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Science Classics

Mark Masthay
University of Dayton, mmasthay1@udayton.edu

SCIENCE CLASSICS

MARK MASTHAY, PHD

Associate professor and chair of chemistry Mark Masthay has worked at the University of Dayton since 2006. He earned his doctorate in physical chemistry from Carnegie-Mellon University in 1988; before coming to UD, he taught at Drake University, New Mexico Highlands University, and Murray State University. His research details statistical mechanics and thermodynamics of magnetic systems and the mechanisms by which light damages the skin and retina. When growing up, he enjoyed novels by Arthur C. Clarke (*2001: A Space Odyssey*) and John Steinbeck (*Of Mice and Men, The Moon is Down*), but it was a short article on particle physics in World Book's 1969 *Science Year* that captured his interest in ninth grade and led him to pursue a career in science. He and his wife, Jean, have six children, who now reside in Kentucky, Missouri, Ohio, and Wisconsin.

INTRODUCTION

If it is true—as one modern writer has stated—that astronomers "look out at the heavens to look back in time,"[1] it is equally true that historians of science look back in time to elucidate our current understanding of the cosmos and its wide variety of natural phenomena. And though the natural sciences—physics and astronomy, chemistry, biology, geology, as well as their close relative medicine—are often perceived as specialties that relate loosely to each other but are disconnected from daily life, nothing could be further from the truth. Far from being an ivory-tower pursuit conducted in dark, dingy laboratories by people wearing white coats, the scientific enterprise has from its outset been a human project pursued by individuals with interests and goals impacted by their personal geographical, historical, and socioeconomic contexts. As such, it both informs

1 William E. Carroll, "Aquinas and Contemporary Cosmology: Creation and Beginnings." *Science & Christian Belief* 24.1 (2012): 5–18.

and is informed by the humanities and social sciences. The Rose Rare Book Collection thus constitutes a treasury of books—scientific and otherwise—that touch on issues as old as the nature and existence of God and as contemporary as the cultural battles surrounding the teaching of evolution in the public schools, the morality of nuclear and chemical weapons, and the use of medical technologies that force families into difficult decisions regarding end-of-life issues for their loved ones.

RIGHT
ALBERT EINSTEIN
DIE GRUNDLAGE DER ALLGEMEINEN RELATIVITÄTSTHEORIE (THE FOUNDATION OF THE GENERAL THEORY OF RELATIVITY)
1916
First edition
Presentation issue

The *Imprints and Impressions* exhibit is a largely Western corpus generated by authors working in North Africa, Europe, and the United States. It spans 2.5 millennia, beginning with the early Greek philosophers Plato and Aristotle and ending with the mid-twentieth-century American works of Flannery O'Connor. Though they now constitute important parts of the scientific, philosophical, and theological canon of the West, many of these books were initially controversial and poorly received, gaining influence only by besting their competition over time in the marketplace of ideas. To use an evolutionary analogy, Charles Darwin—whose seminal *On the Origin of Species* appears in this exhibition—might say that the genius of these works gave them a selective advantage that allowed them to survive against their intellectually inferior competition.

The natural sciences are united by their reliance on the scientific method: a common-sense approach to discerning truth in which hypotheses proposed to explain natural phenomena are tested by experiment and refined until a *theory*—an overarching explanatory model consistent with the collective body of observations—prevails. While the scientific method has been used for centuries, it did not dominate scientific studies in Europe until the Scientific Revolution of the sixteenth and seventeenth centuries. Prior to that time, scientific conclusions about the natural world were commonly based on the word of trusted authorities who had only infrequently arrived at their conclusions by empirical methods. It is not surprising, then, that a number of the nonscientific works in the exhibition played important roles in the development and advancement of science over the past millennium. The *Imprints and Impressions* exhibit is a window into a number of these interactions and the concomitant back-and-forth progress in the development of physics, astronomy, and cosmology (Aristotle, Thomas Aquinas, Nicolaus Copernicus, Johannes Kepler, Galileo Galilei, Isaac Newton, and Albert Einstein), chemistry (Marie Curie), and biology (Carl Linnaeus and Charles Darwin).

782 A. Einstein.

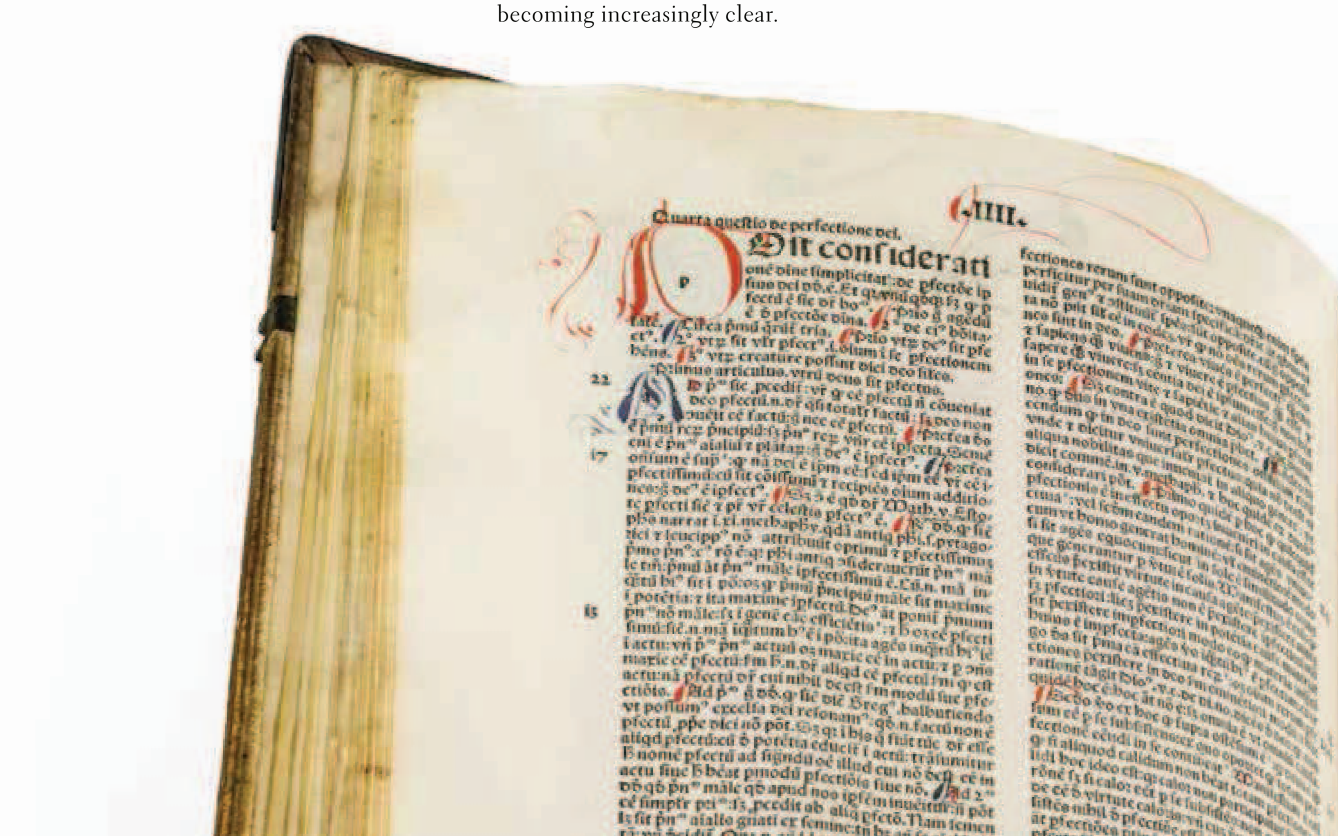
§ 5. Tensoren zweiten und höheren Ranges.

Die Grundlage der allgemeinen Relativitätstheorie. 783

ARISTOTLE + SCRIPTURE = THE NEW THIRTEENTH-CENTURY THEOLOGY: MAIMONIDES AND AQUINAS

Aristotle's philosophy, largely lost to Europe following the decline of the Western Roman Empire and the consequent loss of contact with Byzantium, was reintroduced to Europe by Islamic scholars in the 1100s. It was rapidly incorporated into Jewish and Christian theology, most notably via Moses Maimonides's *The Guide of the Perplexed* (twelfth century) and Thomas Aquinas's *Summa theologica* (1265–1274; never completed). This synthesis of Aristotelian philosophy and the Bible was initially controversial and problematic for both Maimonides and Aquinas because it appeared to place the work of a pagan author on a par with holy writ. Maimonides and Aquinas nevertheless prevailed, the latter in spite of vociferous opposition from some of his colleagues at the University of Paris in the 1260s and '70s. In fact, Aquinas's theology eventually so thoroughly vanquished that of his detractors that the *Summa* was placed on the altar alongside the Bible at the Council of Trent (1545–1563). Thomism—as Aquinas's philosophy came to be known—has been the official philosophy of the Catholic Church since Pope Leo XIII declared it such in 1879.

Though a theologian, Aquinas significantly impacted subsequent scientific developments. By incorporating the earth-centered cosmology of Aristotle into Christian theology, Aquinas helped set the stage for the famous conflict between Galileo and the Church half a century after Trent, when the merits of the heliocentric cosmology of Copernicus and Kepler were becoming increasingly clear.



ABOVE

THOMAS AQUINAS

SUMMA THEOLOGICA, PARS PRIMA

Venice, 1484

Second of the three editions printed by Antonius de Strata

BELOW · DETAIL

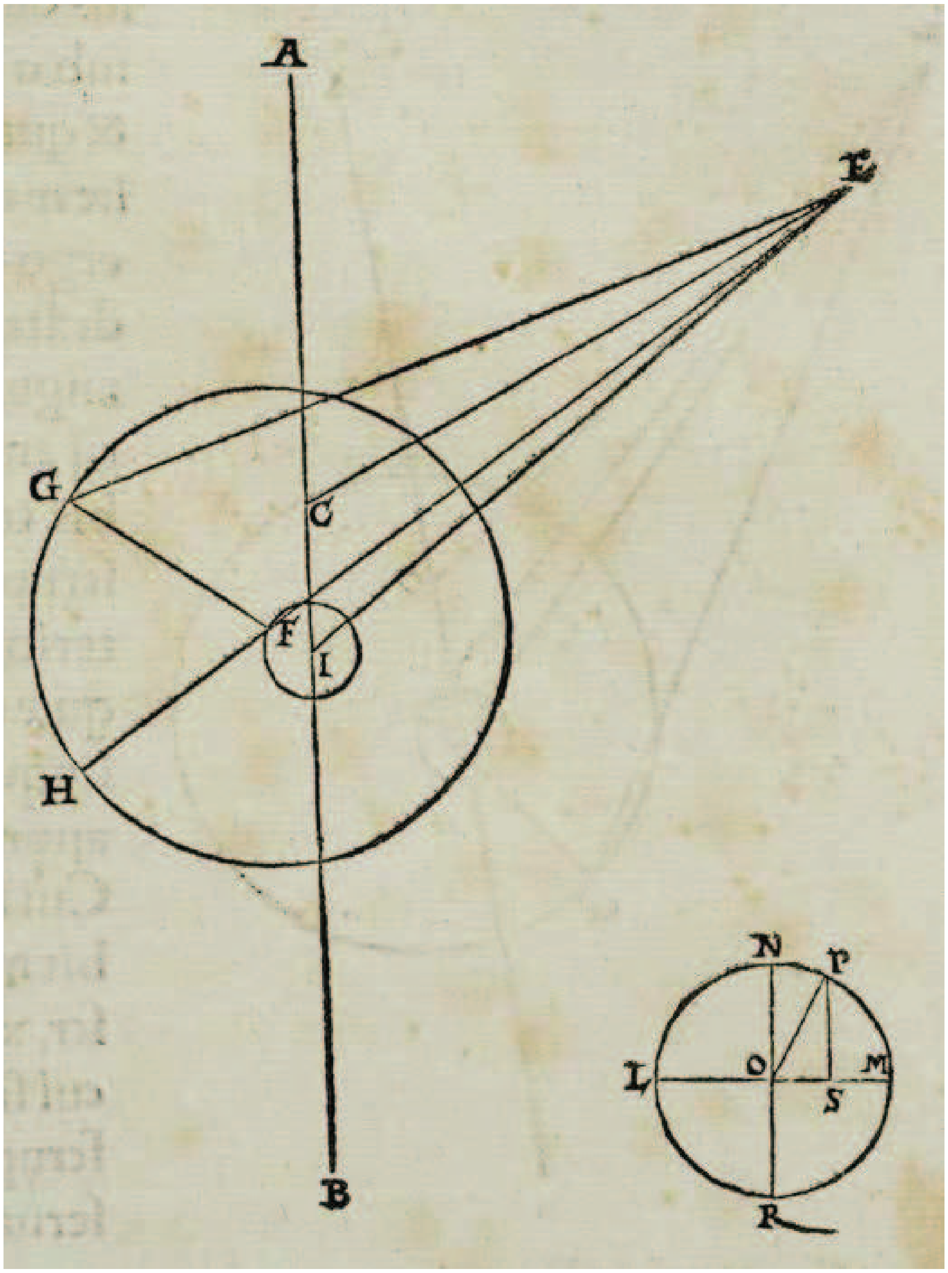
EMPIRICAL SCIENCE CONTRADICTS ARISTOTLE: HELIOCENTRISM AND THE REMOVAL OF HUMANKIND FROM THE CENTER OF THE UNIVERSE

The idea of a universe with the sun at its center—in direct contradiction to the earth-centered cosmos of Aristotle and Ptolemy—crystallized during the sixteenth and seventeenth centuries as a result of the efforts of Copernicus in Poland, Kepler in Austria, and Galileo in Italy. The Aristotelian-Ptolemaic model, which gained strength in Europe via Aquinas's synthesis of Aristotle and scripture, placed the earth at the center of the universe, with the sun and the planets—at that time limited to Mercury, Venus, Mars, Jupiter, and Saturn—revolving in circular orbits around it. Copernicus challenged this traditional view in his *De Revolutionibus Orbium Coelestium (On the Revolutions of Celestial Spheres)* (1543), which placed the sun at the center with the planets—earth included—revolving in circular orbits around it. Though Copernicus's model was a significant improvement over that of Aristotle and Ptolemy, it still contained anomalies that did not fit easily with empirical observations. These anomalies went away, however, if the planets were assumed to follow elliptical orbits around the sun, as demonstrated by Kepler in his *Astronomia Nova (New Astronomy)* (1609).

A year after the publication of the *New Astronomy*, Galileo, a mathematician and scientist loyal to the Church, published his small book *Sidereus Nuncius (Starry Messenger)*, in which he detailed his observations of the lunar surface and confirmed the existence of four large moons orbiting the planet Jupiter—feats remarkable for the time. Unlike the *New Astronomy*, which required forty years to become widely known, *Starry Messenger* was immediately received with enthusiasm and acclaim; the 500 copies of the first edition sold out within a week of publication (the one on display in *Imprints and Impressions* is one of only two known to be remaining from this earliest edition).

In spite of the *Messenger's* initial success, its publication posed a significant risk for Galileo, as it was potentially heretical on at least two counts. First, the presence of craters and mountains on the lunar surface led Galileo to conclude that the moon was composed of ordinary terrestrial substances rather than the *perfect quintessences* (perfect substances), which Aristotle and his disciples believed to be characteristic of all celestial bodies.

> "The *Imprints and Impressions* exhibit reveals the indispensability of the scientific method, with its reliance on empirical observation, as well as the need for magnanimity and deferred judgment on the part of existing authority..."
>
> MARK MASTHAY · PAGE 78



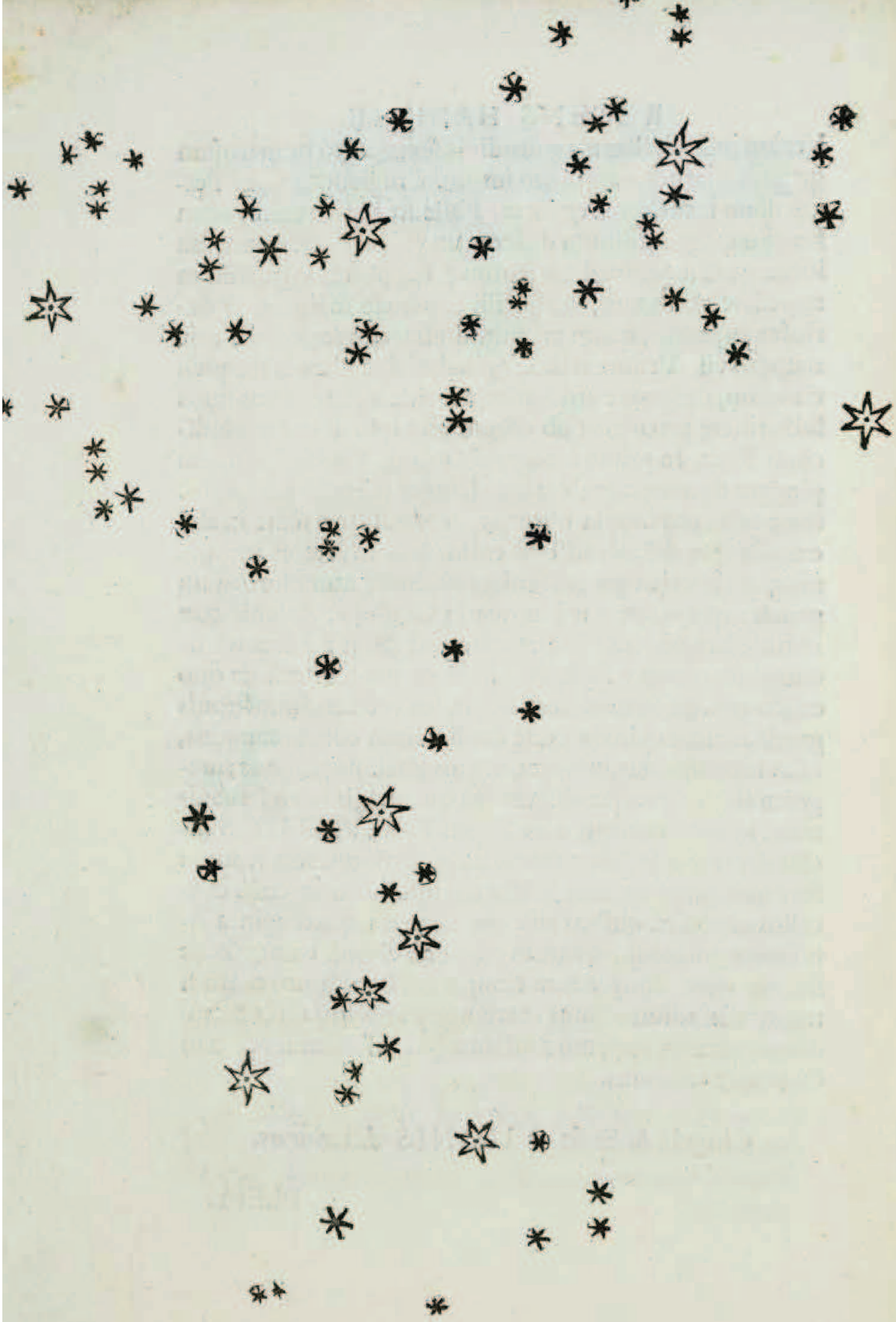
DETAIL

NICOLAUS COPERNICUS

DE REVOLUTIONIBUS ORBIUM COELESTIUM (ON THE REVOLUTIONS OF CELESTIAL SPHERES)

Nuremburg, 1543

First edition



"Fury said to
a mouse, That
he met in the
house, 'Let
us both go
to law: *I*
will prose-
cute *you.*—
Come, I'll
take no de-
nial: We must
have the trial;
For really
this morn-
ing I've
nothing
to do.'
Said the
mouse to
the cur,
'Such a
trial, dear
sir, With
no jury
or judge,
would
be wast-
ing our
breath.'
'I'll be
judge,
I'll be
jury,'
said
cun-
ning
old
Fury:
'I'll
try
the
whole
cause,
and
con-
demn
you to
death.'"

Second, and probably more important, Galileo's observation of moons orbiting Jupiter contradicted the Aristotelian-Ptolemaic assumption that celestial bodies could only orbit the earth. The *Messenger* proved to be a harbinger of later and more profound difficulties for Galileo. He was eventually tried before a commission of seven cardinals and officials of the Congregation of the Holy Office in Rome and placed under house arrest in 1633 following the publication of his *Dialogue Concerning the Two Chief World Systems* during the papacy of Urban VIII. No pope officially uttered the name "Galileo" again until Pope Paul VI mentioned him in a conciliatory speech in 1965.

Galileo's trial and detention had a chilling impact on other thinkers, including his younger French Catholic contemporary René Descartes. To avoid censure, Descartes used cautious, somewhat veiled language when he published his *Discours de la méthode pour bien conduire sa raison, et chercher la verité dans les sciences (Discourse on the Method)* (1637) four years after the trial, thereby launching the ambitious—and potentially heretical—project known today as Cartesian philosophy. There can be little question that the Galileo affair had similar effects on other scholars.

Negative fallout from the Galileo affair proved problematic for the Church in the succeeding centuries. To help mitigate the damage, Pope John Paul II—who had a deep appreciation for the importance of science to philosophy, theology, and society as a whole—reopened the Galileo case for review by a Church commission in 1981, almost 350 years after the trial. The commission's findings—eleven years in the making—vindicated Galileo in part, at the same time minimizing the Church's culpability in the events of 1633. The Galileo affair, one of the most important events in the history of science, continues to be debated by scholars within and outside the Church.

PREVIOUS SPREAD · LEFT · DETAIL

GALILEO GALILEI

SIDEREUS NUNCIUS (STARRY MESSENGER)

1610

One of only two known copies of earliest issue of the first edition

PREVIOUS SPREAD · RIGHT · DETAIL

LEWIS CARROLL

ALICE'S ADVENTURES IN WONDERLAND

New York, 1969

Includes a portfolio of illustrations by Salvador Dalí

Signed by the artist

(see pages 40 and 99)

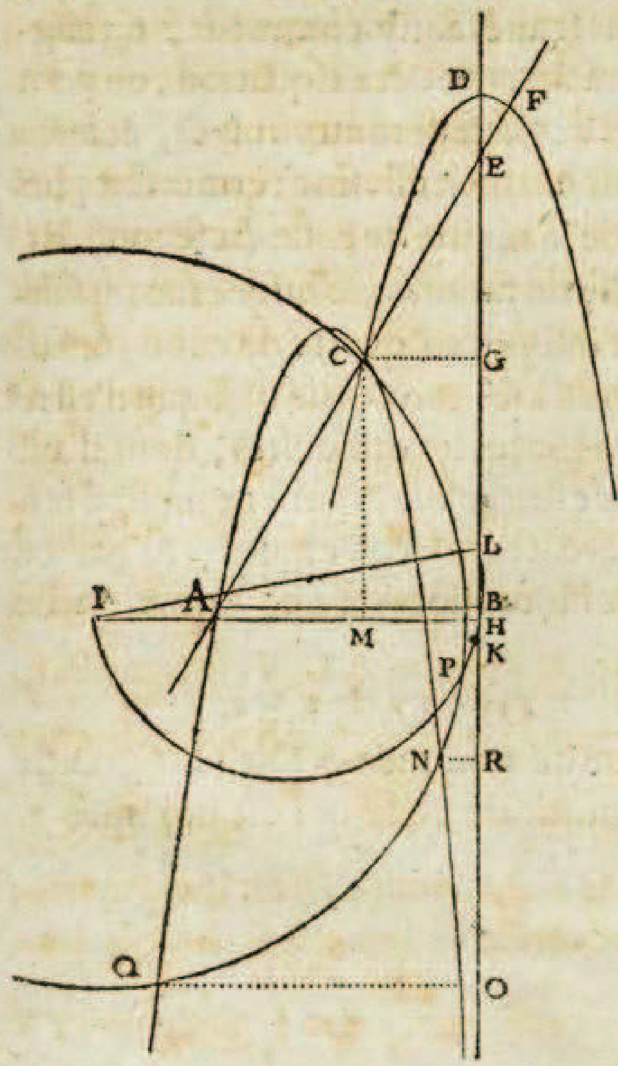
RIGHT · DETAIL

RENÉ DESCARTES

DISCOURS DE LA MÉTHODE POUR BIEN CONDUIRE SA RAISON, ET CHERCHER LA VERITÉ DANS LES SCIENCES (DISCOURSE ON THE METHOD)

Leiden, 1637

First edition



Puis ayant fait la ligne B K indefiniement longue des deux coſtés ; & du point B ayant tiré la perpendiculaire A B, dontla longueur ſoit $\frac{1}{2}p$; il faut dans vn plan ſeparé deſcrire vne Parabole , comme C D F dont le coſté droit principalſoit

$$\sqrt{\frac{t}{\sqrt{v}} + q - \frac{1}{4}pp}.$$

que ie nommeray n pour abreger. Aprés cela il faut poſer le plan dans lequel eſt cete Parabole ſur celuy ou ſont les lignes A B & B K, en ſorte que ſon aiſſieu D E ſe rencontre iuſtement au deſſus de la ligne droite B K: Et ayant pris la partie de cet aiſſieu , qui eſt entre les poins E & D , eſgale à $\frac{2\sqrt{v}}{pn}$, il faut appliquer ſur ce point E vne longue reigle, en telle façon qu'eſtant auſſy appliquée ſur le point A

OPTICKS:

OR, A

TREATISE

OF THE

REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

SPECIES and MAGNITUDE

OF

Curvilinear Figures.

LONDON,
Printed for SAM. SMITH, and BENJ. WALFORD,
Printers to the Royal Society, at the *Prince's Arms* in
St. *Paul's* Church-yard. MDCCIV.

**LIGHT, GRAVITY, AND GOD:
NATURAL THEOLOGY IN THE PHYSICS OF ISAAC NEWTON**

In a 1676 letter to his rival Robert Hooke, Isaac Newton wrote that if he had seen further than his contemporaries, it was only by standing on the shoulders of giants.[2] Those giants must have been very tall indeed, as the sweep of Newton's scientific vision was immense. This letter preceded by nearly a decade Newton's monumental *Philosophia Naturalis Principia Mathematica (The Mathematical Principles of Natural Philosophy)* (1687)[3] and by nearly three decades his *Opticks: Or, a Treatise of the Reflexions, Refractions, Inflexions and Colours of Light* (1704)—the latter of which is on display in *Imprints and Impressions*. Newton was notoriously sensitive to criticism, and he apparently delayed the publication of *Opticks* until the year following Hooke's death because he had taken offense at comments Hooke had made regarding its content.

The *Principia Mathematica* and *Opticks* resulted in revolutionary leaps forward in humankind's understanding of gravity and light, respectively. And though we better understand these two phenomena today as a result of relativity theory and quantum mechanics, the two revolutionary innovations of twentieth-century physics, complete elucidations of the nature of gravity and light and their relationship to each other remain elusive to the present day. For example, the existence of the graviton—the particle believed to mediate the gravitational force—has yet to be demonstrated. Likewise, the relationship of gravity to quantum mechanics and to the other three fundamental forces in nature—electromagnetic, weak nuclear, and strong nuclear, each of which is incomprehensibly stronger than gravity—remains unclear. And one need look no further than the famous wave-particle duality of quantum mechanics to see that physicists are still somewhat in the dark as to the exact nature of the fundamental quantum of light known as the photon: Is it a wave, or is it—as Newton believed—a corpuscle (particle)?

Though he followed closely on the heels of Galileo, Newton (ostensibly an orthodox Protestant, but really a clandestine Unitarian with an interest in alchemy and magic) did not face potential censure from Rome. Even so, the *Principia Mathematica* and *Opticks* were both based in part on natural theology, as Newton derived much of his science from what he believed was the handiwork of God in nature. In fact, Newton consciously intended these books as partial apologetics for theism, as he took pains to make clear in the second edition of *Opticks*, published in 1717, to ensure that his ideas were not being used by freethinkers with antitheistic agendas.

2
Richard S. Westfall, *The Life of Sir Isaac Newton*, ed. H.W. Turnbull (London: Cambridge University Press, 1993) 102–106.

The Correspondence of Isaac Newton, Vol. I, 1661–1675 (London: Cambridge University Press, 1959) 416–417.

3
Though a part of the Rose Rare Book Collection, this volume is not on display in the *Imprints and Impressions* exhibit.

LEFT

ISAAC NEWTON

OPTICKS: OR, A TREATISE OF THE REFLEXIONS, REFRACTIONS, INFLEXIONS AND COLOURS OF LIGHT

London, 1704

First edition

RIGHT · DETAIL

CARL LINNAEUS

SYSTEMA NATURAE (A GENERAL SYSTEM OF NATURE)

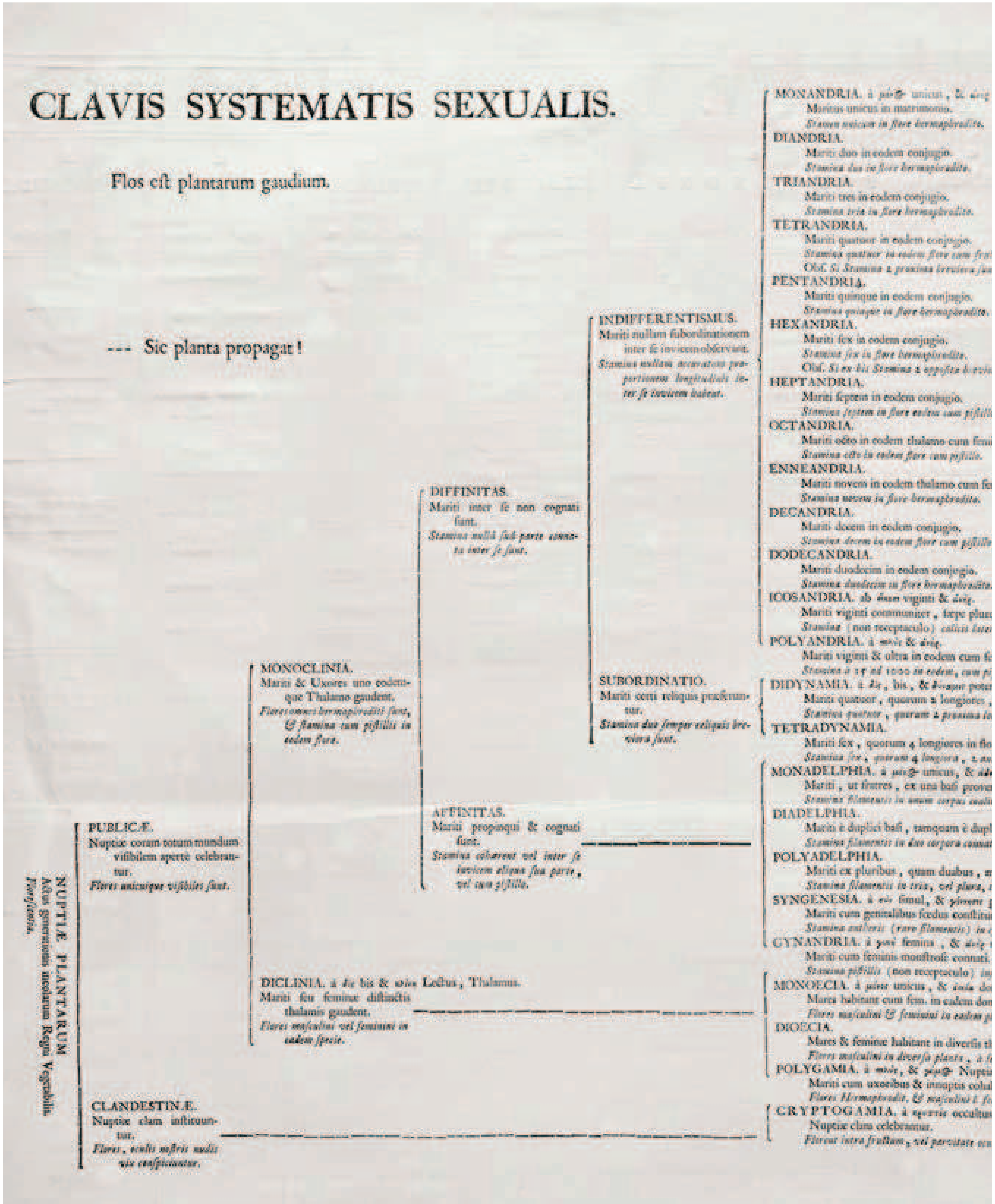
Leiden, 1735

First edition

THE CLASSIFICATION AND ORIGIN OF BIOLOGICAL SPECIES: LINNAEUS AND DARWIN

Carl Linnaeus (1707–1778), the son of a Swedish Lutheran minister, was a gifted observer of nature with a gift for categorization. With the publication of his *Systema Naturae (A General System of Nature)* in 1735, he laid the foundation of the system still used by biologists today for the classification for living organisms. Though principally a botanist (as well as an avowed theist), Linnaeus anticipated Darwin by more than a century when he classified human beings as animals; he numbered them among the primates, as scientists still do today.

Charles Darwin (1809–1882) was raised in a Christian nonconformist home in England in the early 1800s; upon failing in his studies to become a physician, he seriously considered entering Christian ministry. During this time, which preceded his famous journey to South America on the HMS *Beagle*, he was influenced by geologists who advocated the idea of an ancient earth—an idea held by most scientists today. He was thus primed for the gradual revolution in thought that came about during his five-year nautical expedition (1831–1836).



CLAVIS SYSTEMATIS SEXUALIS.

Flos eſt plantarum gaudium.

--- Sic planta propagat!

NUPTIÆ PLANTARUM
Actus generationis incolarum Regni Vegetabilis.
Floreſcentia.

PUBLICÆ.
Nuptiæ coram totum mundum viſibilem apertè celebrantur.
Flores unicuique viſibiles ſunt.

MONOCLINIA.
Mariti & Uxores uno eodemque Thalamo gaudent.
Flores omnes hermaphroditi ſunt, & ſtamina cum piſtillis in eodem flore.

DIFFINITAS.
Mariti inter ſe non cognati ſunt.
Stamina nullâ ſuâ parte connata inter ſe ſunt.

INDIFFERENTISMUS.
Mariti nullam ſubordinationem inter ſe invicem obſervant.
Stamina nullam determinatam proportionem longitudinis inter ſe invicem habent.

MONANDRIA. à ... unicus, & ...
Maritus unicus in matrimonio.
Stamen unicum in flore hermaphrodito.
DIANDRIA.
Mariti duo in eodem conjugio.
Stamina duo in flore hermaphrodito.
TRIANDRIA.
Mariti tres in eodem conjugio.
Stamina tria in flore hermaphrodito.
TETRANDRIA.
Mariti quatuor in eodem conjugio.
Stamina quatuor in eodem flore cum fru...
Obſ. *Si Stamina 2 proxima breviora ſu...*
PENTANDRIA.
Mariti quinque in eodem conjugio.
Stamina quinque in flore hermaphrodito.
HEXANDRIA.
Mariti ſex in eodem conjugio.
Stamina ſex in flore hermaphrodito.
Obſ. *Si ex his Stamina 2 oppoſita brevio...*
HEPTANDRIA.
Mariti ſeptem in eodem conjugio.
Stamina ſeptem in flore eodem cum piſtill...
OCTANDRIA.
Mariti octo in eodem thalamo cum femi...
Stamina octo in eodem flore cum piſtillo.
ENNEANDRIA.
Mariti novem in eodem thalamo cum fe...
Stamina novem in flore hermaphrodito.
DECANDRIA.
Mariti decem in eodem conjugio.
Stamina decem in eodem flore cum piſtillo...
DODECANDRIA.
Mariti duodecim in eodem conjugio.
Stamina duodecim in flore hermaphrodito.
ICOSANDRIA. ab ... viginti & ...
Mariti viginti communiter, ſæpe plur...
Stamina (non receptaculo) *calicis late...*
POLYANDRIA. à ... & ...
Mariti viginti & ultra in eodem cum fe...
Stamina à 15 ad 1000 in eodem, cum pi...

SUBORDINATIO.
Mariti certi reliquis præferuntur.
Stamina duo ſemper reliquis breviora ſunt.

DIDYNAMIA. à ..., bis, & ... pote...
Mariti quatuor, quorum 2 longiores, ...
Stamina quatuor, quorum 2 proxima lo...
TETRADYNAMIA.
Mariti ſex, quorum 4 longiores in flo...
Stamina ſex, quorum 4 longiora, 2 ...

AFFINITAS.
Mariti propinqui & cognati ſunt.
Stamina cohærent vel inter ſe invicem aliqua ſua parte, vel cum piſtillo.

MONADELPHIA. à ... unicus, & ...
Mariti, ut fratres, ex una baſi prove...
Stamina filamentis in unum corpus coali...
DIADELPHIA.
Mariti è duplici baſi, tamquam è dupl...
Stamina filamentis in duo corpora coaua...
POLYADELPHIA.
Mariti ex pluribus, quam duabus, m...
Stamina filamentis in tria, vel plura, ...
SYNGENESIA. à ... ſimul, & ...
Mariti cum genitalibus fœdus conſtitu...
Stamina antheris (raro filamentis) in ...
GYNANDRIA. à ... femina, & ...
Mariti cum feminis monſtroſè connati.
Stamina piſtillis (non receptaculo) *in...*

DICLINIA. à ... bis & ... Lectus, Thalamus.
Mariti ſeu feminæ diſtinctis thalamis gaudent.
Flores maſculini vel feminini in eadem ſpecie.

MONOECIA. à ... unicus, & ... do...
Mares habitant cum fem. in eadem dom...
Flores maſculini & feminini in eadem p...
DIOECIA.
Mares & feminæ habitant in diverſis th...
Flores maſculini in diverſa planta, à f...
POLYGAMIA. à ..., & ... Nupti...
Mariti cum uxoribus & innuptis cohab...
Flores Hermaphroditi, & maſculini l. fe...

CLANDESTINÆ.
Nuptiæ clam inſtituuntur.
Flores, oculis noſtris nudis vix conſpiciuntur.

CRYPTOGAMIA. à ... occultus...
Nuptiæ clam celebrantur.
Flores intra fructum, vel parvitate ocu...

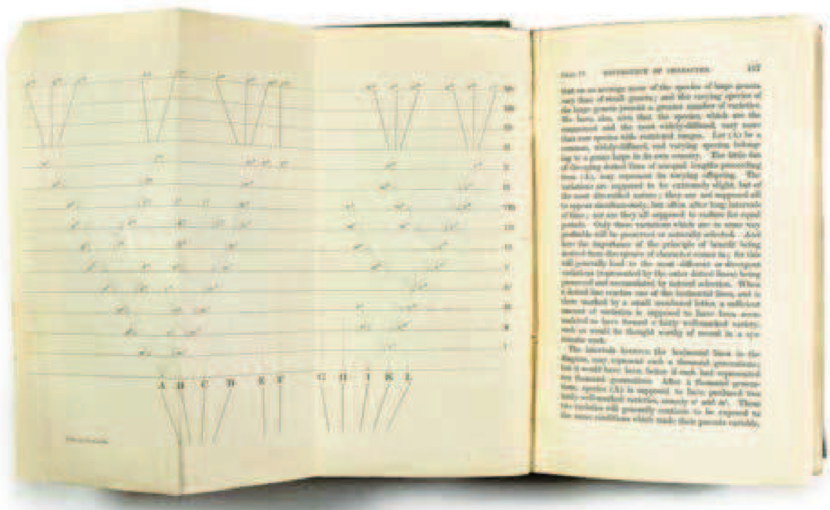
DETAIL

BOOK OF THE DEAD: THE BOOK OF GOING FORTH BY DAY OF THE PRIESTESS TA-ER-PET (THE PAPYRUS MACGREGOR)

Late 1st century BC

23 feet, 6 inches long, divided into nine sections

Includes a unique chart of images depicting 75 protective amulets



The geological observations Darwin made while traveling on the *Beagle* confirmed his preconception that the earth was much older than a literalist reading of the Bible would suggest. More importantly, his careful studies of the plants and animals in various South American locales (most famously, the fourteen different species of finches he observed in the Galapagos Islands, each adapted to its own specific habitat) convinced him that life had developed slowly over eons as a result of organisms progressively adapting. This process of adaptation was mediated by natural selection, in which small but favorable changes in organisms conferred a selective advantage to those that underwent the most favorable changes. Over long periods of time, then, some species survived, while others died off in a kind of biological, Malthusian survival-of-the-fittest contest: evolution.

"Human development is driven by innate tendencies.… Education is most effective when the environment encourages and supports and cultivates these tendencies. In other words, effective education depends on the integration of hereditary and environmental factors."

DONALD J. POLZELLA · PAGE 98

Though his evolutionary ideas began to crystallize during his journeys on the *Beagle*, it was more than twenty years later that Darwin published his seminal work *On the Origin of Species* (1859), in which he for the first time detailed his theory of evolution. The delay was due in part to Darwin's cautious nature. He wanted to be sure he presented a thoroughly convincing case when he went to press and consequently collected reams of data during the twenty or so years between his initial conception and the publication of the *Origin*. He also anticipated that his proposal would be fraught with controversy because of its theological implications, which was another factor in the delay. The *Origin* met with less initial resistance than Darwin anticipated, but opposition eventually did come and continues in the present.

In hindsight, the ideas Darwin presented in the *Origin* are all the more remarkable given that he lived prior to the discovery of genes or DNA and hence could have known little about the chemical mechanisms that give rise to heredity and mutations—the invisible, driving forces behind natural selection. Darwin continued to develop his ideas subsequent to the publication of the *Origin* and eventually published *The Descent of Man*[4] (1871), in which he speculated on the evolution of humankind and the evolutionary origins of religion—anticipating the field known as evolutionary psychology.

4 Though part of the Rose Rare Book Collection, *The Descent of Man* is not on display in the *Imprints and Impressions* exhibit.

For all of his knowledge and genius, Darwin possessed the attractive humility characteristic of many thoughtful agnostics, in whose number he counted himself. Because he was openly ambivalent about the existence of God, Darwin was not given to the hubris that dogmatists on both sides of the theist-atheist divide manifest today. Were he with us now, he would be among the calmer, more reasonable voices in the culture wars that surround evolutionary thought.

LEFT · DETAIL

CHARLES DARWIN

ON THE ORIGIN OF SPECIES

London, 1859

First edition

Presentation copy

THE NUCLEAR AGE: CURIE, EINSTEIN, AND THE SPECIAL THEORY OF RELATIVITY

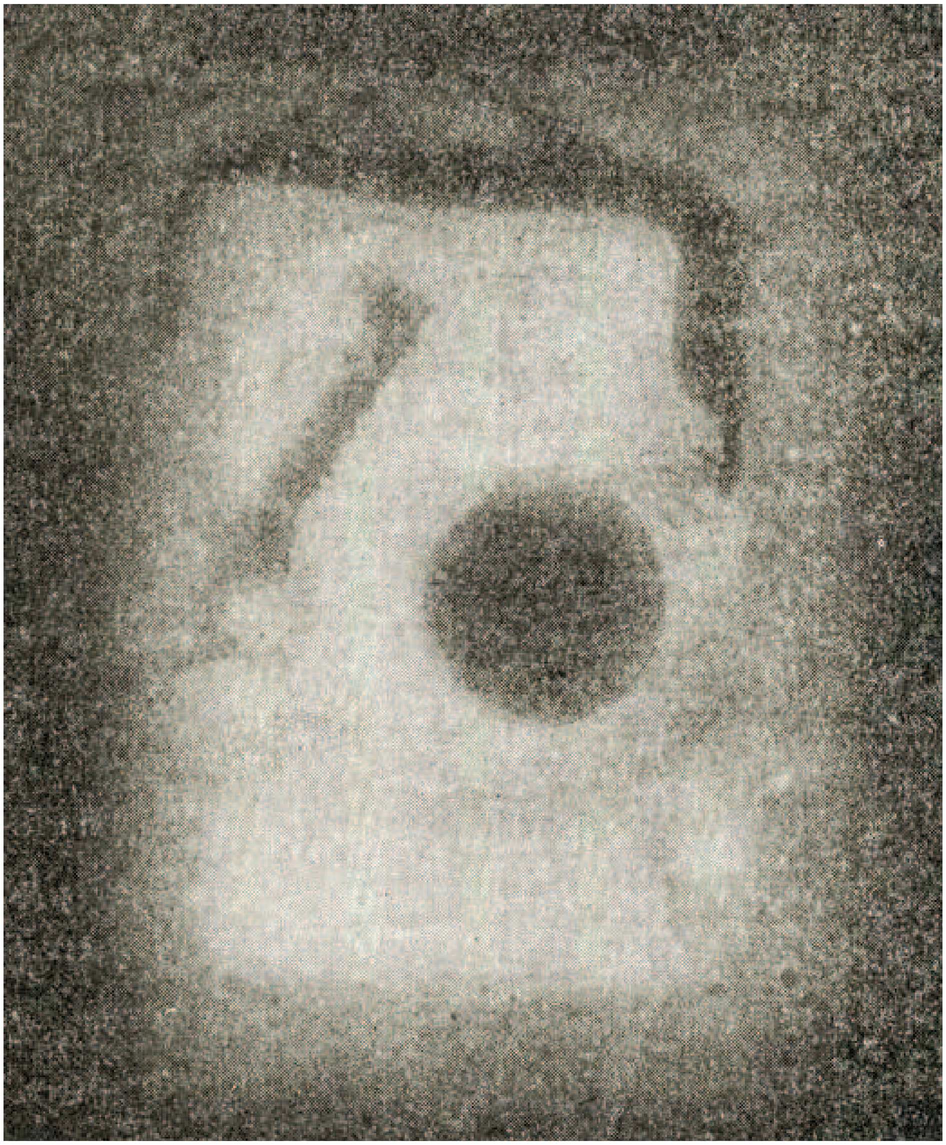
The foundations of the nuclear age, with its blessings and curses, were laid over the course of the last decade of the nineteenth century and the first decade of the twentieth by Marie Skłodowska Curie and Albert Einstein. Curie was a Polish prodigy who, in pursuit of a career in science, overcame remarkable obstacles, not least of which was a strong bias against female academics in her home country and in Paris, where she made her most important discoveries.

Working in collaboration with her research advisor Henri Becquerel and her husband, Pierre, Curie characterized the newly discovered phenomenon of radiation, as well as the radioactive substances from which it emanated. One of these substances was a previously undiscovered element, which Curie named *polonium* in honor of her homeland. Because of the strong bias present in the scientific community of her day, her 1903 doctoral thesis, *Recherches sur les substances radioactives* (*Research into the Properties of Radioactive Substances*), was accepted only with considerable difficulty—yet she received the Nobel Prize in Physics in December of that same year, thereby becoming the first woman to win a Nobel Prize in any discipline.

Her efforts over the next several years involved the purification and isolation of the element radium from the mineral pitchblende. This was difficult and tedious work that required the separation of the new radioactive element radium from its close chemical cousin barium, which is also present in pitchblende. In spite of her efforts, Curie was able to extract only seven-hundredths of a gram of radium from a ton of pitchblende. She was awarded the Nobel Prize in Chemistry in 1911, making her the only person to date to win Nobel Prizes in multiple sciences.

Although scientific research was her life's work, Curie was given to strong humanitarian motivations.

Working with her seventeen-year-old daughter, Irène (who later shared the 1935 Nobel Prize for Chemistry with her husband, Frédéric Joliot-Curie), the elder Curie developed and deployed mobile radiography units to diagnose and disinfect battlefield wounds for more than one million soldiers on the battlefields of France during World War I.



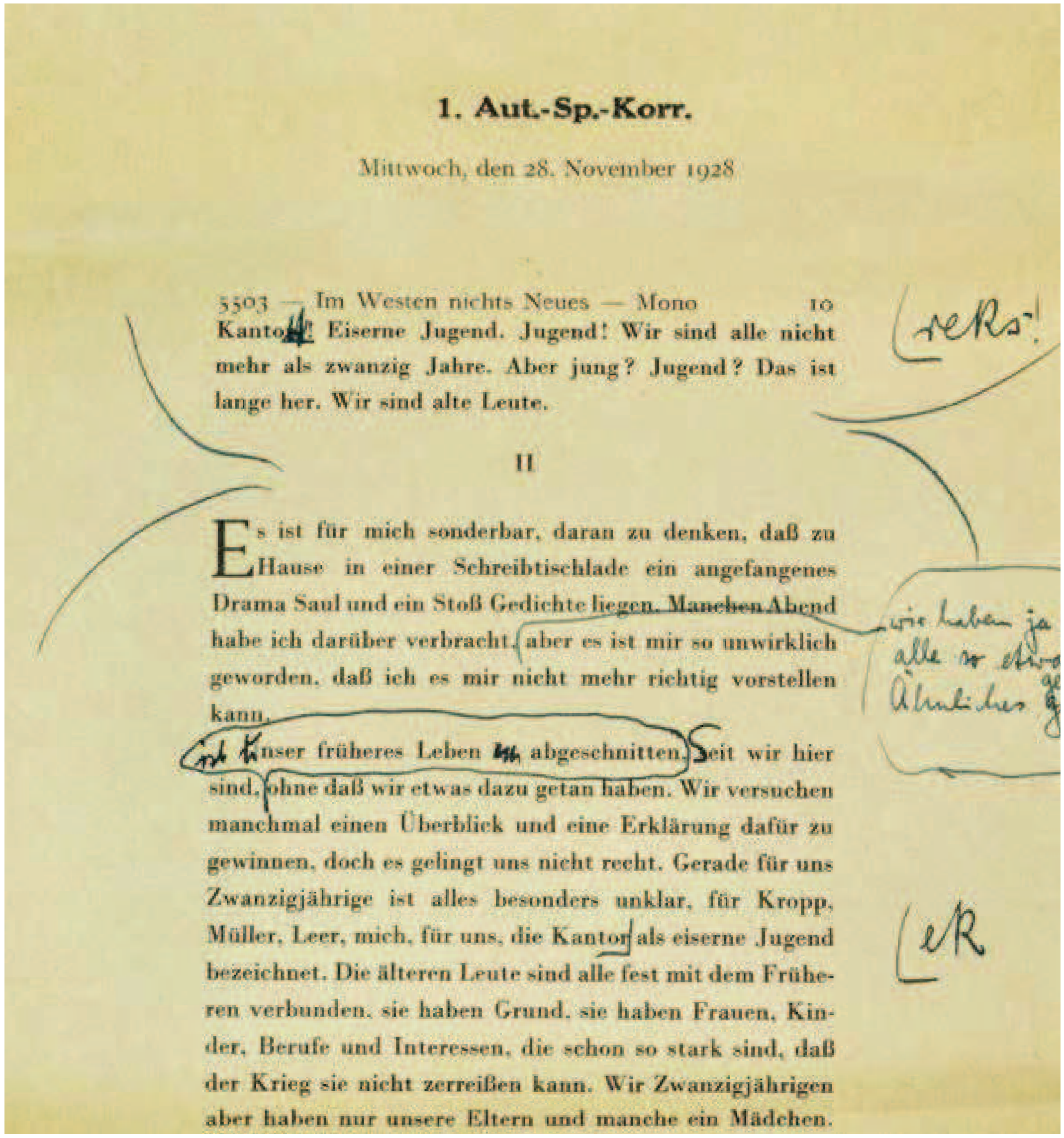
DETAIL

MARIE CURIE

THÈSE DE MARIE CURIE

1903

Presentation copy of thesis, Recherches sur les substances radioactives (Research into the Properties of Radioactive Substances)



1. Aut.-Sp.-Korr.

Mittwoch, den 28. November 1928

5503 — Im Westen nichts Neues — Mono 10

Kantor: Eiserne Jugend. Jugend! Wir sind alle nicht mehr als zwanzig Jahre. Aber jung? Jugend? Das ist lange her. Wir sind alte Leute.

II

Es ist für mich sonderbar, daran zu denken, daß zu Hause in einer Schreibtischlade ein angefangenes Drama Saul und ein Stoß Gedichte liegen. ~~Manchen Abend habe ich darüber verbracht,~~ aber es ist mir so unwirklich geworden, daß ich es mir nicht mehr richtig vorstellen kann.

Unser früheres Leben ist abgeschnitten, seit wir hier sind, ohne daß wir etwas dazu getan haben. Wir versuchen manchmal einen Überblick und eine Erklärung dafür zu gewinnen, doch es gelingt uns nicht recht. Gerade für uns Zwanzigjährige ist alles besonders unklar, für Kropp, Müller, Leer, mich, für uns, die Kantor als eiserne Jugend bezeichnet. Die älteren Leute sind alle fest mit dem Früheren verbunden, sie haben Grund, sie haben Frauen, Kinder, Berufe und Interessen, die schon so stark sind, daß der Krieg sie nicht zerreißen kann. Wir Zwanzigjährigen aber haben nur unsere Eltern und manche ein Mädchen.

After the war, Curie resumed her research efforts and wrote an account of her war experiences, as well as a biography of her husband, who died in an accident on a Paris street in 1907; she never remarried. She became an internationally renowned figure, directed the Radium Institute (known today as the *Institut Curie*), and served on the International Commission for Intellectual Cooperation of the League of Nations and the International Atomic Weights Commission. She died in 1934

CHEMICAL WEAPONS IN
ALL QUIET ON THE WESTERN FRONT

In Chapter 4 of *Im Westen nichts Neues (All Quiet on the Western Front)* (1929), Erich Maria Remarque describes the horrific impact of a poison gas attack on German soldiers fighting in the trenches in France during World War I. There is of course historic fact to back up this fictional account, based in part on Remarque's personal experiences, as chemical weapons (usually chlorine or mustard gas, the large-scale manufacture of which was facilitated by improvements in chemical knowledge and technology) were responsible for more than 91,000 deaths and 1.2 million hospitalizations during the Great War. Remarque forces readers to ask why so much scientific effort is dedicated to the development of destructive technologies. Remarque knew that, like all human endeavors, science is a double-edged sword that can be used for good or evil.

MARK MASTHAY

LEFT · DETAIL

ERICH MARIA REMARQUE

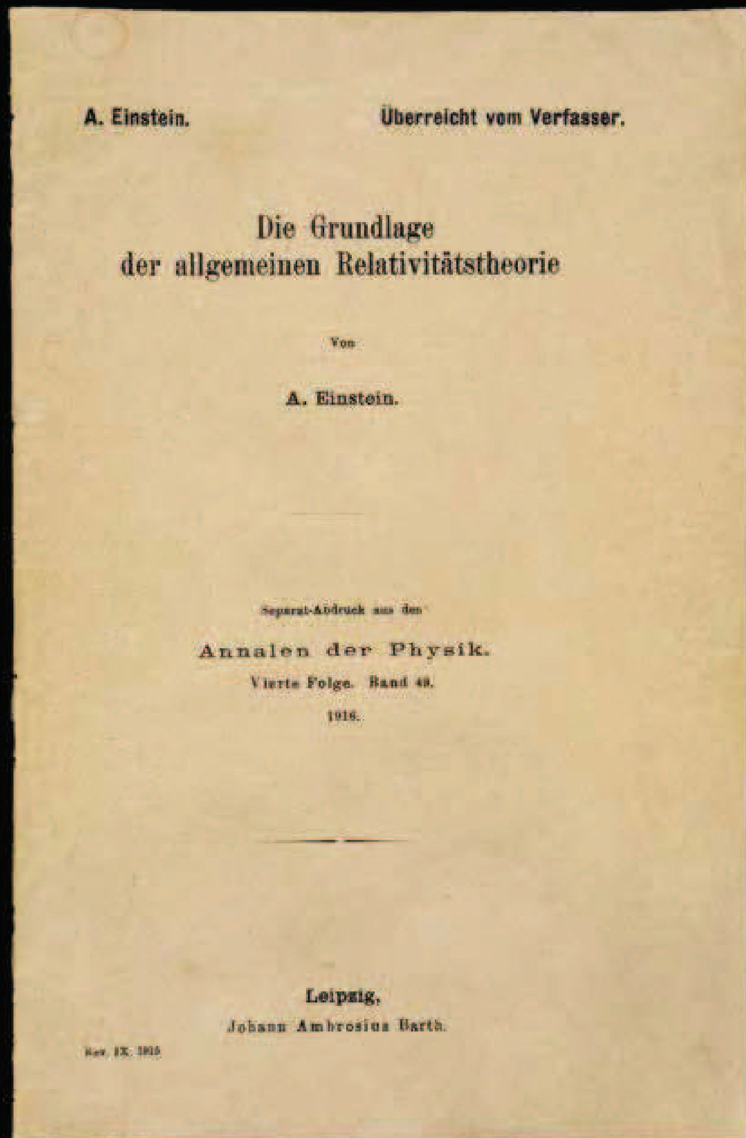
IM WESTEN NICHTS NEUES (ALL QUIET ON THE WESTERN FRONT)

1928

Corrected galley proofs
in author's hand

The 1929 first edition is also included in the exhibition.

of aplastic anemia, which almost certainly originated from her work with radioactive materials without protective equipment for many years; the harmful effects of radiation were not adequately appreciated during the early portion of her scientific career. Her cookbook remains radioactive to this day, as do her research papers from the 1890s—the latter to such an extent that those studying them are required to wear protective clothing.


A. Einstein. Überreicht vom Verfasser.

Die Grundlage
der allgemeinen Relativitätstheorie

Von

A. Einstein.

Separat-Abdruck aus den

Annalen der Physik.

Vierte Folge. Band 49.

1916.

Leipzig,

Johann Ambrosius Barth.

ALBERT EINSTEIN

DIE GRUNDLAGE DER ALLGEMEINEN RELATIVITÄTSTHEORIE (THE FOUNDATION OF THE GENERAL THEORY OF RELATIVITY)

1916

First edition

Presentation issue

ANNE FRANK

HET ACHTERHUIS (ANNE FRANK: THE DIARY OF A YOUNG GIRL)

Amsterdam, 1947

First edition in Dutch

The first edition printed in the United States (New York, 1952) is also included in the exhibition.

During the same years that Curie was isolating radium from pitchblende, the young German physicist Albert Einstein was working as a patent clerk in Switzerland. His research efforts were remarkably productive during this period, resulting in articles that explained, among other things, the photoelectric effect (1905) and the special theory of relativity (1905). This second work led Einstein to the highly counterintuitive and revolutionary conclusion that the speed of light is the same in all inertial reference frames—which by definition move at constant speed with respect to each other—because space contracts and time lengthens proportionally as the speed of a reference frame increases.

"Einstein imagined two men trying to determine the precise moment a speeding train reaches a location along its path. One of the men does this while he is riding on the train; the other does this while he is standing on the station platform as the train passes. According to the theory, each man will mark the event at a different time. The implication for the social sciences is that reality is relative, not objective. Put more simply, one person's experience of an event will be different from another person's experience of the same event."

DONALD J. POLZELLA · PAGE 98

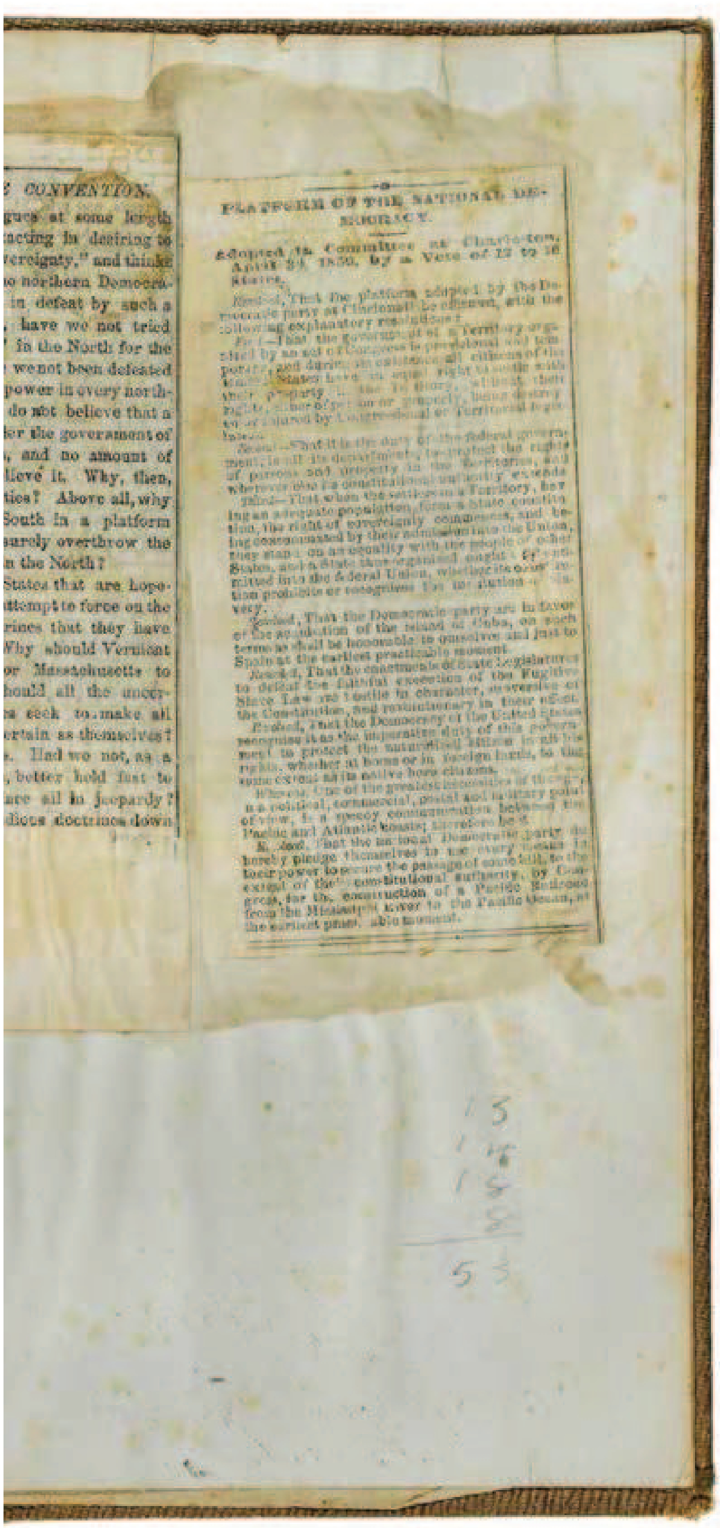
It was in the context of his work on special relativity that Einstein derived his famous equation $E=mc^2$, which states that the energy equivalent E of a mass m is equal to the mass multiplied by the square of the speed of light c. This equation explains the incredible energies released in nuclear reactions and lies at the heart of efforts to harness nuclear energy for peacetime use. It also informed the efforts of the scientists and engineers who developed the atomic bombs dropped on Hiroshima and Nagasaki, Japan, to end World War II—a development Einstein came to regret, at least in part, during his later years.

NEWTON'S GRAVITATIONAL THEORY MODIFIED BUT NOT ABANDONED:

EINSTEIN AND THE GENERAL THEORY OF RELATIVITY

Einstein's 1918 article *Die Grundlage der allgemeinen Relativitätstheorie (The Foundation for the General Theory of Relativity)* was the first publication by Einstein detailing his greatest intellectual achievement, in which—like Isaac Newton three centuries earlier—he attempted to characterize gravity. Like the special theory developed twelve years earlier, the general theory of relativity is counterintuitive and—as its title indicates—applies to a wider variety of systems and conditions. The special theory explained why the speed of light is constant in all inertial reference frames; the general theory explains why light moves with the same speed in all non-inertial reference frames, which are by definition accelerated with respect to each other. According to Newton's Second Law of Motion—force equals mass times acceleration (F=ma)—two reference frames that are accelerated with respect to each other will behave as though a gravitational force is acting between them. The general theory thus specifies the relationship between gravitation and the geometric structure of *space–time*—that all-important, science fiction-sounding, real-but-mysterious fundamental fabric of the universe—essential to modern technologies such as cellphones and satellites.

The general theory amplified Newton's theory of gravitation without contradicting it. Einstein did not negate Newton; Newton's model is perfectly good and is still used by physicists under the conditions to which it applies (which is most conditions). Einstein's model simply applies to a broader range of conditions and explains phenomena Newton's model cannot address. Consequently, Einstein's general theory has become the standard by which all modern theories of gravitation and cosmology are judged today. That said, it is somewhat surprising that though his special and general theories of relativity made him famous, it was for his explanation of the photoelectric effect, published sixteen years earlier, that he received the 1921 Nobel Prize in Physics.



A NONSCIENTIFIC SIDEBAR:
EUCLID, THE SPANISH BIBLE, AND LINCOLN

It is interesting to note that three centuries after the Spanish Protestant Casiodoro de Reina published a translation of the Bible into his native vernacular, Protestant ministers on the Illinois frontier impacted Lincoln's antislavery sentiments as well as his political discourse: He quoted the synoptic Gospels when he laid out the central thesis of his famous "House Divided" speech at the Illinois Republican State Convention in June of 1858, thereby initiating *The Lincoln-Douglas Debates* conducted later that year. While the Spanish Bible in *Imprints and Impressions* did not directly impact Lincoln's politics, ideas similar to de Reina's did.

Also worthy of note: Though it undoubtedly had little impact on his politics, Lincoln prided himself on having mastered the first six books of Euclid's *Elementa Geometrica (Elements of Geometry)* in the years leading up to his presidency.

MARK MASTHAY

DETAIL

ABRAHAM LINCOLN

POLITICAL DEBATES BETWEEN HON. ABRAHAM LINCOLN AND HON. STEPHEN A. DOUGLAS IN THE CELEBRATED CAMPAIGN OF 1858, IN ILLINOIS

Columbus, 1860

First edition

First issue

Presentation copy

CONCLUSION

The books in the *Imprints and Impressions* exhibit played significant roles in a number of the most important events in the history of science, dating from the eleventh century to the present day. These books reveal the genius and the limitations of Maimonides's and Aquinas's Aristotelian–Biblical synthesis in the eleventh and twelfth centuries, as well as a later, negative role in suppressing the heliocentric view of the universe expounded by Copernicus, Kepler, and Galileo.

The books also touch on the radical changes in our view of the universe engendered by the theories of gravitation developed in the seventeenth and twentieth centuries by Newton and Einstein. Newton combined the empirical observations of his heliocentric predecessors with the predictive and explanatory power of mathematical physics. Einstein expanded upon Newton's model in his general theory of relativity without contradicting Newton; his model is now the standard by which all modern gravitational and cosmological models are judged.

Along with Curie, who discovered and characterized radioactive compounds against the difficult odds faced by the female scientists of her day, Einstein gave birth to the nuclear age with his special theory of relativity, which radically changed our view of space and time by demonstrating that they are *relative*—not absolute—entities, contingent upon the reference frame from which they are observed. In the process, he also derived his famous equation $E=mc^2$, which anticipated the promise of nuclear energy and the profound destructive power of nuclear weapons. Within forty years of the date of publication of the special theory, weapons based on this equation were used, a fact for which Einstein was not entirely grateful. Given her humanitarian bent, it is almost certain that Curie would have shared Einstein's regret had she been alive at the end of World War II.

The scientist Curie also shared a common bond with the novelist Remarque: Both had been present on the battlefields of France during the First World War, the latter as a soldier in the German army, the former as a medical worker who used the radium she had procured in her laboratory to disinfect wounds, thereby showing how scientific discovery may be used for humanitarian ends.

The combined efforts of Linnaeus in the eighteenth century and Darwin in the nineteenth gave birth to Darwin's famous theory of evolution, which so radically and controversially changed our view of the origin of life, human and nonhuman, as well as the entire biological research enterprise. Their work lies at the root of many of the battles being fought in today's culture wars.

That said, one important aspect of the scientific research enterprise cannot be revealed by the books in *Imprints and Impressions*, precisely because these books are *classics*. As central as they are to scientific progress, the seeming leaps of reason by luminaries like Aquinas, Galileo, Newton, Darwin, Curie, and Einstein are contingent upon the summative, incremental progress generated by the large numbers of scientists of lesser ability putting in long hours at the research bench and in the field. These average scientists provide the shoulders—individually short yet collectively tall—on which the luminaries stand to see further than the rest of us.

RIGHT

PHILLIS WHEATLEY

POEMS ON VARIOUS SUBJECTS, RELIGIOUS AND MORAL

London, 1773

First book published by an African American

Frontispiece illustration of author is by African American slave artist Scipio Moorhead.

Taken as a whole, the *Imprints and Impressions* exhibit reveals the indispensability of the scientific method, with its reliance on empirical observation, as well as the need for magnanimity and deferred judgment on the part of existing authority in the absence of evidence that convincingly contradicts new findings. In this regard, both conservatives and visionaries have essential roles to play. Conservatives—who resist change and emphasize the value of established doctrines and truths—set a high bar for the acceptance of new ideas. Without them, changing existing scientific paradigms becomes too easy, and truth becomes cheap. Visionaries—who promote change by challenging established doctrines and truths when new evidence becomes available—surmount the conservative high bars when their new evidence is convincing enough. Without them, changing existing scientific paradigms becomes too difficult, and truth becomes ossified.

Time, ink, and my readers' patience will fail if I go on to discuss books in the exhibit that impacted the nonphysical sciences: Karl Marx's *Das Kapital: Kritik der politischen Oekonomie (Capital: A Critique of Political Economy)* (1867), which impacted economics and political theory, not to mention the geopolitics of the twentieth century, and Sigmund Freud's *Die Traumdeutung (The Interpretation of Dreams)* (1900), which initiated psychoanalysis, thereby revolutionizing the field of human psychology. I thus close with an observation made by Marx in his *Theses on Feuerbach*, published posthumously in 1888: "Philosophers have hitherto only interpreted the world in various ways; the point is to change it." On that standard, the authors of the works in the *Imprints and Impressions* exhibit turn Marx on his head: They changed the world by interpreting it.