Byron because of his ongoing extramarital affairs. For financial reasons, she took Ada and went to stay with her parents in Leicestershire. Initially Lady Byron remained affectionate toward Byron and wrote letters to him, but eventually she sought a legal separation from her husband and was awarded custody of Ada. Meanwhile, Lord Byron had run up considerable debt. He fled the country for Continental Europe, sailing from Dover in April 1816, just barely ahead of the debt collectors.[2] Byron never returned to England.

Despite the scandal created by the couple's breakup, Lady Byron did all she could to shield her daughter from the worst of it.[3] Lady Byron was well educated and strongly believed that her daughter should receive a good education.[4] From age four, Ada was homeschooled in topics that included geography, mathematics, music, and French. Lady Byron, fearful that Ada might inherit some of her father's worst tendencies, insisted that Ada be tutored in mathematics because she believed that the rigors of studying the subject would dampen any wild imaginings that Ada might be prone to. Consequently, Ada was closely supervised during her early years to ensure that she develop self-control and learn to be a dutiful child. Ada was often ill during her childhood with severe headaches, and for a while she was prevented from continuing her studies.[5]

Meanwhile, Lord Byron had become involved in the Greek War of Independence from Turkey and died from fever on April 19, 1824. Freed from her former husband's constraints over what she could do with Ada, Lady Byron was now able to take her daughter on a Grand Tour of Europe. Mother and daughter sailed for the Continent in June 1826, returning to England fifteen months later during the fall of 1827.[6]

After their return, Lady Byron rented a country house called Bifrons, located about sixty miles from London. She was away much of the time, and during her absence Ada became fascinated with the idea of flying. She envisioned a steam-powered winged horse and wrote to her mother about the idea. Lady

Figure 1. Ada King, Countess of Lovelace. Engraved by W. H. Mote (c. 1840). Part of the Science Museum Group (UK) collection, licensed under Creative Commons, https://collection.sciencemuseumgroup.org.uk/objects/co62253

Byron reacted to this outburst of imagination by immediately hiring a very expensive mathematics tutor for her daughter.[7]

On May 10, 1833, Ada was presented at court to King William IV and Queen Adelaide.[8] At this time, Ada was considered to be an adult woman of marriageable age, and as such, was eligible to attend society functions.[9]

In early June 1833, Lady Byron and Ada were introduced to the scientist Charles Babbage at a society gathering. Babbage enthusiastically described his ideas for a calculating machine to them, which he called the Difference Engine, and invited them to see the prototype of the device.[10] Lady Byron and Ada duly visited Babbage's London home on June 17, where Babbage's machine, which Lady Byron referred to as a "thinking machine," was on display.[11] The machine used cogwheels arranged in vertical columns to represent numbers. When the gears turned, they carried out a mathematical calculation. Ada immediately understood the mathematics involved and became fascinated by the idea that she could write an algorithm to "program" Babbage's machine, which was in essence an early mechanical computer.[12]

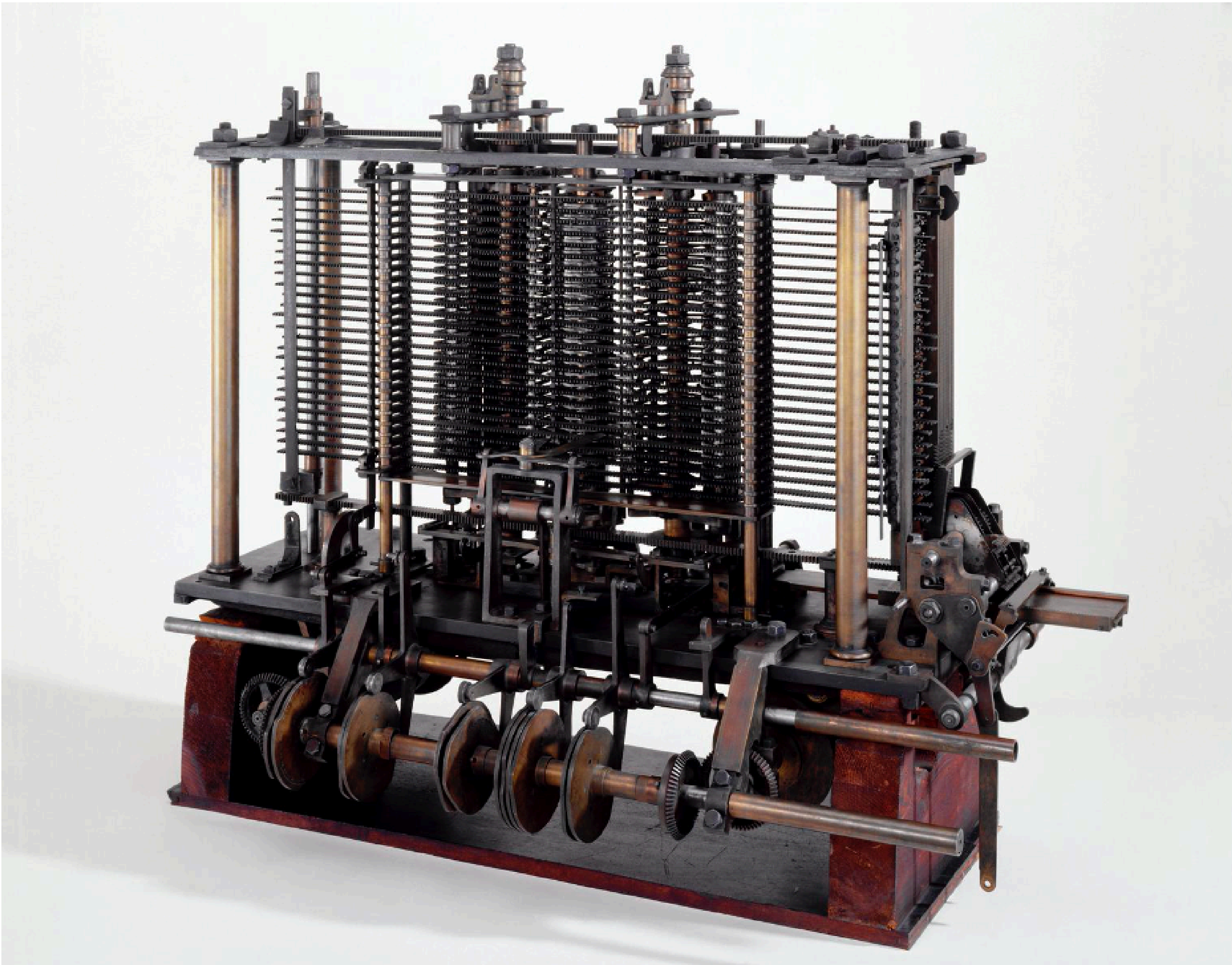


Figure 2. A portion of Charles Babbage's analytical engine. This model, representing one-seventh of the whole machine, was constructed in 1832 by Joseph Clement, who worked for Babbage. The model was never finished, and is in the Science Museum Group Collection (UK), https://collection.sciencemuseumgroup.org.uk/objects/co62245/babbages-analytical-engine-1834-1871-trial-model-analytical-engines

Around this time, Dr. William Frend, who had taught mathematics to both Lady Byron and Ada, introduced them to Mary Somerville, an accomplished mathematician and astronomer and one of the first woman members of the Royal Astronomical Society.[13] By the spring of 1834, Ada and her mother had established a friendship with Babbage and Somerville and they began attending Babbage's fashionable Saturday evening events, which attracted a wide range of intellectuals.[14] Babbage encouraged Ada to continue to pursue mathematics, so Ada worked with Somerville until 1838 and later studied with the mathematician and logician Augustus De Morgan.[15]

Later that year, Lady Byron began looking for a suitor for Ada. Insisting that her daughter marry an aristocrat, in the spring of 1835 Lady Byron introduced the nineteen-year-old Ada to thirty-year-old

William King-Noel, and after a short courtship they were married on July 8, 1835. The couple had three children, Byron (1836), Ralph Gordon (1839), and Anne Isabella (1837). In 1838, William was made the first Earl of Lovelace and Viscount Ockham, and Ada became the Countess Lady Lovelace.

In December 1834, Babbage introduced a new invention that he called the Analytical Engine. Unlike its predecessor, this machine did not need to be manually reset for each new calculation, and it was not hampered by rounding errors. Babbage intended the machine to be programmed with punch cards modeled on those used with Jacquard looms.[16] This loom, invented by French weaver Joseph-Marie Jacquard (1752–1834) and patented in 1804, used interchangeable cards with small holes punched in them to control the raising and lowering of warp threads during the weaving process, which allowed for highly detailed textile designs that could be inexpensively mass produced.[17]

In 1842, the inventor and scientist Charles Wheatstone (1802–1875) approached Ada and asked her to translate a scientific article about Babbage's machine, written in French by the Italian engineer Luigi Federico Menabrea (1809–1896). Entitled "Notions sur la machine analytique de Charles Babbage," ("Elements of Charles Babbage's Analytical Machine"), Menabrea's article had appeared in the October 1842 edition of the *Bibliothèque Universelle de Genève*. Ada embraced the challenge and began work immediately. However, when she spoke to Babbage about her work on the translation, he inquired why she had not written an original paper.[18]

The thought had simply not occurred to Ada. At the time, few women wrote for scientific publications; most who dabbled in science aimed their work at a nonprofessional female audience and stuck to explaining concepts and discoveries made by men.[19] Babbage suggested that Ada write and publish her own notes on Menabrea's article—a task for which Ada was highly qualified, but one that would put her in the novel position of being a woman writing for a *male* scientific audience.[20]

Ada's copious notes were very detailed, and she explained how Babbage's analytical engine differed from his earlier construct, the difference engine. She completed the translation within a few months, but the notes took her nearly a year to complete and during that time she corresponded regularly with Babbage.[21] Finally, in 1843 her translation and notes were published in Taylor's *Scientific Memoirs*, a series of books published between 1837 and 1852 that contained collections of scientific papers translated into English.

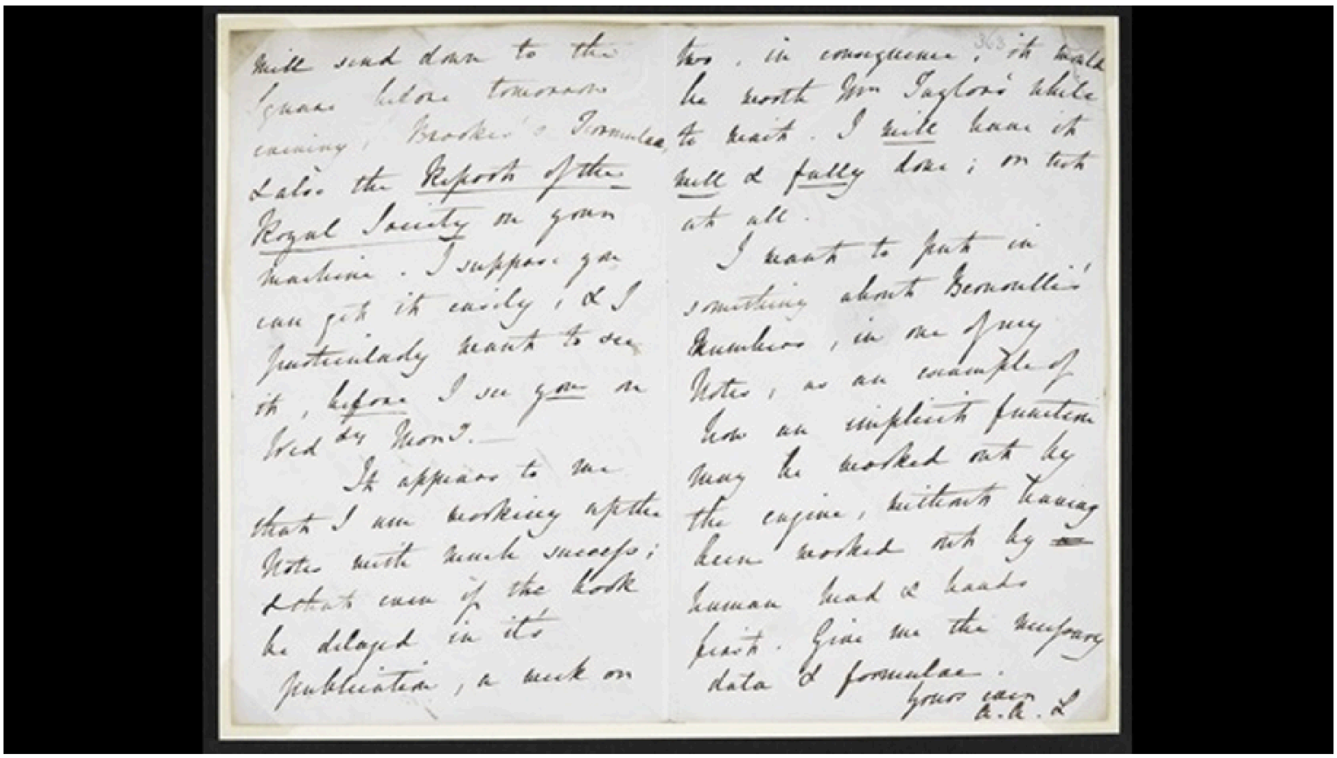
Ada's translation of Menabrea's article ran for 25 pages, but her own "Notes by the Translator" section was more than 40 pages long and offered extensive explanations. In it, she discussed the possible uses of computing machines and provided a set of instructions, or algorithm, for programming them.[22] While Ada published the paper using her initials rather than her full name, she was quickly discovered to be the author, which unfortunately led to the article being taken less seriously than it might have been if she had been a male author.[23]

For the rest of her life, Ada, whom Babbage had called the "Enchantress of Number," maintained an interest in mathematics, but she was also intrigued by philosophy and other scientific discoveries of the era, including mesmerism. Mesmerism was a form of hypnosis (also known as animal magnetism) promoted by the German doctor Franz Mesmer (1734–1815), who believed it had curative properties. Ada also wanted to try her own hand at practical science and even contacted Michael Faraday (1791–1867) about the possibility of repeating some of his experiments.[24]

By the late 1840s, though, Ada's health was in decline. Over the summer of 1851 she began to exhibit symptoms of uterine cancer, including heavy bleeding.[25] Ada took laudanum and other drugs to relieve her bouts of pain, but they did nothing to stem the progress of the disease. She died on November 27, 1852, and was buried in the family vault at Hucknall Torkard in Nottinghamshire.

Ada's mathematical insights, combined with her flair for language (skills that she inherited from both parents), allowed her to make significant contributions to the early field of computer science through her programming ideas and her ability to explain the mathematics behind them.

During the late 1970s, the U.S. Department of Defense wanted a standard programming language for use in military systems. A new language was created, DoD-1, which was later renamed Ada. In 1982, the Association for Women in Computing established the Ada Lovelace Award to honor women working in the computing field for technical achievement and extraordinary service to the computing community.



will send down to the Square before tomorrow evening, Brooke's Formulae, & also the Report of the Royal Society on your machine. I suppose you can get it easily, & I particularly want to see it, before I see you on Wedy Mong.—

It appears to me that I am working up the Notes with much success; & that even if the book be delayed in its publication, a week or two, in consequence, it will be worth Mr Taylor's while to wait. I will have it well & fully done; or not at all.

I want to put in something about Bernoulli's Numbers, in one of my Notes, as an example of how an implicit function may be worked out by the engine, without having been worked out by human head & hands first. Give me the necessary data & formulae.

Yours ever
A.A.L.

Figure 3: Letter from Ada Lovelace to Charles Babbage, dated July 10, 1843. Public domain; held in the British Library, MS 37192.

Further Reading:

Charman-Anderson, Suw. "Ada Lovelace: Victorian Computing Visionary," *Ada User Journal* 36, no. 1 (March 2015): 35–41.

Elliott, Francesca. "Weaving Numbers: The Jacquard Loom and Early Computing." Science and

Industry Museum (Manchester), October 17, 2017. https://blog.scienceandindustrymuseum.org.uk/weaving-numbers-jacquard-loom-early-computing/.

Essinger, James. *Ada's Algorithm: How Lord Byron's Daughter Ada Lovelace Launched the Digital Age.* New York: Melville House, 2014.

Hollings, Christopher, Ursula Martin, and Adrian Rice. *Ada Lovelace: the Making of a Computer Scientist*. Oxford: Bodleian Library, 2018.

Hollings, Christopher, Ursula Martin, and Adrian Rice. "The Early Mathematical Education of Ada Lovelace," *Journal of the British Society for the History of Mathematics* 32, no. 3 (2017): 221–34.

Hollings, Christopher, Ursula Martin, and Adrian Rice. "The Lovelace–De Morgan Mathematical Correspondence: A Critical Re-Appraisal," *Historia Mathematica* 44 (2017): 202–31.

Kim, Eugene Eric, and Betty Alexandra. "Ada and the First Computer." *Scientific American*, May 1999: 76–81.

Lovelace, Ada. "Notes by the Translator," in *Scientific Memoirs, Selected from the Transaction of Foreign Academies of Science and Learned Societies and from Foreign Journals*, vol. 3, ed. Richard Taylor London: Richard and John E. Taylor, 1843: 691–731, https://archive.org/details/scientificmemoir03memo.

Taylor, Brian W. "Annabella, Lady Noel-Byron: A Study of Lady Byron on Education," *History of Education Quarterly* 38, no. 4 (Winter 1998): 430–55.

Toole, Betty Alexandra Toole, ed. *Ada, the Enchantress of Numbers: A Selection from the Letters of Lord Byron's Daughter and Her Description of the First Computer*. Mill Valley, CA: Strawberry Press, 1992.

Woolley, Benjamin. *The Bride of Science: Romance, Reason, and Byron's Daughter*. London: Macmillan, 1999.

[1]. James Essinger, *Ada's Algorithm: How Lord Byron's Daughter Ada Lovelace Launched the Digital Age* (New York: Melville House, 2014), 30; Kara Rogers, "Ada Lovelace, British Mathematician," Encyclopædia Britannica, n.d., https://www.britannica.com/biography/Ada-Lovelace.

[2]. Essinger, *Ada's Algorithm*, 5, 33; Benjamin Woolley, *Ada Lovelace, The Bride of Science: Romance, Reason and Bryon's Daughter* (London: Pan Books, 2015), 81.

[3]. Essinger, *Ada's Algorithm*, 33.

[4]. Brian W. Taylor, "Annabella, Lady Noel-Byron: A Study of Lady Byron on Education," *History of Education Quarterly* 38, no. 4 (Winter 1998): 446; Essinger, *Ada's Algorithm*, 35–36.

[5]. Woolley, *Ada Lovelace*, 88; Essinger, *Ada's Algorithm*, 43–44.

[6]. Woolley, *Ada Lovelace*, 109; Essinger, *Ada's Algorithm*,4 9–51.

[7]. Essinger, *Ada's Algorithm*, 3, 51–55.

[8]. Woolley, *Ada Lovelace*, 132.

[9]. Essinger, *Ada's Algorithm*, 79–80.

[10]. Essinger, *Ada's Algorithm*, 81, 85.

[11]. Woolley, *Ada Lovelace*, 129–30.

[12]. Essinger, *Ada's Algorithm*, 87–90.

[13]. Essinger, *Ada's Algorithm*, 62, 121; Rubenstein Library, "Guide to the Ada Lovelace Letter, August 5, [1841 or 1847]," Historical Note, Duke University Libraries, https://library.duke.edu/rubenstein/findingaids/lovelaceada/#historicalnote; Woolley, *Ada Lovelace*, 136.

[14]. Essinger, *Ada's Algorithm*, 143; Woolley, *Ada Lovelace*, 128.

[15]. Essinger, *Ada's Algorithm*, 134; Wooley, *Ada Lovelace*, 200.

[16]. Essinger, *Ada's Algorithm*, 114–16.

[17]. "Programming Patterns: The Story of the Jacquard Loom," Science and Industry Museum (Manchester), June 25, 2019. https://www.scienceandindustrymuseum.org.uk/objects-and-stories/jacquard-loom.

[18]. Woolley, *Ada Lovelace*, 259–60.

[19]. Woolley, *Ada Lovelace*, 260.

[20]. Essinger, *Ada's Algorithm*, 192.

[21]. Woolley, *Ada Lovelace*, 259–60.

[22]. Ada Lovelace, "Notes by the Translator," in *Scientific Memoirs, Selected from the Transaction of Foreign Academies of Science and Learned Societies and from Foreign Journals*, vol. 3, ed. Richard Taylor (London: Richard and John E. Taylor, 1843): 691–731, https://archive.org/details/scientificmemoir03memo.

[23]. Essinger, *Ada's Algorithm*, 192.

[24]. Woolley, *Ada Lovelace*, 307–08.

[25]. Essinger, *Ada's Algorithm*, 207.

CHAPTER 12 - THOMAS ALVA EDISON

KAREN GARVIN

Thomas Alva Edison (1847–1931), the “Wizard of Menlo Park,” was an American inventor. Considered to be a true genius, Edison created the world’s first research laboratory, where his systematic approach to inventing focused on practical results rather than theoretical knowledge. Although best known for his improvements to the light bulb and for creating the phonograph and motion picture camera, much of Edison’s work was related to the generation and distribution of electricity.

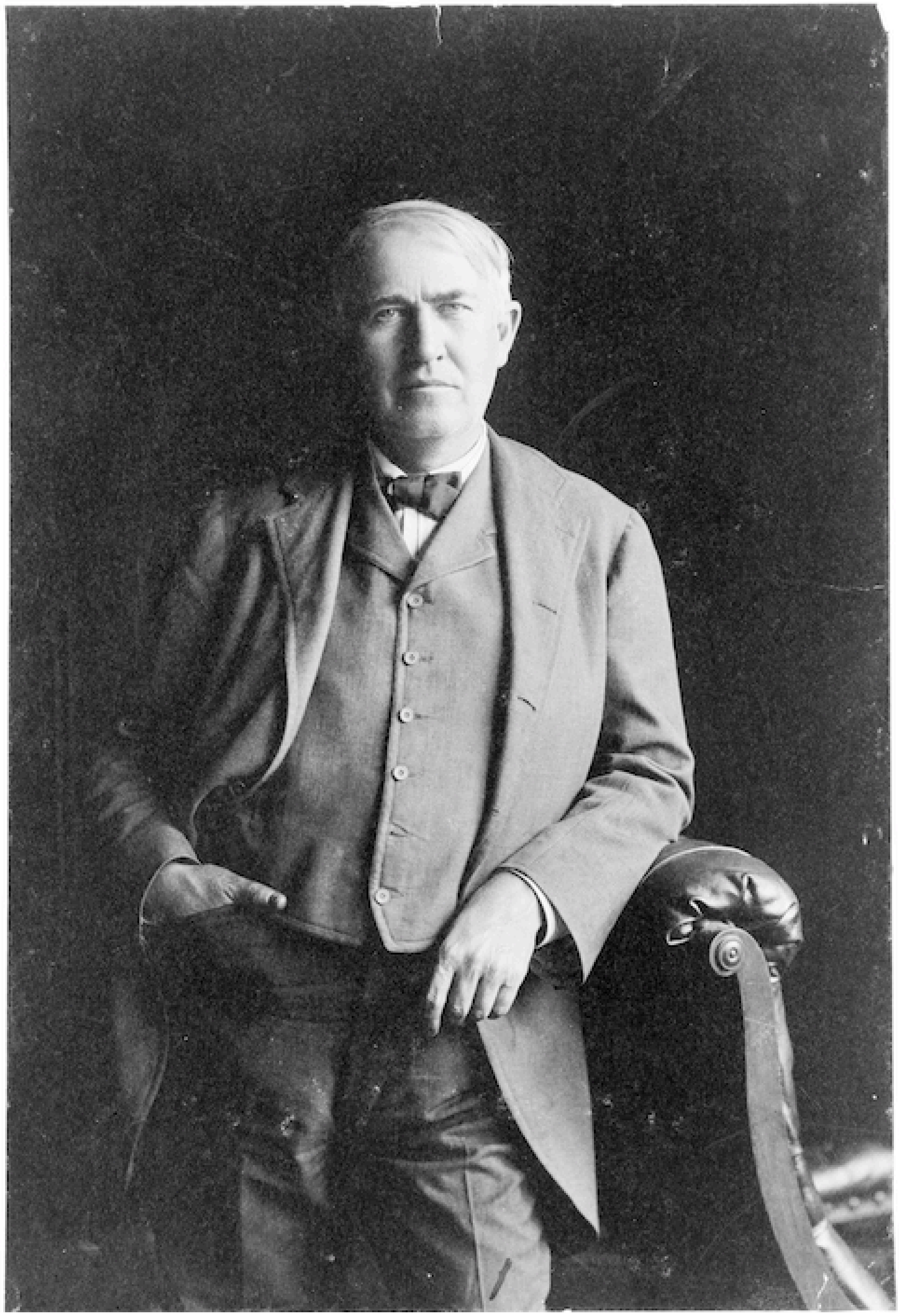


Figure 1. Thomas Alva Edison, c. 1904. Library of Congress, Prints and Photographs Collection, LC-USZ62-108087.

Edison was born on February 11, 1847, in Milan, Ohio. He was the youngest of seven children and had limited formal education, which would later feed the myth that he was "a poor boy, uneducated and entirely self-taught."[1] In fact, during 1854 Edison attended a private school run by Reverend George Engle and from 1859 to 1860 he attended the Port Huron School.[2] Edison, who would later describe himself as a "delicate" small boy, was mostly homeschooled by his mother, a former high-school teacher, who taught her son "how to read good books quickly and correctly."[3] Edison devoured books on history, philosophy, and science. He liked to do chemical experiments and even strung up a telegraph wire to a friend's house so they could send messages to each other.[4]

In 1859, Edison began working as a newsboy on the Grand Trunk Railroad line, where he earned pocket money to buy materials for his home chemical laboratory.[5] The twelve-year-old Edison rode the train and sold newspapers and magazines, but he also had a great deal of free time. In 1862 he purchased a small printing press, which he set up in the baggage car. From this makeshift office, Edison printed his own newspaper, the *Weekly Herald*.[6] Edison also conducted chemical experiments until a fire broke out and he was evicted from the train.[7]

Edison learned telegraphy and, despite noticing that he was developing a hearing loss, spent the next several years working as a telegraph operator. In early 1868 he moved to Boston and took a job with Western Union. During his free time there he designed and patented his first invention: an electronic vote recorder, which was met with indifference by lawmakers in Washington.[8]

Despite this initial setback, Edison quit his job at Western Union in January 1869 so that he could become a full-time inventor. He moved to New York City in April 1869, and in February 1870 he signed a contract with Gold and Stock Telegraph Company to do research and development on improvements to telegraph equipment. Edison began working on designs for an improved stock ticker, which he named the Universal Stock Printer.[9]

Edison sold the rights to the stock ticker to the Gold and Stock Telegraph Company for $40,000.[10] Then, he used the money to set up the Newark Telegraph Works in Newark, New Jersey.[11] That same year, an investor put up enough money for Edison to open a second shop, the American Telegraph Works. Between the two companies, Edison employed more than 160 men.

Edison soon outgrew the facility in Newark, and in December 1875 moved his operations to Menlo Park, New Jersey. He had a two-story laboratory built to his specifications, which housed a machine shop on the ground floor and a chemical laboratory on the second floor. Edison opened the laboratory in the spring of 1876 with a staff of five: two experimenters and three machinists.[12] The Menlo Park lab was quickly dubbed "the invention factory" by reporters,[13] and it was one of the first research and development laboratories.[14] Edison's system was to come up with ideas and assign teams of researchers to work on projects, whom he referred to as "muckers."[15] By having multiple teams engaged in developing marketable products, it was possible for the lab to be more productive than a lone inventor could ever have been.[16]

To keep Menlo Park running, Edison needed money. His method of raising money was to pursue only the inventions that were both "practical and profitable."[17] In the summer of 1877, Edison came up with an idea for a machine that would record and play back sound messages. His prototype used a stylus that vibrated from the pressure of sound waves and carved small grooves on a piece of tin foil wrapped around a cylinder. The foil cylinder was later replaced by wax cylinders.[18] The phonograph became a commercial success and put Edison in the public spotlight, earning him the epithet "Wizard of Menlo Park."

By early 1878, the laboratory staff had increased to 25, and by the 1880s expanded to a maximum of 50 to 60 employees. Edison added a separate machine shop and several other buildings to the Menlo Park site, and even provided a boardinghouse for some of his employees.[19] For a short time, Nikola Tesla (1856–1943) was employed by Edison as an electrical engineer.[20] Both men were dedicated workaholics, but a rift developed between them after Edison supposedly promised Tesla fifty-thousand dollars if he could increase the efficiency of Edison's electric dynamo. After Tesla succeeded, Edison claimed it had been a joke but counteroffered a raise in pay. Tesla, believing he had been cheated, resigned.[21]

In 1878, Edison began work on developing a longer-burning filament for electric light bulbs. Existing bulbs burned out within just a few hours; Edison realized that in order for the bulbs to be commercially viable they needed to last much longer. He did not invent the light bulb, however—the credit for that goes to English scientist Humphry Davy, who, in the early 1800s, had connected batteries to charcoal sticks and generated an arc of electricity to produce incandescent lighting.[22] On October 14, 1878, Edison filed a patent application for "Improvement in Electric Lights," but he continued to refine the bulb and submitted another patent application on November 4, 1879.

Eventually, after Edison and his muckers tested thousands of materials for the light bulb filament, including carbonized cardboard and platinum, Edison discovered that a carbonized bamboo filament would last more than a thousand hours before it burned out.[23] Edison made further improvements, such as evacuating the air from the glass bulb and designing the screw base for the light bulb, which is still in use today.

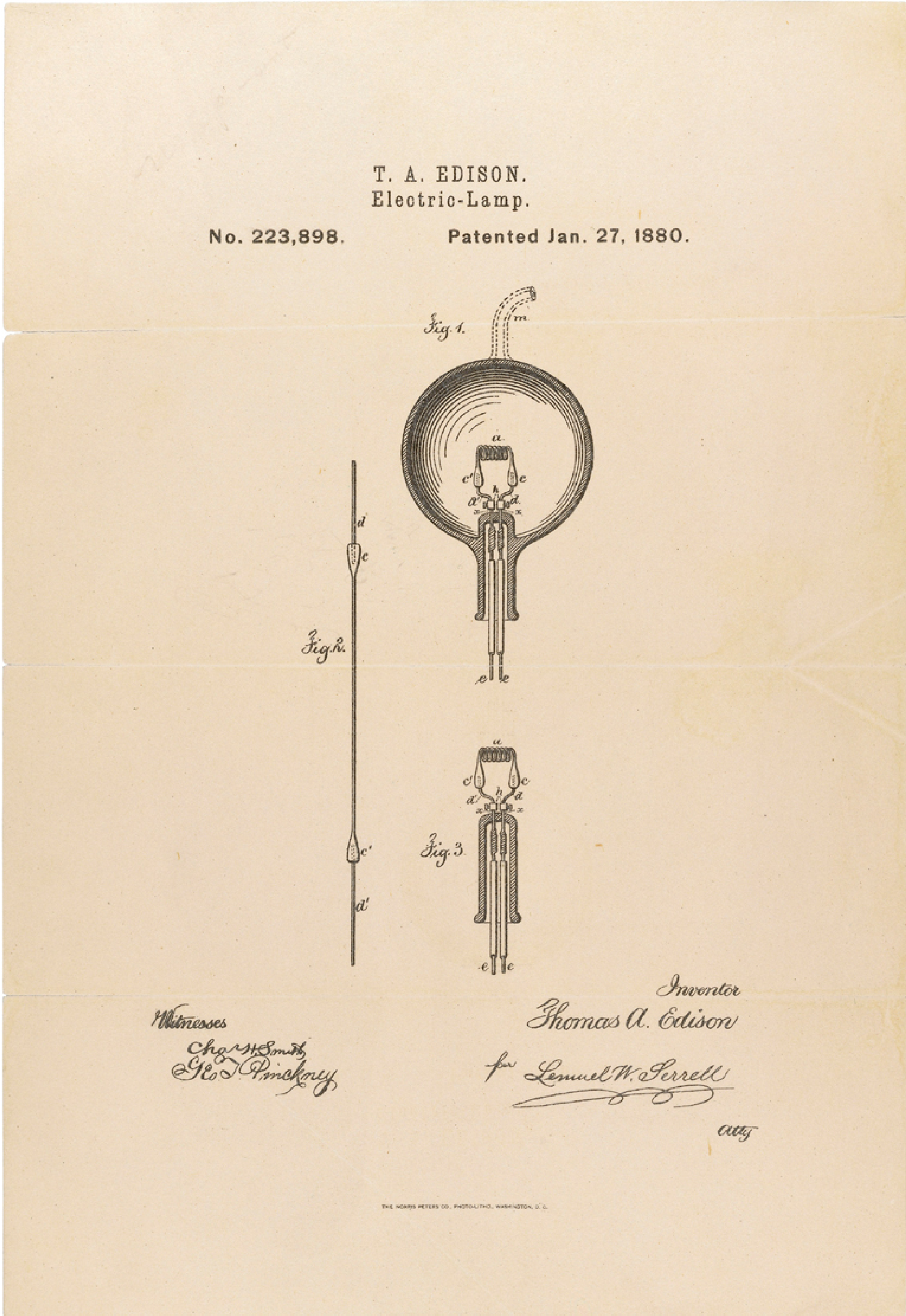

T. A. EDISON.
Electric-Lamp.
No. 223,898.
Patented Jan. 27, 1880.
Fig. 1.
Fig. 2.
Fig. 3.
Witnesses
Chas H. Smith
Geo T. Pinckney
Inventor
Thomas A. Edison
per Lemuel W. Serrell
atty
THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

Figure 2. Edison's patent for the Electric-Lamp. Note the coiled filament inside the bulb. U.S. National Archives and Records Administration, "Drawing for an Electric Lamp," National Archives Catalog, https://catalog.archives.gov/id/595450.

Edison began to manufacture and market his bulbs, but delivering electricity to run them was still problematic. But instead of just fabricating pieces of the electric puzzle, it was Edison's intention to create a whole system, from electrical generation and distribution to the end products for home and business use.[24] In December 1880, Edison founded the Edison Illuminating Company with the purpose of constructing electrical generating stations. In 1881, he purchased a large building in Manhattan and obtained permission from the city to dig up the streets in order to lay nearly fourteen miles of electrical conduits.[25] Edison's Pearl Street Power Station opened in 1882, and it used coal to power an electrical generator. This central power company delivered direct current (DC) electricity to his customers.

In a DC system, electrical current flows in one direction and is relatively low voltage. But while Edison's DC distribution system was successful, it had several major drawbacks: the voltage could only be sent over short distances before it dropped too low to be useful, and the voltage could not be changed easily for varying electrical loads, which meant that each electrical device needed its own power lines. A competing power system, one favored by Edison's ex-employee Tesla, was alternating current (AC), which allowed electricity to be sent over many miles of wire without loss and used a system of transformers to change voltages so that lighting and motors could be operated from the same power lines.

In 1886, William Stanley Jr. (1858–1916) had successfully electrified Great Barrington, Massachusetts, using alternating current. While others, including Tesla and George Westinghouse (1846–1914), believed that an AC distribution system was safe, Edison felt strongly that it was dangerous because of the high voltages it used and its tendency to spark. Indeed, several deaths, including the ghastly public spectacle of the electrocution of lineman John Feeks, had already taken place.[26]

By now Edison had invested a great deal of cash in his own DC system, which served only one square mile of customers, and he was fighting to keep his system financially solvent.[27] He appealed to public emotion about the safety of his DC system, but the differences of opinion between proponents of DC and AC devolved into a bitter rivalry that became known as the "War of the Currents." It was a losing battle for Edison: in 1891 the *Electrical World* magazine reported that there were just over 200 Edison DC power stations in use, versus nearly 1,000 operational AC power stations. When the contract for electrifying the 1893 Chicago World's Columbian Exposition was awarded to Westinghouse, who used Tesla's AC system, it cemented the superiority of alternating current for electrical distribution systems.

Nevertheless, Edison's business continued to grow, and in 1887 he built a larger research facility in West Orange, New Jersey, where he became increasingly involved in management. Construction on the new laboratory began in May and the facility was occupied by the new year. Unlike the informal research facility of Edison's younger days, this new laboratory employed university-trained scientists and utilized large-scale teamwork in its research methods.[28] Although Edison made no claims for himself about being a "pure scientist," he nevertheless read professional literature, even as he disdained the career of a pure scientist.[29]

During his time at his West Orange lab, Edison continued to refine his phonograph and, after seeing the work of photographer Eadweard Muybridge (1830–1904), came to believe that motion could be captured on film. On July 31, 1891, Edison filed a patent for his motion picture camera. Never one to do half measures, Edison built a motion picture studio at the West Orange research park, called the Black Maria, in 1893.[30]

Figure 3. Interior of Thomas. A. Edison Laboratories, Building No. 2, West Orange, New Jersey. Apparatus on the table was used to make a steel master for the mass production of phonograph records. Photo: Jet Lowe, Library of Congress Prints and Photographs Division, HAER NJ,7-ORAW,4-A.

Some of the early films created at the studio were shown in Kinetoscopes, which were wooden boxes that housed rollers and spools for a single film. The first Kinetoscope parlor opened on April 14, 1894, in New York, where viewers could pay to watch the movies. The first commercial motion picture intended for a large audience was projected at Koster and Bial's Music Hall in New York City on April 23, 1896.

During the 1890s, Edison began experimenting with something completely different: he built an iron ore separating plant in Ogden, New Jersey, that crushed rocks and used an electromagnet to separate the iron ore from the rock.[31] After several expensive upgrades to the plant, and the discovery of high-grade iron ore deposits in the Great Lakes area, Edison realized the unprofitability of this venture. But while the iron had never been a moneymaker, his company had sold crushed rock to cement companies. Thus, Edison followed the money trail and in 1899 he organized the Edison Portland Cement Company, which opened in 1901.[32]

Next, Edison turned his attention back to a project that he had been interested in for years: a storage battery.[33] In 1901, he formed the Edison Storage Battery Company and began working on a storage battery for electric cars. An "E" type of alkaline storage battery was produced in 1903, but there were problems with the batteries leaking and they did not recharge properly. In 1909, a new "A" type of nickel-iron alkaline battery was manufactured,[34] and in 1910, two electric cars with Edison batteries climbed Mt. Washington in New Hampshire on a promotional tour.[35]

In 1915, Secretary of the Navy Josephus Daniels (1862–1948) appointed Edison as president of the newly formed Naval Consulting Board. The board comprised civilian experts who would review technology-related suggestions submitted by the public for possible military application.[36] Edison petitioned the government to establish a permanent research laboratory, but resigned from the naval board in January 1921.[37] Eventually the lab was constructed and the Naval Research Laboratory began operations on July 2, 1923.[38]

In 1927, Edison, now 80 years old, joined forces with Henry Ford (1863–1947) and Harvey Firestone (1868–1938) to form the Edison Botanic Research Corporation in Fort Meyers, Florida. The company's goal was to find a domestic source of rubber so that America would not be dependent on foreign sources in case of another war. More than 17,000 plants were tested before goldenrod was selected as the most viable source for rubber.[39]

Edison married twice and had six children, although his heavy work schedule left little time for family.[40] In 1871, he met Mary Stilwell (1855–1884), who was working at the News Reporting Company, a short-lived business venture of Edison's. He proposed and they were married on Christmas Day.[41] They had three children: Marion (1873), Thomas (1876), and William (1878). Mary's health declined and she died in 1884.

In 1885, while on a trip to New Hampshire with a group of friends, Edison met and proposed to Mina Miller (1865–1947). They married on February 24, 1886, and also had three children: Madeleine (1888), Charles (1890), and Theodore (1898).

Edison's research spanned a wide range of electrical improvements and inventions, including small electrical appliances for home use, such as a coffeemaker and iron. He received 1,093 patents and won awards that included the French Légion d'Honneur in 1881 and the Congressional Gold Medal in 1928.[42] He died on October 18, 1931, at his home in Glenmont, New Jersey.

Further Reading:

DeGraff, Leonard. *Edison and the Rise of Innovation*. New York: Sterling Signature, 2013.

Jonnes, Jill. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House, 2004.

Freeberg, Ernest. *The Age of Edison: Electric Light and the Invention of Modern America*. New York: Penguin Books, 2013.

Morris, Edmund. *Edison*. New York: Random House, 2019.

Munson, Richard. *Tesla: Inventor of the Modern*. New York: W.W. Norton, 2018.

Rutgers School of Arts and Sciences, Thomas A. Edison Papers Project, http://edison.rutgers.edu/.

Stross, Randall. *The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World*. New York: Three Rivers Press, 2007.

[1]. Frank Parker Stockbridge, "Rubber from Weeds, My New Goal," *Popular Science Monthly* 3, no. 6 (December 1927): 9–11.

[2]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "The Boyhood Years," last updated October 28, 2016, http://edison.rutgers.edu/educationinventor.htm#5.

[3]. Thomas Alva Edison, letter to the pupils of the grammar schools of New Jersey, April 30, 1912, http://edison.rutgers.edu/yearofinno/Oct13/TAE%20to%20Pupils%20of%20Grammar%20School%20of%20NJ_1912-4-30.pdf.

[4]. Rutgers, "The Boyhood Years"; Leonard DeGraff, *Edison and the Rise of Innovation* (New York: Sterling Signature, 2013), xxi.

[5]. Edison, letter to the pupils.

[6]. DeGraff, *Edison and the Rise of Innovation*, xxii–xxiii; Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Learning to Do Business: Early Entrepreneurship," last updated October 28, 2016, http://edison.rutgers.edu/educationinventor.htm#5.

[7]. Rutgers, "The Boyhood Years."

[8]. DeGraaf, *Edison and the Rise of Innovation*, 3.

[9]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Stock Ticker," last updated October 28, 2016, http://edison.rutgers.edu/ticker.htm.

[10]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Edison's Autobiographical Notes," https://edison.rutgers.edu/yearofinno/TAEBdocs/V1App1_A.pdf, 643.

[11]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Newark, N.J., 1870–1875," last updated October 28, 2016, http://edison.rutgers.edu/educationinventor.htm#5.

[12]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Building the Lab," last updated October 28, 2016, http://edison.rutgers.edu/inventionfactory.htm.

[13]. DeGraaf, *Edison and the Rise of Innovation*, 22.

[14]. "Edison and His Era: 'Muckers' and the Invention Process," Thomas Edison National Historical Park, last updated February 26, 2015, https://www.nps.gov/edis/learn/kidsyouth/edison-and-his-era.htm.

[15]. Thomas Edison National Historical Park, "The Gifted Men Who Worked for Edison," National Park Service, last updated February 26, 2015, https://www.nps.gov/edis/learn/kidsyouth/the-gifted-men-who-worked-for-edison.htm.

[16]. "Edison and His Era: 'Muckers' and the Invention Process."

[17]. Edmund Morris, *Edison* (New York: Random House, 2019), 7.

[18]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Tinfoil Phonograph," last updated October 28, 2016, http://edison.rutgers.edu/tinfoil.htm.

[19]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Expanding the Laboratory," last updated October 28, 2016, http://edison.rutgers.edu/inventionfactory.htm.

[20]. Ernest Freeberg, *The Age of Edison: Electric Light and the Invention of Modern America* (New York: Penguin Books, 2013), 208.

[21]. Munson, *Tesla: Inventor of the Modern*, 53–54.

[22]. DeGraaf, *Edison and the Rise of Innovation*, 48; Freeberg, *The Age of Edison*, 15–17.

[23]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Electric Lamp," last updated October 28, 2016, http://edison.rutgers.edu/lamp.htm.

[24]. Thomas P. Hughes, "The Electrification of America: The System Builders," *Technology and Culture* 20, no. 1 (January 1979): 124.

[25]. Jill Jonnes, *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World* (New York: Random House, 2004), 4, 80.

[26]. Freeburg, *The Age of Edison*, 181.

[27]. DeGraaf, *Edison and the Rise of Innovation*, 90.

[28]. DeGraaf, *Edison and the Rise of Innovation*, 75, 78–79.

[29]. Morris, *Edison*, 7, 46.

[30]. DeGraaf, *Edison and the Rise of Innovation*, 129–30.

[31]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Ore Milling," last updated October 28, 2016, http://edison.rutgers.edu/ore.htm.

[32]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Cement," last updated October 28, 2016, http://edison.rutgers.edu/cement.htm; Jonnes, *Empires of Light*, 347–50.

[33]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Storage Battery," last updated October 28, 2016, http://edison.rutgers.edu/battery.htm.

[34]. Jonnes, *Empires of Light*, 352; Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "A Brief Chronology of Edison's Life," http://edison.rutgers.edu/brfchron.htm.

[35]. "A Brief Chronology of Edison's Life."

[36]. "Thomas Edison's Vision," U.S. Naval Research Laboratory, https://www.nrl.navy.mil/about-nrl/history/edison/.

[37]. "A Brief Chronology of Edison's Life."

[38]. DeGraaf, *Edison and the Rise of Innovation*, 200–03.

[39]. New York Botanical Garden, International Plant Science Center, Mertz Library, "Personal Papers, Thomas Alva Edison (1880–1964)," https://sciweb.nybg.org/science2/libr/finding_guide/edison2.asp.html; Stockbridge, "Rubber from Weeds, My New Goal."

[40]. Jonnes, *Empires of Light*, 353.

[41]. DeGraaf, *Edison and the Rise of Innovation*, 11.

[42]. Rutgers School of Arts and Sciences, Thomas A. Edison Papers, "Later Years," last updated October 28, 2016, http://edison.rutgers.edu/biogrphy.htm; Jonnes, *Empires of Light*, 96; "Historical Highlights: Thomas Edison's Congressional Gold Medal," History, Art, and Archives, United States House of Representatives, https://history.house.gov/HistoricalHighlight/Detail/36558.

CHAPTER 12 - NIKOLA TESLA

KAREN GARVIN

Nikola Tesla (1856–1943) was a Serbian American inventor whose major works included designing and building an alternating current (AC) induction motor and developing and promoting a workable AC power distribution system. His interests ran the gamut from alternating current and motors to wireless power and communication, radio control, radar, and even early robotics.

Tesla was an eccentric genius and visionary, yet this "underappreciated mastermind" is less well-known today than his one-time employer and rival, Thomas Edison (1847–1931).[1] Whereas Edison had a systematic approach to inventing, Tesla was less methodical, and was often criticized by his contemporaries for making vague statements about his projects, many of which were considered to be impractical.[2]

Despite being a prolific inventor with more than three hundred patents to his name, Tesla was a poor businessman. He tore up what could have been a lucrative royalty contract with George Westinghouse (1846–1914) and signed over control of lighting patents to J. P. Morgan (1837–1913).[3] A dreamer and idealist, as Tesla aged he became increasingly distant from people, and in his later years developed a phobia of germs that led him to become even more isolated.[4]

Tesla was born at the stroke of midnight on July 10, 1856, during a thunderstorm.[5] His birthplace was Smiljan, Serbia, a part of the Austrian Empire that later became Croatia. Tesla was the fourth of five children of Milutin Tesla, an Eastern Orthodox parish priest, and Djuka Tesla. In 1863, Tesla's older brother Dane was killed in a riding accident, after which Milutin moved the family to Gospić. Tesla attended the Real Gymnasium (junior high school) until 1870 and went to the Higher Real Gymnasium in Carlstadt, where he excelled in mathematics and became interested in electricity and magnetism.[6]

In 1875, Tesla received a scholarship to the Joanneum Polytechnic School (now the Graz University of Technology), where he studied engineering and electricity.[7] Tesla became disheartened by his father's criticism and dropped out of school, although he later continued his education at the University of Prague.[8]

In 1881, Tesla moved to Budapest, Hungary, where he did electrical work. In the fall of 1882, Tesla moved to Paris and began working for the Continental Edison Company, where he tried unsuccessfully to interest Edison's engineers in adopting his new AC motor design.[9]

Tesla, now twenty-eight years old, was invited by Charles Batchelor (1845–1910), one of Edison's advisors, to travel to New York City and meet Edison in person.[10] Tesla was encouraged to make

Figure 1. Nikola Tesla, aged about 35. Photograph by Napoleon Sarony, c. 1890. George Grantham Bain Collection, Library of Congress, LC-DIG-ggbain-04851. No known copyright restrictions.

the move by Tivadar Puskás (1844–1893), an Edison associate, who sent a letter of introduction to Edison.[11]

Tesla arrived in New York City in June 1884 and met with Edison the day after his arrival. Edison hired Tesla that afternoon, but their working relationship was short-lived: the two men were very different from one another, Tesla worldly and reserved, Edison blunt and straightforward.[12] Tesla worked at the Edison Machine Works in Manhattan for six months, but Edison's personality soon rubbed him raw, and after a disagreement over money, Tesla left the company. With the help of several investors, he established the Tesla Light and Manufacturing Company in 1886.[13]

Despite the hard work that Tesla put into the company, he showed a lack of business acumen by allowing the company to take control of his patents; he received only a stock certificate and was soon pushed out of the company.[14] Almost broke, he did menial work for a year, and then after meeting Alfred Brown, the director of Western Union, and Charles Peck, a New York City attorney, he formed the Tesla Electric Company, which launched in 1887. This time, Tesla was contracted to receive a third of the company's profits.[15]

With a reliable paycheck and a laboratory to work in, Tesla turned his mind to inventing. He worked on improvements to direct-current (DC) motors and other projects, but his true interest lay in continuing the development of his AC induction motor. Tesla began working on a motor that utilized a rotating magnetic field to produce an alternating current. This new motor did not use a commutator, which is a rotary electrical switch that reverses the direction of electrical current. Because commutators have physical contacts they quickly wear down, but Tesla's induction motor used a rotating magnetic field to provide torque.[16]

Within months, Tesla applied for seven patents, including one for his two-phase AC induction motor, and in May 1888 he was awarded a patent for the "Electro Magnetic Motor." On May 16, 1888, Tesla presented his research paper, "A New System of Alternate-Current Motors and Transformers," at a meeting of the American Institute of Electrical Engineers. Tesla's work was well received at the meeting, and the major engineering trade journals reprinted his work. Investors soon became interested, and in July 1888 George Westinghouse signed an agreement with Tesla for the use of several polyphase patents in exchange for shares of stock and royalty payments. Westinghouse also hired Tesla to move to Pittsburg and oversee construction of an AC system.[17]

Tesla's new polyphase motor was a significant acquisition because it allowed Westinghouse to compete with Edison's DC system; it was simpler and easier to maintain than Elihu Thomson's (1853–1937) competing AC motor and was thus more affordable.[18] The polyphase motor was able to handle high voltages and heavy loads, making it ideal for industrial applications.[19] Tesla also patented several modifications to his motor, including a variable speed option, that remain in use today.[20]

During the 1880s, electrical pioneers were competing to distribute electricity on a national level. Some, including Edison, pushed for a DC power distribution system, while others, including William Stanley (1858–1916), George Westinghouse, and Tesla, believed that AC was more efficient. Because existing AC power systems, which were used primarily for arc lighting in cities, had already caused several deaths from high-voltage lines sparking,[21] there was aversion to using it, and the differing opinions on which power system was best eventually turned into a bitter rivalry known as the "War of the Currents."[22]

In 1893, Westinghouse won the contract to electrify the Columbia Exposition in Chicago. It was the first world's fair to be lit by electricity, and was powered by Tesla's polyphase AC electrical system. The Electricity Pavilion showcased new electrical inventions, and Tesla had a personal exhibit in part of the Westinghouse space. On display were several of Tesla's alternating motors, some high-frequency apparatus, and an array of phosphorescent bulbs and tubes.[23]

After the success at the World's Fair, Westinghouse was invited to bid on a hydroelectric project at Niagara Falls. The Westinghouse Company published a book in which it described its alternating current system and noted that the polyphase systems was the "original discovery of Mr. Tesla."[24] Two large generators, based on Tesla's design, went online November 16, 1896.[25]

In early 1895, Tesla established the Nikola Tesla Company with investor Edward Dean Adams, with the aim of manufacturing and selling electrical equipment, but on March 13 a fire gutted the laboratory and destroyed all of Tesla's notes and equipment.[26] Devastated, Tesla nonetheless rebuilt his workshop. Intrigued by the work of Wilhem Röentgen (1845–1923), for a while Tesla dabbled in X-ray research but soon returned to working on wireless communications, which he demonstrated

Figure 2. Tesla's polyphase motor, 1888. University of Pittsburg Library System, Historic Pittsburg, George Westinghouse Museum Collection, 20170323-hpichswp-0044, https://historicpittsburgh.org/islandora/object/pitt%3A20170323-hpichswp-0044 (accessed August 15, 2019). Public domain.

in 1898 using a remote-controlled boat at an electrical exposition at Madison Square Garden in New York.[27]

During the 1890s, Tesla began experimenting with wireless power and high voltage generators. In 1891, the same year he became a U.S. citizen, he patented an oscillating transformer capable of producing an electrical current that changed 30,000 times a second. This transformer became popularly known as the "Tesla coil," arguably his most well-known invention.[28]

In 1899, Tesla moved to Colorado Springs, where he spent eight months experimenting with wireless power transmission. He constructed a laboratory with a retractable roof and installed a large copper ball at the top of a 142-foot metal tower, which in turn was mounted to an 80-foot tower on the roof of the laboratory. Tesla believed that the Earth behaved as a massive conductor, and that by sending signals into the planet he could deliver free electricity without the use of wires. He also mistakenly believed that this would be a lossless system; however, electromagnetic fields weaken over distances, which makes a true lossless system impossible.

Tesla's experiments pulled huge amounts of power from the local electrical company. When he performed one of his experiments, large sparks of man-made lightning flew off the mast and overloaded the El Paso Electric Company's generating plant, bringing down the entire city's power system.[29] Despite his lofty humanitarian goal of providing free energy to the world, Tesla again showed that he did not understand business: it did not occur to him that the El Paso company had to buy fuel to generate power and pay its employees for their labor, which meant they needed to charge for their energy generation.

Tesla also detected a weak oscillating signal that he believed came from outer space. Although Tesla initially kept the information to himself, he eventually told a reporter about the discovery. Tesla did not believe that the signals could be natural emanations from the sun or Earth, and he gushed about the possibility of a message from another world; almost immediately he was ridiculed in the press for speaking to Martians.[30]

Returning to New York in January 1900, Tesla had ambitions to build a large transmission tower that he hoped would produce a handsome profit. Buoyed by the possibilities, he moved into the fashionable Waldorf Astoria hotel.[31] That year, he wrote an article for *Century Magazine* in which he prophesied a future with wireless communications and a host of other fantastic-sounding schemes. Most thought his predictions to be hyperbole, but Morgan offered Tesla $150,000 to build his power plant.[32]

Tesla bought land along Long Island Sound and hired the architect Stanford White (1853–1906) to design a laboratory.[33] Construction began in November 1901. Tesla had originally calculated his transmission tower's height at 600 feet, but rapidly rising costs, partially due to Tesla's penchant toward the grandiose, forced him to reduce his expectations. He settled on a design for a 187-foot tower topped by a 68-foot dome, which resembled a mushroom with a long stalk.[34] The Wardenclyffe Tower project continually needed more cash, but unable to convince Morgan—or any other financier—to invest more funds into it, Tesla struggled along for a few years and reluctantly abandoned the project in 1905.[35]

After the failure of Wardenclyffe, Tesla suffered from a nervous breakdown.[36] The inventor was short of money and he spent several years working as a consultant. After designing a successful bladeless turbine engine in 1912, he was unable to build a successful working model because the materials available to him at the time used were unable to take the strain.[37] Tesla's financial condition continued to worsen, and in 1917 the Waldorf evicted him for unpaid bills.[38] Tesla grew increasingly isolated after the death of several friends and relatives.

In 1917, Tesla was awarded the seventh annual Edison Medal from the American Institute of Electrical Engineers for "early original work in polyphase and high-frequency electric currents."[39] The award ceremony was scheduled for May 18, but midway through the event Tesla disappeared and was found sitting on a park bench covered in pigeons.[40] His fascination with these birds eventually morphed into a "delusional obsession" and Tesla began taking injured birds back to his hotel room to nurse them back to health.[41]

WIRELESS POWER

By RICHARD MAXWELL WINANS

A BOLT of lightning passing through the earth, and returning to the point of entry with undiminished force, was the astounding discovery made by Nikola Tesla, "Wizard of Electricity," inventor, scientist, scholar.

As the issue of this momentous discovery Professor Tesla has perfected a practical system of wireless power distribution. And the universal application of the wireless transmission of energy will speedily solve vast and far reaching problems in commerce and the industries, and will eventually revolutionize the whole structure of the world's social and political economy.

Already Tesla has advanced his discovery of the wireless transmission of electrical energy to the point of practical application. At his great experimental plant on Long Island he has secured actual and satisfactory results in wireless power transmission that go far toward making for its early and successful introduction into commercial and industrial uses. When all the details of his transmitting system are complete, and the world at large shall adopt wireless power in its general utilities, the wonders of science and invention, of dynamics and mechanics, the arts and the social scheme, that we employ and enjoy today will appear as the antiques of a primitive age.

The magic Lamp of Aladdin was never rubbed to such fruitful purpose, nor did it ever create such undreamed-of wonders, as will the application of the wireless transmission of energy to some of the most simple contrivances, the everyday utilities of the present; let alone the improved devices that will develop in its use, with which inventive genius will provide us for the future.

In recounting the incidents leading up to and the elemental details of the discovery that unexpectedly and unquestionably opened the way to this great realization, Tesla recites that during a systematic research, for which he had long trained himself, which he had assiduously conducted for several years, to the end of perfecting a system of wireless transmission of energy through the natural media, the earth and air, he came in 1898 to recognize three essential requirements. The first was to produce a transmitter of tremendous power; the second, to perfect a system for individualizing and isolating the energy transmitted; the third, to acquaint himself with the laws governing the propagation of electrical currents through the earth and air.

IN May, 1899, Professor Tesla selected, for various scientific reasons, a large plateau sixty-five hundred feet above sea level, in the vicinity of Colorado Springs, where the surroundings contributed ideal conditions for careful observations. Such were the climatic and other conditions that he could hear claps of thunder four to five hundred miles away; and he could have improved upon this record had it not been for the tedium of waiting for the sounds to arrive, in definite intervals, as shown by an electrical indicating device—nearly an hour before.

Having established his laboratory and adjusted the highly sensitive instruments necessary to the proposed experiments, he learned that the earth was literally alive with electrical vibrations. Colorado, with its dry and rarefied atmosphere, is famed for its natural displays of electricity; static electricity being abundantly developed. The discharges of lightning during storms are not only frequent, but often violent to an inconceivable degree. During his stay there were in the course of one electrical storm approximately twelve thousand discharges within an observed period of two hours, occurring inside a radius of less than thirty miles. Many of these discharges were so heavy that they resembled gigantic trees of fire.

About a month after his Colorado observations began Tesla was both surprised and puzzled to note that his instruments were affected more decidedly by discharges taking place at great distances than those nearby. This presented a perplexing problem, which was made the more mystifying when careful observation disclosed the fact that the differences were not due to intensity of discharges, nor varying relation between the periods of the receiving circuits and those of the terrestrial disturbances.

"ONE night when meditating over these experiences," says Tesla, "I was suddenly staggered by a thought. The same thought had presented itself to me years ago; but I had then dismissed it as absurd and impossible. And that night when it recurred to me I banished it again. Nevertheless, my instinct was aroused, and somehow I felt that I was nearing a great revelation.

"It was on the third of July (1899) when I obtained the first decisive experimental evidence of a truth of overwhelming importance for the advancement of humanity. A dense mass of strongly charged cloud gathered in the west, and toward evening a violent storm broke loose which, after spending much of its fury in the mountains, was driven away with great velocity over the plains. Heavy and long persisting arcs formed almost in regular time intervals. My observations were now greatly facilitated and rendered more accurate by the experiences already gained. I was able to handle my instruments quickly, and was prepared. The recording apparatus being properly adjusted, its indications became fainter and fainter with the increasing distance of the storm, until they ceased altogether. I was watching in eager expectation. Sure enough, in a little while the indications again began, grew stronger, gradually decreased, and ceased once more. Many times, in regularly recurring intervals, the same actions were repeated, until the storm, as evident from simple computations, with nearly constant speed had retreated to a distance of about two hundred miles. Nor did these strange actions stop then, but continued to manifest themselves with undiminished force.

"When I made this discovery I was utterly astounded. I could not believe what I had seen was really true. It was too great a revelation of Nature to accept immediately and unhesitatingly. Subsequently I confided my discovery to my assistant, and he afterward confirmed it, as did also a noted engineer in a German university. Several opportunities were presented later which brought out still more forcibly and unmistakably the true nature of the wonderful phenomenon. No doubt whatever remained—I was observing stationary waves! Impossible as it seemed, this planet, despite its vast extent, behaved as a conductor of limited capacity.

"All effects diminish as the extreme line of their radius increases. For instance, sound effects would be exhausted within a given radius, which would be determined by atmospheric conditions. The general law is that at one-half the distance the intensity of the effect is fourfold. And this is also true of electrical activities. But this discovery demonstrated something that was altogether contradictory to all previous experience. Not only could an electrical current be passed through the earth with undiminished intensity, but, under certain conditions, its force would be even augmented with distance.

"Had this discovery been worked out at that time it would have given us practical wireless transmission of power on a commercial scale at least ten years ago. The world, however, was not then, and is not yet, ready to receive it. Man—that is, the layman, the man unversed in dynamic forces and scientific engineering—does not understand how one element is related to another. If I had attempted at that time to place upon the market an apparatus for the wireless transmission of power, the world would not have utilized it. It may be years before it is educated to receive these new ideas and the perfection of this discovery. It is difficult for the average citizen to comprehend or to form an adequate idea of the tremendous significance of this marvelous revelation of Nature, or the stupendous possibilities that the development and perfection of this discovery assure as a heritage to humanity."

THE full development of a possible twenty-five hundred millions of horsepower from the waterfalls and streams of the United States has been materially handicapped and restricted by the limited area over which hydroelectric energy may be practically transmitted by wire. The falls of Niagara alone could be made to supply a fifth of all the power used at present by industry and the railroads. At some remote day their power may be entirely utilized by diverting the full volume through tunnels to turbines at night, charging immense storage batteries with its energy for use during the next twelve hours, and again turning the water over the falls during the day to satisfy the sentiment of the people.

Aside from Niagara, however, most of the great power sites of the country are so distant from the centers of

3

Figure 3. This article about Tesla's wireless power distribution appeared in the Sunday Magazine of the Evening Star newspaper on March 3, 1912. Tesla believed that farmers would be the

"greatest beneficiaries" of wireless transmission of electrical energy. Richard Maxwell Winans, "Wireless Power," Evening Star (Washington, DC), March 3, 1912. Public domain.

After World War I, when it seemed likely that another war would break out in Europe, Tesla began working on an energy source that he claimed would make warfare obsolete. He wrote a paper called "The New Art of Projecting Concentrated Non-dispersive Energy through Natural Media" and canvassed several countries for support. Tesla's device was essentially a charged particle beam weapon, and the only country interested was the Soviet Union, which paid Tesla $25,000 for the idea.[42] Another of Tesla's ideas was a vertical takeoff-and-landing vehicle, for which he filed and received a patent in 1928.[43]

One August evening in 1937, the 81-year-old Tesla was hit by a taxi and suffered three broken ribs. He was bedridden and refused both medical care and visitors. Tesla's health began to decline, and on January 7, 1943, he died in his sleep.[44]

His death soon sparked controversy. Tesla's nephew Sava Kosanovic, administrator of his estate, went to Tesla's hotel room shortly after his death. Kosanovic claimed that several of Tesla's technical papers were missing, as well as a black notebook.[45] Tesla had claimed to have perfected his "death beam," which led to the FBI becoming "vitally interested" in his papers, but because Kosanovic was not an American citizen the case was turned over to the Alien Property Custodian Office, which spent weeks attempting to locate all of Telsa's papers and ended up with more than sixty containers of materials.[46]The FBI asserted that it never had any of Tesla's papers in its possession, yet in 2016 the agency declassified 250 pages of documents related to Tesla.[47] Additional documents remain missing, and what happened to them remains a mystery.

Tesla's preferred method of inventing was to work alone, rather than as part of a team.[48] He is credited with having created the modern electrical world, but without his close association with the Westinghouse company, his work on alternating current may never have made it out of the laboratory. Despite his foibles and quirks, Tesla's legacy of engineering lives on in the electrical grid, AC motors, and communications systems that we use every day.

Although, in the end, Tesla ended up being part of a team, he just might have been the most valuable player.

Further Reading:

Bolotin, Norman, and Christine Laing. *The World's Columbian Exposition: The Chicago World's Fair of 1893.* Champaign, IL: University of Chicago Press, 2002.

Carlson, W. Bernard. *Tesla: Inventor of the Electrical Age*. Princeton: Princeton University Press, 2013.

Christopher Newport University, "Primary Sources: Energy: Tesla, Nikola," https://cnu.libguides.com/psenergy/nikolatesla (accessed August 15, 2019).

Cooper, Christopher. *The Truth about Tesla: The Myth of the Lone Genius in the History of Innovation*. New York: Quarto, 2015.

Federal Bureau of Investigation, FBI Records: The Vault, "Nikola Tesla," https://vault.fbi.gov/nikola-tesla (accessed August 15, 2019).

Garvin, Karen S. "Electricity, War of the Currents," in *Technical Innovation in American History* vol. 2, ed. Rosanne Welch and Peg A. Lamphier. Santa Barbara: ABC-CLIO, 2019, 61–63.

Jonnes, Jill. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House, 2004.

Karlsruhe Institute of Technology, "The Invention of the Electric Motor 1856–1893," https://www.eti.kit.edu/english/1390.php (accessed August 15, 2019).

Martin, Thomas Commerford. *The Inventions Researches and Writings of Nikola Tesla*. New York: D. Van Nostrand, 1894.

Munson, Richard. *Tesla: Inventor of the Modern*. New York: W.W. Norton, 2018.

"Nikola Tesla Becomes the Recipient of Edison Medal," May 19, 1917, *Electrical World* 69, no. 20, 980–81, Internet Archive, https://archive.org/details/electricalworld69newy/page/980 (accessed May 16, 2019).

PBS, "Colorado Springs," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_colspr.html (accessed August 7, 2020).

PBS, "The Missing Papers," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_mispapers.html (accessed August 15, 2019).

PBS, "Tesla: Master of Lightning," https://www.pbs.org/tesla/index.html (accessed May 9, 2019).

PBS, "Race of Robots," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_robots.html (accessed August 15, 2019).

Rutgers School of Arts and Sciences, Thomas A. Edison Papers Project, http://edison.rutgers.edu/.

Schiffer, Michael Brian. *Power Struggles: Scientific Authority and the Creation of Practical Electricity before Edison*. Cambridge, MA: MIT Press, 2008.

Tesla, Nikola. *My Inventions: The Autobiography of Nikola Tesla*. New York: Experimenter Publishing, 1919.

Westinghouse Electric and Manufacturing Company, *Transmission of Power: Polyphase System, Tesla Patents* (Pittsburg: Westinghouse, 1893).

[1]. Richard Munson, *Tesla: Inventor of the Modern* (New York: W.W. Norton, 2018), 1.

[2]. Munson, *Tesla: Inventor of the Modern*, 6–7.

[3]. Munson, *Tesla: Inventor of the Modern*, 173–74.

[4]. Munson, *Tesla: Inventor of the Modern*, 223–24.

[5]. Munson, *Tesla: Inventor of the Modern*, 9, 11, 15.

[6]. Carlson, *Tesla: Inventor of the Electrical Age*, 21–22, 26–28.

[7]. Carlson, *Tesla: Inventor of the Electrical Age*, 34; Munson, *Tesla: Inventor of the Modern*, 23, 27.

[8]. Carlson, *Tesla: Inventor of the Electrical Age*, 47; Munson, *Tesla: Inventor of the Modern*, 29.

[9]. PBS, "Coming to America," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_america.html (accessed May 5, 2019); Munson, *Tesla: Inventor of the Modern*, 43.

[10]. Munson, *Tesla: Inventor of the Modern*, 45.

[11]. Munson, *Tesla: Inventor of the Modern*, 46.

[12]. Munson, *Tesla: Inventor of the Modern*, 48, 52–53.

[13]. Munson, *Tesla: Inventor of the Modern*, 54.

[14]. Munson, *Tesla: Inventor of the Modern*, 54–55.

[15]. Munson, *Tesla: Inventor of the Modern*, 56.

[16]. Karen S. Garvin, "AC Induction Motor," in *Technical Innovation in American History* vol. 2, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 10–11.

[17]. Munson, *Tesla: Inventor of the Modern*, 61–65; Tesla Universe, "Tesla's Speech Before AIEE," https://teslauniverse.com/nikola-tesla/timeline/1856-birth-nikola-tesla#goto-281 (accessed August 15, 2019).

[18]. All about Circuits, "Tesla Polyphase Induction Motors," EETech Media, https://www.allaboutcircuits.com/textbook/alternating-current/chpt-13/tesla-polyphase-induction-motors/ (accessed May 10, 2019).

[19]. Munson, *Tesla: Inventor of the Modern*, 63.

[20]. PBS, "Anatomy of a Motor," Inside the Lab, https://www.pbs.org/tesla/ins/lab_acmotor.html (accessed August 15, 2019).

[21]. Ernest Freeburg, *The Age of Edison: Electric Light and the Invention of Modern America* (New York: Penguin Books, 2013), 80–84.

[22]. Karen S. Garvin, "Electricity, War of the Currents," in *Technical Innovation in American History* vol. 2, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 61–63; Munson, *Tesla: Inventor of the Modern*, 91–101.

[23]. Thomas Commerford Martin, *The Inventions Researches and Writings of Nikola Tesla* (New York: D. Van Nostrand, 1894), 477–85; Munson, *Tesla: Inventor of the Modern*, 105–110.

[24]. *Transmission of Power: Polyphase System, Tesla Patents* (Pittsburg: Westinghouse Electric and Manufacturing Company, 1893), iv.

[25]. Munson, *Tesla: Inventor of the Modern*, 113.

[26]. Munson, *Tesla: Inventor of the Modern*, 136–39.

[27]. PBS, "Race of Robots," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_robots.html (accessed August 15, 2019).

[28]. Munson, *Tesla: Inventor of the Modern*, 74.

[29]. PBS, "Colorado Springs," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_colspr.html (accessed August 7, 2020); Munson, *Tesla: Inventor of the Modern*, 163–64.

[30]. Munson, *Tesla: Inventor of the Modern*, 163–64.

[31]. Munson, *Tesla: Inventor of the Modern*, 167.

[32]. PBS, "Tower of Dreams," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_todre.html (accessed August 15, 2019); Munson, *Tesla: Inventor of the Modern*, 167, 173.

[33]. Munson, *Tesla: Inventor of the Modern*, 175.

[34]. Munson, *Tesla: Inventor of the Modern*, 177–78; PBS, "Tesla's Tower with Dome Frame, Completed in 1904," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/td_tow2_pop.html.

[35]. PBS, "Tower of Dreams."

[36]. PBS," Tower of Dreams."

[37]. PBS, "Poet and Visionary," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_poevis.html; Munson, *Tesla: Inventor of the Modern*, 193, 196–198.

[38]. Munson, *Tesla: Inventor of the Modern*, 216.

[39]. "Nikola Tesla Becomes the Recipient of Edison Medal," *Electrical World* 69, no. 20, 980–81, Internet Archive, https://archive.org/details/electricalworld69newy/page/980 (accessed May 16, 2019).

[40]. Munson, *Tesla: Inventor of the Modern*, 209.

[41]. Munson, *Tesla: Inventor of the Modern*, 217.

[42]. PBS, "A Weapon to End War," Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_wendwar.html (accessed may 17, 1029); Nikola Tesla, "The New Art of Projecting Concentrated Non-dispersive Energy through Natural Media," Inventions and Experiments of Nikola Tesla, https://teslaresearch.jimdo.com/death-ray/the-new-art-of-projecting-concentrated-non-dispersive-

energy-through-natural-media-briefly-exposed-by-nikola-tesla-circa-may-16-1935/ (accessed May 17, 2019); Munson, *Tesla: Inventor of the Modern*, 230.

[43]. Munson, *Tesla: Inventor of the Modern*, 198–99.

[44]. Munson, *Tesla: Inventor of the Modern*, 232–33.

[45]. Munson, *Tesla: Inventor of the Modern*, 239; PBS, “The Missing Papers,” Tesla Life and Legacy, https://www.pbs.org/tesla/ll/ll_mispapers.html (accessed August 15, 2019).

[46]. PBS, “The Missing Papers”; Munson, *Tesla: Inventor of the Modern*, 238–40.

[47]. Sarah Pruitt, “The Mystery of Nikola Tesla’s Missing Files,” May 3, 2018, History, A&E Television Networks, https://www.history.com/news/nikola-tesla-files-declassified-fbi (accessed May 17, 2019).

[48]. Munson, *Tesla: Inventor of the Modern*, 244.

CHAPTER 12 - EARLY ELECTRIFICATION

KAREN GARVIN

The modern world runs on electricity. From lighting and heat, to computers and cell phones, almost all technology relies on a steady supply of electrical current for power. Yet despite people being aware of electricity for more than two millennia it has only been within the last 200 years that the study of electricity was formalized, leading to the development of a complete system of electrical power distribution and the invention of numerous electrically powered appliances and machines.

The Greek philosopher Thales of Miletus (circa 626–623 BCE) was one of the first to investigate the phenomenon of electricity. He observed that rubbing a lump of amber with fabric would cause small objects, such as feathers, to cling to it.[1] There was little progress in understanding this strange effect until the English physician and philosopher William Gilbert (1544–1603) began experimenting with various materials to see whether they were magnetic or displayed an electric effect, which he thought was due to "electrical effluvia" that behaved much like flowing water.[2]

Gilbert's legacy of experimentation was taken up by other natural philosophers, and gradually there emerged a small body of knowledge about electricity. The English dyer and astronomer Stephen Gray (1666–1736) worked out how to transmit electricity over a distance but was hampered by the small amounts of electricity he could generate, and so his efforts led nowhere.[3]

There was no way to store electricity until the Leyden jar was developed in the mid-eighteenth century. It was independently discovered by the German cleric Ewald Georg von Kleist (1700–1748) and Dutch mathematician Pieter van Musschenbroek (1692–1761), who generally gets the credit for the invention.[4] This device was a glass jar partially coated with a thin metal foil on both the inside and outside. A metal rod was inserted through the jar's cork, making contact with both the inner and outer foil plates.[5] The Leyden jar was capable of delivering a very high voltage of around 10,000 volts (fig. 1).[6]

the jar, substituting the two armatures for the two plates, A and B, of fig. 493.

Like the condenser, the Leyden jar may be discharged either slowly or instantaneously. For the latter it is held in the hand by the outside coating (fig. 498), and the two coatings are then connected by means of the simple discharger. Care must be taken to touch *first* the external coating with the discharger, otherwise a smart shock will be felt. To discharge it slowly the jar is placed on an insulated plate, and first the internal and then the external coating touched, either with the hand or with a metallic conductor. A slight spark is seen at each discharge.

Fig. 499 represents a very pretty experiment for illustrating the slow

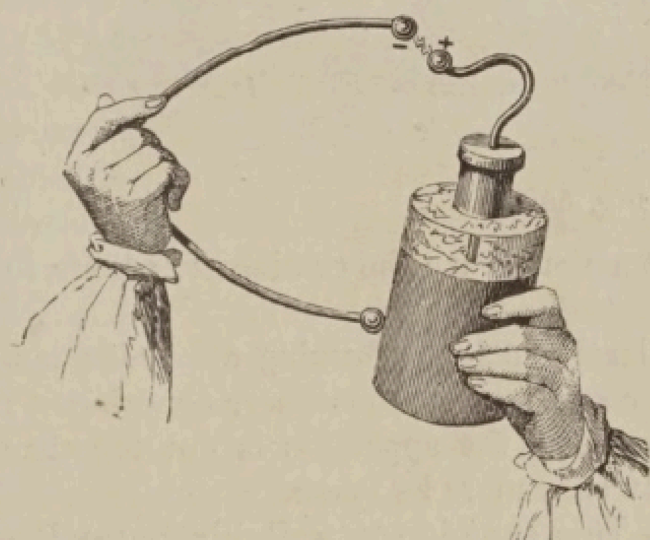


Fig. 498.

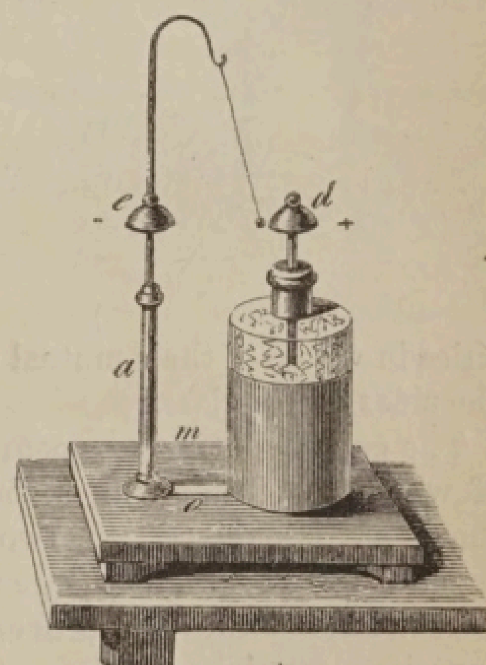


Fig. 499.

discharge. The rod terminates in a small bell, *d*, and the outside coating is connected with an upright metallic support, on which is a similar bell, *e*. Between the two bells a light copper ball is suspended by a silk thread. The jar is then charged in the usual manner and placed on the support *m*. The internal armature contains a quantity of free electricity; the pendulum is attracted and immediately repelled, striking against the second bell, to which it imparts its free electricity. Being now neutralised it is again attracted by the first bell, and so on for some time, especially if the air be dry, and the jar pretty large.

669. **Leyden jar with moveable coatings.**—This apparatus (fig. 500) is used to demonstrate that in the Leyden jar, the opposite electricities are not distributed on the coatings merely, but reside principally on

Figure 1. Illustrations of a Leyden jar being discharged. One method produces a quick discharge (and possible shock to the user), while the second method produces a slow trickle of current. From Adolphe Ganot and Edmund Atkinson, *Elementary Treatise on Physics, Experimental and Applied* (New York: W. Wood and Co., 1868). Public domain; book held by the Library of Congress, https://www.loc.gov/item/17008559/.

In 1800, Alessandro Volta (1745–1827) developed the first chemical storage battery, called a "pile," which consisted of a stack of alternating copper and zinc discs separated by pasteboard.[7] Instead of delivering a high-voltage spark like a Leyden jar, the battery produced a steady electrical current.[8] The English scientists William Nicholson (1753–1815) and Anthony Carlisle (1768–1840) used electricity to separate chemical compounds into elements; this process was named electrolysis and it soon led to other discoveries, including electroplating.[9]

Sir Humphrey Davy (1778–1829) also experimented with electrolysis, building a large battery that he used for the process. Davy also experimented with lighting. In 1801 he demonstrated incandescent lighting, using his battery to heat platinum strips until they glowed. Perhaps Davy's most impressive electrical work was the construction of an arc lamp, which consisted of two carbon rods placed close together but not touching; when electrical current was sent through the rods a spark jumped the gap and gave off a brilliant white light. Sometime between 1802 and 1809, Davy demonstrated the arc light at the Royal Society in London but otherwise did nothing to put the arc lamp to productive use.[10]

Electrical lighting remained impractical until sufficiently powerful electrical generators were developed. During the mid-nineteenth century, most power stations were isolated affairs, with customers building and using their own power sources.[11] The expense of building generators meant that electricity was reserved for large projects, such as lighthouses, or homes of the rich, such as financier J. P. Morgan.[12] A few central power stations existed and by the late 1870s they were providing power for arc street lights in major American and European cities, including New York, London, and Paris.[13]

Arc lamps produced a strong white light that provided ample lighting for streets and cities, and they were increasingly used to replace gas lighting. Early arc lamps were fraught with problems: they tended to flicker, and they produced a harsh light that distorted colors and gave off an annoying hum that rendered them unsuitable for indoor use.[14] Russian military engineer Pavel (Paul) Jablochkoff (1847–1894) developed a commercial version of an arc lamp that produced a milder light, which became known as the Jablochkoff candle.[15]

Inventors such as J. W. Starr (1822–1846) and Heinrich Goebel (1818–1893) turned their attentions to incandescent lighting for indoor use, with Goebel producing a successful vacuum incandescent lamp two decades before Thomas Edison (1847–1931).[16] Alexander de Lodyguine (1847–1923) of Russia created a nitrogen-filled bulb and used them to light St. Petersburg harbor. Joseph Swan (1828–1914) of England began experimenting with carbon filaments for incandescent bulbs and become one of the first commercially successful electrical inventors after he patented his incandescent light bulb in 1880.[17]

By the late 1870s, Edison began experimenting with arc and incandescent bulbs (fig. 2). Sensing the possibility of a commercial market for a more pleasing light, he looked to create safe lighting that included long-lasting bulbs and an inexpensive power source. Edison's concept was not just to make one component, but to create an entire electrical utility system. By 1879 he had a successful light bulb and for the next two years focused on installing a lighting system at his Menlo Park laboratory in New Jersey. In 1882 Edison opened London's Holborn Viaduct electrical station and then turned his attention on New York City.[18]

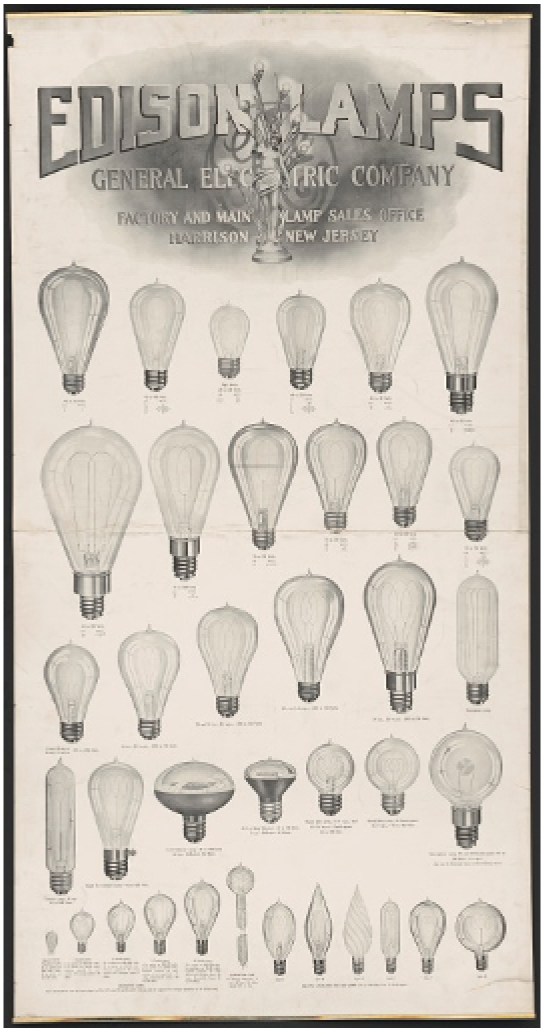


Figure 2. This 1903 advertising poster from the General Electric Company shows the wide variety of Edison-style electric bulbs (lamps) that were available by the turn of the 20th century. "Edison Lamps," General Electric Company, factory and main lamp sales office, Harrison, New Jersey, 1903. No known restrictions on publication; poster held by the Library of Congress, https://www.loc.gov/item/2018694401/.

After purchasing a large building in Manhattan, Edison sought and received permission from the city to dig up the streets in order to lay electrical conduits for his central power station. At the heart of the Pearl Street Power Station were six 27-ton, coal-fueled electrical generators, each capable of producing 100 kilowatts of power. The generators produced an alternating current (AC) that was converted into a safe, low-voltage direct current (DC). The plant went into operation on September 4, 1882. It originally provided service for 85 customers, and within a year the number of customers had increased to 500.[19]

There had been an international lighting system for some time, with companies such as the Société Générale d'Électricté in France, which, after installing lighting systems in Paris, Le Havre, and London, established a Russian subsidiary.[20] By the early 1880s, lighting systems existed in many parts of Europe as well as Asia and South America. But it was Edison's much-publicized success with Pearl Street that helped fuel the further demand for electrical utility systems.[21]

By the late 1800s, two competing electrical transmission systems were in place: AC and DC. Proponents of DC, including Edison, argued that the low voltages required by DC systems made them safer than AC systems, which used very high voltages to distribute power. A number of people had been killed after coming into contact with AC power lines and there was widespread belief that power companies had little interest in public safety.[22]

Nikola Tesla (1856–1943) and George Westinghouse (1846–1914) were proponents of AC, as were many European companies.[23] One solid argument in favor of AC was that it was more efficient at transmitting power over long distances than DC. It also was more versatile because DC systems required separate supply lines for lights and motors, which required different voltages to operate properly. By contrast, a single AC power line could be used with transformers to provide a range of voltages for different electrical equipment.

The ensuing "War of the Currents" evolved into an ugly rivalry over what form the national power distribution system should take. Edison, who had a large monetary stake in his existing DC power systems, attempted to prove how dangerous AC was by electrocuting animals. On August 6, 1890, the dangers of AC were made abundantly clear when convicted murderer William Kemmler (1860–1890) was electrocuted to death in the first electric chair (fig. 3).[24] In turn, Westinghouse and Tesla denounced Edison's system, noting its limitations and promoting their own AC system.

EXTRA

The Evening Edition World.

EXTRA

PRICE ONE CENT.

NEW YORK, WEDNESDAY, AUGUST 6, 1890.

PRICE ONE CENT.

5 O'CLOCK EXTRA

BRUTAL.

Kemmler Dies a Terrible Death in the Electric Chair.

The First Shock Did Not Kill Him and a Second and Third Were Applied.

The Autopsy Shows That the Muscles and Brain Were Literally Baked.

Alive Six Minutes After the Current Was Turned On.

The Wretched Man's Flesh Burned After the Third Shock.

A More Revolting Exhibition Than the Inquisition Ever Saw.

KEMMLER EXTRA---NO. 7.

THE SWITCH OF DEATH.

WALL ST.

STOCK REPORTS.

5 O'CLOCK

RACING.

AN ACCIDENT.

Six Horses and Their Jockeys in a Struggling Mass.

NO FATALITIES RESULTED.

ON THE HILL IN JERSEY.

Figure 3. The execution of convicted murderer William Kemmler by electrocution made front-page news. It was the first use of the electric chair, which was powered by alternating current. *The Evening World* (New York), August 6, 1890. Public domain; newspaper image is from the Library of Congress, https://www.loc.gov/item/sn83030193/1890-08-06/ed-6/.

William Stanley Jr. (1858–1916) produced the first commercially successful AC transformer, which was based on earlier designs. Stanley made changes to improve the efficiency of transformers, which he incorporated into a working high-voltage AC power system in Great Barrington, Massachusetts. On March 20, 1886, Stanley successfully electrified the town using a 500-volt generator to provide power. The "Great Barrington Electrification" relied on Stanley's transformers, which stepped up the generator's output to 3,000 volts for transmission and then safely stepped it back down to 500 volts again at the destination. The success of the installation proved that an AC system could safely provide electricity for a large number of customers.[25] Stanley's success was another early win for AC in the War of the Currents.

Alternating current was showing itself to be better suited for electrical distribution: in 1891, *Electrical World* magazine reported about 200 Edison DC power stations in use nationwide, whereas there were about 1,000 AC power stations in operation.[26] Another win for alternating current was the 1893 Chicago World's Fair (also known as the World's Columbian Exposition). The fair's organizers took bids for lighting the fairgrounds, which sprawled over 600 acres. They awarded the contract for electrifying the fair to George Westinghouse, who was able to underbid the rival company, General Electric, because his cost-effective AC system required less wiring than the competing DC system.[27] Westinghouse's system relied on Tesla's polyphase generator, which could hand high voltages and heavy loads, making it ideal for large-scale applications.

The exposition included a two-story Electricity Pavilion that showcased electrical inventions; the second floor had a display for domestic products, while the main floor showcased companies and inventors, including Edison, Tesla, and Westinghouse, as well as a number of European companies. Many technical breakthroughs were on display at the fair, such as the first fluorescent light bulbs. Tesla gave demonstrations using high voltages to show that it could be used safely; Edison displayed his phonograph; a German company, Allegemeine Elektrizitats Gesellschaft, brought alternating current equipment.[28]

Lighting was not the only use for electricity. Small, yet powerful, electric motors were developed in order to replace steam power for city trams, although it took years to develop a reliable battery. In 1879, the German firm of Siemens & Halske unveiled a narrow-gauge electric train at the Berlin Industrial Exhibition, and in 1881 the company constructed an experimental tram line that used the train's rails as an external power source. Electrified rails were a shock hazard, though, and later tram lines used an overhead power source. Subway systems and railways also increasing used electric motors for propulsion.[29]

With powerful electrical generators to make electricity and a capable delivery system came an increased demand for electric power. Lighting and transportation were important uses for electricity, but new inventions arrived quickly, including domestic appliances such as the electric bread toaster, which was created in 1893 by Scottish inventor Alan MacMasters.[30] In 1889, Singer introduced the first electric sewing machine.[31]

The new electrical utility industry was unlike any other industry. Electricity could not be easily stored and so it needed to be used as soon as it was generated. The equipment required constant upkeep by skilled technicians, and the industry required huge outlays of capital.[32] For this reason, dense urban areas were the first to be electrified because it was unfeasible and uneconomical for individual companies to run miles of transmission lines to rural areas. The increasingly widespread availability of electricity in cities also meant that modern electrical conveniences, including the toaster, were first adopted in the highly populated urban centers. Due to the high costs of building transmission lines, electricity remained a utility primarily for the cities for the remainder of the nineteenth century, although there were exceptions. (fig. 4).[33]

Figure 4. This action-packed poster for Buffalo Bill's Wild West show boasts that its two electric plants can produce illumination that is "lighter than day." *Buffalo Bill's Wild West and Congress of Rough Riders of the World in the Grandest of Illuminated Arenas, 2 Electric Plants, 250,000 Candle Power* (New York: Springer Litho. Co., 1895). No known restrictions on publication; poster held by the Library of Congress, https://www.loc.gov/item/2002719218/.

In 1881, Edison employed Samuel Insull (1859–1938) as his secretary. Insull, who emigrated from England to work with Edison, was given the task of handling finances and helping to reduce Edison's chronic money shortage.[34] Insull was adept at the electricity business and proved to be instrumental in creating the modern electric power grid. By consolidating small electricity providers into larger companies, he was able to leverage the economies of scale, which in turn helped to bring the price of electricity down so that it was no longer a luxury item. With more consumer demand, Insull also expanded electrical utilities out into rural areas, although much of the United States was not electrified until after 1930 (fig. 5).[35]

Figure 5: The Allis-Chalmers five-thousand horsepower electrical generator that was on display in the Palace of Machinery at the 1904 Louisiana Purchase Exposition. Official Photographic Company, and Louisiana Purchase Exposition, *The World's Fair in Colortypes and Monotones: Official Publication* (St. Louis: Official Photographic Co, 1904). Public domain; book held by the Library of Congress, https://www.loc.gov/item/89101355/.

[1]. Jill Jonnes, *Empires of Light* (New York: Random House, 2003), 17.

[2]. Jonnes, *Empires of Light*, 18–19.

[3]. Jonnes, *Empires of Light*, 21–22,

[4]. "E. Georg von Kleist," Britannica.com, https://www.britannica.com/biography/E-Georg-von-

Kleist; and "Pieter van Musschenbroek," Britannica.com, https://www.britannica.com/biography/Pieter-van-Musschenbroek.

[5]. Jonnes, *Empires of Light*, 23–26.

[6]. Michael Littman, "Leyden Jar," Joseph Henry Project, Princeton University, https://commons.princeton.edu/josephhenry/leyden-jar/.

[7]. Ernest Freeburg, *The Age of Edison: Electric Light and the Invention of Modern America* (New York: Penguin, 2013), 15; Jonnes, *Empires of Light*, 31–32.

[8]. Jonnes, *Empires of Light*, 33.

[9]. William J. Hausman, Peter Hertner, and Mira Wilkins, *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878–2007* (Cambridge: Cambridge University Press, 2008), 8.

[10]. Freeberg, *The Age of Edison*, 15–17; Hausman, *Global Electrification*, 8.

[11]. Hausman, *Global Electrification*, 9.

[12]. Freeberg, *The Age of Edison*, 17; Hausman, *Global Electrification*, 9; Jonnes, *Empires of Light*, 13.

[13]. Hausman, *Global Electrification*, 9.

[14]. Freeberg, *The Age of Edison*, 18, 28; Hausman, *Global Electrification*, 11.

[15]. Jonnes, *Empires of Light*, 45.

[16]. Freeberg, *The Age of Edison*, 28–29; Hausman, *Global Electrification*, 11.

[17]. Hausman, *Global Electrification*, 11; "Edison's Incandescent Lamp," Engineering and Technology History Wiki, August 25, 2020.

[18]. Hausman, *Global Electrification*, 321n37; Jonnes, *Empires of Light*, 81.

[19]. Carl Sulzberger, "Thomas Edison's 1882 Pearl Street Generating Station," Engineering and Technology History Wiki, November 23, 2017; and Carl Sulzberger, "Milestones: Pearl Street Station, 1882," Engineering and Technology History Wiki, January 27, 2016.

[20]. Hausman, *Global Electrification*, 75.

[21]. Hausman, *Global Electrification*, 75–76.

[22]. Freeburg, *The Age of Edison*, 181.

[23]. "Initial Tesla Polyphase/'Three-Phase' Alternating-Current Systems and Metering Development," Engineering and Technology History Wiki, July 10, 2015.

[24]. Jonnes, *Empires of Light*, 185–213.

[25]. Jonnes, *Empires of Light*, 133.

[26]. Jonnes, *Empires of Light*, 287.

[27]. Jonnes, *Empires of Light*, 248–56.

[28]. Richard Munsen, *Tesla: Inventor of the Modern* (New York: W.W. Norton, 2018), 108–10; and "Electrical Building," Chicagology.com, https://chicagology.com/columbiaexpo/fair033/.

[29]. Hausman, *Global Electrification*, 15–17.

[30]. Linda Gross, "The History of Making Toast," Hagley Museum, June 19, 2017, https://www.hagley.org/librarynews/history-making-toast.

[31]. "History," Singer, https://www.singer.com/history.

[32]. "History of Electricity: Enter Samuel Insull," Institute for Energy Research, https://www.instituteforenergyresearch.org/history-electricity/#Rise; and Hausman, *Global Electrification*, 19.

[33]. Harold D. Wallace Jr., "Power from the People: Rural Electrification Brought More than Lights," National Museum of American History, Behring Center, February 12, 2016, https://americanhistory.si.edu/blog/rural-electrification.

[34]. John F. Wasik, *The Merchant of Power: Sam Insull, Thomas Edison, and the Creation of the Modern Metropolis* (New York: St. Martin's Press, 2006), 5–14.

[35]. "History of Electricity: Insull Builds the Modern Power Grid," Institute for Energy Research, https://www.instituteforenergyresearch.org/history-electricity/#Insull; and Wallace, "Power from the People."

Further Reading:

"Initial Tesla Polyphase/'Three-Phase' Alternating-Current Systems and Metering Development," Engineering and Technology History Wiki, July 10, 2015.

Freeburg, Ernest. *The Age of Edison: Electric Light and the Invention of Modern America*. New York: Penguin, 2013.

Hausman, William J., Peter Hertner, and Mira Wilkins. *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878–2007*. Cambridge: Cambridge University Press, 2008.

Heilbron, J. L. *Electricity in the 17th and 18 Centuries: A Study of Early Modern Physics*. Berkeley: University of California Press, 1979.

Hughes, Thomas P. (1993). *Networks of Power: Electrification in Western Society, 1880–1930.* Baltimore: Johns Hopkins University Press, 1993.

Institute for Energy Research. "History of Electricity." https://www.instituteforenergyresearch.org/history-electricity/#RevolutionaryPower.

Jonnes, Jill. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House, 2004.

Klein, Maury. *The Power Makers: Steam, Electricity, and the Men Who Invented Modern America*. New York: Bloomsbury Press, 2008.

Munson, Richard. *Tesla: Inventor of the Modern*. New York: W.W. Norton, 2018.

McNichol, Tom. *AC/DC: The Savage Tale of the First Standards War*. San Francisco: Wiley, 2006.

Nelles, H. V. *Politics of Development: Forests, Mines & Hydro-Electric Power in Ontario, 1849–1941*. Montreal: McGill-Queen's University Press, 2005.

Smithsonian Institution, "Joseph Henry's Yale Magnet," https://siarchives.si.edu/collections/siris_sic_13160.

Skrabec, Quentin R. *George Westinghouse: Gentle Genius*. New York: Algora Publishing, 2007.

Stross, Randall. *The Wizard of Menlo Park: How Thomas Alva Edison Invented the Modern World*. New York: Three Rivers Press, 2007.

Wasik, John F. *The Merchant of Power: Sam Insull, Thomas Edison, and the Creation of the Modern Metropolis.* New York: St. Martin's Press, 2006.

CHAPTER 12 - ELECTROMAGNETISM

KAREN GARVIN

The Greeks and Chinese mentioned the phenomenon of magnetism as early as the sixth century BCE and fourth century BCE, respectively, when they noticed that certain types of rocks would attract small pieces of iron.[1] These rocks, known as magnetite, are a form of iron oxide and are very common.[2] Although the ancients made many attempts to explain how magnetism worked, its fundamental nature would remain a mystery until the nineteenth century.

Pliny the Elder (23–79 CE) described magnetite deposits in Spain and also noted that Ethiopia was a good source for magnets.[3] Large numbers of magnets were imported from India; however, few practical uses for magnets existed at the time. While some medical uses were mentioned in one of the Hippocratic treatises, and the stone was reported to have magical power, the main use of magnets seems to have been for their entertainment value.[4]

Magnets were commonly known as lodestones because of their ability to point in a specific direction. The word "lodestone" was coined around 1515, and is a combination of the Old English words "lād" (meaning direction or course) and "stān" (stone).[5] During the first century AD, the Chinese used a compass that incorporated a lodestone as a *feng shui* (Chinese geomancy) divining instrument to determine the best orientation for building sites. This device consisted of a bronze or wood plate on top of which sat a spoon-shaped lodestone that could move freely to indicate direction (fig. 1).[6] The compass, or *zhi nan zhen*, was orientated with south as the primary direction.[7]

Figure 1. Han Dynasty compass with a south-indicating pointer. Creative Commons attribution-share alike 3.0 unported license, https://commons.wikimedia.org/wiki/File:Model_Si_Nan_of_Han_Dynasty.jpg.

Sometime around the twelfth century the Chinese developed a type of compass that used a magnetized needle floating in water.[8] Eventually the water was dispensed with, and a magnetized needle was pinned to a board that had an intricate design marked for *feng shui* purposes.[9] While this type of compass would later prove to be immensely useful to the Europeans for seafaring navigation, the Chinese continued to use a magnetized needle floating in water for navigation purposes until at least the sixteenth century.[10] When the compass arrived in Europe is uncertain; one theory suggests that the Venetian explorer Marco Polo (1254–1324) took it from China to Europe, while another theory suggests that Arab traders may have introduced it. Alternatively, the compass might have been independently developed in Europe.[11]

Theories of magnetism

Magnets were attributed with a wide range of magical and curative properties. No one had attempted to actually prove these claims until physician and philosopher William Gilbert (1544–1603) of England began to conduct formal experiments with magnets and electricity. In 1600, Gilbert published *On the Magnet and Magnetic Bodies, and on That Great Magnet the Earth*, commonly referred to as *De Magnete*, in which he described his experiments and encouraged others to recreate his work.[12] The book is described as being the first textbook on magnetism.[13] Gilbert was the first to recognize that the Earth is a magnet, but despite his experimentation he was unable to offer a complete explanation of magnetism; he also believed that electricity and magnetism were separate phenomena.[14]

Others tried to explain the natures of magnetism and electricity, including the French philosopher René Descartes (1596–1650), the Italian physician and physicist Luigi Galvani (1737–1798), the Italian physicist and chemist Alessandro Volta (1745–1827), and the American philosopher and statesman Benjamin Franklin (1706–1790).[15] During the eighteenth century, the French physicist Charles-Augustin de Coulomb (1736–1806) built a torsion balance to measure the force between a magnet's north and south poles. He also set about describing the magnetic force in mathematical terms: this became his inverse-square law, which said that the strength of a magnetic field or electrical field dropped off the farther it was from an object: for example, at twice the distance, a magnetic field was a quarter of its strength, and at three times the distance, the same magnetic field would be only one-ninth as strong.[16] The inverse-square law, which later became known as Coulomb's Law, contributed to the idea that that there was a link between magnetism and electricity.[17]

In 1820 the Danish physicist Hans Christian Oersted (1777–1851) discovered that an electrical current produced a magnetic field.[18] Oersted had been experimenting with electricity in an attempt to establish a link between electricity and a magnetic field. He noticed that turning an electrical current on and off made the needle on a nearby compass deflect. Although the movement was small, Oersted continued his experiments and eventually was able to show that electricity flowing through a wire produced a magnetic field that circulated around the wire. Oersted had expected any effect from the electrical current to be in parallel with the wire, and finding that the magnetic field "flowed around" the wire in "circulating loops" was a surprise.[19]

The impact that Oersted's discovery would have on technology was tremendous. Magnetic fields had previously only been seen with permanent magnets and lodestones, but Oersted's work showed that a magnetic field could be created by using an electrical current—and that meant that it could be controlled.[20]

André Marie Ampère (1775–1836), a French physicist, heard about Oersted's discovery and set about trying to understand the physics underlying the phenomena. Seeing that an electrical current could induce a magnetic field, Ampère wondered if the reverse was true: Would wires carrying an electrical current generate a magnetic field? He designed an experiment to test whether a pair of electrified wires would behave like magnets and attract or repel one another; Ampère was successfully able to demonstrate a noticeable, but weak, force between the two wires.[21] Ampère carried out many experiments and published his results in his *Memoir on the Mathematical Theory of Electrodynamic Phenomena, Uniquely Deduced from Experience*, in 1827.[22]

Practical applications for magnetism

In 1825, the English scientist William Sturgeon (1783–1850) produced the first practical electromagnet, which consisted of a seven-ounce curved iron bar wrapped with bare copper wire and varnished to prevent it from shorting out (fig. 2). The electromagnet was able to lift nine pounds but was too short-lived and weak for practical use. [23]

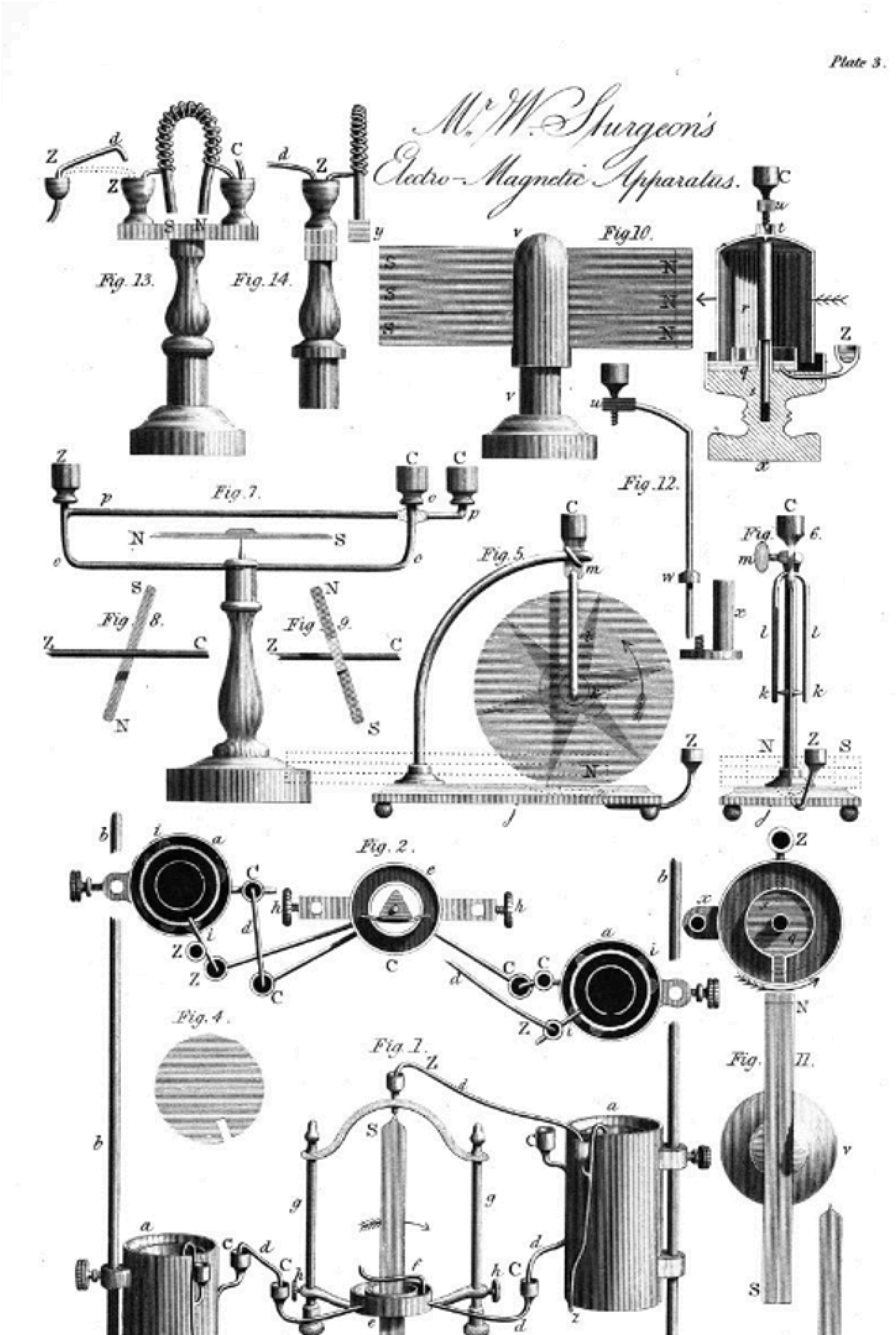


Plate 3.
Mr. W. Sturgeon's
Electro-Magnetic Apparatus.
Fig. 13.
Fig. 14.
Fig. 10.
Fig. 7.
Fig. 12.
Fig. 8.
Fig. 9.
Fig. 5.
Fig. 6.
Fig. 2.
Fig. 4.
Fig. 1.
Fig. 11.

Figure 2. Drawings of William Sturgeon's electromagnets. Smithsonian Institution archives, accession 11-006, MAH-46761D, https://www.si.edu/object/sturgeons-electromagnet:siris_sic_13483. No known restrictions.

Other scientists soon began experimenting with electromagnets, including the Dutch researcher Gerard Moll (1785–1838) and the American scientist Joseph Henry (1797–1878) (fig. 3). Moll built larger electromagnets than Sturgeon, but his versions required large batteries that made the magnets cumbersome, whereas Henry focused on using small batteries to power his creations. The small power source would make Henry's electromagnets versatile, and they were instrumental in the development of the first electric doorbell, created by Henry in 1831.[24] In 1835, Henry created an electromechanical relay, which was an electrical switch that used an electromagnet to open and close contacts in a circuit. By mid-century, Henry's relays were being used in telegraph systems and telephones.[25]

Figure 3. The American scientist Joseph Henry was a pioneer in the field of electromagnetism and was the first secretary of the Smithsonian Institution. Smithsonian Institution Archives, SIA2012-7654 or SIA2012-2690 or 44307 or MAH 44307, created by Joseph Henry Papers Project, "Joseph Henry," SIA2012-7654.

Henry also improved the design of the electromagnet by insulating the wires with silk cloth so that he could wrap more layers of wire around the magnet without shorting them out.[26] Adding more wraps of wire, or “turns,” produced a stronger magnetic field.[27] Henry’s electromagnets became increasing large, including a twenty-one pound version that could lift 750 pounds and, in 1830, the “Yale Magnet,” an eighty-two and a half pound electromagnet that could lift more than a ton.[28] In 1833, Henry built an even larger magnet: it weighed 100 pounds and could lift a staggering 3,500 pounds of weight (fig. 4).[29]

370 Scientific American. [DECEMBER 11, 1880.

AMATEUR MECHANICS.

HINTS ON MODEL MAKING.

It is a simple matter for an experienced instrument maker or machinist to produce a fine model with turned shafts, cut gearing, true pulleys, and smooth working cams, but it is quite another thing for an inventor, without tools or materials, to embody his ideas in a working model even though he may have a mechanical taste.

It is fair to suppose that every mechanical inventor in these days of cheap machinery possesses some sort of a lathe, as these indispensable machines are now made for prices within the reach of almost any one.

It is quite evident, from an inspection of the models of the Patent Office, that most inventors who undertake to make their own models expend a great deal of labor without corresponding results. In the matter of gearing, for instance, one will whittle his wheels in wood, another will borrow his gearing from some defunct clock, while still another will purchase ready-made wheels from one of our well-known firms making a business of furnishing parts of models.

Of the three methods of obtaining the gearing the latter is undoubtedly the best, as all that is necessary to be done, in case of the cast gear wheels, is to bore them and file up the teeth, and as the cut gear wheels are generally bored, the shaft may be fitted without further work on the wheels. It is, however, seldom absolutely necessary to use toothed gearing, as rotary motion may be readily transferred by suitable friction wheels or by grooved or sprocket wheels and a round belt.

Figs. 1 and 2 show a form of friction gearing which is both simple and effective. The larger wheel is simply a disk of sheet brass having rounded edges, and boss spun or soldered on, and a smaller wheel consists of two swaged disks of steel having their convex faces separated by a metal washer a little thinner than the large wheel. These three members are secured to a common boss by spinning the end of the boss partly over one of the disks, as shown in the sectional view, Fig. 2. This form of friction gearing is noiseless and runs strong enough for the requirements of almost any model.

Figs. 3 and 4 show a form of sprocket wheel which is readily made and is almost as positive in its action as gearing. In this case the two wheels are alike; they consist of disks of sheet metal nicked to a uniform depth from the edge, and the arms thus formed are bent alternately in opposite directions, forming a groove for receiving the round belt used in transferring motion from one wheel to the other. It is evident that a belt cannot slip on a wheel of this construction.

Fig. 5 shows a form of friction gearing for transferring motion at right angles, and for imparting a variable speed to a shaft from another shaft running at a uniform rate. The large wheel in this instance is merely a plane disk of metal mounted in the manner already described. The smaller wheel is a grooved metal pulley surrounded by an elastic rubber ring. This is pressed with more or less force against the metallic disk, and its speed may be varied by moving it toward or away from the axis of the disk.

As to the matter of irregular motion usually imparted by cams, it is difficult to make a cam in the ordinary way with the milling machine, and there appears no very simple way of cutting them from solid castings. There is, however, a simple way of building them up from readily obtained materials.

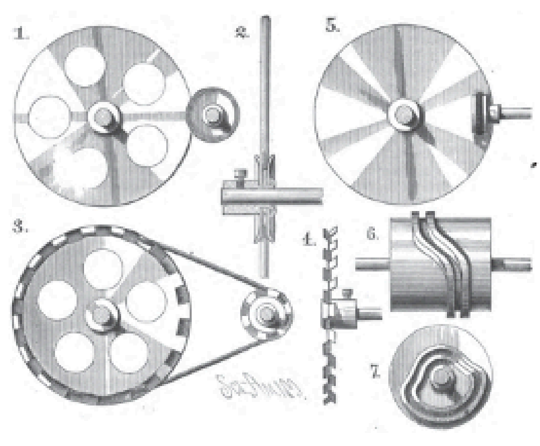
Fig. 6 shows a cam consisting of a cylinder of brass or a short section of brass tubing provided with two heads and mounted on a shaft. The cam groove is laid out on this surface, and two parallel pieces of square brass wire are soldered to the surface of the cylinder, or fastened by means of screws. They are placed uniformly distant throughout the entire circumference of the cylinder.

Fig. 7 shows a cam built up in the same way on the face of a disk.

As to shafts, the model maker may save himself much labor and expense by using Stubb's steel for small shafts, and cold rolled iron for larger ones. Either the steel or iron may be bought in one and three feet lengths.

Almost anything in the way of parts of models may be purchased ready for use, so that all the inventor need do is to combine them and mount them on a suitable frame; but even so simple a matter as a wooden frame for a model sometimes proves troublesome.

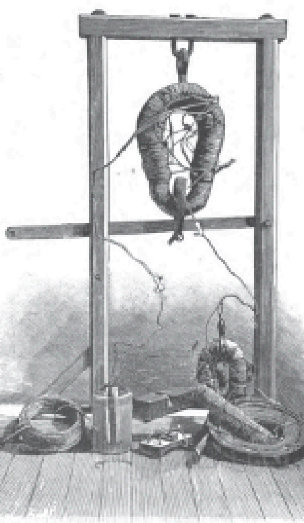
The small tenons and mortises are difficult to make, and the frame to be strong enough to bear handling must be made so heavy as to be entirely out of proportion. A simple and easy method of securing the joints of small frames is to clamp the parts in the position they are to occupy in relation to each other, and then drill, with a sharp twist drill, two holes through one piece from side to side and into the end of the abutting piece, then inserting two hard wood pins, having previously coated them with glue. This makes a joint far stronger than the mortise and tenon, and it is very quickly done. M.



TRANSMITTING AND CONVERTING MOTION.

PROFESSOR HENRY'S BIG MAGNET.

In the course of his pioneer work in the investigation of electro-magnetic action, William Sturgeon, of London, discovered in 1825 that soft iron could be rendered temporarily magnetic by surrounding it with a coil of conducting wire connected with a battery. As the result of this discovery he made the first step toward the construction of an electro-magnet. He bent a piece of iron wire into the form of a horseshoe, insulated it by a coating of varnish, and then



PROFESSOR HENRY'S BIG MAGNET.

wound it with copper wire spirally, the spirals being widely separated, so that the current would be compelled to pass round and round the iron core. When the current was on the wire the core was found to be magnetic; when off, the core was not magnetic.

Professor Henry took up the discovery at this point and carried it an important step further. He wound the copper wire with insulating silk, making it possible to cover the core of the magnet with a much greater length of wire in closely wound coils, and also to lay on coil above coil. The compound helix so made developed great power, the same battery yielding with it a hundred times as much magnetic power as could be obtained with Sturgeon's arrangement. The first magnet on this principle was used by Professor Henry in 1828. It consisted of an iron bar two inches square and twenty inches long, bent, of course, into the form of a U or horseshoe, and wound with 540 feet of insulated copper wire in nine coils. The keeper weighed seven pounds, the core twenty-one pounds, and its lifting power was 750 pounds.

This magnet was used at Albany. In 1833 Professor Henry was called to the chair of Natural Philosophy in the College of New Jersey, at Princeton. Here he made two larger magnets for use in his investigations. One weighing 59½ pounds, and capable of sustaining 2,063 pounds, is now in the cabinet of Yale College. The other, made in 1833, weighed 100 pounds, and could support 3,500 pounds. It was many years before any magnet approaching this in power was constructed.

Through the courtesy of Mr. R. H. Rose, photographer at Princeton, and by permission of Professor Schanck, of the College of New Jersey, we are enabled to present an exact likeness of this historic instrument, as hung in the frame by which the inventor tested its strength. The magnet is deposited in the hall of the School of Science, one of the college buildings erected by the munificence of the late John C. Green. The coil at the right of the engraving represents the original silk-covered ribbon coil used by Professor Henry in his experiments on induction. The wire and battery at the left are modern, to show by contrast the improvement since made in the means for electrical investigation.

In the middle of the foreground is one of the pole changers made and used by the professor. He was accustomed to delight himself and his classes with this by changing the polarity of the big magnet so quickly that a twenty-eight pound armature could not fall off, but was freed and reattracted to its place with a sharp snap.

Dr. C. O. Crosby.

A characteristically American inventor, Dr. C. O. Crosby, died in Brooklyn, November 16.

Dr. Crosby was born in Simsbury, Conn., and for a number of years practiced dentistry in New Haven. His natural bent was rather for invention, to which he early gave his attention. In connection with Henry Kellogg, of New Haven, he invented a machine for making ruffles and another for making pointed tape trimming, creating thereby a new industry from which he acquired a considerable fortune. Later he invented a machine for making fish hooks, a marvel of ingenuity; and afterwards a machine for making needles. These two formed the basis of a large business still carried on in New Haven. A machine for making pins was another of his notable inventions. Others were, a machine for making shoes, a machine for making tatting, and a machine for making cigarettes; all giving evidence of his wonderful versatility and inventive genius.

FROM the inquiries conducted by Prof. Hermann Cohn, of Breslau, since 1865, it appears that short-sightedness is rarely or never born with those subject to it, and is almost always the result of strains sustained by the eye during study in early youth. Myopia, as it is called, is seldom found among pupils of village schools, and its frequency increases in proportion to the demand made upon the eye in higher schools and in colleges. A better construction of school desks, an improved typography of text books, and a sufficient lighting of class rooms, are the remedies proposed to abate this malady.

One Hundred Bushels of Shelled Corn to the Acre.

Mr. Nathan G. Pierce tells the *American Cultivator* how he raises 100 bushels of shelled corn to the acre, having accomplished that feat for the second time this year. He uses for seed an eight-rowed corn which he has improved by careful selection, and believes it to be a good variety to raise in that locality, or, in fact, anywhere between Virginia and the Canada line, or east of the Allegheny Mountains.

The ground selected for planting was a good piece of gravelly loam. It was well plowed last spring, about the first of May, harrowed, treated to a broadcast application of 900 pounds fertilizer to the acre; again harrowed faithfully, rendering the land fine and mellow; rows marked three feet apart, a small amount of fertilizer scattered to each row. May 10th, three kernels of corn planted in each hill, two feet apart in the rows; cultivated and hoed four times, allowing no weeds to grow; passed through the entire piece, cutting each hill down to two stalks; every sucker in each hill cut throughout the field.

During the entire period of growth through the season the field was closely watched, every weed pulled and every ear of smut cut out. At the proper time, after the corn had become hard, it was cut, bound in bundles, and stooked. When dry it was drawn into the barn, where, with the assistance of a hired man, the corn was husked, weighed as husked, and found to yield 110 bushels of shelled corn to the acre, allowing seventy-five pounds of ears to equal one bushel of shelled corn.

WHEN, says the *Polyt. Notizblatt*, a few drops of ether or alcohol are let fall upon a paper equally moistened with cadmium and iodide starch solution, and the volatile liquids are set on fire, the paper will be found, after their evaporation, to be turned blue, owing to the formation of ozone.

Figure 4. An article entitled "Professor Henry's Big Magnet" that mentioned Joseph Henry's increasingly large electromagnets appeared in the December 11, 1880, edition of *Scientific American*.

During the 1820s, the English scientist Michael Faraday (1791–1867) conducted a series of experiments with magnets and current-carrying wires to determine how they interacted.[30] Using a bar magnet, he found that it produced a perpendicular force on a current-carrying wire. He set up an apparatus that consisted of a beaker containing a vertical bar magnet in a pool of mercury. He suspended a wire over the beaker, attached to a pivot, and applied electricity, which caused the wire to move in circles about the magnet. Faraday had created the first electric motor.[31]

In 1831, both Faraday and Henry found that by using a moving magnetic field they were able to generate electricity; this effect was called electromagnetic induction.[32] Faraday noticed that if he wound two coils of wire around opposite sides of an iron ring he could induce a current in the second coil when he applied current to the first coil. However, it appeared briefly, and only when the current in the first coil was changing: if the current in the first coil was constant, the secondary coil registered no current.[33]

During the nineteenth century, the growing body of knowledge surrounding electromagnetic induction led experimenters to create the electrical turbine, which uses rotating magnets to generate an electrical current. The turbine itself can be powered by any source, such as wind, water, or steam, and the ability to generate electrical power on demand soon reshaped the world.[34]

In 1832, the Parisian inventor Hippolyte Pixii (1808–1835) created the first working AC generator. His design was improved by others, including Lucien Gaulard (1850–1888), John Dixon Gibbs (1834–1912), and William Stanley Jr. (1858–1916). The Serbian American inventor Nikola Tesla (1856–1943) became interested in developing his own AC induction motor and eventually created a version that did not use a commutator (a rotary electrical switch).[35]

The invention of alternating current (AC) generators and transformers allowed for the development of an electrical power distribution system that was able to provide electrical power over a larger area than direct current (DC) systems, such as the one created in the 1880s by Thomas Alva Edison (1847–1931) at his Menlo Park laboratory in New Jersey. Edison's DC system used low voltages to provide an electrical current that flowed in one direction; while the voltage he used was relatively safe, Edison's system suffered from power loss and could only deliver power for about one mile (see chapter 12, "Thomas Alva Edison").

On the other hand, alternating current systems used high voltages to send power over long distances. With AC, the current changes direction many times a second, alternating first one way, then the other. However, the high voltages used for AC power lines caused them to spark, which posed a danger to people. Edison's solution at his Pearl Street Power Station was to generate AC current in order to send the electrical power out, but then use step-down transformers at the destination to convert the high-voltage AC power into safer, low-voltage DC power for customers' use. During the latter part of the nineteenth century, the differences of opinion over whether a DC or AC system was better evolved into a bitter dispute in what was known as the "War of the Currents."[36] (See chapter 12, "Early Electrification.")

While electromagnetism was showing itself to be useful in the commercial realm with the creation of numerous electromechanical devices, scientists were perplexed about the fundamental nature of electricity and magnetism, which were still believed to be separate phenomena despite numerous experiments that showed a clear connection between them.[37]

By the 1870s, the Scottish physicist James Clerk Maxwell (1831–1879), a brilliant mathematician, established the mathematical foundations of electromagnetism and was finally able to show that electricity and magnetism were two facets of the same phenomena.[38] In 1865, Maxwell published "A Dynamical Theory of the Electromagnetic Field" in the *Philosophical Transactions of the Royal Society*, in which he included a complete set of equations describing electricity and magnetism.[39] In 1873, he published *Treatise on Electricity and Magnetism*, in which he included twenty mathematical equations that described all the known phenomena of magnetism and electricity.[40]

Maxwell's equations are the basis of understanding complex physical phenomena, including color vision, thermodynamics, and the electromagnetic spectrum, which includes visible light, radio, infrared, and ultraviolet radiation. Building upon Maxwell's work, modern scientists and engineers have taken their understanding of electromagnetism and used it to create communications systems, radar, the global positioning system, and Wi-Fi (wireless network protocols for local networks and internet access).[41]

Further Reading:

Blundell, Stephen. *Magnetism: A Very Short Introduction.* Oxford: Oxford University Press, 2012.

Ditzel, Paul. *Fire Alarm! The Fascinating Story Behind the Red Box on the Corner*. New Albany, IN: Fire Buff House Publishers, 1990.

Forbes, Nancy, and Basil Mahon. *Faraday, Maxwell, and the Electromagnetic Field.* New York: Prometheus Books, 2014.

Freeberg, Ernest. *The Age of Edison: Electric Light and the Invention of Modern America*. New York: Penguin Books, 2013.

Freudenthal, Gad. "Theory of Matter and Cosmology in William Gilbert's *De magnete*." *Isis* 74, no. 1 (March 1983): 22–37.

Good, Gregory. "Magnetic World: The Historiography of an Inherently Complex Science, Geomagnetism, in the 20th Century." *Earth Sciences History* 26, no. 2 (2007): 281–99.

Gorman, Mel. "An Early Electric Motor in India." *Technology and Culture* 9, no. 2 (April 1968): 184–90.

Henry, Joseph. *Scientific Writings of Joseph Henry, Volume 2.* Washington: Smithsonian Institution, 1886.

Hochfelder, David. *The Telegraph in America, 1832–1920.* Baltimore: Johns Hopkins University Press, 2012.

Jonnes, Jill. *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World*. New York: Random House, 2004.

Ley, Willy. "The Invention of the Magnetic Compass." *The Military Engineer* 35, no. 212 (June 1943): 289–93.

Moyer, Albert E. *Joseph Henry: The Rise of an American Scientist*. Washington: Smithsonian Institution Scholarly Press, 1997.

Rivers, P. J. "New Lamps for Old: Modern Nautical Terms for Ancient Marine Practices and the Navigation of the Zheng He Voyages." *Journal of the Malaysian Branch of the Royal Asiatic Society* 85, no. 1 (June 2012): 85–98.

Schiffer, Michael B. *Power Struggles: Scientific Authority and the Creation of Practical Electricity Before Edison*. Cambridge, MA: MIT Press, 2008.

Standage, Tom. *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers*. New York: Bloomsbury, 2014.

Stanley, Matthew. "By Design: James Clerk Maxwell and the Evangelical Unification of Science." *British Journal for the History of Science* 54, no. 1 (March 2012): 57–73.

Turner, Gillian. *North Pole, South Pole: The Epic Quest to Solve the Great Mystery of Earth's Magnetism*. New York: The Experiment, 2011.

Wallace, Richard. "'Amaze Your Friends!' Lucretius on Magnets." *Greece and Rome* 43, no. 2 (October 1996): 178–87.

Wheeler, Tom. *Mr. Lincoln's T-Mails: How Abraham Lincoln Used the Telegraph to Win the Civil War*. New York: Harper Collins, 2006.

Yinke, Deng. *Ancient Chinese Inventions.* Cambridge: Cambridge University Press, 2011.

[1]. Stephen Blundell, *Magnetism: A Very Short Introduction* (Oxford: Oxford University Press, 2012), 3–5.

[2]. Richard Wallace, "'Amaze Your Friends!' Lucretius on Magnets," *Greece and Rome* 43, no. 2 (October 1996): 179.

[3]. Wallace, "Amaze Your Friends!," 179.

[4]. Wallace, "Amaze Your Friends!," 180–82.

[5]. "Lodestone," Merriam-Webster.com, https://www.merriam-webster.com/dictionary/lodestone#note-1.

[6]. Gillian Turner, *North Pole, South Pole: The Epic Quest to Solve the Great Mystery of Earth's Magnetism* (New York: The Experiment, 2011), 9–10.

[7]. Deng Yinke, *Ancient Chinese Inventions* (Cambridge: Cambridge University Press, 2011), 15.

[8]. Turner, *North Pole, South Pole*, 11.

[9]. P. J. Rivers, "New Lamps for Old: Modern Nautical Terms for Ancient Marine Practices and the Navigation of the Zheng He Voyages," *Journal of the Malaysian Branch of the Royal Asiatic Society* 85, no. 1 (June 2012): 93.

[10]. Willy Ley, "The Invention of the Magnetic Compass," *The Military Engineer* 35, no. 212 (June 1943): 292.

[11]. Turner, *North Pole, South Pole*, 12–13.

[12]. Blundell, *Magnetism*, 16–17; Jill Jonnes, *Empires of Light: Edison, Tesla, Westinghouse, and the Race to Electrify the World* (New York: Random House, 2004), 18–20.

[13]. Turner, *North Pole, South Pole*, 34.

[14]. Blundell, *Magnetism*, 17, 23–24.

[15]. Blundell, *Magnetism*, 24–27.

[16]. Turner, *North Pole, South Pole*, 71–75.

[17]. Blundell, *Magnetism*, 28.

[18]. Blundell, *Magnetism*, 28; Jonnes, *Empires of Light*, 36–37; Tom Standage, *The Victorian Internet* (New York: Berkeley Books, 1998), 23.

[19]. Blundell, *Magnetism*, 28–29.

[20]. Blundell, *Magnetism*, 29–30.

[21]. Blundell, *Magnetism*, 30–31.

[22]. Turner, *North Pole, South Pole*, 81.

[23]. Karen S. Garvin, "Coil Magnet/Electromagnet," in *Technical Innovation in American History* vol. 1, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 199.

[24]. Karen S. Garvin, "Electric Doorbell," in *Technical Innovation in American History* vol. 1, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 223.

[25]. Karen S. Garvin, "Relay," in *Technical Innovation in American History* vol. 1, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 280.

[26]. Jonnes, *Empires of Light*, 37.

[27]. Blundell, *Magnetism*, 31–32.

[28]. "Joseph Henry's Yale Magnet," Smithsonian Institution, https://siarchives.si.edu/collections/siris_sic_13160.

[29]. “Big Ben,” Joseph Henry Project, Princeton University, 2021, https://commons.princeton.edu/josephhenry/joseph-henry/big-ben/.

[30]. Turner, *North Pole, South Pole*, 86–88.

[31]. Blundell, *Magnetism*, 32–34.

[32]. Ernest Freeberg, *The Age of Edison: Electric Light and the Invention of Modern America* (New York: Penguin Books, 2013), 17.

[33]. Blundell, *Magnetism*, 34.

[34]. Blundell, *Magnetism*, 37.

[35]. Karen S. Garvin, “AC Induction Motor,” in *Technical Innovation in American History* vol. 2, ed. Rosanne Welch and Peg A. Lamphier (Santa Barbara: ABC-CLIO, 2019), 10–11.

[36]. Jill Jonnes, 15, 150–53.

[37]. Blundell, *Magnetism*, 41.

[38]. Turner, *North Pole, South Pole*, 93–97.

[39]. “The Impact of Maxwell’s Work,” James Clerk Maxwell Foundation, http://clerkmaxwellfoundation.org/html/maxwell-s_impact_.html.

[40]. Turner, *North Pole, South Pole*, 98.

[41]. “Electromagnetic Theory,” Media Library, James Clerk Maxwell Foundation, http://clerkmaxwellfoundation.org/html/media_library.html.

PART VIII

CHAPTER 14 - EARTH SCIENCES AND REVOLUTION IN BIOLOGY AND GENETICS – THE LONG 19TH CENTURY

CHAPTER 14 - THE DISCOVERY OF DEEP TIME

FRIEDEL WEINERT

Deep time refers to the successive realization on the part of geologists, in the eighteenth and nineteenth centuries, that the age of the Earth has to be described in terms of millions, even billions, rather than thousands of years. That the Earth was about 6,000 years old was a time-honored biblical claim, which few doubted before the eighteenth century. In 1611 the Irish Archbishop James Ussher (1581–1656) had calculated that creation occurred on October 22, 4004 BCE. Approximately 100 years later, Benoît de Maillet (1656–1738), a French diplomat and natural historian, calculated a figure of 2 billion years.[1]

Figure 1.
The Age of the Earth and the Existence of Life

- *Age of the Earth*: 4.6 billion years
- *Micro-organisms* in early fossil records: 3.5 billion years
- *Oldest animal fossils:* 700 million years
- *First vertebrates:* 400 million years
- *First mammals:* 200 million years
- *Homo habilis:* 1.8 billion years
- *Homo erectus:* 500 million–1 billion years
- *Homo sapiens:* 25,000 years

Today, the age of the Earth is estimated to be 4.6 billion years, while the age of the universe is estimated to be 13.8 billion years old. The oldest fossil records (micro-organisms) date back to 3.5 billion years (fig. 1).

The discovery of **deep time**, that is, the realization that the Earth must be much older than Ussher's calculation, was basically the result of the lost battle of scriptural chronology against evidence-based natural chronology. The old story that the history of the Earth could be told in terms of the creation and the Flood (deluge) soon met with some serious anomalies: for instance, layered fossil marine shells were found in inland rocks or extinct volcanoes, which were recognized for the first time for what they were: evidence of geological change. Once the facts of geological change were recognized, questions about their temporal sequence became inescapable: what agencies were responsible? Were they the same as those acting now? And how long had they taken to produce their visible effects?[2]

Many different explanations were proposed. For instance, the French naturalist Georges-Louis Leclerc, Comte de Buffon (1707–1788) estimated that a geological history based on the principles of physics would extend the scale of natural chronology to 75,000 years.[3] His calculation was based on the knowledge of cooling rates of different materials found on earth, including iron. The problem for

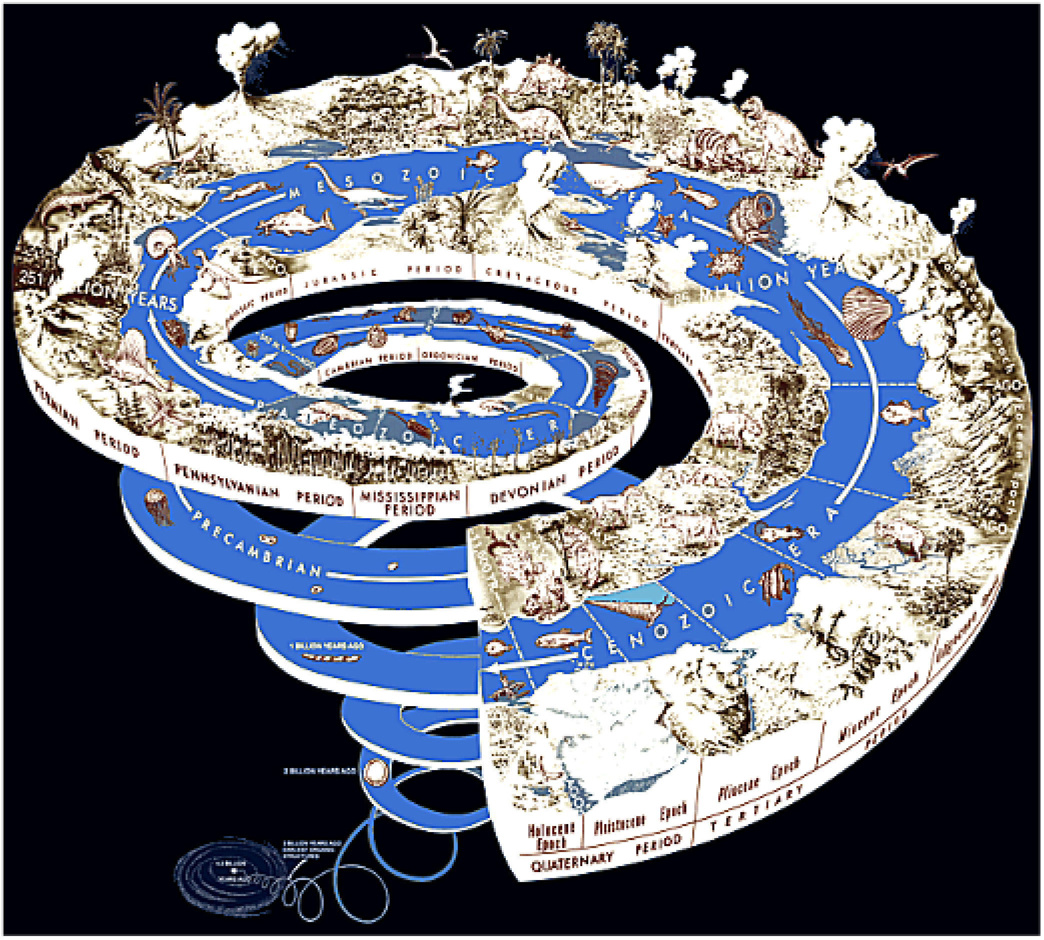


Figure 2: Geological Time Spiral, indicating geological periods and their lifeforms in the history of the Earth, starting 4.5 billion years ago. Wikimedia Commons. Public Domain in the United States.

those scientists who were trying to determine the age of the Earth was to identify the right kind of evidence, such as fossils and rock strata, and to relate it to the history of the Earth.

It took some time before the discovery of a widespread geological order in the nature of the Earth's crust came to be acknowledged as evidence of a temporal order in its formation—instead of being accepted unquestionably as the pattern imposed at the original creation (fig. 2). And it took most of a century for geologists to establish what agencies had been involved in these processes of formation.[4]

What were the agents of geological change? It took geologists some time to establish the mechanism of change and consequently a few competing systems emerged, all of which tried to construct a theory of the Earth's history based on the available evidence. Two predominant schools of thought can be distinguished: **Neptunism** and **Vulcanism** (or Plutonism), which both tried to account for the rock formation on the surface of the Earth. Neptunism put the emphasis on the impact of water and the sedimentation of minerals. Its main proponents were Abraham Gottlob Werner (1749–1817) and Thomas Burnet (1635–1715). Vulcanism stressed the role of fire or volcanic activity in rock formation. One of its main proponents was John Hutton (1726–1797), supported by John Playfair (1748–1819). Furthermore, these theories can be classified according to whether or not they tried to preserve and defend the biblical chronology.

Theories of the Earth representing the framework of biblical chronology

Many clever people prepared or contributed to the eventual findings. Nevertheless, two contributions deserve attention.

Thomas Burnet was an Anglican clergyman and proponent of Neptunism. He published, between 1680 and 1690, his book *The Sacred Theory of the Earth*. Burnet started from the assumption that only the Bible is true. But he dismissed the appeal to miracles. His strategy was that the Earth's scripturally specified history could only be adequately explained when natural causes are identified for the entire panoply of biblical events.[5]For instance, to account for the deluge, Burnet established a physical cause: the Earth's crust cracks, water rises from its layer in the abyss to cover the Earth, and then retreats again to leave the modern continents (with mountains as edges of the cracked crust) and oceans. Thus, Burnet became one of the first thinkers to detect in the material world a sequential history.

The Danish scientist Nicolas Steno (1638–1686) also thought that water played an essential part in the formation of the Earth's crust. Unlike Burnet, who reported far fewer observations, Steno was actively involved in field work (mainly in Tuscany). His work on the formation of rock layers and their fossils was crucial for the later development of geology and paleontology. Steno's most famous contribution is his *law of superposition*, which holds that rock strata were evidence of a temporal sequence: the deeper the layer, the older it was. Steno also found fossils trapped in the rock strata. He argued that fossils could be viewed as snapshots of life at different moments in the history of the Earth. Like others, Steno regarded fossils as remains of once-living organisms. But Steno (who in 1667 converted to Catholicism and gave up his scientific work entirely) remained committed to the biblical chronology. Like Burnet, he forced the entire geological history into the straitjacket of a 6,000-year time span. He held that rock layers, which contained fossils, had formed during the Flood, while lower layers, which lacked fossils, were formed before life existed.

Against such views we have theories disregarding the biblical chronology. These free themselves from religious constraints necessitated by adherence to the Bible story. A transitional figure is the British geologist and priest Adam Sedgwick (1785–1873). He first supported the theory of worldwide floods but abandoned it in 1831 shortly after an influential book, *The Principles of Geology*, appeared. Sedgwick's study of rock strata led to his proposal of the Cambrian and Devonian periods as names for the geological time scale. According to present-day knowledge, these periods date back approximately to 500 and 400 million years. Sedgwick was Darwin's tutor at Cambridge but strongly opposed Darwin's theory of evolution. Although the two men remained on friendly terms, Sedgwick continued to believe in divine creation but over long periods of time.

Let us look at two of the proponents of an indefinite antiquity of the world and the consequences for evolution.

Theories of the Earth which Break the Time Barrier

The first to mention here is the Scottish geologist James Hutton (1726–1797), who published his *Theory of the Earth* in 1795. Hutton's *Theory* marks the conventional discovery of *deep time*. The other one is Charles Lyell, (1797–1885), also a Scottish geologist, who published his major work *The Principles of Geology* in several volumes from 1830 to 1833. Lyell's work builds on Hutton's theory, but there were differences between them: Lyell had more geological facts at his disposal and he felt no need to emphasize that geological changes were evidence of Providence (i.e., the Creator's wisdom and foresight). Toward the end of his life Lyell came close to accepting Darwin's evolutionary theory.

What unites Hutton and Lyell is their method: **uniformitarianism**. The meaning of this method can be gleaned from the full title of Lyell's work: *The Principles of Geology: Being an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*. Lyell's main thesis was

> that all former changes of the organic and inorganic creation are referrible to one uninterrupted succession of physical events, governed by the laws now in operation.[6]

Hence there are uniformities (laws) in nature by which the contemporary features of the planets can be explained. All features of the Earth are due to physical, biological, and chemical processes, which act in the same way throughout the ages. The uniformities are the most impressive evidence for time's vastness. There are no dramatic events, like global catastrophes, no miraculous interventions, like the Flood, which would account for the known phenomena. These events would remain unexplained were it not for the operation of the known physical laws. And for the laws of physics to bring about the present face of the Earth, the time span for their operation had to be vast. Therefore, Hutton concluded that

> Time is to nature endless …The result of our present enquiry is, that we find no vestige of a beginning,—no prospect of an end.[7]

Hutton refused to speculate on origins and confined geologists to Earth dynamics.[8]Thus the uniform processes in nature require a vast amount of time. The vastly extended time scale not only explains the physical features of the Earth but the evolution of the universe, as the German philosopher Immanuel Kant (1724–1804) speculated in "Idea for a Universal History from a Cosmopolitan Point of View" (1755). Kant's treatise was the first systematic attempt to give an evolutionary account of cosmic history. Kant's cosmology openly flouted the chronology of the Bible, as he took his fundamental data from dynamics and astronomy.

Kant agrees with Hutton that "time is to nature endless." And he appeals, like Hutton and Lyell, to mechanical laws to drive the evolution of the universe. But Lyell was not concerned with the cosmos, like Kant. He relied on physical principles to explain geological changes observant on Earth. There are four distinct meanings of "uniformity" in Lyell's *The Principles of Geology*:

1. *Uniformity of law*. Natural laws are constant in space and time; hence geological change was caused by the same laws which acted then and now.
2. *Uniformity of process*. There is no need to appeal to unknown causes or unique events (such as the biblical Flood) to explain geological processes in the past. All features of the Earth are due to physical, biological, and chemical processes, which act in the same way throughout the ages.
3. *Uniformity of rate*. This uniformity is also known as *gradualism* and played a significant part in Darwin's evolutionary theory. The pace of change is usually slow, steady, and gradual. Phenomena of large scale, from mountain ranges to great canyons, are built by the accumulation of small changes, which add up to great effect over millions of years. Catastrophes happen (floods, volcanic eruptions) but they are strictly local and always happen with the same frequency. In particular, the whole of the Earth is never subject to large-scale changes all at once.
4. *Uniformity of state, which is also known as non-progressionism.* Change is not only steady and

> evenly distributed over space and time, the history of the Earth does not follow some vector of progress. Change is continuous but does not lead to a particular aim. Our planet always looked and behaved in the same way. Lyell's non-progressionism stands in contrast to Kant's evolutionary cosmic views and Darwin's evolutionary theory. In fact, Lyell extended the uniformity of state to biological life. Species are real entities, which have an origin in space and time. They show no advances in organization and complexity.[9]But Lyell, in his last years, abandoned this principle and came close to evolutionary thinking in the Darwinian sense.

The discovery of deep time had a significant impact on Darwin's theory of evolution. It eventually granted Darwin's theory the vastness of time that his postulation of the slow and gradual evolution of life required. The middle of the nineteenth century also saw a grounding of the arrow of time, that is, the unidirectional past-to-future direction of time, in the physical sciences (statistical mechanics and thermodynamics).

Further Reading:

Bowler, Peter J. *Evolution: The History of an Idea*. Berkeley: Berkeley University Press, 2004.

Gillispie, Charles Coulston. *Genesis and Geology: The Impact of Scientific Discoveries upon Religious Beliefs in the Decades Before Darwin*. New York: Harper & Row, 1959.

Gould, Stephen Jay. *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*. Hammondsworth: Penguin Books, 1988.

Toulmin, Stephen, and June Goodfield. *The Discovery of Time*. London: Hutchinson, 1965.

Hellman, Hal. *Great Feuds in Science: Ten of the Liveliest Disputes Ever*. New York: Wiley, 1988.

Endnotes

[1]. Hal Hellman, *Great Feuds in Science: Ten of the Liveliest Disputes Ever* (New York: Wiley, 1988), 107–10.

[2]. Stephen Toulmin and June Goodfield, *The Discovery of Time* (London: Hutchinson, 1965), 142; compare Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley: Berkeley University Press, 2004).

[3]. Toulmin, *The Discovery of Time*, 147.

[4]. Toulmin, *The Discovery of Time*, 150.

[5]. Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Hammondsworth: Penguin Books, 1988), 28.

[6]. Quoted in Charles Coulston Gillipsie, *Genesis and Geology: The Impact of Scientific Discoveries upon Religious Beliefs in the Decades Before Darwin* (New York: Harper & Row, 1959), 126.

[7]. Quoted in Gould, *Time's Arrow, Time's Cycle*, 46.

[8]. Gillipsie, *Genesis and Geology*, 46.

[9]. Gould, *Time's Arrow, Time's Cycle*, 119–24, 137–42.

CHAPTER 14 - EVOLUTION BEFORE DARWIN

FRIEDEL WEINERT

The discovery of deep time—the realization that the age of the Earth is much greater than hitherto assumed and that the cosmos has an evolutionary history—had profound implications, since it situated many aspects of human existence in a historical context. This process is known as *temporalization*. Society, geology, the universe acquired a history, and so did life itself. It ultimately emerged in Darwin's evolutionary theory, but the history of organic life had been the subject of intense discussions for centuries. Although Charles Darwin's (1809–1882) work was original, he had forerunners. One of the oldest views, reaching back to the Greeks, was the Great Chain of Being. The Enlightenment, in the wake of the Scientific Revolution (1543–1687), modified this ancient view and added design arguments to the thinking about organic life, its origin, and its purpose.

Before Darwin, many scholars recognized the diversity of species and their adaptation to their environments. The bone of contention was the mechanism of evolution, a question which Darwin finally answered with his theory of natural selection. But even if evolution was recognized, there was still a debate about the mode of existence of species: were species fixed or variable? Darwin threw some light on this debate in his historical sketch, which opens the fifth edition of *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (1869). Darwin wrote:

> Until recently the great majority of naturalists believed that species were immutable productions, and had been separately created. This view has been ably maintained by many authors.[1]

Amongst them were the French naturalist Georges Cuvier (1769–1832) and the Swedish botanist and zoologist Carl Linnaeus (1707–1778). They saw species as fixed populations, which were only subject to creation and extinction. But Darwin went on to consider the views of thirty-four nineteenth-century authors who considered species to be variable:

> Some few naturalists, on the other hand, have believed that species undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms.[2]

Amongst them were the French naturalists Étienne Geoffroy Saint-Hilaire (1772–1844) and Jean-Baptiste Lamarck (1744–1829). Geoffroy believed in the transmutation of species due to environmental causes. Lamarck is notable because he combined design and evolution to build his theory of *progressive* or *linear* evolution (or transmutation), which to a certain extent can be regarded as a forerunner to Darwin's theory of *branching* evolution.[3]The slow evolution of biology must be seen against the background of the rapid progress of the physical sciences, which culminated in Newton's publication of *Philosophiae Naturalis Principia Mathematica*(1687), which perfected the quantitative approach to nature.

The Great Chain of Being

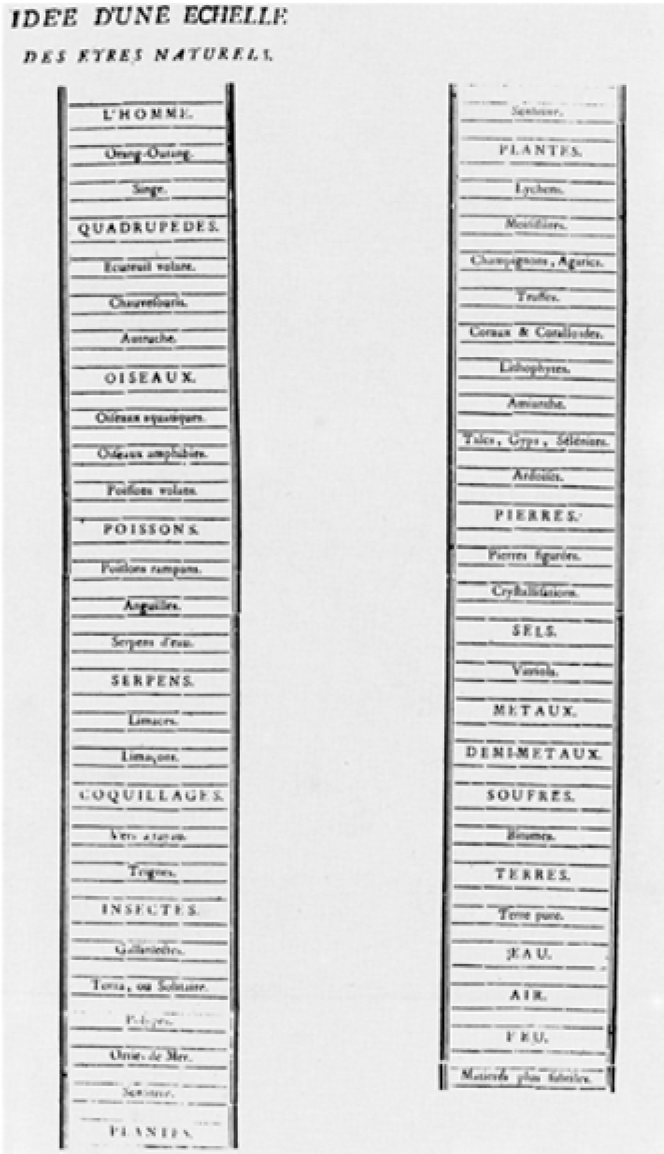


Figure 1. Charles Bonnet's (1720–1793) "échelle des êtres" was a temporalized version of the Great Chain of Being (1745). Wikimedia Commons (Public Domain).

The *Great Chain of Being* had been the dominant concept of organic nature since the Greeks: organic creation was depicted as a chain of being, the links of which consisted of all created lifeforms (fig. 1). It stretches from the humblest and crudest types right up the graded ladder of perfection to the highest forms—God and the angels. The series was perfectly continuous and harmonious, without chasms or gaps, and the forms that made it up were thought to blend insensibly into one another.[4]In this hierarchical order, humans occupy an intermediate position. They stand between the animal world of imperfection and the godly world of perfection, since they are both members of the organic *and* intellectual realms. Three principles underlie this conception: the principles of plenitude, continuity, and unilinear gradation. The principle of plenitude indicates that the world is full; everything which is possible also exists in actuality. This principle stands in strong contrast to evolutionary thinking. The principle of continuity indicates that there are no gaps in the chain of being and species blend insensibly into one another. The principle of unilinear gradation indicates the hierarchical order from the humblest creatures to the highest possible life form. Because the chain of being stretches from the lowest to the highest form of creation, it is a scale of perfection.[5]

Historically, the Great Chain of Being was interpreted in two different ways: either as a static preexisting *chain* of organic life or as an unfolding *ladder* of ascent. The static scheme left no room for evolution and no room for development. It was the ancient scheme, which is associated with the fixity of species. In the eighteenth century the fixity of species gave way to their variability. As new evidence for the transmutation of species accumulated, the need arose for a new, amended vision. The Great Chain of Being had to be temporalized, as the German philosopher Gottfried Wilhelm Leibniz (1646–1716) clearly stated:

> Further, we realize that there is a perpetual and most free progress of the whole universe towards a consummation of the universal beauty and perfection of the works of God, so that it is always advancing toward a greater development.[6]

Naturalists, like Lamarck, transformed the chain of being into a ladder of ascent, but it retained some of its essential features. They believed that the universe evolves toward perfection; its progress is purposeful and follows a divine plan; and the Chain is no longer static, but it still grows and strives toward a goal, as Lamarck claimed.[7] Purposeful design places each species on their respective rung of the ladder, which provides the overall pattern. With the emergence of Darwinism, both finality and perfection finally disappeared.

Design Arguments

Design arguments aim to show that the order and regularity in the natural world are not due to random processes, but instead point to the existence of an intelligent designer (i.e., God). Robert Boyle (1627–1691) is a famous scientist who discovered Boyle's law (fig. 2). Boyle was a devout Anglican and sought to show that natural philosophy could prove the existence of God. He wished to counter the Epicurean view that the beauty and symmetry of nature were the result of pure chance. In 1688 he published an extended proof of design in his book *A Disquisition about the Final Causes of Natural Things*. Boyle first looked at the argument for design from the point of view of inanimate objects. He noted that even so complex an object as a clock cannot match the complexity of animate objects in the biological world:

> There is more of admirable Contrivance in a Mans Muscles, than in … the Celestial Orbs; and that the Eye of a Fly is … a more curious piece of Workmanship, than the Body of the Sun.[8]

The complexity and design of plants and animals was so intricate that an inference to a designer was justified, and it was obvious to Boyle that a divine engineer had created eyes to provide its lucky bearer with vision. It would be the height of irrationality to infer from the beauty and perfection of nature that pure chance had been the author.

Figure 2. Robert Boyle. Wikimedia Commons (Public Domain).

Figure 3. William Paley. Wikimedia Commons (Public Domain).

A bit over a century later, Archdeacon William Paley (1743–1805) published his *Natural Theology, or Evidences of the Existence and Attributes of the Deity, collected from the Appearances of Nature* (1802) (fig. 3). The book presents the famous “watchmaker” argument: from the existence of a watch we infer a watchmaker; by analogy, we ought to infer a designer God from the order of nature. This design paradigm infers from the seeming order and perfection in nature to a divinely gifted engineer. Proponents of design arguments usually dismissed the Epicurean view of pure chance as highly implausible because it contradicted their sensory experiences, which seemed to tell them that the order and symmetry in the organic world must be the work of an intelligent creator. The organic world provided much more concrete evidence of divine artwork, and Boyle conceded that pure chance might have made stones and metals, but not vegetables and animals:

> There is incomparably more Art expressed in the structure of a Doggs foot, then in that of the famous Clock at Strasburg.[9]

In Paley’s work we find a similar preference for biology to establish the design argument. It is true, wrote Paley, that a clock reveals a considerable amount of design. But the organic world offers much more striking instances of design. We discover so much beauty, order and regularity, that only an intelligent designer could have created the natural world.

> There cannot be design without a designer; contrivance without a contriver, order without choice.[10]

With so much attention lavished on plants and animals, each species seemed to be purposefully crafted. Design arguments emphasized the inclinations of humans to read into organic nature a creator’s intention. Paley’s *Natural Theology* had the task of demonstrating “the final intention of the creator in respect to each structure.”[11]And then Lamarck came along and combined the ladder of ascent with design and proposed a now-discredited mechanism for his theory of organic progression.

Jean-Baptiste Lamarck

Lamarck made *progressive* evolution a central pillar of his theory; he thought that the evolution of the *Ladder of Existence* followed some preset aim (fig. 4). The *telos*, or aim, is to produce humans. Nature evolves from simpler to more complex organisms with the aim of bringing forth the most perfect being of them all: *Homo sapiens*. Following this approach, Lamarck worked out a way of temporalizing the Great Chain of Being. In doing so, he abandoned the idea of the fixity of species and the theory of special creations. The immutability of species had been a core element of many naturalist schemes at that time, but according to Lamarck, species evolve. He even proposed a mechanism by which evolution progresses: the inheritance of acquired characteristics, also known as soft inheritance. This theory claims that the characteristics that organisms acquire during their lifetimes can be passed on to the next generation. For instance, giraffes stretch their necks to reach the juicy leaves of tall trees; their necks grow longer, and the giraffes pass this elongated neck on to the next generation of giraffes. Cuvier rejected Lamarck’s evolutionism and Darwin would later ridicule this idea of soft inheritance. But it is to Lamarck’s credit that he taught the non-fixity of species, which later would become a central pillar of Darwin’s theory of evolution.

Apart from the mutability of species, one further element of Lamarck’s theory of progressive evolution lived on and would cause Darwin serious difficulties. Lamarck was a staunch materialist, but materialism has many connotations. In the present-day context it expresses the belief that all the phenomena of organic life can be explained by appeal to physical causes. This includes the higher

Figure 4. Jean Baptiste Lamarck. Wikimedia Commons (Public Domain).

mental capacities of human beings. The doctrine had a long tradition in France with Paul-Henri Dietrich, Baron d'Holbach (1723–1789) and Claude-Adrien Helvétius (1715–1771). It led to Julien Offroy de La Mettrie's (1709–1751) image of man-machine (*l'homme machine*). For the materialist, mental faculties and consciousness are nothing but expressions of brain states. Darwin, too, was a materialist, since he regarded the theory of natural selection as an empirical, testable theory. He, too, aimed to explain the higher mental faculties in humans as subject to a materialist explanation.

The State of Biology

When we consider the state of biology during this period it is obvious that ideas about species, including their origin, state, and possible development, were in a state of flux. By 1859, when Darwin published the first edition of his *Origin of Species*, astronomy and physics were mature sciences. They rested on the firm foundation of Newtonian mechanics, that is, the three laws of motion and the law of gravitation. Heliocentrism—the idea that the sun was at the center of the universe—was the established view of the planetary system. The discovery of a new planet , Neptune, in 1846, had shown the explanatory and predictive power of the Newtonian paradigm. The science of thermodynamics was also making rapid advances during the middle of the nineteenth century. The biological sciences, by contrast, lacked an agreed-upon paradigm and, before Darwin, could offer no convincing explanatory mechanism for the diversity of species. Any evidence in favor of evolutionary descent was only slowly emerging. When evidence became available it showed that at least some of the previous assumptions, like the fixity of species or the late emergence of humankind, could not be upheld.

In the fifty years between the publication of Lamarck's *Philosophie Zoologique* in 1809 and the publication of Darwin's *Origin of Species* in 1859, new discoveries had emerged in diverse fields. In geology, for instance, the age of the Earth was gradually being extended from the miserly 6,000 years of the Bible to Kant's millions of years of cosmic evolution. It was discovered that the rock layers and their fossils contained a hidden arrow of time. The deeper the rock strata, the older the fossils and the rocks. In paleontology, the study of prehistoric life, fossil finds added to the temporalization of the Earth. Fossils of extinct animals, of unknown lifeforms, revealed the fauna of ancient times (fig.5). The discovery of an extinct creature (the *Archaeopteryx* in 1861), a transitional form between dinosaurs and birds, became the subject of intense discussions. Human fossil records were found among fossils of extinct animals, including the cave bear, mammoth, and early horses (fig. 6). Also found were tools and weapons made of flint stone. This suggested that hominoid creatures inhabited regions of Europe that were once home to now extinct animals. These discoveries prepared the way for Darwin's theory of evolution because they provided evidence of the evolution of species and the antiquity of the human race. What was missing from biology was a credible theory that systematized these findings, such as Newton had done for the physical sciences.

However, biology made a giant step toward an established paradigm when Darwin published his *Origin of Species* because his theory of evolution contained a testable mechanism—natural selection—that can account for the diversity and mutability of species.

Figure 5: Iguanodon was classified as a dinosaur. O. C. Marsh, "Dinosaurs", in Nature 55 (March 18, 1897), 465.

Further Reading:

Boyle, Robert. *A Disquisition about the Final Causes of Natural Things*. London: John Taylor, 1688.

Bowler, Peter J. *Evolution: The History of an Idea*. Berkeley: Berkeley University Press, 2004.

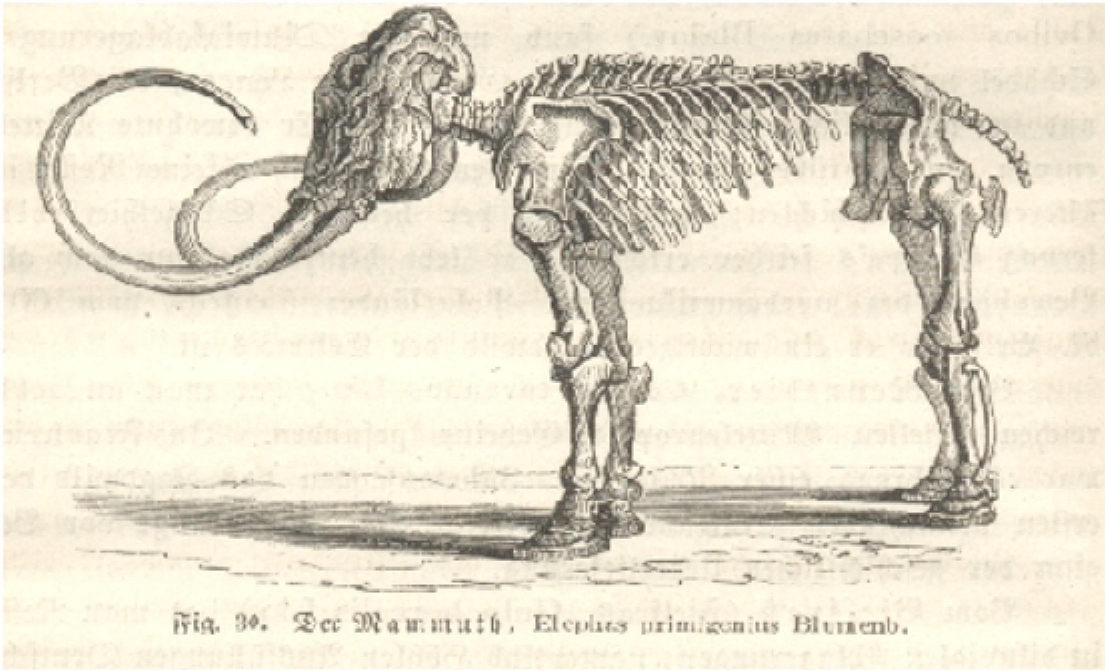


Figure 6: A drawing of a mammoth skeleton. Friedrich Rolle, Der Mensch: seine Abstammung und Gesittung im Lichte der Darwin'schen Lehre, 2nd. ed. (Prag: Verlag von Friedrich Tempsky, 1870), 286.

Darwin, Charles. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray, 1859. See online Darwin.

Eiseley, Loren. *Darwin's Century: Evolution and the Men Who Discovered It*. London: Gollancz, 1959.

Gillispie, Charles Coulston. "Lamarck and Darwin in the History of Science," *American Scientist* 46, no. 4 (December 1958), xlvi, 388–409.

Gillispie, Charles Coulston. *Genesis and Geology: The Impact of Scientific Discoveries upon Religious Beliefs in the Decades Before Darwin*. New York: Harper & Row, 1959.

Gould, Stephen Jay. *The Structure of Evolutionary Theory*. Cambridge, MA: Belknap Press, 2002.

Greene, John C. "The Kuhnian Paradigm and the Darwinian Revolution in Natural History," in Gary Gutting, ed. *Paradigms and Revolutions: Appraisals and Applications of Thomas Kuhn's Philosophy of Science.* Notre Dame: University of Notre Dame, 1980, 297–32.

Larson, Edward J. *Evolution: The Remarkable History of a Scientific Theory.* New York: Modern Library, 2006.

Leibniz, Gottfried Wilhelm. "On the Ultimate Origination of Things," in *Leibniz: Philosophical Writings*, ed. G. H. R. Parkinson, trans. Mary Morris and G. H. R. Parkinson. London: Dent, 1973, 136–44.

Lovejoy, Arthur O. *The Great Chain of Being: A Study of the History of an Idea.* Cambridge, MA: Harvard University Press, 1936.

Rolle, Friedrich. *Der Mensch: seine Abstammung und Gesittung im Lichte der Darwin'schen Lehre*, 2nd. ed. Prag: Verlag von Friedrich Tempsky, 1870.

Ruse, Michael. *Darwin and Design: Does Evolution Have a Purpose?* Cambridge, MA: Harvard University Press, 2003.

Weinert, Friedel. *Copernicus, Darwin & Freud: Revolutions in the History and Philosophy of Science*. Chichester, UK: Wiley-Blackwell, 2009.

Endnotes

[1]. This quote is taken from the fifth edition of Charles Darwin, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (London: John Murray, 1869), xv.

[2]. Darwin, *On the Origin of Species* (1869), xv.

[3]. See Peter J. Bowler, *Evolution: The History of an Idea* (Berkeley: Berkeley University Press, 2004) and Edward J. Larson, *Evolution: The Remarkable History of a Scientific Theory* (New York: Modern Library, 2006) for more detail.

[4]. Charles Coulston Gillispie, *Genesis and Geology: The Impact of Scientific Discoveries upon Religious Beliefs in the Decades Before Darwin* (New York: Harper & Row, 1959), 17–20; and Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge, MA: Harvard University Press, 1936), 59.

[5]. Lovejoy, *The Great Chain of Being*, 52–55.

[6]. Gottfried Wilhelm Leibniz, "On the Ultimate Origination of Things," in *Leibniz: Philosophical Writings*, ed. G. H. R. Parkinson, trans. Mary Morris and G. H. R. Parkinson (London: Dent, 1973), 144; Lovejoy, *The Great Chain of Being*, 244–45.

[7]. Compare this with Michael Ruse, *Darwin and Design: Does Evolution Have a Purpose?* (Cambridge, MA: Harvard University Press, 2003).

[8]. Robert Boyle, *A Disquisition about the Final Causes of Natural Things* (London: John Taylor, 1688), 43–44.

[9]. Boyle, *A Disquisition about the Final Causes of Natural Things*, 47.

[10]. Quoted in Charles Coulston Gillispie, *Genesis and Geology* (New York: Harper & Row, 1959), 36.

[11]. Loren Eiseley, *Darwin's Century: Evolution and the Men Who Discovered It* (London: Gollancz, 1959), 178.

CHAPTER 14 - DARWIN'S THEORY OF EVOLUTION

FRIEDEL WEINERT

Contrary to common belief, Charles Darwin (1809–1882) (fig. 1) is not the father of evolutionary theory. The fact of evolution was recognized by earlier researchers, who also searched for explanations. But it was Charles Darwin who proposed a viable explanation of evolution in his book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, which was published in 1859. The full title of the book is quite revealing because it expresses in a nutshell the gist of Darwin's ideas.

To a certain extent, however, this title is misleading. Darwin did not attempt to show how organic life arose on Earth at the dawn of time. Nor is this work concerned with races, human or non-human. It deals with evolutionary descent by the mechanism of natural selection. Although Darwin's book is quite long, it was originally only meant to be an abstract to a fuller work on evolution that Darwin intended to write later. But Darwin was rushed into publishing his work in order to secure his priority because he had received a paper from Alfred Wallace (1823–1913), "On the Tendency of Varieties to Depart Indefinitely from the Original Type" (1858) in which Wallace presented roughly the same ideas. Receiving a copy of this paper alarmed Darwin because he had already developed his ideas about evolution by 1838, after a five-year voyage on the *Beagle,* which lasted from 1831–1836.There are differences between Darwin's and Wallace's approach: Wallace doubted Darwin's inference from domestic to wild animals; he was more concerned with species than individuals; and, most importantly, he excluded humans from the impact of natural selection.

We should distinguish Darwin's theory of branching evolution from earlier attempts, such as Jean Baptiste Lamarck's (1744–1829) theory of linear, progressive evolution (1809). So, what is Darwin's theory of branching evolution?

Figure 1. Charles Darwin. Nature 10 (1874), frontispiece.

Figure 2. The Lamarckian view of linear or progressive evolution, leading to complexity:

Simple organisms → progress (increase in complexity)→ more complex organisms → highest organisms (human beings)

The Darwinian view of branching evolution, according to which ecological niches impose constraints on the morphology and structure of the organisms:

Genetic mutations and ecological niches → natural selection → local adaptations of organisms

A rough sketch of the theory says that evolution is the survival of the fittest. It is interesting to note that in the first editions of *Origin* Darwin neither used the term "evolution" nor the phrase "survival of the fittest." It was actually the British biologist, philosopher, and sociologist Herbert Spencer (1820–1903) who popularized Darwin's idea of the preservation of favorable variations by the expression "survival of the fittest."

Darwin approved of this and began to use the phrase "natural selection or survival of the fittest" from the fifth edition onward (it appears in the introduction to chapter four). The association has survived in the popular mind: many think of evolution as some progress toward higher forms of life, but his thinking is more Lamarckian than Darwinian (fig. 2).

What did Darwin really say? First, instead of evolution Darwin speaks of his theory of descent with modification. At the end of the nineteenth century "evolution" had a technical meaning in embryology: it was thought that embryos grew from preformed homunculi (or miniature human beings) enclosed in the egg or sperm. The term also stood for progress of developing forms from a rudimentary to a mature or complex state. Second, when Darwin speaks of natural selection he means the preservation of favorable variations, that is, if keeping a characteristic organic feature is favorable in a particular environment for survival and procreation then it tends to be preserved. Natural selection is therefore a statistical principle: it explains what is likely to happen to organisms in a changing environment.

Darwin avoided the term evolution in the sense of progress because he did not think that the development of species could be understood as a progress from lower to higher forms. For Darwin, evolution just meant a better adaptation of organisms to their respective environments. Darwin therefore rejected Lamarck's progressive modification and replaced it by gradual modification. So, instead of saying that species tend toward some kind of perfection—for instance they get more and more complex—Darwin's idea was that organic change leads to local adaptations in a changing environment. In this sense, an organism can, for instance, lose the function of its sight if it adapts to living in dark caves. So, the fittest are not the best in an absolute sense but are simply organisms with the most adequate adaptation to environmental niches. For instance, there are 200 species of cichlids in Lake Tanganyika in Africa, which are often separated by just a few hundred meters. Many of these species exist nowhere else in the world.

So far, we have concentrated on species as populations of organisms. Here evolution means that local adaptations to a changing environment results in greater diversification of species, such as in Lake Tanganyika. The more species diversify, the more ecological niches are filled with organisms. This is what Darwin means by descent with modification.

But let us now leave the bird's-eye view and descend to the level of the individual within a species. How does evolution look from this point of view? Is it only the fittest that survive? Recall that Darwin at first spoke of the preservation of favorable variations in individuals, rather than survival of the fittest. Later, the term "the fittest" was not employed as an absolute term but had to be understood relative to a local environment. From an individual's point of view, to be fit means to be well-adapted to a particular niche.

So how does the individual survive in a given environment? Darwin starts from the idea of a struggle for survival: any given environment can only support a limited number of individuals of a species. There are always many more individuals born than can survive, due to food shortages. Darwin followed Malthus in holding that offspring are born exponentially but food resources only grow arithmetically. In a given environment, individuals with a slight advantage over others have a better chance of surviving and procreating. Individuals with variations that are the most injurious would tend to be eliminated. This is the principle of natural selection: preservation of favorable variations and rejection of injurious variations.

And all adaptations and variations follow from the struggle for life: not only the survival of the individual, but success in leaving progeny (fig. 3).

Figure 3. Species and Individuals

- **Evolution (descent with modification) → species (splitting of lineages, diversification, morphological divergences)**
- **Reproductive system (genes) → random variation (favorable or unfavorable) → individual offspring → natural selection (preservation of favorable variations) → local adaptations**

We can now ask: what causes these variations in individuals? Today, biology can provide the answer: it is due to genetic changes. Biology also distinguishes three levels of variations:

- Species are the unit of evolution (descent with modification);
- Individual organisms are the unit of natural selection (the preservation of favorable characteristics); and
- Genes are the units of variation in individuals.

But Darwin did not know about genes, which were a much later discovery. Nor did he know of the work of the Austrian monk Gregor Mendel (1822–1884), who discovered the basic principles of heredity through his experiments on garden peas. Mendel's work was published in 1866 but remained dormant until its rediscovery at the beginning of the twentieth century. Darwin often spoke of our ignorance of the cause of each particular variation in individuals. Without knowledge of Mendel's genetic discoveries, he suspected that "disturbances in the reproductive system," as he put it, chiefly contributed to the varying or plastic condition of the offspring.[1]What about human beings?

There is only one sentence in *Origin* where Darwin mentions humans: "Light will be thrown on the origin of man and his history."[2]

Only twelve years after the publication of *Origin* did he tackle the question of human origins in a book entitled *The Descent of Man, and Selection in Relation to Sex* (1871), but again, the emphasis is on descent rather than origins.

Unlike Wallace, Darwin did not make an exception for humankind. Because of his change of perspective from progressive to branching evolution, he admitted humans into the natural order. Humans evolved from ape-like creatures through branching evolution. The human brain is as much a product of evolution as any other organ. With Darwin's theory, the traditional world of design passed away. That is, the natural world was no longer seen as the deliberate design of a divine engineer.

Darwin's theory of evolution met with a great deal of resistance, which was partly motivated by religious sensitivities. People believed that evolution had no purpose because it does not strive for perfection; individuals just seek to ensure their own survival and increase their gene representation. Additionally, they believed that evolution has no direction: its aim is not the birth of humankind and organisms only become better adapted to their local environments.[3]Darwin's materialism also disturbed his contemporaries: the evolution of all living organisms is to be explained by appeal to biological mechanisms, like natural selection, not divine intervention. Unlike Lamarck, who held that the emergence of humankind was a necessary consequence of evolution, Darwin rejected such biological determinism. He thought that evolution was contingent, meaning that it depended on many random factors.

Darwin also faced scientific objections. One problem was the paucity of fossil evidence. Darwin's theory assumes that evolution is gradual and imperceptibly slow. This gradualness should be observable in the fossil record: there should be intermediate forms between, say, ancient dinosaurs and modern birds (*Archaeopteryx)*. Such fossils were eventually discovered (the *Archaeopteryx* in 1861) but as their scientific impact was not obvious, the snail-paced march of evolution could be doubted.

Another problem for Darwin's theory was the age of the Earth. At Darwin's time William Thomson, Lord Kelvin (1824–1907), estimated the age of the Earth to be around 100 million years. Even this time span was not sufficient for the slow and gradual evolution of species, which Darwin envisaged in his theory. Darwin died before newer estimates demonstrated that both the Earth and the universe were billions of years old. Such calculations required new techniques that only became available as the nineteenth century drew to a close. In 1902 a breakthrough occurred when Ernest Rutherford (1871–1937) and Frederick Soddy (1877–1956) formulated the decay law. The decay law shows how the number of radioactive nuclei in a given sample of radioactive material decreases (exponentially) with time. The half-life of the decay is the time it takes for the activity to be reduced by half. The decay law gave rise to radioactive dating, a method of providing information about the age of rocks and fossilized life forms.

Further reading:

Coyne, Jerry A. *Why Evolution Is True*. Oxford: Oxford University Press, 2009.

Darwin, Charles. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray, 1859; See also Darwin Online.

Darwin, Charles. *The Descent of Man, and Selection in Relation to Sex.* London: John Murray, 1871. See also Darwin Online.

Desmond, Adrian, and James Moore. *Darwin's Sacred Cause: Race, Slavery and the Quest for Human Origins*. New York: Houghton Mifflin Harcourt, 2009.

Gould, Stephen Jay. *Ever Since Darwin: Reflections on Natural History*. New York: Penguin Books, 1980.

Mayr, Ernst. *What Evolution Is.* New York: Basic Books, 2001.

Lane, Nick. *Life Ascending: The Ten Great Inventions of Evolution*. London: Profile Books, 2010.

Ridley, Mark. *Evolution.* Oxford: Oxford University Press, 1997.

Ruse, Michael. *Darwin and Design: Does Evolution Have a Purpose?* Cambridge, MA: Harvard University Press, 2003.

"The Evolution of Evolution," *Scientific American*, January 2009. https://www.scientificamerican.com/magazine/sa/2009/01-01/

Weinert, Friedel. *Copernicus, Darwin & Freud: Revolutions in the History and Philosophy of Science*. Chichester, UK: Wiley–Blackwell, 2009.

Endnotes

[1]. Charles Darwin, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (London: John Murray, 1859), 131–2.

[2]. Darwin, *On the Origin of Species*, 488. Compare this with Adrian Desmond and James Moore, *Darwin's Sacred Cause: Race, Slavery and the Quest for Human Origins* (New York: Houghton Mifflin Harcourt, 2009).

[3]. Stephen Jay Gould, *Ever Since Darwin: Reflections on Natural History* (New York: Penguin Books, 1980), 12–13; and Darwin, *On the Origin of Species,* 201.

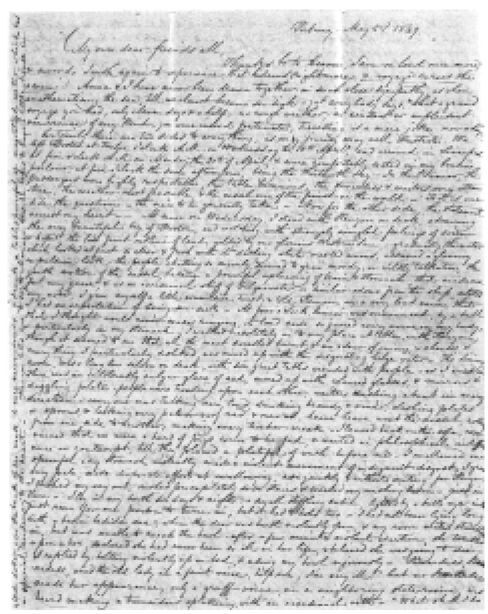
CHAPTER 14 - DOING HISTORY: NETWORKS AND WOMEN DOCTORS

JENNIE BROSNAN

What are Doing History segments?

Women doctors, especially those practicing in the mid to late nineteenth century, played a large role in disseminating information to the public about hygiene and sanitation, as well as being involved in political debate surrounding the female body during the 1860s to 1880s. By examining letters, we can discern much about early networks among women doctors. As you read this Doing History segment, think about how primary sources shape and reshape our understanding of the past.

The following letter is an example of many that Dr. Elizabeth Blackwell (See below.) sent to her family in Cincinnati after moving to New York in 1849 to establish her own medical practice. (Click on the image to enlarge.) As can be seen from this letter, the writing is small and fills the whole page, including writing in the margins.



This indicates that while Blackwell had much to say about her experiences in New York, she was also short of money. Paper was expensive during the nineteenth century and it was common practice to use all the available space on the page.

When researching the topic of female medical networks, a number of different areas of history need to be considered. Not only is this a cross-section of gender history and the history of medicine, but the construction of Victorian society and network theory also have a part. This section will look at the development of the female medical network and the implications this had for modern medicine, including the advent of modern birth control. But first, a basic background on the foundational Elizabeth Blackwell will be useful.

A Brief Biography of Elizabeth Blackwell

Elizabeth Blackwell was the first female doctor to graduate with a medical degree. As such, she is an important figure in the history of medicine, especially since she was influential for the path of women doctors on both sides of the Atlantic.

Blackwell, having graduating in 1849 from Geneva College, New York, gained work experience during 1850 and 1851 at La Maternité in Paris and St. Bartholomew's Hospital in London. There, she reveled in her celebrity as the first female doctor and was welcomed with open arms, principally by the middle and upper classes of London society. One particular group who received Blackwell in London was the "Langham Place Circle;" there, she cemented a network of supportive, financially secure, independently-minded women -or "Lady Bountifuls" –including Lady Byron, Barbara Leigh Smith and the Comtesse de Noailles, . Although these women were not particularly well-educated, they had access to money and connections both in Britain and abroad.

Upon Blackwell's return to New York in 1851, however, she found herself alone. While she still enjoyed letters of support and advice from the "Lady Bountifuls," she also often received hostile letters. She had to fend off unwanted male attention on her walks home from various patients' houses late at night. She struggled to establish herself in New York as a mainstream doctor, and to dispel rumors that she was an abortionist. She found herself isolated in her profession.

For more on Blackwell, see the National Library of Medicine: Dr. Elizabeth Blackwell

Female Medical Networks

Elizabeth Blackwell put her medical degree to good use by founding medical schools in both New York and London, becoming the first woman to be on the General Medical Register in Britain in 1858 and publishing several books. She was at the heart of many campaigns to educate the public about 'moral hygiene' which can be seen as her own brand of sex education, as well as basic hygiene and sanitation. As the first female doctor, Blackwell is the starting point for female medical networks during the nineteenth century as she mentored and taught many of the first women to practice medicine in both Britain and America

Challenges for women trying to break into the medical field were so great that the first generation of female doctors, both in Britain and America, formed networks consisting solely of other women as a means of financial, social and political support. (For example, groups such as the Langham Place Circle, based in London, provided the financial means for Elizabeth Blackwell to establish the New York Infirmary for Women and Children in 1857.) But the relationships within these female medical networks were often fraught and frequently competitive, especially as these women banded together out of necessity: they were in a predominately male environment which was worlds away from the female dominated private sphere they otherwise would have been familiar with, such as the Victorian home and the homes of families they visited.

Biographers of nineteenth-century female doctors have tended to associate these networks with friendship, and, certainly, relationships of a significant length blurred the lines of professionalism and friendship. But the equation of female relationship with friendship is highly gendered and factually incorrect. While it is necessary to highlight that many of the relationships within the female medical network were amicable, many were also strictly professional—just as they would have been with male professionals. Until recently, scholars have belittled these female networks while seeing male networks as legitimate and more tangible.

There were a number of issues the female medical networks faced:

- The relationship that existed within the male-dominated field of medicine and the women who dared to challenge the medical establishment was complex.
- The connections between medical women who struggled to find common ground whilst maintaining a united front was often fraught.

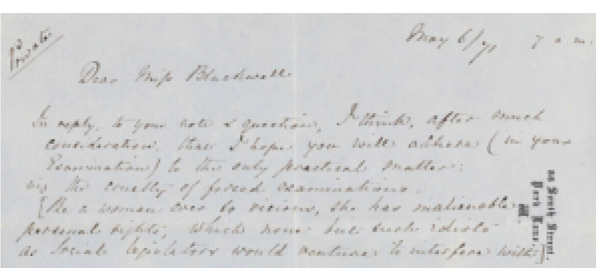
- The groups of respectable middle and upper class women who came together to provide financial support for women in medicine took serious risks by associating themselves with the women who existed on the fringes of the medical establishment.

There are other reasons as to why the female medical network was problematic: the first was competition. Excluded from the standard systems of mentorship and apprenticeship, these women wanted to shine individually—they did not want to share their accomplishments with other women who were also emerging in their field. Nor did they want to share the limelight with others; each had her own agenda. The second reason is that, being first women in their field, these women had no system of mentoring or apprenticeship to avail themselves of; they didn't understand how profession relationships worked. Men who wished to pursue medicine did so under a system of apprenticeship, often 'walking the wards' at hospitals, under the guidance of senior doctors and flourished accordingly. For women, the only way for them to gain experience or gainful employment was to set up their own dispensary.

It is clear from the work of Roy Porter that pioneer women were unable to partake in the kind of fostering activities in their early careers that their male counterparts enjoyed because of the misogynistic attitudes surrounding the patriarchal society they worked in. The atmosphere within medicine at this time was equal to a "fraternity", thus making it nearly impossible for a woman to break into the ranks.

Finally, not all relationships within the female medical network were amicable. For example, Elizabeth Blackwell and Elizabeth Garrett Anderson clashed on the Contagious Diseases Acts, as well as on a number of other medical issues. These acts, in place between 1864 and 1884, sought to regulate prostitution and venereal disease within Britain and its empire by calling for the forced gynecological examination of women suspected of being prostitutes.

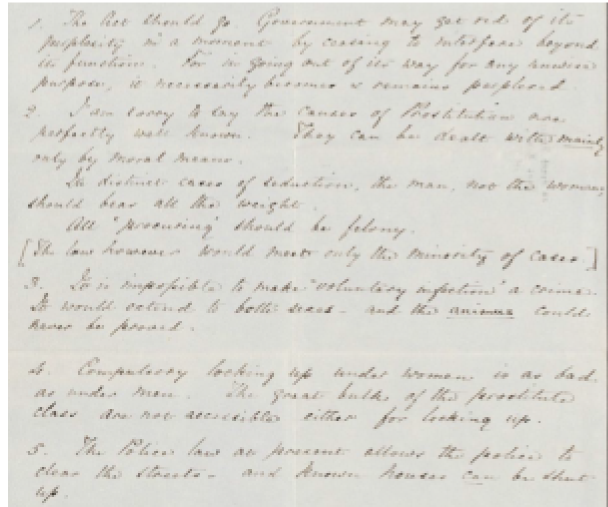
Blackwell had been Garrett Anderson's mentor. But while Anderson chose to side with the mainstream stance of the medical profession and backed the acts, Blackwell did not. Instead, Blackwell joined another network consisting of the Ladies' National Association for the Repeal of the Contagious Disease Acts. This letter from Florence Nightingale to Elizabeth Blackwell, 6th May 1871, discusses the issue of 'forced examination'. (Click on the image to enlarge.)


Private
May 6/71 7 a.m.
Dear Miss Blackwell
In reply to your note & question, I think, after much consideration, that I hope you will adhere (in your Examination) to the only practical matter:
viz. the cruelty of forced examinations.
[As a woman ... vicious, she has inalienable personal rights, which none but such idiots as Social legislators would venture to interfere with.]
35 South Street
Park Lane

While there are no existing letters of the conflict between Blackwell and Garrett Anderson, it has been well-documented by biographers of both women, as well as other secondary sources on the history of women in medicine.

Of course, there is plenty of evidence that suggests that many women in medicine did provide support for one another, as well. For example, Florence Nightingale and Blackwell also discussed the government policy on the Contagious Diseases Acts and agreed as to the implications these laws had for women suspected of being prostitutes. In other correspondence the two medical women discussed the infection rates for soldiers with syphilis and the impact this had on the ability of the British army to carry out their duties. As explored in the following letter, Nightingale and Blackwell contemplated many options as alternatives to the Contagious Diseases Acts, and sought their repeal. (Click on the image to enlarge.)

Medical Women's Impact on Hygiene and Sanitation


1. The Act should go. Government may get out of its perplexity in a moment by ceasing to interfere beyond its function. For in going out of its way for any [illegible] purpose, it necessarily becomes & remains perplexed.
2. I am sorry to say the causes of Prostitution are perfectly well known. They can be dealt with mainly only by moral means.
In distinct cases of seduction, the man, not the woman, should bear all the weight.
All "procuring" should be felony.
[The law however would meet only the minority of cases]
3. It is impossible to make "voluntary infection" a crime. It would extend to both sexes – and the animus could never be proved.
4. Compulsory locking up under women is as bad as under men. The great bulk of the prostitute class are not accessible either for locking up.
5. The Police law at present allows the police to clear the streets – and known houses can be shut up.

These women doctors were highly involved with developing hygiene and sanitation reform. For example, Elizabeth Blackwell founded the National Health Society in 1871 as a means of communicating knowledge about sanitation and hygiene to the lower classes through lectures and classes. In America and Britain, the establishment of female-led medical schools for women doctors helped develop further female medical networks and elevated the position of the woman doctor in the medical profession. Medical Women were involved in a series of public health campaigns throughout the late nineteenth and early twentieth centuries. The Contagious Diseases Acts, mentioned earlier, were a prime example of the role female doctors played in shifting public health policy. Elizabeth Blackwell later called on women doctors in the empire to continue their work in campaigning against the Contagious Diseases Acts, as well as providing excellent medical care to infected women, long after the legislation had been repealed in Britain.

The well-educated, capable female doctors trained by women's medical schools, such as the London School of Medicine for Women, played an important role in the First and Second World Wars, helping to develop and establish the woman doctor's place within medicine.

Advent and Impact of Modern Birth Control

The nineteenth century brought about new advances in the development of modern birth control, as well. The vulcanization of rubber in 1839 during the industrial era brought the condom as a viable method of contraception for men; family limitation and sexual health manuals introduced women to a new world of contraceptive measures. Texts like Richard Carlile's *Every Woman's Book; or What is Love? Containing Most Important Instructions for the Prudent Regulation of the Principle of Love and the Number of the Family* in 1826 described methods of birth prevention including the withdrawal method, the use of the 'sponge' for women and the use of the 'glove' for men.

The Neo-Malthusians, inspired by the economic theorist Thomas Malthus who favored population control, advocated the use of such measures. The beliefs of Neo-Malthusianism in the mid to late nineteenth century were loosely based on Thomas Malthus' *Essay on the Principle of Population* (1798). Malthus, an economic theorist, advocated the use of moral restraint as a means of controlling the population, preventing starvation and unrest. The Neo-Malthusian movement, later called the Malthusian League, was founded in 1877 by C.R. Drysdale. Even though the Neo-Malthusians adapted the name of Malthus, he did not advocate the use of artificial contraception in his writings. Instead, Malthus believed that late marriage and abstinence were the means to population control. Two prominent Neo-Malthusians, Annie Besant and Charles Bradlaugh, were arrested for the publication and distribution of Charles Knowlton's *Fruits of Philosophy* which followed in the same vein as Richard Carlile's text describing methods to avoid conception.

This slow but steady advent of contraception provided women with the opportunity to limit their family size and eventually pursue careers of their own.

Further Reading

Alison Bashford and Joyce E. Chaplin, *The New Worlds of Thomas Robert Malthus: Rereading the Principle of Population* (Princeton University Press, Oxford, 2016)

Julia Boyd, *The Excellent Doctor Blackwell: The Life of the First Female Physician* (Sutton Publishing, London, 2005)

Barbara Caine, "Feminism in London circa 1850-1914", *Journal of Urban History,* 2001, Vol. 27, No. 6, pp. 765-778

Estelle Freedman, "Separatism as Strategy: Female Institution Building and American Feminism, 1870-1930", *Feminist Studies,* 1979, Vol.5, No. 3, pp. 512-529

Stephen Garton, *Histories of Sexuality: Antiquity to Sexual Revolution* (Equinox, London, 2004)

Lesley Hall, *Sex, Gender and Social Change in Britain since 1880* (Macmillan Press, London, 2000)

Elizabeth Hurren, *Dying for Victorian Medicine: English Anatomy and Its Trade in the Dead Poor, c. 1834-1929* (London, Palgrave Macmillan, 2012)

Philippa Levine, "Love, Friendship and Feminism in Later 19th-Century England", *Women's Studies International Forum,* 1990, Vol. 13, No. 12, p. 64

Jo Manton, Elizabeth Garrett Anderson (London, Metheun, 1965)

Charles Newman, *The Evolution of Medical Education in the Nineteenth Century* (London, Oxford University Press, 1957).

Roy Porter, Blood and Guts: A Short History of Medicine (London, Penguin Books, 2002).

Barnes Riznik, "The Professional Lives of Early Nineteenth-Century New England Doctors", *Journal of the History of Medicine and Allied Sciences,* 1964, Vol. 19, No. 1, pp. 1-16

Drury Sherrod, "The Bonds of Men: Problems and Possibilities in Close Male Relationships" in Harry Brod, ed. *The Making of Masculinities: The New Men's Studies* (London, Unwin Hyman Ltd, 1987), pp. 213-240.

PART IX

EDITORS

DANIELLE MEAD SKJELVER, EXECUTIVE EDITOR

Danielle Mead Skjelver is the coordinator of the History Capstone Course Series at the University of Maryland Global Campus where she is also a Collegiate Professor of History. She is a news translator for *Watching America,* and she is the author of the national award winning novel, *Massacre: Daughter of War,* as well as scholarly work on the intersection of gender and language in Early Modern Europe. Her publications include an English translation of *Krigen mot Siouxene,* a Norwegian monograph on the US-Dakota War, which she co-translated with Melissa Gjellstad. She holds a PhD from the University of North Dakota. For her dissertation, Skjelver translated François Hédelin's treatise, *Des Satyres brutes, monstres et démons,* exploring its place in the Early Modern discourse on what defines the human as human. Skjelver serves on the *Scientiae* Executive Committee and chairs the Society for Military History Conduct Committee.

DAVID ARNOLD, EDITOR

A professor of history at the University of Maryland Global Campus since 2014, David Christopher Arnold received his PhD in the history of technology from Auburn University. He served as the editor of Quest: The History of Spaceflight quarterly journal for a decade and has written scholarly works focused on Cold War and space history.

SHARON BAILEY GLASCO, EDITOR

Sharon Bailey-Glasco, PhD, is a professor at Linfield College and teaches for the University of Maryland University College as well. She is the author of *Constructing Mexico city: Colonial Conflicts over Culture, Space, and Authority* (Palgrave Macmillan, 2010.).

HANS PETER BROEDEL, EDITOR

Hans Peter Broedel is an Associate Professor of History at the University of North Dakota and received his Ph.D. from the University of Washington. He is the author of *The* Malleus Maleficarum *and the Construction of Witchcraft*, and has published articles on witches, late medieval apparitions, and Early Modern natural history. His current research focuses on problems in the historical study of epistemology, and more specifically those involving credulity and skepticism in Early Modern attitudes towards fantastic animals.

BONNIE KIM, EDITOR

Dr. Bonnie Kim earned her PhD in East Asian History from Columbia University. She earned her Masters in Asian Studies from Oxford University, UK, and her B.A. in French Literature (*cum laude*) from Smith College.

Dr. Kim has over 15 years of teaching experience, and has taught at institutions such as Columbia University, Wellesley College, and George Washington University as well as UMUC. She has taught numerous courses in the fields of East Asian studies and history, and has a particular interest in the diplomatic, cultural, and social histories of Korea and Japan.

Dr. Kim has also been the recipient of numerous academic prizes and fellowships. She was a postdoctoral fellow at the Heyman Center, Columbia University from 2006-07. In 2002, she was a awarded of a Fulbright Fellowship to conduct dissertation research in Seoul, Korea.

She has presented papers at various academic conferences in Europe, Asia, and the United States, and is currently working on a book manuscript on East Asia's nineteenth-century diplomatic engagement with the West. She contributed an article to "Epistolary Korea: Letters in the Communicative Space of the Choson, 1392-1910," (New York: Columbia University Press), 2009. Most recently, Dr. Kim authored a chapter for *Claims to Territory between Japan and Korea in International Law* (Bloomington: Xlibris).

PART X

AUTHORS

SOLANGE ASHBY

Solange Ashby received her Ph.D. in Egyptology with a specialization in ancient Egyptian language and Nubian religion from the University of Chicago. She has conducted research in Egypt at the temple of Philae and participated in an archaeological excavation in El-Kurru, Sudan (royal Kushite cemetery). Her first book, *Calling Out to Isis: The Enduring Nubian Presence at Philae,* is published by Gorgias Press. Her current research explores the roles of women in traditional Nubian religious practices. Dr. Ashby is working on the first monograph dedicated to the history, religious symbolism, and political power of the queens of Kush.

Dr. Ashby teaches at the Department of Classics and Ancient Studies at Barnard College.

JENNIE BROSNAN

Jennie Brosnan holds a Ph.D. in History and Philosophy of Science and Technology from the University of Leicester as well as a Master of Science from the London School of Hygiene and Tropical Medicine. She has a broad background serving extensively in fields such as computer software, archival research, social media, training, and human resources.

TASHIA DARE

Tashia Dare is a lecturer in Museum Studies at the University of Kansas. Tashia holds an MA in Religious Studies (ancient Near East and Mediterranean), a Graduate Certificate in Peace and Conflict Studies, and a BA in Art History, all from the University of Kansas. Areas of interest include the impacts of armed conflict on cultural heritage and museums, antiquities trafficking and repatriation, and the use of cultural heritage as a peacebuilding, mediation, and reconciliation tool in post-conflict situations. Dare has worked in a variety of museums.

KAREN GARVIN

Karen S. Garvin holds an MA in history from the American Military University and a BA in communications from the University of Maryland University College. She is a copyeditor and writer and has written more than 100 encyclopedia entries, with work appearing in ABC-Clio's *Energy in American History* (forthcoming); *Technical Innovation in American History*; *The British Empire*; *The Sea in World History*; *Encyclopedia of American Myth, Legend, and Folklore*; *Imperialism and Expansionism in American History*; and Salem Press's *Critical Insights: Ray Bradbury*. Her research interests include Victorian detectives and detective fiction, nineteenth-century science and technology, the Industrial Revolution, and Zeppelins.

BENJAMIN GUYER

Benjamin M. Guyer is Lecturer in the Department of History and Philosophy at the University of Tennessee Martin. He holds a PhD and MA in History from the University of Kansas, and an MA in Religion from Florida State University. Most recently, he is co-editor with Paul Avis of *History, Theology, and Purpose – The First 150 Years* which is forthcoming from T&T Clark/Bloomsbury Academic. He has published in the *Sixteenth Century Journal* and contributed to several edited volumes.

Link to Website:
https://utm.academia.edu/BenjaminGuyer

STEPHANIE GUERIN-YODICE

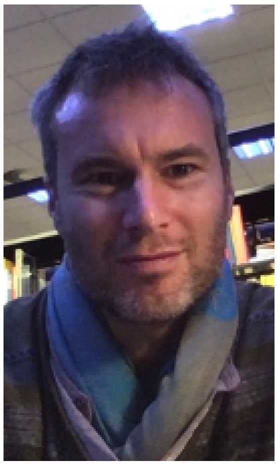
Stephanie Guerin-Yodice is a history professor with educational training that includes degrees in Museum Studies from The College of Notre Dame, History from Excelsior College, and Education from Johns Hopkins. She currently teaches as an adjunct at Montgomery College, Howard Community College, and University of Maryland Global Campus where she also has experience in course development and instructional design. Stephanie enjoys tutoring high school students in AP History and attends the yearly AP World History Reading as a Grader. Her historical areas of interest include ancient and Renaissance history.

SARAH JEONG

Photo Credit: Ken Bennett

Sarah Jeong is a Research & Instruction Librarian for Science at Wake Forest University. She received her MLIS degree from The University of North Carolina-Greensboro and BS degree from Duke University. Jeong has accomplished over 15 publications and more than 25 presentations. She is active in the Science & Technology Section of the Association of College & Research Libraries. Jeong is a member of the Beta Phi Mu International Library and Information Studies Honor Society.

ANTOINE LEVEQUE



Antoine Leveque was born in Paris in 1978. He taught in different colleges and Universities on the North-Eastern Coast of the United-States. In 2017, he obtained his PhD in History of Science from Paris Sorbonne University. His 500 pages long French dissertation focused on the concept of Racial Equality in the History of Science, from 1750 to 1885. He is currently working on a book titled *The Genesis of Psychology* (1575-1605). An abridged English version of his PhD Dissertation will be published in 2021. For more details about his work, see: antoineleveque.com

MATTHEW G. MARSH

Matthew G. Marsh is the Director of Teacher Education at Sul Ross State University, where he is also a lecturer in history for the Behavioural & Social Sciences Department. Currently he is finishing his Doctorate of Arts in History with the University of North Dakota and holds master's degrees in both History and Political Science. He has published articles and reviews in the *Journal of Ancient History and Archaeology* and contributed to the *De Imperatoribus Romanis*, an online encyclopaedia of the rulers of the Roman Empire.

For more information please visit his website at: https://matthewgmarsh.academia.edu/.

RICHARD MCGAHA

Richard McGaha is an adjunct faculty member at Seattle University and University of Maryland Global Campus. He holds a BA in History from Seattle University, MA in History from the University of Calgary, and PhD in History from Ohio University.

MARTIN ODLER

Martin Odler is a researcher at the Czech Institute of Egyptology, Faculty of Arts, Charles University in Prague. His interest lies in the social context of crafts in Ancient Egypt, especially metallurgy of copper and bronze. In 2016, his monograph *Old Kingdom Copper Tools and Model Tools* was published at Archaeopress (Oxford), and the outputs of his research featured e.g. in the journals *World Archaeology*, *Journal of Archaeological Science*, *Aegypten und Levante*. He has been taking part in the missions of the Czech Institute of Egyptology in Abusir since 2009, working mostly as a field archaeologist and a surveyor. Martin Odler is the founder and administrator of the official YouTube channel and official Facebook page of the Czech Institute of Egyptology. For research outputs, visit Martin Odler's academia.edu page.

Photo Credit: SME – Jozef Jakubčo

SHALON VAN TINE

Shalon van Tine is a PhD student in U.S. cultural and intellectual history at Ohio University. She holds a BA in philosophy and cultural studies, an MA in humanities, and another MA in world history. She is currently an adjunct professor at University of Maryland Global Campus, where she teaches courses in humanities and history.

FRIEDEL WEINERT

Friedel Weinert is emeritus professor of Philosophy at Bradford University in the United Kingdom. He holds degrees in Philosophy, Physics and Sociology. He has published widely in the area of history and philosophy of science. He has been a visiting scholar at the universities of Harvard, Sydney, Munich and the London School of Economics. His most recent book is The Demons of Science (2016). He is currently working on a commissioned intellectual biography of the philosopher Karl R. Popper.

Link to Website:
https://sites.google.com/view/friedelweinert/home

PART XI

COVER & BOOK DESIGN

KAREN GARVIN, COPYEDITING, LAYOUT, & BOOK DESIGN

Karen S. Garvin holds an MA in history from the American Military University and a BA in communications from the University of Maryland University College. She is a copyeditor and writer and has written more than 100 encyclopedia entries, with work appearing in ABC-Clio's *Energy in American History* (forthcoming); *Technical Innovation in American History*; *The British Empire*; *The Sea in World History*; *Encyclopedia of American Myth, Legend, and Folklore*; *Imperialism and Expansionism in American History*; and Salem Press's *Critical Insights: Ray Bradbury*. Her research interests include Victorian detectives and detective fiction, nineteenth-century science and technology, the Industrial Revolution, and Zeppelins.

KEVIN TENGESDAL, COVER DESIGN

Kevin R. Tengesdal is a professional graphic designer with twenty-plus years creative history in the print shop, newspaper, advertising and non-profit industries. He holds a bachelors in Biblical Languages and Biblical Studies from Columbia International University, with a year of study in Jerusalem. Kevin is currently working with the Bismarck Veterans Memorial Public Library as their Community Relations Coordinator, and is studying for a Masters in Social Work with the University of North Dakota. Along with varied creative activities, Kevin has been active with community theatre groups, and with social rights advocacy work.

In designing the front cover artwork for this textbook, he looked to creatively incorporate imagery showcasing science and technology from the eras of early man, the Renaissance period, the Industrial Revolution, and the present and future Space age.

Link to Website:
https://bluepinedesign.art/

PART XII

SECTION EDITORS

JAN SUMMERS DUFFY

Jan Summers Duffy is an Archaeologist, Curator and Egyptologist who works in Egypt and in the US. Currently with the OJSmith Museum at The College of Idaho, she formerly worked with the New York State Museum as down-state Archaeologist and Collections Manager at historic Iona Island. She has an AAS, BA and MAs.

Working at several sites throughout Egypt, including Mendes in the Nile Delta with Penn State excavating burials, she has also worked on tombs in Luxor. Her research is on artifacts from the tomb KV62 and others including the Headrests; (A Pillow for His Head"). She is also discoverer of the salvage site 10AA612, a large obsidian biface funerary cache possibly linked to the Western Burial complex. In New York state as a member of the NYSAA, she helped excavate one of the best known Mastodon sites, Duchess Quarry caves.

jduffy@collegeofidaho.edu

Statement:

"Re-use and usurpation defines the tomb of Tutankhamun and its artifacts. The recent theory of hidden rooms in the tomb is realistic. Many believe that Nefertiti is Tutankhamun's stepmother and may have acted as co-regent to Akhenaten, His father."

WHAT ARE PRIMARY SOURCES?

Primary sources are any sources that were created in the era under discussion.

For example, if we are discussing George Washington, anything at all **created during Washington's lifetime** would be primary sources:

- a letter
- an inventory
- a scrap of paper with a list scrawled on it
- a flag
- a shirt
- a comb
- a building

Anything created outside this period would be a secondary or tertiary source. For example, most of the books about Washington or the Revolution at the local bookstore are secondary sources. Secondary sources use, refer to, and quote primary sources.

Textbooks are tertiary sources. They tend to rely more on secondary sources.

Primary: created during the period under study

Secondary: written after the fact, using mostly primary sources

Tertiary: written after the fact, using mostly secondary sources

WHAT ARE DOING HISTORY SEGMENTS?

Each chapter will have a Doing History segment. These segments are designed to illustrate how historians do the work of writing history, which relies heavily on primary sources, the wellspring of historical research. Click here for an explanation of primary sources. Doing History segments allow you to see how historians pull from primary sources to answer research questions and deepen our understanding of the past.

1. The Act should go. Government may get rid of its perplexity in a moment by ceasing to interfere beyond its function. For in going out of its way for any unwise purpose, it necessarily becomes & remains perplexed.

2. I am sorry to say the causes of Prostitution are perfectly well known. They can be dealt with <u>mainly</u> only by moral means.

In distinct cases of seduction, the man, not the woman, should bear all the weight.

All 'procuring' should be felony.

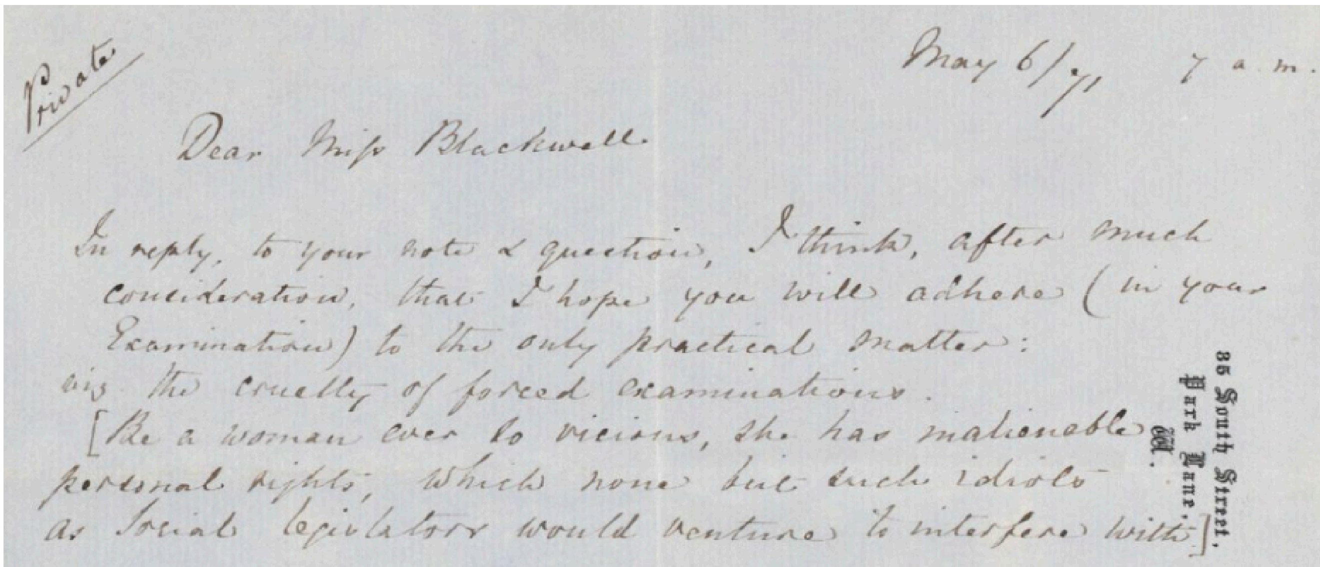
[The law however would meet only the minority of cases.]

3. It is impossible to make 'voluntary infection' a crime. It would extend to both sexes - and the <u>animus</u> could never be proved.

4. Compulsory locking up under women is as bad as under men. The great bulk of the prostitute class are not accessible either for locking up.

5. The Police law at present allows the police to clear the streets - and known houses <u>can</u> be shut up.

FLORENCE NIGHTENGALE MAY 6TH 1871


Private

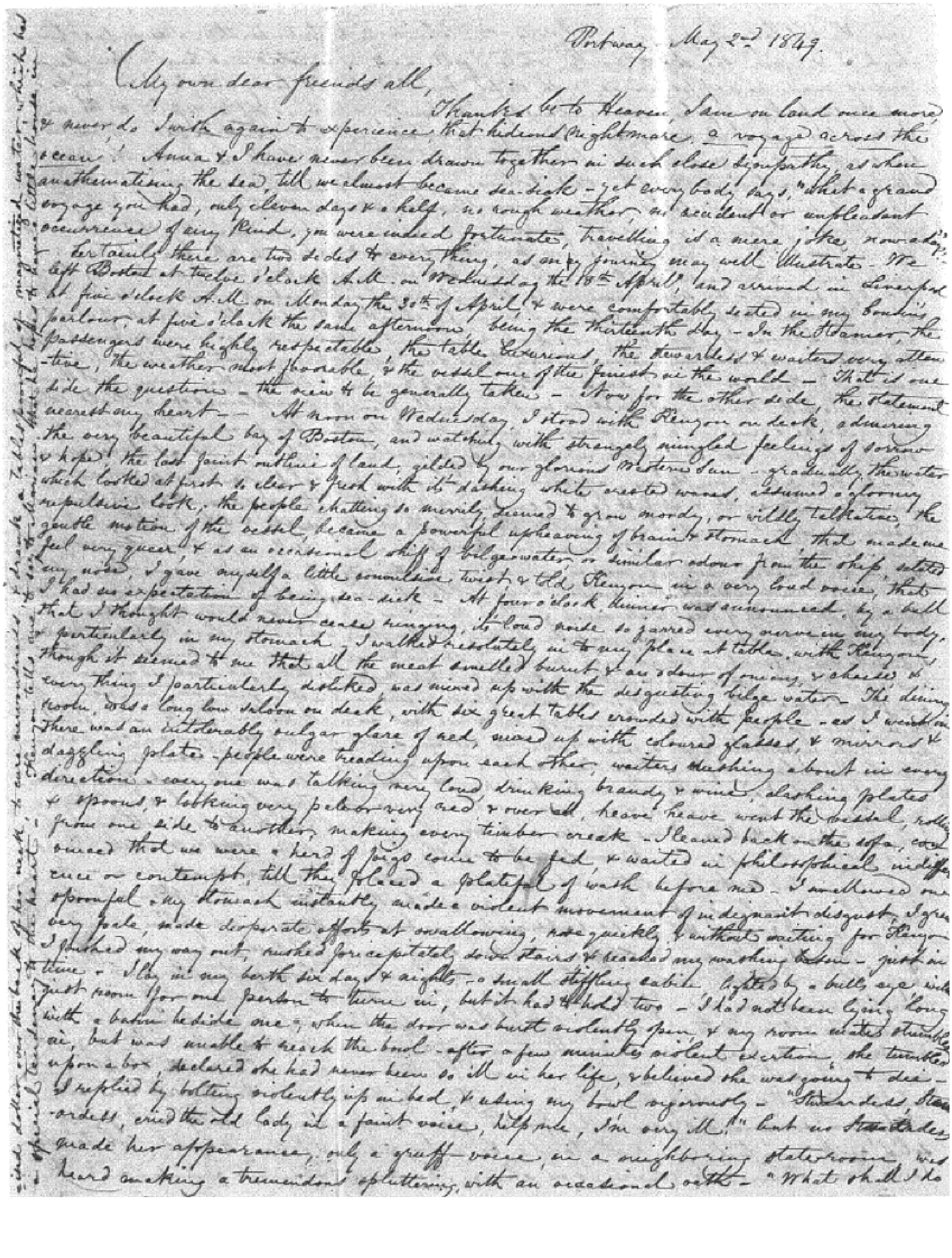
May 6/71 7 a.m.

Dear Miss Blackwell

In reply, to your note & question, I think, after much consideration, that I hope you will adhere (in your Examination) to the only practical matter:
viz the cruelty of forced examinations.
[Be a woman ever so vicious, she has inalienable personal rights, which none but such idiots as Social legislators would venture to interfere with.]

35 South Street,
Park Lane,
W.

ELIZABETH BLACKWELL LETTER MAY 2ND 1849



Portway May 2nd 1849.

My own dear friends all,

Thanked be to Heaven, I am on land once more & never do I wish again to experience that hideous nightmare, a voyage across the ocean! Anna & I have never been drawn together in such close sympathy, as when anathematizing the sea, till we almost became sea-sick - yet every body says, "what a grand voyage you had, only eleven days & a half, no rough weather, no accident or unpleasant occurrence of any kind, you were indeed fortunate, travelling is a mere joke, nowadays".

Certainly there are two sides to every thing, as my journey may well illustrate - We left Boston at twelve o'clock A.M. on Wednesday the 18th April, and arrived in Liverpool at five o'clock A.M. on Monday the 30th of April, & were comfortably seated in my Cousin's parlour, at five o'clock the same afternoon, being the thirteenth day - In the Steamer, the passengers were highly respectable, the tables luxurious, the stewardess & waiters very attentive, the weather most favorable, & the vessel one of the finest in the world - That is one side the question - the view to be generally taken - Now for the other side, the statement nearest my heart - At noon on Wednesday I stood with Kenyon on deck, admiring the very beautiful bay of Boston, and watching with strangely mingled feelings of sorrow & hope, the last faint outline of land, gilded by our glorious Western Sun - gradually the water which looked at first so clear & fresh with its dashing white crested waves, assumed a gloomy repulsive look, the people chatting so merrily, seemed to grow moody, or wildly talkative, the gentle motion of the vessel, became a powerful upheaving of brain & stomach, that made me feel very queer, & as an occasional whiff of bilge water or similar odour from the ship, saluted my nose, I gave myself a little convulsive twist, & told Kenyon in a very loud voice, that I had no expectation of being sea-sick - At four o'clock dinner was announced, by a bell that I thought would never cease ringing, its loud noise so jarred every nerve in my body, & particularly in my stomach. I walked resolutely in to my place at table, with Kenyon, though it seemed to me that all the meat smelled burnt, & an odour of onions, & cheese & every thing I particularly disliked, was mixed up with the disgusting bilge water - The dining room, was a long low saloon on deck, with six great tables crowded with people - as I wended in there was an intolerably vulgar glare of red, mixed up with coloured glasses, & mirrors & dazzling plates - people were treading upon each other, waiters dashing about in every direction - every one was talking very loud, drinking brandy & wine, clashing plates & spoons, & looking very pale or very red & over all, heave heave went the vessel, rolling from one side to another, making every timber creak - I leaned back on the sofa, convinced that we were a herd of pigs come to be fed, & waited in philosophical indifference or contempt, till they placed a plateful of [illegible] before me - I swallowed one spoonful - my stomach instantly made a violent movement of indignant disgust, I grew very pale, made desperate efforts at swallowing, rose quickly & without waiting for Kenyon I pushed my way out, rushed precipitately down stairs & reached my washing basin - just in time - I lay in my berth six days & nights - a small stifling cabin lighted by a bull's eye with just room for one person to turn in, but it had to hold two - I had not been lying long with a basin beside me, when the door was burst violently open, & my room mate stumbled in, but was unable to reach the bowl - after a few minutes violent exertion, she tumbled upon a box, declared she had never been so ill in her life, & believed she was going to die - I replied by bolting violently up in bed, & using my bowl vigorously - "Stewardess, Stewardess, cried the old lady in a faint voice, help me, I'm very ill!" but no Stewardess made her appearance, only a gruff voice, in a neighboring stateroom was heard making a tremendous spluttering, with an occasional oath - "What shall I do

A BRIEF BIOGRAPHY OF ELIZABETH BLACKWELL

Elizabeth Blackwell was the first female doctor to graduate with a medical degree. As such, she is an important figure in the history of medicine, especially since she was influential for the path of women doctors on both sides of the Atlantic.

Blackwell, having graduating in 1849 from Geneva College, New York, gained work experience during 1850 and 1851 at La Maternité in Paris and St. Bartholomew's Hospital in London. There, she reveled in her celebrity as the first female doctor and was welcomed with open arms, principally by the middle and upper classes of London society. One particular group who received Blackwell in London was the "Langham Place Circle;" there, she cemented a network of supportive, financially secure, independently-minded women -or "Lady Bountifuls" –including Lady Byron, Barbara Leigh Smith and the Comtesse de Noailles, . Although these women were not particularly well-educated, they had access to money and connections both in Britain and abroad.

Upon Blackwell's return to New York in 1851, however, she found herself alone. While she still enjoyed letters of support and advice from the "Lady Bountifuls," she also often received hostile letters. She had to fend off unwanted male attention on her walks home from various patients' houses late at night. She struggled to establish herself in New York as a mainstream doctor, and to dispel rumors that she was an abortionist. She found herself isolated in her profession.

For more on Blackwell, see the National Library of Medicine: Dr. Elizabeth Blackwell