



LUND UNIVERSITY

The Literary Construction of the Universe

Narratives of Truth, Transcendence, and Triumph in Contemporary Anglo-American Popularizations of Physics and Astronomy

Helsing, Daniel

2019

Document Version:

Publisher's PDF, also known as Version of record

[Link to publication](#)

Citation for published version (APA):

Helsing, D. (2019). *The Literary Construction of the Universe: Narratives of Truth, Transcendence, and Triumph in Contemporary Anglo-American Popularizations of Physics and Astronomy*. [Doctoral Thesis (monograph), Centre for Languages and Literature]. Centre for Languages and Literature, Lund University.

Total number of authors:

1

General rights

Unless other specific re-use rights are stated the following general rights apply:

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00



The Literary Construction of the Universe

Narratives of Truth, Transcendence, and Triumph in
Contemporary Popularizations of Physics and Astronomy

Daniel Helsing

“Science” is a historically variable, connotationally rich, and contested term. No single institution, individual, or group of individuals can claim definitional authority over its meaning. The use of “science” carries weight and credibility in society, at least in many sectors. Yet while “science” is a contested term over which no one can claim definitional authority, science is defined and carried out in practice around the world daily. It is defined in dictionaries and mission statements by scientific organizations, in education guidelines and high school curricula, in media coverage and science fiction novels, and in popular science books.

In this dissertation, Daniel Helsing analyzes the construction of the universe, science, and humankind in contemporary mainstream Anglo-American popularizations of physics and astronomy. He shows that popularizers use literary techniques and rhetorical strategies to construct and explain science, to represent the universe and humankind’s place in the universe, and to evoke aesthetic and emotional responses in their readers.



LUND
UNIVERSITY

CRITICA LITTERARUM LUNDENSIS
Centre for Languages and Literature
ISBN 978-91-7895-237-3
ISSN 1651-2367



THE LITERARY CONSTRUCTION OF THE UNIVERSE

The Literary Construction of the Universe

Narratives of Truth, Transcendence, and Triumph in
Contemporary Anglo-American Popularizations of
Physics and Astronomy

Daniel Helsing



LUND
UNIVERSITY

Division of Comparative Literature
Centre for Languages and Literature
CRITICA LITTERARUM LUNDENSIS 18

Cover image: Rembrandt, *Faust in His Study*, c. 1652

Cover design: Staffan Hellkvist, Media-Tryck

© Daniel Helsing, Centre for Languages and Literature

ISBN 978-91-7895-237-3 (print)

ISBN 978-91-7895-238-0 (pdf)

ISSN 1651-2367

Printed in Sweden by Media-Tryck, Lund University
Lund 2019



Media-Tryck is an environmentally certified and ISO 14001:2015 certified provider of printed material. Read more about our environmental work at www.mediatryck.lu.se

MADE IN SWEDEN 

*Watched the scientists throw up their hands,
conceding “progress will resolve it all.”*

—Bad Religion, “Faith Alone” (1990)

Acronyms

AAAS—American Association for the Advancement of Science

AIP—American Institute of Physics

ASLE—Association for the Study of Literature and the Environment

BBC—British Broadcasting Corporation

BSA—British Science Association

BSLS—British Society for Literature and Science

CERN—Conseil Européen pour la Recherche Nucléaire (European Organization for Nuclear Research)

CNN—Cable News Network

ERC—European Research Council

ID—Intelligent Design

LHC—Large Hadron Collider

NAS—National Academy of Sciences

NASA—National Aeronautics and Space Administration

NASEM—National Academy of Sciences, Engineering, and Medicine

NPR—National Public Radio

NSB—National Science Board

NSF—National Science Foundation

PBS—Public Broadcasting Service

SLAC—Stanford Linear Accelerator Center

SLSA—Society for Literature, Science and the Arts

SSK—Sociology of Scientific Knowledge

STEM—Science, Technology, Engineering, Mathematics

STS—Science and Technology Studies

TEUSH—Triumphant Epic of the Universe, Science, and Humankind

WCD—Western Culturally Dominant

WEIRD—Western, Educated, Industrialized, Rich, and Democratic

Contents

Introduction.....	13
The Term “Popular Science”.....	18
The Emergence of Western Science and the Challenges of Popularization.....	20
Aim and Research Questions.....	27
Theory, Method, and Material.....	28
Theoretical Frameworks and Concepts.....	28
Selection Criteria, Scope, and Delimitation.....	36
Previous Research.....	47
Outline of the Dissertation.....	49
1. Science and Popularization: Historical Perspectives.....	51
“Popular Science” before the “Scientific Revolution”.....	53
“Science”.....	53
From Ancient Greece to Early Modern Europe.....	56
1632–1834: From Natural Philosophy to Science.....	58
1834–1945: The Consolidation and Professionalization of Science... 63	
1945–: The Growth of Science and the Popular Science Boom.....	69
Popular Science and Gender.....	74
2. Romanticism Meets Science: Revolt, Reform, and Appropriation.....	77
Romanticism and the Disenchantment of the World.....	80
Romantic Science: Johann Wolfgang von Goethe.....	85
Romantic Scientists? Mary Shelley’s <i>Frankenstein</i>	88
The Romanticization of Science: <i>Cosmos: A Personal Voyage</i>	90
3. Notions of “Science”: Contemporary Perspectives and Definitions... 97	
Academic Disciplines and Cultural Debates.....	98
Pursuing the Essence of Science: Philosophy of Science.....	98

The Emergence of Constructivism: Science and Technology Studies.....	102
The Two Cultures and the Science Wars.....	104
Routine Definitions.....	107
Dictionaries.....	107
Scientific Organizations and Government Agencies.....	110
Public Understanding of Science Surveys.....	111
Science Education.....	112
Intelligent Design versus Science in Court.....	116
The Meaning of Science.....	119
Approaching Consensus?.....	119
Mundane and Transcendent Meaning.....	122
An Absence of Values?.....	125
4. The “Science” in Popular Science: Boundary Work, Idealization, and Scientism.....	129
Definitions of Science in Krauss’s <i>The Greatest Story</i> and Tyson’s <i>Astrophysics</i>	129
The Scientific Attitude.....	131
The Science/Philosophy Boundary.....	133
The Science/Fiction Boundary.....	135
The Science/Human Opinion Boundary.....	138
Scientism.....	141
From Science to Scientism.....	141
Scientism in Society.....	144
Scientism in Popular Science.....	146
Scientism and Reductionism: Wilson, Watson, Weinberg.....	147
The Naturalization of Science and the TEUSH Narrative.....	151
5. Defamiliarization: Uprooting the Reader and Unearthing Reality.....	157
Defamiliarization, Foregrounding, and Perspective.....	159
Scientific Defamiliarizations of the Ordinary World: Greene, Krauss, and Tyson.....	163
Appearance and Reality.....	168

The Cosmic Perspective.....	170
6. Refamiliarization: Resituating the Reader and Representing Everything.....	175
From the Familiar to the Unfamiliar: Figurative Language, Forced Marriages, and the Stardust Metaphor.....	176
The Unfamiliar Made Familiar through Science.....	181
Narrating Everything.....	181
The Ambiguities of Scientific Narration.....	186
7. Protagonists of the Universe: Cosmic Agents and Scientific Characters.....	195
Cosmic Protagonists: Life, Hydrogen, and Stardust.....	196
Individual Protagonists: Detectives, Heroes, and (Male) Geniuses..	199
Detectives of Reality, Heroes Seeing the Light.....	199
Scientific Characters and the Privileges of Male Genius.....	206
Historical Protagonists: A Cosmic Band of Brothers (and Sisters)...	213
8. The Varieties of Scientific Emotion: Creating a Sense of Connection in a Cold Universe.....	215
Emotions of Scientific Discovery and Understanding: Beauty and Wonder.....	218
Emotions of the Cosmic Perspective: Awe and Empathy.....	227
The Naturalization of Scientific Curiosity.....	232
9. The Political and Technological Justifications of Science: Undeclared Preconditions of Science and Side Effects of Civilization.....	237
The Political Justification.....	238
The Technological Justification.....	242
The Social Nature of Technology.....	244
The Specter of Climate Change.....	247
Concluding Remarks.....	253
The Literary Construction of the Universe.....	253
Beyond Triumph and Reductionism: Alternative Narratives of Science.....	255
Loneliness and Despair in Science.....	255
Science as a Golem.....	257

Science in Practice.....	258
Science Reinterpreted.....	259
Tragedy and Wildness.....	260
References.....	265
Popularizations.....	265
Critical and Other Works.....	267
Illustrations.....	299
Index.....	301

Introduction

This dissertation deals with the construction of science, humankind, and the universe through literary techniques and rhetorical strategies in contemporary, mainstream, Anglo-American popularizations of physics and astronomy. It covers the past few decades and focuses on a selection of books by some of the most well-known popularizers today, with a particular focus on American theoretical physicist Lawrence Krauss's *The Greatest Story Ever Told—So Far* (2017) and American astrophysicist Neil deGrasse Tyson's *Astrophysics for People in a Hurry* (2017).¹

American theoretical physicist Brian Greene opens his bestselling book *The Fabric of the Cosmos* (2004) by sharing a story from his childhood. He describes his father's bookcase—filled with “massive tomes” weighing heavy on the shelves—and the reverence he felt for the books. Most of the volumes seemed thick and imposing to the young boy, but not all of them: “way up on the highest shelf was a thin little text that, every now and then, would catch my eye because it seemed so out of place, like Gulliver among the Brobdingnagians” (3). One day, after years of hesitation, Greene reached for the book:

“There is but one truly philosophical problem, and that is suicide,” the text began. I winced. “Whether or not the world has three dimensions or the mind nine or twelve categories,” it continued, “comes afterward”; such questions, the text explained, were part of the game humanity played, but they deserved attention only after the one true issue had been settled. The book was *The Myth of Sisyphus* and was written by the Algerian-born philosopher and Nobel laureate Albert Camus. (3)²

¹ Three or fewer references are in the running text; when the number of references exceeds three, they are in a footnote for clarity's sake. When referencing websites: if the site lacks author, I use the title of the website or the name of the organization whose website it is. Sometimes I derive an acronym from the website or the organization. If website lacks publication date, I use the year when I accessed the site and specify the date of access in the list of references.

² A note on citational practice: Unless otherwise specified, emphasized words in quotations are emphasized in the original. Omitted words and sentences are marked by “. . .”

Camus's words captured Greene's imagination, and Greene recalls wondering how various people he met or heard about would answer Camus's question. But as the years went by, Greene revised his outlook: "I remain as convinced now as I did decades ago that Camus rightly chose life's value as the ultimate question, but the insights of modern physics have persuaded me that assessing life through the lens of everyday experience is like gazing at a van Gogh through an empty Coke bottle" (5). Assessing life without understanding the nature of the universe is premature, according to Greene. By peeling "back layer after layer of the cosmic onion," science guides us toward "the true nature of reality" (5). Science is thus needed to reach a well-informed assessment of life's value. Science is the bedrock of meaning, the finder of truth, the gateway to reality.

Greene's invocations of the arts (*Gulliver's Travels*, Vincent van Gogh) and discussions of philosophical questions are not unique in contemporary, mainstream, Anglo-American popularizations of physics and astronomy.³ Popularizers routinely discuss philosophy, invoke aesthetic experiences, and deploy cultural references in their attempts to make science meaningful, relevant, and appealing. A few examples by some of the best-known popularizers of recent decades indicate just how prevalent "non-scientific" themes and references are in popular science. American astronomer Carl Sagan discusses science fiction several times in the book and television series *Cosmos* (Sagan 1980; Sagan et

³ All these specifications of the primary material—contemporary, mainstream, Anglo-American, physics and astronomy—are discussed below (see pp. 36–46), but a few words about "mainstream" are needed already here. *Oxford Living Dictionaries/Lexico* defines "mainstream" as "The ideas, attitudes, or activities that are shared by most people and regarded as normal or conventional," (Lexico 2019a), and "mainstream media" as "Traditional or established broadcasting or publishing outlets" (Lexico 2019b). (According to a frequently asked questions section at *Oxford Dictionaries'* website, *Oxford Living Dictionaries* "have recently partnered with Dictionary.com to offer [their] free English and Spanish dictionary content through www.lexico.com rather than en.oxforddictionaries.com" [OD 2019].) "Mainstream" and "mainstream media" are also used in this general way by the chapter authors in *The Handbook of Media and Mass Communication Theory* (Fortner & Fackler [eds.] 2014): "mainstream" refers to the dominant and conventional, and "mainstream media" refer to established mass media channels, typically owned by a small number of corporations (Denzin 2014; Ward 2014). My use of "mainstream" coincides with these uses. However, in the discussion below, I do add specificity to the definition in order to characterize the primary material. I understand "mainstream popular science" to include, first, popularizations of *legitimate science* (as opposed to "pseudoscience" such as astrology and Intelligent design), and, second, the science presented as legitimate in the mass media (as opposed to science presented in alternative media channels and fringe groups). It is important to note that "legitimate science" is a sociological category that does not necessarily mean that the science in question is "true"; it only means that it is accepted as legitimate science by the scientific establishment and the mainstream media.

al. [1980] 2009).⁴ British theoretical physicist Stephen Hawking claims that the goal of science is to “discover a complete theory” that can answer the questions of “why it is that we and the universe exist” in *A Brief History of Time* ([2016] 1988: 209–210). British astrophysicist and cosmologist Martin Rees uses a quotation from John Steinbeck’s *The Log from the Sea of Cortez* (1951) as the motto for the first chapter of his *Just Six Numbers* (1999). American physicist and cosmologist Sean M. Carroll plays on the title of the 1951 novel and 1953 film *From Here to Eternity* in the title of his book *From Eternity to Here* (2010). American theoretical physicist Lisa Randall includes a reproduction of Romantic painter Caspar David Friedrich’s *Wanderer Above the Sea of Fog* (1818) when discussing the sublime in her book *Knocking on Heaven’s Door* (2011), the title of which she borrows from a song by Bob Dylan.

However, while philosophical discussions, invocations of aesthetic experiences, and cultural references are common in popular science, thus establishing links between science and other domains and discourses, science as such is typically characterized as something unique. Science may address philosophical issues, and popularizers may invoke popular culture and literary history, but science is usually presented as a well-defined enterprise that is set apart from other activities thanks to its exceptional ability to get at the truth about the universe. Through boundary work—rhetorical strategies used to distinguish science from non-science (Gieryn 1983; Mellor 2003)—science is constructed as reliable, rational, and objective, as distinct from unreliable human opinion, irrational religion, and subjective art.

Yet science is not a clearly delineated enterprise or body of knowledge.⁵ Western science, literature, and philosophy are entangled phenomena with a

⁴ When referring to the television series, I use “Sagan et al.” to indicate that numerous people were involved in the writing and production. The script was co-written by Sagan, Ann Druyan, and Steven Soter. The series was directed by Adrian Malone. Even though the series and the book are very similar—often identically phrased—the book only lists Sagan as author. The series’ subtitle—“A Personal Voyage”—puts further spotlight on Sagan, as does the fact that Sagan is the sole on-screen presenter and narrator. Thus, while it is important to recognize the collaborative nature of *Cosmos*, I often refer to the words in *Cosmos* as Sagan’s—both for the sake of convenience and because he was the front man, so to speak, of both the book and the series.

⁵ I use “science” interchangeably with “the natural sciences.” In English, this should not lead to confusion, since “science” is commonly used that way. For fields like psychology and sociology, the qualifier “social”—i.e., “social sciences”—is usually used. However, not specifying the use of “science” in a Swedish context could lead to confusion, since the corresponding term in Swedish—“vetenskap”—is broader than “science” and includes the social sciences and the humanities.

shared history. This entanglement goes beyond casual invocations of ideas and simple lines of influence between purportedly distinct traditions. That science and philosophy are interwoven historically is fairly obvious, as evidenced not least from the fact that theories of the kind we now call “scientific,” such as Newtonian mechanics, were included under “natural philosophy” well into the nineteenth century, which was when the term “science” acquired its modern meaning (Dear 2006). The science–literature connections are perhaps less obvious. But as historians, literary scholars, and science communication scholars have shown, the idea of a “pure” science that is merely “simplified” in popularizations or “adapted” for use in fiction is deeply misleading and problematic.⁶ In fact, the very idea that “science” and “literature” are separable to begin with is an ideological construct. It is related to the “two cultures” debate sparked by C.P. Snow’s lecture and book *The Two Cultures* ([1959] 1998) and F.R. Leavis’s scathing reply in *Two Cultures?* ([1962] 2013). As historian Guy Ortolano (2009) shows, the two cultures debate, which was framed as “science” versus “the arts” or “literary intellectuals” or “traditional culture,”⁷ is more indicative of competing visions of the history and future of the UK than supposed inherent differences between science and literature.⁸ Rather than accepting “the two cultures” as an accurate description of competing worldviews, Ortolano “seeks to dislodge the ‘two cultures’ as a category of analysis” (26). Similarly, this dissertation rejects the distinction between “literature” and “science” as a valid and useful analytical distinction.

Throughout history and into the present moment, scientific knowledge and culture have in part been constructed and consolidated through representations in works of fiction, from Mary Shelley’s *Frankenstein* (1818) and Aldous Huxley’s *Brave New World* (1932) to *Star Trek* (1966–) and Andy Weir’s *The Martian* (2014). The lines between science and literature are blurred even further by major authors and poets who saw themselves as scientists, such as Johann Wolfgang von Goethe and August Strindberg,⁹ and by major popularizers

⁶ See e.g. Beer (1983); Shinn & Whitley (eds.) (1985); McRae (ed.) (1993); Curtis (1994); Drouin & Bensaude-Vincent (1996); Willis (2006); Leane (2007); Sleight (2010); Zakariya (2017).

⁷ Ortolano (2009) shows that Snow uses “the arts,” “literary intellectuals,” and “traditional culture” vaguely and more or less interchangeably; they are not clearly delineated categories, but rather general terms “of reference for non-scientific things” (22, n77).

⁸ See also Emma Eldelin (2006) for an analysis of how the “two cultures” concept was used and reinterpreted in debates in Sweden.

⁹ See Bortoft (1996) for a study of Goethe’s science; see Johnsson (2015) for a study of

who write science fiction in addition to popular science, such as Carl Sagan (*Contact*, 1985) and Brian Greene (*Icarus at the Edge of Time*, 2008). These kinds of texts contribute to the notions of science and scientists that circulate in society.

Some of the most influential works in scientific history, such as Galileo Galilei's *Dialogue Concerning the Two Chief World Systems* (1632) and Charles Darwin's *On the Origin of Species* (1859), resist classification as *either science or popularization or literature*; they are, or can plausibly be considered to be, everything at once. Galileo, Darwin, and others used literary techniques to promote their theories in broadly publicly accessible texts.¹⁰ Their use of literary techniques and public forums was not accidental. As literary scholar Frédérique Ait-Touati (2011) shows, influential early modern natural philosophers such as Johannes Kepler, Christiaan Huygens, and Robert Hooke—figures that would subsequently be identified as pioneers of the so-called “Scientific Revolution”—used fiction as an essential tool for visualizing, spreading, and arguing for their new theories about the solar system and the microscopic world. When science as we know it was being formulated, the natural philosophers involved drew, as literary scholar Tita Chico (2018) puts it, “on empirical experience, of course, but [they] weighed much more heavily on the imaginative possibilities afforded by literary knowledge. Early scientists used metaphor to define the phenomenon they studied. They also used metaphor to imagine themselves into their roles as experimentalists” (1). Literary techniques were more than mere decorative additives or pedagogical tools; they were fundamental in formulating what science is and does, what constitutes scientific objects and methods, and how to argue scientifically. Likewise, the public contexts were essential in establishing, and subsequently maintaining, the image of science as a reliable and objective mode of knowledge production.

The importance of literary techniques for defining and conveying science in the public sphere continues in the present. For example, the importance of figurative language and narrative form is evident already in Greene's words. Greene uses a striking simile to conceptualize the effects of scientific understanding and to suggest that science is valuable, rewarding, and existentially relevant (“the insights of modern physics have persuaded me that assessing life

Strindberg's science.

¹⁰ By “broadly publicly accessible texts” I mean that the texts were available for purchase. That people from privileged segments of society were more likely to be able to find and purchase those texts is significant, and I return to it in chapter 1 below.

through the lens of everyday experience is like gazing at a van Gogh through an empty Coke bottle”). He uses narrative form to relate childhood experiences in an attempt to personalize science and engage the reader. And more generally, he presents a narrative of science according to which science holds the key to the secrets of the universe, including the value and purpose of human life. These kinds of literary techniques abound in popular science, and they influence and shape, to various degrees, people’s attitudes toward, conceptions of, and expectations about science, humankind, and the universe. And since science is a hugely influential and powerful institution in contemporary societies across the globe, it is important to understand how science, humankind, and the universe are constructed in popular science, what those constructions mean, what functions they serve, and what effects they have.

The Term “Popular Science”

Defining “popular science” is a well-nigh impossible task, the difficulties of which are discussed at length in the literature on popular science.¹¹ First, defining “popular science” is difficult because genres are notoriously hard to define analytically and unambiguously. Genres are fluid and change with time, and simple definitions will always be too wide and/or too narrow—i.e., include works not intended to be included, and/or exclude works intended to be included (Fowler 1982; Hættner Aurelius 2014). But, second, there are deeper problems, specific to popular science. Implicit in the very notion of “popular science” is the idea that popular science is not quite science—it is *science for laypeople*, or, a meaning more common prior to the nineteenth and especially twentieth centuries, *science by laypeople* (see Cooter & Pumfrey 1994; Kärfelt 2000; Broks 2006: 5–49). As noted, this notion implies that there is such a thing as “non-popularized” or “pure” science and that the process of popularization leaves “science” intact. But while scientific work does indeed take place in offices and laboratories far from public view, science, as a social phenomenon, is inseparable from images of science. The definitions of science that matter for the distribution of and access to resources, credibility, and authority are those that circulate and find acceptance in society (Gieryn 1983, 1999). The

¹¹ See e.g. Eriksson & Svensson (1986); Hilgartner (1990); Cooter & Pumfrey (1994); Curtis (1994); Kärfelt (2000); Calsamiglia (2003); Johansson (2003); Mellor (2003); Myers (2003); Broks (2006); Leane (2007); Bensaude-Vincent (2009); Daum (2009); O’Connor (2009); Pandora (2009); Topham (2009); Perrault (2013); Bell & Turney (2014).

notion of popular science as *science for laypeople* also implies that whatever is going on in popular science, it is not *science*—it is simplification or distortion (Hilgartner 1990). But, as shown repeatedly by scholars of popular science, popular science does affect the practices and ideas of scientists and the worldviews associated with science. A prominent example is the emergence of non-linear dynamics, or chaos theory, as a field of study in the 1970s and 1980s. As literary scholar Danette Paul (2004) shows, popularizations—most importantly, James Gleick’s bestselling *Chaos* (1987)—played a pivotal role in the formation of chaos theory as a coherent research field. The more general point is that the idea that science is distinct from popular science reifies science as a pure activity—which it is not and never has been. However, *constructing* science as a pure activity, and thus constructing popularization as simplification or distortion, is in the interest of scientists, because it affirms their authority and lets them define the terms of debate. It saves the integrity of “science” by disqualifying instances of popularization as not “true” or “real” science.

Consequently, I will not present a definition of popular science. Instead, I discuss historical perspectives on the development of popular science in chapter 1. I will, furthermore, retain the concept “popular science,” for two reasons. First, “popular science” is a term used by publishers, critics, and bookstores to denote certain kinds of books, and so it has a social reality and material effects in culture and society. “Popular science” came to be used as a genre label in the nineteenth and early twentieth centuries—at first in the UK, in the 1830s, and later in other countries such as Sweden (Kärnfelt 2000; Topham 2007). Even though the characteristics of the books marketed as popular science have changed over time, it is a widespread and recognizable category of books nonetheless, and so it is useful for that reason. Second, in spite of the problems associated with the term, it is still commonly used by scholars. While the term could profitably be replaced by some other term—such as “the public culture of science” (Gouyon 2014)—in this dissertation I retain the term.

In line with not defining “popular science” explicitly, I use “popular science” and “the popularization of science” interchangeably. Some scholars (e.g. Kärnfelt 2000) reserve “popular science” for the genre that emerged in the nineteenth and twentieth centuries, while using “popularization of science” for any text that explains or conveys science, for example novels such as Michael Crichton’s *Jurassic Park* (1990). This distinction makes sense when the object of study is popular science as a genre in the book market, as in the case of intellectual historian Johan Kärnfelt’s (2000) study of the formation of popular science in Sweden. But any distinction here between “popular science” and “popularization of science” would be potentially misleading in my dissertation,

since my method is textual analysis and I focus on the construction of science, humankind, and the universe in the texts themselves. Both popular science “proper” and popularizations of science in the wider sense—including news reporting, policy documents, curricula in the university, and so on—contribute to the construction of science in society. Even though I single out a few popular science texts for analysis, a sharp distinction between “popular science” and “popularization of science” would risk reifying popular science as a uniquely identifiable genre that is separate from other texts that discuss, invoke, or represent science.

The Emergence of Western Science and the Challenges of Popularization

The early nineteenth century is pivotal for understanding not only the emergence of popular science, but also of modern conceptions of science and contemporary science–literature relations. Prior to the nineteenth century, neither “science” nor “literature” existed as distinct concepts. “Science” referred to knowledge in a broad sense (Harrison 2015: 11–16), and “literature” meant “writing” or “book learning,” also in a broad sense (Culler 1997: 21). The more restricted meanings of the terms common today—literature as texts of a special kind and science as the natural sciences—came into being in the nineteenth century. Natural philosophy did exist, with Newtonian physics as the paradigm. But the establishment of science—and physics as the “queen of the sciences”—required a “great deal of work and effort,” as science historian Iwan Rhys Morus (2005: 3) shows in his book on the formation of physics. During this period of formation, sometimes called the “second scientific revolution,” science was professionalized and specialized, and Newtonian physics became the paradigm for all of physics and much of the rest of science. Many Romantic poets and philosophers contested the reductionist and mechanistic character of Newtonian physics as a valid model for science, but in this they largely failed; the image of science that prevailed was one very much in line with Newtonian reductionism. As science historian John Tresch (2013) argues, “After 1850 the classical image of science again took the upper hand; even today, we largely take for granted that real knowledge is possible only where there is a radical divide between subjects and objects and where nature is reduced to discrete, predictable mechanisms” (xi).

Emphasizing the situatedness of current science, I call Tresch’s “classical

image of science”—science as characterized by reductionism, mechanization, and the subject–object divide—“WCD science,” where “WCD” is an acronym for “Western culturally dominant.” It is a culturally specific notion that requires, for its persistence, a steady flow of boundary work that distinguishes this kind of science from other modes of knowledge, thus reaffirming that this—reductionism, mechanization, the subject–object divide—is what science *is*.

But even if reductionism, mechanization, and the subject–object divide won (and keep on winning) the battle for the image of science, there are challenges associated with popularizing science thus constructed. The award-winning science journalist Tim Radford (2007) identifies three major challenges facing science communicators, including journalists and popularizers: first, explaining difficult and technical words, such as “phenotype” or “albedo”; second, explaining difficult and technical concepts, including the principles and theories underlying the difficult words; and third, catching people’s attention and making them interested in science. He sums up the challenges of science communication in two crisp phrases: “science is hard” and “nobody wants to know about science” (96). In other words, popularizers must work to make science appealing, comprehensible, and meaningful beyond their immediate circle of fellow scientists and other actors with vested interests. People’s imagination and understanding of the world do not spontaneously align with the methods and results of science.

The extent to which the challenges of popularizing science are culturally specific is not an issue that I discuss at length. Research in psychology shows that people often “naturally” think in “unscientific” ways. For example, people tend to understand the world teleologically and agentially, and they sometimes diverge from “standard logic” when reasoning and making decisions.¹² But as

¹² For studies on the tendency to interpret the world teleologically and agentially—i.e. interpreting processes and living and non-living entities as goal-directed, purposeful, and intentional—see e.g. Rosset (2008), Kelemen & Rosset (2009), and Urquiza-Haas & Kotrschal (2015). The idea is expressed succinctly by evolutionary psychologists Leda Cosmides and John Tooby: “Teleological explanations are found in Aristotle (invited by his observations, because he was in fact largely a biologist), and arguably constitute an evolved mode of interpretation built into the human mind. Humans find explaining things in terms of the ends they lead to intuitive and often sufficient” (Tooby & Cosmides 2015: 14). For studies on reasoning and decision-making, see Gilovich, Griffin, & Kahneman (eds.) (2002) and Oaksford, Chater, & Stewart (2012). For a comprehensive and accessible monograph on how “natural” thinking diverges from “scientific” thinking, see Andrew Shtulman (2017). For other popular accounts of bias and the “non-rationality” of human reasoning, see e.g. Fine (2005), Haidt (2012), and Sharot (2017).

with most psychology, it is likely that the majority of these studies have been conducted on WEIRD people: Western, educated, industrialized, rich, and democratic (Henrich, Heine, & Norenzayan 2010). The extent to which the results are generalizable to all humans is thus not obvious. However, nothing substantial in my argument hinges on whether it is possible to generalize the psychological results to everyone. First, the audience of contemporary popular science is composed mostly of WEIRD people. These are the kinds of people that popularizers attempt to persuade, and so to the extent that the psychological research is valid for them, it is relevant for analyzing contemporary popular science. Second, and more importantly, many science communicators and popularizers tend to assume that modern science *is* difficult and counterintuitive. Tim Radford’s sentiment is common, as indicated by other popularizers who express similar views. For example, biologist Lewis Wolpert, in a book tellingly called *The Unnatural Nature of Science* (1992), argues that the primary reason for poor levels of public understanding of science and widespread anti-science sentiment, besides cultural prejudices stemming from works of fiction like Shelley’s *Frankenstein*, is to be found in the nature of science itself:¹³

many of the misunderstandings about the nature of science might be corrected once it is realized just how “unnatural” science is. . . . Firstly, the world just is not constructed on a common-sensical basis. This means that “natural” thinking—ordinary, day-to-day common sense—will never give an understanding about the nature of science. Scientific ideas are, with rare exceptions, counterintuitive: they cannot be acquired by simple inspection of phenomena and are often outside everyday experience. Secondly, doing science requires a conscious awareness of the pitfalls of “natural” thinking. For common sense is prone to error when applied to problems requiring rigorous and quantitative thinking; lay theories are highly unreliable. (Wolpert 1992: xi–xii)

Richard Dawkins, world-famous popularizer of biology and advocate for atheism, makes a similar point in his bestselling book *The God Delusion* (2006): “Our imaginations are forlornly under-equipped to cope with distances outside the narrow middle range of the ancestrally familiar. . . . Common sense lets us down, because common sense evolved in a world where nothing moves very fast, and nothing is very small or very large” (363–364). And Krauss, in *The Greatest Story* (2017): “Evolution didn’t prepare our minds to appreciate long or short timescales or short or huge distances that we cannot experience

¹³ Wolpert (1992) formulates these ideas as a part of his larger mission to spread science. It goes without saying that his assessment of the supposed cultural prejudices against science and poor levels of public understanding should not be taken at face value.

directly. So it is no wonder that some of the remarkable discoveries of the scientific method, such as evolution and quantum mechanics, are nonintuitive at best, and can draw most of us well outside our myopic comfort zone” (3).

In other words, there is—or is assumed to be—a kind of gap between WCD science and the imagination. Since I make no assumptions about the generalizability of “the imagination,” I take “WCD” to qualify both “science” and “the imagination.” I thus call this gap between science and the imagination the “WCD science–imagination gap.” This gap pertains both to scientific results and methods: to facts such as the age of the Earth (4.5 billion years) and the distance to the Andromeda galaxy (2.5 million light years); to constitutive modes of explanation in science such as non-teleological and non-agential explanations; and to the view of the world suggested by reductionist and materialist approaches, namely a universe devoid of meaning, purpose, and values.¹⁴ From the point of view of mainstream popularizers, the challenge of science popularization—bridging the WCD Science–imagination gap—can be stated

¹⁴ Non-teleological explanations do not invoke ends or purposes of a phenomenon to account for why it exists or is the way it is. Non-agential explanations do not invoke intentions or agents as causes. Cosmides and Tooby again (cf. p. 21 n12 above) formulate what this means, in particular for biology and psychology:

Of course, the scientific revolution originated in Renaissance mechanics, and seeks ultimately to explain everything (non-quantum mechanical) using forward physical causality—a very different explanatory system in which teleology is not admissible. Darwin outlined a forward causal physical process—natural selection—that produces biological outcomes that had once been attributed to natural teleological processes (Darwin, 1859). The theory of natural selection explains how biological systems could have sets of properties (adaptations) that naturally emerged because of the functions they served. Williams (1966) mounted a systematic critique of the myriad ways teleology had nonetheless implicitly infected evolutionary biology (where it persists in Darwinian disguises). Computationalism assimilated the other notable class of apparently teleological behavior in the universe—the seeming goal directedness of living systems—to physical causation by showing how informational structures in a regulatory system can operate in a forward causal way and yet be directed toward goals (either apparently or actually) (Weiner, 1948). The teleological end that seems to exist in the future as the point toward which things tend is in reality a feedback-driven regulatory process—a regulatory process that need not but sometimes does include a representation of a goal state in the organism in the present. The modern scientific claim would be that adaptationism and computationalism in combination can explain by forward physical causation all events that once would have been explained teleologically. (Tooby & Cosmides 2015: 14)

A general and very brief way to express this is to say that according to non-teleological and non-agential explanations, things happen because of blind, impersonal physical laws, not because an entity willed them or because there is a purpose and goal to events in the universe.

thus: scientific facts, modes of explanation, and worldviews need to be presented in such a way as to be comprehensible, meaningful, and relevant for people.

Popularizers use different techniques and strategies to bridge the WCD science–imagination gap.¹⁵ In mid-nineteenth century Britain, for example, it was common to emphasize the continuities between science and common sense (Bensaude-Vincent 2001: 104). In the United States in the 1950s and 1960s, it was common to use non-sensational language and to emphasize the societal benefits of science (Lewenstein 1992). In the Anglo-American world since the early 1980s, and particularly in popularizations of physics and astronomy, it has been common, first, to use Romantic tropes and themes, and second, to emphasize the mythic qualities and existential relevance of science.

Even though the Romantics largely failed in their attempt to reformulate science, they did have a lasting impact on the image of science. As shown by intellectual historian Richard Holmes (2008), many images, tropes, and attitudes that we now associate with science and scientists—such as the lone genius, the exploratory voyage, and wonder and awe—were either formulated by the Romantics or emphasized by them. The prevailing construction of science in contemporary popular physics and astronomy is not Romantic, since it retains reductionism, mechanization, and the subject–object divide at its core; but the presence of Romantic elements justifies the characterization of science as typically *romanticized* in popular physics and astronomy.

Many of the characteristics of Romanticism that Holmes discusses coalesce in the conception of science as mythic and existentially relevant. In this conception, science holds the key to answering “age-old” questions about meaning, purpose, and truth. It not only holds the key to intellectually understanding and technologically controlling the world—it is also the provider of ultimate truth, existential meaning, emotional satisfaction, and spiritual connection. As religious scholar Lisa H. Sideris (2017) puts it, science, in this conception, “satisfies the intellect as well as the emotions” (10). This conception of science finds its full embodiment in what I call the “triumphant epic of the universe, science, and humankind” narrative, or the “TEUSH” narrative for short.¹⁶ The TEUSH narrative is cosmic in scope and triumphant in tone.¹⁷ It details the

¹⁵ I have been working toward this idea in three articles; see Helsing (2013), (2016), (2017).

¹⁶ As it happens, “Teush” is also a slang word for cannabis in French. This is a serendipitous coincidence, since there are intoxicating as well as sedative aspects to the TEUSH narrative.

¹⁷ Sideris (2017: 1) lists names commonly used by proponents of this narrative: “the Epic of Evolution,” “the Universe Story,” “the New Story,” “the Great Story,” and “Big History.”

history of the universe since the Big Bang some 13.8 billion years ago and culminates with the emergence of *Homo sapiens* on Earth and the invention of science, which it construes as the crowning achievement of both the cosmos and humankind.¹⁸

A critical perspective on this triumphant narrative highlights not only the contingency of identifying knowledge with WCD science, but also the philosophical baggage that goes into this identification. In particular, there are certain imperialistic tendencies, notions of gender, and attitudes toward the natural world that linger in Western science and often surface in popularizations. In the romanticization of science, important parts of the Romantic heritage are appropriated by mainstream popularizers, while the central tenets of Romantic views of nature are excised. Romanticism is thus transformed from a radical challenge to science into a kind of harmless, auxiliary add-on. Similarly, the TEUSH narrative is indicative of the scientism typically present in popular science—the ambition to expand science beyond its current boundaries, whatever they may be, to encompass everything and be the sole provider of truth and meaning (see Ridder 2014; Williams & Robinson [eds.] 2015; Sideris 2017). In so doing, it overestimates the scope of science and devalues other modes of knowledge. Finally, the notions of gender and the attitudes toward the natural world associated with WCD science follow an old tradition in Western thought in which reason and rationality are coded as male. As feminist philosophers have shown, nature is construed as female, and both nature and women are subject to domination and exploitation by male philosophers or scientists (see e.g. Merchant 1980; Keller 1985; Bordo 1987). In this way, the subject–object divide is not a neutral epistemological tool—it is an epistemological approach that contributes to the propagation of misogyny and environmental destruction.

*

There are, in other words, two important tendencies in much of contemporary, mainstream, Anglo-American popularizations of physics and astronomy. On the one hand, science is typically constructed as something unique, as something pure, as something set apart from other fields of activity and belief

¹⁸ Several other scholars have studied cosmic, triumphant narratives in popular science. See e.g. Eger (1993); Turney (2001); Leane (2007); Schrempp (2012); O'Connor (2013); Sideris (2017); Zakariya (2017).

systems. This aspect of the construction of science ensures that epistemological authority stays in the hands of scientists. On the other hand, science is typically constructed as a provider of meaning and purpose. This aspect of the construction of science is designed to make science meaningful, exciting, and satisfying. Considered singly, each aspect of the construction is problematic; and considered in combination, the two aspects pull in different directions.

Science-as-unique-and-pure obscures the historical contingency of prevailing metaphors and concepts in science (e.g., mechanism, energy) and central epistemological presuppositions of science (e.g., the subject–object divide). It obscures the thoroughgoing dependence of science upon society; the influence of “non-scientific” elements, such as literary techniques and ideology, on the formulation of scientific theories and methods; and the entanglement of science with other fields of activity, such as literature, philosophy, and religion. In short, science-as-unique-and-pure obscures the inescapable historical situatedness of science. It embodies what Donna Haraway (1988) calls the “god trick”: the illusion and ideal of detached objectivity, of “seeing everything from nowhere” (581). Doing so is in the interests of scientists. As sociologist Stephen Hilgartner (1990) argued in a now classic paper, distinguishing science from popularization, and so constructing science as a pure activity, “grants scientists (and others who derive their authority from science) something akin to the epistemic equivalent of the right to print money. Genuine knowledge, the ‘gold standard,’ is their exclusive preserve” (534).

Science-as-meaningful obscures the side effects and implications of heralding WCD science as a fundamentally positive force in the world. It shies away from discussing the effects of prevailing metaphors, concepts, and epistemological presuppositions of science on the conceptualizations and treatment of others, including humans, non-human organisms, and the biosphere. It thus shies away from discussing the potential complicity of science in systems of discrimination (e.g., gender, ethnicity) and destruction (e.g., climate change, loss of biodiversity). When science is considered the *sole* provider of meaning and truth—i.e., in scientism—science-as-meaningful also shies away from acknowledging and discussing the imperialistic tendencies inherent in denouncing all “non-scientific” worldviews as mistaken or false. If the “god trick” is illusory and all human knowledge is inescapably situated, then asserting that the current version of science is the one true provider of meaning and truth is counterproductive and harmful. It prevents the formulation of alternative worldviews and conceptions of science that may prove fruitful for enabling increased understanding of the world and valuable courses of action. Furthermore, since science is a powerful institution that enjoys high societal status,

denouncing “non-scientific” worldviews as mistaken or false may have the effect of further disempowering unprivileged people who either have not had access to science or who adhere to alternate worldviews.

Considered in combination, science-as-unique-and-pure and science-as-meaningful pull in different directions. Science-as-unique-and-pure stresses discontinuity between science and other activities; it moves toward an idealized and non-human world of abstract physical laws and eternal truths devoid of meaning. Science-as-meaningful, by contrast, stresses continuity between science and other human activities; it appeals to desires and emotions, and it moves toward historical realities in which scientists live, conduct research, quarrel, love, and die. These contradictory tendencies create ambiguities and tensions in the resultant construction of science. I highlight these tensions and ambiguities throughout my analyses of the popular science texts.

Aim and Research Questions

The aim of this dissertation is to analyze the literary techniques and rhetorical strategies used by some contemporary, mainstream, Anglo-American popularizers of physics and astronomy to construct science as a pure and objective yet meaningful and human endeavor in order to claim epistemological authority for science while simultaneously bridging the WCD science–imagination gap. I focus especially on Krauss’s *The Greatest Story Ever Told—So Far* and Tyson’s *Astrophysics for People in a Hurry*, but I also discuss a handful of other mainstream popular science books. To achieve this aim, the following questions guide my analyses:

1. What notions of science, scientists, gender, human nature, the universe, humankind’s place in the universe, and the meaning of life predominate in the books under investigation, and how are they constructed? In particular, what roles do the romanticization of science and the TEUSH narrative play in the constructions?
2. What tropes, narratives, and notions from the history of philosophy, literature, and science are present in the books under investigation, and how do they affect the meanings of the texts?
3. What societal functions and effects does the construction of science in

the books under investigation have, and in what ways can alternative constructions of science in popular science contribute to more nuanced and fruitful images of what science is and can be?

The three words in the subheading of this dissertation—truth, transcendence, and triumph—indicate the nexuses of my analysis. Science is constructed as being epistemologically superior to all other attempts to explain and understand the world; it has “truth on its side.” Science is constructed as being able to transcend the “frail,” “imperfect” human senses and access ultimate reality. And science is constructed as a triumph of the human intellect, as the pinnacle of human evolution, and even as a guiding force in achieving utopia on Earth or in space.

Theory, Method, and Material

Theoretical Frameworks and Concepts

As the preceding discussions suggest, I use a constructivist framework. “Constructivism,” as I use the term, should not be understood to imply that there is no “world” beyond the constructions analyzed. Rather, it is, first, an acknowledgment of the inescapable situatedness of all human attempts to understand the world; and second, an indication that my analyses are primarily located on the level of language usage.¹⁹ I analyze how texts, concepts, and notions are constructed. I focus on the genealogy of terms of interest such as “science” and “truth,” layers of connotations that inescapably suffuse those terms, and the effects that using those terms may have.

I use “literary techniques” in a broad sense to refer to defamiliarization, narrative, figurative language, character construction, point of view, and so on. By “rhetorical strategies,” I mean “boundary work,” since it is the rhetorical strategy of primary interest for my analyses.²⁰ The use of most of these

¹⁹ Constructivists are sometimes asked if they believe in the existence of “reality.” In the opening chapter of *Pandora’s Box* (1999), science and technology studies scholar Bruno Latour reflects upon this question. He makes the point that a constructivist approach to science instead *adds* reality to science, because it studies science in actual practice rather than in ideal thought. I intend my analyses to add to the reality of science by studying how science is constructed in popularizations of physics and astronomy.

²⁰ The categorization of figurative language as a literary technique is not obvious. Sometimes, figurative language is categorized as “rhetorical devices” or “rhetorical figures” (e.g. Culler

concepts is either fairly straightforward (e.g. figurative language) or specific to particular chapters (e.g. defamiliarization in chapter 5). I define and discuss those concepts in the chapters in which they are used, because they are all consistent with my constructivist framework and therefore do not merit special attention here. However, there is one issue and three concepts that are more foundational in character and relevant to the dissertation as a whole, namely the issue of fiction versus non-fiction and the concepts “narrative,” “boundary work,” and “meaning.”

It is important to specify the use of the term “narrative.” Not every passage in a popular science text is manifestly narrative in character. For example, science communication scholar Felicity Mellor (2003) distinguishes between what she calls three “main modes of address: the narrational, the expository and the investigative” (511). The narrational mode relates stories about episodes in the history of science or lives of individual scientists. The expository mode usually centers around a scientific discipline and explains theories and results in that discipline. The investigatory mode, rare in mainstream popular science, resembles investigative journalism and takes a critical approach to science and its effects. Mellor mentions Rachel Carson’s *Silent Spring* (1962) as the most prominent example of the investigatory mode (512). Mainstream popular science books typically use a mix of the narrational and expository modes, but there is usually an emphasis on one or the other, so that a predominantly narrational book contains expository sections and a predominantly expository book contains narrational sections. From a literary studies perspective, however, all of these modes can be considered as narratives, but in different senses. In a more restricted sense, a narrative is the telling of a story. In an unrestricted sense, a narrative is an account that connects and explains a selected set of events, experiences, and characteristics, intended to support a particular point of view. Thus, while not every passage in popular science books is a narrative in the restricted sense, all passages are typically placed in accounts that are narratives in the unrestricted sense.

The distinction between restricted and unrestricted narratives enables me to specify the sense in which the TEUSH narrative is a narrative. In postmodern theory, following Jean-François Lyotard’s *The Postmodern Condition* (French original in 1979, English translation in 1984), a particular kind of unrestricted

1997: 69–81; Abrams & Harpham [1957] 2012: 342–348). Besides being a testament to the historically intimate connections between literature and rhetoric, I see these inconsistencies in terminology as inconsequential. See also below for further discussions of the relevance of rhetoric for the study of popular science and how I use rhetoric.

narrative called “grand narratives” or “metanarratives” has been the focus of much attention. Avoiding the connotations of “narratives about narratives” implied in the Lyotardian notions, Stephen Kern (2011) defines “master narratives” as narratives that “make sense of experience for large numbers of people” (9). I read contemporary, mainstream popularizers as attempting to turn the TEUSH narrative into a master narrative. However, it is not clear that “large numbers of people” use the TEUSH narrative to “make sense of experience.” Therefore, I instead use the term “core narrative” to characterize this narrative. The difference between a master narrative and a core narrative, as I use these terms, is that a core narrative is a contender for master narrative status. But they have the same function in a text, namely organizing more specific narratives (in the restricted sense) and accounts. As a core narrative, the TEUSH narrative forms the backbone of the specific representations of science and the universe in many popularizations of physics and astronomy. In analyzing both this core narrative and specific narratives, I use narratology—in particular, the concepts and tools developed by Gérard Genette and Seymour Chatman.

Of course, narratology was developed for studying works of fiction, but it has also been used to analyze non-fictional narratives (e.g. Genette 1993; Eldelin 2008; Pickett 2013). Applying the concepts and tools developed in narratology to popular science texts is fairly straightforward, but a few modifications or clarifications are needed. An important distinction between fictional and non-fictional narratives is that in fiction, the story is only accessed *through* the discourse, whereas in non-fiction, the story exists independently of the discourse. For example, the murder of John Boone in Kim Stanley Robinson’s *Red Mars* (1992) is part of the story of the Mars trilogy; but that event does not exist independently of the said trilogy, and the only way the reader learns about the murder is through the particular discourse narrating that event. By contrast, the development of general relativity by Albert Einstein happened in real life. Different narratives portraying the development of general relativity are different ways of recounting those events, but the events themselves occurred independently of any particular account of them. However, distinguishing fiction from non-fiction on the basis of the independent existence of events is not as straightforward as it may seem. Even though it is true that the development of general relativity took place in real life, any narrative account of those events—including Einstein’s—uses discourse to portray them. Literary scholar Peter Stockwell (2002) highlights the importance of narratives in human cognition: “narratives are one of the fundamental aspects of understanding. . . . we do not have access to a pre-cognitive reality, since the act of cognition itself involves

a representation, and this involves selection, omissions, weighting of foreground and background, evaluations of relevance and significance, and personal salience and interests” (122). Cognition takes place in historical, cultural, and social contexts, and those contexts fundamentally shape the narratives we tell, for example by providing recurring plots and by suffusing stories with a multitude of associations and layers of meaning. In other words, any account of Einstein’s development of general relativity is already mediated through discourse. The idea of an “objective story of the development of general relativity” is an impossible idea. The events did occur in real life, and multiple accounts of those events may approximate objectivity collectively, but that is very different from saying that the story of the development of general relativity exists independently of discourse.

This has implications for the distinction between story and discourse in the analysis of popular science texts. When the narratives focus on the universe—e.g. explaining the evolution of matter—then the objects of those narratives—e.g. particles, stars, the cosmos—are given by scientific theories, which are themselves influenced by historical narratives. When the narratives focus on the history of science, then the objects of those narratives are given by historical documents and accounts. In neither case does the story equate “reality itself”; the story is mediated by scientific theories, narratives, and historical accounts. Thus, while the narratological analyses in this dissertation show how popularizers narrate the universe and the history of science, it is important to keep in mind that popularizers are not just simply narrating objectively existing events and entities. They are, in effect, narrating received narratives—narratives received through theoretical and historical mediations and accounts. Furthermore, narratives in popular science *contribute* to future mediations of these events and entities, although it is impossible to specify in what ways and to what extent. This does not mean that there is no difference at all between fiction and non-fiction—I do not adhere to a “pan-fictional” view according to which the use of narrative automatically means fictionalization (see Nielsen 2015). But it does mean that “facts”—or “the factual,” or “the real”—are not as straightforward as one might think. They are not simply given. Narratives mediate and contribute to the construction of facts.

Since “facts” are always mediated somehow, that also means that the meaning of facts vary depending on the narratives in which they are present. This aspect of the representations of facts is downplayed in the simplest conceptualization of what popular science is, namely that popularization consists in “translating” or “simplifying” difficult information so that it can be understood by non-specialists. This model of popularization—construing the task of

popularization as one of increasing the public's understanding of science through simplification—is associated with what is often called “the traditional view,” “the dominant view,” or “the deficit model” of popularization.²¹ In the critical scholarship on popularization, the dominant view/deficit model is routinely attacked as both descriptively inaccurate and ideologically problematic. Not only does this model fail to describe, with any degree of precision, how popularization works—but also, because the audience is defined as lacking in knowledge, the model lets popularizers define the terms of discussion, thus reproducing scientists' and popularizers' claim to authority in defining what science is and does. To counteract this model, many scholars use the concept of meaning. Popularization is better characterized through “recontextualization” than simplification, to use Helena Calsamiglia and Teun A. van Dijk's (2004) term, or in Peter Brok's (2006) words: “The information a statement contains might remain the same, but its meaning can change with context, medium and relationship between people involved” (122). I follow the lead of these scholars and use the concept of “meaning” to analyze popular science texts.²²

The importance of meaning for understanding popularization is fundamental to this dissertation. More specifically, in addition to the general point that meaning is context-dependent, two meanings of “meaning” are relevant to all of my analyses. First, science is presented in the popularizations under investigation as the intellectual framework within which the world “makes sense”; i.e., science is presented as *the framework that grounds meaning*, in the sense of intelligibility and understanding. And second, popularizers attempt to make science meaningful, in the sense of existentially relevant, intellectually appealing, and emotionally fulfilling; i.e., science is presented as *the framework that*

²¹ See e.g. Whitley (1985); Hilgartner (1990); Wynne (1993); Gregory & Miller (1998); Broks (2006).

²² Sociologist Brian Wynne explains the origin of the term “deficit model” in a paper from 1993: “The deficit model was a name first given to the conventional approach by Wynne in a draft paper criticizing it . . .” (335 n8). In other words, from the very beginning the term was derogatory. The term has then been consistently used by science communication scholars as a point of criticism. It is thus unclear to what extent the dominant view/deficit model of popularization actually was the default model of science communication. But because the dominant view/deficit model has been so important in studies on popular science, it is important to address it. Furthermore, many relevant points about popularization have been made through critiquing the dominant view/deficit model—such as the importance of meaning—and these points are more important for my analyses than the extent to which the model is a construction on the part of scholars. In other words, the critiques of the models are valid and relevant, regardless of whether the model itself is used by communicators and popularizers. I wish to thank Jean-Baptiste Gouyon for bringing Wynne's remarks to my attention.

provides meaning, in the sense of purpose and satisfaction. To analyze meaning in the first sense (as grounding), I use literary theories. I show, through literary analysis, how popularizers attempt to situate readers in a universe defined by science. To analyze meaning in the second sense (as purpose), I use research from the “science of meaning in life”—a subfield of psychology devoted to questions about meaning in life (Hicks & Routledge [eds.] 2013; King, Heintzelman, & Ward 2016). I discuss the science of meaning in life further in chapter 4, and I show, through literary analysis, how science is made meaningful in the books under investigation.

Meaning in the first sense—science as the framework that grounds meaning—relies on science being unique and separate. As discussed, popularizers typically differentiate science from non-science through *boundary work*. Sociologist Thomas F. Gieryn’s (1983) coined the term “boundary work” to circumvent and reformulate the long-standing “problem of demarcation” in science studies and philosophy of science. The problem of demarcation, so christened by the Austrian-British philosopher Karl Popper in 1934, denotes the “task of discriminating science from non-science,” where non-science “includes pseudoscience and metaphysics but also logic and pure mathematics, philosophy (including value theory), religion, and politics” (Nickles 2006: 188). Instead of attempting to solve the problem of demarcation, Gieryn shifts the focus from the ideal solution sought by philosophers to *actual* demarcations between science and non-science made by scientists and other actors. For example, “education administrators set up curricula that include chemistry but exclude alchemy; the National Science Foundation adopts standards to assure that some physicists but no psychics get funded; journal editors reject some manuscripts as unscientific” (Gieryn 1983: 781). As shown by Gieryn and many subsequent scholars (e.g. Mellor 2003; Leane 2007; Perrault 2013), popular science is an important site for boundary work.

Many studies on boundary work in popular science and science communication focus on how the boundaries of science are drawn in times of crisis, in discussions about controversial issues, or when scientific fields are formed. In these studies, exceptional cases—the alternatives to or challenges to mainstream science—form the basis of analysis (see e.g. Lewenstein 1995; Gieryn 1999; Locke 2011). By contrast, Felicity Mellor, in her analyses of boundary work in popular physics books (2003), studies what she calls “routine boundary work.” She highlights the striking similarities among most popular physics books, and she argues that the presence of similarities is significant. While only a few books stand out enough to become bestsellers or receive awards, “the same set-piece expositions . . . can be found in countless other popularizations

of physics.” These books—both the bestsellers and the less successful titles—form a stable “intertextual web” which, through its “collective presence,” “is itself constitutive of public images of science and forms a solid cultural backdrop through which scientists’ images of science are maintained” (Mellor 2003: 518). The recognition of the similarities between popular science books is crucial for understanding how mainstream notions of science are maintained and reproduced in ordinary times, when crisis or controversy does not set the agenda.

This dissertation contributes to the study of routine boundary work in mainstream popularizations of physics and astronomy. I use the concept of boundary work to analyze how science is defined in the books under investigation. By tracing passages where science is defined through contrasts with non-science, I describe and discuss the notions of science explicitly advocated by and tacitly presupposed in these books. By deconstructing the definitions, I unearth ambiguities and inconsistencies in the resultant construction of science.

Science and Technology Studies and Rhetoric

Boundary work succinctly illustrates the dominant approach to the study of science in the field known as science and technology studies (STS). STS is, in the words of the introduction to the authoritative *The Handbook of Science and Technology Studies*, “an interdisciplinary field that investigates the institutions, practices, meanings, and outcomes of science and technology and their multiple entanglements with the worlds people inhabit, their lives, and their values” (Felt, Fouché, & Miller et al. 2017: 1). Though STS is a heterogeneous field, constructivism is generally recognized as the unifying, underlying framework: “If there is a central dogma in STS, it is that science, technology, knowledge, and belief are social constructions, or to put it more mildly and to make it more palatable to more of our colleagues: science and technology, or the technosciences, are social and cultural phenomena” (Bauchspies, Croissant, & Restivo 2006: viii). Science is approached as an object of study amenable to analysis in the same way as any other human practice, field, or belief system, such as Western Christianity, neoliberal economics, or Romantic poetry. Following the influential sociologist David Bloor, one of the founders of the sociology of scientific knowledge (what later transformed into STS), the validity of the sciences under study is usually “bracketed” in a constructivist approach, in the sense that a constructivist analysis is “impartial with respect to [the] truth and falsity, rationality or irrationality, success or failure” of knowledge claims (Bloor [1976] 1991: 7). Using Jan Golinski’s (1998: 8) apt term, this approach can be called *methodological relativism*. Studies in STS

thus focus on how knowledge claims come into being through social processes and which actions and social norms are used to determine the fate of those knowledge claims. Another important component of constructivism in STS is the notion of “situatedness,” a term closely associated with Donna Haraway’s influential article “Situated Knowledges” (1988). People are always and inescapably situated in particular geographic locations, historical periods, cultures, and ideologies. In other words, the approach to science in STS can be said to be the opposite of the view of knowledge as characterized by the “God trick”—Haraway’s term for viewing science as embodying detached, impartial objectivity.

Fundamental to a constructivist approach to the term “science” is the recognition that there is no single definition of science that prevails in society and no single person or institution who has definitional authority. Instead, actors make bids to the definition of science. Some of these bids come from more powerful and influential actors than others, and some bids are more widespread than others, but no one bid has absolute authority. These bids change over time, some more slowly than others. Furthermore, all actors have incentives, and a recognition of those incentives is crucial for understanding the proposed definitions. In chapter 1, when discussing the history of popular science, I also discuss notions of science in history and historical scholarship. In chapter 3, I present definitions of science from some influential actors in contemporary society, such as NASA, major dictionaries, and education guidelines in the US.

Throughout the dissertation, I make use of methodological relativism and human situatedness when handling the primary material. I am not interested in whether the theories in the popularizations in question are “true” or “false”; instead, my focus is how the popularizers construct notions of “truth” and “falsity” and how they use of “truth” and “objectivity” as rhetorical strategies in their texts. Similarly, I view popularizers of science as situated spatio-temporally, culturally, and ideologically, thus highlighting how seemingly “external” factors—such as the sociopolitical contexts in which they are writing and the cultural references they use—influence the notion of science they construct. Even though popularizers may attempt to present science as “objective,” they are situated authors writing in specific historical, political, and cultural contexts. In these contexts, mainstream popular science texts usually serve specific societal and cultural functions, such as vying for funding and maintaining the status of science in society (Gieryn 1983; Hansen 1994; Bauer & Gregory 2007). In other words, rather than accepting the popularized theories as “objective,” I address how that “objectivity” is constructed through literary techniques and rhetorical strategies.

The literary theories I use and the approach to science embodied in STS are both compatible with—indeed, constitutive of—the constructivist framework that I use. The same holds for rhetoric. In a general sense, “rhetoric” can be taken to mean, in M.H. Abrams and Geoffrey Galt Harpham’s words ([1957] 2012), “the study of language in its practical uses, focusing on the persuasive and other effects of language, and on the means by which one can achieve those effects on auditors or readers” (343). Rhetoric on this level is relevant for analyzing popular science, since persuasion is one of popular science’s primary purposes—whether it be persuading people that science is true and wonderful, or persuading politicians that science is worthy of investment, or persuading fellow scientists that a particular theoretical development ought to be given more attention. Rhetoric in a more specific sense—e.g. the five canons (inventio, dispositio, elocutio, memoria, and pronuntiatio) or the three audience appeals (logos, pathos, and ethos)—features prominently in some studies (e.g. Fahnestock 1999; Perrault 2013), but not as frequently as rhetoric in the general sense.

Taking rhetoric to the study of persuasive language, a rhetorical perspective is incorporated into my analyses. In practice, this means being alert to the persuasive dimensions to the notions of science advocated in popular science—i.e., that popularizers attempt to persuade readers to view science in certain ways. However, apart from boundary work, the rhetorical aspects are not accentuated in this dissertation because my primary method is literary analysis.

Selection Criteria, Scope, and Delimitation

I divide the primary material into three levels: first, contemporary, mainstream, Anglo-American popularizations of physics and astronomy; second, a sample of books from this wide array of books; and third, two books to which I pay extra attention and that comprise the main material for most of the chapters, namely Lawrence Krauss’s *The Greatest Story Ever Told—So Far* and Neil deGrasse Tyson’s *Astrophysics for People in a Hurry*. Each of the three levels thus comprises a different number of titles. The results of this dissertation pertain primarily to the books I analyze—i.e., to the books (or passages therein, as the case may be) on level 2, and in particular to Krauss’s *The Greatest Story* and Tyson’s *Astrophysics* on level 3. However, to the extent that these books are representative of contemporary, mainstream, Anglo-American popular physics and astronomy, the results illuminate the structure, style, and content of similar books too. In other words, I do not venture strong claims about

popularizations beyond the books analyzed here, but my results should nonetheless be relevant for a host of other similar books, meaning most of the books on level 1.

Level 1: The Wide Array of Books

In deciding which books to choose as my primary objects of analysis, I have surveyed popularizations of physics and astronomy since the late 1970s. I have done this by browsing library catalogues, reading scholarship on popular science, looking up references to other popularizations in popular science books, going through all *New York Times* bestseller lists since 1975,²³ and browsing the Internet using search terms such as “popular science books,” “popularizations of physics,” “popularizations of astronomy,” “mainstream popular science,” and “popular science writers.” Doing so has given me a fair overview of popular science publishing in physics and astronomy since the late 1970s, and it has given me confidence in choosing the books and authors on which to focus for closer analysis.

Delineating the wide array of books that comprise level 1 presupposes choosing “contemporary,” “mainstream,” “Anglo-American,” and “physics and astronomy” as selection criteria. These criteria could have been different. Defining and discussing them thus elucidates not only the primary material and the focus of the dissertation, but also my reasoning in choosing them as selection criteria.

By “contemporary,” I mean books from the late 1970s to the present. The late 1970s saw a marked increase in sales figures, visibility, and number of titles of popular science books in the English-speaking world—a phenomenon often referred to in the literature as the “popular science boom.”²⁴ Science communication scholar Bruce Lewenstein (2007) points to the publication of Carl Sagan’s *The Dragons of Eden* (1977), which won the Pulitzer Prize in general non-fiction in 1978, as a kind of watershed. Prior to 1978, “almost no science books won Pulitzer Prizes,” but beginning with *The Dragons of Eden*, “every year or every other year into the late 1990s, the Pulitzers begin honoring a science book.” And likewise with sales figures: “Before the mid-1970s, only rarely did more than 10 new science-oriented books a year become added to the list of best-sellers maintained by the *New York Times*. But after 1978, only

²³ I have used the archive of *New York Times* bestseller lists, dating back to 1931, maintained by *Hawes Publications* at www.hawes.com.

²⁴ See e.g. Lewenstein (1987); Broks (2006: 88–95); Leane (2007: 41–59); Turney (2007); Lewenstein (2009); Bell & Riesch (2013); Bell & Turney (2014).

rarely did *fewer* than 10 science-oriented books get added to the list” (3). During this time, several scientists also achieved celebrity status, most notably (in the fields of physics and astronomy) Brian Cox, Richard Feynman, Brian Greene, Stephen Hawking, Carl Sagan, and Neil deGrasse Tyson (Fahy & Lewenstein 2014; Fahy 2015).

In many ways, we are still living in this popular science boom. While some scholars and commentators argue that the boom had leveled out by the early twenty-first century, though not necessarily declined (see Leane 2007: 46, with references), the continuing visibility of popular science is attested to not least by the continued presence of titles on the *New York Times* bestseller list and the presence of major popularizers such as Neil deGrasse Tyson and Bill Nye in the mainstream media. But choosing the late 1970s as the starting point of “contemporary” goes beyond considerations of visibility and sales figures. Some books and television series from the early years of the boom—in particular Steven Weinberg’s book *The First Three Minutes* (1977) and Carl Sagan’s television series and book *Cosmos* (1980)—were incredibly influential in shaping the themes, tone (at least Sagan’s case), and structure of later popularizations.²⁵ Of course, there are differences between individual authors, but some

²⁵ The tone of Weinberg’s *The First Three Minutes* stands out somewhat in comparison to most popular science books. While the book is triumphant in the sense that Weinberg deems science the most noble of human enterprises, he ends on a somber note:

It is almost irresistible for humans to believe that we have some special relation to the universe, that human life is not just a more-or-less farcical outcome of a chain of accidents reaching back to the first three minutes, but that we were somehow built in from the beginning. As I write this I happen to be in an aeroplane at 30,000 feet, flying over Wyoming en route home from San Francisco to Boston. Below, the earth looks very soft and comfortable—fluffy clouds here and there, snow turning pink as the sun sets, roads stretching straight across the country from one town to another. It is very hard to realize that this all is just a tiny part of an overwhelmingly hostile universe. It is even harder to realize that this present universe has evolved from an unspeakably unfamiliar early condition, and faces a future extinction of endless cold or intolerable heat. The more the universe seems comprehensible, the more it also seems pointless.

But if there is no solace in the fruits of our research, there is at least some consolation in the research itself. Men and women are not content to comfort themselves with tales of gods and giants, or to confine their thoughts to the daily affairs of life; they also build telescopes and satellites and accelerators, and sit at their desks for endless hours working out the meaning of the data they gather. The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy. (Weinberg 1977: 148–149)

The reference to tragedy is not common in subsequent popular science, but it is clear that Weinberg nonetheless views science as a valuable, even heroic, activity.

features of popularizations of physics and astronomy have been remarkably consistent since the late 1970s—e.g., the romanticization of science, the TEUSH narrative, and the ideology of scientism.

The popular science boom accentuates the prevalence of popular science in contemporary Western culture and the need to examine the notions of science promoted in this literature. A historical focus would, of course, have been possible. I focus on contemporary popular science because I am interested in the notions of science that circulate in society today. This focus is consistent, however, with also discussing the history of philosophy, literature, science, and science popularization, since some historical tropes, narratives, and ideas continue to influence contemporary popularizations.

By “mainstream,” I mean two interconnected things: first, with respect to science, popularizations of *legitimate science*; and second, with respect to media channels, books and authors that are visible in the *mass media* (e.g., CNN, *New York Times*).

Legitimate science means the science that is broadly accepted by the scientific community. This is contrasted with “controversial science,” such as cold fusion; “new age science,” such as unorthodox, spiritual interpretations of quantum mechanics; and “pseudoscience,” such as Intelligent design and astrology (Lewenstein 1995; Mellor 2003; Locke 2011). It is important to note that “legitimate science” does not mean “true science”; it is a sociological concept, used by Gieryn (1983) among others, to indicate that the science analyzed is perceived as legitimate by the establishment and holds an established position in society. The concepts “controversial science,” “new age science,” and “pseudoscience” should similarly be understood not as meaning “false science,” but rather science that the establishment deems false or unscientific. It is also important to note that “legitimate” does not mean that all scientists agree in all respects. For example, Brian Greene’s popularizations of string theory would fall into the category of “legitimate,” even though string theory is not an accepted theory. The point, though, is that Greene builds upon legitimate science and remains materialist and naturalistic in outlook; he adheres to the unspoken norms of mainstream popular science writing according to which atheism, agnosticism, materialism, reductionism, and naturalism are acceptable—but New Age spirituality, mysticism, and transcendentalism are unacceptable, and non-reductionism (or holism) is met with suspicion.²⁶

²⁶ The reception of James Lovelock’s and Lynn Margulis’s Gaia hypothesis is instructive in this regard. The exact interpretation of the Gaia hypothesis is under debate and has evolved since it was proposed in the 1960s (Tyrrell 2013: 4), but the simple and popular version of it is that the Earth as a whole is a living organism. Biotic and abiotic processes act in such a way as

Both globally and in the US, the vast majority of the media are owned by a small number of corporations (Lutz 2012; Ward 2014).²⁷ According to agenda setting theory, the mass media largely shape which issues are deemed to be important in society (McCombs & Shaw 1972; McCombs & Gou 2014). People may have different opinions on an issue such as global warming, but the fact that it is an issue about which people have an opinion to begin with is because the mass media pay attention to it. Mainstream popularizers are popularizers who have a position in the mass media. They publish essays and books in channels that are owned by mass media corporations, and they receive attention, for example when their books are reviewed in newspapers or when they are interviewed in documentaries and television programs that air on mainstream networks. It is thus easy to see how this kind of mass media attention is symbiotically connected with “legitimate” science: by paying attention to certain kinds of scientists as legitimate scientists, the mass media reproduce certain notions of science as legitimate science. People may have different opinions on these popularizers and the science they represent, but they still represent “legitimate” science by virtue of being presented as such in the mass media.²⁸

The reason for focusing on mainstream popularizations is that they offer a window onto the most influential notions of science in society. Understanding these notions is important because science is afforded considerable amounts of status, power, and resources in society. A different kind of study could fruitfully focus on challenges or alternatives to the dominant notions of science, but that is not what I focus on in this dissertation. In the conclusion, however, I discuss some popular science books that, in various ways, do challenge dominant notions of science and popularization.

to preserve the conditions necessary for life, regulating, for example, the pH level in the oceans. In his book on the reception of the Gaia hypothesis, philosopher Michael Ruse (2013) shows that Lovelock strove to emphasize the mechanistic nature of the hypothesis. Even so, the hypothesis has consistently been met with suspicion from mainstream scientists, especially biologists, for employing ideas that either are (in spite of what Lovelock says) holistic or lend themselves easily to holism.

²⁷ In 2012, 90 percent of media outlets in the US were owned by six corporations (Lutz 2012).

²⁸ The past fifteen years or so have of course seen the birth of social media. Social media are emerging as important platforms for science communication (van Eperen & Marincola 2011; Luzón 2013; Mahrt & Puschmann 2014; Marsh 2016). While social media are an integral part of science communication for many popularizers—for example, through the use of Twitter—the mainstream selection criterion requires that the popularizers are recognized in the mass media.

The choice of Anglo-American popular science is also indicative of my focus on the contemporary, the mainstream, and the dominant. Specifically, I limit the material that I use to books that have achieved mainstream recognition in the US. This includes non-American popularizers such as British physicists Stephen Hawking and Brian Cox. Limiting the scope to the American context may seem to make my material unnecessarily homogeneous. But there is a point in the homogeneity because I am interested in similarities in the widespread notions of science. The American context is relevant precisely because it is so influential globally. A different kind of study could fruitfully compare popularizations that are recognized nationally in different countries but do not share a public context, but in this dissertation I focus on the US.

I have limited my material to popularizations of physics and astronomy (with a few exceptions, as I discuss below). Of course, there are plenty of popularizations of other sciences. In particular, popularizations of biology are as visible as popularizations of physics and astronomy, with authors such as Richard Dawkins, Stephen Jay Gould, and E.O. Wilson reaching the *New York Times* bestseller list. The idea that physics, astronomy, and biology comprise the most visible subjects is supported by previous scholarship on popular science. Science communication scholar Jon Turney (2007) describes the “subjects which have been treated most often” in popular science as “the trio of cosmology, consciousness and chaos theory, along with genetics and evolution” (1).²⁹ Science communication scholar Declan Fahy, in his book *The New Celebrity Scientists* (2015), discusses the careers of eight celebrity scientists: Stephen Hawking, Richard Dawkins, Steven Pinker, Stephen Jay Gould, Susan Greenfield, James Lovelock, Brian Greene, and Neil deGrasse Tyson. Of these, three are physicists/astronomers (Hawking, Greene, Tyson), and the remaining five are biologists or close to being so (Richard Dawkins and Stephen Jay Gould are biologists; Steven Pinker is a linguist but most known for his popularizations of evolutionary psychology; Susan Greenfield is a neuroscientist; and James Lovelock is an independent researcher and inventor most known for popularizing the Gaia hypothesis). Finally, science communication scholar Alan G. Gross divides the chapters in his book *The Scientific Sublime* (2018) into two categories: “The Physicists,” with chapters on Richard Feynman, Steven Weinberg, Lisa Randall, Brian Greene, and Stephen Hawking; and “The

²⁹ Consciousness stands out somewhat here, but the books to which he is likely referring—in particular Douglas Hofstadter’s bestselling *Gödel, Escher, Bach* (1979) and Roger Penrose’s bestselling *The Emperor’s New Mind* (1989)—use physics and biology, along with cognitive science and computer science, to attempt to explain consciousness.

Biologists,” with chapters on Rachel Carson, Stephen Jay Gould, Steven Pinker, Richard Dawkins, and E.O. Wilson.

Besides physics, astronomy, and biology, there is another subject in which high-visibility books are written, namely climate change, with authors such as James Hansen (2009), Elizabeth Kolbert (2014), and Mark Lynas (2007). Less visible subjects include chemistry, geology, and botany. Since I focus on physics and astronomy, I will not venture deeply into generalizations about trends in popularizations of other subjects, or how popularizations of other subjects relate to physics and astronomy. However, I do discuss E.O. Wilson’s *Consilience* (1998) in the context of definitions of science because it provides an exceptionally clear and forthright discussion and defense of scientism (chapter 4). I argue that Wilson spells out what many other mainstream popularizers of physics and astronomy only tacitly presume and thus that discussing it is illuminating for the analysis of my primary material.

I have chosen physics and astronomy (rather than, say, biology or chemistry) for three reasons. First, physics (especially) and astronomy enjoy arguably the highest status among the sciences, thus enjoying considerable access to resources and epistemological authority. Second, physics and astronomy cover the entire history of the universe, from the Big Bang to the present, thus being of primary interest for providing the building blocks of secular creation myths that compete with traditional religious creation myths for people’s attention. And third, the ambitions of many popularizers of physics and astronomy—to represent the universe and its history in their entirety—provide uses of language of interest for literary theories of representation and narration.

Level 2: The Sample

From this wide array of books, I have chosen a sample of 23 authors, with a chronological spread from the late 1970s to the present, but with an emphasis on the past fifteen years. The authors are: Sean M. Carroll, Andrew Cohen, Brian Cox, Paul Davies, David Deutsch, Jeff Forshaw, James Gleick, Brian Greene, John Gribbin, Mary Gribbin, Stephen Hawking, Michio Kaku, Lawrence Krauss, Leonard Mlodinow, Roger Penrose, Lisa Randall, Martin Rees, Carlo Rovelli, Carl Sagan, Max Tegmark, Neil deGrasse Tyson, Steven Weinberg, and Edward O. Wilson. The list is based on appearances in the mainstream media, appearances on the *New York Times* bestseller list, and in the literature on popular science,³⁰ all of which are good indicators of being

³⁰ See e.g. Mellor (2003); Broks (2006); Edford (2007); Leane (2007); Fahy (2015); Zakariya (2017); Sideris (2017); Gross (2018).

mainstream. The almost total absence of females from this list is striking, to which I return in chapter 1.

While not being an exhaustive list, these authors are representative, in various senses, of physics and astronomy (except for Wilson, by dint of being a biologist) in mainstream, Anglo-American media and culture. By “representative,” I mean, first, that they are *representatives* of physics and astronomy, in the sense of being informal but recognized spokespersons or ambassadors for physics and astronomy in mainstream, Anglo-American media and culture; and second, their books are *typical* of contemporary, mainstream, Anglo-American popularizations of physics and astronomy, in the sense in which Mellor (2003) describes the more or less homogeneous intertextual web of popularizations contributing to shaping dominant notions of science in society.

A particularly striking commonality between these authors is that they are enthusiastic about science. Rhetorician Sarah Tinker Perrault (2013) calls popularizers of the enthusiastic kind “boosters” of science, and she shows that there are additional roles that popularizers can take on. In addition to boosters, there are what she calls “translators” (writers who see their function primarily as translating technical information) and “critics” (writers who approach science with both “interest and skepticism” and who wish to enable their readers to form informed opinions about science). As Perrault shows, however, most popularizers who achieve mainstream success are boosters, not translators or critics (50–60). This mirrors Mellor’s claim, noted above, that the investigatory mode is rare in mainstream popular science. Thus, while not all popularizers are enthusiastic about science, most mainstream popularizers are. In the concluding remarks to this dissertation, I discuss an example of a popularizer who has received some mainstream attention but who does not use an enthusiastic tone, namely Janna Levin.

Most of the above-mentioned authors I only quote or mention in passing, but four of them I discuss in more depth. These are: Carl Sagan’s *Cosmos* (chapters 2 and 4); E.O. Wilson’s *Consilience* (chapter 4); and Brian Greene’s *Fabric of the Cosmos* (chapter 5). I have chosen these books because they are particularly relevant in a given context or have been particularly influential in shaping public debate about or notions of science.

Level 3: Lawrence Krauss and Neil deGrasse Tyson

The most attention is given to Krauss’s *The Greatest Story Ever Told—So Far* and Tyson’s *Astrophysics for People in a Hurry*. I have chosen these books because, first, they are representative of contemporary, mainstream, Anglo-American popularizations of physics and astronomy, as defined above; and

second, because one of them is a physics book (Krauss's) and the other is an astronomy book (Tyson's), thus covering both physics and astronomy. Beyond representativity and the physics–astronomy combination, there was some degree of arbitrariness in the choice of books. I could have chosen other books—e.g., Kaku (1994), Greene (2004), Carroll (2010), Tegmark (2014), Hawking ([1988] 2016)—and done similar analyses. To be sure, there would have been differences in details, but in many respects, the results would have been similar. Choosing two books from 2017 was appealing because, first, it removes emphasis on temporal differences, and second, it ensures that the books are as contemporary as possible. Choosing two male authors was also deliberate. As noted, contemporary, mainstream, Anglo-American popularizations of physics and astronomy is a heavily male-dominated corpus. It is worth noting that of the 18 authors that have made it to the *New York Times* bestseller list writing about physics, astronomy, or general science, only three are female.³¹ And while most of the male authors on the list are professional scientists, none of the female authors are—they are journalists or independent authors, and their books are more historical in character. I could have chosen one male and one female author as my primary objects of study, but that would have been a different study, focused more on differences between the two books rather than similarities. In the concluding remarks to this dissertation, I discuss alternative ways of doing popular science, and there I highlight female authors.

Focusing on *The Greatest Story* and *Astrophysics* almost exclusively allows me to develop the analyses in depth, as well as to develop a coherent and sustained argument throughout the dissertation. My aim, however, is not primarily to read the two books from start to finish, giving equal weight to all the chapters; instead, I focus on select chapters and passages, sometimes returning to specific quotations repeatedly in order to establish how the two books use certain literary techniques and rhetorical strategies. Many sections of the books are explanatory in character. Turney (2004a) argues that explaining scientific theories is central in popular science texts; they have “a mission to explain” (331). While I do discuss this aspect of *The Greatest Story* and *Astrophysics*, my primary interest lies elsewhere, namely in how science, the universe, and humankind are constructed and made meaningful. These meaning-making

³¹ The authors are: Natalie Angier, Bill Bryson, Sean M. Carroll, Richard Dawkins, David Deutsch, Brian Greene, Stephen Hawking, Michio Kaku, Lawrence Krauss, Leonard Mlodinow, Randall Munroe, Steven Pinker, Carlo Rovelli, Margot Lee Shetterly, Simon Singh, Dava Sobel, Leonard Susskind, and Neil deGrasse Tyson. (The title page of Lisa Randall's *Knocking on Heavens Door* [2011] states that it is a *New York Times* bestseller, but I have not been able to find it on the list.)

passages are more prevalent in some chapters and passages than others, which is mirrored in my analyses.

Neil deGrasse Tyson is, together with Bill Nye in the US and Richard Dawkins and Brian Cox in the UK, arguably the most famous science popularizer alive today. He has hosted or been featured in numerous science documentaries. Notably, he hosted the 2014 remake of *Cosmos: A Personal Voyage*, called *Cosmos: A Spacetime Odyssey*, co-written with two of the writers of the original *Cosmos*, Ann Druyan and Steven Soter. He is a regular guest on talk shows, such as *Conan* and *The Daily Show with Jon Stewart*, and he hosts the podcast *StarTalk* since 2009. He is the Frederick P. Rose Director of the Hayden Planetarium at the Rose Center for Earth and Space in New York City since 1996. He has written (as sole author or co-author) several popular science books. *Astrophysics for People in a Hurry* has been on the *New York Times* bestseller list for 83 weeks at the time of writing (May 24, 2019), thus surpassing Carl Sagan's *Cosmos* (70 weeks) and second only to Stephen Hawking's *A Brief History of Time* (112 weeks) in the history of popular science books on that bestseller list. Tyson is the subject of a chapter in Declan Fahy's *The New Celebrity Scientists* (2015: 179–201), "Neil deGrasse Tyson's Star Quality." In late 2018, two women accused Tyson of sexual misconduct. Fox, the network at which *Cosmos: A Spacetime Odyssey* aired, and National Geographic launched an investigation into the allegations (Cadenas 2018). At the time of writing (24 May, 2019), even though Fox and National Geographic have concluded their investigation, they have not released the results. Tyson is, however, confirmed to return to television (North 2019).

Lawrence Krauss is less famous than Tyson, but his book *The Physics of Star Trek* (1995) received much attention, and his book *A Universe from Nothing* (2012) reached the *New York Times* bestseller list. He has been interviewed on television shows such as *The Colbert Report* and *Real Time with Bill Maher*. Mellor (2003), in analyzing *The Physics of Star Trek*, argues that Krauss, through his books and media presence, "acquires a textual prominence which identifies him as a public scientist and spokesperson for physics" (517). He has been active in the science–religion debate, for example featuring in the documentary *The Unbelievers* together with Richard Dawkins (Holwerda [dir.] 2014). He was professor of theoretical physics at Arizona State University (ASU), and he was the director of the Origins Project at ASU from 2008 to 2018.³² He has chaired the *Bulletin of the Atomic Scientists* Board of Sponsors,

³² Following the results of ASU's investigation into sexual harassment allegations against Krauss, discussed more further down in the running text, ASU decided to include the Origins Project in their Interplanetary Initiative rather than keep it as a separate project. The name

an organization that, among other things, sets the so-called “Doomsday Clock”—an estimate, made by world-leading scientists, of how close human-kind is to global catastrophe due to such things as potential nuclear war and catastrophic climate change. Krauss, too, has been accused of sexual misconduct, but unlike Tyson, in Krauss’s case the complaints have been upheld. In February 2018, in the wake of the #MeToo movement, *BuzzFeed* published an article citing numerous women who accused Krauss of sexual harassment (Aldhous, Ghorayshi, & Hughes 2018). In March 2018, ASU put Krauss on paid leave, and in July they decided not to renew his directorship of the Origins Project (Shea 2018b). In August 2018, an investigation conducted by ASU concluded that Krauss had violated ASU sexual harassment policies (Rapanut 2018). It is therefore likely that Krauss’s position as a leading representative of mainstream science and popularization is over, at least as a spokesperson.

A final point about Krauss and Tyson concerns the author and the authorial voice in a text. The concept of the “implied author” is sometimes used in analyses of popular science texts. Mellor (2003), for example, uses it because

the audience will construct an understanding of the author out of the clues within the text and the web of texts surrounding it. Thus, for the purposes of understanding the public construction of science, the author of a popular science book is significant as a textual presence, not as a living and breathing human being interacting with other living, breathing human beings. In other words, in so far as we discuss authors, we need to look at the “implied author” of a book rather than the actual author. (519)

I agree with Mellor and follow her example. Thus, unless otherwise stated, when I use “Tyson” or “Krauss,” I mean the implied authors of *Astrophysics* and *The Greatest Story*, respectively. It is important, though, to underline the importance of their public personae in relation to their texts. Tyson has created a public persona marked by a passion for science, a sense of wonder at the universe, and humor—and this persona permeates the text itself. Similarly with Krauss: his persona is (or used to be) one of a rationalist atheist and debunker of religion and superstition, while also emphasizing the existential import of science. Following the accusations of sexual harassment against both men, their personae (or at least Krauss’s) are also marked by sexual misconduct. This affects the reading of the texts, as I discuss further in chapter 7.

“Origins Project” thus no longer exists (Shea 2018a). The Interplanetary Initiative “brings together faculty to work on the science, public policy, education and technology of humanity’s future in space” (Shea 2018a).

Previous Research

The study of popular science is an interdisciplinary field. Contributors to this field come from a variety of disciplines, including literary studies (e.g. Leane 2007), rhetoric (e.g. Perrault 2013), sociology (e.g. Gieryn 1999), history (e.g. Lightman 2007), media and communication studies (e.g. Broks 2006), and religious studies (e.g. Schrempp 2012). Most of these studies are interdisciplinary and informed by an STS perspective. Throughout the dissertation, I make extensive use of the literature on popular science.

Of particular interest for my purposes are the scholars who use literary theories and concepts in their study of popular science.³³ An early anthology devoted to the literary aspects of popular science was *The Literature of Science: Perspectives on Popular Science Writing* (1993), edited by Murdo William McRae. It includes essays on Stephen Jay Gould's writings (Masur 1993), on popularizations of chaos theory (Porush 1993), and on Primo Levi's *Periodic Table* (Clarke 1993). Subsequent scholars have studied literary aspects of popular science writing, for example narrative structure (Curtis 1994; Charney 2003; Dahlstrom & Scheufele 2018), metaphors (Turney 2004a; Knudsen 2005; Edford 2007), genre (Varghese & Abraham 2004), style (Bucchi 2013), and aesthetics (Turney 2004b; Gross 2018).³⁴ Most of these scholars come from fields other than literary studies, such as sociology, history, and communication studies.

Particularly important in this dissertation are physicist and philosopher Martin Eger's essay "Hermeneutics and the Epic of Science," published in McRae (ed.) (1993), and science historian and rhetorician Nasser Zakariya's comprehensive *A Final Story* (2017). Eger identifies what he calls "the new epic": a collaborative effort to tell the story of the universe from the Big Bang to present day humankind. He sees the epic as distributed over many books: "So vast is this new epic, and so detailed, that no one book can encompass it. What we have instead is a large number of major and minor works, on various levels of 'scientific literacy,' each telling some part of the story, or commenting on it, or interpreting it. Yet taken together, all these constitute the epic

³³ There is also a burgeoning field dedicated to the intersections of science and literature, usually called simply "science and literature." There are big societies devoted to bringing together scholars in the field, such as Society for Literature, Science and the Arts (SLSA), European Society for Literature, Science and the Arts (SLSAeu), and British Society for Literature and Science (BSLS).

³⁴ Some readers may note the omission of Eger (1993), Mellor (2003), Leane (2007), and Zakariya (2017) in this list. I discuss them in the subsequent paragraphs.

itself” (Eger 1993: 198). Zakariya complements and significantly expands on Eger’s idea in *A Final Story* (2017) by identifying four “genres of synthesis” that popularizers and others have used to synthesize all sciences and all knowledge into grand narratives intended to tell the definitive story of the universe. He traces these genres from the second third of the nineteenth century to the present.³⁵

My dissertation, however, tracks most closely science communication scholar Felicity Mellor’s sharp and lucid article “Between Fact and Fiction” (2003) and literary scholar Elizabeth Leane’s groundbreaking book *Reading Popular Physics* (2007). Mellor analyzes routine boundary work—the ways in which popularizers routinely define “science” through contrasts with “non-science”—in popular physics books. Her analyses emphasize the importance of routine boundary work—in addition to boundary work in exceptional cases or times of crisis—and she captures, in my view, the essential dynamics involved. Leane’s nuanced and rich book is the first monograph in literary studies on mainstream popularizations of physics. She situates her analyses in the “two cultures” debate and the science wars, and she analyzes popularizations in three subfields in popular physics: quantum physics (the very small), cosmology (the very large), and chaos theory (the very complex). She analyzes narrative structures, metaphors, boundary work, and genre conventions in a handful of influential and representative popularizations.

My main contributions to the literary study of popular science lie in expanding the repertoire of literary techniques analyzed. I show how popularizers use defamiliarization techniques to construct science, and I discuss some of the ways in which their version of defamiliarization relates to more traditional literary understandings of defamiliarization. I use narratology à la Genette and Chatman to trace ambiguities in popularizers’ construction of science.³⁶ I use the concept of core narrative, in particular the TEUSH narrative, to emphasize the similarities in the books I study, to open them up to the kinds of narrative analyses I do, and to argue that the TEUSH narrative is tailored to promote scientism. I trace the influence of Romanticism on the construction of science

³⁵ As I mentioned above, several scholars besides Eger and Zakariya have identified and analyzed the epic or mythic as a narrative form in popular science; see especially Turney (2001); Schrempf (2012); O’Connor (2013); Sideris (2017).

³⁶ Nasser Zakariya uses Chatman in his dissertation from 2010, *Towards a Final Story*. His *A Final Story* (2017) is a substantive revision and expansion of his dissertation. Though he mentions Chatman in two footnotes (433 n25, 522 n66), he does not use Chatman in his analyses.

in contemporary popular science. And I situate the narratives of science, humankind, and the universe in an environmental context.³⁷

Outline of the Dissertation

Chapters 1–3 form background chapters. They lay the groundwork for the textual analyses in chapters 4–9.³⁸ Chapters 1 and 2 are historical in character. In chapter 1, I discuss the history of science and popularization, including issues in the historiography of science and popularization. In chapter 2, I discuss some aspects of the complicated relationship between science and Romanticism, highlighting the resistance to reductionism evident in many Romantic writers' work, as well as the influence of Romantic tropes in contemporary popular physics and astronomy. Chapter 3 looks at notions of science in contemporary culture and society, including controversies such as the science wars and routine acts of definition such as dictionary definitions.

Chapters 4–9 are devoted to literary and rhetorical analyses of the popular science books specified earlier in the introduction. Chapter 4 focuses on definitions of science, chapter 5 on defamiliarization, chapter 6 on refamiliarization through narrative and figurative language, chapter 7 on protagonists in the texts, chapter 8 on the use of emotions, and chapter 9 on material preconditions and unintentional side effects of science not mentioned by the popularizers under study. Whereas chapters 5–8 focus on what I call existential justifications of science—ways in which science is made meaningful by appealing to existential questions about who we are, where we come from, and how we fit in the universe—chapter 9 focuses on what I call political and technological justifications of science—ways in which science supposedly contributes to desirable societal goals benefits humankind through its application in technology.

The dissertation ends with concluding remarks, in which I summarize the dissertation and discuss alternative forms of science writing. I end by discussing tragedy and wildness as illuminating counterpoints to the triumphant narrative analyzed in the dissertation.

³⁷ Religious scholar Lisa H. Sideris, in her book *Consecrating Science* (2017), also situates the epic narratives of science and the universe in an environmental context. Her focus is not popular science, however, but the epic itself and its consequences for environmentalism. I discovered this book too late to be able to substantially include it in my arguments. However, I have striven to include it where possible.

³⁸ I do, however, perform some textual analyses in chapters 1–3, but they supplement the text rather than form the focus.

1

Science and Popularization Historical Perspectives

In this chapter, I introduce science and popularization through historical perspectives on their entwined history. I wish to emphasize historical *perspectives*. Historical scholarship over the past few decades has shown just how difficult writing a macrohistorical account of science popularization is.³⁹ The shifting meanings of “science” and “popular,” in combination with changes in society and culture over historical time, make any such attempt challenging, both theoretically and practically. When does science start historically, i.e., when is there such a thing as “science” that can be “popularized”? Is “popularization” a stable category over historical time? And if so, what is the time frame? Can popularizations be distinguished from non-popularized science

³⁹ See especially Cooter & Pumfrey (1994); Secord (2004); Broks (2006). The journal *ISIS: A Journal of the History of Science Society* devoted a focus section in 2009 to “Historicizing ‘Popular Science,’” including the articles Topham (2009); Daum (2009); O’Connor (2009); Pandora (2009); Bensaude-Vincent (2009). Spanish science historian Augustí Nieto-Galan (2016) attempted one of the first book-length historical accounts of what he calls “science in the public sphere,” using Jürgen Habermas’s concept “the public sphere” in addition to concepts from Ludwik Fleck and Antonio Gramsci. In a review of the book, Bensaude-Vincent, who has written several articles on the history of science popularization (e.g. 1997, 2001, 2009), lauds Nieto-Galan’s attempt but adds that more work is needed: “None of the models developed so far can really provide a better understanding of the role of scientific authority and its collusions or clashes with political regimes or public opinion. . . . I am not sure that this eclectic composite constitutes a consistent theoretical framework, but it certainly initiates a political turn in the tradition of cultural history of science and the public” (2017: 199). In Sweden, science historian Gunnar Eriksson and librarian Lena Svensson (1986) have written a book-length history of popularization from antiquity to the present. As they themselves acknowledge, however, it is more an attempt to initiate research in the field than a comprehensive historical account.

texts? Is there a stable notion of “the audience” that would make “popularization” a useful category over historical time? Are the societal functions of “popularizations” sufficiently similar to justify using the term over historical time? If so, what are the time frames?

Instead of providing answers—or, indeed, presupposing that clear-cut answers exist—I let these questions guide the perspectives on the history of science and popularization discussed in this chapter. The aim of the chapter is to historicize science and popularization and to highlight themes, tropes, and genres that illuminate contemporary popular science. I focus on texts and aspects of history that are relevant for the analyses in later chapters. However, because romanticization and the triumphant epic of the universe, science, and humankind—the TEUSH narrative—are so central in this dissertation, I discuss them in later chapters rather than this one (romanticization in chapter 2, the TEUSH narrative in chapter 4).⁴⁰

I start in Ancient Greece and Rome. This section is divided in two subsections: “Science,” where I discuss whether it is appropriate to talk about “science” and “popularization” prior to the seventeenth and the nineteenth centuries; and “From Ancient Greece to Early Modern Europe,” where I discuss some influential authors and genres that may be seen as precursors of modern popular science.⁴¹ In the next section (1632–1834), I focus on continental

⁴⁰ In addition to the studies mentioned in the previous footnote, there are historical overviews of popularization, studies focused on historical periods, and studies focused on national contexts. See e.g. Kuritz (1981); Myers (1985); Bensaude-Vincent (1997); Gregory & Miller (1998: 19–51); Burns (2000); Grundmann & Cavaillé (2000); Kärfelt (2000); Bensaude-Vincent (2001); Godhe (2003); Johansson (2003); Kärfelt (2004); Fyfe & Lightman (eds.) (2007); Leane (2007: 19–40); Lightman (2007); Bowler (2009); Kärfelt (2009); Lewenstein (2009); O’Connor (2009); Pandora (2009); Perrault (2013: 37–47); LaFollette (2014); Bowler (2017); Zakariya (2017).

⁴¹ In line with most surveys of the history of popular science, I skip the medieval period. Eriksson and Svensson (1986) devote one paragraph to the medieval period: “Under medeltiden förstärks snarast tendensen att en allmän och bred filosofi dominerar vetenskapen mer än några fackvetenskaper—i varje fall så länge vi som här håller oss till förhållandena inom det naturvetenskapliga kunskapsfältet. De behändiga handböckerna, encyklopedierna, som åtminstone till stor del tangerar vårt begrepp populärvetenskap, spelar en avgörande roll. Men ett språk som endast de lärda förstår, latinet, drar en markerad gräns i samhället” (179). My translation: “During the medieval period, the tendency for a single general and broad philosophy, rather than science, to dominate the branches of science strengthens—at least when we consider only the natural sciences. The convenient handbooks and companions, the encyclopedias, which at least partly approximate what we call popular science, play a key role. However, the use of Latin, a language that only learned people understand, draws a clear dividing line in society.”

Europe and the UK, since that is where the “Scientific Revolution” is usually located and where early popularizations were published. In the following section (1834–1945), I narrow the focus to the UK and the US, primarily because the dissertation focuses on Anglo-American popularizations. The same geographical focus is maintained for the last section (1945–), though with an even stronger emphasis on the US. Throughout, I concentrate on popularizations of physics and astronomy, again in line with the dissertation’s focus, while touching on popularizations of other disciplines when relevant for the issues at hand. I end the chapter with a discussion of the gender disparity in contemporary popular science.

“Popular Science” before the “Scientific Revolution”

“Science”

There is what could arguably be called a standard narrative of the origins of modern science. It dominated historical scholarship in the mid-twentieth century and still shapes common perceptions of the history of science (Shapin 1996; Bowler & Morus 2005; Harrison 2015). In this narrative, the crucial moment was the “Scientific Revolution” of the seventeenth century, associated with such figures as Nikolaus Copernicus, Tycho Brahe, Francis Bacon, Galileo Galilei, Johannes Kepler, René Descartes, Blaise Pascal, Robert Boyle, Christian Huygens, and Isaac Newton.⁴² In the standard narrative, natural philosophers in Ancient Greece had made some headway toward a scientific understanding of the universe, but their efforts did not gain momentum. Fundamentally, they lacked the combination of ideas and methods that characterized the Scientific Revolution and that still characterize science today: the use of mathematics; the use of controlled experiments to test hypotheses; the idea of the universality of physical laws; the use of mechanistic metaphors in conceptualizing nature; and the rejection of notions of teleology in explaining motion.⁴³ These ideas and practices, along with the development of scientific instruments, meant a break with previous views of nature. The Scientific

⁴² Science historian David Wootton (2015: 1) dates the Scientific Revolution to 1572–1704. For brevity and simplicity, I will refer to this time period as the seventeenth century.

⁴³ In the Aristotelian worldview, teleology—purpose-directedness—was invoked to explain both motion of objects and growth of organisms; see also pp. 21–26, in particular footnotes 12 and 14, in the introduction above.

Revolution changed both the world and people's worldview, and we are still living in the wake of this monumental historical rupture.

Some historians adhere to the standard narrative of the Scientific Revolution. David Wootton, for example, defends it in his book *The Invention of Science* (2015). However, most scholars are skeptical of the standard narrative, and it has been questioned thoroughly in historical scholarship in recent decades. Steven Shapin sets the tone in the oft-quoted opening sentence to his *The Scientific Revolution* (1996): “There was no such thing as the Scientific Revolution, and this is a book about it” (1). Of course, Shapin's point is not that nothing important, with regard to views on knowledge and the universe, happened during the seventeenth century. Rather, he is polemicizing against the mid-twentieth century scholarly tradition, espoused by scholars such as Alexandre Koyré and Herbert Butterfield, which coined the phrase “the Scientific Revolution” and cemented the standard narrative of the Scientific Revolution. The scholars who question the occurrence of the Scientific Revolution usually do not take issue with the claim that changes in views of knowledge occurred—but they do object to the purported uniqueness of the event and the purported pervasiveness of the changes. Even though the Scientific Revolution presents discontinuities with ancient and medieval understandings of nature and continuities with present-day science, there are also continuities with ancient and medieval thinking and discontinuities with modern science. For example, in addition to formulating ideas that we now regard as scientific, many of the drivers of the Scientific Revolution were also preoccupied with practices and ideas that would clearly be regarded as unscientific today, such as astrology, alchemy, and eschatology—and they saw no contradiction in this.⁴⁴ And modern science differs profoundly from seventeenth century practices in terms of the institutionalization of science, the professionalization and division of labor, and the infrastructure necessary to conduct science.

If the idea of the “Scientific Revolution” as a sharp historical break does not stand up to scrutiny, then when can science be said to have started historically? Science historian David C. Lindberg argues for a continuity thesis in his book on science from antiquity to 1450, *The Beginnings of Western Science* ([1992] 2007). While not ignoring the differences, Lindberg highlights commonalities between pre-1450 science and modern science that, to him, justify the use of the term “science” to describe certain practices in antiquity and the medieval period. These practices include “languages for describing nature,

⁴⁴ See e.g. Shapin (1996); Bowler & Morus (2005); Lindberg ([1992] 2007); Principe (2011); Harrison (2015).

methods for exploring or investigating it . . . , factual and theoretical claims . . . that emerged from such explorations, and criteria for judging the truth or validity of the claims thus made” (2). For Lindberg and other proponents of the continuity thesis (e.g. Taub 2017), the seeds of modern science are thus to be found in antiquity.⁴⁵

Science historian Peter Dear (2006), in contrast to both the standard narrative and the continuity thesis, argues that two previously independent endeavors coalesced in the nineteenth century to form what we know as “science”: *understanding nature* and *manipulating objects*. It is important to reiterate that the words “science” and “scientist” did not acquire their contemporary meaning until the nineteenth century. When Isaac Newton is identified as a “scientist,” that is an anachronism, at least on the level of word usage. People like Newton were “natural philosophers,” and what they were doing was “natural philosophy.” From antiquity through the Middle Ages and into the early modern period, “natural philosophy” referred only to “intellectual understanding of the natural world” (Dear 2006: 11). It was distinct from what Aristotle had called *technê*, the “skilled practice of manipulating material things” (9), or what we call technology. In the seventeenth and eighteenth centuries, natural philosophy gradually incorporated *technê*. These changes “resulted in the establishment of a new enterprise that took the old ‘natural philosophy’ and articulated it in the quite alien terms of instrumentality—science was born a hybrid of two formerly distinct endeavors” (11). In other words, Dear argues, equating science with natural philosophy is misleading, and one cannot really talk about science prior to the nineteenth century.

In the context of popular science as a genre label, Dear’s account is compelling. It coincides with the professionalization of science and the simultaneous invention of popular science, to which I return. Dear’s dating of science as a nineteenth century invention—which, to be clear, Dear was by no means the first to do (Cunningham & Williams 1993)—is also compelling and supported by much scholarship in the past decades (e.g. Morus 2005; Knight 2009; Tresch 2013). However, both the continuity thesis and the standard narrative provide perspectives relevant for understanding the history of science and popularization—the continuity thesis for understanding the style and structure of later popularizations, and the standard narrative for understanding the role of

⁴⁵ In cognitive psychological hypotheses of the origins of science, some defend a different notion of “continuity,” positing a continuity that goes back to hunter-gatherers in prehistory. These hypotheses suggest that everyday activities such as tracking game and foraging plants are the precursors of science. See Carruthers, Stich, & Siegal (eds.) (2002).

accessible texts in constructing and spreading knowledge in a public arena. Thus, while my overarching framework aligns with Dear's, I argue that taking a longer perspective is illuminating for understanding the historical development of popularizations and the construction of science in publicly accessible texts.

From Ancient Greece to Early Modern Europe

If the applicability of the word “science” prior to the seventeenth and nineteenth centuries is unclear, the meaning of “popular” is even more unclear. Prior to the emergence of capitalism and the use of the printing press in late fifteenth century Europe, there was no book market in the modern sense. Nonetheless, “popular accounts” of natural philosophy and knowledge of the natural world were written in antiquity. Some scholars trace the history of popular science back to these texts. Science communication scholars Jane Gregory and Steven Miller (1998) call a passage in Herodotus's *The Histories* “perhaps the oldest surviving popularization of geology” (19). Gunnar Eriksson and Lena Svensson (1986: 177–179) suggest that the Platonic dialogues could be construed as an early form of popular science. Lindberg ([1992] 2007: 136–145) devotes a ten-page long section called “Popularizers and Encyclopedists” to Roman texts about nature and the universe in his above-quoted book on the history of science prior to 1450. He discusses the works of several Roman writers whom he considers popularizers and encyclopedists—poets and scholars who compiled and presented observations, philosophical ideas, and scientific explanations of natural phenomena in accessible texts available to a readership beyond specialists. These Romans—including Posidonius, Varro, Cicero, Lucretius, and Pliny the Elder—built on the work of their Greek predecessors, whom they considered authoritative, thus popularizing the accepted knowledge at the time.

Science historian Liba Taub, in her *Science Writing in Greco-Roman Antiquity* (2017), discusses the genres that ancient writers used to write about nature: poetry, letter, encyclopedia, commentary, and biography. She argues that “many of the texts that we would identify as ‘scientific’ or ‘mathematical’ were written by individuals who were not themselves experts, some of whom might have been described (in a different time and place) as ‘popularisers’” (10). Perhaps of most relevance for contemporary popularizations are poetry, encyclopedia, and biography.

In his didactic poem *De rerum natura* (*On the Nature of Things*), written in the first century BCE, Lucretius discusses and makes accessible the philosophy

of Epicurus. He conceptualizes Epicurus's work in a way that resonates with contemporary popular science: "Twice in *De rerum natura*, Lucretius stated that he thought using poetry as a medium of communication might make his subject—Epicurean philosophy—more palatable to his readers. He drew an analogy to the way physicians coat the rims of cups with honey to persuade children to take medicine" (Taub 2017: 30). Poetry as such is not the preferred form of popular science today, but the use of poetic language to entertain as well as to teach is pervasive. But there are more reasons for why Lucretius is relevant in this context. The philosophy of Epicurus and Lucretius is materialistic; atoms exist in the void, and that is all there is. Gods, if they exist, are composed of atoms and have no power over humans. Religion is construed as the source of much suffering and is therefore bad. It is no coincidence that Neil deGrasse Tyson uses a quotation from Lucretius to open the first chapter of *Astrophysics for People in a Hurry*: "The world has persisted many a long year, having once been set going in the appropriate motions. From these everything else follows" (Tyson 2017: 17).

In the preface to his monumental *Naturalis Historia* (*Natural History*), written in 77–79 CE, Pliny the Elder explained that he will "deal with subjects that are part of what the Greeks term 'all-round education' [*enkuklios paideia*], but which are unknown or have been rendered obscure by scholarship" (quoted in Taub 2017: 73). The resulting encyclopedia—possibly the first of its kind, but certainly the only one to have survived in its entirety from antiquity (Taub 2017: 72)—foreshadows popular science through its intention to make knowledge accessible. It also foreshadows the comprehensiveness of popularizations of the TEUSH variety: Pliny aims to encompass everything in his encyclopedia. Taub quotes scholars who have argued that "for Pliny *natura* meant 'the world, both as a whole and as its separate components'; *natura* is everything (Beagon 1992: 26). Trevor Murphy has suggested that 'we might just as well translate *Naturalis Historia* as *Inquiry into Everything*' (Murphy 2004: 33)" (Taub 2017: 74). Much like popularizers deploying the TEUSH narrative, Pliny attempted to create a framework in which all knowledge could be presented. And much like the expansionism of scientism embedded in the TEUSH narrative and the use of science for military and imperialist means in the nineteenth and twentieth centuries (Bennett & Hodge [eds.] 2011; Harding [ed.] 2011), scholars have argued that *Natural History* should be understood in the context of Roman imperialism: "the emphases on the imposition of order and the extraction of resources—both understood as vital to the Roman peace—were fundamental aims of the empire, and are both crucial to Pliny's work as well. To be organised in an orderly fashion and to encourage the

extraction of what is useful: these are the hallmarks of Pliny’s presentation and use of the genre of the encyclopaedia” (Taub 2017: 77).

Biographies of natural philosophers, usually inserted into explanatory or expository texts, were common in ancient “science” writing. Aristotle wrote biographies of philosophers to trace the history of philosophy in his works. According to Taub (2017), biographies served a double purpose: first, to celebrate certain individuals, to present them as heroes; and second, to “present intellectual history and lineage” (111–114, at 112). Mini-biographies of famous scientists are ubiquitous in contemporary popular science, and the purpose is essentially identical: first, to present heroes and role models; and second, to present scientific history.⁴⁶

Thus, while the extent to which one can talk about “popular science” prior to the “Scientific Revolution” is unclear, texts that share some similarities with later popularizations were written in antiquity. Because of the feudal system, the Catholic church’s near-monopoly on learning, and the use of Latin as the learned language, the medieval period is not particularly relevant in the history of popularization (see p. 52 n41 above). But as ancient texts were rediscovered and reread in the early modern period, proponents of natural philosophy used tropes and literary forms from these and other texts in their efforts to spread heliocentrism and the new understanding of nature.

1632–1834: From Natural Philosophy to Science

Whatever the nature, uniqueness, and pervasiveness of the “Scientific Revolution,” the consensus remains that something of importance for changes in views on knowledge and nature *did* happen in the seventeenth century. At the very least, as Peter Bowler and Iwan Morus argue in their textbook *Making Modern Science* (2005), the people involved conceptualized their own activities and views as radical and profound:

many of the protagonists who participated in the Scientific Revolution unquestionably appear to have been convinced in their own minds that something momentous was going on. They demonstrate a rare degree of unanimity (a very rare degree for the period in question) not only that something significant was going on in terms of their understanding of the universe but also regarding just what that something was. On the whole, protagonists agreed that what was

⁴⁶ See the discussion of Galileo in this chapter. See also chapter 7.

special about their approach to knowledge was that it was based on the interrogation of experience rather than authority. Instead of consulting Aristotle they were consulting their own senses. It is a moot point whether this perception was accurate. (Bowler & Morus 2005: 51)

This is important for understanding early modern texts about the new natural philosophy. Even though the term “popular science” did not exist at the time, the seventeenth and eighteenth centuries saw the publication of books that share important similarities with what we now know as popular science. Many natural philosophers published books in an attempt to spread the new ideas. They made an effort to make their texts accessible, and they relied heavily on literary techniques to do so. They attempted to persuade not only fellow scholars but also learned and influential people outside the universities (Grundmann & Cavaillé 2000; Ait-Touati 2011; Chico 2018).

I have chosen 1632 as the starting point of this section because Galileo published his *Dialogo sopra i due massimi sistemi del mondo* (*Dialogue Concerning the Two Chief World Systems*) that year. Galileo had published other influential books before, such as *Il Saggiatore* (*The Assayer*) (1623), but there are several aspects of *Dialogue* that make it one of the first major works of popularization.

Dialogue is written as a dialogue between an advocate of Copernican heliocentrism (Salviati) and an advocate of Aristotelian and Ptolemaic geocentrism (Simplicio), with an intelligent amateur bystander who becomes more and more convinced of heliocentrism (Sagredo). In 1616, the Catholic Church had declared heliocentrism a heresy, and so Galileo was unable to defend and teach the Copernican model of the solar system publicly. He was nevertheless allowed to publish *Dialogue* since it was written as a debate between heliocentrism and geocentrism. However, even though Galileo does not explicitly side with Salviati in the book, it is clear where his sympathies lie. Salviati is Galileo’s mouthpiece, and Simplicio, whose name is borrowed from an ancient commentator on Aristotle but also implies simplemindedness, is portrayed as incoherent and incapable of explaining natural phenomena. Furthermore, when he eventually surrenders to Salviati, Simplicio uses a phrase that the pope at the time, Pope Urban VIII, was known to use. The book led to a trial in 1633 in which Galileo was sentenced to house arrest for the remainder of his life. *Dialogue* was banned.⁴⁷

Dialogue is written in the vernacular Italian, not Latin as was the standard

⁴⁷ Shea (1998); Galilei (2001); Heilbron (2001); Stillman ([1980] 2001); Wootton (2010).

for learned books at the time, including books by natural philosophers (Lewenstein 2003: 667). Copernicus, Tycho Brahe, and Johannes Kepler all used Latin, as did Galileo in some of his technical works. The choice of Italian is indicative of Galileo's aim to reach an audience beyond professional mathematicians and astronomers. Furthermore, the dialogue form not only enabled Galileo to explicate the Copernican system without lending it explicit support—it was also a popular literary genre in Italy at the time, modeled on ancient authors such as Plato and Cicero (Cox 1992). Galileo's language is both accessible and engaging, lively and witty, and he “occupies a place among the stylists of Italian literature” (Heilbron 2001: xx). *Dialogue* has been described as “indisputably the greatest Italian dialogue of ideas” (Cox 1992: 32) and “the most influential of Galileo's writings” (Heilbron 2001: xx). *Dialogue* discusses complex and technical issues, but it does so through simplifications and analogies—some of the hallmarks of later popular science. The use of literary techniques and genres to promote and make difficult theories accessible—thus constructing a method and a knowledge content that would later be identified as “scientific”—makes *Dialogue* an extremely important text in the history of popularization.

Though the trial to which the publication of *Dialogue* led had a negative impact on Galileo's personal life, the “Galileo affair,” as the trial and condemnation are called, had enduring positive consequences for the image of Galileo. He has become a scientific hero, one of the major, if not *the* major, martyrs of science (Segre 1998). In particular, he figures prominently in contemporary popular science in that capacity. Lawrence Krauss refers to his “revolutionary nature” and his “epic battle” with the Catholic Church in *The Greatest Story* (2017: 45–47). The Galileo affair has become, in popularizations as well as in undergraduate textbooks, what Thomas M. Lessl (1999: 146) calls “scientific folklore.” As such, it functions as a founding myth of modern science, and it plays into the popular image of a struggle between science and religion, where science is conceptualized as objective and disinterested and religion as subjective and irrational.

Galileo's *Dialogue* is perhaps best described as a hybrid of fiction and non-fiction: it uses drama and fictional elements to discuss and explicate theories about the world. Galileo was not alone in his use of fictional elements to popularize heliocentrism. As Frédérique Ait-Touati (2011) shows, many proponents of natural philosophy used fiction to convey the new worldview. Johannes Kepler, best known for his three laws of planetary motion, wrote a piece of fiction to visualize and popularize the Copernican model: *Somnium (The Dream)*. Kepler wrote the story in 1610, but it was not published until 1634,

four years after his death. *The Dream* recounts a dream in which the protagonist, with the help of a daemon, goes on a trip to the Moon. In the process of describing the trip, Kepler illustrates properties of the Copernican model, for example how lunar eclipses work and the fastest path between the Earth and the Moon given how they move in space. Kepler draws on ancient texts, in particular Lucian's fantastical tale of a voyage to the moon in *A True Story* and Plutarch's *The Face of the Moon* (Christianson 1976; Ait-Touati 2011: 17–44). While *The Dream* was not as influential as Galileo's *Dialogue*, it has been described as the “*fons et origo* of modern science fiction” (Christianson 1976: n.p.). The journey motif continues to be influential in contemporary popular science. Carl Sagan (1980: 65), who also credits *The Dream* as one of the first works of science fiction, devises a “ship of the imagination” in the television version of *Cosmos*. He uses the ship to travel in the universe and illustrate science and astronomical objects and principles. The ship of the imagination is also used in the 2014 remake of *Cosmos* with Neil deGrasse Tyson as host.

Both Galileo and Kepler were writing at a time when Copernicanism was controversial. When Bernard le Bovier de Fontenelle published *Entretiens sur la Pluralité des Mondes* (*Conversations on the Plurality of Worlds*) in 1686, the new worldview had become more accepted, though not necessarily well understood and universally accepted. *Conversations* was enormously influential—it saw numerous editions and translations into other languages (Gelbart 1990). It is sometimes credited as the first popular science book (Frängsmyr 1979; Bensaude-Vincent 2001: 102). Like Galileo, Fontenelle uses the dialogue form to convey Copernicanism,⁴⁸ and like Galileo, Fontenelle writes in the vernacular (French). But unlike *Dialogue*, *Conversations* is not a struggle between two supposed equals. Instead, it is a conversation between a philosopher and an ignorant but intelligent marquis. Thus, incorporated in the very form of *Conversations* is the precursor of the dominant view or deficit model of popularization: an expert explaining, in a simplified yet vivid and engaging language, the prevailing theories at the time. It is also significant that the conversational partner is female. In the eyes of its proponents, the new natural philosophy was so clear and rational that it could be understood “even by women,” who at the time were considered to be much less rational than men. Thus, while the philosopher thinks highly of the Marquis's intellect, there is

⁴⁸ In addition to popularizing Copernicanism, Fontenelle also popularizes Descartes's theory of vortices as the explanation of planetary motion. Ironically enough, only a year after the publication of *Conversations*, Newton published *Philosophiæ Naturalis Principia Mathematica*, which was to supplant much of Cartesian physics.

a clear, gendered difference in status and power between the two.

Thanks to the influence of Fontenelle's *Conversations*, there was an upswing in female readership of popularizations of natural philosophy: "In England, at least as much as in France, Fontenelle's *Conversations* became a classic for women readers, and his Marquise a model for the 'scientific lady.' Magazines, books, and lecture series began to be aimed at women" (Gelbart 1990: xxix). This eventually led to a strong tradition of female popularizers in nineteenth-century Britain (Lightman 2007: 95–167).

Fontenelle represents a transition to the Enlightenment (Gelbart 1990: xix). The beginnings of the growth of the middle classes in Europe, in combination with Enlightenment ideals of producing and spreading knowledge, meant an increase in the number of publications of popularizations: "Newtonian physics and heliocentric astronomy were widely popularized in England in the late seventeenth and eighteenth centuries, forming part of a new market for popular science books produced by increased leisure; 'literally hundreds' of popularizations of Newtonian theory were published in the eighteenth century" (Leane 2007: 21, citing Rousseau 1982). In addition to books, from the late seventeenth century onwards magazines and periodicals were used for popularizations (Burns 2000: 516–517).

On an institutional level, the formation of the Royal Society of London in 1660 is a landmark in the history of science and popularization. It is "the world's oldest surviving scientific institution, and their texts are considered the beginning of 'the public production and reception of scientific knowledge'" (Perrault 2013: 37, citing Payne 2001). The Royal Society and its members are also illustrative of the changes in what we think of as "popular." Today, the main meaning of the term, in the context of popular science, is "making accessible to the public." This was indeed part of the Society's aim; spreading knowledge was a core part of the Society's mission from its inception. However, a parallel aim was to gather knowledge from amateurs. The Society incorporated Francis Bacon's ideal of the importance of practical skills in addition to philosophical speculation, and so the Society attempted to persuade craftsmen to share their knowledge of their crafts, though it was not always successful in accomplishing this (Dear 2000: 540). Moreover, most of the members in the early history of the Society were wealthy amateurs. They did not have professional training in relevant fields. Anyone who had insight, whether practical or theoretical, was in principle welcome to contribute. Thus, in addition to spreading knowledge to the public, the Society was also open to insights and contributions from amateurs (Perrault 2013: 37–39). In this, they differed from their French counterpart, the Académie des sciences (founded in

1666), which had a more hierarchical structure and was more elitist in terms of member constituency. The French Academy was, furthermore, directly tied to the government, while the Royal Society was a private initiative, albeit with the King's blessing. While the French Academy's funding was secured through its ties to the government, the Royal Society depended on contributions from its members and other benefactors. This was another reason for the Society's engagement with the public, and it accounts for why the French academy engaged less with the public than the Royal Society (Kärnfelt 2000: 74–76). It is important, though, to recognize that “the public” of the seventeenth and eighteenth centuries differed from the public of the nineteenth and twentieth centuries. In the latter period, the public came to include ordinary people in mass consumer societies, whereas earlier the amateur philosophers and the readers of popularizations were more often restricted to the upper classes and the emerging bourgeoisie (Leane 2007: 20; Topham 2007: 136).

By the early nineteenth century, natural philosophy was in a very different position than in the early seventeenth century. The Copernican model was accepted, Newtonian mechanics was well developed, the Industrial Revolution had begun in the UK, and there were numerous scientific societies in the West—over 150, in fact (Kärnfelt 2000: 74, citing McClellan 1985). Accumulating knowledge and making it accessible were established practices.

1834–1945: The Consolidation and Professionalization of Science

Up until the early nineteenth century, the distinction between amateurs and professionals was loose and of relatively small importance. Work “we now call science was being done by ordinary people—‘farmers, tradesmen, clerical workers, and manual laborers’—as much as by what we now think of as scientists” (Perrault 2013: 40, citing Thurs 2007). This began to change in the first half of the nineteenth century. There was an increasing professionalization and specialization of the sciences, seen for example in the founding of the British Association for the Advancement of Science in 1831 (known as the British Science Association as of 2009). Some scholars have called the changes that occurred in this period “the second scientific revolution,” referring to a “sudden series of breakthroughs in chemistry, biology and astronomy” (Hadzigeorgiou & Schulz 2014: 1965, n5) and the establishment of the disciplines we

associate with “science.”⁴⁹ Other scholars, who are skeptical of the usefulness of the term “revolution” or the existence of science prior to the nineteenth century, credit this period with the creation of science itself.⁵⁰

The increasing professionalization and specialization of the sciences meant an increasing fragmentation. To counteract this trend, William Whewell coined the word “scientist” in the periodical *The Quarterly Review* in 1834. With this term, Whewell attempted to invent a “name by which we can designate the students of the knowledge of the material world collectively” (quoted in Watson 2016: 10). Through finding a single word to collect these “students of the knowledge of the material world,” Whewell contributed to the creation of the common view of science as a unified enterprise and scientists as inquirers and manipulators of nature. The name did not catch on immediately, but over the course of the nineteenth century, “scientist” replaced “natural philosopher” and “science” replaced “natural philosophy.”⁵¹

Importantly, Whewell coined the term “scientist” in a review of Mary Somerville’s book *On the Connexion of the Physical Sciences* (1834). In this book, Somerville attempts to demonstrate the unity of the sciences concretely, by showing how different areas of inquiry and different natural phenomena are linked. She covers astronomy, physics, chemistry, atmospheric sciences, and biology, although with a definite focus on physics and astronomy, and she does it in an accessible language without using mathematical equations. In the introduction, she explains her views on understanding and science—and, by extension, on popularization:

A complete acquaintance with physical astronomy can be attained by those only who are well versed in the higher branches of mathematical and mechanical science, and they alone can appreciate the extreme beauty of the results, and of the means by which these results are obtained. It is nevertheless true, that a

⁴⁹ See Cunningham & Jardine (1990); Heringman (2003); Baker (2007); Holmes (2008); Watson (2010).

⁵⁰ See Cunningham & Williams (1993); Dear (2006); Knight (2009); Harrison (2015).

⁵¹ As I noted earlier, Peter Dear (2006) argues that “science was born a hybrid of two formerly distinct endeavors” (11)—understanding nature and manipulating it. This duality is reflected in the discussions that lead to the coining of “scientist.” Whewell had originally proposed the term “scientist” during the first meetings of the British Association for the Advancement of Science. In those discussions, alongside suggestions such as “philosopher” and “savant,” two less flattering names were suggested and promptly rejected: “nature-peeper” and “nature-poker” (Heilbron 2003). However, in view of the gendered metaphors that pervade science, especially the Baconian metaphors of seduction and marriage (see especially chapters 6 and 7 below), these names are oddly apt.

sufficient skill in analysis to follow the general outline—to see the mutual dependence of the different parts of the system, and to comprehend by what means the most extraordinary conclusions have been arrived at,—is within the reach of many who shrink from the task, appalled by difficulties, not more formidable than those incident to the study of the elements of every branch of knowledge. There is a wide distinction between the degree of mathematical acquirement necessary for making discoveries, and that which is requisite for understanding what others have done. (Somerville [1834] 1849: 2–3)

Connexion was enormously influential and widely read: “The first edition of 2,000 copies quickly sold out, and the book remained in print for over forty years, with ten editions selling 17,500 copies in all. It was translated into German, French, and Italian, and publishers in Philadelphia and New York in the United States issued pirated editions” (Secord 2014: 119). Richard Holmes (2014) credits *Connexion* with “arguably launch[ing] popular science writing” (432). While this may be something of a simplification, it is clear that Whewell and Somerville were at the forefront of conceptualizing science in a new way: as a unified enterprise composed of different fields and subfields all linked together (Watson 2016). And it is clear that Somerville spread that conception in one of the most widely read popularizations of the nineteenth century.

The professionalization of science also meant a sharper distinction between professional science on the one hand and popularized science and amateur science on the other. Peter Broks (2006) argues that “science” and “popularization” are mutually dependent categories: “No longer could [popular science] properly stand for that egalitarian participation in the Republic of Science, but rather it was to be the science which is popularized, and in this new sense emerged as a stable publishing genre. ‘Scientist’ and ‘popularization’ was a twin birth; each helps us to understand the other” (24). Thus, while texts that made difficult theories accessible existed prior to the nineteenth century, popular science, as the genre we know today, emerged in the early nineteenth century.

In addition to the professionalization of science and the concomitant distinction between expertise and laity, the formation of a mass market for books in the nineteenth century contributed to the shape popular science. “Popular science” as a term and genre label was coined in the 1820s and 1830s in the UK. The rise of popular science was a result of the emergence of cheap publications and the parallel trend of the populace increasingly being defined as consumers (Broks 2006: 33–38; Fyfe & Lightman [eds.] 2007). In addition to the part played by the professionalization of science in establishing popular science, it is important to keep the financial aspects in mind. While it is clear

that one of the functions of popular science is ideological—to establish a distinction between “real” science and “popularized” science, and to propagate for science in society—publishing houses also saw an opportunity to make money (Topham 2007). This is a reminder of the multitude of interests and purposes behind popular science for various actors. Individual authors, scientific organizations, governments, and publishing houses all have a stake in popular science. Popular science can be a vehicle for a wish to make science accessible; for a wish to contribute to the shape of science itself by summarizing the state of a field; to help establish science as a profession or the source of legitimate knowledge; to promote the cause of science in society; to promote policies in legislative contexts; and to make money by publishing books and magazines (Bowler 2009).⁵²

The early nineteenth century was also when popular science emerged in America, influenced by the developments in the UK through the import of British publications (Pandora 2009: 352). Several journals and magazines were launched, for example the *American Journal of Science* (1818), *Scientific American* (1845), and *Popular Science Monthly* (1872) (Keeny 2001: 449; LaFollette 2014: 270). Marcel Chatkowski LaFollette (2014) remarks that the “popularization of science . . . has fit comfortably within the political and social framework of the United States. Democracy, capitalism, and the nation’s cultural and legal defense of free expression have resulted in few inhibitions imposed on public communication of scientific ideas and, often to the dismay of scientists, have encouraged a proliferation of interpretive voices through emergent new communications media” (267–268). In 1847, the American Association for the Advancement of Science was formed “with the central aim of drawing a clear line between professional and amateur science” (Gregory & Miller 1998: 23), thus mirroring the developments in the UK.

In the second half of the century, two areas of science in particular attracted popularizations: thermodynamics and evolution by natural selection. Thermodynamics—the physics of heat, temperature, energy, and work—came together as a discipline with the formulation of the principle of the conservation of energy in the 1840s (Watson 2016: 15–44). Popularizations of thermodynamics in the mid-to-late nineteenth century tended to focus on everyday objects, for

⁵² Beyond the printed word, popularization of science took place in multiple forms and venues in the nineteenth century. Science museums, public lectures, the World Exhibitions, and— from the turn of the century and onward—radio and television were all used for popularizations of science, both in the UK and America (see Bensaude-Vincent 2001; Fyfe & Lightman [eds.] 2007; Lightman 2007). But since this dissertation focuses on books, these forms of popularization will, for the most part, not be discussed.

example John Tyndall's *Heat: A Mode of Motion* (1863), which illustrates physical principles in a concrete manner through simple experiments. Part of the reason for the focus on practical, everyday science was that many successful popularizations, including Tyndall's *Heat* and Michael Faraday's *The Chemical History of a Candle* (1861), were based on public lectures that included demonstrations (Leane 2007: 22). However, as in present-day popularizations, many popularizers of thermodynamics also presented their discussions of technical theories in moral, social, philosophical, and religious frameworks (Myers 1985; Leane 2007: 22).

The tendency to discuss moral and social questions was also evident in popularizations of evolution. Charles Darwin, the co-discoverer of evolution by natural selection together with Alfred Russel Wallace, caused great controversy with the publication of *On the Origin of Species* in 1859, not least compelling authors of fiction to grapple with his theory (Beer 1983; Levine 1988; Jonsson 2017). Darwin himself can be considered a popularizer of evolution, since *Origin* was written in an accessible language with an educated public in mind. However, it was also a lengthy and detailed book aimed at biologists and natural historians. Darwin was convinced that evolution had to be popularized if it were to be accepted, and so he tried to convince his friends to do so. He was not always successful:

Darwin must have been constantly disappointed by the way in which prominent popularizers—even his friends—presented his theory. Evolution was rarely popularized in ways that reflected Darwin's major contribution to biology, his theory of natural selection. This meant that the reading audience more often encountered an alternative to Darwin's naturalistic, non-directional and non-progressive evolutionary perspective. There were at least four different versions of evolution circulating in the period from 1860 to 1900, and only one conformed to Darwin's vision. (Lightman 2010: 6)

In its popularized form, evolution was often put to work in discussing spiritual development and even Christianity, as well as social evolution and competition, often with racist and imperialist undertones (Hawkins 1997; Lightman 2010). This is a reminder of the importance of historical context in understanding the construction of science in popular science. Science is often used for ideological purposes shaped by the beliefs and concerns of the day—which in turn contribute to the construction of science.

At the turn of the twentieth century, there was a downturn in popularization in both the UK and the US (Leane 2007: 23, citing Burnham 1987 and Bensaude-Vincent 1997). Meanwhile, however, physics was undergoing

fundamental changes, with the theory of relativity and quantum mechanics being developed in the first decades of the twentieth century. In 1919, astronomer Arthur Eddington was acknowledged to have confirmed Albert Einstein's general theory of relativity during a solar eclipse.⁵³ This launched Einstein as a celebrity, both in Europe and the US. Elizabeth Leane (2007) calls the ensuing upturn in physics popularizations "the Einstein boom" (24). Einstein himself published a popularization of his theories—*Relativity: The Special and General Theory* (written in 1916, first English translation in 1920)—and he was followed by popularizations by Eddington (*Space, Time and Gravitation*, 1920) and philosopher Bertrand Russell (*The ABC of Relativity*, 1925), among others. A few hugely successful popular physics books were published toward the end of the decade, most notably Eddington's *The Nature of the Physical World* (1928) and James Jeans's *The Mysterious Universe* (1930), both of them British. Jeans's *The Mysterious Universe*, in particular, was a sensation. It had sold 70,000 copies by the end of 1930 and nearly 140,000 copies by 1937 (Bowler 2009: 101). Even though Jeans's book did not meet with a favorable response among intellectuals at the time (Bowler 2009: 103), it is notable for its rhetorical resonances with of the late twentieth-century popularizations. Leane (2007: 26–27) notes similarities with Steven Weinberg's *The First Three Minutes* (1977) and Paul Davies's *The Last Three Minutes* (1994)—invocations of grandeur, wonder, and cosmic loneliness in a vast universe. There is also a telling likeness to Krauss's *The Greatest Story* is also present. Jeans opens *The Mysterious Universe* by quoting Plato's cave allegory; Krauss uses the same cave allegory in constructing science (see chapters 4, 7, and 8 below).

During the 100 or so years discussed in this section, science went from being professionalized and defined as a unified enterprise to being an established and important societal force. Popular science, likewise, took shape as a recognizable genre, through the distinction between expertise and laity and the emergence of a mass market for books. The creation of science as the coming together of intelligibility (natural philosophy) and instrumentality (*techné*) had also been increasingly brought out in the nineteenth century. Science historian

⁵³ A consequence of the general theory of relativity is that massive objects bend light. This idea can be tested during a solar eclipse. Arthur Eddington led an expedition to South Africa in 1919 to do that. Eddington and his team announced that their measurements were in agreement with the predictions of the general theory of relativity. Subsequently, there has been some debate as to whether Eddington's observations were accurate enough to actually confirm the predictions made (Kennefick 2009). Regardless of whether they actually were precise enough, the announcement was perceived as a confirmation, and Einstein became a celebrity.

Jon Agar, in a wide-ranging history of twentieth century science (2012), highlights the importance of industry in the development of science:

From the mid-nineteenth century . . . physics laboratories, within universities dedicated to research, emphasized the value of precision measurement of physical quantities. Very little of this work was what in the twentieth century would be considered theoretical physics. Instead it was intimately connected with the industrial and commercial projects of the day. Under a gathering second industrial revolution, science-based industries exploited electrical phenomena and new chemistry. . . . In Germany, Britain and the United States, measurement of ohms, amperes and volts was essential to new electrical systems of electrical power and electric light. Science, industry, economy, and national and international competition were ever more intertwined. (Agar 2012: 15)

World War I intensified the ties between science, industry, and government (Agar 2012: 89–117). The interwar years and World War II saw a scaling up of science—in terms of organization, resources, number of scientists, and size of instruments—culminating in the Manhattan Project and the creation of the atomic bomb (Agar 2012: 161–185, 229–300). The success of the Manhattan Project would have lasting consequences for the shape of science following World War II: “Science as scaled-up, goal-driven, manager-organized, American-led projects would be a prominent, but by no means hegemonic, feature of the post-war world” (Agar 2012: 292).

1945–: The Growth of Science and the Popular Science Boom

Following World War II, there were mixed feelings about science among the public. Peter Broks (2006) describes the postwar world as “deeply contradictory in its attitudes towards science” (73). On the one hand, science had helped win the war for the Allies through the atomic bomb, and it was key in gaining the upper hand in the Cold War. Science helped put a man on the moon in 1969, and there were dreams of colonizing space. Science was involved in producing ever new inventions and products for people’s comfort and leisure, such as medicine, communications technology, and transportation systems. On the other hand, the atomic bombs dropped over Hiroshima and Nagasaki had caused untold suffering, and the Cold War saw the world gripped in the seemingly never-ending fear of a nuclear holocaust. Rachel Carson published *Silent Spring* in 1962 and brought environmentalism, with its focus on saving the

Earth rather than venturing into space, to the public's attention. And the technologization of everyday life and commodification of science met resistance among the countercultural movement, which rebelled against scientific authority and a society based on production and consumption rather than community and participation (Broks 2006: 73–88).

Through all this, Western governments tried to secure the public's support for science—in part because science relied on public funding, and in part because of the need to recruit researchers and administrators. The universities expanded dramatically in the West in the 1960s, transforming universities from elite institutions to a mass education system (Bathmaker 2003; Scott 2008). The number of people involved in research and higher education grew drastically, with consequences for research output worldwide. If scientific growth is measured by the number of publications and cited references, then statistics can give some sense of the growth of science. The number of scientific publications had an annual growth rate of about 3 percent between 1980 and 2012, and the number of cited references had an annual growth rate of 8-9 percent between the interwar period and 2012 (Bornmann & Mutz 2015). These figures are indicators of the exponential growth of science since World War II.

Post-war science is notable for its scale and organization. While traditional, small scale research is still being done, the conspicuous trend in science has been big science (Galison & Hevly [eds.] 1992; Agar 2012). This is especially the case for the disciplines of primary interest in this dissertation. Advancements in physics and astronomy require the development and construction of ever more powerful and sophisticated instruments—in particular, telescopes, space probes, and particle accelerators. This, in turn, requires the resources, levels of organization, and large-scale collaborations characteristic of Big Science.

Big Science can be characterized by five Ms: money, manpower, machines, media, and military (Agar 2012: 330). Big science is expensive, requires many laborers, utilizes large machines, needs and receives media coverage, and has often been developed for military purposes. Notable examples of Big Science in physics, astronomy, and space exploration include the Apollo program of the 1960s and 1970s, the SLAC particle accelerator in Stanford, the CERN particle accelerator in Switzerland, and the Hubble Space Telescope. Another way of characterizing big science is in terms of its organizational features. Agar (2012: 331–332) lists four such features. First, big science is goal-oriented. The creation of the atomic bomb in the Manhattan Project is a good example. But in peacetime as in wartime, goals are needed: “No huge sum of money could be dedicated without a mission, without outcomes that could be

articulated and measured” (331). Second, this leads to a concentration of resources, and thus to the prominence of a few research centers, such as NASA and CERN. Third, big science requires a division of labor and a hierarchical organization of managers and groups. CERN is a good example. There are theoreticians, engineers, experimenters, maintenance staff, administrators, contractors for materials, and so on. Fourth, these projects have had a high political significance, especially during the Cold War. One could almost say that the space race between the United States and the Soviet Union produced science as a by-product; its main significance was political and economic. Success in science and engineering is important for national prestige, industrial capability, and the demonstration of military power. Thus, big science is never just about the production of knowledge; it is also about marketing science, displaying national power and prestige, and cultivating collaborations with industry.

The fourth M—media—is, of course, of particular importance in the context of this dissertation. Bensaude-Vincent (1997) puts it plainly: “Because scientific research is to a very large extent state funded, it is dependent on taxation. Therefore, disseminating research results among the public [is] an important way of maintaining confidence” (332). In the interwar years, after science’s implication in the abominations of World War I, there had already been efforts to avert a crisis of faith in science on the part of the public through popularizations. The horrors of the atomic bomb brought with them similar efforts to market science as a force for good, involving the scientific community, science journalists, and government agencies. The prevailing style in science reporting in the 1950s was “unsensational, factual, serious,” and the idea among those disseminating science was that “more information about science would automatically improve the public’s attitude toward science” (Bensaude-Vincent 1997: 331–332). Bruce Lewenstein (1992) argues that the term “public understanding of science” in fact meant “public appreciation for the benefits that science provides to society” (46). To some extent, these efforts seem to have been successful. In spite of nuclear worries, the 1950s is often considered a decade of optimism: “For many Americans in the 1950s, science promised a brighter future filled not only with hitherto unimaginable opportunities for better, easier lives but also with prospects for greater national security” (Schwartz 2003: 45).

Beyond science reporting in the media, several prominent popularizers emerged in the 1950s and 1960s: George Gamow, Fred Hoyle, Arthur C. Clarke, Richard Feynman, and Isaac Asimov (Leane 2007: 30). However, the 1960s in general saw an increasing skepticism toward science. This was due not least to the growing environmental movement: “A new era for popular

science began in the early 1960s, when criticism began to appear of the unbridled enthusiasm for science that had reigned in the United States for the previous 20 years or so. . . . With the rise of a new, politically-oriented environmental journalism, the close ties between science journalism and mainstream scientific institutions began to break down” (Lewenstein 1992: 62). Science reporting was more critical, and there was a general downturn in popular science books well into the 1970s (Leane 2007: 30, citing Lewenstein 2002 and interviews with Paul Davies).

Yet the 1960s was also a decade of enthusiasm for space. In 1961, president John F. Kennedy ([1961] 2004) spoke before the American Congress to convince them how important it was that the US “commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.” NASA was tasked with achieving this goal. The moon landing was a bid to win the space race. The initial moon landing in July 1969 was followed by five more landings in 1969–1972. But the end of the Apollo program meant a dramatic decrease of funding for NASA, and it fell from more than 4 percent of US government spending in 1966 to less than 1 percent in 1975 (The Guardian Datablog 2010). NASA focused its efforts on developing space shuttles, the Skylab space station, and unmanned space probes. However, the Apollo program had sparked dreams of continued space exploration on a large scale.

Carl Sagan, who rose to fame as a popularizer in the 1970s, was one of the most vocal proponents of the dream of continued space exploration. He advocated it in popular science books such as *The Cosmic Connection* ([1973] 2000) and on the *Tonight Show Starring Johnny Carson*, where he was a recurring guest from 1973 onward. Thanks to *The Tonight Show*, Sagan became a household name, “America’s best-known scientist” (Davidson 1999: 263). His bestselling book *The Dragons of Eden* (1977) earned him the Pulitzer Prize for General Nonfiction in 1978—a watershed publication in popular science books, according to Lewenstein (2007). Yet it was the television series *Cosmos: A Personal Voyage* (1980), co-written with Ann Druyan and Steven Soter, which made Sagan an international celebrity. *Cosmos* first aired on PBS (Public Broadcasting Service) in the US in the fall of 1980. It consists of 13 episodes, modeled on Jacob Bronowski’s BBC series *The Ascent of Man* (1973), and it conveys science on an epic scale (Zakariya 2017: 307–339; Sorensen 2017). It was an instant success and became the most watched series on PBS, a position it held for a decade (Spangenburg & Moser 2004: 141). It has been called “a watershed moment for science-themed television programming” (Itzkoff 2011). The accompanying book, called simply *Cosmos* and only

listing Sagan as the author, became a bestseller, spending 70 weeks on the *New York Times* bestseller list, which was unprecedented at the time in the English language for a science book (Davidson 1999: 334). Lewenstein (2009) highlights the importance of *Cosmos* for popular science: “With *Cosmos*, science books became dramatically more visible in the publishing world. Until then, most science-oriented volumes had sales in the region of 100,000–200,000 hardcover copies, with a few reaching sales of 500,000. *Cosmos* sold 900,000 copies while on the best-seller list and continued to sell well for years” (357).

Sagan’s fame, and especially the success of *The Dragons of Eden* and *Cosmos*, was part of—indeed, a significant cause of—the popular science boom. The popular science boom was a marked increase in the visibility, sales, and number of titles of popular science books. Sagan was even featured on the cover of *Time Magazine* in 1980, with the caption “Showman of Science.” Bookstores devised sections dedicated to popular science to meet the supply and demand, and some stores published guides to the genre (Broks 2006: 89).

Fittingly, Sagan wrote the preface to the first edition of a book that would be the next major bestseller: Stephen Hawking’s *A Brief History of Time* ([1988] 2016). And if Sagan’s success with *Cosmos* was unparalleled at the time, then Hawking’s success with *A Brief History* broke even the records set by Sagan. Upon its publication, it spent more than two years on the *New York Times* bestseller list and more than five years on the *Sunday Times* bestseller list. During the first twenty years of its run, it sold more than ten million copies and was translated into more than 30 languages (Griffin 2018). Hawking became a global celebrity, an icon for science, “without doubt the most famous scientist of the modern era” (Fahy 2015: 20). *A Brief History* was a huge success, making the 1990s the peak of the popular science boom in terms of sales figures (Leane 2007: 46).

Judging by the presence of titles on the *New York Times* bestseller list, popular science continues to be a successful genre in the book market. In physics, astronomy, and general science, several authors have appeared on the list since 2000, including Natalie Angier, Bill Bryson, Sean M. Carroll, Richard Dawkins, David Deutsch, Brian Greene, Stephen Hawking, Michio Kaku, Lawrence Krauss, Leonard Mlodinow, Randall Munroe, Steven Pinker, Carlo Rovelli, Margot Lee Shetterly, Simon Singh, Dava Sobel, Leonard Susskind, and Neil deGrasse Tyson.⁵⁴

⁵⁴ I have only listed bestsellers in physics, astronomy, and general science. Broadening the topics to other sciences, there are many more titles, for example Malcolm Gladwell’s *Blink* (2005), on psychology, and Elizabeth Kolbert’s *The Sixth Extinction* (2014), on climate change and the Anthropocene. See the section “Popular Science and Gender” below for a discussion of

In addition to books, there are several other media and forums in which science is constructed and communicated, for example science museums, science festivals, newspapers, popular science magazines, and television. Science shows on television continue to be influential. As mentioned above, there was a remake of *Cosmos* in 2014, hosted by Neil deGrasse Tyson and co-written by Tyson and two of the original *Cosmos* authors, Ann Druyan and Steven Soter (Carl Sagan passed away in 1996). This remake received a great deal of attention, including a 30 second endorsement by President Obama introducing the first episode. Bill Nye, often called “the face of science” in the US (Milman 2017; 500 Women Scientists 2018), hosted the enormously successful show *Bill Nye the Science Guy* (1993–1998), episodes of which were regularly shown to American schoolchildren during science class (Rockman et al. 1996). In the UK, the rise to fame of Brian Cox is credited with an increase in interest in science, his BBC show *Wonders of the Universe* (among other shows) having a major impact. Commentators have noted a “Brian Cox effect” likely responsible for an increase, even called a “boom,” in students taking physics classes (Highfield 2011). The past fifteen or so years have also seen the birth and rapid growth of social media, with repercussions for science popularization (Van Eperen & Marincola 2011; Luzón 2013; Mahrt & Puschmann 2014). Major popularizers like Tyson, Nye, and Cox maintain widely read Twitter accounts, and the blog *I Fucking Love Science* is suggestive of the new media climate: it started in 2012 as a Facebook page created by the biology undergraduate Elise Andrew and has since transformed into an independent blog with several staff writers (Marsh 2016).

Popular Science and Gender

A conspicuous feature of the list of bestselling authors above is the small number of women represented: only 3 out of 18 authors.⁵⁵ The numbers are similar for popular science books shortlisted for awards. Jo Marchant (2011), in an essay for *The Guardian*, notes that “of 144 shortlisted books [for the Royal Society Winton Prize for Science Books]—six each year over 24 years—just nine were by women, with two others that had a woman as second author, including a husband-wife team. Out of these female authors, only one has won

the gender disparity evident in this list.

⁵⁵ The title page of Lisa Randall’s *Knocking on Heavens Door* (2011) states that it is a *New York Times* bestseller, but I have not been able to find it on the list.

(the husband-wife team).” The numbers are similar for other awards. The American Institute of Physics (AIP) awarded prizes for popular science books in the category “Journalists” in the Science Communication Award from 1968 to 2012. Out of 45 awards given, 9 were to women, the first one in 1982 (Marcia F. Bartusiak) and seven of them from 1997 onward. In 2013, the category “Science Writing: Books” replaced the journalist category; all of the recipients in this category since then have been men (AIP 2018). The Pulitzer Prize for general nonfiction is no different. Since 1980, when the award started listing runners up, nine science books have been awarded the prize; of these, two authors were female (Tracy Kidder in 1982, Elizabeth Kolbert in 2015). Twenty science books have been runners up (i.e. the two or three on the shortlist that did not win); two of those had female authors (Judith Rich Harris in 1999, Diane Ackerman in 2012) (Pulitzer 2018). Marchant (2011) notes that while the gender balance is equal among editors and writers at the journals *New Scientist* and *Nature*, relatively few women write science books and very few reach wide recognition and readership. These trends may have to do with the gender gap in research in general: less than 30 percent of the world’s researchers are women, and on average women publish less, are paid less, and do not advance as far as their male counterparts (UNESCO 2018). Few female popularizers reaching the very top is thus consistent with a similar trend in research in general. This trend stands in contrast to the prevalence of female popularizers in the UK in the nineteenth century, as noted (Lightman 2007: 95–167)—a time when female researchers were far fewer than today. However, these female popularizers mostly tapped into what Lightman calls the “maternal tradition”—women writing for an audience of mostly women and children. Furthermore, the very fact that they were, for the most part, excluded from “real” scientific work may explain why many of them channeled their interest in science into popularizations.

In addition to the gender disparity in salaries, opportunities, and visibility, there are deep issues that have to do with cultural representations of men and women in the West. Declan Fahy, in his study of celebrity scientists (2015), discusses these issues in a chapter on British neuroscientist and popularizer Susan Greenfield (111–133). Greenfield was the first woman to become director of the Royal Institution in the UK, and she was the first woman to give the prestigious Royal Institution Christmas lectures for children in 1994. The treatment of her in the media, however, differs from the treatment of male scientists. The media tended to focus on her appearance and tended to thematize the fact that she was a woman. Fahy puts this into a long tradition of media representations: “While male scientists were discussed in terms of their public role,

female scientists were presented in terms of their domestic, personal, and professional lives” (119). This taps into the tradition of science as such being culturally coded as male. A male scientist is a scientist, period, while a “scientist who is a woman is then always a *woman* scientist, not simply a scientist” (Leane 2007: 160; quoted in Fahy 2015: 119).

Fundamentally, these representations of men and women coincide with the very origins of Western philosophy and science, as discussed by Evelyn Fox Keller in her classic *Reflections on Gender and Science* (1985). Keller analyzes the ways in which Plato and Francis Bacon, both of whom have had a formative influence on Western philosophy and science, conceptualize the project of acquiring knowledge about the world. For both, the inquirer is male, and both use imagery of eroticism and love. Yet in “neither vision is material nature (female for both Plato and Bacon) invited into a partnership of love: in one [Plato] she is relegated into another realm, in the other [Bacon] she is seduced and conquered. Laid bare of her protective covering, exposed and penetrated even in her ‘innermost chambers,’ she is stripped of her power” (Keller 1985: 31). Objectivity and reason, foundational virtues of science, are coded as male, while women are identified with subjectivity and feeling—as *obstacles* to scientific understanding. The observer and inquirer position is male, while the object of observation and inquiry—nature—is female (6–7). Against this long-standing cultural background, it is perhaps not surprising that there is a gender disparity in mainstream science popularization. The public culture of science, especially physics and astronomy, is, essentially, male.

2

Romanticism Meets Science

Revolt, Reform, and Appropriation

While science is most plausibly considered a nineteenth-century (and beyond) phenomenon, many components of the worldviews and philosophical positions associated with science date back several centuries. This is especially true of reductionism and mechanization. Reductionism and mechanization have been conceived of by many as the defining features of natural philosophy and science since the seventeenth century. A worldview characterized by reductionism and mechanization offers no firm footing for meaning and value. Things happen because of the blind, impersonal laws of nature, not because a transcendent being has a grand plan in mind. Perceiving that world as “cold” and “pointless” is close at hand.

There have been many reactions to this perceived coldness and pointlessness of a reductionist and mechanistic worldview. One of the most eloquent early reactions to this worldview, as it was emerging among natural philosophers, is Blaise Pascal’s:

When I consider the short duration of my life, swallowed up in the eternity before and after, the little space which I fill, and even can see, engulfed in the infinite immensity of spaces of which I am ignorant, and which know me not, I am frightened, and am astonished at being here rather than there; for there is no reason why here rather than there, why now rather than then. Who has put me here? By whose order and direction have this place and time been allotted to me? . . . The eternal silence of these infinite spaces frightens me. (Pascal 1958: 61)

Pascal, who had been a mathematical child prodigy and an important natural philosopher, became a devout Christian and left natural philosophy for

Christianity. He had a “first conversion” in 1646, after which he stuck to his philosophical and mathematical work. But in 1654, after an emotionally intense “second conversion” that ended a period of exhaustion and dissatisfaction, he formally renounced natural philosophy. From that point on, he dedicated most of his time to writing an apology for Christianity: *Pensées* (“Thoughts”), from which the quotation is taken (Davidson 1983; Rogers 2003).⁵⁶

To what extent Pascal’s conversion was due to the perceived pointlessness of the universe is less important than the poignancy with which he expressed that sentiment and the resonance it has had.⁵⁷ Several scholars have pointed to the quotation, or to Pascal’s turn to Christianity in the face of a pointless universe, as an early response to the “disenchantment of the world” (Khalifa 2003: 139; Zakai 2010: 125–162; Wootton 2015: 448). Though Pascal’s particular trajectory may not be representative of philosophers and artists since the seventeenth century, many have responded by lamenting the loss of an enchanted world (e.g. Friedrich Schiller), by wanting to reform science itself (e.g. Johann Wolfgang von Goethe), and by warning scientists about the dangers of scientific pursuits taken too far (e.g. Mary Shelley).

The Romantic period in Europe was crucial in influencing the shape of modern science, as well as formulating enduring challenges to a worldview characterized by reductionism and mechanization. During the Romantic period (c. 1770–1830), the meaning and value of science were under intense debate. At the time when science as we know it was taking shape, the Romantics were contesting the reductionist and mechanistic character of Newtonian physics as a valid model for science. Romanticism in general is usually seen as a reaction to Enlightenment and neo-classicist ideals of order, harmony, and rationality (Brown 1993). In the popular conception of Romanticism, the Romantics dismissed science. This is a misconception.⁵⁸ Many of them did, however, challenge reductionist and mechanistic conceptions of the universe associated with

⁵⁶ As Rogers (2003) notes, however, “Pascal himself never used the word ‘apology,’ which can have misleading implications if it encourages the view that he was aiming to ‘prove’ the truth in Christianity; Pascal believed that where religion was concerned, you had to believe it, to see it” (19, note 12).

⁵⁷ Pascal used different rhetorical strategies in his attempts to convert different kinds of people. It is thus not certain that the sentiment he expresses in the quotation discussed is his own. According to historian J.V. Field (1995), “The famous remark about being frightened by the silence of infinite space is not presented as expressing Pascal’s own feelings but those of a postulated *libertin*, that is a ‘free thinker’ or atheist” (227).

⁵⁸ See e.g. Heringman (2003); Baker (2007); Holmes (2008); Tresch (2013).

natural philosophers such as René Descartes, Isaac Newton, Christian Huygens, and John Locke.

The Romantic challenges to science—the dissatisfaction with reductionism and mechanization by most Romantics and the attempt by some Romantics to reform science itself—is part of the cultural background in which Lawrence Krauss and Neil deGrasse Tyson popularize science. When Krauss (2017: 2) says: “Contrary to many popular perceptions, this scientific story also encompasses both poetry and a deep spirituality,” this is, to a large extent, a reaction to lingering Romantic views of mechanistic science. But by the same token, it is also a testament to the influence of Romanticism on science.

The legacy of Romanticism is mixed. On the one hand, the attempts by some Romantics to reform the reductionist and mechanistic character of the emerging science have had little impact. As John Tresch (2013) argues: “This alternative scientific tradition [Romantic science] rose to prominence in the 1820s, 1830s, and 1840s amid the upheavals of early industrialization. . . . After 1850 the classical image of science again took the upper hand; even today, we largely take for granted that real knowledge is possible only where there is a radical divide between subjects and objects and where nature is reduced to discrete, predictable mechanisms” (xi). On the other hand, many of the images, tropes, and attitudes that we now associate with science and scientists—such as the lone genius, the exploratory voyage, and the idea of a “pure,” “disinterested” science separate from political ideology and religion—were either formulated by the Romantics or emphasized by them (Holmes 2008; Haynes 2017). The distinction between “Romantic science” and “the romanticization of science,” introduced in the introduction, is intended to make this mixed legacy clearer. “Romantic science” refers to attempts by Romantics to reform science, whereas “the romanticization of science” refers to the appropriation of Romantic themes and tropes by advocates of science who wish to maintain the image of science as reductionist and mechanistic.

I thus begin this chapter by discussing attitudes among Romantic poets and philosophers toward natural philosophy and science of the reductionist variety, while also discussing challenges involved in characterizing “Romanticism” and its relationship with science. I continue by discussing the idea that science, and modernity in general, “disenchants the world”—an idea, most famously formulated by Max Weber in the first decades of the twentieth century, that to a large extent originated with the Romantics. I then go on to discuss what an alternative “Romantic science” might look like, illustrating this through a characterization of science as perceived and practiced by Johann Wolfgang von Goethe. I then discuss Mary Shelley’s *Frankenstein*, one of the most influential

novels of the Romantic era, and show how the ambivalence of the characterization of Frankenstein—reductionist scientist and passionate Romantic—contributed to the romanticization of science. I end by characterizing and specifying the romanticization of science with a reading of the popular science television show *Cosmos: A Personal Voyage*.

Romanticism and the Disenchantment of the World

Modern scholars writing about Romanticism typically note the difficulties involved in defining the term.⁵⁹ Characterizing “the Romantic worldview” is more treacherous still, not least because it is a term that brings together views by a variety of people lumped together as “Romantics.” These difficulties are aggravated by modern scholarship showing that the received view of Romanticism in some respects stems from twentieth-century scholars who sometimes exaggerated the hostility with which the Romantics treated science. As Tresch (2013) argues, sweeping yet clear-cut distinctions between Romanticism and mechanism—with associated binaries such as passion/reason, spirit/matter, and organisms/machines—tend to be difficult to uphold under close scrutiny. In particular, Tresch shows that the Romantics typically were not opposed to machines and science per se. What they did not like were “classical machines” such as clocks and levers which imply an image of nature as stable and fixed, reducible to simple deterministic laws, and suggesting “a view of knowledge as a detached, impersonal, and emotionless objectivity” (xi). Instead, they were fascinated by what Tresch calls “Romantic machines,” which were “understood as flexible, active, and inextricably woven into circuits of both living and inanimate elements. These new devices accompanied a new understanding of nature, as growing, complexly interdependent, and modifiable, and of knowledge, as an active, transformative intervention in which human thoughts, feelings, and intentions—in short, human consciousness—played an inevitable role in establishing truth” (xi). Thus, it is a misconception that the Romantics were uniformly anti-science or anti-technology.

The received view of the Romantics as anti-science and anti-technology was influential in shaping the intellectual climate of the twentieth century, including the two cultures debate and the science wars (Tresch 2013: 1–3).⁶⁰ For

⁵⁹ See e.g. Brown (1993); Berlin (2001); Baker (2007); Hogle (2010).

⁶⁰ See chapter 3 for a discussion of the two cultures and the science wars.

example, even though William Wordsworth was interested in science, the following stanza from his poem “The Tables Turned” (1798) is frequently used as an example of Romantic dislike of science (Heringman 2003: 7):

Sweet is the lore which Nature brings;
Our meddling intellect
Mis-shapes the beauteous forms of things:—
We murder to dissect.⁶¹

Through the repeated quotations of poems like this, the Romantics have been constructed by many scholars as anti-scientific, even though the historical reality was more complex.

While it is important to be careful and nuanced when discussing the Romantics’ view of science and nature, it is still possible to discern some commonalities and tendencies. Many Romantics *did* dislike the reductionist view of nature associated with Newtonianism. They tended to view reductionism and unchecked use of analysis as responsible for humankind’s separation from nature. William Blake, for example, expresses resistance to the influence of rationalization in his poem “London” (1794). The first two stanzas read:

I wander thro’ each charter’d street,
Near where the charter’d Thames does flow.
And mark in every face I meet
Marks of weakness, marks of woe.

In every cry of every Man,
In every Infants cry of fear,
In every voice: in every ban,
The mind-forg’d manacles I hear.⁶²

The phrase “mind-forg’d manacles” is at once a reference to the rationalization of nature through Newtonian science and the rationalization of human life through oppressive systems of authority (Sayers & Monin 2012). It is significant that the manacles are *mind-forg’d*: it is a violence done to nature, society, and humankind by reason and mechanization—it is not the natural state of being.

M.H. Abrams, in his influential study of Romanticism, *Natural Supernaturalism* (1971), reads the leading Romantics’ worldview as a reformulation of

⁶¹ Wordsworth & Coleridge ([1798, 1800, 1968] 1991: 104).

⁶² Quoted in Sayers & Monin (2012: 3).

the Christian narrative of original sin and redemption. But for the Romantics, the culprit was not the eating of an apple; it was knowledge gained through rationality and analytic reason, or the division of the world into parts: “As Novalis summarized what was a Romantic commonplace: ‘All evil and wickedness is isolating’” (Abrams 1971: 181). Andrew Cunningham and Nicholas Jardine (1990), in the introduction to the anthology *Romanticism and the Sciences* (Cunningham & Jardine [eds.] 1990), argue that these acts of division and isolation found their clearest expression in natural philosophy of the Newtonian kind: “for the Romantics mechanistic natural philosophy is the culmination of the analytic and judgemental approach responsible for our fall from grace with nature” (3–4). In other words, reductionist science distorts the world through division, and it inflicts violence on both nature and humans. It turns nature into a dead mechanism—and in so doing, it loses sight of life itself. Reducing life to mechanism means bypassing the very essence of life. The lesser known Austrian Romantic poet Nikolaus Lenau expresses this idea succinctly in a scene in his poem *Faust* (first edition 1836, second edition 1840). While performing an autopsy on a corpse, Faust declares:

If only this corpse could laugh!
 It would break out in laughter
 because we are cutting and observing it,
 because we are inquiring the dead about life.⁶³

In the place of mechanism and division, the Romantics championed vitalism and an organic, holistic vision of the universe. And typically, salvation would come not through the traditional Christian God, but through aesthetics and utopian politics.

John Keats, another poet who disliked reductionism, formulated an oft-quoted view of natural philosophy as a cold destroyer of wonder in his poem *Lamia* (1820):

Do not all charms fly

⁶³ My translation. The original reads:

Wenn diese Leiche lachen könnte, traun!
 Sie würde plötzlich ein Gelächter schlagen,
 Daß wir sie so zerschneiden und beschaun,
 Daß wir die Toten um das Leben fragen.

(Lenau [1840] 2017: 6)

At the mere touch of cold philosophy?
There was an awful rainbow once in heaven:
We know her woof, her texture; she is given
In the dull catalogue of common things.
Philosophy will clip an Angel's wings,
Conquer all mysteries by rule and line,
Empty the haunted air, and gnoméd mine—
Unweave a rainbow . . .⁶⁴

By “awful” Keats does not mean “bad” or “terrible”; rather, he means “awe-inspiring” or wonder-inducing (Fisher 1998: 90). In other words, scientific explanations demystify natural phenomena and make them cold. They become points of entry in the “dull catalogue of common things.” Science destroys awe and wonder. Friedrich Schiller voices a similar sentiment in his poem “Die Götter Griechenlands” (“The Gods of Greece,” 1788, revised 1800). In this poem, the lyrical I looks back nostalgically to a time when gods and spirits populated the Earth and the world was magical. It is unclear to what extent Schiller actually believed that gods and spirits existed; they are more likely poetic personifications of his idea that the Greeks, in Sara Lyon’s (2014) words, “perceived the cosmos as holistic and magical, suffused with divinity” (879). In any case, if there was any magic and divinity in the world, Newtonian science destroyed it. The Christian purging of paganism also played a role in this, but, as scholar of religion Jason Josephson-Storm (2017) argues, the “real resentment in ‘The Gods of Greece’ was directed against a natural philosophy that reduced the vibrant world of the primitive humanity into dead mechanism” (83).

Summing up such sentiments, philosopher Rüdiger Safranski (2014) argues that Romanticism “belongs to the movements that for the last two hundred years have wanted something to oppose to the disenchantment of the world through secularization. In addition to the many other things it can be, Romanticism is the continuation of religion by aesthetic means” (xiv). Regardless of the historical accuracy of Schiller’s claim, the idea of the demystification of the world was taken up by sociologist Max Weber in the early twentieth century. Sara Lyons (2014: 879) shows that there is a direct line of influence from Schiller to Weber. Weber formulated the idea of “Die Entzauberung der Welt” (“the disenchantment of the world”) in, among other texts, the lecture “Wissenschaft als Beruf” (“Science as a Vocation”) in 1917. By his account, science is not the only agent of disenchantment—it is, more generally, Western

⁶⁴ Quoted in Cunningham & Jardine (1990: 3).

modernity, interpreted as an increasing rationalization and bureaucratization of society in combination with a monotheistic ontology. Disenchantment started with the Protestant Reformation but found its full expression in science. For Weber, the point is not that science has developed a full understanding of the world, but rather that science fosters a mindset that extinguishes the mysterious and inexplicable:

Thus the growing process of intellectualization and rationalization does *not* imply a growing understanding of the conditions under which we live. It means something quite different. It is the knowledge or the conviction that if *only we wished* to understand them we *could* do so at any time. It means that in principle, then, we are not ruled by mysterious, unpredictable forces, but that, on the contrary, we can in principle *control everything by means of calculation*. That in turn means the disenchantment of the world. (Weber, “Science as a Vocation”; quoted in Wootton 2015: 449)

The details of Weber’s thesis are complex, and there is still some debate about what he meant exactly. Nonetheless, a simple version of the idea of the disenchantment of the world has been enormously influential—to the point of having become, according to many scholars, a standard narrative of modernity, secularization, and science.⁶⁵ This standard narrative has been called into question on numerous fronts in recent decades. One strand of criticism aims at re-enchancing the world, for example by construing matter as alive and agential, as opposed to the “dead” matter of Newtonianism (e.g. Bennett 2001; Barad 2007; cf. Josephson-Storm 2017: 5). Another strand of criticism sets out to show that there has been a parallel tradition of enchantment throughout modernity and into the present, in such traditions and movements as poetry, philosophy, “new age” spiritualism, and fringe science (e.g. Landy & Saler [eds.] 2009; Locke 2011). Yet another strand of criticism, forcefully pursued by the above-quoted religious scholar Josephson-Storm (2017), aims at showing that disenchantment does not characterize the modern mindset to begin with. First, citing survey studies on beliefs and attitudes, Josephson-Storm shows that disenchantment does not characterize “the general mentality,” since supernatural beliefs are alive and well among the public. For example, according to a survey study in 2005, 73 percent of Americans hold at least one paranormal belief, such as a belief in ghosts or telepathy (24–26). Second, Josephson-Storm shows that even scholars in the nineteenth and twentieth centuries who

⁶⁵ Bennett (2001: 7–8), Locke (2011: 33), Harrison (2017), and Josephson-Storm (2017: 4) all argue that disenchantment is a standard narrative of modernity.

formulated and/or championed the idea of disenchantment—scholars as different as Weber, members of the Vienna Circle, and members of the Frankfurt School—were either intensely interested in or involved with occultist movements and paranormal beliefs, and furthermore frequently used terminology from the realm of magic to formulate their positions and research programs. In other words, while “the disenchantment of the world through science” is a vague and simple idea that does not really stand up to careful scrutiny, the idea that science disenchants the world has been, and to some extent continues to be, influential in the reception of science in some traditions of thought.

When it comes to disenchantment and popular science, the issue needs to be specified. If the idea of disenchantment is taken to mean the loss of belief in spirits and supernatural entities, then popularizers tend to laud disenchantment (Harrison 2017). But if disenchantment means the loss of a sense of awe and wonder, then popularizers tend to disagree that science is incompatible with these emotions and attitudes (Sideris 2017; Gross 2018). As will be shown, science’s ability to induce wonder, awe, and experiences of beauty is at the heart of the popularizers’ construction of science.

Before examining this aspect of popular science, however, it is instructive to discuss what a Romantic science could look like. It is instructive not only because it highlights reactions toward reductionistic and mechanistic science among Romantic poets and philosophers, but also because it brings into sharper relief the specific ways in which mainstream popularizers have appropriated Romantic ideas.

Romantic Science: Johann Wolfgang von Goethe

Most of the defining Romantics were authors and philosophers rather than scientists, and so they did not conduct scientific research of note. However, one of the major poets of the Romantic era did: Johann Wolfgang von Goethe. To call Goethe a Romantic is not uncontroversial, but toward the end of his life “he acknowledged . . . that Schiller had convinced him that ‘I myself, contrary to my own will, was a Romantic’” (quoted in Richards 2002: 3). Furthermore, he is usually counted as a major proponent of Romantic science by modern scholars.⁶⁶ Thus, a brief characterization of his science will serve to illustrate

⁶⁶ See Cunningham & Jardine (1990); Richards (2002); Ruse (2013); Hadzigeorgiou & Schulz (2014).

what a Romantic science could look like.

Goethe developed an interest in nature and pursued science for many years in parallel with his other activities. He studied geology, botany, and physics. Today, his work on plant physiology and the theory of color are the best known of his scientific studies (Amrine & Zucker 1987; Holdrege 2014). As with many of the Romantics, Goethe's main target was Newton. In particular, Newton's theory of light bothered Goethe. Newton had used prisms in elaborate experimental setups to show that rays of white light can be divided into the spectrum of colors with which we are all familiar (see Fig. 4.1, p. 136 below). In Newton's interpretation, white light consists of all colors, and the prism serves to divide the light into its constituent colors. By contrast, "for Goethe [the colors] *came into being* out of a relationship between light and darkness" (Bortoft 1996: 20). "Goethe attempted to develop a physics of color which was based on everyday experience. He worked to achieve an authentic wholeness by *dwelling in the phenomenon* instead of replacing it with a mathematical representation" (Bortoft 1996: 19).

In Goethe's view, Newtonian experimentation, explanation, and mathematization exemplified what was wrong with mechanistic science: studying nature under highly artificial conditions to prove abstract theories. Goethe did not disapprove of experience and empiricism as the basis for science, nor did he disapprove of experimentation; rather, he wanted *more* experience and empiricism, and he thought that *Newtonian* experimentation was too narrow: "He was driven by what he thought the defects of the Newtonian approach: insufficient experiment and hasty generalization, which violated 'the rights of nature'" (Richards 2002: 439). Newtonian science restricted the encounter with nature to a kind of idealized "objective subject" whose attitude was one of distance and control. The Goethean way of approaching nature instead emphasizes fuller, gentler, and more immersive and imaginative encounters with nature. It looks to wholes rather than parts, and it praises closeness and connection over distance and detachment. In line with this, Goethean science requires the scientist not only to develop her/his understanding of nature, but *her-self/himself* as well: "the growth of science resides as much in the self-development of the scientist as in the accumulation of data" (Amrine & Zucker 1987: xii). Through cultivating themselves and their senses—through developing "[their] perceptual faculties on *all* levels—including [their] aesthetic and emotive 'antennae'" (Amrine & Zucker 1987: xv)—the Goethean scientist moves away from the reductive approach that results in quantifiable laws and instead starts seeing patterns of a different kind. The end result of this approach is the identification of "archetypal" or "primal" phenomena ("Urphänomen")

in nature: “The primal phenomenon is not to be thought of as a generalization from observations, produced by abstracting from different instances something that is common to them. . . . For Goethe, the primal phenomenon was a concrete instance—what he called ‘an instance worth a thousand, bearing all within itself.’ In a moment of intuitive perception, the universal is seen within the particular, so that the particular instance is seen as a living manifestation of the universal” (Bortoft 1996: 22).

Perhaps surprisingly for a posterity that knows him primarily for his works of literature, Goethe valued his contributions to science higher than his poetic achievements: “I do not attach importance to my work as a poet, but I do claim to be alone in my time in apprehending the truth about colour” (quoted in Sherrington 1949: 5). Numerous scientists, philosophers, and artists have taken an interest in Goethe’s science. There are many monographs and edited volumes on it;⁶⁷ some have tried to develop it as an alternative to the dominant version of science (e.g. Bortoft 1996; Holdrege 2014); and it has been interpreted as a precursor to phenomenology and phenomenologically oriented studies in the humanities (Robbins 2006). However, despite Goethe’s efforts, and despite others’ attempts to reform science in a Goethean fashion, it is not an exaggeration to say that posterity disagrees with Goethe’s appraisal: he is widely regarded as one of the greatest poets in Western literature, but his scientific work has not been taken seriously by mainstream science. The central tenets of Goethean science—anti-reductionism, organicism, wholes over parts, connection over detachment—have not been incorporated into mainstream science. Edward O. Wilson’s assessment is telling:

the German Romantics, led by Goethe, Hegel, Herder, and Schelling, set out to reinsert metaphysics into science and philosophy. The product, *Naturphilosophie*, was a hybrid of sentiment, mysticism, and quasi-scientific hypothesis. . . . Goethe can be easily forgiven. After all, he had a noble purpose, no less than the coupling of the soul of the humanities to the engine of science. He would have grieved had he foreseen history’s verdict: great poet, poor scientist. He failed in his synthesis through lack of what is today called the scientist’s instinct. . . . In the philosophers’ empyrean I imagine [Francis] Bacon has long since lectured Goethe on the idols of the mind. Newton will have lost patience immediately. (Wilson 1998: 38–39)

Wilson’s condescending tone is a mark of the degree to which Goethe is dismissed in mainstream representations of science. If he is not attacked more

⁶⁷ See e.g. Nisbet (1972); Amrine, Zucker, & Wheeler (eds.) (1987); Stephenson (1995); Seamon & Zajonc (eds.) (1998).

than he is it is because he is not seen as a serious contender in the interpretation of science and the universe. And to the extent that Goethean science is representative of Romantic science in general, this verdict applies to it too. As Tresch (2013) argues, the Romantics largely failed in their attempts to combat reductionism, mechanization, and the divide between subject and object. While the future trajectory of science may have been uncertain in the 1830s and 40s, “After 1850 the classical image of science again took the upper hand” (xi). In other words, even though the Romantics did influence science in various ways, they lost the battle that mattered most to them: getting rid of reductionism, mechanization, and the subject–object divide. It is important to note that, like Tresch and other STS scholars, I am speaking of the image of mainstream science and the dominant scientific rhetoric rather than the actual practices of science day-to-day (see Bauer 1992; Collins & Pinch 1993; Agar 2012). Whether, and to what extent, actual scientific practices adhere to reductionism, mechanization, and the subject–object divide is largely irrelevant when analyzing popular science texts; the important point is that these texts typically construct science as reductionist, mechanistic, and characterized by the subject–object divide.

Romantic Scientists? Mary Shelley’s *Frankenstein*

In her comprehensive study of fictional representations of scientists in Western culture since the early modern period, literary scholar Roslynn D. Haynes (2017) argues that until very recently, scientists were primarily shown in a negative light: “the portrayals of unattractive scientists, whether as suspicious, foolish, arrogant, inhuman, amoral, mad, evil, dangerous, or helpless, predominate in both fiction and film” (337).⁶⁸ She traces these negative portrayals back to the Faust myth at the turn of the seventeenth century, through the Enlightenment satires of Margaret Cavendish, Alexander Pope, and Jonathan Swift, to the Romantic critiques of mechanization and the inhuman nature of science (12–104).⁶⁹ Mary Shelley’s *Frankenstein* ([1818] 1981) occupies a central role

⁶⁸ Haynes (2017) attributes these negative portrayals to protests against “the official history of science,” against “the ‘great men’ account of science, which tells us that we have nothing to fear because these good and brilliant people are in control and trustworthy” (3–4). I return to this contrast between the positive and negative versions of the history of science in chapter 7.

⁶⁹ In Haynes’s account, the largely negative portrayals of scientists continued for much of the

in the history of fictional representations of scientists. Haynes devotes a separate chapter to *Frankenstein* “because of the extraordinary influence it has continued to exert on subsequent presentations of the scientist. Frankenstein has become an archetype in his own right, universally referred to and providing the dominant image of the scientist in twentieth-century fiction and film and the media” (91). Together with Faust—who sells his soul to the devil in exchange for knowledge, experience, and power—Frankenstein has become a symbol of science taken too far and spun out of control.

Written as a frame story with three nested levels of narration—Captain Walton, Victor Frankenstein, and the creature—*Frankenstein* tells the story of a young scientist, Frankenstein, who, through a scientific experiment, creates a living being referred to as “the creature” ([1818] 1981: 42), “the wretch” (42), “the being” (42), and “the monster” (43), among other terms. Though the details of the experiment are left unexplained, Frankenstein states that he has “[infused] life into an inanimate body” (42). Repelled by his own creation, Frankenstein abandons the creature. The creature, who craves affection and companionship, tries to force Frankenstein to create a female creature to be his companion. Frankenstein begins to do so but abandons the project, afraid of the potential consequences of two such creatures roaming the world. Having killed Frankenstein’s brother earlier in the story, the creature proceeds to kill a friend of Frankenstein and Frankenstein’s bride. Frankenstein sets out on a journey to kill the creature, pursuing him to the Arctic. During the chase Frankenstein meets Captain Walton, to whom he tells his story. Toward the end of the novel, Frankenstein dies on Walton’s ship. The creature shows up, mourns the death of Frankenstein, and decides to commit suicide. Having said farewell to Walton, the creature “sprang from the cabin window . . . , upon the ice raft which lay close to the vessel. He was soon borne away with the waves and lost in darkness and distance” (206). Frankenstein’s last words to Walton amount to an ambivalent warning: “The forms of the beloved dead flit before me, and

nineteenth and twentieth centuries, through influential works like Robert Louis Stevenson’s *Strange Case of Dr Jekyll and Mr Hyde* (1886), Aldous Huxley’s *Brave New World* (1932), and Stanley Kubrick’s *Dr. Strangelove* (1964). Haynes goes on to argue, however, that the negative portrayals in fiction to some extent have been replaced by more positive portrayals in the past two decades. She discerns two trends that, in her view, have disrupted the traditional attitude: environmental issues, fictional portrayals of which typically frame Big Business rather than scientists as antagonists; and nuanced portrayals of mathematicians in such movies as *Breaking the Code* (1995), *A Beautiful Mind* (2001), and *The Imitation Game* (2014). She argues that in the contemporary risk society (see Beck 1992), scientists are portrayed as risk monitors and potential risk averters in addition to risk producers. Terrorists and big corporations have taken over the role as antagonists (Haynes 2017: 337–339).

I hasten to their arms. Farewell, Walton! Seek happiness in tranquility and avoid ambition, even if it be only the apparently innocent one of distinguishing yourself in science and discoveries. Yet why do I say this? I have myself been blasted in these hopes, yet another may succeed” (200).

Throughout the novel, Frankenstein is described as obsessed and passionate. Even on his deathbed, and even after his creation has killed his loved ones, Frankenstein hesitates in his warning against ambition and science (“I have myself been blasted in these hopes, yet another may succeed”). *Frankenstein* is central to the history of representations of scientists not only because it has been so influential, but also because Shelley’s characterization of the scientist is complex and ambivalent. Frankenstein is not just a cold rationalist. He is also an idealist and a passionate Romantic. Haynes (2017) argues that Frankenstein

embraces both the scientific rationalism and reductionism condemned by the Romantics and the ultimate Romantic quest for knowledge of the absolutes of life and death. [Shelley] thereby suggests that these apparently contrary positions are, in the final analysis, merely variations of the same basic type—the overreacher whose aspirations lead inevitably to the destruction of himself and others, yet who is admired as the heroic genius. (93)

Reductionist science and Romanticism thus fuse in the figure of Victor Frankenstein. In this way, *Frankenstein* can be seen as a step toward the romanticization of science.

The Romanticization of Science: *Cosmos: A Personal Voyage*

In *Frankenstein*, Shelley warns against the fusion of reductionist science and Romanticism: reductionist science, fueled by Romantic idealism and passion, may have consequences that cannot be contained. In contemporary popular science, the romanticization of science bears no trace of this warning. In addition to being conceptualized as the path to truth, science is conceptualized as a positive force in the world. If there are negative consequences, it is not because of science, but because of bad management.

What characterizes the romanticization of science is that it wishes to retain reductionism, mechanization, and the subject–object divide as core characteristics of science—yet also, as it were, add in Romantic tropes and themes to

this core. It does not matter whether science really is reductionist and so on in actual practice; what matters is that popularizers typically construct science as reductionist, mechanistic, and characterized by the subject–object divide. It is important for them to maintain that image of science. Plausibly, this is because reductionism, mechanization, and the subject–object divide are associated with objectivity and truth. Thus, presenting science in this way lets popularizers be authorities on what counts as knowledge, on the one hand, and what counts as “superstition” or “mere opinion” on the other hand. Scientists are the guardians of truth, the gatekeepers of reality. But adding Romantic tropes and themes makes science more appealing; it lets popularizers construct science as intriguing, meaningful, and emotionally satisfying.

The romanticization of science is characterized by more features than passion and idealism. In his *The Age of Wonder* (2008), author and biographer Richard Holmes discusses the influence of Romanticism on science. He uses the term “Romantic science” in a broad sense, referring to a surge of interest in fluidity, electricity, and other phenomena that resonated with Romantic interests. Thus, he does not restrict the term to efforts, such as Goethe’s, to rid science of reductionism, mechanization, and the subject–object divide. However, his account is useful for defining the romanticization of science. He lists several characteristics—some of which are also prominent in *Frankenstein*—which I have found useful in my characterization of the romanticization of science: “The idea of the exploratory voyage, often lonely and perilous”; “the dazzling idea of the solitary scientific ‘genius,’ thirsting and reckless for knowledge, for its own sake and perhaps at any cost”; “the idea of the ‘Eureka moment,’ the intuitive inspired instant of invention or discovery”; “The notion of an infinite, mysterious Nature, waiting to be discovered or seduced into revealing all her [sic] secrets”;⁷⁰ “The ideal of a pure, ‘disinterested’ science, independent of political ideology and even religious doctrine”; “a new commitment to explain, to educate, to communicate to a general public”; and “the ‘experimental method’ [as] the basis of a new, secular philosophy of life, in which the infinite wonders of Creation (whether divine or not) were increasingly valued for their own sake” (Holmes 2008: xvi–xix).

To illustrate the romanticization of science, I turn to the television series *Cosmos: A Personal Voyage* (Sagan et al. [1980] 2009), written by Carl Sagan, Ann Druyan, and Steven Soter. *Cosmos*, as I have shown, has been enormously influential in shaping the construction of science in contemporary popular

⁷⁰ This feminization of nature is, as I discussed in chapter 1, a legacy of Platonic and Baconian philosophies. I return to this in chapters 6 and 7.

science, and it uses Romantic tropes pervasively.⁷¹ *Cosmos* runs to thirteen episodes and covers a wide range of topics, with a particular focus on physics, astronomy, evolutionary theory, and exobiology (what is now known as astrobiology). Sagan is present on-screen, describing and explaining scientific theories and the history of science, and there are dramatizations of historical moments in the history of science and exploration—for example, a biography of Johannes Kepler (episode 3) and an account of the world of trade and exploration of the seventeenth-century Dutch Republic (episode 6). In these dramatizations, Sagan acts as a voice-over narrator.

In addition to instantiating the triumphant epic of the universe, science, and humankind—the TEUSH narrative—*Cosmos* is structured by the journey motif. This is indicated already by the subheading of the series: “A Personal Voyage.” The centrality of the journey motif is further made evident five minutes into the first episode. The episode, called “The Shores of the Cosmic Ocean,” opens with Sagan standing on a cliff by the ocean talking about science, the cosmos, and *Cosmos*. He explains that we—meaning Sagan and the viewers—are “going to explore the cosmos in a ship of the imagination. Unfettered by ordinary limits on speed and size, drawn by the music of cosmic harmonies, it can take us anywhere in space and time” (Sagan et al. [1980] 2009, episode 1: 4^m22^s–4^m36^s). The ship of the imagination recurs throughout the series; in it, Sagan travels in the universe and lets the viewers explore and witness the wonders of the cosmos. The ship, which is largely empty except for a computer, and it has two windows through which Sagan can view the universe.

The visual and auditory aspects of these journeys are crucial: objects in the universe are presented as wonders, often accompanied by the transcendental-sounding music of the Greek composer Vangelis, with Sagan’s face and voice expressing delight and wonder, heightened by poetic descriptions of the cosmos and the enterprise of science. When Sagan is in the ship, his voice is heard as a voice-over, thus enabling a simultaneous focus on his voice, words, and facial expressions. These are examples of journeys in *Cosmos* at what might be called the *individual* level, by which I mean that the subject of the journey is the individual. Most immediately, that individual is Carl Sagan, journeying through the cosmos in the ship of the imagination. He is completely alone in the ship. At times, he appears apprehensive, as though he is not sure what is

⁷¹ The television series and the book are very close. Often, the text in the book is a direct transcript of Sagan’s words in the show. While I focus on the book more in other chapters, I discuss the series here because the visual language and audio track make the romanticization of science especially salient.

going on or if he is in danger; but most of the time, he is relaxed, observing and admiring the wonders of the universe. Thus, while it is not exactly perilous, Sagan is on a lonely exploratory voyage—a hallmark of Romantic science, according to Holmes—in the vast and mostly unknown cosmos. Through the soundtrack, imagery, and Sagan’s voice, words, and facial expressions, the universe is also presented as “an infinite, mysterious nature, waiting to be discovered or seduced into revealing all her secrets” (Holmes 2008: xviii).

But the individual can also be the viewer of the show. In a vicarious and metaphorical way, everyone can, potentially, embark on a similar voyage: “the cosmos is also within us. We’re made of star-stuff. We are a way for the cosmos to know itself. *The journey for each of us begins here.* We’re going to explore the cosmos in a ship of the imagination . . .” (episode 1: 4^m10^s–4^m26^s; emphasis added). When uttering the italicized words, Sagan points to his head, indicating that the journey is an inner journey of discovery as well as a fictionalized outer journey. In other words, even though the journeys in the ship are his personal journeys, they are also, potentially, everyone’s. Here one can see one of *Cosmos*’ main agendas playing itself out: presenting science as an appealing, exciting, meaningful, and emotionally satisfying enterprise, thereby attempting to enthuse people about science and gain their support. This is a manifestation of Sagan’s belief in the importance of educating the public—another trait in Holmes’s characterization of Romantic science.

This inducement of enthusiasm about exploring the universe is strengthened by the use of the journey motif on another level, one that might be called the *historical* level. One of the central metaphors in *Cosmos*, also introduced on the cliffs at the beginning of the first episode, is that of *space as ocean*. The Earth—the shore of the cosmic ocean—is where the human species evolved and made its first discoveries about the universe. But humanity is still only at the beginning of that exploration: the entire ocean lies ahead, waiting to be discovered. The historical kind of journey could be said to have two slightly different meanings, which combine in the image of humanity sailing the ocean of space. Firstly, and more metaphorically, humanity itself is making, through the history of science, a journey of discovery. A quotation from the final episode makes this clear: “even 400 years ago, we still had no idea of our place in the universe. The long journey to that understanding required both an unflinching respect for the facts and a delight in the natural world” (episode 13: 44^m13^s–44^m26^s). The second meaning of the historical journey is that we are now, in the space age, making our first literal journeys out into space, exploring the planets and the moons of our solar system. Sagan explicitly frames modern day explorations of space as a continuation of previous centuries’ exploration of

the Earth: “The Dutch called their ships ‘flying boats,’ and the Voyager spacecrafts are their descendants” (episode 6: 32^m30^s–32^m38^s). An animated sequence at the very end of episode 6, where a graphic of a Voyager spacecraft metamorphoses into a drawing of a Dutch sailing ship against the backdrop of the Horsehead Nebula, makes this point clear. Thus, also on the historical level there are exploratory voyages. These kinds of voyages are less lonely than the individual journeys, but they are more perilous, with the potential for regressive turns of events in history and rocket failures in space.

Throughout *Cosmos*, there are also dramatizations and discussions about developments in the history of science. In the last episode, Sagan discusses the murder of mathematician and philosopher Hypatia by a Christian mob, the destruction of the library of Alexandria, and the question of why the ideas and sciences pursued in Alexandria, “the seeds of our modern world,” did not “take root and flourish.” Sagan says that he cannot give a full answer to this question, but one part of the explanation is, he believes, that the scientists of the library did not communicate with the public: “The vast population of this city [Alexandria] had not the vaguest notion of the great discoveries being made within these walls [of the library]. How could they? The new findings were not explained or popularized. . . . Science never captured the imagination of the multitude. There was no counterbalance to stagnation, to pessimism, to the most abject surrender to mysticism” (episode 13: 28^m45^s–35^m15^s). In other words, Sagan stresses the importance of popularization, of a “commitment to explain, to educate, to communicate to a general public” (Holmes 2008: xix). He does this both implicitly, through his own popularization of science, and explicitly, by discussing why it is important.

Hypatia is one among many historical scientists portrayed in *Cosmos*. Notably, she is the only woman portrayed. And although Sagan notes the unequal opportunities available to women in male-dominated domains throughout history, and although he notes her “extraordinary range of accomplishments,” he cannot resist commenting on her appearance: “By all accounts, she was a great beauty.” Conjoined with this comment is the idealization of “the solitary scientific ‘genius,’ thirsting and reckless for knowledge, for its own sake and perhaps at any cost” (Holmes 2008: xvii): “And although she had many suitors she had no interest of marriage.” Apart from Hypatia, however, it is only male scientists who are cast in the role of genius. *Cosmos* includes dramatizations and/or narrated mini-biographies of Eratosthenes (episode 1), Johannes Kepler (episode 3), Robert Goddard (episode 5), Christiaan Huygens (episode 6), Democritus (episode 7), Albert Einstein and Leonardo Da Vinci (episode 8), Milton Humason and Edwin Hubble (episode 10), and Jean-François

Champollion (episode 12). In all these biographies, curiosity, obsession, and perseverance are portrayed as key character traits that produce genius and enable world-changing discoveries. Though not as frequent as one might expect given the high degree of romanticization of science in *Cosmos*, in some cases (e.g. Kepler, Goddard), these geniuses have revelations, epiphanies, or visions—“Eureka moments.”

History and humanity are connected to the cosmos even more expressively and extensively on yet another level of the journey motif: the *cosmic* level. The primary dimension in which the cosmic journey operates is time. Consider, for example, the following: “We’re just beginning to trace the long and tortuous path which began with the primeval fireball and led to the condensation of matter: gas, dust, stars, galaxies, and—at least in our little nook of the universe—planets and life, intelligence, and inquisitive men and women” (episode 1: 52^m29^s–52^m48^s). Admittedly, a path is not exactly the same thing as a journey or a voyage, but it is rather close to it. In essence, the path in question consists of matter “journeying” through time, creating ever more complex forms, and eventually, on planet Earth, leading to our own species. An animated sequence in episode 2, guiding the viewer through the evolution of life on Earth from molecules to humans, illustrates the cosmic journey visually through metamorphosing outline drawings.

Thus far I have considered journeys on three distinct levels: the individual level, the historical level, and the cosmic level. Crucially, however, the three levels come together, making the TEUSH narrative the core narrative of *Cosmos*. Cosmic evolution, in the form of matter evolving over cosmic time, takes center stage in the “star stuff” metaphor made famous by Sagan: “[We are] star stuff contemplating the stars, organized collections of ten billion billion billion atoms contemplating the evolution of matter, tracing that long path by which it arrived at consciousness here on the planet Earth and, perhaps, throughout the cosmos” (episode 13: 54^m13^s–54^m33^s).⁷² The chiasmic structure of the TEUSH narrative is here presented through the use of the journey motif: the journey motif reconnects the individual to the cosmos, returning her/him to her/his cosmic roots. According to Sagan, this wondrous idea is manifestly the result of science, not religion: “It has the sound of epic myth, but it’s simply a description of the evolution of the cosmos as revealed by science in our time” (episode 13: 53^m43^s–53^m53^s). In other words, the epic narrative is expressed

⁷² Sagan was not the first to use the star stuff metaphor, but he made it famous (O’Toole 2013). It has since become a staple metaphor in popular science, sometimes relabeled as “stardust.” In chapters 5, 6, and 7, I discuss Tyson’s use of the metaphor.

throughout the series using the journey motif, and it forms “the basis of a new, secular philosophy of life, in which the infinite wonders of Creation (whether divine or not) [are] valued for their own sake” (Holmes 2008: xix). Through boundary work on the science/religion boundary—“It has the *sound* of epic myth, but it’s *simply a description*”—science is presented as “pure, ‘disinterested’ . . . independent of political ideology and even religious doctrine” (Holmes 2008: xviii). While a “proper” understanding of science and appreciation of the cosmic perspective are typically presented as promoting peace, harmony, and understanding, science and technology are presented as, essentially, neutral: “Science is not perfect. It’s only a tool. But it’s the best tool we have: self-correcting, ever-changing, applicable to everything” (episode 13: 48^m48^s–49^m02^s). In other words, science and technology are presented as politically and ideologically neutral in themselves; they can be used for good or bad.

In addition to these tropes and themes that amount to a romanticization of science—the exploratory voyage, the lone genius, the Eureka moment, the infinite and mysterious universe, science as pure and disinterested, a commitment to popularization, and science as the basis for a secular philosophy of life—there is one pervasive literary technique, intimately connected with Romanticism, that Holmes does not mention in his list of Romantic science traits: defamiliarization, or the presentation of a familiar object or phenomenon as unfamiliar. Defamiliarization, though not under that label, was championed by Romantics such as William Wordsworth and Samuel Taylor Coleridge. It also plays a key role in contemporary popular science. *Cosmos* abounds in defamiliarization. For example, after giving a brief tour of the cosmos in the ship of the imagination, Sagan returns to Earth and tells the viewers: “The end of our long journey is the world where we began. Our travels allow us to see the Earth anew, as if we came from somewhere else. . . . Welcome to planet Earth: a place with blue nitrogen skies, oceans of liquid water, cool forests, soft meadows” (episode 1: 27^m37^s–28^m59^s).

Chapter 5 below focuses on defamiliarization in popular physics and astronomy. Subsequent chapters focus on other aspects of the romanticization of science—in particular, science as the foundation for a secular philosophy of life and cosmological creation myth (chapter 6), genius tropes and character construction (chapter 7), and emotions such as awe and wonder (chapter 8).

3

Notions of “Science”

Contemporary Perspectives and Definitions

Many actors besides popularizers contribute to the notions of science in culture and society. Even though it seems to be common in the West to equate science with reductionism, mechanization, and the subject–object divide, there are nuances that such a broad identification misses. This general view of science does not capture the tensions between the various notions of science in society, nor the details of how those notions are interpreted and valued. In this chapter, I discuss how science is studied, interpreted, defined, and evaluated by various actors in society and culture. The focus is contemporary, but when relevant I also include historical perspectives. Importantly, I make no claims to comprehensiveness; I do not claim to present a complete or exhaustive picture of notions of science in society. However, to understand the notions of science presented by mainstream popularizers, it is important to understand that those notions are presented in wider academic, societal, and cultural contexts. The chapter thus prepares the ground for the analyses in later chapters by mapping some of the cultural and societal terrain relevant for understanding why and how popularizers construct science in certain ways.

I begin by discussing how science has been studied, represented, and debated in academia and the general culture. Here I highlight controversies and debates surrounding the definition, interpretation, and evaluation of science, in particular in the two cultures debate and the science wars. I go on to discuss how science is routinely defined in everyday ways by influential actors such as government agencies, scientific organizations, and major dictionaries. Here, similarity and agreement stand out among the definitions. I end by discussing

tendencies in the definitions discussed and issues raised by the preceding discussions, in particular how the question of meaning relates to common definitions of science.

Academic Disciplines and Cultural Debates

In this section, I discuss how science has been studied in academia, specifically in twentieth century analytic philosophy of science and science and technology studies (STS). Philosophy of science is relevant in several ways: first, because it has been influential in debates about the definitions of science; second, because it forms a major part of why and how social studies of science emerged in the 1960s; and third, because it remains influential, through the work of Karl Popper in particular, in the construction of science in popular science texts (as I discuss further in the chapter 4). Social science studies—or what today is known as STS—is relevant because it too has been influential in debates about science, especially as a counterpoint to the narratives of science espoused by people who adopt an idealistic view of science. Since STS was defined in the introduction, I focus on other aspects of social science studies than in the introduction, namely how it emerged historically and how it differs from traditional philosophy of science. Furthermore, since STS forms the theoretical framework of this dissertation, it informs the methodology of the chapter itself. What this means is that I approach the question “What is science?” not by trying to find a definition that would supposedly capture the “essence” of science, but rather by analyzing how the term “science” has been defined by various actors. I end this section by discussing debates and controversies surrounding science that continue to influence both perceptions of science in society and popularizations of science, in particular the two cultures debate and the science wars.

Pursuing the Essence of Science: Philosophy of Science

Philosophy of science, in its modern form, is usually traced back to the 1920s and the Vienna Circle in Austria (Pfeifer & Sarkar 2006). One of the main problems in philosophy of science, at least up until a few decades ago, is the so-called “problem of demarcation.” The problem of demarcation, so christened by Austrian-British philosopher Karl Popper in 1934, denotes the “task of discriminating science from non-science,” where non-science “includes

pseudoscience and metaphysics but also logic and pure mathematics, philosophy (including value theory), religion, and politics” (Nickles 2006: 188). In some ways, the problem of demarcation is continuous with literally ancient concerns in philosophy: how to distinguish “true knowledge” from “mere opinion” and “superstition.”⁷³ Western philosophy is usually said to have been born with the Presocratic philosophers and their attempts to find unity in the multitude of natural phenomena by coining naturalistic explanations of the world.⁷⁴

⁷³ Some scholars argue that positing a continuity between ancient Greek philosophy and modern Western philosophy and science is misleading. French historian of philosophy Pierre Hadot (2002) argues that whereas philosophy today is mainly a theoretical and conceptual endeavor, in antiquity it was inextricably linked with practice and the attempt to lead a good life. The ancients did indeed conduct theoretical inquiries into the nature of knowledge and the nature of the universe, but they did it *for the sake of* living well. Also, philosophy was practiced in schools, in communities dedicated to communally practicing philosophy. Philosophy was a “way of life” rather than an academic discipline. Historian Peter Harrison (2015), agreeing with Hadot, develops this point in a critique of the standard view of Greek philosophy as a precursor of modern science: “the classical Greek engagement with nature, while often touted as an ancestor to modern science, was so imbued with theological and moral elements that its relationship to ‘science’ as we now understand it is at best complicated. It is not just that astronomy and natural philosophy had some additional ethical elements that were largely peripheral and have now fallen by the wayside. It is rather that the study of nature was given a role in a broader philosophical enterprise that had moral goals and, quite often, theological presuppositions. Unlike anything in the modern sciences, the study of physics or natural philosophy was an exercise directed toward the transformation of the self. To claim that our science was born in ancient Greece is to overlook what for ancient Greek philosophers was the main point of the exercise” (33).

⁷⁴ The “Presocratic philosophers” are the philosophers prior to Socrates (c. 470–399 BCE) and include Thales of Miletus (the first of the Presocratics, b. 625 BCE), Anaximander of Miletus, Anaximenes of Miletus, Pythagoras and the Pythagoreans, Xenophanes of Colophon, Heraclitus, Parmenides, Zeno of Elea, Empedocles, Anaxagoras, Leucippus of Miletus, Democritus of Abdera, and Protagoras and the sophists (Kenny 2004: 4–32). Patricia Curd ([2007] 2016: n.p.) discusses why the term arose and some of the problems with it: “Calling this group ‘Presocratic philosophers’ raises certain difficulties. The term, coined in the eighteenth century, was made current by Hermann Diels in the nineteenth, and was meant to mark a contrast between Socrates who was interested in moral problems, and his predecessors, who were supposed to be primarily concerned with cosmological and physical speculation. ‘Presocratic,’ if taken strictly as a chronological term, is not accurate, for the last of them were contemporaneous with Socrates and even Plato. Moreover, several of the early Greek thinkers explored questions about ethics and the best way to live a human life. The term may also suggest that these thinkers are somehow inferior to Socrates and Plato, of interest only as their predecessors, and its suggestion of archaism may imply that philosophy only becomes interesting when we arrive at the classical period of Plato and Aristotle. Some scholars now deliberately avoid the term, but if we take it to refer to the early Greek thinkers who were not influenced by the views of Socrates, whether his predecessors or contemporaries, there is probably no harm in using it.” Traditionally, the sophists—identified by Plato as the

In the conventional view of the Presocratics, the invention of philosophy was a rejection of myth and religion (e.g. Russell 1945; Wedberg 1982), although that view has been modified slightly by recent scholarship. There are significant continuities between Greek myth and Greek philosophy (Kenny 2004; Harrison 2015). Nonetheless, philosopher Anthony Kenny (2004), in his four-volume history of philosophy, suggests that “Parmenides might well claim to be the founder of epistemology: at least he is the first philosopher to make a systematic distinction between knowledge and belief” (145). Distinguishing knowledge from opinion or belief was a main concern of Plato’s, who dedicated the influential dialogue *Theaetetus* to the problem (Kenny 2004: 152–156). It has been a major problem area in philosophy ever since. What sets modern philosophy of science apart from the longer history of epistemology is that philosophy and science’s precursor—natural philosophy—were not separated until the nineteenth century. Philosophy, including natural philosophy, was, among other things, the attempt to understand the world and our knowledge of it. When science emerged as a broadly distinct field of activity, it separated itself from philosophy and largely took over the project of explaining the natural world. Thus, with science considered by many to be the primary way of knowledge production, philosophy of science emerged as that philosophical discipline which attempts to understand what science is and how it is able to produce knowledge. But not only that. Philosophy of science is often normative in addition to being descriptive and explanatory; it attempts to say why and how some principles are *better* than others.⁷⁵

The main solution to the problem of demarcation proposed by the members of the Vienna Circle—or “logical positivists” and “logical empiricists,” as they called themselves (Stadler 2006)—was the criterion of verification: a theory is scientific if, and only if, it is verifiable, that is, possible to verify through empirical methods. Popper, who was part of the Vienna Circle but disagreed with the criterion of verification, formulated a criterion of his own: falsifiability. Popper’s version is one of the most influential criteria of demarcating science from non-science, and it states that a theory is scientific if, and only if, it is falsifiable (rather than verifiable). Science advances by disproving theories rather than proving them, because proving theories definitively is impossible. The theories that survive the most severe tests survive longer and are closer to the truth than their competitors. Although Popper and the logical positivists

enemies of philosophy—have not been included among the philosophers, but Kenny does so, and Curd explains that there has been a reappraisal of them in later years.

⁷⁵ Godfrey-Smith (2002); Pfeifer & Sarkar (2006); Rosenberg ([2000] 2012: 1–20).

differ on details with regard to the criterion, they agree on many issues: that scientific knowledge is somehow unique; that testability is the mark of scientific theories; and that it is important to distinguish between science and non-science if our aim is to produce ever more accurate theories about the world. In arguing this case, they routinely contrast science with other systems of beliefs, such as myth, religion, and ideology. For example, Popper claims that Marxism and psychoanalysis fail to satisfy the criterion of falsifiability, and so they are not to be regarded as scientific theories.⁷⁶

In contemporary philosophy of science, the problem of demarcation has lost some of its currency. This is partly due to shortcomings with the specific formulations of the principle of demarcation, and partly because of logical inconsistencies in the formulation of the problem itself. But it is also due to the influence of historical and social perspectives on science. Applied retrospectively to historical developments, the specific proposals for candidates of the principle of demarcation seem to be largely unable to capture what was actually going on in the development of natural philosophy and science (Nickles 2006: 193). Philosophers of science tended to produce idealized narratives of the history and workings of science, often exemplifying what is called “Whig history”—“history that attempts to construct the past as a series of steps toward (and occasionally away from) present views” (Sismondo [2004] 2010: 12). Furthermore, seen as a social phenomenon rather than as a purely intellectual endeavor, the demarcation between science and non-science involves more aspects than the development of reliable knowledge, for example cultural prestige and access to resources.

However, even though the problem of demarcation may have lost some of its currency, demarcations are still made daily, as Gieryn (1983, 1999) points out. And—as I show in the next chapter—mainstream science popularizers tend to agree with the position of the logical positivists and Popper on the problem of demarcation: scientific knowledge is somehow unique and more reliable than other kinds of knowledge claims, and demarcating science from non-science is important. Thus, while philosophers of science today may have tended to move away from the problem of demarcation, the problem lives on in debates about science.

⁷⁶ Godfrey-Smith (2002: 19–74); Okasha (2002: 13–17); Nickles (2006); Stadler (2006); Thornton (2006); Sismondo ([2004] 2010: 1–6); Rosenberg ([2000] 2012: 16–18).

The Emergence of Constructivism: Science and Technology Studies

In contrast to the relatively abstract, disconnected, and idealized way of studying demarcation exemplified by the logical positivists and Popper, scholars in STS argue that the problem of demarcation must be seen in wider societal contexts. Thomas Kuhn's *The Structure of Scientific Revolutions* ([1962] 1996) was a landmark study that historicized science and influenced social studies of science by emphasizing the collective nature of knowledge production and the importance of socialization in shaping that knowledge.⁷⁷ But the formation of the so-called “strong programme in the sociology of knowledge”—also known as the “Sociology of Scientific Knowledge” (SSK) and the “Edinburgh School”—is usually seen as the birth of what was to become STS.⁷⁸ This was a program for studying science formulated by philosophers, sociologists, and historians at the University of Edinburgh (Sismondo [2004] 2010: 47–56; Wyatt, Milojević, & Park et al. 2017: 88–91). Understanding what it reacted to is instructive for understanding the development of STS and the views of science incorporated into STS.

The strong program was in part a rejection of philosophy of science's idealization of science and its focus on the internal properties of scientific theories and science's supposed uniqueness. But the strong program was also a rejection of the main sociological approach to science at the time: Robert Merton's functionalism or institutional sociology of science. Merton had championed an approach to science according to which four institutional norms made science science. 1. *Universalism*: “the criteria used to evaluate a [knowledge] claim [should] not depend upon the identity of the person making the claim.” 2. *Communism*: “scientific knowledge—the central product of science—is commonly owned. Originators of ideas can claim recognition for their creativity, but cannot dictate how or by whom those ideas are to be used. Results should be publicized, so that they can be used as widely as possible.” 3. *Disinterestedness*: “a form of integrity, demanding that scientists disengage their interests from their actions and judgments. They are expected to report results fully, no matter what theory those results support.” 4. *Organized skepticism*: “the tendency for the community to disbelieve new ideas until they have been well established.”

⁷⁷ Kuhn cites Ludwik Fleck's *Genesis and Development of a Scientific Fact* (1935; English translation 1979) as an influence on his ideas. Fleck is now regarded as a key forerunner to STS, but his work was largely unknown when Kuhn wrote *Revolutions*.

⁷⁸ For accounts of the history of social science studies, from pre-Kuhnian studies to SSK to STS, see Sismondo ([2004] 2010: vii–ix); Tresch (2014); Felt, Fouché, & Miller et al. (2017); Law (2017).

(Sismondo [2004] 2010: 23–24.) Merton’s norms may sound intuitive and reasonable, but when they are put to use in analyzing actual scientific practice they are too vague and flexible. In actual conflicts between scientists, both sides of a dispute can claim that *they*, but not their opponents, adhere to Merton’s norms. The norms can become weapons in the battle rather than impartial principles of arbitration. STS scholar Sergio Sismondo ([2004] 2010) discusses interpretations of Einstein’s attitude toward quantum mechanics as an example of the flexibility of these norms. Einstein famously rejected fundamental aspects of quantum mechanics, in particular non-determinism. Was he guided by healthy skepticism and disinterestedness—or by stubbornness and a biased investment in deterministic physics? “Supporters of quantum mechanics are apt to see Einstein as a conservative in his later years. Opponents of quantum mechanics are apt to see him as maintaining a youthful skepticism throughout his life” (32). Furthermore, in our culture these four norms are positively valenced and not unique to science—other institutions claim them, or some of them, as well. Distinguishing science on the basis of Merton’s criteria is thus problematic and misleading.

The strong program sought to replace Merton’s focus on the professed norms of science with a focus on actual scientific practice. It had a solid constructivist footing: its adherents studied scientific knowledge by studying the social processes that produced it. This is, by and large, still the dominant approach in STS: science is studied as a product of human activity and social processes. In this way, the view of science characteristic of STS differs from the view of science according to which there is such a thing as a stable and uniquely identifiable “essence” of science. The traditional philosophy of science and STS are thus quite different in this regard. The traditional philosophy of science assumes, first, that science is uniquely identifiable by virtue of some inherent properties, and second, that science is superior in producing knowledge. STS scholars tend to dispute both of these assumptions, arguing, first, that science is not uniquely identifiable by virtue of inherent properties, and second, that assuming the superiority of scientific knowledge is historically naive and ideologically problematic. As STS scholar Steve Woolgar puts it in his 1988 book *Science: The Very Idea*: “The social study of science begins with the recognition that science is a highly variable animal” (15). And as Wenda K. Bauchspies, Jennifer Croissant, and Sal Restivo put it in their 2006 introduction to STS: “While we [STS scholars] may be critical of modern science as a social institution, our theoretical position is not based on denying an antecedent reality. What we do deny is the idea that there is an already and always existing description of reality that we approach through closer and

closer approximations” (viii).

The Bauchspies, Croissant, and Restivo quotation bears traces of disputes between essentialist and constructivist views of science—disputes that played out in public in the so-called science wars in the 1990s.

The Two Cultures and the Science Wars

The science wars were preceded by a concept introduced by British novelist and chemist C.P. Snow. In 1959, Snow gave a lecture, subsequently published, that turned out to be enormously influential in debates about science and its relation to society and culture: *The Two Cultures* (Snow [1959] 1998). In his lecture, Snow pitted literary intellectuals against scientists: “Literary intellectuals at one pole—at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension—sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding. They have a curious distorted image of each other” (4). The idea that there is some kind of difference between artistic and scientific worldviews and modes of thought can plausibly be traced back to the early modern period, and it was heightened in the Romantic era. It was debated publicly in the UK in the late nineteenth century by Matthew Arnold, who represented the arts and humanities, and Thomas Henry Huxley, who represented the natural sciences (Collini 1998: ix–xvii). Snow’s lecture and book revisited and reignited these debates. Snow, who envisaged a reconciliation of the “two cultures” but in practice sided with the natural sciences, was countered by literary critic F.R. Leavis in his scathing lecture and book *Two Cultures? The Significance of C.P. Snow* (Leavis [1962] 2013).⁷⁹

Snow’s formulation of the problem has long been seen as simplistic and outdated by critics (see e.g. Leane 2007: 61–64; Ortolano 2009). He glosses over differences in epistemology, uses of language, and methods, and instead focuses on a mutual ignorance in knowledge of the facts in the respective fields. Snow’s example is knowing about the second law of thermodynamics versus having read Shakespeare (Snow [1959] 1998: 14–15). Snow also glosses over differences within the sciences and the arts, painting them with broad, homogeneous strokes. Even so, the term “the two cultures” took on a life of its own, arguably having “entered the bloodstream of modern culture”

⁷⁹ As Ortolano (2009) points out, reducing the two cultures debate to just another iteration of “art versus science” misses the nuances and historical specificities of both “art versus science” as a transhistorical category in general and the two cultures debate in particular.

(Collini 2013: 3).⁸⁰

Social studies of science emerged in the 1960s, and with it methodological relativism as a methodological approach—bracketing the question of the truth or validity of the sciences studied. Methodological relativism provoked reactions among scientists and popularizers. These reactions culminated in the science wars of the 1990s: a war fought over the meaning, legitimacy, and implications of science, with social critics of science on one side of the battle lines and what Ullica Segerstråle (2000) calls “proscience activists” on the other.⁸¹ While tension had been building over many years, what sparked the war was the publication of scientists Paul Gross’s and Norman Levitt’s book *Higher Superstition: The Academic Left and Its Quarrels with Science* (1994) (Segerstråle 2000: 6). Gross and Levitt argued that critics of science, whom they labeled as anti-intellectuals, disagreed with science for political reasons without really understanding the science they were criticizing. Gross and Levitt inspired physicist Alan Sokal to write a supposedly serious article in which he parodied the style of postmodernist theorists. He managed to get the article published in the prestigious journal *Social Text* in 1996. The “Sokal affair” further fanned the flame; for proscience activists, the acceptance of Sokal’s paper proved that there was a lack of rigor in postmodernism and critical theory.

As Segerstråle (2000) explains, the reactions to science studies and the Sokal affair spread beyond proscience activists: “What probably most upset scientists in general, however—not only the proscience activists—was the suggestion that science was not the objective enterprise it purported to be, or worse, that it could not be objective” (9). In the eyes of proponents of science, social science studies in the post-Mertonian tradition relativized and trivialized science, turning it into a human “practice” on an equal footing with other human “practices” such as astrology or New Age spirituality. In the eyes of science studies scholars, by contrast, proscience activists disregarded the far-reaching epistemological implications of the social and cultural embeddedness of science, turning science into an ideology and sidestepping the social consequences of science and technology as practiced on a day-to-day basis. While the heat had gone out of the debate by the early 2000s, tensions between social

⁸⁰ For an illuminating study on how the concept took on a life of its own in a context outside of the UK, see Emma Eldelin (2006), which traces the ways in which the term was appropriated and used in Swedish cultural debates from 1959 to 2005.

⁸¹ For more on the science wars, see Segerstråle (ed.) (2000); Brown (2001); Leane (2007: 61–80).

critics of science and proscience activists linger to this day.⁸²

The two cultures debate and the science wars are relevant to any analysis of popular science because they form part of the cultural background of popular science texts. For example, popularizers' frequent use of pop culture and literary references can be interpreted as a way of claiming literacy in the "artistic" side of culture. And when popularizers insist that science accesses reality and reveals the truth about the universe, that can be read as reiterating the realist and essentialist view of science characteristic of proscience activists in the science wars. Leane (2007) argues that in some popular science books, "issues related to the 'Science Wars' are dealt with, implicitly and possibly subconsciously, in the structure of popularizations themselves" (78). But not only that: some major popularizers—e.g. Richard Dawkins, Steven Weinberg, and E.O. Wilson—played an active part in the science wars. They published books and articles, attacking constructivism as false, unproductive, and silly (Segerstråle 2000; Brown 2001: 19–21; Leane 2007: 70–80).

Furthermore, many of today's leading popularizers—including Richard Dawkins, Lawrence Krauss, and Martin Rees—are, or have been, managed by literary agent John Brockman, who played a significant role in shaping and promoting popular science books in the popular science boom (Brown 2005; Schrempp 2012: 13). Brockman coined the term "the third culture" in the 1995 anthology *The Third Culture: Beyond the Scientific Revolution*, which he edited. The opening sentence of his introduction can only be read as a proclamation of victory over the "literary intellectuals" and constructivist science scholars: "The third culture consists of those scientists and other thinkers in the empirical world who, through their work and expository writing, are taking the place of the traditional intellectual in rendering visible the deeper meanings of our lives, redefining who and what we are" (Brockman 1995: 17). The conciliatory-sounding term "the third culture," suggesting a productive consensus across enemy lines, amounts to an attempt to do away with "traditional" intellectuals and constructivists by claiming that science now forms the foundation of a new form of culture that can answer existential questions. Rather than neutrally reflecting a historical process, as his opening statement purports to do, Brockman attempts to bring about his preferred state of affairs. As will be apparent over the chapters to come, similar statements permeate contemporary

⁸² For example, in 2018 three proscience activists (Peter Boghossian, James A. Lindsay, and Helen Pluckrose) took Sokal's method further, publishing a series of parody articles in humanist and social science journals—a project that has been called "Sokal squared" (Kafka 2018).

mainstream popularizations of physics and astronomy. It is safe to say that mainstream popularizers can be described as proscience activists.

Routine Definitions

In this section, I discuss definitions of science by actors who have official or semi-official roles in society and who contribute to the routine definitions of science. By “official role,” I mean publicly appointed actors, such as NASA and the National Science Foundation in the US. By “semi-official role,” I mean actors whose status and influence are such that they may be thought to be authoritative in the public sphere, such as major dictionaries and independent scientific organizations. In contrast to the previous section, where controversies and differences in opinion were highlighted, this section shows that there is a remarkable agreement among the views and definitions of science provided by influential actors.

Dictionaries

Dictionaries both reflect and reinforce common meanings of words. Even though dictionaries may appear neutral—merely recording language use—they are written by people embedded in cultural and ideological contexts. As lexicographer Lynda Mugglestone (2011) points out, dictionaries “are often all too human products, able to reflect the social and cultural assumptions of the time in which they are written, and telling, as a result, their own stories of society, culture, innovation, and ideals” (xii). By virtue of being short and intending to reflect standard usage, dictionary definitions provide a window into ideas about the bare bone of the nature of science in contemporary culture and society. Examining definitions of “science” in major dictionaries thus not only shows what “science” is typically taken to mean, but also which notions of science are promoted and perpetuated as standard by dictionaries.

I chose major dictionaries in the English language for the definitions to examine because I am interested in the standard, most widespread definitions (see Table 3.1, p. 109). In determining which dictionaries to count as “major,” I used information from two *Wikipedia* pages: a list under the subheading “Major English dictionaries” on the page “Dictionary” (Wiki 2019a); and a list under the subheading “Full-size” on the page “Comparison of English

dictionaries” (Wiki 2019b).⁸³ All of the dictionaries except one—*Wikipedia*—are listed as major English dictionaries on *Wikipedia*’s “Dictionary” page (see Table 3.1). Five of the seven dictionaries quoted are listed under the “Full-size” subheading; the exceptions are *MacMillan*, which is an “advanced learner’s dictionary” rather than a full-size dictionary, and *Wikipedia*. *Wikipedia* is an encyclopedia rather than a dictionary (i.e. it includes information beyond language use), but I included it—more specifically, the first sentence in the entry “Science”—because *Wikipedia* is so widely used. In the cases of *The American Heritage Dictionary of the English Language* and *Concise Oxford English Dictionary/Lexico* (see p. 14 n3 above for information about the name of the latter), I have removed sub-definitions that are marked as “archaic”: “3. *Archaic* Knowledge, especially that gained through experience” (AHD 2019); “1.3 *archaic* Knowledge of any kind” (Lexico 2019c).

The contrast with archaic meanings of science is, in fact, telling. In all of the definitions, knowledge is a component of science, but it is not any kind knowledge; it is knowledge that possesses certain traits or is obtained in certain ways. All definitions except CED (2019) include the words “system” or “systematic,” showing that scientific knowledge is not haphazard or chaotic. Most definitions add methods that are said to characterize science, namely observation, classification, experimentation, prediction, and explanation. These components of the definitions can be summarized under the term “method.” Thus, all definitions include a methodological component in their definition of science.⁸⁴

There are also domains of knowledge specified. All definitions except *Wikipedia*’s include references to the natural and/or physical world. Similarly, they all include sub-definitions that open up to fields outside the natural sciences, either with references to specific fields—e.g. “A systematic method or body of knowledge in a given area: *the science of marketing*” (AHD 2019)—or through open-ended formulations—e.g. “A systematically organized body of knowledge on a particular subject” (Lexico 2019c).

In other words, it is presupposed, and often spelled out, that science *produces knowledge*. This may seem self-evident, but it is worth stressing. Science is not characterized as a belief system, or an ideology, or a philosophy, or a religion. *Knowledge* is the hallmark of science.

⁸³ I have refrained from using *Wikipedia* as a source, except in this case. I have cross-checked the dictionaries listed and confirmed that they are important dictionaries.

⁸⁴ CED (2019) also mentions method, but more vaguely: “**Science** is the study of the nature and behaviour of natural things and the knowledge that we obtain about them.”

Dictionary	“science”
<p><i>The American Heritage Dictionary of the English Language</i> (AHD 2019)</p>	<p>1a. The observation, identification, description, experimental investigation, and theoretical explanation of phenomena: <i>new advances in science and technology</i>. 1b. Such activities restricted to a class of natural phenomena: <i>the science of astronomy</i>. 2. A systematic method or body of knowledge in a given area: <i>the science of marketing</i>.</p>
<p><i>The Chambers Dictionary</i> (CD 2019)</p>	<p>1. the systematic observation and classification of natural phenomena in order to learn about them and bring them under general principles and laws. 2. a department or branch of such knowledge or study developed in this way, eg astronomy, genetics, chemistry. 3. any area of knowledge obtained using, or arranged according to, formal principles • <i>political science</i>. 4. acquired skill or technique, as opposed to natural ability.</p>
<p><i>Collins English Dictionary</i> (CED 2019)</p>	<p>1. (uncountable) Science is the study of the nature and behaviour of natural things and the knowledge that we obtain about them. 2. (countable) A science is a particular branch of science such as physics, chemistry, or biology. Synonyms: discipline, body of knowledge, area of study, branch of knowledge. 3. (countable) A science is the study of some aspect of human behaviour, for example sociology or anthropology.</p>
<p><i>Concise Oxford English Dictionary/Lexico</i> (Lexico 2019c)</p>	<p>1. The intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment. 1.1. A particular area of science. 1.2. A systematically organized body of knowledge on a particular subject.</p>
<p><i>MacMillan Dictionary</i> (MMD 2019)</p>	<p>1. (uncountable) the study and knowledge of the physical world and its behaviour that is based on experiments and facts that can be proved, and is organized into a system. 2. (countable) a scientific subject such as chemistry, physics, or biology. 3. (countable) an organized way of making, arranging, or dealing with something.</p>
<p><i>Merriam-Webster</i> (MW 2019)</p>	<p>1: the state of knowing: knowledge as distinguished from ignorance or misunderstanding. 2a: a department of systematized knowledge as an object of study. 2b: something (such as a sport or technique) that may be studied or learned like systematized knowledge. 3a: knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method. 3b: such knowledge or such a system of knowledge concerned with the physical world and its phenomena: NATURAL SCIENCE. 4. a system or method reconciling practical ends with scientific laws.</p>
<p><i>Wikipedia</i> (Wiki 2019c)</p>	<p>Science (from the Latin word <i>scientia</i>, meaning “knowledge”) is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.</p>

Table 3.1. Definitions of “science” in major English dictionaries

Thus, three components stand out in the definitions listed in Table 3.1 as running themes: *system*, *method*, and *knowledge*. Science is characterized by systematically deploying methods that produce bodies of knowledge.

Scientific Organizations and Government Agencies

Scientific organizations such as the American Association for the Advancement of Science (AAAS), government agencies such as the National Science Foundation (NSF), and international bodies such as the European Research Council (ERC) are influential actors in shaping notions of science. They classify sciences in publicly available documents, they lobby for science in political arenas, and they allocate funding to projects deemed to be scientific. Because of the amount of resources involved, the stakes are high. The NSF is a US government agency in charge of, among other things, allocating funding. About 25 percent of federal support for academic institutions for basic research flows through the NSF in the US (NSF 2019a). Gieryn (1999) details the discussions and controversies surrounding the decision to include social science within the purview of the NSF (65–114). As of 2019, the research areas covered by the NSF are biological science; computer and information science and engineering; education and human resources (focused on STEM, i.e. science, technology, engineering, mathematics); engineering; environmental research and education; geosciences; integrative activities; international science and engineering; mathematical and physical sciences; and the social, behavioral and economic sciences (NSF 2019b). The humanities are not included.

I have attempted to find short definitions of science by major scientific organizations and government agencies by looking through their websites, including, when possible, reports and brochures published online. In most cases, I have been unable to locate definitions.⁸⁵ Two organizations that do provide

⁸⁵ I have looked through many organizations' and agencies' websites, including American Association for the Advancement of Science (AAAS), the British Science Association (BSA), National Academy of Sciences (NAS), the European Research Council (ERC), and the Royal Society. I did find a definition for children at NASA's website, which I discuss below. It goes without saying that I have been unable to look through *all* documents published on these websites. For example, AAAS regularly publishes statements regarding science policy decisions in the US. However, the point is also accessibility and availability; if there are definitions of science proposed in, say, statements from 2016 buried in the digital archive, then other people will likely not find them and read them either. The definitions proposed by the two organizations I discuss in the running text are relevant precisely because they are visible and easy to find.

short definitions of science are the Science Council and the American Physical Society. The Science Council, a UK-based organization that advises governments on science policy and represents the views of scientists to the UK government and international bodies, defines science thus: “Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence” (SC 2018). The American Physical Society, the world’s second largest organization of physics, defines science thus: “Science is the systematic enterprise of gathering knowledge about the universe and organizing and condensing that knowledge into testable laws and theories” (APS 2018). The definitions proposed by the Science Council and the American Physical Society are very similar, except that the Science Council includes the social world in their domain of science where the American Physical Society has the more ambiguous “universe.” Presumably, “the universe” includes society, but its connotations are more immediately physical than the broader “the natural and social world.” This difference in domain is plausibly explained by the membership reach of the organizations: while the American Physical Society gathers physicists, the scope of the Science Council is broader, including disciplines such as sports and exercise science and food science (they do not, however, include social sciences such as sociology and psychology). Both definitions are strikingly similar to the dictionary definitions: science is *systematic*, it is characterized by particular *methods*, and it produces *knowledge*.

Public Understanding of Science Surveys

Survey studies of public understanding and appreciation of science and technology have been conducted by science communication scholars over the past decades in the US. Roughly speaking, the questions in the surveys can be grouped into three categories: knowledge about scientific facts, understanding of the scientific process (or the scientific method), and attitudes toward science and technology. Even though these surveys have been criticized for being simplistic and potentially misleading (e.g. Bauer 1992), Bruce Lewenstein (2013) makes the argument that since the surveys, flawed as they may be, have been conducted over a long period of time, they at least provide an indication of public knowledge and attitudes toward science, including changes, or the lack thereof, over time.

In 2018, the National Science Board (NSB), governing body of the National Science Foundation (NSF), published the latest data from the survey studies in a report (NSB 2018). As for facts, public knowledge varies considerably

depending on the topics and questions, but the average number of correct answers to nine true-or-false or multiple-choice items has been fairly consistent between 1992 and 2016—between 5.3 and 5.8 correct answers to nine questions (NSB 2018: ch. 7, p. 35).⁸⁶ In terms of percentage, this means between 59 and 64 percent. Understanding of the scientific process is not as high—it has remained below 50 percent between 1999 and 2016, with an average of 39 percent over nine surveys (NSB 2018: ch. 7, p. 48).⁸⁷ Public appreciation of science and technology is higher. A majority of people, about 70 percent, believe that “benefits of scientific research strongly/slightly outweigh harmful results.” The remaining 30 percent either believe that benefits and harms are about equal, that harms outweigh benefits, or they do not know. These attitudes have been fairly consistent over the time period 1979–2016 (NSB 2018: ch. 7, p. 53).

Of particular interest in these studies are the actors conducting the surveys. The surveys were pioneered by science communication scholar Jon D. Miller (Miller 1998) and have since been performed by scholars following in his footsteps. The surveys have been sponsored by various scientific organizations, such as the NSF, and various universities, such as the University of Chicago (NSB 2018: ch. 7, pp. 13–15). While the scholars conducting the surveys do not necessarily have an incentive to support science—being scholars *of* science—the sponsoring organizations typically do. The definition of science presupposed in the structure of the surveys mirrors, and thus reproduces, these definitions: the first two categories of questions—knowledge of facts and understanding of the process—correspond to science as characterized by *knowledge* and *method*.⁸⁸

Science Education

Education Guidelines

The large and influential non-governmental organization the National

⁸⁶ Examples of the kinds of questions and statements testing knowledge of facts: “Does the Earth go around the Sun, or does the Sun go around the Earth?”; “All radioactivity is man-made”; “Antibiotics kill viruses as well as bacteria” (NSB 2018: ch. 7, pp. 44–45).

⁸⁷ To test their understanding of the scientific process, participants answer questions about probability, experimental design, and what it means to study something scientifically (NSB 2018: ch. 7, p. 48).

⁸⁸ The third component concerns appreciation, not knowledge and understanding.

Academy of Sciences, Engineering, and Medicine (NASEM), of which the National Academy of Sciences is a part, published education guidelines in 1996 and 2013. The 1996 edition, *National Science Education Standards*, details how science should be taught in primary and secondary school in the US. They argue for the importance of imparting scientific literacy to schoolchildren, defining “scientific literacy” as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.” Understanding science is further characterized through understanding “facts, concepts, principles, laws, theories, and models,” as well as “an understanding of how scientists study the natural world” (National Research Council 1996: 22–23). In other words, implicit in these guidelines is a definition of science according to which science is composed of *knowledge* and *method*.

The guidelines were updated in 2013. They now use four “major domains” in their framework: “the physical sciences; the life sciences; the earth and space sciences; and engineering, technology, and the application of science” (National Research Council 2013: 114). They further use “three dimensions” in their framework to structure the teaching of science: “practices” (instead of inquiry, to refer to “the range of cognitive, social, and physical practices that [science] requires”); “crosscutting concepts” (concepts that “have application across all domains of science” and hence serve to unify science); and “disciplinary core ideas” (“core knowledge” in each of the domains that enables the students to “acquire additional information on their own”). Thus, both knowledge and method is central here too, but interdisciplinarity is introduced to further strengthen the ties between the sciences.⁸⁹

National Public Radio

National Public Radio (NPR) is a non-profit media organization in the US. It was established by the American Congress in 1967 and is privately and publicly funded. NPR’s website *MonkeySee* produces short informational videos on various topics. In a two-minute video from 2009 called “What is Science?” “science expert” Emerald Robinson defines science in the following way:

“Science” can be defined as the process of observing and questioning the world around us. We also sometimes call the things we learn through experimentation

⁸⁹ Note that these are *guidelines* for teaching, not what teachers actually teach. For example, in spite of the use of word “practices,” suggesting diversity in how science is performed, science education is still largely practiced under the guise of a single scientific method (Anderson & Hepburn 2015, with references).

science. In fact, the term “science” itself comes from a Latin word that means “knowledge.” And the names of mini branches of science end with “-ology,” which means “study” in Greek. Scientists aim to gain new knowledge through a disciplined set of steps called “the scientific method.” The scientific method consists of asking a question, proposing a possible solution called a hypothesis, testing the hypothesis through a series of experiments, examining the results of the experiments to see if the hypothesis has been supported or refuted, and then proposing a new question or a new hypothesis. Scientists can specialize in one of hundreds of different fields, all which focus on different types of knowledge. For example, physical sciences, like chemistry and physics, examine the laws of nature. They are considered to be the fundamental sciences because everything in the universe obeys these natural laws. (Robinson 2009: 00^m08^s–01^m08^s)

This definition is similar to the definitions hitherto discussed: it focuses on knowledge and method. But it goes further than the short definitions in that it specifies what the scientific method means and details the steps purportedly involved. In so doing, it suggests, even more so than the others, that scientific discovery is a streamlined process and that there is a *single* scientific method.

NASA

The National Aeronautics and Space Administration (NASA) is an independent agency of the US Government, most famous for its various space missions. On *NASA Space Place*, a website targeted at children, there is a page dedicated to the question “What is science?” It reads:

Science is ...

- **Observing the world.**
- **Watching and listening**
- **Observing and recording.**

Science is **curiosity in thoughtful action** about the world and how it behaves.

Anyone can have an idea about how nature works. Some people think their idea is correct because “it seems right” or “it makes sense.” But for a scientist (who could be you!), this is not enough. A scientist will test the idea in the real world. An idea that predicts how the world works is called a **hypothesis**.

If an idea, or hypothesis, correctly predicts how something will behave, we call it a **theory**. If an idea explains all the facts, or evidence, that we have found, we also call it a **theory**.

“**Scientific method**” usually means a series of steps that scientists follow to discover how nature works [includes a link to a webpage detailing these steps].

These steps will work fine for a school science fair project. But this is not usually the way science actually happens! . . .

Sometimes the observations come **before** the idea or theory. For thousands of years, people observed certain “stars” wander around the night sky in looping

patterns. Finally, in 1514 Nicolaus Copernicus came up with the idea of “Heliocentrism” (meaning Sun centered). He thought the Sun was the center of the Universe, with Earth being one of many spheres orbiting the Sun. That idea explained the wandering patterns of the planets. It also predicted where they would “wander” next. **This idea became a theory.** Of course, we later improved that theory. After all, the Sun is not the center of the whole universe, but only our own solar system.

Sometimes science happens mostly inside a scientist’s head.

Albert Einstein and his theories were like that. It took a long time before scientists were able to test them and show that were were [sic] correct.

- **Science is not just a tidy package of knowledge.**
- **Science is not just a step-by-step approach to discovery.**
- **Science is more like a mystery inviting anyone who is interested to become a detective and join in the fun.**

(NASA 2018; images, captions, and a subheading excluded; emphases in the original)

That children comprise the target audience of this text is evident from the reference to “school science fair project” and phrasings such as “But for a scientist (who could be you!),” as well as from the images used (cartoon images of a child and an Albert Einstein-looking scientist). What is noticeable in NASA’s definition of science is that there is both continuity and discontinuity between everyday life and science. Science is defined as “Observing the world,” “Watching and listening,” and “Observing and recording,” as well as “curiosity in thoughtful action”—approaches practiced (by some people, at least) in everyday life. But then they stress that “it seems right” or “it makes sense” are not the marks of the scientific approach to an idea; an additional step is necessary, namely testing the idea against the real world. And that testing is accomplished through the scientific method, which, as in NPR’s *MonkeySee* video, is referred to in the singular. In NASA’s version, the scientific method, detailed in a link, consists of a series of steps: 1. ask a question or formulate a hypothesis; 2. define the variables in the experiment designed to answer the question or test the hypothesis; 3. find out what people have said before on the same subject; 4. devise the experiment; 5. perform the experiment and record the data; 6. interpret the data, calculate, and make graphs if applicable; and 7. draw conclusions and write a report.⁹⁰ Interestingly, they qualify their specification of the method: “These steps will work fine for a school science fair project. But this is not usually the way science actually happens! . . . Sometimes the

⁹⁰ I use quotations or near-quotations in my description of NASA’s formulation of the scientific method. Their description is longer than mine.

observations come **before** the idea or theory.” The example they use—Copernicus’s heliocentric model of the solar system—is telling. They apparently do not count Ptolemaic astronomy—the geocentric model of the solar system—as scientific, even though it used mathematics and was empirically successful (Sismondo [2004] 2010: 2). This is a case of boundary work: they define predecessors to the “Scientific Revolution” as non-scientific. The word “finally” in the sentence “Finally, in 1514 Nicolaus Copernicus . . .” suggests that people were at a loss as to how to explain the movements of the planets across the sky until Copernicus came along—a narrative that is clearly historically inaccurate. The pre-Copernicans may have had the “wrong” model; but it was a model and it was empirical. The examples of science that NASA cite thus appeal both to formal features of science—the scientific method—and to the contents of science—heliocentrism. This is borne out in the final three bullet-pointed sentences: “Science is not just a tidy package of knowledge. Science is not just a step-by-step approach to discovery. Science is more like a mystery inviting anyone who is interested to become a detective and join in the fun.” Apart from expanding the definition of science beyond the informative—appealing to emotions surrounding science—they suggest that science is characterized by both a “package of knowledge” and a “step-by-step approach to discovery.”

Intelligent Design versus Science in Court

In the US, there is a vocal movement, with roots in evangelical Christianity, that attempts to discredit evolutionary theory. It goes by the name of Creationism or Intelligent design (ID). Attacking Creationism/ID is common in contemporary mainstream popular science, especially in popularizations of biology and popularizations that deploy the TEUSH narrative. These attacks are instances of defining science through boundary work on the science/religion boundary (i.e., defining science through contrasts with non-science, in this case religion).

The Creationism/Intelligent design versus evolution debate was the context of an illuminating definition of science that gained substantial media attention. It also affected high school science curricula in the US. The definition was proposed by Judge John E. Jones III during a case in the US District Court for the Middle District of Pennsylvania concerning the teaching of Intelligent design in high school biology classes: *Kitzmiller v. Dover Area School District*.⁹¹

⁹¹ For detailed accounts of the trial and its relation to controversies surrounding evolution in the US, see Chapman (2007); Humes (2007); Pennock (2011).

Proponents of ID claim it to be a scientific theory, although its detractors argue that it is not. ID claims that some adaptations in biological organisms—e.g. eyes—are so complex that they cannot be explained without invoking an intelligent designer, overtly or covertly identified with the Christian God. While the definition of science that emerged in *Kitzmiller v. Dover Area School District* may not be “routine” in the same way as dictionary definitions, it falls into this category because of the judicial setting and its influence on science education.

The Dover Area School District had introduced Intelligent design in their curriculum to be taught as an alternative to evolution by natural selection. The board of the school district was subsequently sued by eleven parents of students enrolled in the Dover Area School District. The plaintiffs argued that ID is not science, but rather religion, and so should have no place in a biology class. The plaintiffs had six expert witnesses: science education scholar Brian Alters, philosopher Barbara Forrest, theologian John Haught, biologist Kenneth R. Miller, paleontologist Kevin Padian, and philosopher Robert T. Pennock. Judge Jones III ruled in favor of the plaintiffs, citing the plaintiffs’ expert witnesses’ view of science as the grounds for ID not being science. The ruling is worth citing at length because it can, in effect, be viewed as the legally recognized definition of science in the US. It also attracted considerable media coverage and attention, both in the US and internationally. It was the first case where the teaching of ID was tried, building on precedents where Creationism had been tried in similar ways, for example in the *McLean v. Arkansas Board of Education* in 1981.⁹² As a PBS Nova documentary about the trial,⁹³ *Judgment Day: Intelligent design on trial*, puts it: “It was a six-week trial in which modern biology was Exhibit A, and hanging in the balance was not just the Dover biology curriculum. The future of science education in America, the separation of church and state, and the very nature of scientific inquiry were all on trial” (PBS NOVA 2007). The following is an excerpt from the 139-page Memorandum Opinion written by Judge Jones III. It is worth quoting at length:

After a searching review of the record and applicable caselaw, we find that while ID arguments may be true, a proposition on which the Court takes no

⁹² Intelligent design grew out of Creationism in an attempt to challenge evolutionary theory through a more “scientific” framework and without references to the Bible, after Creationism had been discredited. Judge Jones III argues that ID is a form of Creationism, relying on defense expert witness STS scholar Steve Fuller (Jones III 2005: 35).

⁹³ PBS is short for Public Broadcasting Service, an American non-profit organization. Nova is a popular science television series in production since 1974.

position, ID is not science. We find that ID fails on three different levels, any one of which is sufficient to preclude a determination that ID is science. They are: (1) ID violates the centuries-old ground rules of science by invoking and permitting supernatural causation; (2) the argument of irreducible complexity, central to ID, employs the same flawed and illogical contrived dualism that doomed creation science in the 1980's; and (3) ID's negative attacks on evolution have been refuted by the scientific community. As we will discuss in more detail below, it is additionally important to note that ID has failed to gain acceptance in the scientific community, it has not generated peer-reviewed publications, nor has it been the subject of testing and research.

Expert testimony reveals that since the scientific revolution of the 16th and 17th centuries, science has been limited to the search for natural causes to explain natural phenomena. (9:19-22 (Haught); 5:25-29 (Pennock); 1:62 (Miller)). This revolution entailed the rejection of the appeal to authority, and by extension, revelation, in favor of empirical evidence. (5:28 (Pennock)). Since that time period, science has been a discipline in which testability, rather than any ecclesiastical authority or philosophical coherence, has been the measure of a scientific idea's worth. (9:21-22 (Haught); 1:63 (Miller)). *In deliberately omitting theological or "ultimate" explanations for the existence or characteristics of the natural world, science does not consider issues of "meaning" and "purpose" in the world.* (9:21 (Haught); 1:64, 87 (Miller)). While supernatural explanations may be important and have merit, they are not part of science. (3:103 (Miller); 9:19-20 (Haught)). *This self-imposed convention of science, which limits inquiry to testable, natural explanations about the natural world, is referred to by philosophers as "methodological naturalism" and is sometimes known as the scientific method.* (5:23, 29-30 (Pennock)). *Methodological naturalism is a "ground rule" of science today which requires scientists to seek explanations in the world around us based upon what we can observe, test, replicate, and verify.* (1:59-64, 2:41-43 (Miller); 5:8, 23-30 (Pennock)).

As the National Academy of Sciences (hereinafter "NAS") was recognized by experts for both parties as the "most prestigious" scientific association in this country, we will accordingly cite to its opinion where appropriate. (1:94, 160-61 (Miller); 14:72 (Alters); 37:31 (Minnich)). NAS is in agreement that science is limited to empirical, observable and ultimately testable data: "Science is a particular way of knowing about the world. In science, explanations are restricted to those that can be inferred from the confirmable data—the results obtained through observations and experiments that can be substantiated by other scientists. Anything that can be observed or measured is amenable to scientific investigation. Explanations that cannot be based upon empirical evidence are not part of science." (P-649 at 27).

This rigorous attachment to "natural" explanations is an essential attribute to science by definition and by convention. (1:63 (Miller); 5:29-31 (Pennock)). We are in agreement with Plaintiffs' lead expert Dr. Miller, that from a practical perspective, attributing unsolved problems about nature to causes and forces that lie outside the natural world is a "science stopper." (3:14-15 (Miller)). As Dr. Miller explained, once you attribute a cause to an untestable supernatural

force, a proposition that cannot be disproven, there is no reason to continue seeking natural explanations as we have our answer. . . .

ID is predicated on supernatural causation, as we previously explained and as various expert testimony revealed. (17:96 (Padian); 2:35-36 (Miller); 14:62 (Alters)). ID takes a natural phenomenon and, instead of accepting or seeking a natural explanation, argues that the explanation is supernatural. (5:107 (Penock)).

(Jones III 2005: 64–67; emphases added)

In Judge Jones III’s verdict, the key feature that distinguishes science from Intelligent design—and, by extension, religion—can be summarized with the term *methodological naturalism*: the idea that science limits itself and its explanations to the natural as opposed to the supernatural. This implies that “science does not consider issues of ‘meaning’ and ‘purpose’ in the world.” While supernatural entities, meaning, and purpose may or may not exist, the mark of science is the deliberate *exclusion* of such entities and purposes when explaining the world. Hence the term “methodological”: science does not exclude the existence of a transcendent realm, but its method is such that explanations invoking transcendent beings or properties are not allowed. “Natural,” in turn, is defined in two ways: negatively, through a contrast with “supernatural”; and positively, as “what we can observe, test, replicate, and verify.” The negative definition demarcates science from religion, and the positive definition sets the standard for what counts as scientific knowledge.

The Meaning of Science

Approaching Consensus?

Seen across all actors involved in discussions about science, there is no consensus on what science is. The contentious question in debates between pro-science activists and STS scholars, for example, is not just about how to evaluate an enterprise on whose nature everyone agrees. Rather, the question goes to the heart of how science is conceived and approached. Is science, as argued by pro-science activists, first and foremost a way to reach “truth” and “objectivity”? Or is science, as argued by STS scholars, first and foremost a set of practices embedded in social, cultural, political, and economic contexts? In this sense, there is no one definition of science on which everyone agrees.

The short, routine definitions of science are strikingly similar, however. Even though my examples are nowhere exhaustive, the similarities in the

definitions, across the sources and examples, do suggest that there are some traits that recur in influential and widespread notions of science. Recurring traits are systematicity, knowledge, and method. Science is a systematic enterprise, characterized by the scientific method, which produces knowledge about the world—primarily the natural or physical world, but also the social world. This definition is evidently much closer to the proscience activists’ approach to science than the STS scholars’ approach to science.

A prime example of how short, routine definitions are closer to proscience activist views than STS views is with regard to the unity of science. In routine definitions, science is typically invoked in the singular. Even though many definitions include uses of “science” as a countable noun—as in “the science of marketing”—when the uncountable noun is defined, science is defined as a unitary enterprise. This impression is supported by STS scholar and chemist Henry H. Bauer (1992), who argues that “the common view of science” is one of science as a “unitary, monolithic enterprise” (32). This unitary view is based on the idea of a single scientific method. Bauer argues, through discussing science in practice, that this idea is a myth; there is no one single method that characterizes science. Nonetheless, the idea of a single, unifying, universal scientific method not only permeates these definitions, but science education as well (see Anderson & Hepburn 2015).

Bauer (1992: 36–37) goes on to argue that the view of science as a unified enterprise leads to a hierarchy of the sciences, with physics providing a foundation for the other sciences. Though the view that science is a unified enterprise has attracted considerable criticism from many scholars of science,⁹⁴ it seems to be a widespread view. It is presented humorously by Randall Munroe in the award-winning and widely read webcomic *xkcd*:

⁹⁴ See e.g. Feyerabend (1975); Cartwright (1983); Woolgar (1988); Galison & Stump (eds.) (1992); Dupré (1993); Shapin (1996); Fuller (1997); Agar (2012); Hepburn & Anderson (2015); Kamminga & Somson (eds.) (2016); Cat ([2007] 2017).

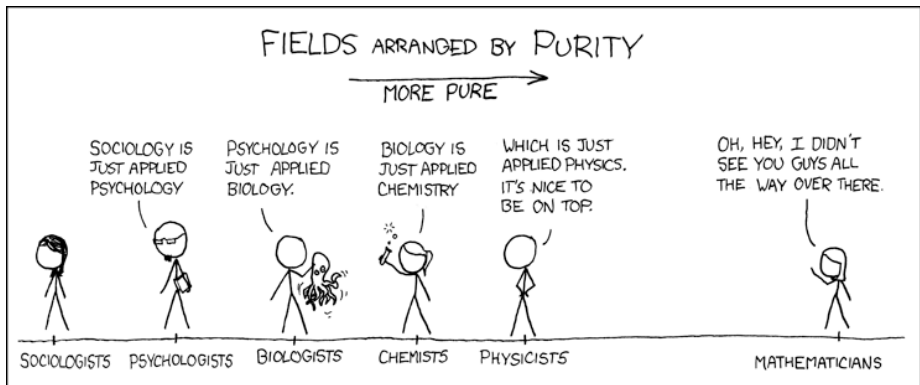


Figure 3.1: “Purity,” #435 in *xkcd* (Munroe 2008).

Though Munroe toys with purity as the governing principle, the hierarchical structure of the sciences is recognizable. It is traceable at least back to the early nineteenth century, when Mary Somerville and William Whewell, as discussed in chapter 1, envisioned links connecting the sciences and a unity of science as a whole. Contemporaneously with Somerville and Whewell, French philosopher Auguste Comte formulated a hierarchy of the sciences that, with very little revision, is still the most popular today. In a series of books, *The Course in Positive Philosophy* (1830–1842), Comte laid out his hierarchy: mathematics, astronomy, physics, chemistry, biology, sociology (Bourdeau 2018).

This kind of hierarchy is an instance of what Nasser Zakariya (2017) identifies as “genres of synthesis”—genres that have allowed scientists, historians, and popularizers to conceptualize science as a unified enterprise and to fuse human, natural, and cosmic history into single coherent frameworks, often used for political ends. Zakariya traces these genres of synthesis from the second third of the nineteenth century to the present, and he shows that they structure not only many prominent popularizations of science, but also some large-scale, long-term research projects, such as NASA’s Cosmic Origins Program.⁹⁵ He identifies four genres of synthesis: the scalar, the historical, the foundational (of which Comte’s hierarchy is an example), and the fabulaic:

Scalar syntheses construct accounts via a diagramming of space and/or time, often involving the expansion and contraction of spatial scales, or scales of both

⁹⁵ NASA’s Cosmic Origins Program gathers research on the cosmic history of the universe. One of its stated primary goals is to the answer to the question “How did we get here?” (NASA 2019).

space and time. Historical syntheses deploy some version of a timeline or thicker historical narrative. Foundational syntheses attempt to reduce (via presumed or implied mathematical and logical consequence) their accounts to the existence of atemporal universal laws. And fabulaic syntheses often rely on quasi-fictional narratives that employ storytelling devices such as a journey taken through different domains. (Zakariya 2017: 2–3)

Through the widespread use of these genres of synthesis in popularizations of science and in formulations of research projects, the idea that science forms a unified enterprise can be hypothesized to be a component of common and popular conceptions of science.

Thus, while there is a degree of consensus among proscience activists and routine definitions that science is a unified enterprise, there is no consensus across all actors. On the one hand, proscience activists typically want to go further than the routine definitions and include more functions for science, a point I develop in the next chapter; they typically advocate for *scientism*. On the other hand, STS scholars disagree with both proscience activists and routine definitions on how to approach, study, and define science to begin with.

Mundane and Transcendent Meaning

Even though there is disagreement about the meaning of “science,” the relative agreement between the proscience activists and the routine definitions is significant. Combined, they are influential in shaping common notions of science. They are also silent on the question of meaning in the existential sense. Often—especially traditionally in the West and presently in the US—meaning is discussed in terms of God or a transcendent purpose: God is the provider of meaning; without God, there can be no such thing as meaning. This is implicit in Judge Jones III’s definition of methodological naturalism discussed above: “In deliberately omitting theological or ‘ultimate’ explanations for the existence or characteristics of the natural world, science does not consider issues of ‘meaning’ and ‘purpose’ in the world.” Judge Jones III does not say that science claims that meaning does not exist; but he does say that *because* science does not consider “theological or ‘ultimate’ explanations,” it does not “consider issues of ‘meaning’ and ‘purpose’ in the world.”

I have made the point that this view of science—as an annihilator of meaning—is common (see the introduction and chapter 2). Science dissects and sterilizes, reduces wholes to parts, and disenchants the world. Here, I wish to expand on the perceived lack of meaning in a scientific universe because it is relevant for how science is constructed and received in contemporary culture.

As I show in coming chapters, popularizers attempt to infuse science with existential meaning. For this reason, it is relevant to discuss views on meaning in life, in particular psychological research that has studied how people tend to view meaning in life.

Even though some psychologists—e.g. A. Will Crescioni and Roy F. Baumeister (2013)—argue that the decline of religion in the West correlates with a decline of perceptions that life has meaning, psychologists typically do not see God or religion as the main or only provider of meaning. A central assumption among psychologists studying meaning in life is that “perceiving life as meaningful is essential for healthy human functioning” (Hicks & Routledge 2013: ix, with references; see also King, Heintzelman, & Ward 2016, with references). But the perception that life is meaningful can have many sources, including religion. In their review article “Beyond the Search for Meaning: A Contemporary Science of the Experience of Meaning in Life” (2016), psychologists Laura A. King, Samantha J. Heintzelman, and Sarah J. Ward argue that “Research using self-reports of meaning in life has identified several robust correlates of the experience” (212). They go on to cite and categorize these studies into five main categories: 1. *social relationships*, including feeling that one’s needs for relatedness are met, feeling a sense of belonging, and feeling close to and supported by one’s family; 2. *religious faith*, especially in times of crisis; 3. *socioeconomic status*; 4. *being in a pretty good mood*; and 5. *living in a world that makes sense* (212–213). King, Heintzelman, and Ward make clear that not all five categories need to be present for someone to experience life as meaningful.

Of particular interest is the fourth category: being in a pretty good mood. King, Heintzelman, and Ward use the word “pretty good” to “indicate that the level of positive mood that appears to contribute to meaning in life need not be extremely high. Rather, even the kind of mild mood boost that might come from a mood induction such as reading newspaper comics or listening to happy music leads to higher meaning in life” (214, n1). They further claim that this is “perhaps the most robust of all predictors” (213) and argue that it can compensate for other forms of meaning:

Interestingly, research has shown that positive affect can compensate for low levels of a range of correlates of meaning in life, including social relatedness, religious faith, and socioeconomic status. Even among those who are lonely, who lack religious faith, and who are poor, a pretty good mood can facilitate a level of meaning in life commensurate with that of people who have many friends, religious faith, and high levels of financial resources . . . One can be lacking in many of the things that are considered to make life meaningful, and

yet a good mood may suffice to make life feel meaningful. (King, Heintzelman, & Ward 2016: 213)⁹⁶

To the extent that this research is reliable, it shows that God or religious faith is not essential for providing meaning. While religion is *a* source of the experience of meaning in life, it is not *the* source of meaning. Not everyone needs faith in their life to experience life as meaningful. I stress this because science-as-religion—interpreting science as a new kind of religion, providing meaning in a religious sense—is a prominent theme in critical scholarship on science (Midgley 1992; Schrempf 2012; Sideris 2017). And while this kind of meaning-making certainly does take place in popular science, it is not the only kind.

The five categories delineated by King, Heintzelman, and Ward can be grouped into two supercategories: mundane meaning and transcendent meaning.⁹⁷ By *mundane meaning* I mean those forms of meaning that are not supernatural; they include *social relationships*, *socioeconomic status*, *being in a pretty good mood*, and *living in a world that makes sense*.⁹⁸ *Transcendent meaning* is reserved for religious faith because that is the only form of meaning that invokes the supernatural. With this supercategorization, it becomes possible to hypothesize that one of the reasons that religion is often associated with meaningfulness is that in addition to providing transcendent meaning, religion typically also provides most of the mundane kinds of meanings as side effects, so to speak. Religious communities are good at providing social relationships and a sense of belonging; faith and social belonging can put people in a pretty good mood; and religion makes sense of the world. Socioeconomic status is more contingent with regard to religion, even though the social networks that religious communities can provide can act as a buffer and help those in need.

As with most psychology, it is likely that the studies cited by King, Heintzelman, and Ward (2016) were conducted on WEIRD people: Western, educated, industrialized, rich, and democratic (Henrich, Heine, & Norenzayan 2010). Whether or not these characterizations of meaning extend to everyone is unclear. However, this does not matter, in the present context, because the

⁹⁶ They discuss the fifth category, *living in a world that makes sense*—a category that researchers have begun “to build a strong case” for as one of the predictors (King, Heintzelman, & Ward 2016: 213)—after the good mood-category, which is why it is not included in the quoted discussion.

⁹⁷ These supercategories do not appear in King, Heintzelman, & Ward (2016); they are my way of categorizing their categories.

⁹⁸ *Living in a world that makes sense* does not necessarily invoke the supernatural, which is why I have it as a form of mundane meaning.

audience of contemporary popular science is mostly composed of WEIRD people—the sort that Krauss, Tyson, and other popularizers hope to persuade.

As I show over the chapters to come, Krauss and Tyson appeal to both transcendent and mundane meaning in their narratives of science, humankind, and the universe. They do not invoke supernatural entities, but they do construct science as the provider of a new, secular, all-encompassing narrative that is able to replace the transcendent meaning associated with religion. But they also appeal to the mundane kinds of meaning: they tap into needs for social belonging through constructing science as a collective enterprise spanning the generations; they attempt to put their readers in a good mood by attempting to evoke positive emotions and emotional experiences such as beauty, wonder, and empathy; they construct science as an enterprise that produces positive emotions; and, of course, they attempt to provide a framework that makes the reader feel as though s/he is living in a world that makes sense. The socioeconomic dimension is less clear, but insofar as popularizers attempt to influence the reader to become a scientist—one function among many of popular science—there is a socioeconomic appeal because being a scientist is a relatively well-paid and well-regarded profession. Furthermore, reading popular science can act as a marker of identity. Thus, to the extent that readers of popular science typically belong to a relatively affluent demographic, then that would provide some kind of meaning in the socioeconomic sense as well: the reader has, by association, a relatively high socioeconomic status.

An Absence of Values?

Just as meaning is excluded from the domain of science in routine definitions—either explicitly, as in Judge Jones III’s ruling, or implicitly, by not mentioning it—so too values are typically excluded in routine definitions. Science is often portrayed as dealing with “objective facts,” while values are “subjective add-ons.”

The separation between facts and values, known in philosophy as “Hume’s law,” dates back to at least David Hume’s work in the eighteenth century, and it states that no inference about values can legitimately be drawn from facts about the world (Cohon [2004] 2010). An “ought” can never be derived from an “is.” Philosopher John Dupré (2007) discusses the separation of facts and values in the context of science: “There is a view of science, as stereotyped in the hands of its critics as advocates, that goes as follows: Science deals only in facts. Values come in only when decisions are made as to how the facts of science are to be applied. Often it is added that this second stage is no special

concern of scientists, though this is an optional addition” (27). In other words, according to this view science is descriptive and factual; considerations of questions of value are beyond the scope of science. Following Judge Jones III and his concept of methodological naturalism (which he borrowed from philosopher Robert Pennock), I call this view *methodological nihilism*.⁹⁹

Methodological nihilism is separate from the view that no values *exist*. It only states that the explanations and theories of science do not, by themselves, imply any particular moral judgment or course of action. The development of nuclear weapons is a good example. Evidently, the science behind nuclear weapons says nothing about whether or not we should construct or use such bombs; it only describes what certain radioactive atoms do under certain conditions. Claiming that nuclear weapons should not be constructed or used requires an extra step, beyond the factual to the moral.

Carl Sagan provides an illustration of this. In a post-1989 update to *Cosmos*, which follows immediately after the last episode in the DVD edition of the series, he says:

Our science and our technology have posed us a profound question: Will we learn to use these tools with wisdom and foresight before it's too late? Will we see our species safely through this difficult passage so that our children and grandchildren will continue the great journey of discovery still deeper into the mysteries of the cosmos? That same rocket and nuclear and computer technology that sends our ships past the farthest known planet can also be used to destroy our global civilization. Exactly the same technology can be used for good and for evil. It is as if there were a god who said to us: "I set before you two ways. You can use your technology to destroy yourselves or to carry you to the planets and the stars. It's up to you" (Sagan et al. [1980] 2009: episode 13: 58^m29^s–59^m43^s).

In other words, science and technology are presented as politically and ideologically neutral in themselves. They can be used for good or bad, but in themselves, so to speak, they are neither.¹⁰⁰

Methodological nihilism has been criticized in a variety of scholarly traditions: from gender studies and STS, where scholars tend to argue that what

⁹⁹ Even though methodological nihilism is arguably part of most routine definitions of science, whether explicitly or implicitly, to the best of my knowledge no one has used the term “methodological nihilism” as I define it.

¹⁰⁰ Even though Sagan does adhere to methodological nihilism in this quotation, his views on the connection between science and values are more complicated most of the time. See further chapter 4.

counts as facts is not a given and that implicit value judgments go into the formulation of the scientific method, experimental design, and choice of research questions (e.g. Keller 1985); to philosophers on the other side of the spectrum like Sam Harris (2010), who argue that evolutionary biology in fact does provide a basis for value judgments and that we should therefore base our ethics on science. But in this context, the point is not that methodological nihilism is ideologically problematic, analytically impossible, or undesirable; the point is that methodological nihilism is often associated with science. The strong reactions it elicits are an indication of its persistence and ubiquity.

While popularizers typically adhere to methodological naturalism in the sense that they do not see any purpose or meaning in the universe, they typically do not adhere to methodological nihilism. As I argue in the next chapter, popularizers typically defend a form of scientism that includes the *naturalization of science*, which in turn incorporates the idea that science is, in fact, connected to values in a very specific and fundamental way.

4

The “Science” in Popular Science

Boundary Work, Idealization, and Scientism

In the previous chapter, I discussed definitions of science in academia and by influential actors in society. Even though I discussed proscience activists and touched upon popularizers, I did not focus on definitions of science in popular science. In this chapter, I focus on those definitions. In the first section, I define “boundary work,” “idealization,” and “philosophical asides.” Using these concepts, I then go on to analyze how Krauss and Tyson define science. In the second section, I define and discuss scientism, and I argue that contemporary popularizers tend to want to push the definitions of science that circulate in society in the direction of scientism.

Definitions of Science in Krauss’s *The Greatest Story* and Tyson’s *Astrophysics*

Neither Krauss’s *The Greatest Story* nor Tyson’s *Astrophysics* are devoted to the question of what science is, but both define and describe science as part of popularizing physics and astronomy. One of the most common techniques that popularizers use to define science is *boundary work*. As I explained in the introduction, boundary work denotes the rhetorical strategies used to distinguish science from non-science (see pp. 33–34). As has been shown by many

scholars, popular science is an important site for boundary work.¹⁰¹ Popularizers demarcate science from non-science not just for pedagogical reasons but also for ideological reasons. The term “boundary work” suggests something about the nature of this way of defining science: it is about constructing boundaries between science and non-science in order to protect science from various other practices and belief systems. But boundary work does not mean that the boundaries are sealed tight. As Felicity Mellor (2003) and Elizabeth Leane (2007) and others have shown, part of boundary work is drawing upon similarities *as well as* differences. This is the case with the most prevalent site of boundary work in contemporary popular science, namely the science/religion boundary. In demarcations of science from religion, popularizers tend to, in the same breath, disregard religion as a way of explaining the world yet claim some of religion’s characteristics for science.

As noted in chapter 3, there are similarities between the views of science present in philosophy of science (à la Popper and the Vienna Circle) and popular science: scientific knowledge is somehow unique and more reliable than other kinds of knowledge claims, and demarcating science from non-science is important. Popper in particular—or at least the name “Popper”—is generally well received by popularizers. Philosophers James Ladyman and Don Ross (2013) claim that “Popper has long been a favourite philosopher of science among scientists,” although they do not provide sources for this claim (115). Science communication scholar Hauke Riesch (2008), who has surveyed popular science books and interviewed scientists about their views on philosophy of science, shows that Popper is indeed the most referenced philosopher of science “by some margin” in popular science books (135).¹⁰² The similarities between views of science in traditional philosophy of science and popular science speak to the *idealization* of science in popularizations of physics and astronomy: popularizers tend to seek the “essence” of science in their definitions rather than describe science in practice.

Apart from specific philosophers such as Popper, remarks or reflections on the nature of science are very common in popular science. Adam Nieman (2000), in his dissertation on popular science, identifies what he terms “pithy”

¹⁰¹ See e.g. Gieryn (1999); Nieman (2000); Mellor (2003); Broks (2006); Leane (2007); Riesch (2008); Locke (2011); Gunnarsson (2012).

¹⁰² In the 30 popular science books (28 authors) surveyed in Riesch’s dissertation, eight authors mention Popper. Riesch’s analysis shows that Popper is typically identified with scientific rigor, and so he is invoked as an authority justifying the author’s argument. However, the references to Popper are often incidental and display a lack of thorough comprehension of his philosophy.

definitions: “A ‘pithy’ definition of science is one that *appears* to provide a simple method of assigning knowledge unproblematically to the categories ‘science’ and ‘non-science’” (159). Riesch (2008) builds on Nieman’s discussion and identifies what he calls *philosophical asides*: “generally very short [comments that] in a way merely shift the appeal to authority that any presentation of facts [relies] on in popular science, to an appeal to authority that ‘this is just how things work in science,’ i.e. about the scientific method” (88). Pithy definitions and philosophical asides (which is the term I use in my analyses) do boundary work and present science in a definitive and idealized form.¹⁰³

The Scientific Attitude

Both Krauss and Tyson see the adoption of a scientific attitude as paramount. In the chapter “The Shadows of Reality,” which deals with the experiments and observations leading up to the development of quantum mechanics in the early twentieth century, Krauss discusses the work of physicist Max Planck. Planck was studying electromagnetic radiation emitted from light bulbs, but he was unable to develop a theory that could explain the observed radiation while remaining consistent with physics as it was then understood. According to the prevailing physics, radiation was a wave. In the mathematical equations derived by Planck, he instead construed radiation as coming in packets, or “quanta.” He was not happy with this solution, however—he called it “an act of despair . . . I was ready to sacrifice any of my previous convictions about physics” (quoted in Krauss 2017: 79). Krauss goes on to comment:

This reflects to me the fundamental quality that makes the scientific process so effective, and which is so clearly represented in the rise of quantum mechanics. ‘Previous convictions’ are just convictions waiting to be overturned—by empirical data, if necessary. We throw out cherished old notions like yesterday’s newspaper if they don’t work. And they didn’t work in explaining the nature of radiation emitted by matter. (Krauss 2017: 79)

This is a philosophical aside—Krauss returns to Planck’s achievements and the development of quantum mechanics—but it is a typical and therefore important aside. It lets Krauss reaffirm, in passing, what he sees as essential to

¹⁰³ In addition to these short kinds of comments and definitions, there are, in some books, longer reflections on the nature of science. Some books even focus on philosophy of science—Riesch mentions David Deutsch’s *The Fabric of Reality* (1997), Ernst Mayr’s *This is Biology* (1997), and Edward O. Wilson’s *Consilience* (1998).

being a scientist: the willingness to give up deeply held convictions if they are inconsistent with experiments or observations.

Tyson makes a similar aside in *Astrophysics* in the chapter “Dark Matter,” in which he discusses one of the major puzzles in contemporary physics: that only about 20 percent of the matter in the universe is made up of currently observable matter (the kind of matter that we see around us). The remaining 80 percent are unknown and unobservable (with respect to current theories and technology)—hence the label “dark.” The existence of dark matter is deduced from its effects on the rotation of galaxies. After discussing possible candidates and explanations of dark matter, Tyson says:

Other unrelenting skeptics might declare that “seeing is believing”—an approach to life that works well in many endeavors, including mechanical engineering, fishing, and perhaps dating. It’s also good, apparently, for residents of Missouri. But it doesn’t make for good science. Science is not just about seeing, it’s about measuring, preferably with something that’s *not* your own eyes, which are inextricably conjoined with the baggage of your brain. That baggage is more often than not a satchel of preconceived ideas, postconceived notions, and outright bias. (Tyson 2017: 90)

Like Krauss, Tyson constructs, in passing, the scientific character as someone who is willing to give up preconceived notions and biases. Noticeable is also Tyson’s humor, which is typical of him—in particular, the remarks on dating and Missouri.¹⁰⁴

What is particularly striking about these asides is that they claim, simply and straightforwardly, that the scientific attitude is one of casting away preconceived notions if those notions contradict observations. In this, both are close to Popper’s falsificationism. They do not, however, discuss well-known problems with falsificationism—problems so severe that they have led most philosophers to view falsificationism as a dead end. The discovery of the planet Neptune in the 1840s is a standard example. Astronomers had noted anomalies in the orbit of Uranus: the planet did not exactly match the trajectory predicted by Newtonian mechanics. But instead of rejecting Newtonian mechanics as a “preconceived notion,” two astronomers, John Couch Adams in the UK and Urbain Le Verrier in France, independently of each other suggested that there was another planet, further out in the solar system, whose presence gravitationally perturbed the orbit of Uranus. This was indeed the case, and in 1846 Neptune was discovered. Adams and Le Verrier thus persevered with a theory in

¹⁰⁴ The unofficial state nickname of Missouri is “The Show-Me State.”

spite of observations suggesting that the theory might be wrong. Philosopher Samir Okasha, in *Philosophy of Science: A Very Short Introduction* (2002) extrapolates from this example, reflecting the standard view today in philosophy of science: “In general, scientists do not just abandon their theories whenever they conflict with observational data. Usually they look for ways of eliminating the conflict without having to give up their theory” (16). The important point here is that there are no simple, general rules in science governing when to persevere with a theory and when to give it up. It is a messy and complex process without clear guidelines. This historical messiness and complexity is absent from Krauss’s and Tyson’s asides. This is not to suggest that Krauss and Tyson are unaware of the problems with falsificationism; but their asides do not show evidence of those problems, and thus, these asides serve more to present science as a reliable endeavor—and scientists as heroic figures—than indicators of historical and philosophical complexities.

In Tyson’s aside, more than in Krauss’s aside, there is important boundary work going on. Tyson contrasts scientists with, ironically enough, “unrelenting skeptics” who rely too much on their unmediated senses. There is an appeal to “authority that ‘this is just how things work in science’” (Riesch 2008: 88): “Science is not just about seeing, it’s about measuring” (Tyson 2017: 88). There is also an invocation of the boundary to technology: the “seeing is believing” approach is not appropriate in science, but it is good enough—fruitful even—for “mechanical engineering.” This is indicative of an ambivalence toward technology shared by many popularizers. Science is presented as distinct from technology. It is nobler because it addresses existential concerns and the meaning of life. It is also deeper because it can access the world “as it is,” whereas the measure of technology is what works. Yet at the same time, technology is needed in science; without it, the ability to measure the unseen would go away. Technology is also regularly praised for benefiting humanity, and as such it comprises a major justification for science (see chapter 9 for a discussion of the technological justification).

The Science/Philosophy Boundary

The two quoted asides are brief and serve simultaneously as constructions of science and scientists and as justifications for the narratives and arguments at hand. However, boundary work is often developed over the span of chapters or even entire books. For both Krauss and Tyson, one of the most fundamental and valuable features of science is that science can reveal the world “as it is,” beneath the potentially misleading impressions of the world as produced by

ordinary sense experience. They develop this notion through boundary work. I now turn to boundary work as it manifests at three boundaries: philosophy (Krauss), fiction (Tyson), and human opinion (Tyson).¹⁰⁵

Tracing ideas back to the ancient Greeks is common practice in both philosophy and popular science. Karl Popper (1962) traces the history of science to the Presocratics and argues that philosophy took a wrong turn with Plato. Plato, in Popper's reading, sowed the seeds of the idea that "truth is manifest": the idea, again in Popper's reading, that Western philosophy has been dominated by the notion that truth reveals itself—and that if truth does not reveal itself, then it is because we are corrupted or unreceptive. Popper, while calling Plato "the greatest epistemologist of all time" (9), laments the decline of what he perceives as a kind of Presocratic free spirit: the practice among the Presocratic philosophers of wildly speculating about the nature of the universe and then criticizing one another in the attempt to approach the truth. The influence of Plato, with his claim that true philosophers can access the transcendent realm of absolute truth through a kind of purification of the soul, meant that the development of science was hampered. Carl Sagan, in *Cosmos* (1980), praises the Presocratics and laments Plato (along with Pythagoras) in a similar tone. For Sagan, the Presocratics invented science and the empirical approach to nature, while Plato and Pythagoras, with their fascist overtones, turned away from the world of the senses and delved into mysticism, reserving truth for the initiated few who knew the secrets of mathematics and philosophy (167–194). In Krauss's *The Greatest Story*, Greek philosophy also plays a pivotal role in defining science, but whereas both Popper and Sagan lament that Plato corrupted Presocratic philosophy, Krauss credits Plato with being a major precursor of science.

Krauss develops his view on philosophy as a precursor of science in his first chapter, "From the Armoire to the Cave" (9–17). In Krauss's account, one of the most fundamental assumptions of science is the existence of ordered hidden realities beneath the world of the senses: "the story of the rise of modern science and its divergence from superstition is the tale of how the hidden realities of nature were uncovered by reason and experiment through a process in which seemingly disparate, strange, and sometimes threatening phenomena were

¹⁰⁵ The boundary science/religion also serves this purpose. The importance of the science/religion boundary for both Krauss and Tyson is apparent not least from the title of Krauss's book (*The Greatest Story Ever Told—So Far*) and the title of chapter 1 of Tyson's book ("The Greatest Story Ever Told"). *The Greatest Story Ever Told* was a radio series (1947), novel (1949), and film (1965) about the life of Jesus Christ, and more generally Christianity. However, I only touch upon that boundary here and return to it further in chapters 5–8.

ultimately understood to be connected just beneath the visible surface” (5). Krauss traces the longing for a world beyond the senses to religious impulses predating science, but in his account, the founding story of *rationality* approaching the otherworldly realm is Plato’s cave allegory, arguably the most famous and influential allegory in Western philosophy. Krauss views the cave allegory as a precursor of science and argues that it is useful for illustrating science. Like Plato’s philosophers, scientists realize that there is a hidden reality behind the world of the senses; and like Plato’s philosophers, they use reason to try to grasp that reality. However, there is one crucial difference between Plato’s philosophers and modern scientists: “Plato’s vision of ‘pure thought’ has been replaced by the scientific method, which, based on both reason *and* experiment, allows us to discover the underlying realities of the world” (14). Thus, Greek philosophy plays a dual role: on the one hand, as *allied* with science in opposition to common sense, irrationality, and religious explanations of the world; and on the other hand, as a point of *contrast* to modern science, as a way to explicate what is unique about modern science, namely the combination of reason and experiment.

The Science/Fiction Boundary

Krauss uses “story” throughout *The Greatest Story*, as in “The story of our origins and our future is a tale that keeps on telling” (2) and “the story of the rise of modern science and its divergence from superstition . . .” (5). It is clear that story as such is not a boundary with science; Krauss uses it unproblematically as the natural form for relating series of events. He also uses the determinate form—“the story of *x*”—thus suggesting that the events related unambiguously form a coherent narrative waiting to be told. Fiction, on the other hand, is only occasionally used as a boundary, as in “Antimatter has become the stuff of science fiction. Starships such as the USS *Enterprise* in *Star Trek* are invariably powered by antimatter, and the possibility of an antimatter bomb was the silliest part of the plot in the recent mystery thriller *Angels & Demons* [by Dan Brown]. But antimatter *is* real” (95). Science fiction is used in a similarly routine and sparing way in Tyson’s *Astrophysics*: “Yes, antimatter is real. And we discovered it, not science fiction writers” (20). Felicity Mellor (2003) shows that science fiction is used in boundary work in some popular science books, including a previous book by Krauss, *The Physics of Star Trek* (1995). Her analysis shows that these popularizers use science fiction to erect a firm boundary separating fiction and non-fiction, thus reinforcing the authority of science (which deals with “the truth”), while at the same time using tropes and

themes found in science fiction to claim affinity with it and draw upon its appeal. This takes place in Krauss’s *The Greatest Story* and Tyson’s *Astrophysics* as well, but on a small scale, in asides, not as a major area of boundary work.

There is, however, one use of fiction in Tyson’s *Astrophysics* that sheds additional light on his conception of science. Chapter 9, “Invisible Light,” has as motto three lines from Shakespeare’s *Hamlet*: “And therefore as a stranger give it welcome. / There are more things in heaven and earth, Horatio, / Than are dreamt of in your philosophy” (147). The chapter is about the discovery that the electromagnetic spectrum extends beyond the visual range (*c.* 400–700 nm) to include both longer and shorter wavelengths. Infrared radiation, discovered by William Herschel in 1800, was the first kind to be discovered. On the longer side—wavelengths longer than *c.* 700 nm—there are radio waves, microwaves, and infrared radiation. On the shorter side—wavelengths shorter than *c.* 400 nm—there are gamma rays, x-rays, and ultraviolet radiation. The visible range—i.e. visible to the human eye—is very small compared to the full range of the electromagnetic spectrum (Figure 4.1).

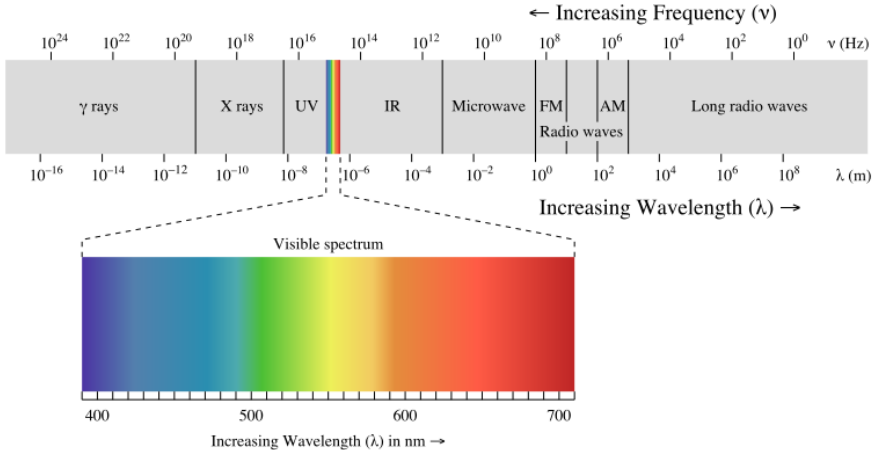


Figure 4.1. The electromagnetic spectrum.

The discovery of the invisible parts of the spectrum, in combination with the development of telescopes designed to measure invisible wavelengths, eventually enabled observations of the universe in all parts of the spectrum. Thanks to these telescopes, many phenomena in the universe have been discovered or better understood, including interstellar gas, the cosmic microwave

background radiation, and black holes.

There is no discussion of the *Hamlet* quotation in the chapter itself, but at the very end of the chapter Tyson returns to it, creating a chiasmic structure. The concluding paragraph reads:

We've come a long way since Herschel's experiments with rays that were "unfit for vision," empowering us to explore the universe for what it is, rather for what it seems to be. Herschel would be proud. We achieved true cosmic vision only after seeing the unseeable: a dazzlingly rich collection of objects and phenomena across space and across time that we may now dream of in our philosophy. (164)

The first thing to note is that Tyson has replaced "your philosophy" in the *Hamlet* quotation with "our philosophy."¹⁰⁶ Hamlet says these lines to Horatio after he has met the ghost of his dead father. The ghost has explained that he had been murdered by Claudius, his own brother. Hamlet is shaken up by what he has seen and heard. Hamlet and Horatio studied together in Wittenberg, and "your" in "your philosophy" is usually taken to be the general "your," rather than a personal attack on Horatio's intellectual powers and beliefs, though that interpretation has been made too (Thompson & Taylor [eds.] 2006: 225, n166; Hui 2013). This interpretation—that "your philosophy" refers to a limited view of the world, or the received wisdom of the day, or the systematic but narrow-minded worldview developed at the university—is presumably also the sense in which Tyson uses it. Just as the received philosophy left Hamlet wholly unprepared for the appearance of the ghost, so too William Herschel did not expect to discover infrared radiation when he did his experiments on light in 1800. That *we* may now dream of the unseeable in *our* philosophy, thanks to Herschel and the researchers and engineers that came after him, suggests a story of progress from Hamlet's time to our own.

Indeed, that story of progress is more than suggested by the words leading up to Tyson's paraphrase of *Hamlet*. Science is presented as that activity which lets us "explore the universe for what it *is*, rather than for what it *seems* to be" (emphasis added). Through science, we have achieved "*true* cosmic vision" (emphasis added). It is implied that while fiction is concerned with appearances and impossible phenomena, science dives into the depths of the actual

¹⁰⁶ Curiously enough, there is no consensus of whether the line in *Hamlet* should read "your philosophy" or "our philosophy"; the second Quarto edition of 1604–05 reads "your," whereas the Folio edition of 1623 reads "our" (Thompson & Taylor [eds.] 2006: 225, n166). This is of no importance in the present context, however, since Tyson uses "your."

universe and uncovers the true nature of things. This reading is borne out by a passing remark about science fiction earlier in the chapter: “Anybody who watches too many sci-fi movies knows that gamma rays are bad for you. You might turn green and muscular, or spiderwebs might squirt from your wrists” (161). Of course, common knowledge, in combination with the formulation “*too many sci-fi movies*” (emphasis added), suggest that turning green and shooting spiderwebs are meant to be taken jokingly. Tyson is not dismissing fiction as such—the contrast between science and fiction is not meant as an attack on fiction. Rather, the point is that through this contrast, Tyson is able to highlight what he sees as the nature of science: the uncoverer of the true nature of the universe.

The Science/Human Opinion Boundary

Tyson develops his views on science more straightforwardly in an earlier chapter, “On Earth as in Heaven” (34–47). Like David Wootton (2015), in whose conception of science the idea of the universality of physical laws is crucial, Tyson holds that universality to be fundamental. But unlike Wootton, who dates this idea to Tycho Brahe’s spotting of a nova in 1572, Tyson dates it to Newton: “Until Sir Isaac Newton wrote down the universal law of gravitation, nobody had any reason to presume that the laws of physics at home were the same as everywhere else in the universe. Earth had earthly things going on and the heavens had heavenly things going on” (Tyson 2017: 34). Tyson explains that this discovery opened the floodgates of science, unleashing the power of science to explain the world. He discusses its role in understanding the chemical composition of the sun, in understanding the orbits of binary stars far away in the galaxy, and in understanding storms on Jupiter. He gives it a central place in science: “This universality of physical laws drives scientific discovery like nothing else” (35). Yet even in this chapter, there is significant boundary work going on. First, science is contrasted with *psychology*: “To the scientist, the universality of physical laws makes the cosmos a marvelously simple place. By comparison, human nature—the psychologist’s domain—is infinitely more daunting” (45). Implicit in this assessment is that psychology is not a science. Science is identified with universality and simplicity, while psychology is identified with messiness. Second, science is contrasted with *opinion as such*: “The power and beauty of physical laws is that they apply everywhere, whether or not you choose to believe in them. / In other words, after the laws of physics, everything else is opinion” (45). This example is crucial. By contrasting science with opinion, science is identified with the truth. It is the

modern equivalent of Platonic philosophy. Science is the authority in questions of knowledge. Opinion is mere human frailty; physical laws are absolute. Tyson goes on to qualify this somewhat:

Not that scientists don't argue. We do. A lot. But when we do, we typically express opinions about the interpretation of insufficient or ratty data on the bleeding frontier of our knowledge. Wherever and whenever a physical law can be invoked in the discussion, the debate is guaranteed to be brief: No, your idea for a perpetual motion machine will never work; it violates well-tested laws of thermodynamics. No, you can't build a time machine that will enable you to go back and kill your mother before you were born—it violates causality laws. And without violating momentum laws, you cannot spontaneously levitate and hover above the ground, whether or not you are seated in the lotus position. (45–46)

Two things stand out here. First, rhetorically this qualification only serves to strengthen the contrast between science and opinion: there are opinions on the “bleeding frontier of our knowledge,” but the foundations of knowledge are secure. Second, the challenges to the physical laws cited—perpetual motion machine, time machine, and levitation—are evasive and, put plainly, rather silly. They are straw men, used to deflect cases of serious uncertainty and disagreement about theories and principles, as well as deep issues about the ontological status of scientific theories and results. Do our theories about physical laws, if true, correspond to an independently existing reality? Do physical laws “get at reality,” as realists claim? Or are these laws more a reflection of our conceptual schemes and models, as instrumentalists and constructivists claim? (Okasha 2002: 58–76.)

The deflection of these issues is indicative of a slippage between statements about scientific attempts to describe the universe on the one hand, and statements about the universe as such on the other hand. On the one hand, Tyson suggests that fundamental laws, such as Newton's law of gravity, are open to revision. And this particular physical law was indeed revised when Einstein formulated the general theory of relativity, a theory that applies to domains where Newton's equations break down, such as extremely massive objects. In this sense, “physical laws” refer to our attempts to describe the universe, and as such they are, in principle, never absolutely certain, since future observations or theories might require that they be revised. It is true that Newton's law still applies for “ordinary household gravity,” as Tyson puts it (44); but it also means that since Newton's law is not strictly universal, it cannot be the final word on the matter and hence does not “get at reality,” as is required for true physical laws. On the other hand, Tyson's formulation “after the laws of

physics, everything else is opinion” taps into the sense of physical laws *not* as models or conceptual constructs, but as real, as independent of our attempts at describing the universe. Thus, the term “physical laws” is ambiguous: it refers at times to laws as formulated in the current state of science, and hence in principle open to revision; and at times to laws “out there,” in physical reality, never open to revision and untouchable by human opinion. This slippage allows Tyson to construct science as, on the one hand, open to revision, and hence as both flexible and noble (scientists are open-minded and ready to accept reality when reality contradicts science); and, on the other hand, as the authority on knowledge claims thanks to its unique access to reality. This conception of science can then be used to claim authority in arguments about the value of science: sometimes science is valuable because it is flexible, sometimes because it is absolute. Thus, the slippage between model and reality allows for flexibility when invoking the authority of science in matters of knowledge.

*

All these definitions and descriptions of science point to a significant feature of Krauss’s and Tyson’s characterizations of science: they are idealizations of science, stripped (for the most part) of the historical messiness and philosophical complexity with which science is inextricably linked. Also absent are nuanced discussions of the socioeconomic realities necessary for the practice of science in today’s world (Resnik 2007; Agar 2012; Mirowski 2011)—a point to which I return in chapter 9. In both Krauss’s and Tyson’s conception of science, the crucial ingredients are reason and experiment. Using reason and experiment, science can peel away the layers of appearance that we encounter in everyday life and discover the true, underlying nature of the universe. Both emphasize that the current state of knowledge is nowhere near complete—the “So Far” in the title of Krauss’s book is intended as a testament to that, and Tyson says “ignorance is the natural state of mind for a research scientist” (Tyson 2017: 32)—but both make it clear that they believe that ignorance is not total, that we know a great deal about the universe thanks to science, and that science is the only way to produce genuine knowledge about the underlying reality. This view of science is conveyed using rhetorical and literary techniques. The philosophical asides let Krauss and Tyson construct science and scientists in passing; the longer reflections incorporate ambiguities and avoid

serious philosophical discussions; and boundary work serves to construct science through contrasts with other activities and belief systems, which are, in turn, thereby demoted to a lesser epistemological status (see also Gieryn 1999; Mellor 2003; Leane 2007).

In principle, a definition of science, whether direct or indirect, does not by itself say anything about the value of science, or whether science is worth pursuing and investing in. Two additional assumptions are needed: first, that producing knowledge of the kind that science produces is good; and second, that science, as it is currently practiced, is worthwhile, given the risks and costs that come with it. Both Krauss and Tyson provide explicit justifications for science. Yet there is a kind of justification of science implicit in boundary work itself—one that is not spelled out by Krauss and Tyson but that nonetheless has a rhetorical impact. “Truth” and “reality” have positive connotations in our culture; they are the marks of things worth taking seriously. Thus, when science is presented as that activity which discovers the truth about some phenomenon, or as that activity which has access to the underlying reality behind the mere appearances of everyday life; and when, furthermore, science is contrasted with activities and belief systems that purportedly do not discover the truth or access the underlying reality quite as well as science (if indeed at all)—then it becomes clear that boundary work, as a rhetorical strategy, functions as an implicit justification of science.

Scientism

From Science to Scientism

In the previous chapter, I posited that even though there are crucial similarities between routine definitions of science and mainstream popularizers’ definitions, popularizers tend to want to extend the purview of science. The preceding analyses of the definitions of science in *The Greatest Story* and *Astrophysics* indicate some aspects of how this is done. Science is not only a producer of knowledge about the universe—it is also the *uncoverer of the true nature of the universe*. In this sense, science is transcendent because it breaks “the chains that our limited senses have imposed upon us” (Krauss 2017: 303), enabling us to transcend sense experience and common sense to gain access reality. Krauss also phrases this as a process of peeling: “Each time we peel back one layer of reality, other layers beckon” (275). In this, he is not alone. For example, bestselling physicist Michio Kaku (1994): “The purpose of science is to

peel back the layer of the appearance of objects to reveal their underlying nature” (vii). Brian Greene (2004) uses the same metaphor, but in an elaborated form, to characterize science and its impact: “*The overarching lesson that has emerged from scientific inquiry over the last century is that human experience is often a misleading guide to the true nature of reality. . . . [We know this thanks to] the work of ingenious innovators and tireless researchers—the men and women of science—who have peeled back layer after layer of the cosmic onion, enigma by enigma, and revealed a universe that is at once surprising, unfamiliar, exciting, elegant, and thoroughly unlike what anyone ever expected*” (5). Even Lisa Randall (2011), who discusses the nature of physical models at length and develops relatively sophisticated (for popular science) arguments about the epistemological status of scientific theories, falls back onto the metaphor of peeling: “The universe evolves and so does our scientific knowledge of it. Over time, scientists peel away layers of reality to expose what lies beneath the surface” (4). This emphasis on epistemological realism—accessing and representing reality—is indicative of many popularizers’ wish to expand the domain of science beyond methodological naturalism as defined by Robert T. Pennock and Judge Jones III (see chapter 3). Carl Sagan’s definition of science in *Cosmos* is a good example.

Sagan (1980) defines science in the last chapter, “Who Speaks for Earth?”: “[Science] is by far the best tool we have, self-correcting, ongoing, applicable to everything. It has two rules. First: there are no sacred truths; all assumptions must be critically examined; arguments from authority are worthless. Second: whatever is inconsistent with the facts must be discarded or revised. We must understand the Cosmos as it is and not confuse how it is with how we wish it to be” (333). A few pages later, having presented the history of the universe from the Big Bang to present-day humanity and science, he says: “It [the history of the universe] has the sound of epic myth, and rightly. But it is simply a description of cosmic evolution as revealed by the science of our time” (338). The use of the word “reveal”—in addition to its religious connotations, with science as the successor of religious myth—suggests epistemological realism: science not only models the universe but accesses it. These statements should be read in the light of the opening sentence of the first chapter: “The Cosmos is all that is or ever was or ever will be” (4). Reading these statements together suggests that Sagan not only subscribes to methodological naturalism but a stronger version of naturalism: ontological naturalism, or the idea that the natural or physical is all that exists (McMullin 2011; Papineau [2007] 2016).¹⁰⁷

¹⁰⁷ McMullin (2011: 82) cites the opening words of *Cosmos* as an example of ontological

This is one step further than Judge Jones III's definition and other definitions discussed in the previous chapter. Methodological naturalism does not exclude the possibility of the existence of the supernatural, but it says that *science* is limited to the natural or physical world. Sagan suggests that *existence* is limited to the natural or physical and that science is the best way "by far" to access existence.

In a way, equating "the cosmos" with "all that is" could be viewed as a definitional strategy: Sagan simply defines the totality of existence as "the cosmos" and claims that the scientific method is the best way to access it. If that is the case, then "the supernatural" is simply a self-contradictory category, since whatever exists—whatever it may be—is by definition natural. This is a legitimate philosophical position—but one with a certain amount of hidden baggage, and whose definition of "the cosmos" goes beyond standard usage. Defining "the cosmos" simply as "all there is" is unlikely to go unchallenged. But even if it does, there is an additional claim: that science is the best way to understand this cosmos, understood as *everything*. In other words, whatever the semantic status of the opening sentence—definition or assertion—Sagan claims that the totality of existence is within the purview of science.

The combination of methodological naturalism, epistemological realism, ontological naturalism, and the unity of science results in a view usually called "scientism." "Scientism" is a pejorative term, and so it is not always used by its proponents, but it is a recognizable view nonetheless. "Scientism" is also a controversial and rather vague term, but it can be said to come in two varieties: epistemological scientism and ontological scientism. Philosopher Jeroen de Ridder (2014) defines them in the following way: "Epistemological scientism holds that science is our only source of knowledge about ourselves and the world, while remaining non-committal on whether it is also the final arbiter of what exists. Ontological scientism maintains that science has the last word on what exists: Only those things exist that science—or perhaps a future, finalized science—recognizes or postulates" (25). In principle, epistemological scientism and ontological scientism are independent of each other. One can subscribe to epistemological scientism and still believe that there are dimensions of reality beyond the scope of science. Conversely, one can subscribe to ontological scientism and still maintain that forms of knowledge other than science are valuable—they just do not get at reality. I term the combination of epistemological scientism and ontological scientism—the view that science is the only source of knowledge *and* the final arbiter of what exists—simply

naturalism.

“scientism.” When I discuss either of the two varieties, I qualify it with “epistemological” or “ontological.”

Scientism in Society

As suggested by the definitions of science discussed in chapter 3, common definitions of science in society do not add up to scientism. However, given the ties between science, government, and industry, it should come as no surprise that epistemological scientism can be and has been a part of governments’ positions—although, again, not necessarily with that label. In fact, Ian Welsh and Brian Wynne (2013) argue that scientism has been the “dominant policy–institutional . . . mode of dealing with public controversies and debates involving science and technology in the UK and elsewhere since WWII” (559). They exemplify this with controversies over genetically modified food and environmental issues. In general, the approach to science identified here as epistemological scientism has been used to promote science-oriented policies in governance and to prevent democratic participation in matters of science (see Olson 2016; Jasanoff 2017).

Yet the fact that epistemological scientism is a practiced part of many government policies does not mean that it is an accepted and widespread view. Richard N. Williams (2015), in an anthology dedicated to (critiques of) scientism (Williams & Robinson 2015 [eds.]), does call scientism “the new orthodoxy” and argues that it “has generated such enthusiasm and enjoyed such popularity that it often receives unquestioned acceptance by scholars and by the public” (2). But given the definitions of science discussed in the previous chapter, I would contest Williams’s claim somewhat. While it may be true that popularizers tend to embrace scientism, and while epistemological scientism may be useful for governments, I see no evidence of a widespread “unquestioned acceptance [of scientism] by scholars and by the public.” To the contrary, scientism is a controversial and hotly contested position. Though epistemological scientism, at least, seems to be a fairly common view in analytic philosophy (Okasha 2002: 121–125), scientism of all varieties is rejected by most scholars in STS and the humanities.

As for the public, scientism does not seem to be the dominant view of science and the world. This can be seen in two ways. First, on a practical and policy-related level, the very fact that there are disputes about some policies involving science indicates that segments of the public remains skeptical of scientism. In a study of debates about new science and technology, STS scholar Melanie Smallman (2018) identifies diverging attitudes in experts and

policymakers vis-à-vis the public in the UK in the period 2002–2011. Experts and policymakers adhere to a “science to the rescue” narrative according to which “science is a driver of our economy and competitiveness and can solve our problems and deliver social goods.” The public, by contrast, displays a “contingent progress” view according to which “science and technology are seen not only as producing goods and solutions but also as producing (unforeseen) problems, problems which are as inherent to the technologies as the benefits they bring, where industry is a necessary but distorting influence that needs to be managed by the state” (669–670). More broadly, this kind of divergence is manifest not least in the public understanding of science movement (and its predecessors and successors), as discussed briefly in chapter 1. The perceived lack of a public understanding and appreciation of science, and the concerted efforts to remedy it, testify to the public being perceived, by policymakers and science promoters, as *not appreciative enough* of science. Second, on a more cognitive, existential, and moral level, scientism seems to be even weaker. In a study of the idea of the disenchantment of the world, Josephson-Storm (2017: 22–37) argues that even though some scholars believe that science and rationality have “disenchanted” the world, in fact many people in the West still believe in things that manifestly contradict scientism, such as premonitions, telepathy, witches and wizards, angels, demons, ghosts, haunted houses, and God:

Roughly an amazing three-quarters of Americans hold at least one supernatural belief. Sure, we have plenty of skeptics, and one might hazard the guess that more of them are housed in the academy than elsewhere; still, evidence suggests that higher education merely opens one up to some paranormal beliefs rather than others. In most respects it would appear these skeptics are in the minority. (Josephson-Storm 2017: 34)

Indeed, from a public relations point of view, scientism has been perceived to be strategically misguided. Science communicator Thomas Burnett (2018) identifies the presence of scientism in major popular science publications by popularizers such as Sagan, Steven Weinberg, and E.O. Wilson, and he argues that it is detrimental to the public image of science. Significantly, Burnett argues this case in an essay on the American Association for the Advancement of Science’s website, explicitly citing financial reasons and public support for the detriment of scientism: “Scientism today is alive and well, as evidenced by the statements of our celebrity scientists [quotations by Sagan, Weinberg, Wilson] . . . Whether one agrees with the sentiments of these scientists or not, the result of these public pronouncements has served to alienate a large segment

of American society. And that is a serious problem, since scientific research relies heavily upon public support for its funding” (Burnett 2018). What Burnett is reacting to here is evidently scientism, *not* epistemological scientism. Rather, his argument is that scientism can get in the way of the public understanding and appreciation of science—and thus, by extension, of epistemological scientism.

Scientism in Popular Science

As indicated by Burnett and borne out in studies by several scholars, scientism is present in much popular science. Sarah Tinker Perrault (2013: 50–60) identifies three roles that popularizers can take on: “boosters” (writers who are enthusiastic about science and see their function as not only explaining science but promoting it); “translators” (writers who see their function primarily as translating technical information); and “critics” (writers who approach science with both “interest and skepticism” and who wish to enable their readers to form informed opinions about science as it actually works). She shows that boosters dominate popular science, especially of the bestselling and visible kind. Boosters typically subscribe to a “traditional-idealist” view of science according to which science embodies realism, rationalism, and objectivism—a trio of traits that, combined, claim that knowledge about an independently existing world is possible; that rationality, epitomized in logic and mathematics, is the means by which to attain knowledge of that world; and that the knowledge so attained is objective. The traditional-idealist view of science “can lead to scientism,” which she defines as “a belief in scientific knowledge that ignores the limits of that knowledge and attempts to apply it in areas where its relevance is dubious, at best.” “The ‘principal tenet’ [of scientism],” she adds (quoting Ziman 2000), “is that science is producing a complete, comprehensive, «scientific world picture,» which will constitute the ultimate «reality»” (Perrault 2013: 19–20). While she does not say it outright, Perrault suggests that a majority of popularizers, the boosters, subscribe to scientism. Many studies corroborate the prevalence of scientism in contemporary popular science.¹⁰⁸

¹⁰⁸ E.g. Lessl (1996); Nieman (2000); Lessl (2007); Hughes (2012); Ridder (2014); Sideris (2017); Pigliucci (2018). These studies explicitly discuss scientism as a prevalent ideology in popular science. Studies on popular science that do not invoke the term “scientism” but nonetheless argue that popularizers use science for mythologizing or totalizing ambitions are legion; e.g. Turney (2001); Mellor (2003); Leane (2007); Schrempp (2012); Zakariya (2017).

In essence, scientism is about the scope and value of science. Advocates of scientism view science as, in principle, extendable to all areas of inquiry, and they regard science as incredibly valuable. The addition of the valuation of science as something incredibly valuable I term “exultant expansionism.” The other actors defining science discussed in chapter 3 also regard science as valuable, but they tend to be more cautious and less jubilant in their tone. One could make the case that their definitions imply something about the value of science. Simply the fact that science is conceptualized as knowledge production implies something about it being valuable, since knowledge is usually valued in Western society. However, they do not expand science in the same kind of way that popularizers tend to do. This is crucial and speaks to a general point: while common definitions by governmental agencies and major organizations tend to be cautious supporters, mainstream popularizers tend to be exultant expansionists. Mainstream popularizers tend to want to *expand* the domain of science to encompass everything.

Perhaps the most infamous expression of scientism comes from the opening page of Stephen Hawking and Leonard Mlodinow’s book *The Grand Design* (2010). After characterizing humans as “a curious species” and posing questions such as “How can we understand the world in which we find ourselves?” and “What is the nature of reality?” they claim:

Traditionally these are questions for philosophy, but philosophy is dead. Philosophy has not kept up with modern developments in science, particularly physics. Scientists have become the bearers of the torch of discovery in our quest for knowledge. The purpose of this book is to give the answers that are suggested by recent discoveries and theoretical advances. They lead us to a new picture of the universe that is very different from the traditional one, and different even from the picture we might have painted just a decade or two ago. (5)

There is no clearer expression of scientism than the view that scientists are arbiters not just of scientific matters, but also of matters of ontology, epistemology, and the human condition itself.

Scientism and Reductionism: Wilson, Watson, Weinberg

Most popularizers convey scientism without labeling it as such and without justifying its metaphysical presuppositions. Indeed, it may well be more efficiently promoted as unanalyzed, through philosophical asides and boundary work. However, some popularizers do attempt to spell out the presuppositions and consequences of scientism. The most developed vision of scientism is

likely Edward O. Wilson's in his book *Consilience: The Unity of Knowledge* (1998). Wilson is one of the most famous scientists and popularizers today.¹⁰⁹ He has been awarded the Pulitzer Prize in general nonfiction twice (in 1979 and 1991) and is recognized as a major public intellectual in the US. He has also been controversial ever since his book *Sociobiology* (1975) with its attempts to use evolutionary biology to explain human societies and human behavior. *Consilience* is a systematic attempt to formulate a coherent worldview based on scientism.

Wilson borrows the term "consilience" from William Whewell's *The Philosophy of the Inductive Sciences* ([1840] 1847). As discussed in chapter 1, Whewell coined the term "scientist" and championed the idea of the unity of the sciences. Citing Whewell's definition, Wilson (1998) defines "consilience" as "literally a 'jumping together' of knowledge by the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation" (8). The project of consilience, in Wilson's formulation, is to link the natural sciences, the social sciences, and the humanities into one coherent, explanatory framework. Much like Comte's framework, the sciences form a hierarchical structure: physics, chemistry, biology, the social sciences, the humanities. Crucially, in this worldview the hierarchical structure of the sciences mirrors the structure of the universe. The main idea is that laws or principles on lower levels (e.g. physics) constrain what can happen on higher levels (e.g. chemistry). Conversely, systems on higher levels (e.g. biology) have larger degrees of organizational complexity than lower level systems (e.g. chemistry), but they can never contradict lower level laws. Wilson admits that this view contains ontological and (as of yet) unprovable assumptions, but he claims that the past success of the natural sciences, as well as the prospects for a unified explanatory framework, are good reasons for adopting the consilience framework. Wilson further claims that consilience is already a fundamental part of the natural sciences, a kind of default assumption and guiding principle (e.g. 11, 291). The crucial next step in the consilience project will be the assimilation of the social sciences and the humanities: "The main thrust of the consilience world view . . . is that culture and hence the unique qualities of the human species will make complete sense only when linked in causal explanation to the natural sciences. Biology in particular is the most proximate and hence relevant of the scientific disciplines" (292). In practice this means that evolutionary biology forms, or will form, the conceptual and explanatory foundation for disciplines such as psychology, sociology, and anthropology, which in turn

¹⁰⁹ Fahy & Lewenstein 2014; Sideris 2017; Zakariya 2017; Gross 2018.

form, or will form, the conceptual and explanatory foundations for disciplines such as history, religious studies, and literary studies.

Wilson does not shy away from the charge of scientism. In fact, he embraces it: “[Professional philosophers] will draw this indictment: *conflation, simplism, ontological reductionism, scientism*, and other sins made official by the hissing suffix. To which I plead guilty, guilty, guilty” (11). The polemical tone is likely due in part to the fact that Wilson wrote *Consilience* at the height of the Science Wars of the mid to late 1990s. But the polemical tone also neatly parallels the perception of scientism among its critics: that scientism unabashedly and unapologetically wishes to expand science beyond the traditional domains of scientific explanation and aims to assimilate, with revisions if necessary, all forms of knowledge into its framework.

The key to scientism-in-practice is another loaded term, one to which Wilson also subscribes: reductionism. Wilson calls it “ontological reductionism” in the quotation above, but reductionism also comes in epistemological and methodological varieties. For Wilson, reductionism is the “cutting edge of science . . . , the breaking apart of nature into its natural constituents” (58). The word “natural” is a testament to Wilson’s view that reductionism is both epistemological, methodological, and ontological: not only do scientists as a matter of practice break nature apart into constituents—they break nature apart into its *natural* constituents, a feat possible only if scientific knowledge mirrors nature. Wilson places reductionism at the heart of the scientific enterprise: “Practicing scientists, whose business is to make verifiable discoveries, view reductionism [as] the search strategy employed to find points of entry into otherwise impenetrably complex systems. Complexity is what interests scientists in the end, not simplicity. Reductionism is the way to understand it” (59).

Wilson is not alone in seeing reductionism as a defining feature of science. Journalist and intellectual historian Peter Watson, whose book *Convergence* (2016) essentially makes the same argument as Wilson’s but through a more historical lens, claims: “The idea that the sciences are linked in some hierarchical way is not new, of course, and is known as reductionism. Although reductionism has been criticized—especially in the last twenty to thirty years, even as the evidence in its favor has grown stronger than ever—for the most part, leading scientists themselves have overridden these objections” (xxviii). Steven Weinberg, a leading scientist and also a major popularizer, is one of the scientists that Watson invokes. Weinberg calls the epilogue to his book *To Explain the World* (2015) “The Grand Reduction,” and he ends it with the following words, paraphrasing the oft-quoted ending of Darwin’s *On the Origin*

of Species:¹¹⁰

This is a grand story—how celestial and terrestrial physics were unified by Newton, how a unified theory of electricity and magnetism was developed that turned out to explain light, how the quantum theory of electromagnetism was expanded to include the weak and strong nuclear forces, and how chemistry and even biology were brought into a unified though incomplete view of nature based on physics. It is toward a more fundamental physical theory that the wide-ranging scientific principles we discover have been, and are being, reduced. (Weinberg 2015: 268)

Wilson, Watson, and Weinberg are part of a longer tradition associating knowledge with reductionism. As I have argued, reductionism has been a major part of the intellectual traditions of natural philosophy and science since the seventeenth century. Philosopher Michael Ruse (2013), in a book detailing the reception of James Lovelock's and Lynn Margulis's Gaia theory,¹¹¹ identifies three major views of matter and nature running through Western thought: hylozoism, mechanism, and organicism. Reductionism is intimately linked with the mechanistic view of the world. Ruse argues that from the ancient Greeks to the Scientific Revolution, all matter was generally conceived of as alive, and processes and entities were conceived of as having purposes. Ruse identifies this view of nature as "hylozoism." The view of nature associated with the Scientific Revolution meant a break with hylozoism among many thinkers. Philosophers started to conceptualize the universe as a machine rather than as a living being, and thus mechanistic metaphors and a reductionist mindset took over. Ruse further elucidates the link between mechanism and reductionism:

It is fairly easy to see how mechanism and reductionism get linked up If you want to find out how a machine works—for example, the diesel engine in your truck—your best strategy is take it apart, trying to ferret out the purpose of each part and what it contributes to the larger system. . . . Hence, it is often thought that the best way to realize the mechanistic program is to pursue a reductionist strategy. (71)

Ever since the Scientific Revolution, Ruse argues, mechanism and

¹¹⁰ The last sentence in *On the Origin of Species* reads: "There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed laws of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved" (Darwin 1859: 490).

¹¹¹ Cf. pp. 39–40 n26 in the introduction above.

reductionism have gone hand in hand, forming the dominant view among scientists and scientifically minded thinkers. But he also shows that there have been dissenting voices. He identifies proponents of hylozoism up until the present moment, as well as a tradition of organicism that occupies a kind of middle ground between mechanism and hylozoism: organicists do not view all matter as alive, and they do not view all processes as having purposes, but they resist reductionism and mechanistic metaphors, instead preferring such terms as “holism” and “emergence.” Romanticism is one of the most prominent and influential reactions to mechanism and reductionism. Yet in spite of this, mechanism and reductionism have been the dominant conceptualizations of matter and the Earth in natural philosophy and science since the Scientific Revolution, in Ruse’s reading—or at least since 1850, in John Tresch’s (2013) reading, when “the classical image of science again took the upper hand” (xi).

The Naturalization of Science and the TEUSH Narrative

Both adherents of scientism and more cautious proponents of science in society view science as valuable. Naturally, however, not everyone in society does. Religious critics of science, particularly in the US, argue that some science is corrosive with regard to traditional values. Typically, the sciences indicted are those that are perceived to undermine belief in God, especially evolutionary biology and Big Bang cosmology (see NSB 2018: ch. 7, 38–40). Social critics of science, by contrast, argue that parts of science incorporate values that are destructive and act to preserve problematic ideologies and structural inequality—whether through the construction of gender (Keller 1985; Bordo 1987), in the unequal distribution of power and resources (Hornborg 2001; Harding [ed.] 2011), or in the instrumentalization and destruction of the environment through the subject-object-oriented approach to nature (Heidegger [1954] 1977; Plumwood 2002).

As I have argued, mainstream popularizers of science tend to disagree with both the cautious attitude of proponents of science and the critics of science. In contrast to the cautious supporters and the separation between fact and value discussed in the previous chapter, popularizers tend to fuse science with values. But in contrast to the critics of science, popularizers tend to view the values fused with science as positive rather than negative. Indeed, this is already implied in scientism and its exultant expansionism: science is something

incredibly valuable.

However, the fusion of values and science is more than a straightforward appraisal. If it were simply a positive attitude on the part of the proponent of science, then the separation between facts and values could in principle be maintained. Science would deal only in facts, and the appraisal of science would be a separate act, so to speak. But many popularizers go one step further and fuse science and values in a substantial way. This fusion serves to provide a justification of science—a justification stronger than a simple evaluation of the results or effects of science in terms of technological applicability and economic productivity. It provides the foundation for an existential justification of science. The “existential fusion of facts and values,” as it might be called, relies on a *naturalization* of science.

A “naturalization” of a phenomenon is, in general, an account of that phenomenon that explains its characteristics as “natural” or “rooted in nature,” whether explicitly or not—it can be so taken for granted so as to just be experienced as “natural” (Fairclough 1985; Chandler & Munday [2010] 2016). A naturalization of science resulting in an existential fusion of facts and values thus explains science itself as somehow natural or rooted in nature. The fusion of facts and values comes about because science is presented as rooted in a specific set of facts, namely that humans are an evolved species with a specific set of traits. These facts of human evolution then serve as a justification for science. Science is, the reasoning goes, the satisfaction of natural needs, desires, or instincts. Thus, combined with the often silent assumption that satisfying natural needs, desires, or instincts is good, science is valuable because of its ability to satisfy those needs, desires, or instincts. This presentation need not be spelled out in detail, but sometimes it is. A prime example of this is provided by Lawrence Krauss in the epilogue, titled “Cosmic Humility,” to *The Greatest Story*. After first stating an instrumental justification for science—science is good because its application in technology benefits humanity—Krauss offers his main justification of science:

But ultimately I believe we are driven to do science because of a primal urge we have to better understand our origins, our mortality, and ultimately ourselves. We are hardwired to survive by solving puzzles, and that evolutionary advantage has, over time, allowed us the luxury of wanting to solve puzzles of all sorts—even those less pressing than how to find food or to escape from a lion. What puzzle is more seductive than the puzzle of our universe? (Krauss 2017: 301)

Similar passages, with varying degrees of explicitness, can be found in the

works of many major popularizers. Here are just a few examples:

Carl Sagan, in *Cosmos* (1980):

The size and age of the Cosmos are beyond ordinary human understanding. Lost somewhere between immensity and eternity is our tiny planetary home. In a cosmic perspective, most human concerns seem insignificant, even petty. And yet our species is young and curious and brave and shows much promise. In the last few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival. I believe our future depends on how well we know this Cosmos in which we float like a mote of dust in the morning sky. (4)

British physicist Paul Davies (1987), whose books were particularly read in the 1980s and 1990s:

Something buried deep in the human psyche compels us to contemplate creation. It is obvious even at a casual glance that the universe is remarkably ordered on all scales. Matter and energy are distributed neither uniformly nor haphazardly, but are organized into coherent identifiable structures, occasionally of great complexity. From whence came the myriads of galaxies, stars and planets, the crystals and the clouds, the living organisms? How have they been arranged in such harmonious and ingenious interdependence? The cosmos, its awesome immensity, its rich diversity of forms, and above all its coherent unity, cannot be accepted simply as a brute fact. (3)

Michio Kaku (1994):

Our curiosity is part of the natural order. Perhaps we as humans want to understand the universe in the same way that a bird wants to sing. As the great seventeenth-century astronomer Johannes Kepler once said, "We do not ask for what useful purpose the birds do sing, for song is their pleasure since they were created for singing. Similarly, we ought not ask why the human mind troubles to fathom the secrets of the heavens." (334)

Brian Greene (2004):

Cosmology is among the oldest subjects to captivate our species. And it's no wonder. We're storytellers, and what story could be more grand than the story of creation? (14)

Brian Cox and Jeff Forshaw (2009):

We walk in the midst of wonders, and if we open our eyes and minds to them, the possibilities are boundless. Albert Einstein will be remembered for as long as there are humans in the universe both as an inspiration and an example to all those who are captivated by a natural curiosity to understand the world around them. (242)

Stephen Hawking and Leonard Mlodinow (2010):

We exist for but a short time, and in that time explore but a small part of the whole universe. But humans are a curious species. We wonder, we seek answers. Living in this vast world that is by turns kind and cruel, and gazing at the immense heavens above, people have always asked a multitude of questions (5)

Astrophysicist Martin Rees (2011), Britain's Astronomer Royal since 1995:

The dark night sky is an inheritance we've shared with all humanity, throughout history. All have gazed up in wonder at the same "vault of heaven," but interpreted it in diverse ways. There is a natural fascination with the big questions: Was there a beginning? How did life emerge? Is there life in space? And so forth. (19)

Carlo Rovelli (2015):¹¹²

It is not against our nature to be curious: it is in our nature to be so.

One hundred thousand years ago our species left Africa, compelled perhaps by precisely this curiosity, learning to look ever farther afield. Flying over Africa by night, I wondered if one of these distant ancestors setting out toward the wide-open spaces of the North could have looked up into the sky and imagined a distant descendent flying up there, pondering on the nature of things, and still driven by his very same curiosity. (77)

Neil deGrasse Tyson (2017):

We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun. (33)

¹¹² Rovelli (2015) stands out somewhat in that he expresses more pessimism than the other authors quoted here (he argues that humankind will likely soon go extinct). However, he is similar to the others in his naturalization of science.

Thus, the naturalization of science extends beyond the separation of facts and values. Science is presented as sprung from nature itself and as rooted in basic human needs and dispositions. In contemporary popularizations of physics and astronomy, this naturalization is most readily incorporated into the TEUSH narrative—the triumphant epic of the universe, science, and humankind. Humankind is a product of laws of nature working on matter/energy on a cosmic timescale. This evolutionary process created humans with a specific set of needs. Humankind developed science to satisfy some of the noblest needs so evolved—the need to understand the universe, ourselves, and our place in the universe. The pursuit of science is thus a way of following nature’s lead and satisfying basic and noble human needs—in effect, realizing what it means to be human. I return to the naturalization of science in the analyses in the remaining chapters.

5

Defamiliarization

Uprooting the Reader and Unearthing Reality

“Defamiliarization” is a twentieth-century concept, introduced and defined by the Russian formalist Viktor Shklovsky in his influential article “Art, as De-vice” (2015), published in 1917. However, similar ideas were central to the aesthetic ideas and practices of many Romantic poets a century before Shklovsky (Economides 2016; Gorodeisky 2016). William Wordsworth and Samuel Tayler Coleridge, in particular, regarded the presentation of familiar objects as unfamiliar as central to the power and purpose of poetry:

The principal, ascertained object, then, which I proposed to myself in these Poems [*Lyrical Ballads*] was to chuse incidents and situations from common life, and to relate or describe them, throughout, as far as was possible, in a selection of language really used by men; and, at the same time, *to throw over them a certain colouring of imagination, whereby ordinary things should be presented to the mind in an unusual way*; and, further, and above all, to make these incidents and situations interesting. (Wordsworth in his preface to the *Lyrical Ballads*; Wordsworth & Coleridge [1798, 1800, 1968] 1991: 235–236; emphasis added)

To carry on the feelings of childhood into the powers of manhood; to combine the child’s sense of wonder and novelty with the appearances which every day, for, perhaps, forty years, had rendered familiar; . . . this is the character and privilege of genius, and one of the marks which distinguishes genius from talents. And therefore, it is the prime merit of genius, and its most unequivocal mode of manifestation, . . . *so to represent familiar objects as to awaken in the minds of others a kindred feeling concerning them, and that freshness of sensation which is the constant accompaniment of mental, no less than of bodily*

convalescence. (Coleridge 1834: 55–56; emphasis added)

The idea that the poet has the capacity to present familiar objects as unfamiliar through the use of language, thus making the reader see those objects in a new light, with a “freshness of sensation,” is central to the concept of defamiliarization. It has been viewed by some scholars, including Shklovsky (at least in the above-cited article), as the very essence, or primary function, of literature. Today, with the influence of postmodernism and constructivism, the question of “the essence of literature” is largely regarded as misguided, not least because the very concept of “literature” is usually seen as a historically and culturally specific construction (e.g. Guillory 1993; Culler 1997). Nonetheless, defamiliarization is typically discussed in overviews of literary theory and is typically regarded as one of the things that literature can do. Furthermore, in some contemporary research fields—such as cognitive poetics, stylistics, and empirical reader-response studies—the concept of defamiliarization has been studied and developed with the help of theories and methods from psychology, linguistics, and neuroscience.

As the Carl Sagan quotation with which I ended chapter 2 makes clear, defamiliarization is also used in popular science: “The end of our long journey is the world where we began. Our travels allow us *to see the Earth anew, as if we came from somewhere else*. . . . Welcome to planet Earth: a place with blue nitrogen skies, oceans of liquid water, cool forests, soft meadows” (Sagan et al. [1980] 2009: episode 1: 27^m37^s–28^m59^s; emphasis added). In this example, the familiar world is presented as unfamiliar through a combination of an unusual perspective—viewing the Earth from the ship of the imagination after a tour of the cosmos—and an unusual use of language that mixes everyday words with scientific-sounding words and phrasings—“blue nitrogen skies,” “oceans of liquid water.” The “freshness of sensation” that Sagan aims to evoke is one made possible not only through a novel use of language, but also through a scientific perspective on the ordinary world.

Sagan is not the only popularizer to use defamiliarization techniques to convey science. It is, in fact, common in mainstream popularizations of physics and astronomy.¹¹³ Why is this the case? What functions does defamiliarization

¹¹³ To the best of my knowledge, no one has studied the use of defamiliarization in popular science texts. As I show in this chapter, Greene (2004), Krauss (2017), and Tyson (2017) all use defamiliarization. In Helsing (2017), I identified defamiliarization in Elizabeth Kolbert’s *The Sixth Extinction* (2014). The analyses of defamiliarization developed in this chapter would be extendable to other popularizations of physics and astronomy, e.g. Weinberg (1977), Kaku (1994), Randall (2011), and Hawking ([1988] 2016).

have in popular science texts? In addressing these questions, I begin with a discussion of the literature on defamiliarization in cognitive poetics, stylistics, and empirical reader-response studies, resolving it into a formulation of a concept of defamiliarization that is useful for analyzing defamiliarization in popular science. I then go on to analyze defamiliarization in Krauss's *The Greatest Story* and Tyson's *Astrophysics*.

Defamiliarization, Foregrounding, and Perspective

Shklovsky's article "Art, as Device" (2015) is a standard reference in discussions about defamiliarization.¹¹⁴ Shklovsky developed the concept ("ostranenie" in the original Russian; "enstrangement" [sic] in the translation I am using [2015]) in an attempt to define the "literariness" of literature.¹¹⁵ What is it about a work of literature that makes it literary? Shklovsky criticizes earlier accounts according to which imagery or metaphor is the key. Instead, Shklovsky argues, the purpose of art is to enable the reader to see the world afresh and to feel life anew: "this thing we call art exists in order to restore the sensation of life, in order to make us feel things, in order to make a stone stony. The goal of art is to create the sensation of seeing, and not merely recognizing, things" (162). He relies upon an account of human cognition according to which habituation causes us to go through life without really perceiving our surroundings and sensing life. We become too familiar with the ordinary world; we become automatized. The technique he identifies as defamiliarization is a means to overcome habituation and familiarity: by describing familiar objects in unfamiliar ways, authors can break down the automatized perceptions of world. The key to art is that it "increases the duration and complexity of perception" (162); by so doing, art reinvigorates the reader or viewer.

Literary scholar Willie Van Peer (1986) notes a fundamental ambiguity in Shklovsky's concept of defamiliarization: "On the one hand it is meant to describe properties of the actual text, i.e. the literary devices that can be located in *the text* itself. On the other hand it points to *the effect* such devices may have on a reader. These two meanings are in fact blended together in the terms employed by Šklovskij and several other Formalists" (3). In subsequent formalist theorizing, there was a tendency to discard the psychological effects and focus

¹¹⁴ See Erlich ([1955] 1965); Steiner (1984); Douthwaite (2000); Berlina (2017).

¹¹⁵ "Literariness" is actually a term introduced by Roman Jakobson in 1921 (Salgado 2015).

on the formal features of literary language (Erlich [1955] 1965; Van Peer 1986). In more recent studies on defamiliarization by scholars in cognitive poetics and empirical reader-response studies, however, the psychological effects of literature are central.¹¹⁶ Thus, the work of these scholars can be seen as a continuation of research on issues discussed by the Russian formalists, but within cognitive, linguistic, psychological, and neuroscientific frameworks, often using empirical methods to study actual readers' responses to literary texts.

In order to disambiguate the concept of defamiliarization, many scholars distinguish between *defamiliarization*, *technique*, and *foregrounding*. Linguist and literary scholar John Douthwaite (2000), in his comprehensive work on foregrounding, offers a succinct definition:

Impeding normal processing by showing the world in an unusual, unexpected or abnormal manner is termed **defamiliarization**. Thus defamiliarization may be achieved by subverting the rules governing perception and behaviour. The **linguistic technique** employed in subverting the world in this manner is termed **foregrounding**. (Douthwaite 2000: 177; emphases in the original)

Similar definitions are employed by several other scholars.¹¹⁷ The advantage of this kind of definition is that it distinguishes between *psychological effect* (defamiliarization), the *technique* used to achieve the psychological effect, and the particular *kind* of technique, identified as foregrounding, which is often used in literary texts. Defamiliarization is seldom viewed as *the* mark of literariness in these studies, even though it is considered an important part of literature (see Stockwell 2002; Miall 2006; Tsur [1992] 2008). This approach—widening the concept of literariness—was already adopted by many Russian formalists who developed Shklovsky's initial ideas, for example Roman Jakobson. However, since my main focus here is defamiliarization, not the wider question of what constitutes literature, I limit my discussion to defamiliarization and foregrounding.

The concept of foregrounding, as used by these scholars, originates in a

¹¹⁶ See e.g. Van Peer (1986); Miall & Kuiken (1994); Douthwaite (2000); Stockwell (2002); Miall (2006); Alexandrov (2007); Stockwell (2007); Tsur ([1992] 2008); Bohrn, Altmann, & Lubrich et al. (2012); Peplow & Carter (2014); Jacobs (2015); Koopman (2016); Whiteley & Canning (2017).

¹¹⁷ See Van Peer (1986); Miall & Kuiken (1994: 390); Stockwell (2002: 14); Miall (2006: 18); Leech (2008); Bohrn, Altmann, & Lubrich et al. (2012: 2); Kuzmičová, Mangen, & Støle et al. (2017: 140).

distinction between background and foreground, or figure and ground—a distinction that refers to the ability to focus on salient pieces of information in the face of a wealth of information. This distinction is then put to work in the study of literature. The concept is used to refer to the ways in which literary or poetic language tends to differ from everyday communication—for example, by employing original metaphors or unusual syntax. Scholars typically distinguish between kinds of foregrounding. Van Peer (1986: 23–24) uses three main categories: phonology, grammar, and semantics. Douthwaite (2000: 206–263) uses nine main categories: graphology, phonology, lexis, syntax, semantics, pragmatics, sociolinguistic use of rules, genre conventions, and world rules. Most scholars follow Van Peer’s simple division (e.g. Miall 2006; Borhn, Altmann, & Lubrich et al. 2012), while some devise more elaborate categorizations (e.g. Castiglione 2017).

Theories of foregrounding and defamiliarization typically make a few core assumptions about the nature of cognition and communication and the effects of literature. First, they assume that there is a normal way in which cognition and communication works. Specifically, they assume that this normal way includes habituation. Habituation refers to cognitive processes through which we become familiar with our surroundings, processes that exist to enable efficient cognition and communication. For example, instead of paying attention to every detail of a chair I come across, I categorize it as a “chair” and move along with my day; and in referring to the chair in a conversation with someone, I typically use the word “chair” rather than a description of its surface texture or details of its shape. Theories of foregrounding and defamiliarization emphasize that this is not a shortcoming of our cognition and communication, but a necessary feature of them; if we did not tend toward habituation, we would be overloaded with information and would not be able to function in daily life. Second, the theories assume that a consequence of this feature of our cognition is that it we become *too* familiar with our surroundings. Due to efficient categorization, our senses and thought processes become dulled. Shklovsky (2015) even goes so far as to claim that habituation turns life into nothing: “This is how life becomes nothing and disappears. Automatization eats things, clothes, furniture, your wife, and the fear of war” (162). Not everyone uses such drastic formulations as Shklovsky, but the underlying idea is usually similar. Third, the theories assume that literature is a means of breaking with this habituation. By reading texts rich in foregrounding, readers may become shaken in their perceptions and suddenly see the world with fresh eyes. Shklovsky again: “this thing we call art exists in order to restore the sensation of life, in order to make us feel things, in order to make a stone stony. The goal of art is to create the

sensation of seeing, and not merely recognizing, things” (162).

For analyzing how defamiliarization functions in popular science, it is useful to emphasize more fully one particular technique that may be used to achieve defamiliarization, namely *unusual perspective*. Scholars of foregrounding typically include unusual perspective in the category of semantics. For example, a striking metaphor can persuade the reader to view the world from an unexpected angle. However, there is a sense in which perspective can be disentangled from linguistic foregrounding techniques: if the perspective used is highly unusual relative to ordinary cognition, a defamiliarization effect can be achieved even when the language is relatively ordinary. To be sure, in linguistic artifacts the defamiliarization effect is always achieved through language; still, the *emphasis* can be on the perspective rather than on the use of language. This is an important point for my analyses. In my choice of terminology, I thus distinguish between two kinds of techniques used to achieve defamiliarization: *perspective* and *foregrounding* (as defined above). By “perspective” I denote the vantage point from which the ordinary world is viewed. Perspective and foregrounding are not mutually exclusive concepts. Sometimes the defamiliarization effect is achieved primarily by perspective, sometimes primarily by foregrounding, and sometimes by an intricate combination of the two. Two examples will make defamiliarization through perspective and foregrounding clearer.

In illustrating defamiliarization, Shklovsky (2015: 163–165) famously uses examples from the works of Leo Tolstoy. He quotes passages from a short story by Tolstoy, “Kholstomer: The Story of a Horse,” in which a horse grapples with the concept of “property.” The horse is baffled by what “belonging to someone” means and tries to figure it out by reflecting on his experiences and observations. The point of Shklovsky’s example is that since we are thoroughly familiar with the concept of “property” through its common and pervasive use, letting a horse try to figure out what it means suddenly makes it seem strange and unfamiliar. Tolstoy’s language in the (lengthy) sections of the story that Shklovsky quotes is straightforward and simple. The defamiliarization effect is achieved primarily through the unusual perspective, not through foregrounding.

By contrast, consider a poem discussed by Willie Van Peer (1986). In his empirical study of foregrounding, Van Peer analyzes six poems that vary in style and difficulty. As mentioned above, he uses three main categories to systematize the deviances from ordinary language in the poems: phonology, grammar, and semantics. One of the poems in his study is “yes is a pleasant country” by E.E. Cummings. It is a short, dense, and difficult poem. Van Peer

comments: “It is on a traditional theme of spring and love, in which a high amount of parallelism and cohesion binds together all elements tightly. The whole presents itself at first glance as a simple traditional poem, but on close inspection turns out to be one of extreme strangeness” (70). Van Peer then analyzes the poem and lists deviances from ordinary language under the three categories. In Cummings’s poem, foregrounding occurs on all three linguistic levels—for example, lexical rule violation, in the category of grammar, in the first line of the second stanza (“both is the very weather”). The perspective in the poem, however, is familiar: it is that of someone (the lyrical I) addressing her/his beloved. Defamiliarization is evident linguistically in such things as the unusual grammar and unusual word combinations; but unlike the Tolstoy example, the perspective is not defamiliarizing.

Scientific Defamiliarizations of the Ordinary World: Greene, Krauss, and Tyson

Of course, a piece of fiction or a poem could deploy defamiliarization using both perspective and foregrounding. For example, if Tolstoy had used original metaphors in “Kholstomer,” or if Cummings had let the perspective in “yes is a pleasant country” be that of a person addressing their cat, then they would have been combinations of defamiliarization through perspective and foregrounding. Popular science often includes both. A paragraph from the introductory chapter in Brian Greene’s *The Fabric of the Cosmos*, also discussed in the introduction above, provides a good example.

Greene introduces himself and his subject matter by discussing Albert Camus’s *The Myth of Sisyphus* and the meaning of life. In *The Myth of Sisyphus*, Camus had argued that the question of whether life is worth living precedes all scientific inquiries into the nature of the universe. Greene pondered Camus’s question intensely as a child, but he eventually reached a conclusion that differs from Camus’s in an important respect:

Breakthroughs in physics have forced, and continue to force, dramatic revisions to our conception of the cosmos. I remain as convinced now as I did decades ago that that Camus rightly chose life’s value as the ultimate question, but the insights of modern physics have persuaded me that assessing life through the lens of everyday experience is like gazing at a van Gogh through an empty Coke bottle. *Modern science has spearheaded one assault after another on evidence gathered from our rudimentary perceptions, showing that they often yield a*

clouded conception of the world we inhabit. And so whereas Camus separated out physical questions and labeled them secondary, I've become convinced that they're primary. For me, physical reality both sets the arena and provides the illumination for grappling with Camus' question. Assessing existence while failing to embrace the insights of modern physics would be like wrestling in the dark with an unknown opponent. By deepening our understanding of the true nature of physical reality, we profoundly reconfigure our sense of ourselves and our experience of the universe. (Greene 2004: 5; emphases added)

For Greene, having a scientific understanding of the nature of the universe is indispensable for assessing the value of life. People who are not oriented toward or interested in scientism may well find this an unusual position in its own right, but the point of the example is to draw attention to defamiliarization through *both* foregrounding and perspective. On a linguistic level, Greene uses two similes (see the underlined parts in the quotation). They are instances of foregrounding: they stand out from the surrounding text, though the first one arguably stands out more than the second. The first one is unexpected and original. It brings together “high” culture (Van Gogh) with “popular” capitalist culture (a Coke bottle) in an unusual way, thus defamiliarizing the ordinary world and our perception of it. The second simile does that too, but it is more conventional and less striking than the first. But there is also defamiliarization on the level of perspective. This is a result of the vantage point from which Greene makes his claims: that of science. That vantage point is present throughout the paragraph, and it comes out sharply in a few places. A clear example is the italicized sentence. Apart from the metaphorical expressions “spearhead an assault” and “clouded conception”—which arguably approach being dead metaphors—the sentence is straightforward; on a linguistic level, there is not much foregrounding. However, Greene suggests that viewing the world through science produces an entirely different view of reality than we are used to in everyday life. Viewing the world through the lens of science defamiliarizes the everyday world, over and above the level of linguistic techniques.

At this point in Greene's text, this is a mere assertion; but as such, it serves to make the everyday seem strange. It also functions as a preparation for what is to come: a view of the world from the vantage point of science. The last sentence—“By deepening our understanding of the true nature of physical reality, we profoundly reconfigure our sense of ourselves and our experience of the universe”—points toward something different than defamiliarization—something closer to what literary scholar David S. Miall and psychologist Don Kuiken call *refamiliarization* (Miall & Kuiken 1994). As I show in the coming

chapters, defamiliarization is only part of what popularizers do to convey science. Equally important is what comes afterward: familiarizing the reader with science and the universe as viewed through the lens of science; situating the reader in a cosmic-scientific context. But in order to get there, the ordinary world is typically defamiliarized.

To be clear, the defamiliarizing perspective in the Greene example is accessed through language. Whether, and to what extent, a perspective can actually be disentangled from its linguistic expression is irrelevant here. The point is that this is the thrust of Greene's language and worldview: the defamiliarizing perspective points to and is anchored in a domain supposedly outside of language, namely science. This is, again, why it is important to draw a distinction between foregrounding and perspective when studying popular science: while foregrounding is used in popular science—sometimes frequently, sometimes sparingly—defamiliarization of the ordinary world through the perspective of science is very common. It is so common, and such an important part of most contemporary popularizations, that it could be called one of the hallmarks of the genre.

If there is some ambiguity in what Shklovsky's concept of defamiliarization refers to—textual features or psychological effects—there is also a lack of clarity about the role of a text's place in history in achieving defamiliarization. If foregrounding techniques are meant to break familiarity and habituation, what happens when a particular technique becomes familiar and habitual? The answer seems obvious: it loses its ability to defamiliarize. Thus, it seems that the defamiliarizing effect of a given technique cannot be ascribed solely to inherent characteristics of that trait; it must be contextualized and considered historically. The Russian formalists were not unaware of this problem. Yury Tynyanov, in particular, developed an elaborate theory about the dynamics of literary history (Erlich [1955] 1965: 251–271; Steiner 1984: 99–137). Does this temporal-dynamic aspect apply to defamiliarization in popular science as well? This question does not have a straightforward answer. The star stuff metaphor, as discussed in chapter 2, provides an instructive illustration.¹¹⁸

The star stuff metaphor was made famous by Carl Sagan in *Cosmos*, and it has since become a staple metaphor in popular science. Neil deGrasse Tyson's invocation of the stardust metaphor is very similar to Sagan's formulations in

¹¹⁸ It is important to note, though, that the star stuff metaphor is only partly a defamiliarization technique. While it does serve to disrupt habitual ways of viewing the world and to uproot the reader from non-scientific perspectives on humanity, it also has a refamiliarizing function, serving to resituate the reader in a universe defined by science, as I show in the chapters to come.

Cosmos.¹¹⁹ Sagan (Sagan et al. [1980] 2009): “the cosmos is also within us. We’re made of star stuff. We are a way for the cosmos to know itself” (episode 1: 06^m14^s–06^m22^s), and: “[We are] star stuff contemplating the stars, organized collections of ten billion billion billion atoms contemplating the evolution of matter, tracing that long path by which it arrived at consciousness here on the planet Earth and, perhaps, throughout the cosmos” (episode 13: 54^m13^s–54^m33^s). Tyson (2017): “every one of our body’s atoms is traceable to the big bang and to the thermonuclear furnaces within high-mass stars that exploded more than five billion years ago. / We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun” (33). Between Sagan and Tyson, numerous popularizers have used the star stuff or stardust metaphor (e.g. Gribbin & Gribbin 2000; Cox & Cohen 2011; Rovelli 2015). One would thus expect the metaphor to have lost some of its defamiliarizing effect, and so one can ask why it is still used.

There is no clear-cut answer to this question, but a few reflections may provide some elucidation. First, the manifest target audience of much popular science is laypeople, or people who are supposedly not very knowledgeable about science. If these readers have not read popular science texts before, or are unfamiliar with the star stuff metaphor from other contexts, it is novel to them and thus has the potential to defamiliarize them. Second, and in contrast to the previous point, there may be a point to over-using the metaphor. By using it over and over, to the point of it becoming a standard metaphor, it becomes established as a key to human-cosmos relations, thus reinforcing scientists’ authority in questions of knowledge and interpretations of the universe. Third, popularizers typically rely on psychological accounts according to which some aspects of science are inherently counterintuitive. Our minds are simply not equipped to fully grasp the cosmic origins of the matter that make up our bodies and minds—the spatio-temporal scales are too vast, the molecular dynamics too complex, and the quantum-level matter-energy conversions unimaginable. Viewed from this perspective, the star stuff metaphor has a kind of “perennial” defamiliarization potential, no matter how widespread and over-used it is: when properly presented and discussed, it cannot but defamiliarize human minds.

These considerations raise questions about the purpose of defamiliarization in popular science. For Wordsworth, Coleridge, and Shklovsky, the main point of defamiliarization was to impart a “freshness of sensation,” to “restore the

¹¹⁹ While Sagan used “star stuff,” others, including Tyson, use “stardust.” I will mostly use “stardust,” since that is Tyson’s preferred word.

sensation of life.” What is the purpose of defamiliarization in popular science? This is a multilayered question with many possible answers. One aspect is pedagogical. While popular science cannot be reduced to “textbooks for the masses,” as literary critic Magnus von Platen (1996: 117) calls popular science texts in passing, pedagogical aspects are still relevant, since expository sections are a key ingredient in much popular science (Mellor 2003; Turney 2004a). Furthermore, scientists-popularizers are also often teachers or educators in their daytime jobs. For example, Brian Greene is a professor at Columbia University, Krauss was (until accusations of sexual harassment were upheld against him) a professor at Arizona State University, and Tyson is the director of Hayden Planetarium in New York City. In pedagogy, defamiliarization is a recognized technique that is sometimes used to introduce new perspectives and theories (King 2004; Zuba 2016).

Another aspect of defamiliarization in popular science is related to scientific imagination and creativity. In an article on instinct blindness, evolutionary psychologists Leda Cosmides and John Tooby quote philosopher and psychologist William James: “It takes . . . a mind debauched by learning to carry the process of making the natural seem strange, so far as to ask for the *why* of any instinctive human act” (James quoted in Cosmides & Tooby 1994: 66). Their reason for quoting James is to draw attention to the myriad cognitive “mechanisms” that must exist and function smoothly for there to be cognition at all. When cognition does work smoothly, one does not notice these mechanisms “because they process information so effortlessly and automatically” (Cosmides & Tooby 1994: 66). In order to notice their existence, the mind has to be defamiliarized, for example by studying “non-human minds that differ profoundly from our own—animal minds and electronic minds, broody hens and AI programs” (Cosmides & Tooby 1994: 73). The more general point I want to make here is that defamiliarization is a way to identify hidden, unquestioned assumptions and to encourage the kind of creativity and originality that popularizers typically manifestly promote: questioning everything, “thinking outside the box.” I use the word “manifestly” to highlight that even though this is the message popularizers typically promote, the range of skeptical questions encouraged is usually quite narrow. For example, they do not typically dwell on the cultural and social factors that enable the existence of “scientific facts” to begin with, or science’s role in systems of oppression and inequality, or science’s dependence on fossil fuels.¹²⁰

¹²⁰ In this way, this dissertation can be viewed as a defamiliarization of *popular science*: it attempts to make familiar popular science books about the universe unfamiliar.

These two functions of defamiliarization in popular science—pedagogy and creativity—combine with other functions—in particular, making science the foundation for meaning, priming the reader for accepting scientific explanations, and claiming epistemic authority for science. In the following sections, I discuss these functions by analyzing defamiliarization in Krauss’s *The Greatest Story* and Tyson’s *Astrophysics*.

Appearance and Reality

I touched upon one of the main functions of defamiliarization when discussing Greene’s *Fabric of the Cosmos*: defamiliarization establishes science as the authoritative, foundational framework for understanding the world. That science plays this role for Krauss as well is made clear from the very beginning of the prologue to *The Greatest Story*: science is on a “quest to uncover the hidden realities underlying the world of our experience” (2017: 1); science replaces “the myths and superstitions that more ignorant societies found solace in centuries ago” (1); science has “liberated humanity from the shackles of enforced ignorance” (2). Almost immediately, Krauss suggests that “the business of science is to make people uncomfortable” (2). That this amounts to a defamiliarization of the ordinary world through the perspective of science is evident a few sentences later: “Evolution didn’t prepare our minds to appreciate long or short timescales or short or huge distances that we cannot experience directly. So it is no wonder that some of the remarkable discoveries of the scientific method, such as evolution and quantum mechanics, are nonintuitive at best, and can draw most of us well outside our myopic comfort zone” (3). And a few paragraphs later: “We will find that reality is not what we think it is. Under the surface are ‘weird,’ counterintuitive, invisible inner workings that can challenge our preconceptions of what makes sense as much as a universe arising from nothing might” (4).

At a first glance, it might seem as though the object of defamiliarization in *The Greatest Story* is not the ordinary world at all, but rather science (or the universe described using science). After all, such scientific theories as evolutionary theory and quantum mechanics, as well as the discoveries made possible by them, are described as “‘weird’” and “‘counterintuitive.’” However, Krauss has already established that in his view, science reveals the truth about the world. Science uncovers reality. Thus, against the background of science-as-truth, what is weird is rather our everyday perspective of the world—“our myopic comfort zone.” The fact that there are scare quotes around the word “weird” but not around “counterintuitive” reinforces this reading: the

“invisible inner workings” of reality *are* counterintuitive, but they only *appear* weird relative to our intuitions and preconceptions. In other words: there is nothing weird about reality; it is appearance, our everyday perception of reality, that is weird. This is a prime example of defamiliarization through the perspective of science, and it is reinforced numerous times throughout the book, for example: “As the frontiers of science have moved further and further away from the world of the familiar and the world of common sense as inferred from our direct experience, our picture of the reality underlying our experience is getting increasingly difficult for us to comprehend or accept. Some find it more comforting to retreat to myth and superstition for guidance” (13); “Common sense tells us that light cannot be both a wave and a particle at the same time. However, in spite of what common sense suggests, and whether we like it or not, experiments tell us it is so. Unlike the Creed, developed in the fifth century, this fact is not a matter of semantics or choice or belief. So we don’t need to recite quantum mechanics creeds every week to make them seem less bizarre or more believable” (72); the title of chapter 7, “A Universe Stranger than Fiction” (83); “Conventional wisdom might suggest that physicists love to invent crazy esoterica to explain the universe around us, either because we have nothing better to do, or because we are particularly perverse. However, as the unveiling of the quantum world demonstrates, more often than not it is nature that drags us scientists, kicking and screaming, away from the safety of what is familiar” (83); and so on.

Thus, Krauss’s defamiliarization of the ordinary world of sense experience amounts to making science the standard by which everything is measured. In so doing, Krauss does boundary work on two boundaries: the science/common sense boundary, and the science/religion boundary. Science unearths reality, while common sense presents us with a distorted and unreliable view of the world. Those who are not brave or open-minded enough to be defamiliarized by science, to let their common-sense perspective of the world be uprooted, revert to religion (or myth, or superstition). Truth is the exclusive domain of science, and scientists are guardians of that truth. In other words, this kind of defamiliarization lets scientists maintain their authority on matters of knowledge and truth.

The identification of science with truth and reality is a way not only to reinforce the authority of scientists, but also to encourage the reader to accept Krauss’s explanations and expositions in *The Greatest Story*. If science is weird to common sense, yet science equals truth and reality, then readers who lack scientific training are forced into a position in which they must accept Krauss’s explanations if they wish to align themselves with truth and reality.

In this way, the defamiliarization of the ordinary world serves to establish the groundwork for the explanations and expositions in the text.

Incidentally, emphasizing the weirdness of common sense is not a constant in the history of popularization. In the nineteenth century, popularizers typically stressed the mundanity of science and the continuity between science and common sense (Leane 2007: 22). Bernadette Bensaude-Vincent (2001) attributes this change in style to the character of post-classical physics: “The new scientific spirit generated by the new physics required a radical break with common-sense views of the world” (107). Another plausible factor, more social in character, has to do with the book market. Contemporary popular science has carved out a recognizable niche in the market ever since the popular science boom of the late 1970s, and defamiliarization is a staple technique of the genre. This genre has achieved mainstream popularity in tandem with fantasy fiction (e.g. J.R.R Tolkien) and science fiction (e.g. *Star Trek*)—genres that are closely related to popular science and similarly noted for their extensive use of defamiliarization (Suvin 1972; Alkestrand 2016).

Furthermore, and more generally, presenting something as mysterious and weird will tend to evoke curiosity. In her book *The Influential Mind* (2017), neuroscientist Tali Sharot discusses why article headlines such as “The Ten Celebrities You Never Knew Were Enthusiastic Gardeners” catch readers’ attention. In her interpretation, such headlines “create gaps of knowledge in people’s mind that were not there to begin with. . . . Once we are told what we do not know, we want to know” (111). In a similar way, when popularizers tell their audience that they do not know what matter is or why the Earth revolves around the sun, those popularizers may be working under the assumption, made consciously or unconsciously, that this strategy evokes curiosity. Thus, the simultaneous invocation of science-as-truth and common sense-as-weird, encapsulated in the defamiliarization of the ordinary world through the perspective of science, may be a way to both reaffirm the authority of science and to evoke curiosity.

The Cosmic Perspective

That Tyson shares Krauss’s view of science as fundamental for understanding the world is apparent already from the motto of *Astrophysics*: “The universe is under no obligation to make sense to you” (Tyson 2017: 13). The motto is signed “NDT”—Neil deGrasse Tyson himself. Tyson also defamiliarizes the ordinary world through the appearance–reality distinction, for example in one of the passages already analyzed in connection to boundary work: “Science is

not just about seeing, it's about measuring, preferably with something that's *not* your own eyes, which are inextricably conjoined with the baggage of your brain. That baggage is more often than not a satchel of preconceived ideas, postconceived notions, and outright bias" (90). However, in contrast to *The Greatest Story*, the appearance–reality distinction does not explicitly take a prominent place in *Astrophysics*. This may be because Tyson is an astrophysicist and *Astrophysics* focuses more, though not exclusively, on space and astronomical objects than particle physics and physical laws. I thus focus on defamiliarization through the cosmic perspective in *Astrophysics*.

Both the appearance–reality distinction and the cosmic perspective involve a proper understanding of reality, but whereas the appearance–reality distinction is preoccupied with truth, the cosmic perspective is preoccupied, as its name suggests, with gaining a proper perspective on the cosmos and humankind's place in that cosmos. The cosmic perspective is present in the above-quoted instance of defamiliarization in Sagan's *Cosmos* (Sagan et al. [1980] 2009): "The end of our long journey is the world where we began. Our travels allow us to see the Earth anew, as if we came from somewhere else. . . . Welcome to planet Earth: a place with blue nitrogen skies, oceans of liquid water, cool forests, soft meadows" (episode 1: 27^m37^s–28^m59^s). The cosmic perspective involves seeing humankind and the Earth in the cosmic context—as tiny creatures on a tiny planet in a cosmos where everything is connected by the laws of physics, chemistry, and biology. The cosmic perspective, which incorporates the stardust metaphor as an essential part, is the explicit focus of chapter 12 of *Astrophysics*, titled "Reflections on the Cosmic Perspective," where Tyson meditates on the cosmic perspective and its implications. He also tries to evoke it, for example by explaining that there are "more stars [in the universe] than words and sounds ever uttered by all the humans who ever lived" and by penning aphorisms such as "We do not simply live in this universe. The universe lives within us" (202–203). While defamiliarization occurs in chapter 12, the main thrust of the chapter is refamiliarization, or making the reader feel at home in the universe. I analyze chapter 12 further in chapters 8 and 9 below. Here I focus on chapter 11.

The title of chapter 11—"Exoplanet Earth"—suggests the defamiliarization to come. An exoplanet is a planet outside our solar system, and so calling Earth an exoplanet is a contradiction in terms. The point of the title is to suggest a view of the Earth from "the outside," from somewhere in outer space, as though we were observing it as just another planet in the universe. The chapter goes on to do just this.

Tyson opens the chapter by encouraging the reader to do what Wordsworth,

Coleridge, and Shklovsky also aimed for: notice their surroundings. The chapter begins: “Whether you prefer to sprint, swim, walk, or crawl from one place to another on Earth, you can enjoy close-up views of our planet’s unlimited supply of things to notice. You might see a vein of pink limestone on the wall of a canyon, a ladybug eating an aphid on the stem of a rose, a clamshell poking out from the sand. All you have to do is look” (178). However, instead of zooming in on these phenomena and describing them in original ways, Tyson proceeds to zoom out: “From the window of an ascending jetliner, those surface details rapidly disappear. No aphid appetizers. No curious clams. Reach cruising altitude, around seven miles up, and identifying major roadways becomes a challenge” (178). He continues by zooming out, past the International Space Station, the Moon, and finally Neptune, the outermost planet of our solar system, describing the Earth from ever greater distances. This kind of imaginative journey is reminiscent of Sagan’s cosmic voyages. And indeed, Sagan is invoked: “A celebrated photograph taken in 1990 from just beyond Neptune’s orbit by the *Voyager 1* spacecraft shows just how underwhelming Earth looks from deep space: a ‘pale blue dot,’ as the American astrophysicist Carl Sagan called it. And that’s generous. Without the help of a caption, you might not even know it’s there” (180–181). This description of the photograph serves as a defamiliarization of Earth. A planet that to ordinary human sense experience is so big that it does not even seem like a *planet* is described as a tiny dot from the depth of space, the presence and color of which would likely go unnoticed without pointers.

Tyson does not continue on this imaginary journey further. Instead, he introduces hypothetical alien astronomers: “What would happen if some big-brained aliens from the great beyond scanned the skies with their naturally superb visual organs, further aided by alien state-of-the-art optical accessories? What visible features of planet Earth might they detect?” (181). This alien perspective serves as a defamiliarization not only of Earth, but also of the state of our science and the extent of our knowledge. Nonetheless, on the following page Tyson invokes reality: “Time for a reality check” (182). “Reality” here refers to the difficulties, due to the vastness of space and the large differences in brightness between stars and planets, involved in detecting and gaining information about exoplanets. He uses a simile to spell it out: “It’s like trying to detect the light of a firefly in the vicinity of a Hollywood searchlight” (182–183).

Tyson goes on to discuss the history of and methods used in exoplanet astronomy. He returns several times to the perspective of the hypothetical alien astronomers, including their hypothetical attempts to discover life on Earth and

their hypothetical views of humanity. In so doing, Tyson presents humanity in a defamiliarized way. When discussing potential biomarkers (evidence of life) in the analyses of spectra gathered from the light of distant planets, he defines “anthropogenic,” in passing, as “produced by the widespread species *Homo sapiens*” (188), thus conveying the peculiarity of the human species when viewed from the outside. When discussing what the hypothetical aliens might deduce from their imagined spectral analyses of the light from Earth, or from the radio waves emanating from Earth, he says: “they might come to the . . . conclusion: a planet where there’s advanced technology must be populated with intelligent life-forms, who may occupy themselves discovering how the universe works and how to apply its laws for personal or public gain” (191). In this hypothesis about the hypothetical aliens’ conclusions, Tyson adopts a kind of naive, cosmic universalism according to which science and technology are more or less the same everywhere in the universe—they operate according to the same principles—even if some details may differ. He shows no awareness of the influence of his own situatedness—in terms of being human, male, Western, a scientist—on the interpretations he makes, instead assuming that his interpretations are automatically valid and translatable. However, his speculations about aliens serve as a defamiliarization of humanity rather than as a serious consideration of alien cognition and communication. The figure of the alien is a device rather than an object of analysis. This reading is reinforced by the continuation of the hypothetical aliens’ conclusions: “Looking more closely at Earth’s atmospheric fingerprints, human biomarkers will also include sulfuric, carbonic, and nitric acids, and other components of smog from the burning of fossil fuels. If the curious aliens happen to be socially, culturally, and technologically more advanced than we are, then they will surely interpret these biomarkers as convincing evidence for the absence of intelligent life on Earth” (191–192). Tyson here plays on the multiple meanings of intelligence—the ability to invent technology versus the ability to foresee the consequences of one’s actions—while also, in a satirical way, making a statement in the polarized and politicized climate change debate in the US.

The statement about climate change may make it seem as if Tyson is hesitant about whether his narrative really is triumphant. But Tyson is talking about humanity collectively, *not* scientists who understand what is going on and stand up for solutions to climate change. However, he does bring up humility and a sense of smallness numerous times. For him, science is inextricably linked with humility, with realizing that there is a great deal that we do not know about the universe. This humility is part of the cosmic perspective. Thus, the climate change reference primarily aims to defamiliarize ignorant or

arrogant people. And more generally, the cosmic perspective serves to deflate egos. In an interview with Tyson on the late-night talk show *Conan* following the release of *Astrophysics*, host Conan O'Brien (2017) asks Tyson what the cosmic perspective is. Tyson explains that “as humans, we have big egos,” and reflections on cosmic discoveries can “dismantle” that ego and “disrupt [one’s] sense of self-importance” (00^m06^s–00^m31^s). The defamiliarization of Earth and humanity is a crucial step leading up to the formulation of the cosmic perspective. And the cosmic perspective, in turn, serves, as I show over the coming chapters, to refamiliarize people with the cosmos—to, in effect, formulate a purportedly secular and scientifically based creation myth that grounds meaning and provides emotional satisfaction and spiritual connection.

6

Refamiliarization

Resituating the Reader and Representing Everything

The previous chapter showed how Krauss and Tyson use defamiliarization techniques in an attempt to reconfigure what the reader sees as normal or given. In this sense, defamiliarization is a “disruptive” or “destabilizing” technique. But disruption and destabilization is combined with reconstruction and stabilization. As I mentioned in the previous chapter, some scholars have developed the concept of “refamiliarization” (or “re-contextualization”) to describe what happens after defamiliarization: the attempt to regain a firm ground for meaning, and in particular, a ground that incorporates the insights gained through the disruption of defamiliarization (Miall & Kuiken 1994; Fialho 2007). These scholars primarily locate refamiliarization in the act of reading rather than in the text itself. They study defamiliarization and refamiliarization among actual readers in experimental settings. The concept of refamiliarization that I use differs from their concept in that rather than focusing on strategies that *readers* use to interpret the text, I focus on strategies that *popularizers* use to situate the reader in a universe defined by science.

Both defamiliarization and refamiliarization involve the interplay of the familiar and the unfamiliar, but they are characterized by different directions of movement. Whereas defamiliarization goes from the familiar to the unfamiliar, refamiliarization goes from the unfamiliar to the familiar. Refamiliarization can happen in two ways. First, the unfamiliar world of stars or subatomic particles can be made familiar by the use of terms and phenomena derived from the familiar, ordinary world. Second, having established, through defamiliarization, that the familiar is in fact unfamiliar, the familiar-made-unfamiliar can

be refamiliarized by being placed in new contexts that imbue it with new meaning. Popularizers use both ways to construct science. In this chapter, I analyze chapter 1 in Tyson's *Astrophysics* from the perspective of refamiliarization. I also briefly discuss a section from chapter 6 to illustrate how the TEUSH narrative is represented in a condensed manner. In the first section, I focus on strategies that make the unfamiliar world familiar through the use of terms and phenomena derived from the familiar, ordinary world. In the subsequent two sections, I focus on strategies that make the familiar-made-unfamiliar refamiliarized by putting them in new meaningful contexts. In both, I use narratology as a tool for analyzing the text. In the first of these sections, I focus on techniques to represent and encompass everything. In the second, I focus on the naturalistic creation myth and the naturalization of science.

From the Familiar to the Unfamiliar: Figurative Language, Forced Marriages, and the Stardust Metaphor

Simile is perhaps the most straightforward technique used in popular science. It is also one of the main techniques used in expository sections where scientific theories are explained. Since explanations and expository sections are core features of popular science texts, similes are used frequently. A typical example is when Krauss discusses the discovery of the neutron. In 1930, Walther Bothe and Herbert Becker had discovered a new kind of radiation that they interpreted as a new sort of gamma ray radiation (gamma ray radiation was already known at the time). Irène Joliot-Curie (Marie Curie's daughter) and her husband, Frédéric Joliot-Curie, developed new experiments involving a paraffin target to explore this radiation further. The results of their experiments made it clear that the radiation discovered could not be gamma rays. In explaining Joliot-Curies' conclusion, Krauss uses a simile involving popcorn:

This observation made it clear that the radiation couldn't be a gamma ray. Why?

The answer is relatively simple. If you throw a piece of popcorn at an oncoming truck, you are unlikely to stop the truck or even break a window. That is because the popcorn, even if you throw with great energy, carries little momentum because the popcorn is light. To stop a truck you have to change its momentum by a large amount because, even if it is moving slowly, it is heavy. To stop a truck or knock a heavy object off the truck, you have to throw a big rock.

Similarly, to knock out a heavy particle such as a proton from a paraffin, a

gamma ray, made of massless photons, would have to carry great energy (so that the momentum carried by the individual photons was large enough to kick out a heavy proton), and not enough energy was available, by an order of magnitude at least, in any known nuclear-decay processes for this. (117)

This is an extended simile, developed over two paragraphs. It is visual in character, and it illustrates the unfamiliar world of subatomic particles with the familiar world of popcorns and trucks. The simile is explanatory in the sense that the same dynamics—collisions of objects with momenta of different orders of magnitude—are involved in both cases. It is eye-catching in that it makes the reader imagine the absurdity of throwing a piece of popcorn at an oncoming truck in an attempt to affect its trajectory. It thus has a defamiliarizing dimension, but it is also refamiliarizing in that the unfamiliar is made comprehensible through the familiar.

Shorter similes are also common. For example, when explaining the dynamics of interplanetary spaceflight—specifically, how the gravitational fields of planets are utilized—Tyson uses a simile from the world of billiards: “The *Cassini* probe, for example, which visited Saturn, was gravitationally assisted twice by Venus, once by Earth (on a return flyby), and once by Jupiter. Like a multi-cushion billiard shot, trajectories from one planet to another are common” (Tyson 2017: 176). This simile is also visual in character, although it is not as straightforward as the popcorn simile. Probes can gain or lose speed through planetary flybys depending on the type of flyby. On a first glance, one might think that the cue ball in billiards inevitably loses speed after cushion impact because of friction, and hence that the simile is flawed. However, studies show that giving the cue ball a certain spin and letting it hit the cushion at certain angles will make it go faster after the impact than it did prior to the impact (Mathavan, Jackson, & Parkin 2010). But the physical principles involved are different. In spaceflight, gravity changes the trajectories of probes. In billiards, friction and spin change the trajectory of the cue ball. Thus, as in Krauss’s popcorn simile, the two worlds of interplanetary spaceflight and billiards correspond to each other visually, even though the correspondence is not as straightforward as in the popcorn simile because different physical principles are involved. But regardless of these intricacies, the simile explains the unfamiliar world of interplanetary space flight dynamics in terms of the familiar world of billiards.

Metaphors come in different varieties in popular science and have been studied by various scholars (e.g. Knudsen 2005; Edford 2007; Leane 2007). For understanding their role in popular science texts, it is helpful to distinguish between the various kinds of metaphors used. I distinguish between three

kinds: single metaphors; recurring metaphors; and defining metaphors. A *single metaphor* I define as a standalone metaphor without a major function in the text. An example would be the following by Tyson, used in the context of discussing models of the evolution of the universe as whole: “As far as observers were concerned, the universe was ‘open’ for business, riding a one-way saddle into the future” (108). The concept “open universe” is used in cosmology to describe models in which the so-called density parameter in the equations describing the universe, the Friedmann equations, are less than one (Schneider [2006] 2015: 173–209). The open universe models are also called “saddle universes” because three-dimensional visualizations of them resemble horse saddles. Tyson thus crafts a metaphor that builds upon established cosmological concepts and metaphors and then develops it in a humorous way. The metaphor could be analyzed in terms of its invocations of the mythic American West—new, promising opportunities reachable by horse—but it does not play a major structuring role in the chapter or the book as a whole.

Recurring metaphors—metaphors that feature throughout the book or throughout a chapter—play a more formative, meaning-making role. An illuminating example is metaphors of love and marriage in chapter 1 of *Astrophysics* (17–33). This chapter, called “The Greatest Story Ever Told,” presents a brief account of the origin and evolution of the universe. In addition to single metaphors such as “Quarks are quirky beasts” (22), Tyson uses metaphors of love and marriage throughout the chapter. After a brief discussion of the challenges involved in combining the two main theoretical frameworks in modern physics—quantum mechanics, which deals with the very small, and general relativity, which deals with the very large—Tyson says:

But in the beginning, during the Planck era, the large was small, and we suspect there must have been a kind of shotgun wedding between the two. Alas, the vows exchanged during that ceremony continue to elude us, and so no (known) laws of physics describe with any confidence the behavior of the universe over that time. (19)

A few pages later, when describing the creation of heavy particles in the early universe: “This tepid universe was no longer hot enough or dense enough to cook quarks, and so they all grabbed dance partners, creating a permanent new family of heavy particles called hadrons” (24). Later in the development of the universe, when most of these hadrons and their antiparticles were annihilated, thus creating photons, Tyson uses a metaphor that, given the love and marriage metaphors of the chapter, can be read in the light of love: “For every billion annihilations—leaving a billion photons in their wake—a single hadron

survived. Those loners would get to have all the fun: serving as the ultimate source of matter to create galaxies, stars, planets, and petunias” (25–26). Two pages later, another marriage takes place after a period of single life:

For another 380,000 years not much will happen to our particle soup. Throughout these millennia the temperature remains hot enough for electrons to roam free among the photons, batting them to and fro as they interact with one another.

But this freedom comes to an abrupt end when the temperature of the universe falls below 3,000 degrees Kelvin . . . and all the free electrons combine with nuclei. The marriage leaves behind a ubiquitous bath of visible light, forever imprinting the sky with a record of where all the matter was in that moment, and completing the formation of particles and atoms in the primordial universe. (27–28)

Taken together, these metaphors reveal an ambivalence toward love and marriage. A “shotgun wedding” enabled the combination of the physics of the very small and the physics of the very large;¹²¹ the “single” hadrons, the “loners,” “get to have all the fun”; electrons “roam free”; but the “freedom comes to an abrupt end” when the electrons and nuclei get married.

More than as mere suggestions of a potentially idiosyncratic ambivalence toward marriage, these metaphors should be read in the light of long-standing metaphors of love and marriage in the history of Western philosophy and science. As I discussed in chapter 1, Evelyn Fox Keller shows in her *Reflections on Gender and Science* (1985) that metaphors of love and marriage form the bedrock of the epistemologies of Plato and Francis Bacon, both of which have been pivotal in the development of science. Nature is coded as female, and the philosopher is coded as male. Keller shows that desire (Plato) or seduction (Bacon) is the primary disposition or task of the philosopher. Nature is to be desired and/or seduced and then either left behind (Plato) or made subservient (Bacon). For Plato, the philosopher restrains himself from sensuous love, instead directing his erotic energy to the transcendent world of ideas. For Bacon, the philosopher marries nature, but it is a chaste marriage characterized by mastery and subservience. Keller highlights the subjugation of women implicit in these images: “In neither vision is material nature (female for both Plato and Bacon) invited into a partnership of love: in one she is relegated to another realm, in the other she is seduced and conquered” (31).

In *Astrophysics*, the two parties do not consist of a philosopher and nature.

¹²¹ A shotgun wedding is a wedding that is arranged to avoid social stigma when a woman has become pregnant without being married.

Instead, the partners consist of particles. Nonetheless, the persistent use of love and marriage metaphors throughout the chapter reveal something of the problematic history of misogynic metaphors in the history of science and philosophy. The ambivalence toward love and marriage in Tyson's metaphors—the conceptualization of consummated marriages as forced—furthermore mirrors the ideal of restraint and chastity in Plato's and Bacon's metaphors. The un-commented reference to a “shotgun wedding” is particularly problematic, since shotgun weddings signal patriarchal traditions in which women do not have control over their bodies.

The recurring metaphors of love and marriage build toward what I call the *defining metaphor* of the chapter: the stardust metaphor. By calling it a defining metaphor, I mean that it is the central metaphor of the chapter in the sense that it is the metaphor that connects humankind and the universe, which is central for the TEUSH narrative and Tyson. The last two sentences of the chapter read: “every one of our body's atoms is traceable to the big bang and to the thermonuclear furnaces within high-mass stars that exploded more than five billion years ago. / We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun” (33). In the previous chapter, I emphasized the defamiliarizing aspect of the metaphor, but the refamiliarizing function is just as important. Since it comes after a string of metaphors conceptualizing the union of particles in terms of marriage and love, producing all the light and all the matter in the universe, humans are the metaphorical children of the universe. In this way, the stardust metaphor refamiliarizes the reader as an offspring of cosmic processes, as a citizen in a cosmic society composed of matter in various forms.

This sequence of refamiliarizing metaphors—particles leading lascivious lives but eventually conforming, through force if necessary, to conventional married life, producing children—points to unexamined biases in the construction of science. Even if Tyson explicitly claims, in a matter-of-fact manner, that science is universal and objective, historically specific norms and narratives still find their way into the story. His metaphors not only evoke an image of humans as children of the cosmos—they also reproduce and reinforce the notion that the “natural” form of adulthood and reproduction is the nuclear family.

The Unfamiliar Made Familiar through Science

Narrating Everything

In analyzing the narrative in chapter 1 of Tyson's *Astrophysics*, I use the frameworks and concepts developed by Gérard Genette in *Narrative Discourse* (1980) and Seymour Chatman in *Story and Discourse* (1978).

It is important to note that while both Genette and Chatman use "story" to designate the "what" of a narrative, Genette and Chatman use different terms for the "how": Genette uses "narrative" and Chatman uses "discourse." I use Chatman's concept, mainly because "narrative" is a broader term that is convenient to be able to use in more ways than the strict "how" of a story in a narratological analysis of a specific text. This sense of "narrative" is related to the "how" of representing the universe, but it signifies more than a particular instance of telling that "how" because it is a composite of the discourses of many popular science books (see the introduction, pp. 29–32, where I define it). In particular, I want to be able to use "narrative" when discussing the triumphant epic of the universe, science, and humankind—the TEUSH narrative—as a core narrative.

From a narratological point of view, the scope of the story in chapter 1 of *Astrophysics* is truly enormous: the entirety of the known universe, starting with the Big Bang 13.8 billion years ago. This can be seen from the first sentence: "In the beginning, nearly fourteen billion years ago, all the space and all the matter and all the energy of the known universe was contained in a volume less than one-trillionth the size of the period that ends this sentence" (17). The rest of the chapter recounts, with various degrees of detail, how the universe developed up until the present moment. Genette (1980) develops the concept of "distance," in the category of mood, for describing the amount of detail about the story that is given in the discourse (162–164). Using this concept presents a challenge for an analysis of a story like Tyson's. Since *everything*—or at least everything in the known universe—is the story, the amount of detail in any given description of that story will be miniscule, simply because the number of events in the universe is, for all practical purposes, infinite. Merely detailing the trajectories of the stars in our galaxy is a daunting (and practically impossible) task, let alone all the stars in the known universe and all the particles that make up those stars.¹²²

¹²² On a different level—the level of theories about the universe rather than events in the universe—the theories that Tyson presents (general relativity, quantum mechanics, and others) are complex in themselves. There is a distance here too: the amount of detail given in

A way to address the challenge of applying the concept of distance is to relativize the concept of distance: some representations have a larger distance than others. For example, the distance in the following sentences is very large: “For the first billion years, the universe continued to expand and cool as matter gravitated into the massive concentrations we call galaxies. Nearly a hundred billion of them formed, each containing hundreds of billions of stars that undergo thermonuclear fusion in their cores” (28). Tyson uses seven lines to encompass one billion years of time and billions upon billions of stars and galaxies. Compared to this, the distance in an historical account earlier in the chapter devoted to explaining the etymology of names of particles—“boson,” “lepton,” and “quark”—is relatively small, even though it is still big compared to the historical events covered: it uses 11 lines for these explanations (21–22).

I would argue that another way to address the challenge of applying the concept of distance is to introduce a distinction between “types of events,” “collective events,” and “singular events.” This distinction is likely best illustrated using the example of the birth of a star. The birth of a star is a *type of event*: it typically happens in the same kind of way (through contraction of interstellar gas). The birth of all stars, meanwhile, is a *collective event*, as in: “For the first billion years, the universe continued to expand and cool as matter gravitated into the massive concentrations we call galaxies. Nearly a hundred billion of them formed, each containing hundreds of billions of stars that undergo thermonuclear fusion in their cores” (28). The birth of the sun is a *singular event*: it happened once, about 4.5 billion years ago. The distinction between types of events, collective events, and singular events is useful for understanding how Tyson narrates the universe. Most of the time in the chapter, Tyson’s narrative revolves around collective events and types of events: sometimes he describes how the universe developed by describing (for example) the behavior of particles collectively, and sometimes how a particular kind of particle interaction occurs. Yet sometimes he describes singular events, most significantly when he recounts events connected to Earth and humankind. I develop the significance of this in the next section. The point I want to make here is that these different kinds of events enable Tyson not only to encompass everything by using certain kinds of words and categories, but it also enables him to single out some events as particularly significant for his narrative. While not every thing or event gets represented in the text, “everything” can still be represented, and *some* things receive special attention. The distance between story and discourse is still practically infinite, but these techniques—the use of types

presentations of these theories can vary a great deal.

of events and collective events—can foster a *sense* of encompassing everything within a narrative.

There is also a temporal relation between story and discourse, crucial for understanding representations of the universe. Genette (1980: 86–112) uses the concept “duration” to describe the temporal relation between story and discourse in terms of “speed.” While the duration of a story is relatively straightforward—it is simply the time elapsed from the first event to the last—determining the duration of the discourse is a trickier question. Genette considers using “normal reading time,” but since this is difficult to define and determine, he opts for counting lines or pages. It is not a perfect solution, but it gives a rough indication of the speed of a discourse, which he consequently defines as “the relationship between a duration (that of the story, measured in seconds, minutes, hours, days, months, and years) and a length (that of the text, measured in lines and pages)” (87–88). Within any given discourse, there are sections of varying speed, and Genette identifies four types: *pause* (Story Time = 0, Discourse Time \neq 0); *scene* (ST = DT); *summary* (ST > DT); and *ellipsis* (ST \neq 0, DT = 0) (Genette 1980: 94–95).¹²³ Genette further discusses the possibility of a fifth type, where ST < DT—i.e., a kind of slow motion—but he dismisses its usefulness for analyzing novels because “big scenes in novels, and especially in Proust [whose *À la recherche du temps perdu* is Genette’s object of analysis], are extended mainly by extranarrative elements or interrupted by descriptive pauses, but are not exactly slowed down” (95). In the Tyson chapter, there are descriptive pauses as well—but in addition, there is the kind of slow motion that Genette disregards. I thus add *slow motion* (ST < DT) to the types. The existence of extranarrative elements in the chapter is a subtle one to which I return in the next section.

These concepts illuminate the extraordinarily varied temporal proportions between story and discourse in the chapter. The story time is 13.8 billion years, or the age of the known universe. The discourse is 17 pages or 376 lines long, which means that the average speed of the chapter is a staggering 36.7 million years per line. But of course, this is the average speed. There is a considerable variation in speed throughout the chapter. There are plenty of pauses (i.e., when no time elapses in the story), for example the aforementioned etymological explanation (11 lines), explanations of scientific concepts,¹²⁴ and general

¹²³ Since Genette uses “narrative” for “discourse,” the abbreviations I use differ slightly from Genette’s (he has “NT” where I have “DT”).

¹²⁴ E.g.: “Quarks are quirky beasts. Unlike protons, each with an electric charge of +1, and electrons, with a charge of –1, quarks have fractional charges that come in thirds” (22).

philosophical reflections.¹²⁵ There are also, as one would expect, plenty of summaries (i.e. when the story time is greater than the discourse time), for example: “For the first billion years, the universe continued to expand and cool as matter gravitated into the massive concentrations we call galaxies” (28). Scenes (where the story time and discourse time are the same, primarily used for dialogues) do not occur in the chapter. And of course, since the story is the history of the known universe, ellipses (parts of the story that are left out in the discourse) are the rule: most of the singular events in the story are not mentioned in the discourse.

Slow motion (when the discourse time/length is longer than the story time), however, is used. There is a distinctive break that occurs eleven pages into the chapter, i.e. roughly two-thirds in. In particle physics and cosmology, the processes that occurred in the first few minutes after the Big Bang are pivotal for determining the properties and subsequent development of the universe. The Tyson chapter follows this logic: three pages in, after having described the extraordinarily hot and dense conditions that, according to modern physics, prevailed at the beginning, Tyson breaks the flow of the text with an asterisk, followed by a time marker and another asterisk, thus:

*

A trillionth of a second has passed since the beginning.

*

(20)

After this time marker, the text resumes the account of the early universe, describing the kinds of particles and interactions that took place and how they developed over time. Another four pages later, a second time marker is introduced in a similar layout, with asterisks: “A millionth of a second has passed since the beginning” (24). Then, two pages later: “By now, one second of time has passed” (26). And one page after that, the last time marker: “Two minutes have now passed since the beginning” (27). Following this time marker, the text continues: “For another 380,000 years not much will happen to our particle soup. Throughout these millennia the temperature remains hot enough for electrons to roam free among the protons, batting them to and fro as they interact with one another. / But this freedom comes to an abrupt end when the temperature of the universe falls below 3,000 degrees Kelvin,” etc. (27–28). This

¹²⁵ E.g.: “People who believe they are ignorant of nothing have neither looked for, nor stumbled upon, the boundary between what is known and what is unknown in the universe” (32–33).

marks a distinctive break in the chapter: the first eleven pages are devoted to describing what occurred in the first two minutes. These pages thus illustrate extreme slow motion—most extreme for the first four pages covering one trillionth of a second, second most extreme for the subsequent four pages covering one millionth of a second, and so on. By contrast, the last six pages of the chapter cover the rest of the history of the universe, namely 13.8 billion years minus two minutes (which means 13.8 billion years, since that figure is an approximation). Thus, the average speed before the break is about 0.5 seconds per line, whereas the average speed after the break is about 99 million years per line. This difference not only mirrors the importance that physicists attach to the first few minutes of the history of the universe, but it also illustrates the flexibility of language in representing and narrating the universe.

As noted, the chapter builds toward the formulation of the defining metaphor of the chapter, the stardust metaphor. The chapter is thus an expression of the TEUSH narrative, going from the beginning of time to the emergence of humankind and science, linking them all together in a grand narrative that is triumphant in tone. Compared to the span of cosmic time, this is, of course, a condensed representation of the events. However, there are even more condensed expressions later in the book, expressions that illustrate even more clearly in what sense the TEUSH narrative functions as a core narrative (i.e., forming the backbone of specific narratives and accounts in popular science texts). Oftentimes in popularizations of physics and astronomy, the TEUSH narrative, or central parts of it, are expressed in exceptionally condensed form in one or two paragraphs. For example, in chapter 6, a chapter devoted to the puzzle of dark energy, Tyson situates the discussion of dark energy in cosmic history. After briefly describing Einstein and the development of the general theory of relativity, Tyson addresses the recent discovery of gravitational waves. The second paragraph in the quotation presents the TEUSH narrative in a condensed form:

Every few years, lab scientists devise ever more precise experiments to test the theory [of general relativity], only to further extend the envelope of the theory's accuracy. A modern example of this stunning knowledge of nature that Einstein has gifted us, comes from 2016, when gravitational waves were discovered by a specially designed observatory tuned for just this purpose. These waves, predicted by Einstein, are ripples moving at the speed of light across the fabric of space-time, and are generated by severe gravitational disturbances, such as the collision of two black holes.

And that's exactly what was observed. The gravitational waves of the first detection were generated by a collision of black holes in a galaxy 1.3 billion light-years away, and at a time when the Earth was teeming with simple, single-

celled organisms. While the ripple moved through space in all directions, Earth would, after another 800 million years, evolve complex life, including flowers and dinosaurs and flying creatures, as well as a branch of vertebrates called mammals. Among the mammals, a sub-branch would evolve frontal lobes and complex thought to accompany them. We call those primates. A single branch of these primates would develop a genetic mutation that allowed speech, and that branch—*Homo sapiens*—would invent agriculture and civilization and philosophy and art and science. All in the last ten thousand years. Ultimately, one of its twentieth-century scientists would invent relativity out of his head, and predict the existence of gravitational waves. A century later, technology capable of seeing these waves would finally catch up with the prediction, just days before that gravity wave, which had been traveling for 1.3 billion years, washed over Earth and was detected. (Tyson 2017: 96–98)

While this mini-narrative does not cover the entire TEUSH narrative from the Big Bang to the present—it starts 1.3 billion years ago—it does present the pivotal moments, such as the evolution of humankind, the naturalization of science, and the construction of science as a pinnacle of human and cosmic evolution. Even though not every section of *Astrophysics* presents the TEUSH narrative, the invocation of the entirety of cosmic history in such passages serves to situate all discussions and expositions in the book in a cosmic-heroic narrative. Furthermore, the short expression of the TEUSH narrative in chapter 6 recapitulates the already condensed presentation in chapter 1, thus reinforcing that narrative as the cosmic origin story for humankind, and further re-familiarizing the reader with the scientific-cosmic context.

The Ambiguities of Scientific Narration

In contrast to the religious connotations of the chapter's title—"The Greatest Story Ever Told" is a reference to the radio series (1947), novel (1949), and film (1965) *The Greatest Story Ever Told* about the life of Jesus Christ—the chapter itself starts with a motto from the first-century BCE materialist poet Lucretius: "The world has persisted many a long year, having once been set going in the appropriate motions. From these everything else follows" (quoted in Tyson 2017: 17). The juxtaposition of these religious and materialist references suggests that Tyson intends to formulate a naturalistic creation myth, making traditional religious creation myths superfluous. The opening sentence of the chapter, quoted above, reinforces this impression: "In the beginning, nearly fourteen billion years ago, all the space and all the matter and all the energy of the known universe was contained in a volume less than one-trillionth the size of the period that ends this sentence" (17). This is boundary

work: Tyson paraphrases the Bible, thus claiming some aspects of religion for science while simultaneously differentiating the two and asserting that science is the true path to knowledge. As I have shown, the chapter then goes on to tell the history of the universe—from the creation of matter in the early universe to the evolution of humans on Earth and the development of science—intermingled with episodes from the history of science. It ends with the stardust metaphor: “We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun” (33).

The significance of singling out specific events from a background of types of events and collective events now becomes clear. Creation myths are not just about accounting for the creation of the universe in general; they are also about accounting for the origin of a specific group of beings (e.g. a particular tribe, humankind) in a specific place (e.g. a piece of land, the Earth) (Schrempp 2012: 15–16). Tyson uses types of events and collective events when narrating events in the early universe and the creation of stars during the first few billion years of the history of the universe. He then singles out a specific, single event, namely the formation of the sun (starting with the sentence starting with “After”):

These elements [elements heavier than hydrogen necessary for the creation of life] would be stunningly useless were they to remain where they formed [in the cores of stars about ten times as massive as the sun]. But high-mass stars fortuitously explode, scattering their chemically enriched guts throughout the galaxy. After nine billion years of such enrichment, in an undistinguished part of the universe (the outskirts of the Virgo Supercluster) in an undistinguished galaxy (the Milky Way) in an undistinguished region (the Orion Arm), an undistinguished star (the Sun) was born. (Tyson 2017: 29)

What follows is a condensed account of Tyson’s secular-materialist creation myth (i.e., an instantiation of the TEUSH narrative). Over the course of 71 lines, Tyson gives an historical account of the solar system. In addition to the distinction between types of events, collective events, and singular events, Chatman’s (1978) distinction (which he develops from Roland Barthes) between *kernel* and *satellite* events is useful for analyzing the structure and significance of Tyson’s narrative. Chatman defines “kernels” as “narrative moments that give rise to cruxes in the direction taken by events,” moments that “cannot be deleted without destroying the narrative logic” (53). A “satellite,” by contrast, “is not crucial in this sense. It can be deleted without disturbing the logic of the plot” (54). This distinction highlights the role of the narrator: only from the perspective of a perceiving and discerning subject can there be

a distinction between important and unimportant events in the first place. To an “objective subject,” if such a thing were possible, all events would be equally important or unimportant. Importance/unimportance would cease to be a meaningful distinction—events would just “be” (and even assuming that “event” would be a meaningful category is assuming too much). Furthermore, Chatman’s distinction operates on the level of discourse: both kernels and satellites are events presented in the text, and then given greater or lesser importance. In the analysis of a creation myth like Tyson’s, it is more useful to identify satellite events with events in the story (i.e. the history of the universe) that are not represented in the discourse at all. Not everything in the history of the solar system catches Tyson’s narrative attention. The things that do catch his attention thus acquire significance. In this way, all the events presented in the discourse become kernel events.¹²⁶

The events thus singled out are indicative of the *point* of Tyson’s narrative. After describing the history of life on Earth and the mass extinction event, caused by an asteroid impact, in which almost all dinosaurs died 65 million years ago, Tyson concludes his version of the creation myth thus:¹²⁷ “This ecological catastrophe enabled our mammal ancestors to fill freshly vacant niches, rather continue to serve as hors d’oeuvres for *T. rex*. One big-brained branch of these mammals, that which we call primates, evolved a genus and species (*Homo sapiens*) with sufficient intelligence to invent methods and tools of science—and to deduce the origin and evolution of the universe” (31). For Tyson, a twenty-first century human and a representative of science, the narrative culminates with the emergence of humankind and science. The events and circumstances presented—the formation of the Earth, the location of the Earth relative to the sun, the creation of life, the evolution and diversity of life, the extinction event, the emergence of mammals—are kernels with respect to this goal: humankind and science. If the goal were something else—e.g., ants, or amoebas, or trees, or mountains—other events would have been kernels. Thus, while the narrative is presented as an objective account of the history of Earth, the concept of kernels enables the recognition of the constructedness of the narrative. The history of the Earth is “presented as ‘found’ in the events rather

¹²⁶ This modification of Chatman’s distinction is useful primarily when analyzing sections that present the creation myth only. In other cases, where historical episodes interrupt the flow of the narrative, the distinction might be useful. For example, the above-mentioned etymological explanation of the names of particles could plausibly be characterized as satellite event.

¹²⁷ I say “almost all dinosaurs” because birds are, technically, dinosaurs—thus survivors of the extinction event (Naish 2017).

than put there by narrative techniques,” to quote historian Hayden White (1987: 21).

The choice of the word “useless” in the penultimate sentence leading up to the creation myth—“These elements would be stunningly useless were they to remain where they were formed [i.e. in stars]” (29)—is curious. Of fundamental importance for the kind of science that both Tyson and Krauss construct is *non-teleology*: entities and events do not have purposes built into them. Something can only be “useless” if things can be “useful” to begin with. The distinction between usefulness and uselessness implies that there is a goal according to which a particular entity or event will be judged. Thus, asserting that chemical elements would be “useless” if they were not spread out in the galaxy to become the building blocks of life implies that the creation of life, humankind, and science is somehow the goal (or a goal) to be achieved by cosmic evolution. Given the worldview that Tyson and mainstream popularizers construct, this is patently not to be taken literally: Tyson is not seriously suggesting that the universe or a transcendent being has a purpose in mind for physical process. Nonetheless, he does imply or play with that idea. And this too is indicative of the TEUSH narrative: the creation of humankind and science is the endpoint—one is tempted to say the point—of cosmic evolution. Tyson thus employs a kind of “pseudo-teleology,” already implied by the kernels he chooses, in presenting the trajectory of the evolution of life on Earth. One could say that the emergence of humankind and science is the *endpoint* of the story and the *point* of the TEUSH narrative.

This raises an interesting question about the relation of the narrator to the story. Genette (1980) distinguishes between different kinds of narrators with respect to whether they are a part of the story. He makes two distinctions: extradiegetic versus intradiegetic narrators; and heterodiegetic versus homodiegetic narrators (248). What kind of narrator is Tyson in *Astrophysics*? With regard to the extradiegetic versus intradiegetic distinction, the answer is straightforward: he is an extradiegetic narrator because he does not construct a narrator who then tells the story of the universe.¹²⁸

¹²⁸ Even though Genette’s distinction between heterodiegetic and homodiegetic narrators is straightforward, Richard Walsh (1997) shows that Genette’s concepts become complicated when all their nuances and implications are teased out and examined closely. However, for my purposes the foundational distinctions—heterodiegetic/homodiegetic and intradiegetic/extradiegetic—are sufficient. I use Walsh’s convenient clarifications of the terms. *Intradiegetic versus extradiegetic* is “a matter of level; that is, the distinction between a narrator who narrates within a larger, framing narrative, and one whose narration itself constitutes the primary narrative.” *Homodiegetic versus heterodiegetic* is “a matter of person; that is, in place of the common distinction between first- and third-person narrators, a more exact

Whereas the categorization of Tyson as an extradiegetic narrator is straightforward, determining whether he is a heterodiegetic or homodiegetic narrator is not straightforward. A heterodiegetic narrator is a narrator who is not part of the story, whereas a homodiegetic narrator is. Is Tyson a heterodiegetic or homodiegetic narrator? *On the one hand*, Tyson is evidently not part of most of the story, when “story” signifies, for example, the early history of the universe or the formation of the Earth. Furthermore, he does not present himself as an active constructor in narrating these historical episodes or the history of the universe. In this sense too he is—or rather, presents himself as—an extradiegetic narrator: he has literally *no* part in the story, not even that of constructor. This is part of the construction of objectivity: Tyson presents the events and facts as “found,” not as constructed. Thus, in both these senses—non-involvement in historical episodes, manifest non-involvement in constructing the historical episodes—Tyson is an extradiegetic narrator. But *on the other hand*, the TEUSH narrative encompasses *everything*, including Tyson and other scientists. And as I have argued, the emergence of humankind and science is the point of the TEUSH narrative. It is of absolute importance for Tyson that he, as a human being and a scientist, is part of the story. We are all, after all, children of the cosmos. In this sense, Tyson is a homodiegetic narrator.

Thus, there is a fundamental ambiguity in Tyson-the-narrator’s relation to the story: he is *both* heterodiegetic and homodiegetic. When it comes to relating historical episodes in which Tyson was not present, he is an extradiegetic narrator. When it comes to being a human being and a scientist, he is a homodiegetic narrator. These conflicting narrator roles are invoked when different aspects of are emphasized. In other words, the ambiguity is functional: the narrator-as-heterodiegetic is part of constructing science as objective; the narrator-as-homodiegetic is part of constructing science as an existential and triumphant enterprise.¹²⁹

contrast between involvement and noninvolvement in the story” (497). Thus, Tyson is an extradiegetic narrator because he is not a narrator within a larger, framing narrator; he has not constructed a narrator who tells the story. “Tyson” not being identical with the real-life human being, but rather the persona Tyson, does not change his status as an extradiegetic narrator.

¹²⁹ In a less fundamental sense, Tyson is sometimes heterodiegetic, sometimes homodiegetic. For example, in chapter 1 he does not figure as an acting subject. In this sense, he is heterodiegetic. In chapter 2, he does figure as an acting subject: at the end of the chapter, he tells an anecdote about what happened to him at a restaurant in Pasadena, California (46–47). While this less fundamental sense of heterodiegetic versus homodiegetic can be important—for example, that anecdote serves to underline the universality of physical laws—it is incidental to my argument.

This ambiguity—Tyson-the-narrator as sometimes heterodiegetic, sometimes homodiegetic—also clarifies the question of the existence of extranarrative elements. Genette (1980) does not define extranarrative elements explicitly, but his discussion of them in the context of slow motion—“big scenes in novels, and especially in Proust, are extended mainly by extranarrative elements or interrupted by descriptive pauses, but are not exactly slowed down” (95)—suggests that they are elements not connected to the story at hand—e.g. philosophical reflections, historical tangents, and so on. Are there extranarrative elements thus defined? In the most obvious sense, the answer is no because the story is the history of the known universe. In this sense nothing can, by definition, be extranarrative, even if it is a philosophical reflection or historical tangent. However, some things are presented as extranarrative in the text. In particular, two passages stand out.

First, the etymological explanation of the names of particles mentioned above can be interpreted as extranarrative. Tyson begins the explanation thus: “Bosons, by the way, are named for the Indian scientist Satyendra Nath Bose” (Tyson 2017: 21–22). The inserted phrase “by the way” is a marker that what is to come is incidental to the main narrative. For Tyson, names can be simple or complicated and serve philological, philosophical, or pedagogical purposes. But fundamentally, names are arbitrary for Tyson. It is a historical accident that bosons are named after an Indian scientist and that quarks were named by physicist Murray Gell-Mann after “a characteristically elusive line in James Joyce’s *Finnegans Wake*: ‘Three quarks for Muster Mark!’” (22). What matters is that bosons are bosons and quarks quarks. In addition to constructing science as something that focuses on the essentials, the etymological explanation also allows Tyson to make an amusing historical digression, thus appealing to a presumed appreciation for trivia and humor in his audience.

Second, immediately following the myth-section, Tyson delves into philosophy:

What happened before all this? What happened before the beginning?

Astrophysicists have no idea. Or, rather, our most creative ideas have little or no grounding in experimental science. In response, some religious people assert, with a tinge of righteousness, that *something* must have started it all: a force greater than all others, a source from which everything issues. A prime mover. In the mind of such a person, that something is, of course, God.

But what if the universe was always there, in a state or condition we have yet to identify—a multiverse, for instance, that continually births universes? Or what if the universe just popped into existence from nothing? Or what if everything we know and love were just a computer simulation rendered for entertainment by a superintelligent alien species?

These philosophically fun ideas usually satisfy nobody [emphasis added]. Nonetheless, they remind us that ignorance is the natural state of mind for a research scientist. People who believe they are ignorant of nothing have neither looked for, nor stumbled upon, the boundary between what is known and unknown in the universe. (32–33)

I interpret these reflections as extranarrative because Tyson marks them as distractions. The true path to knowledge that Tyson wants to delineate is one that goes from the Big Bang to science. Religious doctrine and excessive, unsupported philosophical speculation are detours along the way. Yet pointing them out as such serves a function: boundary work. Once again, it allows Tyson to construct science not only as a rational pursuit capable of discovering the truth, but also as humble (in contrast to religious righteousness) and serious (in contrast to philosophical frivolity).

Thus, while in a strict interpretation of the story as being everything in the known universe the existence of extranarrative elements will be oxymoronic, Tyson marks some ideas and events as extranarrative relative to his narrative. In other words, Tyson acts both as a *chronicler* of the universe and a *proponent* of a certain tradition in that universe, namely science. This ambiguity is then incorporated into the naturalization of science. I have argued that mainstream popularizers often naturalize science, that is, present science as somehow rooted in nature. In particular, I argued that the naturalization of science relies on the invocation of a particular set of facts regarding human nature in combination with a specific set of values regarding the satisfaction of needs and desires such that science is inherently valuable because of its ability to satisfy natural needs and desires. I return to those needs, desires, and instincts in chapter 8. Here, I focus on the implications of this naturalization in Tyson's presentation of the significance of science.

On the one hand—in the Tyson-as-chronicler and story-as-everything interpretation—science is described as the natural outcome of cosmic evolution. It is simply a “fact” that matter evolved over cosmic time to produce stars, planets, life, humankind, and science. This is one meaning of the naturalization of science, expressed succinctly in Tyson's naturalistic creation myth. But on the other hand—in the Tyson-as-proponent and some events-as-extranarrative interpretation—science is presented as a choice. But it is not any other choice: it is the *right* choice, in the sense that it is the choice that leads to emotional satisfaction and spiritual fulfillment. Stronger still, given Tyson's pseudo-telology, science can be described as the *telos* (the goal or purpose) of being human in an almost Aristotelian sense. While Tyson may not share Aristotle's teleological worldview, there are structural similarities in their views of the

good life. In Aristotle's view, every living being strives to realize its latent potentiality, which is the purpose of its existence. For Aristotle, what sets humans apart is rationality, which finds its highest expression in philosophy, including physics and metaphysics. Accordingly, the fullest realization of human potentiality—and thus of being human—is intellectual activity (Kraut 2018). For Tyson, this intellectual activity has found its fullest realization in science. In other words, the naturalization of science in this sense means that affirming science is the fullest realization of being human. It is latent throughout the chapter (and the book), and it comes out in the stardust metaphor and in marking some elements as extranarrative. The oscillation between these two senses of naturalization—fact versus *telos*—enables Tyson to present science as factual and normative at the same time: it is the natural outcome of cosmic evolution; and it is the full realization of human nature.

Science constructed in this way is refamiliarization by presenting the familiar-made-unfamiliar in a context imbued with new meaning. Ultimately, for Tyson—as for others who use the star stuff or stardust metaphor—it is a return to our cosmic home. We are children of the cosmos, as the love and marriage metaphor in combination with the stardust metaphor made clear. We have always been cosmic creatures, but thanks to science we now know our roots. Science is thus a way to return home. This is the ultimate refamiliarization—and reification—of science. It speaks to the desire for transcendent meaning, as defined in chapter 3. Not everyone needs this kind of meaning, according to psychologists who study meaning in life. But some do, and it is to them that the naturalistic creation myth attempts to speak.

7

Protagonists of the Universe

Cosmic Agents and Scientific Characters

In the previous chapter, I argued that Tyson, along with many other mainstream popularizers, naturalizes science, but with a moral twist: on the one hand, science is presented as the natural outcome of 13.8 billion years of cosmic evolution; on the other hand, science is presented as a choice (choosing rationality and truth over religion and superstition). In this chapter, I consider the protagonists of the history of the universe and science. Who, or what, is the protagonist in the triumphant epic of the universe, science, and humankind? How are scientists portrayed? Where in the previous chapter I focused almost exclusively on transcendent meaning and techniques that appealed to a desire for that kind of meaning, this chapter broadens the question of meaning to include mundane meaning. Of particular importance is the category “social relationships” (see chapter 3, pp. 122–125 above). Of course, reading a book will not automatically increase the sense of meaning that can be derived from social relationships. However, by populating their narratives of science with protagonists and fascinating characters, popularizers attempt to make science meaningful by, first, creating a kind of “imagined community” of scientists and scientifically minded people,¹³⁰ and second, by letting the reader experience

¹³⁰ Benedict Anderson coined the term “imagined communities” in his analysis of nationalism ([1983] 2006) to denote constructed communities that are held together by ideas and media representations rather than by personal relationships. A nation is an imagined community “because the members of even the smallest nation will never know most of their fellow-members, meet them, or even hear of them, yet in the minds of each lives the image of their communion” (6).

vicariously what it may be like to participate in the enterprise of science.

I discern protagonists of three different types that exist on three levels in popularizations of physics and astronomy: the cosmic level, the individual level, and the historical level. On the *cosmic* level are protagonists that are far removed from what is usually thought of as protagonists: life, hydrogen, and stardust—in other words, abstract concepts, atomic particles, and metaphors. I discuss cosmic protagonists in the first section of this chapter, and I discuss both Krauss’s *The Greatest Story* and Tyson’s *Astrophysics*. On the *individual* level are protagonists of the familiar kind: individual human beings. I discuss protagonists of this kind in the second section, which is divided into two subsections. On the *historical* level are protagonists that are comprised of several people, in particular communities and groups of people. These communities and groups can consist of anywhere between a few people to thousands of people or more. I discuss protagonists on the historical level in the third section of this chapter. I concentrate on *The Greatest Story* in the sections on protagonists on the historical and individual levels.

Cosmic Protagonists: Life, Hydrogen, and Stardust

In his analysis of Carl Sagan’s *Cosmos*, Nasser Zakariya (2017) poses a crucial question. Who is the protagonist of Sagan’s “epic myth”? Just as there was an ambiguity in the matter of story-as-everything versus choice in the development of science in Tyson’s *Astrophysics*, so there is an ambiguity as to exactly who the protagonist is. Zakariya suggests that there are, in fact, two protagonists in Sagan’s *Cosmos*, operating on different levels of the narrative: first, *scientists*, “the delegates of humanity, its essence and its hope,” are the manifest protagonists; second, on a deeper level, *life itself* is the protagonist, “represented as what is important and potent, the fuller flower or potency of which the audience waits to see emerge from the cosmos” (331). However, even in *Cosmos* one can discern an even deeper-level protagonist. In the final chapter/episode, after presenting the TEUSH narrative in a condensed and concentrated form, Sagan comments: “These are some of the things that hydrogen atoms do, given fifteen billion years of cosmic evolution.”¹³¹ Thus, one can

¹³¹ Sagan (1980: 338); Sagan et al. ([1980] 2009: episode 13: 53^m33^s–53^m41^s). In the book, the sequence is 64 lines long Sagan (1980: 337–338). In the show, the sequence is about 16.5 minutes long and includes a condensed history of science and space exploration (Sagan et al. [1980] 2009: episode 13: 37^m18^s–53^m41^s).

argue that hydrogen atoms are the deepest level of cosmic protagonists in *Cosmos*: they are presented as the agents that evolved to produce life, humanity, and science. While life or hydrogen may be unusual protagonists, they instantiate a pervasive trope in literary history: the anthropomorphism of nature.

The same kind of protagonist can be identified at the deepest level in Tyson's *Astrophysics*. As I have shown, in his first chapter Tyson uses metaphors of love and marriage to describe the evolution of matter. In so doing, he presents particles as agents involved in an amorous drama producing the atoms and molecules that eventually produce humankind and science. The collective metaphor for these atoms and molecules is stardust. Thus, stardust is the protagonist at the deepest level in *Astrophysics*: stardust is the agent that produces everything of significance. However, the last sentence of that chapter suggests that scientists are the new protagonists: "We are stardust brought to life, then empowered by the universe to figure itself out—and we have only just begun" (33). The "we" in this sentence is equivocal: the first part, before the comma, implies humanity as a whole because everyone is composed of the same chemical elements; but the second and third parts, after the comma and after the em dash, imply those individuals that the universe uses to figure itself out, namely scientists. This suggests that scientists have a similar function in *Astrophysics* as they do in *Cosmos*: they are, in Zakariya's formulation, "the delegates of humanity, its essence and its hope" (2017: 331). This is connected to the naturalization of science: with the trajectory going from stardust to scientists, Tyson implies that scientists are the natural heirs of 13.8 billion years of cosmic evolution. They have taken over as cosmic protagonists.

In other places in *Astrophysics*, the cosmos itself is presented as the protagonist: "After the big bang, the main agenda of the cosmos was expansion, ever diluting the concentration of energy that filled space. With each passing moment, the universe got a little bit bigger, a little bit cooler, and a little bit dimmer" (48). Cosmos-as-protagonist is more incidental, however; it does not play a structural role in *Astrophysics* in the same way that stardust does. Its function is probably more to vary the language and defamiliarize readers so as to hold their attention.

Krauss does not explicitly present particles or the cosmos as protagonists in the same way as Tyson does. Occasionally, he does use phrases reminiscent of Tyson's—for example, "the cosmos doesn't care about our sensibilities" (Krauss 2017: 71) and "Two protagonists in our tale [the W and Z particles and the Higgs boson]" (248)—but as with Tyson's cosmos-as-protagonist

sentence, their use is more incidental than structural.¹³² However, it is noteworthy that Krauss and Tyson *can* use such phrases, in passing, without those phrases standing out and without Krauss and Tyson having to explain their meaning. Arguably, this is only possible because the TEUSH narrative comprises the meaning-making framework. For both authors, the evolution of matter—from simple particles to complex molecules to complex arrangements of complex molecules (including life, humankind, and science)—is the sequence of events that explains everything else. Tyson spells this out at length in chapter 1 of *Astrophysics*. Krauss makes it clear in the introduction to *The Greatest Story* that this is his perspective as well. In discussing *The Greatest Story* in relation to his previous book—the bestselling *A Universe from Nothing* (2012), which attempts to give a scientific answer to the question “Why is there something rather than nothing?”—Krauss says:

In contrast to *A Universe from Nothing*, in this book I explore the other end of the spectrum of our knowledge and its equally powerful implications for understanding age-old questions. The profound changes over the past hundred years in the way we understand nature at its smallest scales are allowing us to similarly co-opt the equally fundamental question “Why are we here?” . . .

And like the conclusion I drew in my last book, the ultimate lesson from the story I will tell here is that there is no obvious plan or purpose to the world we find ourselves living in. (Krauss 2017: 4)

Thus, while Krauss does not explicitly make stardust his deepest-level protagonist, it is clear that he could have done so, given the logic of his narrative. The difference between Krauss and Tyson is more indicative of stylistic choices than diverging worldviews or epistemologies.

¹³² The context in which “two protagonists” occurs in the second Krauss quotation has to do with the situation in particle physics in the 1960s, when the W and Z particles and the Higgs boson needed to be discovered to confirm crucial parts of the standard model in particle physics. The full paragraph in which “two protagonists” occurs reads as follows: “But as remarkable as this story is, two elephants remain in the room. Two protagonists in our tale could until recently have meant that the key aspects of the story comprised a mere fairy tale invented by theorists with overactive imaginations” (Krauss 2017: 248). The subsequent three paragraphs go on to describe the need to find the W and Z particles and the Higgs boson.

Individual Protagonists: Detectives, Heroes, and (Male) Geniuses

Detectives of Reality, Heroes Seeing the Light

Krauss may not use stardust as his protagonist, but, as noted in the previous chapter, the “story” in *The Greatest Story* is multilayered: it is, at once, the story of the universe, the story of humankind, and the story of science. These levels are nested: the story of science is part of the story of humankind which, in turn, is part of the story of the universe. Within this hierarchy of stories, Krauss’s focus is the history of science—in particular, the history of physics, with an additional focus on the development of theories of matter and particles (or what is called particle physics today). The discourse (narratologically speaking) is largely chronological, starting in prehistoric and religious “proto-scientific” patterns of thought, going through Plato’s philosophy and the history of physics since Galileo and (especially) James Clerk Maxwell, and ending at the current state of particle physics and cosmology. Krauss uses a tripartite structure for his historical narrative: Genesis–Exodus–Revelation. This structure is, of course, in line with the title of the book, referring to the Christian worldview. This is boundary work on the science/religion boundary, claiming some aspects of religion for science while simultaneously asserting that science is superior. As such, it is also a way to represent everything because these three parts—Genesis, Exodus, Revelation—encapsulate the totality of history in Christianity. But for Krauss, it is also a way to present the history of particle physics as a story of progress, going from the beginnings of science through struggles and breakthroughs to eventual victories. In this section, I analyze the ways in which Krauss presents that history as a story of progress, including the role of individual scientist in that narrative.

In some passages, Krauss seems to want to counteract the tendencies toward hero worship and simple narratives of progress in mainstream popular science. Early on he announces: “I don’t believe in hero worship, but if I did, Faraday would be up there with the best” (24). Later he says: “Physics doesn’t proceed in the linear fashion that textbooks recount. In real life, as in many good mystery stories, there are false leads, misperceptions, and wrong turns at every step. The story of the development of quantum mechanics is full of them” (86). However, in spite of his awareness of the tendency to present the history of science as a story of progress, his account is largely one of a sequence of successes. In fact, the quotation about wrong turns continues: “But I want to cut to the chase here, and so I will skip over Niels Bohr, whose ideas laid out the

first fundamental atomic rules of the quantum world as well as the basis for much of modern chemistry. We'll also skip Erwin Schrödinger, who was a remarkably colorful character, fathering at least three children with various mistresses, and whose wave equation is the most famous icon of quantum mechanics" (86). Not only does Krauss skip these figures and their theories—figures and theories which in fact were pivotal in the development of quantum mechanics—but he also skips less influential figures and alternative formulations and interpretations of quantum mechanics, thus reinforcing the traditional narrative of linear progress. In the narratological terminology introduced in the previous chapter, Krauss singles out some events as kernels while relegating others to satellite status or passing them by in silence. Furthermore, contrary to his manifest dislike of hero worship, Krauss's narrative centers on heroic individuals and their breakthroughs. In the next section, I analyze the presentation of scientific characters and character traits in both Krauss's *The Greatest Story* and Tyson's *Astrophysics*, including the tendencies toward hero worship in both books. In the remainder of this section, I analyze Krauss's presentation of the history of science.

The reference to mystery stories in the second quotation in the previous paragraph is not a one-off. Krauss repeatedly refers to "puzzles" (e.g., "Returning to the puzzle I mentioned at the beginning of this chapter" [120]) and "mysteries" (e.g., "the mystery of the nucleus" [167]). Starting chapter 15, he says: "In hindsight the answer may seem almost obvious, just as the little clues that reveal the murderer in Agatha Christie stories are clear after the solution. But, as in her mysteries, we also find lots of red herrings, and these blind alleys make the eventual resolution even more surprising" (191). Krauss is not alone among popularizers in his reference to and use of the logic of detective fiction. As many scholars have shown, conceptualizing scientists as detectives has been common in Western culture since the late nineteenth century—Arthur Conan Doyle's Sherlock Holmes was particularly influential.¹³³ Likewise, using detective fiction is fairly common in popular science. Elizabeth Leane (2007) argues that this is not a coincidence: first, in letting the process of science mirror the process of solving a mystery, science is presented as following clues to eventually discover "the truth" of a particular question, or "the truth" about how nature works; second, in letting the scientist mirror the detective, the "long-standing stereotype of the socially isolated scientist" is reinforced, since detectives typically also work in isolation and solve cases through their

¹³³ See e.g. Agassi (1982); Curtis (1994); Leane (2007: 140–150); Haynes (2017: 177–178).

extraordinary intellects (140–150 at 149).¹³⁴ Both these points apply to Krauss’s presentation of the history of particle physics too.

Krauss uses devices from detective fiction, or suspense fiction in general, to keep the reader’s attention and create a forward movement. In general, the chapters are linked through series of puzzles and solutions. Typically, a chapter will begin by posing a puzzle faced by physicists at a particular moment in time. The chapter then goes on to describe the theories and experiments devised to solve that puzzle. Yet the solution so proposed is usually limited, only able to capture a particular aspect of reality. The theories and experiments that solve the given puzzle thus typically give rise to new puzzles, often described toward the end of the chapter. The subsequent chapter goes on to pick up where the previous chapter left off, typically after an introductory section that is philosophical, personal, or humorous in nature. In this way, the history of particle physics is presented as a series of puzzles and solutions. The overarching puzzle that scientists attempt to solve, corresponding to the case in a detective novel, is the nature of reality. But as Krauss makes clear in the title of his book, as well as in the prologue and final chapters, physicists have yet to solve this puzzle. The complete truth remains elusive. This stress on incompleteness could be interpreted as having two main functions: first, it serves to invite the reader to join Krauss and his fellow detectives in the heroic quest to find the truth; second, it constructs scientists as humble characters. Their humility is contrasted with religious people, who are constructed as people who not only presume to know the truth, but also assert that humans have a special role in the cosmos.

But to see the full implications of the parallel between science and detective fiction, two additional recurring distinctions and terms need to be considered in conjunction with Leane’s two points (scientists as discoverers of the truth and scientists as socially isolated): the distinction between appearance and reality; and the use of “light” in various ways and contexts. Krauss views science as a way—or rather, *the way*—to discover deeper levels of “reality” beneath

¹³⁴ Elizabeth Leane (2007) differentiates between the classic detective novel (e.g. Arthur Conan Doyle) and the hard-boiled detective novel (e.g. Dashiell Hammett). She specifically analyzes the use of the figure of the hard-boiled PI in two popularizations of chaos theory. She shows that the use of hard-boiled PIs mirrors chaos theory in that randomness and unpredictability play an important role in both. It is significant that Krauss refers to Agatha Christie, whose novels belong to the classical detective novel tradition; in that tradition, the detective “retire[s] to contemplation” as an essential way of solving the case, in contrast to the hard-boiled PI who “submerge[s] himself in the sordid world of his client” (148). Krauss’s account is relatively smooth and linear, similar to the classic detective novel and in contrast to the random and disorderly narratives of hard-boiled fiction (147).

the “appearances” of the world of sense experience. The overarching historical narrative is one of a gradual uncovering of reality by scientists. Krauss uses the same peeling metaphor as so many other popularizers: “Each time we peel back one layer of reality, other layers beckon” (Krauss 2017: 275). Scientists can be construed as a kind of detectives of reality: they follow clues gathered through theories and experiments in an attempt to remove the layers of appearances that obscure reality.

Light plays a crucial role in this process of uncovering. Of course, “light” is one of the most central symbols in all of Western literature, philosophy, and religion, and Krauss taps into some of its central connotations and meanings, such as reason, understanding, and truth. Sometimes, Krauss uses it in the codified, everyday phrase “to shed light” (= to help explain or clarify), as in: “Feynman had missed out on the discovery of parity violation by not following his own line of questioning, but had since realized that his work on quantum electrodynamics could shed light on the weak interaction” (163). A more developed, Platonic use is the following: “percolating in the background were theoretical ideas that would draw back the dark curtains of ignorance and confusion, revealing an underlying structure to nature that is as remarkable as it is strangely simple” (152). Here, ignorance and confusion are identified with darkness—dark curtains, even—and thus light is, by implication, identified with understanding and clarity. This is an implicit reference to Plato’s cave allegory. Indeed, Krauss is explicit about the light–cave allegory connection: “Light played a major role in our story, as it did in Plato’s allegory” (304).

In the cave allegory, light symbolizes truth. In Krauss’s account, it plays additional roles—most obviously, as an object of study in physics. It appears as such throughout the book. Theories about light are discussed at length—both classical theories (by Newton, Huygens, Faraday, and Maxwell) and post-classical theories (i.e., relativistic and quantum mechanical theories). Less obviously, light is used as a literary device to move the narrative forward. When light is not the primary object of attention it frequently occurs in variations of the phrase “Once again light played a crucial role” (185; similar phrases on 71, 77, 98 [twice], 127, 130, 139, 152, 171, 227, 304). It thus functions as a kind of leitmotif throughout the text, marking kernels (key moments in Krauss’s version of history) and creating a narrative thread.

Krauss typically locates the narrative kernels in individuals or small groups of individuals who are often, though not exclusively, male. As noted above, he manifestly tries to resist hero worship and narratives of simple progress. He also emphasizes that physics “is a collaborative discipline. Too often science stories are written as if the protagonist had a sudden Aha! experience alone late

at night. . . . Every major triumph we celebrate with a name and a prize is accompanied by a legion of hardworking, often less heralded, individuals, each of whom moves forward the line of scrimmage by a little bit. Baby steps are the norm, not the exception” (85). Yet in spite of this awareness, Krauss frequently falls back into the habit of telling the history of physics as though it were precisely that: a series of breakthroughs by extraordinary individuals or small groups of extraordinary individuals. Krauss’s presentation of Scottish physicist James Clerk Maxwell is a good example. Maxwell, with his “voracious intellect,” “mathematical ability,” and “inquisitive nature,” “changed the world—four times” during a period of five years at King’s College, London (34–35). Krauss is primarily referring to theories developed by Maxwell, including, most significantly, the four equations now called “Maxwell’s equations,” which combine electricity and magnetism in a coherent mathematical framework.¹³⁵ Maxwell’s equations explain how light is produced from oscillations in the electromagnetic field. The concluding words of the chapter are worth quoting: “like the mythical character Prometheus before him, who stole the fire from the gods and gave it to humans to use as a tool to forever change their civilization, so too Maxwell stole fire from the Judeo-Christian God’s first words and forever changed their meaning. Since 1873, generations of physics students have proudly proclaimed: / ‘Maxwell wrote down his four equations and said, *Let there be light!*’” (43).

Other scientists are similarly and routinely presented as heroes and geniuses, sometimes in connection with revelatory breakthroughs or “Eureka” moments: “[Thomas] Young was not just any brilliant hardworking individual. He was a prodigy . . .” (73); “Other familiar names, [Niels] Bohr, [Erwin] Schrödinger, [Paul] Dirac, and later [Richard] Feynman and [Freeman] Dyson, each made great leaps into the unknown” (85); “the brilliant German scientist Arnold Sommerfeld” (85); “the remarkable Austrian theoretical physicist Wolfgang Pauli” (122); “the brilliant Italian physicist and colleague of Pauli’s— Enrico Fermi” (123); “Enter Hans Bethe. Another . . . incredibly talented and prolific theoretical physicist[. . .]” (134); “[Julian] Schwinger was refined, formal, and brilliant. Feynman was brilliant, casual, and certainly not refined” (175); “[Sheldon] Glashow was no clone of Schwinger’s. Refined and brilliant, yes, but also brash, playful, and boisterous” (177); “Their [John Bardeen, Leon Cooper, and Robert Schrieffer’s] work was a tour de force, built on a

¹³⁵ The three other breakthroughs that Krauss refers to are “the development of the first light-fast color photograph; the development of the theory of how particles in a gas behave . . .; and finally his development of ‘dimensional analysis’ . . .” (35–36).

succession of insights made over several decades of work” (184); “Then one day in 1967 while driving to MIT, he [Steven Weinberg] saw the light, literally and metaphorically” (215); “many of [Gerard] ’t Hooft’s insights, and there were many . . . seemed to come from some hidden reservoir of intuition” (220). These are just a few of the many examples. However, Einstein receives the highest praise, first together with Maxwell and then by himself:

Albert Einstein was born in 1879, the same year that James Clerk Maxwell died. It is tempting to suggest that their combined brilliance was too much for one simple planet to house at the same time. (46)

The great epic stories of ancient Greece and Rome revolve around heroes such as Odysseus and Aeneas, who challenged the gods and often outwitted them. Things have not changed that much for more modern epic heroes.

Einstein overcame thousands of years of misplaced human perception by showing that even the God of Spinoza could not impose his absolute will on space and time, and that each of us evades those imaginary shackles every time we look around us and view new wonders amid the stars above. (55)

The point I want to make with these examples is not that Krauss necessarily misrepresents physicists or their achievements by calling them “brilliant.” Rather, the point I want to make is that Krauss emphasizes the importance of specific theories and experiments and the “brilliance” of individual physicists at the expense of almost all other factors. In so doing, he makes these factors—theoretical development, experimental design, the brilliance of individuals—the drivers of history. But history is much more complex than that. For example, in the case of Maxwell, if there had not been people who picked up Maxwell’s theories and canonized them, he would not have “changed the world—four times” (35). Theories and experiments are inert; to be influential, they need networks of influential people that support and promote them in concrete ways, for example lauding the theories publicly, publicizing them, building upon them, and teaching them. And equally fundamentally: for theories and experiments to be formulated and conducted at all, there has to be institutions, infrastructure, resources, and people in place. Thus, even though Krauss gestures toward the importance of “a legion of hardworking, often less heralded, individuals” (85) and the existence of “false leads, misperceptions, and wrong turns at every step” (86), the thrust of his narrative remains centered on individuals and oriented toward progress. In other words, rather than avoiding the pitfalls he identifies, the narrative itself reinforces the kind of history writing that he manifestly tries to resist.

However, Krauss only tries to resist narratives of heroes and steady

progress in some passages. In other passages, he seems to endorse them. For example:

There is remarkable poetry in nature, as there often is in human dramas. And in my favorite epic poems from ancient Greece, written even as Plato was writing about his cave, there emerges a common theme: the discovery of a beautiful treasure previously hidden from view, unearthed by a small and fortunate band of unlikely travelers, who, after its discovery, are changed forever.

Oh, to be so lucky. That possibility drove me to study physics, because the romance of possibly discovering some new and beautiful hidden corner of nature for the first time had an irresistible allure. This story is all about those moments when the poetry of nature merges with the poetry of human existence. (201)

I return to this passage later, but my point here is how Krauss conceptualizes the history of physics and what he focuses on. For him, the history of physics is a heroic epic in which epic heroes unearth hidden realities. The focus of the story is “those moments when the poetry of nature merges with the poetry of human existence”—that is, those revelatory moments when scientists have breakthroughs and peel back yet another layer of reality. This idea is presented in the prologue, priming the reader for the kind of narrative that Krauss is about to tell:

The discovery of connections between otherwise seemingly disparate phenomena is, more than any other single indicator, the hallmark of progress in science. The many classic examples include Newton’s connection of the orbit of the Moon to a falling apple; Galileo’s recognition that vastly different observed behaviors for falling objects obscure that they are actually attracted to the earth’s surface at the same rate; and Darwin’s epic realization that the diversity of life on Earth could arise from a single progenitor by the simple process of natural selection. None of these connections was all that obvious, at first. However, after the relationship comes to light and becomes clear, it prompts an “Aha!” experience of understanding and familiarity. One feels like saying, “I should have thought of that!” (5)

The history of science as a story of progress is then brought out in a condensed form and with the use of the light symbolism yet again toward the end of the book: “But the most remarkable characteristic of all in this long march toward the light is how different the fundamental nature of reality is from the shadows of reality that we experience every day, and in particular how the fundamental quantities that appear to govern our existence are not fundamental at all” (245).

Light thus serves several functions in Krauss’s historical account of particle

physics: first, as a symbol of truth, explicitly modeled on the symbolism of light in Plato's cave allegory; second, as a metaphor for insight and understanding; third, as an object of study in physics; and fourth, as a literary device driving the narrative forward. Missing from this schematization is light as perceived in everyday experience. Krauss does not explore this aspect of light, but it is an aspect that seems inescapably implied. After all, the experience of light is the most immediate aspect and the one that all others build on, in one way or other.

The omission of light-as-appearance is significant. It is indicative of the low regard in which Krauss holds the senses—and conversely, the high regard in which he holds that which transcends the senses, namely science. In the epilogue, reflecting upon the history of science, he says: “I know of no better or more lyrical representation of the actual history of science [than Plato's cave allegory]. The triumph of human existence has been to escape the chains that our limited senses have imposed upon us” (303). In phrasing science and its history like this, not only does Krauss convey a limited, idealized, and biased view—a view that disregards historical contingency, sociocultural factors in the construction of science, and environmental consequences of the material conditions of science. He also reproduces the gendered mind-body dualism that has been so prominent in Western thought ever since Plato. Even within the TEUSH narrative, with its use of evolution to naturalize science, the phrase “the chains that our limited senses have imposed upon us” does not quite make sense. It implies that there is a kind of objective “I” to which the subjective senses are added. This, in turn, suggests that science is the natural state for this “I”—a state that the senses somehow corrupt. This is, of course, reminiscent of a kind of view that Plato expressed at times, for example in *Phaedo* (Plato 1975): when a human is born, a soul is somehow “injected” into the body, and in that process the soul loses the ability to access the truth directly. Only through philosophy can the soul counteract the corruption of the senses and regain access to the truth. While it seems clear that Krauss, given his scientism and use of evolution, would likely not subscribe to the belief that there is a soul separate from the body, the view he expresses still amounts to a modern and historically oriented version of Platonic philosophy: the history of science is a process in which scientists' I's or souls gradually purify themselves and move closer and closer toward the truth.

Scientific Characters and the Privileges of Male Genius

As is apparent from the previous section, scientists play an important role in

the historical narrative of science that Krauss presents. And while Krauss manifestly wishes to resist hero worship, his actual characterizations of scientists for the most part amount to hagiographies. Of course, Krauss's aim is not to write biographies of scientists, and so it is not surprising that the characterizations are brief. Some people get a few lines or paragraphs (e.g. Michael Faraday), while others only get a sentence or a few words (most contemporary scientists). Even so, the characterizations are stereotypical. The characters are flat rather than round. This does not mean, of course, that the actual people that Krauss portrays are flat. But what is relevant in an analysis of Krauss's construction of science is his *presentation* of scientific characters—which traits he singles out as significant or interesting and how those traits relate to stereotypes of scientists—not what those scientists were or are like in real life.

Krauss's characters lack depth and are typically defined by brilliance and genius. Beyond this, in the instances where he mentions other traits, his characters mostly fall into two categories: prosocial protagonists and eccentric geniuses.

Prosocial traits include generosity, altruism, and a generally obliging attitude toward others. Literary scholar Joseph Carroll and colleagues have shown that prosociality is the mark of protagonists in the fiction of Jane Austen and nineteenth century British novels (Carroll, Gottschall, Johnson, & Kruger 2012a; Carroll, Gottschall, Johnson, & Kruger 2012b). Krauss's portrayal of Michael Faraday is a prime example of this kind of character:

Perhaps more than any other scientist of the nineteenth century, [Faraday] is responsible for the technology that powers our current civilization. Yet he had little formal education and at age fourteen became a bookbinder's apprentice. Later in his career, after achieving world recognition for his scientific contributions, he insisted on keeping to his humble roots, turning down a knighthood and twice turning down the presidency of the Royal Society. Later on he refused to advise the British government on the production of chemical weapons for use in the Crimean War, citing ethical reasons. And for more than thirty-three years he gave a series of Christmas lectures at the Royal Institution to excite young people about science. What's not to like? (24–25)

Not only is Faraday portrayed as an underdog who went on to succeed and change the world—he is also humble and generous. He is not motivated by greed or selfishness, as antagonists typically are, but rather by a wish to understand the world and to do good to his fellow human. Other scientists who are characterized by prosocial traits include Richard Feynman (“gregarious and a charming storyteller” [98]; “tried to be generous with ideas” [164]); Subrahmanyan Chandrasekhar (“unassuming,” “dedicated teacher” [153]), and

Gerard 't Hooft (“gentle, shy, and unassuming,” “generosity of spirit” [220–221]).

Eccentric geniuses, meanwhile, are typically less agreeable than prosocial protagonists. Portraying scientists and philosophers as eccentric geniuses and absentminded professors has a long history in the Western tradition (Winston 2016; Haynes 2017: 135). Thales, usually regarded as the first Western philosopher, “supposedly once fell into a well because he was stargazing as he walked” (Burkeman 2018). Presently, one of the main characters of the hugely successful situational comedy show *The Big Bang Theory* is Sheldon Cooper, a physicist who fits the eccentric genius trope perfectly. In her analysis of the traits that make Sheldon Cooper an eccentric genius, Christine N. Winston (2016) lists and discusses the following: regressive behaviors (i.e. being child-like); egocentrism; narcissism; psycho-social dysfunction, including social skills deficit and alexithymia (“difficulties in identifying and describing emotional experiences”); obsessive-compulsive tendencies; mild impairments in reality-testing; and other pathological behaviors, including multiple phobias and hypochondriasis. Some of Krauss’s characterizations of scientists align with some of these traits. For example, the “brilliant and irascible” (85) Wolfgang Pauli “had no patience for fools. He was famous for supposedly rushing up to the blackboard during lectures and removing the chalk from the speaker’s hand if he felt that nonsense was being spouted” (123). This behavior would likely be regarded as insensitive and insulting if an ordinary person did it, but when done by a genius, it is interpreted as eccentric. It is an instance of the kind of behavior that, in philosopher Joseph Heath’s (2017) interpretation, “is conventionally known as a ‘dickhead move.’ It shows total indifference to other people’s needs and feelings. And yet when a professor does it, it’s treated as though it were cute, and possibly a sign of genius.”¹³⁶ It is also a typically male move, as the less flattering word “dickhead” suggests and Heath argues. A similarly forgiving attitude is usually not granted female scientists. Women are not constructed as geniuses and absentminded professors in the same way as men. In fact, they are more often diminished through sexualization. In their study of representations of female scientists in British mainstream media, Mwenya Chimba and Jenny Kitzinger (2010) show that female scientists are typically represented in such a way that their physical appearances are highlighted. They are often sexualized. The representations “often imply (even as they may seek to address) a contradiction between ‘airheads’ and ‘eggheads,’

¹³⁶ The specific behavior that Heath is referring to is promising someone to give a ride and then not showing up.

‘bimbos’ and ‘boffins’” (621).

On the more quirky and obsessive-compulsive side is Enrico Fermi. Fermi was part of the team of physicists who developed the first nuclear bomb in the Manhattan Project, and he attended the first nuclear explosion in New Mexico. “Typical of Fermi,” Krauss comments, “while the others stood in awe and horror, he conducted an impromptu experiment to estimate the bomb’s strength by dropping several strips of paper when the blast wave came by, to see how far they were carried” (129). Paul Dirac, however, probably takes the prize for eccentricity:

Dirac was notoriously laconic, and a host of stories exist about his unwillingness to engage in any sort of repartee, and also about how he seemed to take everything that was said to him literally. Once, while Dirac was writing on a blackboard during one of his lectures, someone in the audience was reputed to have raised his hand and said, “I don’t understand that particular step you have just written down.” Dirac stood silent for the longest while until the audience member asked if Dirac was going to answer the question. To which Dirac said, “There was no question.” . . . Some years later, when Dirac first met the physicist Richard Feynman . . . Dirac said after another awkward silence, “I have an equation. Do you?” (91–92)

These characterizations portray these physicists as socially awkward, eccentric, quirky, and (at least in the case of Dirac’s comment to Feynman) narcissistic. Again, it is beside the point whether the characterizations and anecdotes are actually true; the point is that Krauss includes them in his account, presenting them as interesting pieces of information about famous physicists. In so doing, he reproduces the stereotype of the eccentric genius. Especially significant is the tone or attitude of Krauss’s account. The eccentricities are portrayed as funny-yet-adorable, as cute perks that accompany genius. The physicists are portrayed as childlike, as “quirky but lovable despite being isolated by their inside jokes and scientific knowledge,” as Margaret A. Weitkamp (2017) characterizes the characters in *The Big Bang Theory* (43). In this way, the physicists so depicted are infantilized and thus made unaccountable for their actions.

While this infantilization may be seen as relatively harmless in some cases, it contributes to a culture of unaccountability. This is especially salient in Krauss’s treatment of gender issues. Krauss is mostly silent on gender issues, but he does address the relative lack of women in the history of science twice. In connection with descriptions of experiments carried out in the 1950s at Columbia University by, among others, the female Chinese physicist Chien-Shiung Wu, Krauss comments: “Even as we bemoan today the paucity of female physicists trained at American institutions, the situation was much worse in

1956. After all, women weren't even admitted as undergraduates at Ivy League institutions until the late 1960s" (159). A few pages later, Krauss discusses the German mathematician Emmy Noether. He calls her "remarkable" and "one of the most important mathematicians in the early twentieth century" (169). He goes on to comment: "Noether had two strikes against her. First, she was a woman, which made obtaining education and employment during her early career difficult, and second, she was Jewish, which ultimately ended her academic career in Germany" (169–170). He quotes mathematician David Hilbert, who defended Noether's right to do research and thereby "eternally reinforced [Krauss's] admiration for Hilbert": "I do not see," Hilbert had said, "that the sex of the candidate is an argument against her admission as a *Privatdozent*. After all, we are a university, not a bathhouse" (170). Apart from these two comments, gender does not feature in the book, and all the other scientists mentioned—save for a brief mention of Marie Curie and her daughter Irène Joliot-Curie (116–117, 119)—are men.

Krauss is not alone in this omission of female geniuses in representations of scientists and scientific history. Arguably, the only female scientist who is instantaneously recognizable and has a genius reputation comparable to male scientists such as Newton, Darwin, and Einstein is Marie Curie. Yet, as Eva Hemmungs Wirtén (2015) argues, popular narratives of Curie differ from narratives of her male counterparts: "In contrast to Newton, Darwin, Freud, Einstein, Keynes, or any other Great Male Scientist targeted for a storyline using The Man to get at The World, Curie resists abstraction. The male scientist, for all his idiosyncrasies, retains his ability to function as a catalyst for *generalizable* observations about science. He *fits*, even as a misfit. Curie, on the other hand, circulates in the closed loop reserved for a specific historical actor, whose experience as a woman is so extraordinary that it cannot be abstracted or generalized" (2). By barely mentioning Curie and other female scientists, Krauss thus both mirrors and reproduces the dominance of males in the construction of the history of physics.

But the culture of male unaccountability through genius is reproduced in other, more insidious, ways too. The old Platonic-Baconian (and generally Western-philosophical) tradition of conceptualizing nature as female recurs in Krauss's text through the use of the phrase "Mother Nature" (167). Krauss's insensitivity to the implications of this conceptualization becomes especially clear in a paragraph in which he both uses the Baconian metaphor of science-as-seduction-and-domination *and* praises physics as an enterprise free from discrimination. Speaking of the "thousands of individuals" who, over the span of a few decades, developed the Standard Model in particle physics, he says:

Their story was marked by incredible heights of intellectual bravery, years of confusion, bad luck and serendipity, rivalries and passion, and above all the persistence of a community focused on a single goal—to *understand nature at her most fundamental scales*. Like any human drama, it also included its share of envy, stubbornness, and vanity, but more important, it involved *a unique community built completely independent of ethnicity, language, religion, or gender*. It is a story that carries with it all the drama of the best epic tales and reflects the best of what science can offer to modern civilization. (273; emphases added)

This language of universality obscures both the misogyny implied in the Baconian conceptualization of nature and the misogyny actually present in everyday life. This is especially relevant in the case of Krauss himself, who, as noted above, has been convicted of sexual harassment.

Krauss's own behavior should be read in the light of his excuses for the sexual exploits of male geniuses. In her essay on Krauss and sexual misconduct among celebrity scientists, Marina Koren (2018) describes Krauss's biography of Richard Feynman, *Quantum Man* (2011), thus: "*Quantum Man* is a tremendous exercise in hagiography. Krauss documents Feynman's bad behavior, but couches it in language that removes any responsibility the scientist may have possessed." She goes on to quote passages from *Quantum Man*, including: "When [Feynman] spent a year in Brazil, he actually devised a set of simple rules for seducing women, including prostitutes, at bars. He became famous for seducing women at conferences abroad" (quoted in Koren 2018). Koren comments that "Krauss failed to mention that in this game, Feynman considered women who did not put out after he bought them drinks as 'worthless bitches.'" The same tendency to mention-yet-excuse is evident in *The Greatest Story*: "While Dirac was too shy to meet women, Feynman, after the death of his first wife, sought out female companions of every sort" (98). The same goes for physicist Erwin Schrödinger. Schrödinger is only mentioned in passing a few times, but on two of those occasions Krauss includes quips about Schrödinger's amorous life: "We'll also skip Erwin Schrödinger, who was a remarkably colorful character, fathering at least three children with various mistresses, and whose wave equation is the most famous icon of quantum mechanics" (86); "Schrödinger (who derived his famous wave equation during a two-week tryst in the mountains with several of his girlfriends)" (92). In this context, it is beside the point how Schrödinger actually behaved and what his life with his mistresses was like; the point is that Krauss frames Schrödinger's sexual inclinations and practices as quirks of his personality, as perks that come

with being a genius.

Thus, whether the physicists are portrayed as prosocial protagonists or eccentric geniuses, they are “good guys,” with “guys” being gendered. Prosocial protagonists are generous and altruistic and thus align with common traits of classical protagonists in fiction. The less desirable traits of eccentric geniuses and absentminded professor are excused by brilliance and/or admired as perks that accompany brilliance. This tendency—to present physicists as good and/or unaccountable—is pervasive in *The Greatest Story*. In no case is a physicist described as “bad” or morally reprehensible. The same is true for scientific discoveries and technological development: unintended side effects, sometimes disastrous, that accompany discovery and invention go unmentioned (I return to this question in chapter 9).

The characterization of scientists as good (or excusable) stands in contrast to the historically dominant ways of portraying scientists in fiction. As noted in chapter 2, Roslynn D. Haynes (2017) shows that until very recently, scientists have been portrayed in a negative light: “the portrayals of unattractive scientists, whether as suspicious, foolish, arrogant, inhuman, amoral, mad, evil, dangerous, or helpless, predominate in both fiction and film” (337). In Haynes’s interpretation, this is because science is linked with power, privilege, and exclusivity; fiction is a site where questions can be raised and protests can be launched against “the official history of science [which] records the discoveries of great scientists, the successes, the chain of influence, and the breakthroughs” (3). It is easy to see that Krauss here clearly represents “the official history of science.” He acts as a chronicler and proponent of science, and so it is not surprising that his account “records the discoveries of great scientists [and] breakthroughs” and that his character depictions consist of heroes, of “great men.”

As further noted in chapter 2, Haynes goes on to argue that the conventional negative portrayals in fiction to some extent have been replaced by more positive portrayals in the past two decades. Terrorists and big corporations have, in Haynes’s reading, taken over the role as antagonists (Haynes 2017: 337–339). While books such as *The Greatest Story* may benefit from this change in attitudes, Krauss does not portray big corporations or terrorists (unless religiously motivated) as antagonists. His main antagonist is, as mentioned several times, religion—or, more generally, superstition, irrationality, and anti-science. His account does not amount to a struggle between ordinary people and scientists or terrorists or corporations, but rather to a struggle between brilliant and heroic scientists and ignorant and cowardly religious people.

Historical Protagonists: A Cosmic Band of Brothers (and Sisters)

Thus far, I have considered cosmic entities and individual scientists as protagonists in popular science. There is an additional level at which protagonists can be found, however: history. As hinted at several times already, scientists as a group or collective can play the role of protagonist in a historical drama spanning the history of science or the history of humankind, as the case may be. This is implicit when casting religious people as antagonists, because it is (typically) not individual believers who stand opposed individual scientists—rather, it is believers as a collective who stand opposed scientists as a collective.

History as a sequence of extraordinary individuals is only one aspect of the construction of science in Krauss's account. While brilliance resides in the individual and revolutionary ideas occur to the individual, individuals often band together. I already quoted the following passage: “in my favorite epic poems from ancient Greece, written even as Plato was writing about his cave, there emerges a common theme: the discovery of a beautiful treasure previously hidden from view, unearthed by a small and fortunate band of unlikely travelers, who, after its discovery, are changed forever” (201). In this case, the band of travelers is composed of a few individuals, thus located in a particular historical time. In other passages, scientists are considered *en masse*:

The effort spanned the entire history of modern science, from Galileo's investigations of the nature of moving bodies, through Newton's discovery of the laws of motion, through the experimental and theoretical investigations of the nature of electromagnetism, through Einstein's unification of space and time, through the discoveries of the nucleus, quantum mechanics, protons, neutrons, and the discovery of the weak and strong forces themselves.

But the most remarkable characteristic of all in this long march toward the light is how different the fundamental nature of reality is from the shadows of reality that we experience every day, and in particular how the fundamental quantities that appear to govern our existence are not fundamental at all. (245)

Here Krauss begins with Galileo; in other passages, he extends science (by proxy) backward in time, to the precursors of science—be they Plato, whose cave analogy presaged the history of science by being the best “representation of the actual history of science” (303), or our prehistoric ancestors, specifically those in whose “consciousness [it dawned] that there is more to the universe than meets the eye” (4). Whatever the temporal extent of scientific history, intelligent and perceptive people are joined together in a cosmic band of

brothers (and sisters) intent on rationally understanding the universe and themselves. I put “and sisters” in parentheses because even though Krauss manifestly includes women in this band, the language he uses and the way in which he narrates history makes the band more of a brotherhood than a humanhood, so to speak. Not only are the vast majority of participants male, but scientific rationality and methodology are themselves coded as male, while nature—the object of scientific rationality and methodology—is coded as female.

By constructing scientists *en masse* as a historical protagonist acting over historical time, Krauss taps into social relations and group belonging as a form of mundane meaning in life. This is thus a way in which Krauss attempts to make science meaningful: by constructing science as a quest in which the heroic collective “scientists” act as the protagonists, fighting the dragons of superstition and attempting to unearth the treasure of reality. The reader who is not a scientist is, in some ways, excluded from this collective; but constructing scientists as a collective invites the reader to become a part of that collective, either directly—by becoming a scientist—or vicariously—by experiencing it through the eyes of others, thereby getting a sense of what it would be like to be a part of that collective. The reader also becomes part of the group of people who read popular science.

Thus, in the case of protagonists, science is made meaningful not through the universe itself, but by experiencing the universe through the visions and struggles of scientists and through participating, directly or vicariously, in the heroic collective composed of all scientists throughout history.

The Varieties of Scientific Emotion

Creating a Sense of Connection in a Cold Universe

In the Platonic tradition of Western philosophy, emotions are contrasted with reason. Emotions are identified with the female position, danger, subjectivity, irrationality, and chaos. Reason, by contrast, is identified with the male position, mastery, objectivity, truth, and order. However, in parallel with this dominant tradition in Western thought, some philosophers—Baruch Spinoza, David Hume, and Arthur Schopenhauer—have emphasized that emotions are important, primary even in relation to reason. Emotions guide reason, or as social psychologist Jonathan Haidt (2012) puts it: “The head can’t even do head stuff without the heart” (41). In recent decades, emotions have received much attention in affective science—including neuroscience and psychology—as well as in the humanities.¹³⁷ In many ways, emotions have been put at the center of cognitive life, no longer relegated to playing the role of reason’s antagonist.

Emotions are complex phenomena, involving components of different

¹³⁷ “Affective science” refers to studies on emotions in the behavioral and biological sciences, including psychology and neuroscience; see Davidson, Sherer, and Goldsmith (eds.) (2003); Sander & Sherer (eds.) (2009). In the humanities, there has been what is called an “affective turn”; see Clough & Halley (eds.) (2007); Gregg & Seigworth (eds.) (2010). For an overview of affective science and affect theory and how they relate to each other, see Hogan (2018). Emotion and affect are related, but they are not identical, and they are defined slightly differently by different authors. For example, Eric Shouse (2005: n.p.) sums up influential affect theorist Brian Massumi’s distinction between feelings, emotions, and affects thus: “Feelings are *personal* and *biographical*, emotions are *social*, and affects are *prepersonal*.” For my purposes, the distinction between affect and emotion is not important. As I explain in the running text, my analyses do not presume a specific or exact definition of emotion.

kinds: subjective experiences, physiological activity, personal history, interpersonal dynamics, social dimensions, historical dimensions, and so on. In line with this complexity, as well as with differences in method in the different disciplines in which emotions are studied, there is no single, agreed-upon definition of emotions. But because my analyses do not rely on any particular theory of emotion, I will not venture deeply into definitions and theories. For my purposes, it is sufficient to proceed on the assumption that mainstream popularizers such as Krauss and Tyson intend to elicit certain emotional responses from their readers. I am more interested in what the intended emotional responses are and which functions emotions have in Krauss's and Tyson's narratives than exactly what emotions are.

Krauss and Tyson occupy an interesting position with regard to the emotions. On the one hand, they place reason, with its connotations of objectivity and order, front and center of their worldviews. For example, Krauss (2017): "What determines intellectual consistency or lack thereof in the sciences is a combination of rational arguments with subsequent evidence and continued testing. It is perfectly reasonable to claim that religion, in the Western world, may be the mother of science. But as any parent knows, children rarely grow up to be models of their parents" (22). And Tyson (2017): "The power and beauty of physical laws is that they apply everywhere, whether or not you choose to believe in them. / In other words, after the laws of physics, everything else is opinion" (45). As shown many times in the preceding chapters, Krauss and Tyson construct science as a rational pursuit of truth.

But on the other hand, Krauss and Tyson also invoke emotions frequently, and they attempt to evoke emotions in their readers through literary techniques and poetic language. For example, Krauss: "The progress of science has made it clear just how violent and hostile the universe can be for life. But recognizing this does not make the universe less amazing. Such a universe has ample room for awe, wonder, and excitement" (304). And Tyson: "The cosmic perspective finds beauty in the images of planets, moons, stars, and nebulae, but also celebrates the laws of physics that shape them" (206). Both attempt to retain science's rationalist core (as they see it), while simultaneously wrapping that core in layers of emotion.

In this chapter, I focus on a number of key emotional responses that Krauss and Tyson intend to elicit: beauty, wonder, awe, empathy, and curiosity. Of these, wonder, awe, and empathy are likely most commonly identified as emotions. Beauty is perhaps the furthest from what one would ordinarily think of as an emotion, most often signifying features of an object. In this, however, I follow literary scholar Patrick Colm Hogan (2016: 1–12), who treats aesthetic

responses—responses involving beauty or sublimity—as a form of emotional response (alongside others) to literature. A similar argument can be made for curiosity. Curiosity is often described as a “drive” more than an emotion in the literature (Leslie 2014; Kidd & Hayden 2015), but the experience of curiosity can be treated as an emotional response to mysteries or objects that grab one’s attention. I discuss these emotions in detail in connection with the readings of Krauss and Tyson.

To put Krauss’s and Tyson’s use of emotions in perspective, popular science has not always been as suffused with emotions as it currently is. For example, as Johan Kärnfelt (2000: 279–289) shows, when popular science took shape as a distinct genre in Sweden in the early twentieth century, the ideal and dominant form was a factual and authoritative style free from emotions and personality. Likewise, in the years following World War II in both the US and France, the prevailing style in popular science was “unsensational, factual, serious,” as Bernadette Bensaude-Vincent shows (1997: 331–332). In other words, there is no necessary connection between popularization and the kinds of grand emotions prevalent in contemporary popularizations. This raises the question of why contemporary popular science is so suffused with emotions. STS scholar Steve Fuller (2006) interprets the “re-enchantment” of science, as he calls it, as a response to science losing the “state-protected monopoly it enjoyed in the Cold War era” (8). Fuller identifies re-enchantment with “a kind of evangelism or pastoral mission” (115) and focuses his analysis on the political implications of scientism. His point about government defunding of science is also relevant. I touched on this in chapter 1, in connection with Carl Sagan’s *Cosmos*. A way to attempt to gain support for science and space exploration following the defunding of NASA was deploying the triumphant epic of the universe, science, and humankind and romanticizing science. When the space race and the Cold War could no longer be invoked to justify big spending, romanticizing science and making it existentially meaningful was close at hand. In this existential kind of popularization, science becomes an end in itself, and so spending money on science is justified. This is not to say that Sagan and other popularizers—or, for that matter, readers and supporters of popular science—do not sincerely believe that science is Romantic and existentially meaningful. Rather, making this point is a way to historically situate the romanticization of science and the attention given to expressions of the existential relevance of science. People can romanticize science even when it is not societally functional to doing so; but understanding the surge of romanticization in the popular science boom requires one to take into account societal factors that can explain that surge.

The prevalence of the TEUSH narrative and the romanticization of science in the wake of Sagan’s *Cosmos* and the popular science boom can thus productively be seen in this light—as a response, at least in part, to government cutbacks in funding. However, there are longer historical processes at play as well. As I have shown, the reductionism and mechanization associated with modern science pose challenges to finding the universe as seen through science meaningful. Suffusing science with emotions is a way to make science meaningful because certain kinds of emotions are linked with meaningfulness. In particular, the kinds of emotions that counteract the image of the scientific worldview as cold, science as pointless, and scientists as heartless play a pivotal role in contemporary popular science. These emotions form the focus of this chapter.

Emotions of Scientific Discovery and Understanding: Beauty and Wonder

As noted in the previous chapter, the “story” in Krauss’s *The Greatest Story* is multilayered: it is, at once, the story of the universe, the story of humankind, and the story of science. Because the discourse, narratologically speaking, is historical, pivotal moments in the history of science, as perceived by Krauss, take a prominent place—discoveries, experiments, theoretical developments, prescient intuitions. Emotions accompany these pivotal moments. Sometimes Krauss describes or guesses the emotions experienced by the scientists who were responsible for the moments presented. For example: “A famous story claims that when Albert Einstein finished his General Theory of Relativity and compared its predictions for the orbit of Mercury to the measured numbers, he had heart palpitations. One can only imagine, then, the excitement that Maxwell must have had when he performed his calculation [showing that the speed of electromagnetic waves matched the independently measured speed of light]” (Krauss 2017: 42). Most expressions of emotions in *The Greatest Story*, however, are the implied author’s reactions to the story he is telling.

I argued in the previous chapter that Krauss’s historical narrative conforms more to the smooth and linear narrative logic of classical detective fiction than the disorderly and random narrative logic of hard-boiled detective fiction. In line with this harmony-oriented narrative logic, one of the primary emotions—or rather, emotional experiences—expressed by Krauss is beauty. Beauty may not be primarily an emotion, but it can be seen as an emotional response. Using Hogan’s (2016) terminology—aesthetic responses are a form of emotional

response—one can say that Krauss has a strong aesthetic and therefore emotional response to the history of physics. More precisely, he has a strong aesthetic and emotional response to *his construction* of the history of physics.

Throughout *The Greatest Story*, Krauss refers to “poetry” or “poetic” several times. He does not specify what he means by poetry, and his usage is not entirely clear. In his dismissal of the aptness of describing the Bible as “the greatest story ever told,” he still grants that there is “a bit of poetry in the Psalms” (2). He goes on to say that “Contrary to many popular perceptions, this scientific story also encompasses both poetry and a deep spirituality” (2). Here, poetry is connected to the level of history, or more precisely, to the history of science as history of “steady march of . . . discovery” (2). When narrating the history of the discovery of the properties of atomic nuclei, he says: “The poetry of discoveries was rivaled only by the drama in the private lives of the researchers” (115). Here, poetry is a feature of a “series of experiments [that] provided just the clues that were needed to unravel the nuclear paradox” (115). The most concentrated, and revealing, use of “poetry,” however, occurs in chapters 17 and 18. The first four paragraphs of chapter 17, “The Bearable Heaviness of Being: Symmetry Broken, Physics Fixed,” read:

There is remarkable poetry in nature, as there often is in human dramas. And in my favorite epic poems from ancient Greece, written even as Plato was writing about his cave, there emerges a common theme: the discovery of a beautiful treasure previously hidden from view, unearthed by a small and fortunate band of unlikely travelers, who, after its discovery, are changed forever.

Oh, to be so lucky. That possibility drove me to study physics, because the romance of possibly discovering some new and beautiful hidden corner of nature for the first time had an irresistible allure. This story is all about those moments when the poetry of nature merges with the poetry of human existence.

Much poetry exists in almost every aspects of the episodes I am about to describe, but to see it clearly requires the proper perspective. Today, in the second decade of the twenty-first century, we might easily agree about which of the great theories of the twentieth century are most beautiful. But to appreciate the real drama of the progress of science, one has to understand that, at the time they are proposed, beautiful theories often aren't as seductive as they are years later—like a fine wine, or a distant lover.

So it was that the ideas of [Chen-Ning] Yang and [Robert] Mills, and [Julian] Schwinger and the rest, based on the mathematical poetry of gauge symmetry, failed at the time to inspire or compete with the idea that quantum field theory, with quantum electrodynamics as its most beautiful poster child, wasn't a productive approach to describe the other forces in nature—the weak and strong nuclear forces. For forces such as these, operating on short ranges appropriate to the scale of atomic nuclei, many felt that new rules must apply, and that the old techniques were misplaced. (Krauss 2017: 201-202)

These paragraphs involve at least three senses of poetry: first, there is poetry in nature, i.e. in the universe or reality “itself”; second, there is poetry in human actions and historical developments; and third, there is poetry of the mathematical kind, in theories. Thus, poetry exists on three different levels: history, reality, and theory.

On the historical level, “poetry” seems to be used in the sense of a “well-constructed plot.” The chapter goes on to describe the historical twists and turns that showed that contrary to what many felt at the time, gauge symmetry was indeed the key to solving the problem—it led physicist Peter Higgs to develop the theory of what is now known as the Higgs boson, whose experimental discovery is described in later chapters of *The Greatest Story* (especially chapter 21). The last paragraph of chapter 17, which begins with the words “One last bit of poetry” (207), reinforces this impression: it adds additional twists and turns, describing further historical coincidences, misunderstandings, and eventual realizations regarding the importance of the Higgs boson. This is also the sense in which “poetry” is used in the next chapter: historical coincidences and unexpected but significant personal relations among physicists working on the Standard Model (212, 218). The significance of this use of poetry emerges when it is combined with the poetry of nature or reality: “This story is all about those moments when the poetry of nature merges with the poetry of human existence” (201). What does it mean for “the poetry of nature” to “merge” with “the poetry of human existence”? Krauss leaves this unspecified, but clearly, it has something to do with truth and reality. If the twists and turns in historical development that Krauss lays out had not contributed to the “steady march of scientific discovery” (2), then they would surely not have been described as poetic. This suggests that the plot is not only well-constructed but also aligns with reality. In other words, poetry is somehow connected to truth.

The third sense of poetry—the level of theory—is the least common. Krauss’s use of it in the above quotation—“the mathematical poetry of gauge symmetry” (202)—indicates that it too is related to reality and truth: gauge symmetry was the key to solving the puzzle resulting in the development and eventual confirmation of the theory of the Higgs boson. But mathematical poetry is also connected to beauty—which the invocation of poetry suggests to begin with.

Beauty is invoked far more frequently than poetry in *The Greatest Story*. Similar to how poetry is used, beauty occurs on three levels: history, reality, and theory (or science generally, including predictions, calculations, experiments, etc.). Beauty is Krauss’s preferred way to describe his reactions to the

story he is telling. Important theories (43, 85, 202), equations (92), calculations (41), experiments (286), results (46, 47), and predictions (219) are described as beautiful. Reality, too, is described as beautiful:

Thus, even as scientist-philosophers of the twentieth century had stumbled—often by a convoluted and dimly lit path—outside our cave of shadows to glimpse the otherwise hidden reality beneath the surface, one more force [the strong force] relevant to understanding the fundamental structure of matter was conspicuously missing from the beautiful emerging tapestry of nature. (229)

Another passage seems to describe the immediate world of ordinary experience as beautiful: “the properties of the particles that produce the characteristics of the beautiful world we observe around us” (246). However, the surrounding sentences explain how the properties of the unseen, underlying reality produce the “characteristics of the beautiful world we observe around us.” Thus, this beauty is more indicative of the underlying reality than of an immediate sense experience. In other words, it is primarily the universe as revealed through science that is described as beautiful, not the immediate experience of the world.¹³⁸ Finally, on the historical level, the story is described in terms of beauty: “Motion, a subject first explored by Galileo, ultimately provided, three centuries later, a key to a new reality—one in which not only electricity and magnetism were unified, but also space and time. No one could have anticipated this saga at its beginning. / But that is the beauty of the greatest story ever told” (70).

In other words, Krauss’s typical response to theories that “get at reality,” as well as to the historical development of those theories, is to find them beautiful or poetic. The use of poetry and beauty on these three levels—history, theory, reality—thus suggests, by association if not by deduction, that beauty and truth are connected. That which is true is beautiful. The connection between truth and beauty is, of course, not new. For example, it is present in the oft-quoted ending of John Keats’s poem “Ode on a Grecian Urn” (1820): “Beauty is truth, truth beauty, ’—that is all / Ye know on Earth, and all ye need to know” (Keats 1820; reprinted in Prickett & Haines [eds.] 2010: 80–82). Furthermore, it is a connection often made in contemporary popular science. Carl Sagan provides, yet again, a good example. Discussing the possibility of pessimism in the face

¹³⁸ However, incidental uses of beauty does occur on occasion, as in: “Similarly when I take a photo of a beautiful landscape, as I just did in Northern Ireland where I began writing this chapter, the scene I captured is not a scene merely spread out in space, but rather in space *and* time” (Krauss 2017: 56).

of modern evolutionary biology's interpretation of living organisms as "machines constructed by the nucleic acids to arrange for the efficient replication of more nucleic acids," he says: "We are, in a way, temporary ambulatory repositories for our nucleic acids. This does not deny our humanity; it does not prevent us from pursuing the good, the true, and the beautiful" (Sagan [1973] 2000: 6). More generally, scientists' response to "true" or "powerful" theories often include beauty (Ivanova 2017; Sideris 2017). Krauss's use of the truth-beauty connection should be seen in the light of these precursors and traditions: he makes ample use of Plato's cave analogy; he uses tropes and themes from the Romantics in his romanticization of science; and he is part of the public scientific culture in which aesthetic responses to mathematical and physical theories are ubiquitous.

But the truth-beauty connection seems to suggest that physics in fact has discovered the truth about reality. The resultant tension runs deep in *The Greatest Story*, just as in many other popular science texts. In *Astrophysics* Tyson deploys a slippage between model and reality to establish the authority of science on matters of knowledge, encapsulated in the term "physical laws." The term is ambiguous, at times referring to laws as formulated in the current state of science, and hence in principle open to revision; and at times referring to laws "out there," in physical reality, never open to revision and untouchable by human opinion. The same kind of slippage occurs in *The Greatest Story*. It is easily seen in the contrast between, on the one hand, the repeated invocations of reality, and, on the other hand, the "—*So Far*" of the title and such statements as "There is likely to be far more that we don't understand than what we now do" (305). In the previous chapter, I suggested that the expression of incompleteness can be interpreted as having two main functions: first, it serves to invite the reader to join Krauss and his fellow detective-scientists in the heroic quest to find the truth; second, it constructs scientists as humble characters. In the present context of the truth-beauty connection, incompleteness also highlights two other prominent emotions often expressed in popular science: awe and wonder.

While Krauss does invoke awe on four occasions (98, 129, 269, 304), of which the first two refers to other scientists' reactions, his general tone is not marked by awe as much as Tyson's *Astrophysics* is. Consequently, I discuss awe in the next section, in connection with the cosmic perspective in *Astrophysics*. Wonder is invoked more frequently in *The Greatest Story*. Wonder is a complex emotional phenomenon with a long and complex history. There is much scholarship on wonder in literary studies, religious studies, history,

philosophy, and psychology.¹³⁹ In an article on the use of wonder in Carl Sagan’s *Cosmos* (Helsing 2016), I build on research by Andrea Wilson Nightingale (2004), Mary-Jane Rubenstein (2008), and Sophia Vasalou (2015) to distinguish between *Platonic wonder* and *Aristotelian wonder*: “Aristotelian wonder is akin to curiosity: the philosopher finds some phenomenon puzzling, but through inquiry and understanding the puzzlement ceases and the wonder disappears. . . . Whereas Aristotelian wonder is a transitory state, which is overcome by knowledge, Platonic wonder is, ideally, permanent, an enduring attitude or emotional response toward existence and oneself” (272–273). This distinction is useful for analyzing wonder in *The Greatest Story* as well.

Twice in *The Greatest Story*, Krauss refers to objects as “wonders”: “While Plato doesn’t explicitly mention it, not only would his fellow prisoners view the poor soul who had ventured out and returned as handicapped, but they would likely think he was crazy if he talked about *the wonders that he had glimpsed*: the Sun, the Moon, lakes, trees, and other people and their civilizations” (13; emphasis added); and “Einstein overcame thousands of years of misplaced human perception by showing that even the God of Spinoza could not impose his absolute will on space and time, and that each of us evades those imaginary shackles every time we look around us and *view new wonders* amid the stars above” (55; emphasis added). In my analysis of *Cosmos*, I relate this kind of wonder to “a recurring theme in travel writing: describing the ‘wonders’ of foreign places and peoples” (Helsing 2016: 273; see also Daston & Park 1998: 25; Thompson 2011: 66). While Krauss does not use the journey motif to structure his narrative, he still taps into this tradition of travel writing.

Encounters with objects can elicit emotions of wonder and curiosity, as can unresolved problems and puzzling phenomena. This points to a second sense of “wonder,” one related to emotional experience. For example: “For some time, scientists and natural philosophers had *wondered* if the two forces [electricity and magnetism] might have some hidden connection, and the first empirical clue came to [Hans Christian] Oerstad by accident” (Krauss 2017: 25; my emphasis); and “Alternatively, we might *wonder* if the collision could break apart two electrons from a Cooper pair in the condensate—sort of like knocking off the rearview mirror when a truck collides with a post” (187; emphasis added). Here, wonder is close to Aristotelian wonder, a kind of curiosity

¹³⁹ For recent important contributions to the study of wonder that also include overviews of the scholarship on wonder, see Vasalou (ed.) (2012); Vasalou (2015); Economides (2016); Sideris (2017). A comprehensive study that most subsequent scholars in the humanities writing about wonder build upon is Daston & Park (1998). For a study based in social science and evolutionary thinking, see R. Fuller (2006).

or puzzlement.

This kind of wonder—Aristotelian—ceases when the puzzle is solved.¹⁴⁰ For example, when Maxwell showed that electricity and magnetism are indeed connected in a single force, electromagnetism, there was no need for scientists and natural philosophers to wonder about it any longer. But the emotional experience of wonder can be prolonged and developed into a “sense of wonder,” which is the most significant and interesting use of wonder in popular science. After describing some of the technological innovations made possible by Michael Faraday’s discoveries, Krauss says: “But technology wasn’t what motivated Faraday, which is why he stands so tall in my estimation; it was his deep sense of wonder and his eagerness to share his discoveries as broadly as possible that I admire most” (30). In contrast to Aristotelian wonder, this “sense of wonder” does not disappear when an answer is provided for a question that elicited curiosity. It is clear that Krauss values this sense of wonder deeply. It recurs at key moments in the text: first, in justifying the particle accelerator Large Hadron Collider (LHC) at CERN in Switzerland; and second, in explaining the point of science in the epilogue.

In chapter 21, “Gothic Cathedrals of the Twenty-First Century,” Krauss discusses the construction and characteristics of LHC and the discovery of the Higgs boson. As the chapter title suggests, Krauss engages in boundary work. He compares the LHC to gothic cathedrals: “The gothic cathedrals stretched the technology of the time . . . they were built for no more practical reason than to celebrate the glory of God. / The LHC is the most complicated machine ever built . . . it was built for no more practical reason than to celebrate and explore the beauty of nature” (269).¹⁴¹ Krauss’s reading of the purpose of cathedral building in medieval Europe—solely to celebrate God—is, of course, naive: it is an apolitical reading that omits other possible functions of the cathedrals, such as displays of wealth, demonstrations of power, and tools for social control. The same is true of his interpretation of the purpose of the construction of the LHC: no mention is made of possible socioeconomic functions such as maintaining and reinforcing the status of science in society, or the role of science in technological development in the private sector.

Krauss completes the comparison between the LHC and gothic cathedrals thus:

¹⁴⁰ Sideris (2017) calls this kind of wonder “serial wonder” (16).

¹⁴¹ Krauss explains that this comparison was first made by Victor Weisskopf, director general of CERN between 1961 and 1966.

Seen in this perspective, the cathedrals and the collider are both monuments to what may be best about human civilization—the ability and the will to imagine and construct objects of a scale and complexity that requires the cooperation of countless individuals, from around the globe if necessary, for the purpose of turning our *awe and wonder at the workings of the cosmos* into something concrete that may improve the human condition. Colliders and cathedrals are both works of incomparable grandeur that celebrate the human experience in different realms. Nevertheless, I think the LHC wins, and its successful construction over two decades demonstrates that the twenty-first century is not yet devoid of culture and imagination. (Krauss 2017: 269–270; emphasis added)

Here “wonder” is used in the Platonic sense, as an enduring emotion or attitude toward the universe. While the LHC does provide answers to scientific questions, the enduring sense of wonder does not wane with increasing knowledge. This sense of wonder returns in the epilogue:

The progress of science has made it clear just how violent and hostile the universe can be for life. But recognizing this does not make the universe less amazing. Such a universe has ample room for awe, wonder, and excitement. If anything, recognition of these facts gives us greater reason to celebrate our origins, and our survival. (304)

The greatest gift that science can give us is to allow us to overcome our need to be the center of existence even as we learn to appreciate the wonder of the accident we are privileged to witness. (304)

Again, the sense wonder does not stand in opposition to knowledge. To the contrary: the more we understand about the universe, the deeper this sense of wonder can be. It can co-exist with both knowledge and ignorance, but it grows with increasing knowledge.¹⁴²

In this way, wonder serves to ease the tension between knowledge and ignorance, or in other words: the tension inherent in the construction of physics as incomplete-yet-true. On the one hand, stressing that the sense of wonder increases with increasing knowledge ensures that there is no risk of boredom

¹⁴² Sideris (2017) discusses the dialects between wonder, knowledge, and ignorance in contemporary popularizers, including Richard Dawkins and E.O. Wilson. She argues that their concept of wonder is quite limited, historically speaking, and she links it to the drive toward power and control that she identifies in science of a reductionist and mechanistic kind. She also compellingly shows how the object of wonder for scientists like Dawkins and Wilson is not primarily nature or the universe, but rather the human mind and the scientific enterprise. She thus argues that for Dawkins, Wilson, and like-minded people, wonder is associated with self-aggrandizement rather than with truly opening up to otherness.

or meaninglessness in physics. Increasing knowledge will only make science more meaningful and wonderful. But on the other hand, wonder is also associated with ignorance. This is apparent in Aristotelian wonder with its qualities of curiosity and puzzlement. Stressing that there are many aspects of reality that we still *do not* understand thus equally ensures that there is no risk of boredom or meaninglessness. There are plenty of unresolved puzzles in science that can elicit wonder and curiosity.

In both these senses—the wonder associated with knowledge and the wonder associated with ignorance—wonder is thus inherently connected to *the process of science*. The engagement with the ongoing and never-ending enterprise of science is guaranteed, through these multiple uses of wonder, to continue to elicit wonder and thus to be inherently meaningful: the strange objects of the universe evoke curiosity and wonder; the unresolved puzzles and mysteries of the current state of science evoke Aristotelian wonder; and the contemplation of the knowledge already gained through science elicits Platonic wonder. The process of science is the point, and this point can be experienced both directly—by becoming a scientist or understanding the universe through reading popular science—and indirectly—by experiencing the process of science vicariously, through the eyes of historical scientists.

But wonder transcends the supposedly secular realm staked out by popularizers. As many scholars of wonder suggest, wonder is also connected to spirituality. Religious scholar Robert Fuller (2012) argues that “wonder, as an emotional experience, broadens our cognitive repertoire in ways that facilitate a stance toward life that might be considered broadly spiritual” (67). Claiming wonder for science like Krauss does is thus part of the boundary work he is performing on the science/religion boundary. Science is the new religion—not only does it construct the “cathedrals of the twenty-first century,” it also provides people with spirituality and meaning. But of course, again, science is superior: the LHC “wins” in any competition with the gothic cathedrals (269), and the recognition of the progress of science in understanding the universe “gives us greater reason to celebrate our origins, and our survival” (304).

But Krauss is not only doing work on the science/religion boundary. He is also performing work on the science/literature, or science/Romanticism, boundary. Wonder was a key emotion for many Romantics, as literary scholars Philip Fisher (1998) and Louise Economides (2016) have shown. The construction of science as a wonder-inducing, emotionally satisfying spiritual quest should be read against the background not only of appropriating religious spirituality, but also Romantic sentiments. When Krauss says: “Contrary to many popular perceptions, this scientific story also encompasses both poetry

and a deep spirituality” (2), I suggest that “popular perceptions” should be read to encompass not only religious objections to science, but Romantic objections to reductionism as well.

Emotions of the Cosmic Perspective: Awe and Empathy

These spiritual components of wonder and science are even more pronounced in Tyson’s *Astrophysics*. Tyson too invokes beauty and wonder, for example: “The cosmic perspective finds beauty in the images of planets, moons, stars, and nebulae, but also celebrates the laws of physics that shape them” (Tyson 2017: 206); and: “At one time or another every one of us has looked up at the night sky and wondered: What does it all mean? How does it all work? And, what is my place in the universe?” (12). The last quotation is clearly an attempt to make science existentially and spiritually meaningful, claiming for science the ability to answer supposedly age-old questions posed by religion and philosophy since the emergence of humanity. In essence, Tyson’s construction of science as a wonder-inducing, emotionally satisfying spiritual quest is identical to Krauss’s. And this is no isolated occurrence; Krauss’s construction is not his own but rather a common way of narrating science in contemporary popular science (see Sideris 2017; Gross 2018). However, even though Krauss’s and Tyson’s constructions are, for all practical purposes, identical, they differ in emphasis. In particular, Tyson focuses more on awe and empathy than Krauss.

As Krauss’s use of the phrase “awe and wonder” suggests (Krauss 2017: 269; 304), awe and wonder are associated. While distinguishing them absolutely, whether historically or psychologically, makes no sense (because of the complexity of these emotions and their history), Robert Fuller makes a useful distinction that seems to capture what many other scholars think too. Building on psychologists who have studied awe in experimental settings, he says:

It appears that awe is thus a biological response to stimuli that are sufficiently vast (i.e., physical size, fame, authority, prestige) that they diminish our sense of self and challenge our accustomed frame of reference. . . . awe often prompts people to see themselves as part of a greater whole, instigating “the sense of being in the presence of something greater than the self and a feeling of being connected with their surroundings.” (Fuller 2012: 68-69).¹⁴³

¹⁴³ The quotation that Fuller ends with is from Shiota, Keltner, & Mossman (2007). He also cites

Fuller relates awe to wonder in the following way:

Wonder belongs to the same family of emotions as awe. Wonder, like awe, is elicited by novel or unexpected stimuli that defy assimilation to pre-existing conceptual categories. Vastness and the need for cognitive accommodation are the principal factors that elicit wonder just as they serve to elicit awe. Indeed, wonder most frequently occurs as a response to something that strikes us as intensely powerful, real, or beautiful. Wonder differs from awe, however, in that it isn't accompanied by fear or submission. Wonder diminishes the sense of self, yet does so without inducing interpersonal submissiveness. (Fuller 2012: 69–70)

Fuller's approach to wonder is somewhat narrow, both in the sense that he emphasizes wonder as a response to "novel or unexpected stimuli," thus not fully allowing for a sustained Platonic sense of wonder; but also in the sense that he does not emphasize enough the historical dimensions and intricacies of wonder and related emotions. In spite of these limitations, Fuller's distinction is useful for capturing the kinds of emotions that Tyson associates with the cosmic perspective.

Tyson does not use the word "awe" in *Astrophysics*, but the emotions he attempts to evoke are clearly marked by awe. In chapter 6, I quoted Tyson's explanation of the cosmic perspective when he was interviewed by Conan O'Brien on *Conan*: "as humans, we have big egos," and reflections on cosmic discoveries can "dismantle" that ego and "disrupt [one's] sense of self-importance" (O'Brien 2017: 00^m06^s–00^m31^s). This is a primary theme in *Astrophysics*: the cosmic perspective functions as a "ego softener[. . .]" (201):

Again and again across the centuries, cosmic discoveries have demoted our self-image. Earth was once assumed to be astronomically unique, until astronomers learned that Earth is just another planet orbiting the Sun. Then we presumed the Sun was unique, until we learned that the countless stars of the night sky are suns themselves. Then we presumed our galaxy, the Milky Way, was the entire known universe, until we established that the countless fuzzy things in the sky are other galaxies, dotting the landscape of our known universe. (Tyson 2017: 204–205)

This demotion of our self-image extends to our view of ourselves: "no such

Keltner & Haidt (2003). Later psychological studies on awe, published after the publication of Fuller's article, include Valdesolo & Graham (2014) and Piff, Dietze, & Feinberg et al. (2015).

gap [between humans and nature] exists. Instead, we are one with the rest of nature, fitting neither above nor below, but within” (Tyson 2017: 201).

In other passages in *Astrophysics*, Tyson attempts to demote our self-image not through direct demolitions of it but through “comparisons of quantity, size, and scale” (201). As described by Fuller and other psychologists studying awe, one of the main characteristics of awe is the sensation of feeling small. This is clearly the emotion that Tyson attempts to evoke in his comparisons:

Take water. It’s common, and vital. There are more molecules of water in a cup of the stuff than there are cups of water in all the world’s oceans. . . .

How about air? Also vital. A single breathful draws in more air molecules than there are breathfuls of air in Earth’s entire atmosphere. . . .

Time to get cosmic. There are more stars in the universe than grains of sand on any beach, more stars than seconds have passed since Earth formed, more stars than words and sounds ever uttered by all the humans who ever lived. (Tyson 2017: 201–202)

For Tyson, merely mentioning numbers like these makes the self feel small because the numbers involved are unimaginable. But not only that: the juxtaposition of the unimaginable and the ordinary defamiliarizes readers, making objects in their surroundings ordinary-yet-unimaginable. Similar to the function of defamiliarization, this is a way of positing science as the bedrock of truth and meaning. This aligns with the effects of awe as described by Fuller and the other psychologists mentioned above: awe tends to make people submissive.

In Tyson’s account, the submissiveness in the face of an all-powerful science does not exclude empathy. Accompanying the feeling of smallness is a sense of empathy for other people. Although Tyson says that, as a working astronomer, he sometimes forgets that not everyone has the opportunity to ponder the cosmic perspective on a daily basis—“Not the migrant farmworker. Not the sweatshop worker. Certainly not the homeless person rummaging through the trash for food” (194)—he makes this point in a string of arguments from which he concludes that a proper appreciation of the cosmic perspective indeed does promote empathy.¹⁴⁴ He has a grand vision for the cosmic perspective. He argues that if only “everyone, but especially people with power and influence, [would adopt] an expanded view of our place in the cosmos,” then “our problems [including poverty, wars, and climate change] would shrink—

¹⁴⁴ Tyson’s connection between awe and empathy parallels the above cited psychological study on awe (Piff, Dietze, & Feinberg et al. 2015), according to which the feeling of smallness accompanying awe tends to increase prosocial behavior.

or never arise at all—and we could celebrate our earthly differences while shunning the behavior of our predecessors who slaughtered one another because of them” (197). This is clearly yet another way in which Tyson attempts to make science meaningful: science holds the key not only to the secrets of the universe, but it also holds the key to meaningful political change, transforming the current world marked by inequality and environmental destruction into an earthly paradise of cosmic harmony. I return to this political justification for science in the next chapter.

Tyson thus presents both the conundrum and the answer in the same breath. The cosmic perspective is awe-inspiring, but it is more than that: it is comforting. It provides the promise of utopia. It also provides an existential home for the newly uprooted reader. As the director of the Hayden Planetarium in New York, Tyson has produced space shows attempting to impart the cosmic perspective in the audience. After one such show, *Passport to the Universe*, a psychologist wrote a letter to Tyson, claiming that the show had “elicited the most dramatic feelings of smallness and insignificance he had ever experienced” (198). Tyson is perplexed by this response: “How could that be? Every time I see the space show (and others we’ve produced), I feel alive and spirited and connected” (198). The cosmic perspective not only defamiliarizes us, making us perceive our surroundings as alien; more importantly, it makes us identify with the cosmos, recognizing that “We do not simply live in this universe. The universe lives within us” (203). With science as *the* way to access the universe, the feeling of connectedness and being-at-home thus provides an existential justification for science.

Smallness, however, is only part of the cosmic perspective. Immediately after declaring that he feels “alive and spirited and connected,” Tyson goes on to say: “I also feel large, knowing that the goings-on within the three-pound brain are what enabled us to figure out our place in the universe” (198). This sudden switch—a feeling of largeness rather than smallness—is significant and in line with the TEUSH narrative. While the cosmic perspective may induce humility, equally significant is the feeling of aggrandizement accompanying the contemplation of the brilliance of the human mind and the awesomeness of science. This is not incidental. While Tyson says that we are “one with the rest of nature, fitting neither above nor below, but within” (201), he also grants humans a very special place: “I know what you’re thinking: we’re smarter than bacteria. / No doubt about it, we’re smarter than every other living creature that ever ran, crawled, or slithered on Earth” (199). He makes this point in an attempt to be humble. After explaining how bad chimpanzees are at math—“Even if you’re bad at math, you’re probably much better at it than the smartest

chimpanzee” (199–200)—he goes on to relativize human intelligence through a thought experiment:

Imagine a life-form whose brainpower is to ours as ours is to a chimpanzee’s. To such a species, our highest mental achievements would be trivial. Their toddlers, instead of learning their ABCs on Sesame Street, would learn multivariable calculus on Boolean Boulevard. Our most complex theorems, our deepest philosophies, the cherished works of our most creative artists, would be projects their schoolkids bring home for Mom and Dad to display on the refrigerator door with a magnet. These creatures would study Stephen Hawking . . . because he’s slightly more clever than other humans. Why? He can do theoretical astrophysics and other rudimentary calculations in his head, like their little Timmy who just came home from alien preschool. (Tyson 2017: 200-201).

While this may seem like a humble perspective, it clearly singles out one specific form of intelligence as the gold standard: human intelligence, and more specifically still, mathematical intelligence above all, with philosophical and artistic intelligence as runners-up. As in the example of the hypothetical alien studying the Earth in chapter 11 (see chapter 5 above), Tyson seems to hold to a naive form of universalism according to which intelligence comes in only one variety throughout the universe, even though it comes in degrees. While humans are undoubtedly the most intelligent creatures in the history of life on Earth, it is nothing compared to hypothetical alien supe-intelligence. From a posthumanist and animal studies perspective (see e.g. Wolfe 2010; Haraway 2016), Tyson’s way of thinking is anthropocentric, vaunting human supremacy in the extreme: it makes human intelligence the only intelligence that counts, thus disregarding the forms of intelligence that trees, ants, lizards, chimpanzees, and so on, and so on, possess. But even restricting the point to the humankind, it amounts to making a narrow selection of kinds of intelligence the gold standard: mathematical (above all), philosophical, and artistic. Tyson thus disregards other forms of human intelligence as well, such as social intelligence, craft skills, and wilderness survival skills. He also reifies science as a gendered enterprise because mathematical intelligence is coded as male, while other forms of intelligence, such as social intelligence and caretaking, are coded as female. And finally, he reifies Western styles of thought, disregarding non-Western bodies of knowledge and forms of intelligence.

The Naturalization of Scientific Curiosity

Tyson's reification of human and scientific intelligence is indicative of a reification of science and scientific emotions that recurs throughout both Krauss's *The Greatest Story* and Tyson's *Astrophysics*. I have argued that Krauss, Tyson, and other popularizers naturalize science: science is presented as sprung from nature itself and as rooted in basic human needs. This naturalization is particularly salient with regard to curiosity. In both Krauss and Tyson, curiosity holds the key to why science exists as well as to why science is important.

Curiosity may seem to be very straightforward and "natural." According to contemporary thinking in biology and psychology, curiosity is a fundamental part of the psychology of both humans and other animals.¹⁴⁵ In talking about the naturalization of curiosity, I do not mean to imply that curiosity is not "natural." Rather, what I mean is that Krauss and Tyson construct and cultivate a particular kind of curiosity as natural for the purpose of constructing science as an enterprise that is uniquely suited to satisfy our curiosity.

In the literature on curiosity, curiosity is typically categorized as a drive rather than an emotion. In his popular book on the subject, journalist and author Ian Leslie (2014: 7–8) refers to curiosity as the "fourth drive," the three other being food, sex, and shelter. According to psychologist George Loewenstein (1994), who has been very influential in the study of curiosity, curiosity is characterized by the awareness of "information gaps": when we become aware that there is a gap in our knowledge of some topic or issue, we tend to want to close that gap by finding more information.¹⁴⁶ Like beauty, however, curiosity also has emotional components. Leslie (2014) reports that curiosity "has been called the 'the knowledge emotion'" (74). He goes on to describe this emotion as an "itch": "An information gap isn't just recognized rationally; its onset is like an itch that we have to scratch. Information gaps cause us pain, but it's a pain we invite in" (74).

Both Krauss and Tyson appeal to curiosity in their justifications of science, but they do it in slightly different ways. To illustrate the role of curiosity in Krauss's construction of science, I return to a passage in *The Greatest Story*

¹⁴⁵ See Loewenstein (1994); Byrne (2013); Kidd & Hayden (2015); Gottlieb & Oudeyer (2018).

¹⁴⁶ Importantly, on Loewenstein's theory, being aware that one lacks information does not automatically propel one to want to close that gap. We are more likely to be motivated to close the gap if we already possess a certain amount of knowledge about the topic or issue in question, but not so much knowledge that new information is likely to be trivial. See also Leslie (2014: 61–95) for an accessible account of Loewenstein's research.

that I discussed in chapter 4 above. After proposing an instrumental justification for science—science is good because its application in technology benefits humanity—Krauss offers a justification that is more fundamental to his narrative:

But ultimately I believe we are driven to do science because of a primal urge we have to better understand our origins, our mortality, and ultimately ourselves. We are hardwired to survive by solving puzzles, and that evolutionary advantage has, over time, allowed us the luxury of wanting to solve puzzles of all sorts—even those less pressing than how to find food or to escape from a lion. What puzzle is more seductive than the puzzle of our universe? (Krauss 2017: 301)

Krauss uses an evolutionary framework to explain curiosity. In addition to explaining that human curiosity in general is an “evolutionary advantage” that has made us “hardwired to survive by solving puzzles,” Krauss specifically asserts that we have a “primal urge” to “better understand our origins, our mortality, and ultimately ourselves.” He does not, however, offer an account as to how evolution has produced this “primal urge.” Even if one accepted Krauss’s explanation—that we are “hardwired” to survive by solving puzzles—this still does not explain why we would have a “primal urge” to understand our origins, our mortality, and ourselves. The point I want to make is not that an evolutionary explanation of the kind Krauss envisions would be impossible to devise—rather, the point is that Krauss’s use of evolution is more an appeal to authority than an explanation. It resembles the kind of appeal to authority that Krauss disregards when it comes to religion. It is a discussion stopper akin to appealing to God because it is an appeal to “this is just the way things are.” I made the point in chapter 4 that scientism may be more effectively promoted as unanalyzed, through boundary work and philosophical asides, because it reaffirms, in passing, the authority of science. The appeal to evolution in explaining curiosity is arguably open to the same interpretation: it reaffirms, in passing, that evolution, and therefore science, explains why things are the way they are.

What Krauss is saying through his invocation of evolution is as important as what he is not saying. By advancing evolution alone as the explanation for curiosity, he is, in effect, saying that there is no need to contextualize curiosity, whether historically, socially, or politically. As many scholars show, however, curiosity has taken on multiple meanings, both throughout history and in different philosophical traditions.¹⁴⁷ For example, science writer Philip Ball

¹⁴⁷ See e.g. Daston (1995); Daston & Park (1998); Ball (2013); Leslie (2014: 99–124), with

(2013) distinguishes between two types of curiosity that stand opposed to each other. After quoting a passage in which Michel Foucault speaks about curiosity, Ball comments: “Foucault seems to wish to be enchanted and beguiled by curiosity, to be awakened to wonder, to feel a hunger for experiences strange and new that will break down old ideas and distinctions. Here curiosity is a radical force. In science, on the other hand, curiosity is more often enlisted in the name of taming the world—it is a compulsion to understand” (3).¹⁴⁸ Krauss’s curiosity is clearly in the “scientific” camp: for him, curiosity is a motivational emotion in the project of understanding the world by taming it, conceptually and/or physically. If in “old ideas and distinctions” one includes canonized science, Krauss’s curiosity is not about breaking down conceptual structures to enable “strange and new” ideas and experiences. It is, instead, about reproducing and solidifying existing science. With this quotation I do not seek to enter into a historical exploration of the meanings and uses of curiosity; instead, the point is to show that Krauss’s approach is not the only possible approach to curiosity. Curiosity in Krauss’s sense is not a human universal. But by presenting his concept of curiosity as curiosity *period* and explaining it through evolution, Krauss turns his concept of curiosity into a “natural” phenomenon—i.e., he naturalizes it.

With this denaturalization of Krauss’s concept of curiosity in mind, it is instructive to discuss Krauss’s uses of his concept. He discusses curiosity in the context of justifying science. But the version of science that he attempts to justify is a very specific one. It is *not* an approach focused on science as a social phenomenon, or one focused on the historical complexities of scientific metaphors, or one focused on the resource-intensive infrastructure needed to conduct science. It is, instead, an idealized version of science that focuses on science as the enterprise that purportedly provides answers to our existential questions. In other words, it is the science of the TEUSH narrative. In this way, Krauss co-constructs science and curiosity. Curiosity prompts us to ask existential questions about ourselves and our place in the universe. Similarly, the most significant aspect of science is that it provides us with answers to our existential questions. Thus, science is constructed as the “natural” response to our “natural” need to answer existential questions. Science is the key that fits in the lock of curiosity.

Curiosity plays a pivotal role in Tyson’s *Astrophysics* too. While his narrative is so similar to Krauss’s that he would likely not disagree with Krauss’s

references.

¹⁴⁸ Ball refers to Foucault (1996).

evolutionary explanation of curiosity, Tyson stresses a different aspect. Earlier, I discussed awe and empathy as emotions associated with the cosmic perspective in the final chapter of *Astrophysics*. Toward the end of that chapter, Tyson characterizes the cosmic perspective in a series of aphorisms, such as: “The cosmic perspective is humble” and “The cosmic perspective enables us to grasp, in the same thought, the large and the small” (206). One of the aphorisms seems to invoke curiosity as the “fourth drive”: “The cosmic perspective enables us to see beyond our circumstances, allowing us to transcend the primal search for food, shelter, and a mate” (206–207). After the series of aphorisms about the cosmic perspective, the book ends with three paragraphs of running text in which Tyson develops the idea of seeing “beyond our circumstances” by invoking curiosity:

At least once a week, if not once a day, we might each ponder what cosmic truths lie undiscovered before us, perhaps awaiting the arrival of a clever thinker, an ingenious experiment, or an innovative space mission to reveal them. We might further ponder how those discoveries may one day transform life on Earth.

Absent such curiosity, we are no different from the provincial farmer who expresses no need to venture beyond the county line, because his forty acres meet all his needs. Yet if all our predecessors had felt that way, the farmer would instead be a cave dweller, chasing down his dinner with a stick and a rock.

During our brief stay on planet Earth, we owe ourselves and our descendants the opportunity to explore—in part because it’s fun to do. But there’s a far nobler reason. The day our knowledge of the cosmos ceases to expand, we risk regressing to the childish view that the universe figuratively and literally revolves around us. In that bleak world, arms-bearing, resource-hungry people and nations would be prone to act on their “low contracted prejudices.” And that would be the last gasp of human enlightenment—until the rise of a visionary new culture that could once again embrace, rather than fear, the cosmic perspective. (Tyson 2017: 207–208)

In Tyson’s account, curiosity is intimately connected with the will to explore the unknown. This, in turn, is intimately connected with science. Tyson contrasts the curiosity of the scientist—and more generally, the curiosity of someone who adopts the cosmic perspective—with “provincial farmer[s]” and “cave dweller[s],” both of which are derogatory labels. This contrast is boundary work: Tyson constructs the scientific mindset in opposition to the supposedly unimaginative mindset of farmers and hunter-gatherers. He reserves curiosity and exploration for people who adopt the cosmic perspective, while people who adopt different ways of life are caricatured. He clearly implies that

there is something wrong with being content with what you have if you happen to be a self-sufficient farmer with forty acres of land. And he openly ridicules hunter-gatherer life by disregarding the extraordinary set of skills required to subsist on hunting and gathering (see e.g. Carruthers, Stich, & Siegal [eds.] 2002; Henrich 2016). Even more tellingly, he reserves curiosity and exploration for scientists, denying that farmers and hunter-gatherers are curious to begin with. In this way, and similar to Krauss's treatment of curiosity, Tyson narrows the concept of curiosity in such a way that scientifically minded people are coextensive with curious people. In other words, if you are a curious person, then you are also a scientifically minded person; if you are not a curious person, then you are not a scientifically minded person.

By dint of these contrasts, curiosity is thus associated with science and the cosmic perspective. As in Krauss's account, curiosity also serves as a justification for science. For Tyson, the "fun" of exploration is part of this justification. But he goes further. The "far nobler" reason for affirming science and curiosity is that without them, the cosmic perspective would wither away. And if the cosmic perspective were to wither away, then chaos would ensue. The cosmic perspective, and its enabler curiosity, is the safeguard of science, and hence of our civilization. Curiosity thus plays a pivotal role in Tyson too: it is the hallmark of science and the safeguard against violence and irrationality.

The Political and Technological Justifications of Science

Undeclared Preconditions of Science and Side Effects of Civilization

Thus far I have focused on the existential justifications of science—ways in which science is conceptualized as contributing to a sense of meaning, emotional satisfaction, and spiritual connection. But there are “instrumental” justifications as well—ways in which science is conceptualized as contributing to social progress and material benefits. This chapter focuses on two prominent such instrumental justifications: first, the *political justification*, according to which the values and attitudes associated with science promote a peaceful and prosperous society; and second, the *technological justification*, according to which science’s application in technology benefits humankind. Both of these justifications are connected to the triumphant tone of the TEUSH narrative. Science is a triumph of the human species not only because it is able to get at the truth of the universe, but also because it has the potential to bring about a utopian society and technological benefits for us all.

In this chapter, my guiding questions are: Triumph for whom? On what timescale? At what costs? The core of my argument is that when Krauss and Tyson suggest the possibility of utopia through science, their narratives are, in fact, more about defending current science and preserving the status quo than about actually envisioning utopias. In the first section, I focus on the political justification of science and analyze Tyson’s claim that an adoption of the cosmic perspective will lead to utopia. In the second section, I focus on the technological justification of science and analyze Krauss’s claim that technology

benefits people and allows us to have greater control of our environment.

More than previous chapters, this chapter focuses on what is left unsaid in Krauss's *The Greatest Story* and Tyson's *Astrophysics*. The critical edge of my analyses are also directed more at the genre conventions of contemporary mainstream popularizations of physics and astronomy than Krauss and Tyson as individual authors. Nonetheless, they do adhere to the conventions, and so instead of challenging those conventions their books serve to reinforce them.¹⁴⁹

The Political Justification

In the final chapter of *Astrophysics*, Tyson makes a case for science as a force for social progress. I showed in the previous chapter that while Tyson claims the cosmic perspective to impart humility in people who adopt it, his narrative is in fact anthropocentric and in the service of scientism. This tension between progressive-sounding arguments and a defense of the status quo runs through the chapter. It is encapsulated in Tyson's use of the word "we."

Tyson opens the chapter by quoting a justification of astronomy from 1757 by Scottish astronomer James Ferguson: "Of all the sciences cultivated by mankind, Astronomy is acknowledged to be, and undoubtedly is, the most sublime, the most interesting, and the most useful. For, by knowledge derived from this science, not only the bulk of the Earth is discovered . . . ; but our very faculties are enlarged with the grandeur of the ideas it conveys, our minds exalted above [their] low contracted prejudices" (quoted in Tyson 2017: 193).¹⁵⁰ Tyson endorses this sentiment, saying that Ferguson's words, "apart from their eighteenth-century flourish, could have been written yesterday" (194). That being said, however, Tyson puts the cosmic perspective in perspective:

But who gets to think that way? Who gets to celebrate this cosmic view of life? Not the migrant farmworker. Not the sweatshop worker. Certainly not the homeless person rummaging through the trash for food. You need the luxury of

¹⁴⁹ In 2018, Tyson co-authored (with Avis Lang) a book about the connections between astrophysics and war: *Accessory to War: The Unspoken Alliance between Astrophysics and the Military* (Tyson & Lang 2018). This book is more attuned to social realities and problematic aspects of science than *Astrophysics*. However, Tyson and Lang still posit that science and technology can, in principle, be divorced from destructive dimensions and be a force for peace and harmony. Furthermore, it was published separately from *Astrophysics*, and the year after, so I leave it out in my reading of *Astrophysics*.

¹⁵⁰ ". . ." and "[their]" are Tyson's modifications of the quotation.

time not spent on mere survival. You need to live in a nation whose government values the search to understand humanity's place in the universe. You need a society in which intellectual pursuit can take you to the frontiers of discovery, and in which news of your discoveries can be routinely disseminated. By those measures, most citizens of industrialized nations do quite well. (194)

In this passage, there is no universal “we”; there is instead a differentiated “we,” marked by global politics and financial inequality. Tyson does acknowledge that citizens of industrialized nations in general, and people who have the time to study science in particular, are privileged. However, there are assumptions in the passage that raise questions about what Tyson's acknowledgement of privilege actually means. First, Tyson asserts that unprivileged people do not get to “celebrate this cosmic view of life.” This patronizing attitude toward the intelligence and imagination of unprivileged people in effect disqualifies them from reflecting on matters that are not linked to their immediate survival. Second, the very form of the question “Who gets to celebrate this cosmic view of life?” shows that Tyson equates intellectual pursuit and philosophical reflection with the specific version of science he is advocating, i.e. the TEUSH narrative. Tyson thus reproduces the idea that science is the only way to produce knowledge about the world and understand our place in the universe.

Tyson also highlights the dependence of science on society in the quoted passage, both for funding and for the infrastructure necessary to disseminate news of scientific discoveries. However, he does it in such a way that he reproduces the idealized version of science characteristic of the book as a whole. By saying that in order to be able to “celebrate [the] cosmic view of life” you “need to live in a nation whose government values the search to understand humanity's place in the universe,” he, first, suggests that governments actually value the search to understand humanity's place in the universe; and second, he singles out this aspect of science as the aspect that should be cultivated.

At this point in the chapter, the “we” is still differentiated. As the chapter progresses, Tyson develops his ideas about the role of science and the cosmic perspective in unifying this “we.” After suggesting that the cosmic perspective is liberating because it shows us a world that does not revolve around us, he asserts that the cosmic perspective holds the key to achieving utopia. I quoted this passage in chapter 8, but it is worth revisiting:

Now imagine a world in which everyone, but especially people with power and influence, holds an expanded view of our place in the cosmos. With that perspective, our problems would shrink—or never arise at all—and we could

celebrate our earthly differences while shunning the behavior of our predecessors who slaughtered one another because of them. (197)

After this assertion, Tyson develops his view of what the cosmic perspective is. In so doing, he uses the word “we” consistently, as in the following aphorisms: “The cosmic perspective comes from the frontiers of science, yet it is not solely the provenance of the scientist. It belongs to everyone” (205–206); “The cosmic perspective opens our eyes to the universe, not as a benevolent cradle designed to nurture life but as a cold, lonely, hazardous place, forcing us to reassess the value of all humans to one another” (206); and “The cosmic perspective reminds us that in space, where there is no air, a flag will not wave—an indication that perhaps flag-waving and space exploration do not mix” (207). In other words, the cosmic perspective has the potential to unite all of humanity in a single “we.” If only everyone, and especially those in power, would adopt the cosmic perspective, then “our problems would shrink—or never arise at all.” This, in a nutshell, is the political justification of science: science, if properly adopted and embraced, will produce peace and harmony on Earth.

There are many problems with the political justification of science thus stated. It presupposes epistemological imperialism, i.e. the displacement of “non-scientific” forms of knowledge. It reduces human conflict to a matter of having or not having the “proper perspective” on the world, thus disregarding as sources of conflict such things as emotional complexity, historical factors, conflicting claims on resources, and conflicting views on how to manage resources. It purports to unite all of humanity in a single we, even while dismissing “provincial farmer[s]” and “cave dweller[s]” (207–208) who do not conform to Tyson’s version of scientific curiosity, thus tacitly identifying “we” with “scientifically minded people.”¹⁵¹ And it presupposes that everything is potentially controllable by humans and science.

These objections to the political justification are fairly straightforward. I wish instead to focus on a less apparent aspect of the political justification—one that further highlights how *Astrophysics*, and more generally the conventions of the genre, can be read as a defense of status quo.

The unification of the “we” through the cosmic perspective in effect presupposes that the financial inequalities of the global economic system could be extinguished with a proper adoption of science. By contrast, critics of capitalism tend to argue that inequality is inherent to capitalism (e.g. Hornborg 2001;

¹⁵¹ See chapter 8 for an analysis of Tyson’s construction of curiosity.

Harvey 2010; Piketty 2014). I do not wish to enter into a discussion about the nature of capitalism here—but neither does Tyson, and that is the point. Tyson opens the chapter by lamenting the fate of migrant farmworkers, sweatshop workers, and the homeless. He then proceeds to argue that science, courtesy of the cosmic perspective, has the potential to rectify all these ills. He does not explain how this would be achieved, however. If wages were not kept low for some kinds of labor in some countries, would scientific projects still be viable to the same extent, given that they would be more expensive? If job security, political stability, and decent wages were available for everyone, would enough people still be willing to perform the hard and dangerous labor involved in mining the metals required for computers and other forms of scientific equipment? Naturally, I do not have answers to these questions. The point, however, is that Tyson neither poses nor provides answers to these questions. He simply asserts that adopting the cosmic perspective would lead to peace and harmony. By not trying to show how or why this would happen, the political justification turns out to be more about promoting a specific ideology than presenting a plausible trajectory for society.

What ideology is that? The answer, again, can be surmised from the passage quoted above: “You need to live in a nation whose government values the search to understand humanity’s place in the universe. You need a society in which intellectual pursuit can take you to the frontiers of discovery, and in which news of your discoveries can be routinely disseminated” (194). These specifications, in combination with the lack of specificity about or arguments for the science–utopia connection, suggest that what Tyson is defending is, essentially, the status quo. He is not defending a future utopia in which everyone is equal, because he does not imagine it to begin with. Instead, he is defending what we already have. We already (supposedly) have governments that value “the search to understand humanity’s place in the universe,” and we already have the infrastructure necessary for the dissemination of research. We simply need more of the same. In this sense, Tyson’s utopia turns out to be less radical than it first appears. It is more about preserving the status quo and promoting scientism than about addressing structural problems in society. To reiterate, this is indicative of the genre conventions of mainstream popularizations of physics and astronomy; it does not necessarily say much about Tyson’s personal opinion on economics. Nonetheless, by adhering to these conventions, Tyson reproduces the status quo rather than problematize it.

The Technological Justification

In chapters 4 and 8, I quoted Krauss's main justification of science: we are "hardwired to survive by solving puzzles," and we have a "primal urge" to understand ourselves and our place in the universe (Krauss 2017: 301). As I also noted, Krauss posits this existential justification for science after having offered a technological justification:

Why do we do science? Surely it is in part so that we can have greater control of our environment. By understanding the universe better we can predict the future with greater accuracy, and we can build devices that might change the future—hopefully for the better. (301)

The two justifications—the existential and the technological—are mentioned in close proximity earlier in the book as well:

Curiosity-driven research may seem self-indulgent and far from the immediate public good. However, essentially all of our current quality of life, for people living in the first world, has arisen from the fruits of such research, including all the electric power that drives almost every device we use. (26)

In a nutshell, the technological justification states that science is a key factor in the development of technology, and the development of technology improves people's quality of life. It varies whether "people" includes only some people—the people in "the First World"—or humankind as a whole. The fundamental point is that science enables us to "have greater control of our environment" and that technology improves our lives.

The idea that technology improves our lives is an idea that needs to be approached carefully. What does "improve our lives" or "raising the quality of life" mean? Commonly, such questions are answered on an individual level. For example, a washing machine can improve my life by washing my clothes for me. The question can also be answered by extrapolating from the individual to the collective. A water purification plant can improve the lives of many people by providing them with potable water. Viewed from this perspective, technology consists of discrete machines that can be used to improve the lives of individuals. And from this perspective, it is difficult not to see technology as beneficial, or at the very least, as something that can be used for either good or bad, depending on the circumstances and the details of use.

But if the matter is viewed from a perspective that takes into account all the factors and components that need to be in place for technology to exist and

work at all, then “technology raises the quality of life” becomes a more complicated proposition. Understanding and evaluating it involves factoring in both social and environmental factors, such as the workplace conditions of factory workers or the environmental impact of resource extraction and consumption.

To approach these issues, I draw on the work of human ecologist Alf Hornborg (2001, 2016). For Hornborg and other human ecologists, it is essential to view human cultures and societies in the context of ecosystems and, ultimately, the biosphere.¹⁵² In biologist Paul Ehrlich’s definition of “human ecology” in the foreword to Robert Dyball’s and Barry Newell’s textbook *Understanding Human Ecology* (2015): “Human ecology can be thought of as dealing with the intersection of two complex adaptive systems . . . , a human social-economic-technological system that is embedded in a physical-chemical-living biosphere” (Ehrlich 2015: xv). In other words, the fundamental premise is that human cultures and societies cannot be divorced from the biophysical systems in which they are embedded.

My purpose here is not to develop a full account of the relationship between science, technology, and the environment. Rather, the purpose is to highlight two aspects of this relationship that go unmentioned in *The Greatest Story*: first, the thoroughgoing dependence of science and technology on industrial civilization; and second, some of the environmental consequences of powering civilization through fossil fuels.¹⁵³ Again, the critical edge of my argument is

¹⁵² The difference between an ecosystem and the biosphere is one of scale. An ecosystem is the system that comprises all the biotic (living) and abiotic (non-living) factors in a particular area. The biosphere is the sum of all ecosystems on Earth.

¹⁵³ “Civilization” is a somewhat loaded and ambiguous term. It has been, and still is, used in a normative way to distinguish “well-mannered” and “sophisticated” people from “wild” or “barbaric” people (Fernández-Armesto 2001). I instead use civilization in the more descriptive sense of “a specific combination of technological, socioeconomic, political and ideological features,” in Josep R. Llobera’s (2003: 136) definition in his textbook in anthropology. Llobera goes on to specify ten traits that are commonly used to define civilization, including the rise of cities, the “centralised accumulation of surplus wealth,” and the “invention of writing” (136–137). “Industrial civilization” hence refers to that particular form of civilization that is characterized by powered machines, mass production, and mass consumption. The most concise yet highly informative definition of civilization that I have come across is environmental activist Derrick Jensen’s (2006): “a culture—that is, a complex of stories, institutions, and artifacts—that both leads to and emerges from the growth of cities (*civilization*, see *civil*; from *civis*, meaning *citizen*, from Latin *civitas*, meaning *city-state*), with cities being defined—so as to distinguish them from camps, villages, and so on—as people living more or less permanently in one place in densities high enough to require the routine importation of food and other necessities of life” (17).

not directed at Krauss as an individual, but rather at the genre conventions of contemporary popularizations of physics and astronomy.

The Social Nature of Technology

Hornborg (2001, 2016) argues that viewing technology as discrete machines that can aid individuals systematically misrepresents the nature of technology. The crucial factor left out in the neat image above of a washing machine improving my life is the fact that no piece of technology can exist in a societal vacuum. The washing machine is a product of a long chain of events: materials such as metal and plastic need to be mined and produced; the components of the machine need to be designed, constructed, and put together in factories using machines that in turn need to be constructed; the finished product needs to be delivered to a retailer, and then to my home; and for the machine to work, I need to connect it to the electrical grid. In her book *The Story of Stuff* (2010), Annie Leonard gives a detailed, accessible account of the life of commodities in the global capitalist economy. She uses five categories to categorize the incredibly complex system necessary for producing the commodities of everyday life: extraction, production, distribution, consumption, and disposal.

Hornborg argues that while nature (in the form of resources) and knowledge (of how to use resources) are indeed necessary for technology to exist, conceptualizing technology as set apart from social relations is deeply misleading:

If technology is nature plus knowledge plus exchange [social relations of a certain kind], we tend to forget the last part of the equation. The social processes through which its components are supplied are visualized as external to the definition of technology. Our machines fool us into thinking that they can exist without the socioeconomic premises that I have just outlined, and that they are simply revealed regularities of nature. . . . *We seem to have difficulties understanding that machines, being material structures, for their very existence depend on social relations.* (Hornborg 2001: 12; emphasis added)

These social relations—the “socioeconomic premises” to which Hornborg refers—are what ensures that the system of extraction–production–distribution–consumption–disposal works to begin with. Without the existence of the social relations that enable the system, the washing machine would not be produced at all. Or, if the system were to suddenly stop functioning the minute my washing machine had been delivered, I would not be able to use the machine, since there would be no electricity coming from the electrical sockets in my walls and no water running through the pipes of my house. Conceptualizing the

washing machine as a piece of technology that is useful and powerful “in itself”—by virtue of its efficiency and design—obscures the fundamental fact that the machine literally would not work without the necessary infrastructure and hours of labor that go into maintaining the socioeconomic system. The machine is not just an ingeniously put together piece of machinery—it is a part of a socioeconomic system: “Locally, it may seem perfectly adequate to account for a machine by referring to its design, but from a global perspective, such an account is as insufficient as it would be to explain what keeps an organism alive by referring only to its anatomy” (Hornborg 2016: 7).

Neither Hornborg nor Leonard discuss the production of scientific instruments and tools specifically, but the production of those instruments and tools is inseparable from the same system. In today’s world, science and technology are inextricably linked to industrial civilization. Science and technology would literally *not work* if civilization stopped working or did not exist. Telescopes and particle accelerators—vital for the development of physics and astronomy—are complex machines that depend on the functioning of industrial civilization. The same holds for all important aspects of modern science, from the computers needed to develop models of physical systems to the publication of books and journals and the logistics of international conferences.¹⁵⁴

These aspects of contemporary science and technology—their thoroughgoing dependence on industrial civilization—are typically left out of or downplayed in mainstream popularizations of physics and astronomy. Science and technology are divorced from the social relations that underpin them; they are conceptualized primarily through their “ingenuity” and “rationality,” not as components of a socioeconomic system.

According to Hornborg, the social relations that underpin technology are inherently exploitative. It is not necessary for my argument to go into the details of Hornborg’s theory, but it is worth noting that it is an inescapable fact of global, industrial civilization that there are disparities in the distribution of resources and environmental pollution: resources flow from unprivileged sectors to privileged sectors of society, while waste and pollution flow from privileged to unprivileged sectors (see also Nixon 2011). The question is whether this disparity is a necessary part of the functioning of global, industrial civilization, as Hornborg argues, or if it can be remedied through the development of more science and technology, as Krauss seems to claim.

In juxtaposing Krauss and Hornborg, I do not wish to suggest that Hornborg is necessarily right and Krauss is necessarily wrong. However, it is productive

¹⁵⁴ And of course, the same general point holds for the social sciences and the humanities.

to contrast Krauss's narrative of progress and triumph with Hornborg's theory. Given what I take to be two inescapable facts about technology and global civilization—first, the social nature of technology, and second, the disparity in the distribution of resources and pollution—it seems to me that Krauss's narrative, to be credible at all, needs to be able to refute Hornborg's theory. In other words, I am not saying that Hornborg is correct; but I am saying that given the facts, Hornborg's theory is a challenge to narratives of progress and triumph, a challenge that proponents of these narratives need to address successfully before their narratives can be accounted credible.

Hornborg (2001) combines the idea of the social nature of technology with the idea of the exploitive nature of industrial civilization in the following way. He argues that the prevalent view of technology as powerful “in itself” *obscures* the exploitative nature of the socioeconomic system that makes technology possible. He uses the Marxian notion of “fetishism” to denote this obfuscation. Marx famously used the concept of “fetishism” to suggest that in capitalism, commodities appear “inherently valuable,” thus obscuring the fact that they are products of social relations.¹⁵⁵ Hornborg argues that the machine is a fetish: “The fetish character of the machine resides in its ability to present itself to our consciousness as a local achievement rather than as a product of the confluence of global [resource] flows” (147). Because machines seem powerful “in themselves,” thus obscuring unequal exchange between privileged and unprivileged sectors of society as a precondition for their very existence, they can be viewed as having the potential to improve the lives of everyone. But if, instead, unequal exchange is a prerequisite for technology, then technology can never be a means to improve the quality of life for everyone: “The technological benefits of industrial society cannot be generalized for the total population because the very constitution of these technologies . . . relies on unequal exchange between sectors of that population” (153).

Using Hornborg's terminology, it is clear that Krauss fetishizes the machine. Krauss does admit that thus far, technology has primarily raised the quality of life for people living in privileged parts of the world: “essentially all of our current quality of life, for people living in the first world, has arisen from the fruits of [curiosity-driven] research” (Krauss 2017: 26). Nowhere, however, does Krauss suggest that technology would not—or will not—be able to raise the quality of life for everyone. In fact, he suggests that technology has the potential to improve “the human condition,” which presumably includes all

¹⁵⁵ As Hornborg (2001: 131–146) shows, the Marxian concept of “fetishism” is complex and has been interpreted in numerous ways. I only present a simple version in the running text.

humans. As I discussed in chapter 8, Krauss compares the Large Hadron Collider particle accelerator at CERN in Switzerland to Gothic cathedrals. He lauds both for their existential and technological significance:

the cathedrals and the collider are both monuments to what may be best about human civilization—the ability and the will to imagine and construct objects of a scale and complexity that requires the cooperation of countless individuals, from around the globe if necessary, for the purpose of turning our awe and wonder at the workings of the cosmos into something concrete that may improve the human condition. (269)

Interestingly, Krauss highlights the social complexity needed to construct cathedrals and particle accelerators, but he does so in idealized way, blind to the details of how the social relations are maintained, who they benefit, and what the consequences of this system of production are. In essence, he operates within a framework that sees technology as discrete machines that can do good for everyone—he does not see technology as part of a global, industrial civilization in which machines facilitate flows of resources that benefit some people but not others. He operates within a framework that presupposes that the essence of technology can be divorced from the particular social relations that produce and maintain that technology. In this way, the view of technology presupposed by Krauss resembles his view of science: it is an idealization. As such, it is also ideological because it serves the interests of current science. Just as Tyson’s political justification turned out to be a defense of the status quo rather than a program for actual change, Krauss’s technological justification turns out to be a defense of the status quo too. However the costs and side effects of technology are construed, the benefits of technology come at a cost. Yet no such costs are mentioned by Krauss. Instead, he advocates more science of the present variety—which, since science is thoroughly dependent on advanced technology, means more technology.

The Specter of Climate Change

In justifying science through technology, Krauss uses a phrase that turns out to be morbidly ironic: “Why do we do science? Surely it is in part so that we can have *greater control of our environment*” (2017: 301; emphasis added). I have argued that technology cannot be divorced from the socioeconomic system that underpins it. Here I highlight the side effects of that socioeconomic system as currently managed: climate change due to the use of fossil fuels, and environmental destruction in general.

As with the idea that technology can improve our lives, the idea that science and technology give us greater control of our environment needs to be approached carefully. Controlling one's immediate environment to some degree can plausibly be said to be a feature of most life forms—from foraminifera creating protective shells to birds building nests to hunter-gatherers using fire to prepare food. The context in which Krauss formulates the idea of control, however, suggests that he is primarily thinking of ways in which present-day humans in industrial civilization control many aspects of their environment—from food production in industrial agriculture or transportation by road to indoor temperature control using air conditioners and radiators. In a framework that sees humans as thoroughly natural, the difference between organisms' manipulation of their environment and present-day civilization's manipulation of its environment may seem to be a matter of degree: all organisms modify their surroundings, and so do we. This would certainly be in line with Krauss's naturalization of humankind and science. While Krauss does not explicitly frame technology as a natural continuation of organisms' modification of their environment, it is close at hand, and the lack of specificity in "control of our environment" leaves the phrase open to interpretation.

Importantly, however, to view technology as natural does not contradict an emphasis on human uniqueness and superiority. The idea that science and technology enable us to have "greater control of our environment" is related to a celebration of humankind's unique trajectory from hunter-gatherers to urbanites. Since the Enlightenment, the standard narrative of history has been one of gradual growth in knowledge, power, and control: as a species, we have progressed from the primitive to the sophisticated, from ignorant to knowledgeable, from being helpless victims of nature's whims to being rulers of nature and masters of our own fate (Horkheimer & Adorno 2002). We have created a civilization to help and protect us where there only used to be barbarism and misery.

The narrative of progress singles out and cultivates some aspects of science and technology at the expense of others. Even if—and this is a big if—the emergence and growth of civilization is viewed in terms of progress for humans, there are side effects of industrial civilization that are left out in the narrative of progress—in particular, humankind's impact on the biosphere. To be sure, humans have always impacted the environment. The ongoing mass extinction, the sixth in Earth's history, is thought to have been initiated by humans thousands of years ago, primarily through hunting (see Kolbert 2014, with references). However, the pace and scale of human impact on the environment have accelerated—first, with the emergence of agriculture some

10,000 years ago; second, and most significantly, with the advent of fossil fuels as a source of energy about 250 years ago.

Ever since the Industrial Revolution in the late eighteenth century, industrial civilization, and hence science and technology, has been thoroughly dependent upon the use of fossil fuels. As is well known, the use of fossil fuels is causing climate change. Since the late nineteenth century, the global average temperature has risen by about 1.25°C. The time lag in the climate system—it takes about ten years for the temperature effects of emissions of carbon dioxide emissions to be fully realized—guarantees that the Paris target of limiting the global average temperature rise to 1.5°C is impossible to meet without negative emissions technologies (see Helsing 2017, with references). Furthermore, in spite of government pledges and an increase in “green energy,” emissions of greenhouse gases keep rising annually and globally (Saxifrage 2017; Pierre-Louis 2018). It seems that instead of trying to limit or slow down climate change, industrial civilization is consistently and continuously speeding up the process.

One of the fundamental ways in which climate change is manifested is through an increase in extreme weather events, such as storms and heatwaves (Pidcock, Pearce, & McSweeney 2019). Extreme weather events not only impact people directly, for example through flooding or drought, but also indirectly, by disrupting food production and infrastructure. As climate change progresses, it is probable that there will be an increase in agricultural and infrastructural disruptions (Betts, Alfieri, & Bradshaw et al. 2018). If these disruptions become progressively more severe, we will have less and less control of our environment. If, for the sake of argument, technology has given us greater control of our environment, the side effects of the system on which technology depends—industrial civilization—are starting to counteract that control. And if the side effects become sufficiently severe and persistent, then the control that Krauss envisions will evaporate. In a post-civilization world—if such a world is still habitable for humans—individuals may still exert some degree of control over their immediate environment, but large-scale, industrialized control will be long gone.¹⁵⁶

The idea of control and triumph through science and technology assumes that we actually do have control of our environment. It is clear, of course, that

¹⁵⁶ I add “if such a world is still habitable for humans” because in some of the worst-case scenarios of climate change impact, the world will undergo changes of such a magnitude and at such a pace that no humans will be able to survive. See McPherson (2016); Carana (2017); Helsing (2017), with references.

we do control aspects of our environment, for example the temperature in a room with a functioning air conditioner and radiator. But the phrase “greater control of our environment” in the context of the TEUSH narrative may give readers the impression that control over *all* aspects of our environment is possible *in principle*. We may not be there yet, but if we keep developing science and technology we will get there. We will, eventually, have *total* control. In this sense, climate change can be read as a phenomenon that reveals that the idea of “control in principle” is delusional. We were never on a path toward total control. We did not take into account that nature would “strike back,” which means that we never understood the biosphere and industrial civilization’s impact on the biosphere to begin with. The idea of a “controllable environment” in the totalizing sense was always delusional.

*

The idea of triumph through science and technology depends on the idea that they can be divorced from the side effects of the socioeconomic system of which they are a part. I have argued that Krauss and Tyson omit or fail to address questions about these side effects. In their view, science and technology are already forces for good in the world, and with future innovations and better management, science and technology can be used to bring about a utopian society.

My readings suggest that the supposedly triumphant aspects of Krauss’s and Tyson’s political and technological justifications of science are one-sided. Rather than envisioning utopia, the narratives amount to a defense of the status quo. This is not to say that “triumph” is a completely unwarranted term. The construction of the Large Hadron Collider and the discovery of the Higgs boson can be called triumphs of human intelligence and ingenuity. The same can be said of modern medicine and long-distance transportation. But to properly evaluate these achievements, they must be seen in a wider context.

The universal scope claimed for science by Krauss and Tyson is not sufficiently explained or justified in the narratives of triumph and progress. The universal scope is asserted, not supported. Far from it, in fact, because in the context of global wealth disparity and environmental destruction, it seems likely that to the extent that there is triumph, it is localized in space and time. For privileged people in the short-term, science and technology represent triumph; for unprivileged people, for many non-human species, and in the long

term, “triumph” is most likely not an appropriate description. The question is whether the local triumphs of science and technology can be universalized, or whether they are necessarily local.

The question of universalizability, though fundamental, is immeasurably complex, since it requires taking into account a host of issues relating to the ethics of intercultural encounters, the ethics of interspecies encounters, the nature of civilization, the nature of capitalism, the nature of the biosphere, and the nature of the climate system—issues such as how to think about intercultural and interspecies encounters given the history of Western colonialism and imperialism, whether civilization can ever be sustainable, whether increasing standards of living is possible for everyone in a capitalist society, whether capitalism and industrial civilization are desirable to begin with, and whether technology can successfully deal with climate change. Naturally, this falls outside the scope of this dissertation. Instead of pursuing these questions further here, I discuss alternatives to the narratives of triumph and progress characteristic of mainstream popularizations of physics and astronomy in the concluding remarks. Toward the end of the concluding remarks, though, I do return to questions of universalizability and control.

Concluding Remarks

Confusion is a fundamental state of mind.

—Bad Religion, “Sanity” (1989)

In this dissertation, I have analyzed literary techniques and rhetorical strategies used by some contemporary, mainstream, Anglo-American popularizers of physics and astronomy to construct science, the universe, and humankind. In these concluding remarks, I reiterate the main premises and arguments of this dissertation. I then discuss alternatives to the kind of mainstream popular science that has been the focus of this dissertation. I highlight four books that, in different ways, differ from the triumphant and reductionist narratives exemplified by Lawrence Krauss’s *The Greatest Story Ever Told—So Far* and Neil deGrasse Tyson’s *Astrophysics for People in a Hurry*. I end by discussing the concepts of tragedy and wildness as productive counterpoints to triumph and control.

The Literary Construction of the Universe

“Science” is a historically variable, connotationally rich, and contested term. Its contemporary, dominant, mainstream meaning dates from the nineteenth century, when natural philosophy (understanding nature) and technology (manipulating objects) were combined and the resulting hybrid enterprise was professionalized and thus made distinct from amateur pursuits and popularizations. The use of “science” carries weight and credibility in society, at least in many sectors. Yet no single institution, individual, or group of individuals can claim definitional authority over its meaning. At the time when science was taking shape, the Romantics were contesting the reductionist and mechanistic character of Newtonian physics as a valid model for science. Since then, challenges to the prevailing view of science have been presented—e.g. by feminists

and environmentalists—and alternative approaches to science attempted—e.g. Goethean science and Intelligent design.

Yet while “science” is a contested term over which no one can claim definitional authority, science *is* defined and carried out in practice around the world daily. It is defined in dictionaries and mission statements by scientific organizations, in education guidelines and high school curricula, in media coverage and science fiction novels, and through decisions about which projects receive funding and which papers get published in scientific journals. Science is carried out in practice in laboratories, offices, classrooms, and at conferences. Science is also defined and carried out in popular science books.

Popularizers use literary techniques and rhetorical strategies to construct and explain science, to represent the universe and humankind’s place in the universe, and to evoke emotional responses. The two popularizations I have examined specifically—Lawrence Krauss’s *The Greatest Story Ever Told—So Far* (2017) and Neil deGrasse Tyson’s *Astrophysics for People in a Hurry* (2017)—use a number of techniques and strategies to accomplish these aims. These techniques and strategies include boundary work to define science in contrast to other, “non-scientific” human practices and beliefs; defamiliarization to establish science as the foundation of truth and meaning; figurative language and narratives to refamiliarize the reader with a universe defined by science; Romantic tropes and themes such as the exploratory voyage and the genius figure; literary genres such as the detective novel; protagonists of different kinds; and scale comparisons to evoke a sense of awe and wonder.

These techniques and strategies are put to use to construct science as a heroic enterprise through which both individual humans and humankind as a whole may fulfill their true potential and connect with the universe. Science holds the key not only to uncovering the truth about the universe and humankind’s place in the universe, but also to finding true meaning and spiritual fulfillment. The science thus constructed contains a fundamental tension between the “objectivity” of science and “meaningfulness”: on the one hand, science is constructed as something unique, pure, and rational; on the other hand, science is constructed as a provider of meaning and purpose, able to satisfy human needs and emotions.

The fundamental tension between science-as-unique-and-pure and science-as-meaningful gives rise to several ambiguities in the construction of science, humankind, and the universe. For example, the scientist is constructed as someone who is open to the possibility that all scientific theories may be revised, but still contrasts human fallibility with absolute physical laws. Popularizers sometimes invoke physical laws as human constructs, sometimes as

absolutes, and they do so when they want to emphasize different aspects of science. Sometimes the openness of science is emphasized, sometimes its unassailable truth.

Ultimately, the popularizations studied here all idealize science. Science is divorced, for the most part, from historical complexity, problematic ideological baggage, negative social consequences, concrete material preconditions, and the consequences of those preconditions. The guiding narrative in the popularizations under study is what I have called the “triumphant epic of the universe, science, and humankind.” This dissertation has instead historicized the popularizations, highlighted some of the ideological baggage, and teased out unstated presuppositions and meanings. It has identified the appropriation of Romantic themes and tropes by mainstream popularizers. And it has questioned the usefulness and validity of the TEUSH narrative.

Beyond Triumph and Reductionism: Alternative Narratives of Science

As I explained in the introduction, the TEUSH narrative is not all-pervasive in mainstream popularizations of physics and astronomy. Even if the epic scale and the triumphant mode are common and widespread, there are authors and popularizers who engage with science in other ways in their writing. In this section, I discuss four such alternatives, exemplified by four books. They diverge from the TEUSH narrative in a variety of ways. While they do not exhaust the range of alternatives to the triumph narrative, the point of this section is not to paint a comprehensive picture of alternative narratives. Rather, the point is, first, to show that alternatives exist; second, to further defamiliarize mainstream popularizations by contrasting them with alternative narratives; and third, to encourage continued reflection on more productive ways of engaging with science.

Loneliness and Despair in Science

Theoretical cosmologist Janna Levin has published two popular science books: *How the Universe Got Its Spots: Diary of a Finite Time in a Finite Space*

(2002) and *Black Hole Blues: And Other Songs from Outer Space* (2016).¹⁵⁷ Both are somber in tone, thus distinguishing them from the triumphant tone of mainstream popularizations. Here, I focus on Levin's first book.

How the Universe Got Its Spots departs from the narratives of triumph from the very start. The title suggests a non-triumphant tone, directing the reader's attention to the imperfections of the universe. The preface then explains that the book consists of letters, "originally written to Sandy Levin, my mom, my friend" (ix). In other words, rather than addressing a general reader directly, as standard popularizations do, *How the Universe* addresses Levin's mother. Levin thus prepares the reader for a personal narrative, an impression that is reinforced in the next paragraph: "For anyone wanting a less personal account of life in the cosmos, there are many excellent books" (ix). The first paragraph of the first chapter goes on to show that *How the Universe* is not another typical wonder-and-triumph book:

Some of the great mathematicians killed themselves. The lore is that their theories drove them mad, though I suspect they were just lonely, isolated by what they knew. Sometimes I feel the isolation. I'd like to describe what I can see from here, so you can look with me and ease the solitude, but I never feel like giving rousing speeches about billions of stars and the glory of the cosmos. When I can, I like to forget about maths and grants and science and journals and research and heroes. (1)

Somber moods and depressive states recur throughout the book. For example: "Yesterday was a bad day. Couldn't sleep. I had a minor crisis at 2 a.m. wondering what I'm doing with my research" (135), or "Today is a tiring day. Today I myself am a scar of creation. We're all the scars of creation; our thoughts, our pyramids and monuments are the scars of creation" (219). While mainstream popularizers typically do share personal experiences, Levin takes it to another level. She also acknowledges loneliness and human fragility in a way that mainstream popularizers typically do not. Levin is not only open about her thoughts and feeling, she is also open about feeling bad.

Despite the differences, however, *How the Universe* is also similar to mainstream popularizations in some ways. In particular, Levin discusses and reflects on mathematical and physical theories extensively. In this sense, she does what is sometimes taken to be the defining trait of popular science: she explains difficult theories in a pedagogical manner. Furthermore, she

¹⁵⁷ She has also written a novel, *A Madman Dreams of Turing Machines* (2006), a fictionalized account of the lives of the two mathematicians Kurt Gödel and Alan Turing.

popularizes “legitimate science,” defined as the kind of science accepted as “science” by the scientific establishment and mainstream media (see pp. 39–40 in the introduction above). In other words, while the format and the tone of the book diverge from typical popularizations, Levin takes the science itself more or less for granted and popularizes standard scientific theories.

Science as a Golem

STS scholars Harry Collins and Trevor Pinch published a book in 1993 that amounts to a popular science book from an STS perspective: *The Golem: What Everyone Should Know About Science*. Collins and Pinch explain that they wrote *The Golem* for “the general reader who wants to know how science really works and to know how much authority to grant experts; it is for the student studying science at school or university; and it is for those at the very beginning of a course in the history, philosophy or sociology of science. In sum, the book is for the citizen living in a technological society” (1993: x). As a conscious effort to write a popular science book from an STS perspective, it is nothing like the standard narrative of science in mainstream popular science. Collins and Pinch develop a novel metaphor for science, which diverges from the standard metaphors of science as a savior of humanity or a path to truth: the golem. In their words: “A golem is a creature of Jewish mythology. It is a humanoid made by man from clay and water, with incantations and spells. It is powerful. It grows a little more powerful every day. It will follow orders, do your work, and protect you from the ever threatening enemy. But it is clumsy and dangerous. Without control, a golem may destroy its masters with flailing vigour” (1). This, then, is their image of science: a powerful, clumsy, and dangerous creature that was created by people. Collins and Pinch explain that they are going to do “something almost unheard of” in a book about science for the general public: “we are going to display science, with as little reflection on scientific method as we can muster. We are simply going to describe episodes of science, some well known, and some not so well known” (2). The seven chapters cover case studies taken from the history of science, four of which are about physics and astronomy (the remaining three are about chemistry and biology). By abstaining from abstract definitions of “the essence” of science and instead focusing on science in practice, they avoid the idealistic view of science found in mainstream popularizations.

Science in Practice

My next example is Kate Brown's *Manual for Survival: A Chernobyl Guide to the Future* (2019). Unlike the two previous books, this book is not a popular science book first and foremost. Rather, it is a long, detailed, scholarly, historical account of the Chernobyl disaster and its aftermath. It is thus science-in-practice-in-practice, so to speak: a historical account that details, among other things, how nuclear physics and radiation medicine were conducted and used in a politically charged situation by a variety of actors, including the Soviet government, the US government, the UN, and dissenting physicians and scientists.

I include *Manual for Survival* in the discussion about alternative ways to do popular science in order to push back the boundaries of what we may think of as being popular science. In addition to being a scholarly presentation of original research, *Manual for Survival* is accessible and written in a beautiful prose style. Brown figures in the account, interviewing people and traveling around the affected areas. The book was published by Penguin/Allen Lane. It is thus intended for a general audience. In many ways, with its focus on environmental issues, politics, and uses of dangerous technology by people in power, it operates in the same tradition as Rachel Carson's *Silent Spring* (1962).

The account of science in *Manual for Survival* also contrasts sharply with the idealized version of science presented in mainstream popular science. Instead of explaining nuclear physics in a detached manner, Brown goes into the political realities of radiation research and practice. For example, she shows how political agendas heavily influenced what counted as "safe lifetime doses of radiation." She also details instances in which power and privilege shaped what counted as "knowledge" and "legitimate science":

Unfortunately, slander is one tool in the cultivation of knowledge. When villagers said they were sick from Chernobyl fallout, they were derided as frightened and ignorant. When Belarusian scientists who had spent the previous four years studying the effects of Chernobyl exposures said people were ill, they were dismissed as poorly trained and incompetent by experts who visited for just a few days. (212)

Eastern European researchers and citizens were looked down on by Western scientists and officials. This directly contradicts Krauss's utopian idea of science as a universal enterprise transcending national boundaries and gender differences. The denigration of "Soviet science" by Western scientists and officials shows how prejudices and ideologically charged notions can influence

science in actual practice. While this denigration took place in a specific socio-historical context for specific political motives, it would be a mistake to disregard it as an aberration. All uses and developments of science take place in specific contexts, and rather than laud “science” in the abstract, Brown’s example encourages science writers to dive into the specifics of the constructions of science and be attentive to political and economic interests that influence which versions of science that get promoted and why.

Science Reinterpreted

My last example is likely the furthest removed from mainstream popular science: Samantha Frost’s *Biocultural Creatures: Toward a New Theory of the Human* (2016). Frost is a professor of political science, and she explains that she, thanks to a sabbatical and a fellowship, was able to study science, as a student enrolled at the university, full-time for 18 months (22). The result of these activities is a book that reads, simultaneously, as a work of popular science and posthuman theory.

Biocultural Creatures, published by Duke University Press, is aimed at scholars in the humanities. It intervenes in posthuman debates. The reason for discussing the book here is that Frost engages with science—from physics to chemistry to biology—and attempts to explain and reinterpret scientific results in a new, posthuman context. In the first chapter, she situates her arguments in the context of critical thought about the concept of “the human.” She reviews decades of scholarship that reveal the problematic history of the concept—how it has been used to justify racism, sexism, human supremacism, and other forms of exploitation and domination. As Frost explains, because of the historical connections between the universalizing concept of “the human” and scientific discourse, humanist scholars have been skeptical about engaging with the sciences themselves. Frost argues that, in fact, the sciences themselves have begun to undermine the concept of “the human.” Her aim is to show how and why this is happening, to encourage more humanists to engage with the sciences, and to argue that the “critical acumen” of theorists in the humanities is essential “as we reimagine and refigure human being” in the light of new research (20).

The chapters go into the details of atomic structure, chemical reactions, cell membranes, genetics, and the like. Frost explains the scientific theories and results in “lay” terms in a pedagogical manner for readers who are not scientists. To this extent, *Biocultural Creatures* is like a popular science book. In other respects—and in particular, the fact that Frost situates the book in

academic debates and writes for scholars in the humanities—it is a traditional, specialized, academic book. The reason for discussing the book here is, first, to further challenge the standard notion of popular science, and second, to highlight a book that challenges the reductionist and mechanistic versions of science present in mainstream popular science. Frost does not romanticize science in the same vein as the mainstream popularizers; instead, she formulates narratives of science that go against reductionism and mechanization.

Tragedy and Wildness

Perhaps the most salient features of the TEUSH narrative is the idealization of science, the triumphant tone, and the construction of science as the only path to the truth. The narrative reads almost like a stereotypical Hollywood action movie, with science as its protagonist. It is clear to the audience who the hero is and who the villain is. Although it may seem, for a while, as though the villain—usually religion, superstition, relativism, and/or ignorance—is winning, the hero develops and matures, overcomes his (sic) enemies, and ultimately prevails. There is no moral ambiguity, and such surface ambiguities as exist are all revealed to be products of a limited perspective. The limitations are eventually transcended. The hero triumphs and saves the world.

The chosen alternatives challenge this action hero narrative of science in various ways. In Levin (2002), no feelings of glory and triumph accompany the achievements of science. In Collins and Pinch (1993), science is not a hero, but rather an ambiguous and rather foolish creature. In Brown (2019), science serves, in part, the wishes and ideologies of the elite. In Frost (2016), the notion of the “triumphant human” is undermined from within, so to speak, using results from science. Common to all four books is a refusal to build on the idealistic, triumphant construction of science. They emphasize that science exists in a world populated by socially and emotionally complex organisms—and there is no desire to leave that world. Science is shaped, in part, by societal forces, the power of metaphor, and the accidents of history; science is not a historical development of an internally superior logic that just waited to be discovered. Science has consequences in the real world; it is not just an ideal enterprise whose effects remain undisclosed.¹⁵⁸

¹⁵⁸ Levin (2002) stands out somewhat here in that she emphasizes social issues and factors less than the others.

At several points in this dissertation, I have discussed Krauss's invocation of Plato. That invocation is not incidental: like Plato, both Krauss and Tyson idealize knowledge, posit "truth" as an ideal, regard the world of sense experience as illusory or limited, believe in the eradication of ambiguity and incoherence, and assert the moral superiority of the enterprise that seeks "the truth." I have argued that, on the one hand, it is ideologically problematic to idealize science and truth in the manner of Plato, Krauss, and Tyson; and, on the other hand, that in spite of their best efforts, the science that Krauss and Tyson end up constructing actually does incorporate ambiguities and tensions.

In my view, the existence of limitations and ambiguities is not necessarily problematic. What is problematic is the injunction to extinguish limitations and ambiguities from one's worldview—the claim that it is possible and desirable to do so and the claim to have done so already. Even though they acknowledge that the scientific project is still incomplete, Krauss, Tyson, E.O. Wilson, and many other popularizers maintain that they have already found the foundational framework—the TEUSH narrative in particular—within which we are able to reach the truth. All we need to do is to refine that framework, expand it, and implement it everywhere. The framework thus incorporates problematic assumptions about the objectivity and universalizability of the scientific notions and ideas that are currently in use.¹⁵⁹ In this way, questions about unacknowledged ideology—such as misogyny, racism, imperialism, and destruction of the environment—can be brushed aside in the name of "truth," "rationality," and "objectivity." Challenges to that framework can be construed as "unscientific" and hence not be taken seriously. To claim that we have now, finally, found "the method" that allows us to access "the truth" risks disregarding the inevitable historical blind spots that exist in all worldviews. The wish to eradicate limitations and ambiguities materialize in the tone of certainty and the rhetorical technique of deferring to the authority of "science." Again, the

¹⁵⁹ An example from interpretations of sexual dynamics in biology illustrates this. Donna Haraway (1991: 21–42) shows that mid-twentieth century formulations of theories about sexual dynamics were phrased in such a way that they mirrored the subordination of women. Women were passive and receptive. When two female biologists subsequently formulated theories about sexual dynamics in the late 1960s, they instead used the word "female choice," thus construing women as more active. Similarly, biologist Anne Fausto-Sterling (2001) criticizes evolutionary psychologists for using the word "coy" to describe female mating strategies, pointing to the presence of sexually aggressive behavior among female primates. The point here is not just that "passive," "receptive," and "coy" are inaccurate descriptions of behavior; it is also that these terms reflect and reinforce the prevailing societal subordination of women. The general point is that unrecognized prejudices and blind spots, which reflect societal structures and ideologies, can infiltrate scientific—purportedly "objective" and "neutral"—notions and ideas.

problem is not necessarily the existence of limitations and ambiguities. Rather, the problem is the *claim* that science is able to eradicate limitations and ambiguities—and the view that it is desirable to do so.

These questions matter for how we relate to other beings, human and non-human alike. The certainty and one-sidedness associated with scientism risks positing destructive ideals for people, disqualifying marginalized bodies of knowledge, and silencing alternative views. In the final episode of *Cosmos*, Carl Sagan says: “An organism at war with itself is doomed” (Sagan et al. [1980] 2009: episode 13: 24^m38^s–24^m42^s). Sagan says this in the context of advocating for the dismantlement of nuclear weapons; he uses “organism” metaphorically, arguing that a “new consciousness is developing which sees the earth as a single organism” (episode 13: 24^m31^s–24^m38^s). Nonetheless, the metaphor only works if organisms in the literal sense require inner harmony to exist and flourish. Thus, Sagan’s metaphor—which clearly mirrors the unitary view of science and knowledge characteristic of scientism—operates on two levels: that of society, and that of the individual. For Sagan, healthy human beings and societies are harmonious entities.

Laudable as the effort to prevent nuclear war may be, the unity, harmony, and coherence that Sagan advocates is problematic. In his book on tragedy, philosopher Simon Critchley traces the ideal of unity and coherence to Plato, who famously rejected tragedy, and he argues that Plato’s ideal is unrealistic: “We are divided against ourselves in much of our living activity. The burden of proof lies with those theories that aspire to the unity of the psyche and morality. Tragedy describes another state of affairs. It shows us human beings at odds with themselves, often in state of profound contradiction” (73). Critchley locates the confusion, contradiction, and conflict characteristic of ancient tragedies both at the level of the individual and at the level of society. He argues that not only is Plato’s ideal unrealistic—it is also destructive, because it assumes that there is something wrong with people who are conflicted and confused. Rather than positing harmony as the default state from which we have somehow strayed, tragedy shows us a world that is fundamentally characterized by conflict, violence, and war. While this may be a disconcerting perspective, ultimately, Critchley argues, it is productive: “In opposition to forms of vapidly hopeful idealism that leads only to despair, I see tragedy’s philosophy as offering a bracing, skeptical realism that heavily qualifies what we think of as hope, but perhaps also deepens it into a form of courage” (29). And contrary to narratives in which the hero slays the villain and harmony prevails, Greek tragedy, according to Critchley, challenges what we see as heroic: “Greek tragedy is a war story without a John Wayne figure, without a swaggering

individualist who is the sole source of good in a world gone bad. On the contrary, in Greek tragedy, the hero is not the solution to the problem, but the problem itself” (Critchley 2019: 19). A tragic perspective on science in Critchley’s vein is, I posit, more productive than triumphant narratives of science. It does not shy away from portraying confusion, contradiction, and conflict as features of ourselves and the world. It acknowledges that the world is complex, consisting of a multitude of voices and perspectives often in contradiction with each other. It refrains from presuming a form of idealism that disregards the actual world in favor of an abstract narrative in which science ultimately prevails. And it lets us conceptualize science as a hero who is problematic rather than a savior.

In addition to this tragic perspective on science, a concept from environmental discourse highlights the problem of the TEUSH narrative from a complementary perspective. What characterizes science and technology in the triumphant narrative is the ideal of controlling nature, both conceptually and materially. Drawn to its logical endpoint, scientism and the TEUSH narrative aspire to total mastery over all intellectual pursuits and all aspects of the environment. Against this totalizing effort, it is important to emphasize, again, the limitations and ambiguities inherent in human pursuits and perspectives. A particularly productive distinction in this regard is that between “wilderness” and “wildness,” developed by philosopher Christopher J. Preston (2018) and literary scholar Louise Economides (2019).¹⁶⁰ Preston and Economides argue that in the Anthropocene, the notion of “wilderness” has lost its original meaning, since there are no places left on Earth untouched by human activity in one form or other.¹⁶¹ However, this does not exclude the persistence of *wildness*, which they locate in nature, human beings, and human artifacts alike. Wildness denotes the unpredictability and lack of control that can become evident in beings and events whenever and wherever. It is a reminder that we are not in control—that both nature and our creations take on lives of their own, beyond the reach of our technologies and conceptual schemes. Preston emphasizes that this aspect of wildness is a “mixed blessing”:

On the one hand, [wildness] ensures that the beauty, the spontaneity, and the

¹⁶⁰ Economides developed this distinction during her presentation at the 2019 Association for the Study of Literature and Environment (ASLE) Thirteenth Biennial Conference “Paradise on Fire,” June 26, 2019, at University of California, Davis. She referenced Preston (2018) in her presentation.

¹⁶¹ Even remote places, of course, are impacted by anthropogenic changes in the composition of the atmosphere.

enchanting unpredictability of the world outside of our grasp will always exist alongside our inventions. . . . However, there is another side to this wildness that it would be foolish to forget. In its fickleness, its unpredictability, and its capacity continually to exceed our expectations, wildness will ensure that re-making the earth will always remain a game of high chance. When we insert ourselves so deeply into the workings of a planet, we are unlikely to be able to predict all of the consequences of our actions. There are serious risks to letting ourselves be seduced by the sublime beauties of technology. (Preston 2018: 177–178)

Wilderness may be a thing of the past, but wildness is not.

Tragedy and wildness thus challenge the triumphant epic of the universe, science, and humankind in fundamental ways. More than just providing challenges, they can also be used to narrativize science itself. Science is not a John Wayne figure who will deliver the solution to all our problems; it is more like a tragic hero who is problematic in itself. Science is not a domesticator of the wildness of the world; it is, rather, a social phenomenon in whose heart wildness persists, ready to emerge when we least expect it.

References

Popularizations¹⁶²

- Carroll, Sean M. 2010. *From Eternity to Here: The Quest for the Ultimate Theory of Time*. New York: Dutton.
- Collins, Harry, and Trevor Pinch. 1993. *The Golem: What Everyone Should Know about Science*. Cambridge: Cambridge University Press.
- Cox, Brian, and Andrew Cohen. 2011. *Wonders of the Universe*. New York: Harper-Collins.
- Cox, Brian, and Jeff Forshaw. 2009. *Why Does $E=mc^2$? (And Why Should We Care?)* Cambridge, MA: Da Capo Press.
- Davies, Paul. 1987. *The Cosmic Blueprint: New Discoveries in Nature's Creative Ability to Order the Universe*. New York: Simon and Schuster.
- . 1994. *The Last Three Minutes: Conjectures about the Ultimate Fate of the Universe*. New York: Basic Books.
- Dawkins, Richard. 1976. *The Selfish Gene*. Oxford: Oxford University Press.
- . 2006. *The God Delusion*. New York: Bantam Books.
- Deutsch, David. 1997. *The Fabric of Reality: Towards a Theory of Everything*. London: Allen Lane.
- Gladwell, Malcolm. 2005. *Blink: The Power of Thinking without Thinking*. New York: Back Bay Books.
- Gleick, James. 1987. *Chaos: Making a New Science*. New York: Viking Books.
- Gould, Stephen Jay. 1977. *Ever Since Darwin: Reflections in Natural History*. New York: W.W. Norton & Company.
- Greene, Brian. 1999. *The Elegant Universe: Superstrings, Hidden Dimensions, and*

¹⁶² In this section, I only include popularizations from the popular science boom, i.e. from the late 1970s to the present. Popularizations that were published earlier are included in “Critical and Other Works” below, as are works of fiction written by contemporary popularizers. (Although published in 1973, Carl Sagan’s *The Cosmic Connection* is included because Sagan played such an important role in the boom.) I also include popularizations of disciplines other than physics and astronomy, such as biology and Earth science.

- the Quest for the Ultimate Theory*. New York: W.W. Norton & Company.
- . 2004. *The Fabric of the Universe: Space, Time, and the Texture of Reality*. New York: Vintage Books.
- Gribbin, John, and Mary Gribbin. 2000. *Stardust: The Cosmic Recycling of Stars, Planets and People*. London: Allen Lane.
- Hansen, James. 2009. *Storms of My Grandchildren: The Truth about the Coming Climate Catastrophe and Our Last Chance to Save Humanity*. New York and London: Bloomsbury.
- Hawking, Stephen. (1988) 2016. *A Brief History of Time: From Big Bang to Black Holes*. Updated edition. London: Bantam Press.
- Hawking, Stephen, and Leonard Mlodinow. 2010. *The Grand Design*. New York: Bantam Books.
- Hofstadter, Douglas. 1979. *Gödel, Escher, Bach: An Eternal Golden Braid*. New York: Basic Books.
- Kaku, Michio. 1994. *Hyperspace: A Scientific Odyssey Through Parallel Universes, Time Warps, and the Tenth Dimension*. New York and Oxford: Oxford University Press.
- Kolbert, Elizabeth. 2014. *The Sixth Extinction: An Unnatural History*. New York: Henry Holt and Company.
- Krauss, Lawrence. 1995. *The Physics of Star Trek*. New York: HarperCollins.
- . 2011. *Quantum Man: Richard Feynman's Life in Science*. New York and London: W.W. Norton.
- . 2012. *A Universe from Nothing: Why There Is Something Rather Than Nothing*. New York: Free Press.
- . 2017. *The Greatest Story Ever Told—So Far: Why Are We Here?* New York: Atria Books.
- Levin, Janna. 2002. *How the Universe Got Its Spots: Diary of a Finite Time in a Finite Space*. Princeton: Princeton University Press.
- . 2016. *Black Hole Blues: And Other Songs from Outer Space*. New York: Vintage Books.
- Lynas, Mark. 2007. *Six Degrees: Our Future on a Hotter Planet*. London: Fourth Estate.
- Mayr, Ernst. 1997. *This is Biology: The Science of the Living World*. Cambridge, MA: Belknap Press of Harvard University Press.
- Penrose, Roger. 1989. *The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics*. Oxford: Oxford University Press.
- Randall, Lisa. 2011. *Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World*. New York: HarperCollins.
- Rees, Martin. 1999. *Just Six Numbers: The Deep Forces that Shape the Universe*.

- London: Weidenfeld & Nicolson.
- . 2011. *From Here to Infinity: Scientific Horizons*. London: Profile.
- Rovelli, Carlo. 2015. *Seven Brief Lessons on Physics*. Italian original 2014. Translated by Simon Carnell and Erica Segre. London: Penguin.
- Sagan, Carl. 1977. *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*. New York: Ballantine.
- . 1980. *Cosmos*. New York: Random House.
- . (1973) 2000. *The Cosmic Connection: An Extraterrestrial Perspective*. Cambridge: Cambridge University Press.
- Sagan, Carl, et al. (1980) 2009. *Cosmos: A Personal Voyage*. Cosmos Studios. (DVD)
- Tegmark, Max. 2014. *Our Mathematical Universe: My Quest for the Ultimate Nature of Reality*. New York: Random House.
- Tyson, Neil deGrasse. 2017. *Astrophysics for People in a Hurry*. New York and London: Norton.
- Tyson, Neil deGrasse, and Avis Lang. 2018. *Accessory to War: The Unspoken Alliance between Astrophysics and the Military*. New York and London: Norton.
- Weinberg, Steven. 1977. *The First Three Minutes: A Modern View of the Origin of the Universe*. New York: Basic Books.
- . 2015. *To Explain the World: The Discovery of Modern Science*. New York: HarperCollins.
- Wilson, Edward O. 1978. *On Human Nature*. Cambridge, MA: Harvard University Press.
- . 1998. *Consilience: The Unity of Knowledge*. New York: Vintage Books.
- Wolpert, Lewis. 1992. *The Unnatural Nature of Science: Why Science Does Not Make (Common) Sense*. Cambridge, MA: Harvard University Press.

Critical and Other Works

- 500 Women Scientists. 2018. “Bill Nye Does Not Speak for Us and He Does Not Speak for Science.” *Scientific American: Blogs* 30 January. <https://blogs.scientificamerican.com/observations/bill-nye-does-not-speak-for-us-and-he-does-not-speak-for-science/>.
- Abrams, Meyer Howard. 1971. *Natural Supernaturalism: Tradition and Revolution in Romantic Literature*. New York and London: W.W. Norton & Company.
- Abrams, Meyer Howard, and Geoffrey Galt Harpham. (1957) 2012. *A Glossary of Literary Terms*. Tenth edition. Boston: Wadsworth.
- Agar, Jon. 2012. *Science in the Twentieth Century and Beyond*. Cambridge: Polity

Press.

- Agassi, Joseph. 1982. "The Detective Novel and Scientific Method." *Poetics Today* 3(1): 99–108.
- AHD. 2019. "science." *American Heritage Dictionary of the English Language* (website). Accessed July 7. <https://ahdictionary.com/word/search.html?q=science&submit.x=0&submit.y=0>.
- AIP. 2018. "Science Communication Awards." *American Institute of Physics* (website). Accessed July 7. <https://www.aip.org/aip/awards/science-communication..>
- Aït-Touati, Frédérique. 2011. *Fictions of the Cosmos: Science and Literature in the Seventeenth Century*. French original (diss.) 2008. Translated by Susan Emanuel. Chicago & London: The University of Chicago Press.
- Aldhous, Peter, Azeen Ghorayshi, and Virginia Hughes. 2018. "He Became a Celebrity for Putting Science Before God. Now Lawrence Krauss Faces Allegations of Sexual Misconduct." *BuzzFeed* February 22. <https://www.buzzfeednews.com/article/peteraldhous/lawrence-krauss-sexual-harassment-allegations>.
- Alexandrov, Vladimir E. 2007. "Literature, Literariness, and the Brain." *Comparative Literature* 59(2): 97–118.
- Alkestrand, Malin. 2016. *Magiska Möjligheter: Harry Potter, Artemis och Cirkeln i skolans värdegrundarbete*. Göteborg: Makadam.
- Amrine, Frederick, and Francis J. Zucker. 1987. "Introduction." In: Amrine, Frederick, Francis J. Zucker, and Harvey Wheeler (eds.). *Goethe and the Sciences: A Reappraisal*. Dordrecht: D. Reidel Publishing Company. xi–xv.
- Amrine, Frederick, Francis J. Zucker, and Harvey Wheeler (eds.). 1987. *Goethe and the Sciences: A Reappraisal*. Dordrecht: D. Reidel Publishing Company.
- Anderson, Benedict. (1983) 2006. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. Revised Edition. London and New York: Verso.
- Anderson, Hanne, and Brian Hepburn. 2015. "Scientific Method." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Summer 2016 edition. <https://plato.stanford.edu/entries/scientific-method/>.
- APS. 2018. "Ethics and Values: 99.6: 'What is Science?'" *American Physical Society* (website). Accessed July 29. https://www.aps.org/policy/statements/99_6.cfm.
- Bad Religion. 1989. "Sanity." Lyrics by Brett Gurewitz. From the album *No Control*. Los Angeles: Epitaph Records. (CD)
- . 1990. "Faith Alone." Lyrics by Greg Graffin. From the album *Against the Grain*. Los Angeles: Epitaph Records. (CD)
- Baker, Jennifer J. 2007. "Natural Science and the Romanticisms." *A Journal of the American Renaissance* 53(4): 387–412.
- Ball, Philip. 2013. *Curiosity: How Science Became Interested in Everything*. Chicago and London: University of Chicago Press.
- Barad, Karen. 2007. *Meeting the Universe Halfway: Quantum Physics and the*

- Entanglement of Matter and Meaning*. Durham: Duke University Press.
- Bathmaker, Ann-Mari. 2003. "The Expansion of Higher Education: A Consideration of Control, Funding and Quality." In: Bartlett, Steve, and Diana Burton (eds.). *Education Studies: Essential Issues*. London: Sage. 169–189.
- Bauchspies, Wenda K., Jennifer Croissant, and Sal Restivo. 2006. *Science, Technology, and Society: A Sociological Approach*. Malden: Blackwell Publishing.
- Bauer, Henry H. 1992. *Scientific Literacy and the Myth of the Scientific Method*. Urbana and Chicago: University of Illinois Press.
- Bauer, Martin W., and Jane Gregory. 2007. "From Journalism to Corporate Communication in Post-War Britain." In: Bauer, Martin W., and Massimiano Bucchi (eds.). *Journalism, Science, and Society: Science Communication between News and Public Relations*. New York and London: Routledge. 33–51.
- Beagon, Mary. 1992. *Roman Nature: The Thought of Pliny the Elder*. Oxford: Clarendon Press.
- Beer, Gillian. 1983. *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot, and Nineteenth Century Fiction*. London: Routledge and Kegan Paul.
- Bell, Alice R., and Hauke Riesch. 2013. "Researching Popular Science: More Diverse than the Limitations of Apparent Publishing 'Booms'." *Public Understanding of Science* 22(5): 516–520.
- Bell, Alice R., and Jon Turney. 2014. "Popular Science Books: From Public Education to Science Bestsellers." In: Bucchi, Massimiano, and Brian Trench (eds.). *Routledge Handbook of Public Communication of Science and Technology*. London: Routledge. 15–26.
- Bennett, Brett M., and Joseph M. Hodge (eds.). 2011. *Science and Empire: Knowledge and Networks of Science Across the British Empire, 1800–1970*. Basingstoke: Palgrave MacMillan.
- Bennett, Jane. 2001. *The Enchantment of Modern Life: Attachments, Crossings, and Ethics*. Princeton: Princeton University Press.
- Bensaude-Vincent, Bernadette. 1997. "In the Name of Science." In: Krige, John, and Dominique Pestre (eds.). *Science in the Twentieth Century*. Amsterdam: Harwood. 319–338.
- . 2001. "A Genealogy of the Increasing Gap Between Science and the Public." *Public Understanding of Science* 10(1): 99–113.
- . 2009. "A Historical Perspective on Science and Its 'Others.'" *Isis* 100(2): 359–368.
- . 2017. "Science in the Public Sphere: A History of Lay Knowledge and Expertise." *Ambix* 64(2): 199–200.
- Berlin, Isaiah. 2001. *The Roots of Romanticism*. Princeton: Princeton University Press.
- Berlina, Alexandra. 2017. "Translator's Introduction." In: *Viktor Shklovsky: A Reader*. Edited and translated by Alexandra Berlina. New York: Bloomsbury. 1–50.

- Betts, Richard A., Lorenzo Alfieri, Catherine Bradshaw, John Ceasar, Luc Feyen, Pierre Friedlingstein, Laila Gohar, Aristeidis Koutroulis, Kirsty Lewis, Catherine Morfopoulos, Lamprini Papadimitriou, Katy J. Richardson, Ioanna Tsanis, and Klaus Wyser. 2018. "Changes in Climate Extremes, Fresh Water Availability and Vulnerability to Food Insecurity at 1.5°C and 2°C Global Warming with a Higher-Resolution Global Climate Change Model." *Philosophical Transactions of the Royal Society A* 376: article ID 20160452: 27 pp.
- Bloor, David. (1976) 1991. *Knowledge and Social Imagery*. Second edition. Chicago and London: The University of Chicago Press.
- Bohrn, Isabel C., Ulrike Altmann, Oliver Lubrich, Winfried Menninghaus, and Arthur M. Jacobs. 2012. "Old Proverbs in New Skins—An fMRI Study on Defamiliarization." *Frontiers in Psychology* 3: article 204.
- Bordo, Susan R. 1987. *The Flight to Objectivity: Essays on Cartesianism and Culture*. Albany: State University of New York Press.
- Bornmann, Lutz, and Rüdiger Mutz. 2015. "Growth Rates of Modern Science: A Bibliometric Analysis Based on the Number of Publications and Cited References." *Journal of the Association for Information Science and Technology* 66(11): 2215–2222.
- Bortoft, Henri. 1996. *The Wholeness of Nature: Goethe's Way Toward a Science of Conscious Participation in Nature*. New York: Lindisfarne Books.
- Bourdeau, Michel. 2018. "Auguste Comte." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Summer 2018 edition. <https://plato.stanford.edu/entries/comte/>.
- Bowler, Peter J. 2009. *Science for All: The Popularization of Science in Early Twentieth-Century Britain*. Chicago and London: The University of Chicago Press.
- . 2017. *A History of the Future: Prophets of Progress from H.G. Wells to Isaac Asimov*. Cambridge: Cambridge University Press.
- Bowler, Peter J., and Iwan R. Morus. 2005. *Making Modern Science: A Historical Survey*. London and Chicago: The University of Chicago Press.
- Brockman, John. 1995. "Introduction: The Emerging Third Culture." In: Brockman, John (ed.). *The Third Culture: Beyond the Scientific Revolution*. New York: Simon & Schuster. 17–36.
- Brockman, John (ed.). 1995. *The Third Culture: Beyond the Scientific Revolution*. New York: Simon & Schuster.
- Broks, Peter. 2006. *Understanding Popular Science*. Berkshire: Open University Press.
- Brown, Andrew. 2005. "The Hustler." *The Guardian* April 30. <https://www.theguardian.com/books/2005/apr/30/featuresreviews.guardianreview25>.
- Brown, James Robert. 2001. *Who Rules in Science? An Opinionated Guide to the Wars*. Cambridge, MA, and London: Harvard University Press.

- Brown, Kate. 2019. *Manual for Survival: A Chernobyl Guide to the Future*. London: Allen Lane.
- Brown, Marshall. 1993. "Romanticism and Enlightenment." In: Curran, Stuart (ed.). *The Cambridge Companion to British Romanticism*. Cambridge: Cambridge University Press. 34–55.
- Bucchi, Massimiano. 2013. "Style in Science Communication." *Public Understanding of Science* 22(8): 904–915.
- Burkeman, Oliver. 2018. "Is the Absent-Minded Genius Just a Clever Jerk?" *The Guardian* March 30. <https://www.theguardian.com/lifeandstyle/2018/mar/30/absent-minded-professor-oliver-burkeman-change-life>.
- Burnett, Thomas. 2019. "What is Scientism?" *Dialogue on Science, Ethics, and Religion*, at AAAS: American Association for the Advancement of Science (website). Accessed July 12. <https://www.aaas.org/programs/dialogue-science-ethics-and-religion/what-scientism>.
- Burnham, John C. 1987. *How Superstition Won and Science Lost: Popularizing Science and Health in the United States*. New Brunswick: Rutgers University Press.
- Burns, William E. 2000. "Popularization." In: Applebaum, Wilbur (ed.). *Encyclopedia of the Scientific Revolution from Copernicus to Newton*. New York and London: Garland Publishing. 515–517.
- Byrne, Richard W. 2013. "Animal Curiosity." *Current Biology* 23(11): R469–R470.
- Cadenas, Kerensa. 2018. "Neil deGrasse Tyson Denies Sexual Misconduct (Updated)." *Vanity Fair* December 1. <https://www.vanityfair.com/hollywood/2018/12/neil-degrasse-tyson-is-being-investigated-for-alleged-sexual-misconduct>.
- Calsamiglia, Helena. 2003. "Popularization Discourse." *Discourse Studies* 5(2): 139–146.
- Calsamiglia, Helena, and Teun A. van Dijk. 2004. "Popularization Discourse and Knowledge about the Genome." *Discourse and Society* 15(4): 369–389.
- Carana, Sam. 2017. "Abrupt Warming—How Much and How Fast?" *Arctic News* (blog) May 13. <http://arctic-news.blogspot.com/2017/05/abrupt-warming-how-much-and-how-fast.html>.
- Carroll, Joseph, Jonathan Gottschall, John A. Johnson, and Daniel J. Kruger. 2012a. "Graphing Jane Austen: Agonistic Structure in British Novels of the Nineteenth Century." *Scientific Study of Literature* 2(1): 1–24.
- . 2012b. *Graphing Jane Austen: The Evolutionary Basis of Literary Meaning*. New York: Palgrave MacMillan.
- Carruthers, Peter, Stephen Stich, and Michael Siegal (eds.). 2002. *The Cognitive Basis of Science*. Cambridge: Cambridge University Press.
- Carson, Rachel. 1962. *Silent Spring*. Boston: Houghton Mifflin.
- Cartwright, Nancy. 1983. *How the Laws of Physics Lie*. Oxford: Oxford University

Press.

- Castiglione, Davide. 2017. "Difficult Poetry Processing: Reading Times and the Narrativity Hypothesis." *Language and Literature* 26(2): 99–121.
- Cat, Jordi. (2007) 2017. "The Unity of Science." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Fall 2017 edition. <https://plato.stanford.edu/entries/scientific-unity/>.
- CD. 2019. "science." *The Chambers Dictionary* (website). Accessed July 12. <https://chambers.co.uk/search/?query=science&title=21st>.
- CED. 2018. "science. 1. uncountable noun." *Collins English Dictionary* (website). Accessed July 29. <https://www.collinsdictionary.com/dictionary/english/science>.
- . 2019. "science." *Collins English Dictionary* (website). Accessed July 7. <https://www.collinsdictionary.com/dictionary/english/science>.
- Chandler, Daniel, and Rod Munday. (2010) 2016. "Naturalization (naturalizing)." *A Dictionary of Media and Communication*. Second edition. Oxford: Oxford University Press. Online version. <http://www.oxfordreference.com/view/10.1093/acref/9780191800986.001.0001/acref-9780191800986-e-1838?rkey=fLz9eG&result=2067>.
- Chapman, Matthew. 2007. *40 Days and 40 Nights: Darwin, Intelligent Design, God, Oxycontin, and Other Oddities on Trial in Pennsylvania*. New York: HarperCollins.
- Charney, Davida. 2003. "Lone Geniuses in Popular Science: The Devaluation of Scientific Consensus." *Written Communication* 20(3): 215–241.
- Chatman, Seymour. 1978. *Story and Discourse: Narrative Structure in Fiction and Film*. Ithaca and London: Cornell University Press.
- Chico, Tita. 2018. *The Experimental Imagination: Literary Knowledge and Science in the British Enlightenment*. Stanford: Stanford University Press.
- Chimba, Mwenya, and Jenny Kitzinger. 2010. "Bimbo or Boffin? Women in Science: An Analysis of Media Representations and How Female Scientists Negotiate Cultural Contradictions." *Public Understanding of Science* 19(5): 609–624.
- Christianson, Gale E. 1976. "Kepler's *Somnium*: Science Fiction and the Renaissance Scientist." *Science Fiction Studies* 8(3): neither page numbers nor number of pages specified.
- Clarke, Bruce. 1993. "Aspects of the Daemonic in Primo Levi's *Periodic Table*." In: McRae, Murdo William (ed.). *The Literature of Science: Perspectives on Popular Scientific Writing*. Athens and London: The University of Georgia Press. 169–185.
- Clough, Patricia Ticineto, and Jean Halley (eds.). 2007. *The Affective Turn: Theorizing the Social*. Durham: Duke University Press.
- Cohon, Rachel. (2004) 2010. "Hume's Moral Philosophy." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Fall 2010 edition.

<https://plato.stanford.edu/entries/hume-moral/>.

- Coleridge, Samuel Taylor. 1834. *Biographia Literaria; Or, Biographical Sketches of My Literary Life and Opinions*. New York: Leavitt, Lord & Co.
- Collini, Stefan. 1998. "Introduction." In: Snow, C.P. *The Two Cultures*. Cambridge: Cambridge University Press. vii–lxxi.
- . 2013. "Introduction." In: Leavis, F.R. *Two Cultures? The Significance of C.P. Snow*. Cambridge: Cambridge University Press. 1–49.
- Cooter, Roger, and Stephen Pumfrey. 1994. "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture." *History of Science* 32: 237–267.
- Cosmides, Leda, and John Tooby. 1994. "Beyond Intuition and Instinct Blindness: Toward and Evolutionary Rigorous Cognitive Science." *Cognition* 50: 41–77.
- Cox, Virginia. 1992. *The Renaissance Dialogue: Literary Dialogue in its Social and Political contexts, Castiglione to Galileo*. Cambridge: Cambridge University Press.
- Crescioni, A. Will, and Roy F. Baumeister. 2013. "The Four Needs for Meaning, the Value Gap, and How (and Weather) Society Can Fill the Void." In: Hicks, Joshua A., and Clay Routledge (eds.). *The Experience of Meaning in Life: Classical Perspectives, Emerging Themes, and Controversies*. Dordrecht: Springer. 3–15.
- Critchley, Simon. 2019. *Tragedy, the Greeks and Us*. London: Profile Books.
- Culler, Jonathan. 1997. *Literary Theory: A Very Short Introduction*. Oxford: Oxford University Press.
- Cunningham, Andrew, and Nicholas Jardine. 1990. "Introduction: The Age of Reflexion." In: Cunningham, Andrew, and Nicholas Jardine (eds.). *Romanticism and the Sciences*. Cambridge: Cambridge University Press. 1–24.
- Cunningham, Andrew, and Nicholas Jardine (eds.). 1990. *Romanticism and the Sciences*. Cambridge: Cambridge University Press.
- Cunningham, Andrew, and Perry Williams. 1993. "De-Centering the 'Big Picture': *The Origins of Modern Science and the Modern Origins of Modern Science*." *The British Journal for the History of Science* 26(4): 407–432.
- Curd, Patricia. (2007) 2016. "Presocratic Philosophy." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Winter 2016 edition. <https://plato.stanford.edu/entries/presocratics/>.
- Curtis, Ron. 1994. "Narrative Form and Normative Force: Baconian Story-Telling in Popular Science." *Social Studies of Science*, 24(3): 419–461.
- Dahlstrom, Michael F., and Dietram A. Scheufele. 2018. "(Escaping) the Paradox of Scientific Storytelling." *PLOS Biology* 16(10): e2006720.
- Darwin, Charles. 1859. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray, Albemarle Street.

- Daston, Lorraine. 1995. "Curiosity in Early Modern Science." *Word & Image*, 11(4): 391–404.
- Daston, Lorraine, and Katherine Park. 1998. *Wonders and the Order of Nature: 1150–1750*. New York: Zone Books.
- Daum, Andreas W. 2009. "Varieties of Popular Science and the Transformation of Public Knowledge." *Isis* 100(2): 319–332.
- Davidson, Hugh M. 1983. *Blaise Pascal*. Boston: Twayne Publishers.
- Davidson, Keay. 1999. *Carl Sagan: A Life*. New York: John Wiley & Sons.
- Davidson, Richard J., Klaus R. Sherer, and H. Hill Goldsmith (eds.). 2003. *Handbook of Affective Sciences*. Oxford: Oxford University Press.
- Dear, Peter. 2000. "Public Knowledge." In: Applebaum, Wilbur (ed.). *Encyclopedia of the Scientific Revolution from Copernicus to Newton*. New York and London: Garland Publishing. 538–540.
- . 2006. *The Intelligibility of Nature: How Science Makes Sense of the World*. Chicago and London: The University of Chicago Press.
- Denzin, Norman K. 2014. "Symbolic Interactionism and the Media." In: Fortner, Robert S., and P. Mark Fackler (eds.). *The Handbook of Media and Mass Communication Theory*. Two volumes. Malden, MA: John Wiley & Sons. 74–94.
- Douthwaite, John. 2000. *Towards a Linguistic Theory of Foregrounding*. Torino: Edizioni dell'Orso.
- Drouin, Jean-Marc, and Bernadette Bensaude-Vincent. 1996. "Nature for the People." In: Jardine, Nicholas, James A. Secord, and Emma C. Spary (eds.). *Cultures of Natural History*. Cambridge: Cambridge University Press. 408–425.
- Dupré, John. 1993. *The Disorder of Things: Metaphysical Foundations of the Disunity of Science*. Cambridge, MA: Harvard University Press.
- . 2007. "Fact and Value." In: Kincaid, Harold, John Dupré, and Alison Wylie (eds.). *Value-Free Science? Ideals and Delusions*. Oxford: Oxford University Press. 27–41.
- Dyball, Robert, and Barry Newell. 2015. *Understanding Human Ecology: A Systems Approach to Sustainability*. London and New York: Routledge.
- Economides, Louise. 2016. *The Ecology of Wonder in Romantic and Postmodern Literature*. New York: Palgrave MacMillan.
- . 2019. "Synthetic Wilderness in Jeff VanderMeer's Anthropocene." Presentation at *Association for the Study of Literature and Environment (ASLE) Thirteenth Biennial Conference "Paradise on Fire"*. June 26. University of California, Davis. Abstract in conference program, available online, <https://www.asle.org/wp-content/uploads/ASLE2019FinalProgram.pdf>.
- Edford, Rachel. 2007. "The Elegance of *The Elegant Universe*: Unity, Beauty, and Harmony in Brian Greene's Popularization of Superstring Theory." *Public Understanding of Science* 16(4): 441–454.

- Eger, Martin. 1993. "Hermeneutics and the New Epic of Science." In: McRae, Murdo William (ed.). *The Literature of Science: Perspectives on Popular Scientific Writing*. Athens and London: The University of Georgia Press. 186–209.
- Ehrlich, Paul R. 2015. "Foreword: A Challenge for Human Evolution." In: Dyball, Robert, and Barry Newell. *Understanding Human Ecology: A Systems Approach to Sustainability*. London and New York: Routledge. xv.
- Eldelin, Emma. 2006. "*De två kulturerna*" flyttar hemifrån: C.P. Snows begrepp i svensk idédebatt 1959–2006. Stockholm: Carlsson. Diss.
- . 2008. "Vid tänkandets gränser: Om Peter Nilsons essäistik." *Samlaren* 129: 239–269.
- Eriksson, Gunnar, and Lena Svensson. 1986. *Vetenskapen i underlandet: Två studier av populärvetenskap*. Stockholm: Norstedts.
- Erlich, Viktor. (1955) 1965. *Russian Formalism: History—Doctrine*. Second, revised edition. London: Mouton & Co.
- Fahnestock, Jeanne. 1999. *Rhetorical Figures in Science*. New York and Oxford: Oxford University Press.
- Fahy, Declan. 2015. *The New Celebrity Scientists: Out of the Lab and into the Limelight*. Lanham: Rowman & Littlefield.
- Fahy, Declan, and Bruce V. Lewenstein. 2014. "Scientists in Popular Culture: The Making of Celebrities." In: Bucchi, M. & Trench, B. (eds.). *Routledge Handbook of Public Communication of Science and Technology*. London: Routledge. 83–96.
- Fairclough, Norman L. 1985. "Critical and Descriptive Goals in Discourse Analysis." *Journal of Pragmatics*, 9(6): 739–763.
- Fausto-Sterling, Anne. 2001. "Beyond Difference: Feminism and Evolutionary Psychology." In: Rose, Hilary, and Steven Rose (eds.). *Alas, Poor Darwin: Arguments Against Evolutionary Psychology*. London: Vintage. 174–189.
- Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr. 2017. "Introduction." In: Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (eds.). *The Handbook of Science and Technology Studies*. Fourth edition. Cambridge, MA, and London: The MIT Press. 1–26.
- Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (eds.). 2017. *The Handbook of Science and Technology Studies*. Fourth edition. Cambridge, MA, and London: The MIT Press.
- Fernández-Armesto, Felipe. 2001. *Civilizations: Culture, Ambition, and the Transformation of Nature*. New York: Touchstone.
- Feyerabend, Paul. 1975. *Against Method: Outline of an Anarchistic Theory of Knowledge*. London: New Left Books.
- Fialho, Olívia da Costa. 2007. "Foregrounding and Refamiliarization: Understanding Readers' Response to Literary Texts." *Language and Literature* 16(2): 105–123.

- Field, J.V. 1995. *The Invention of Infinity: Mathematics and Art in the Renaissance*. Oxford: Oxford University Press.
- Fine, Cordelia. 2005. *A Mind of Its Own: How Your Brain Distorts and Deceives*. Thriplow: Icon.
- Fisher, Philip. 1998. *Wonder, the Rainbow, and the Aesthetics of Rare Experiences*. Cambridge, MA and London: Harvard University Press.
- Fleck, Ludwik. 1979. *Genesis and Development of a Scientific Fact*. German original 1935. Translated by Fred Bradley and Thaddeus J. Trenn. Chicago and London: The University of Chicago Press.
- Fontenelle, Bernard le Bovier de. 1990. *Conversations on the Plurality of Worlds*. French original 1686. Translated by H.A. Hargreaves. Berkeley and Los Angeles: The University of California Press.
- Fortner, Robert S., and P. Mark Fackler (eds.). 2014. *The Handbook of Media and Mass Communication Theory*. Two volumes. Malden, MA: John Wiley & Sons.
- Foucault, Michel. 1996. *Foucault Live: Collected Interviews, 1961–1984*. Edited by Sylvère Lotringer. New York: Semiotext(e).
- Fowler, Alastair. 1982. *Kinds of Literature: An Introduction to the Theory of Genres and Modes*. Oxford: Oxford University Press.
- Frängsmyr, Tore. 1979. "Inledning." In: Fontenelle, Bernard le Bovier de. *Samtal om världarnas mångfald*. Translated by Jan Stolpe. Uppsala: Bokförlaget Carmina. 5–14.
- Frost, Samantha. 2016. *Biocultural Creatures: Toward a New Theory of the Human*. Durham: Duke University Press.
- Fuller, Robert C. 2006. *Wonder: From Emotion to Spirituality*. Chapel Hill: University of North Carolina Press.
- . 2012. "From Biology to Spirituality: The Emotional Dynamics of Wonder." In: Vasalou, Sophia (red). *Practices of Wonder: Cross-Disciplinary Perspectives*. Eugene: Pickwick Publications. 64–87.
- Fuller, Steve. 1997. *Science*. Minneapolis: The University of Minnesota Press.
- . 2006. *The Philosophy of Science and Technology Studies*. London and New York: Routledge.
- Fyfe, Aileen, and Bernard Lightman. 2007. "Science in the Marketplace: An Introduction." In: Fyfe, Aileen, and Bernard Lightman (eds.). *Science in the Marketplace: Nineteenth-Century Sites and Experiences*. Chicago and London: The University of Chicago Press. 1–19.
- Fyfe, Aileen, and Bernard Lightman (eds.). 2007. *Science in the Marketplace: Nineteenth-Century Sites and Experiences*. Chicago and London: The University of Chicago Press.
- Galilei, Galileo. 2001. *Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican*. Italian original 1632. Translated by Stillman Drake, 1953. New

- York: The Modern Library.
- Galison, Peter, and Bruce Hevly (eds.). 1992. *Big Science: The Growth of Large-Scale Research*. Stanford: Stanford University Press.
- Galison, Peter, and David J. Stump (eds.). 1996. *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford: Stanford University Press.
- Gelbart, Nina Rattner. 1990. "Introduction." In: Fontenelle, Bernard le Bovier de. *Conversations on the Plurality of Worlds*. Translated by H.A. Hargreaves. Berkeley and Los Angeles: The University of California Press. vii–xxxii.
- Genette, Gérard. 1980. *Narrative Discourse: An Essay in Method*. Excerpts from *Figures III*, published in French 1972. Translated by Jane E. Levin. Ithaca: Cornell University Press.
- . 1993. *Fiction and Diction*. French original 1991. Translated by Catherine Porter. Ithaca and London: Cornell University Press.
- Gieryn, Thomas F. 1983. "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists." *American Sociological Review* 48(6): 781–795.
- . 1999. *Cultural Boundaries of Science: Credibility on the Line*. Chicago and London: The University of Chicago Press.
- Gilovich, Thomas, Dale Griffin, and Daniel Kahneman (eds.). 2002. *Heuristics and Biases: The Psychology of Intuitive Judgement*. Cambridge: Cambridge University Press.
- Godfrey-Smith, Peter. 2002. *Theory and Reality: An Introduction to the Philosophy of Science*. Chicago and London: The University of Chicago Press.
- Godhe, Michael. 2003. *Morgondagens experter: Tekniken, ungdomen och framsteget i populärvetenskap och science fiction i Sverige under det långa 1950-talet*. Stockholm: Carlssons. Diss.
- Golinski, Jan. 1998. *Making Natural Knowledge: Constructivism and the History of Science*. Cambridge: Cambridge University Press.
- Gorodeisky, Keren. 2016. "19th Century Romantic Aesthetics." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Fall 2016 edition. <https://plato.stanford.edu/entries/aesthetics-19th-romantic/>.
- Gottlieb, Jacqueline, and Pierre-Yves Oudeyer. 2018. "Towards a Neuroscience of Active Sampling and Curiosity." *Nature Review Neuroscience* 19(12): 758–770.
- Gouyon, Jean-Baptiste. 2014. "Making Science at Home: Visual Displays of Space Science and Nuclear Physics at the Science Museum and on Television in Post-war Britain." *History and Technology* 30(1–2): 37–60.
- Greene, Brian. 2008. *Icarus at the Edge of Time*. New York: Alfred A. Knopf.
- Gregg, Melissa, and Gregory J. Seigworth (eds.). 2010. *The Affect Theory Reader*. Durham: Duke University Press.
- Gregory, Jane, and Steve Miller. 1998. *Science in Public: Communication, Culture,*

- and Credibility*. New York and London: Plenum Trade.
- Griffin, Andrew. 2018. "Stephen Hawking's *A Brief History of Time*: How an Unlikely Book Became a Mainstream Bestseller." *The Independent* March 14. <https://www.independent.co.uk/news/science/stephen-hawking-a-brief-history-of-time-book-theoretical-physics-why-good-a8255251.html>.
- Gross, Alan G. 2018. *The Scientific Sublime: Popular Science Unravels the Mysteries of the Universe*. Oxford: Oxford University Press.
- Gross, Paul, and Norman Levitt. 1994. *Higher Superstition: The Academic Left and Its Quarrels with Science*. Baltimore: The Johns Hopkins University Press.
- Grundmann, Reiner, and Jean-Pierre Cavaillé. 2000. "Simplicity In Science And Its Publics." *Science as Culture* 9(3): 353–389.
- Guillory, John. 1993. *Cultural Capital: The Problem of Literary Canon Formation*. Chicago and London: The University of Chicago Press.
- Gunnarsson, Andreas. 2012. *Unleashing Science Popularization: Studies on Science as Popular Culture*. Gothenburg: University of Gothenburg. Diss.
- Hadot, Pierre. 2002. *What is Ancient Philosophy?* French original 1995. Translated by Michael Chase. Cambridge, MA, and London: The Belknap Press of Harvard University Press.
- Hadzigeorgiou, Yannis, and Roland Schulz. 2014. "Romanticism and Romantic Science: Their Contribution to Science Education." *Science & Education* 23(10): 1963–2006.
- Haidt, Jonathan. 2012. *The Righteous Mind: Why Good People are Divided by Politics and Religion*. New York: Pantheon Books.
- Hansen, Anders. 1994. "Journalistic Practices and Science Reporting in the British Press." *Public Understanding of Science* 3(2): 111–134.
- Haraway, Donna J. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14(3): 575–599.
- . 1991. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge.
- . 2016. *Staying with the Trouble: Making Kin in the Chthulucene*. Durham and London: Duke University Press.
- Harding, Sandra (ed.). 2011. *The Postcolonial Science and Technology Reader*. Durham: Duke University Press.
- Harris, Sam. 2010. *The Moral Landscape: How Science Can Determine Human Values*. London: Bantam Press.
- Harrison, Peter. 2015. *The Territories of Science and Religion*. Chicago and London: The University of Chicago Press.
- . 2017. "Science and Secularization." *Intellectual History Review* 27(1): 47–70.

- Harvey, David. 2010. *A Companion to Marx's Capital*. London and New York: Verso.
- Hættner Aurelius, Eva. 2014. "Genrens rörlighet: Genredefinitionens dilemma sett i ett semantiskt perspektiv." *Tidskrift för litteraturvetenskap* 44(3-4): 95–104.
- Hawkins, Mike. 1997. *Social Darwinism in European and American Thought 1860–1945: Nature as Model and Nature as Threat*. Cambridge: Cambridge University Press.
- Haynes, Roslynn D. 2017. *From Madman to Crime Fighter: The Scientist in Western Culture*. Baltimore: Johns Hopkins University Press.
- Heath, Joseph. 2017. "Absent-Mindedness as Dominance Behaviour." *In Due Course: A Canadian Public Affairs Blog* September 5. <http://induecourse.ca/absent-mindedness-as-dominance-behaviour/>.
- Heidegger, Martin. (1954) 1977. "The Question Concerning Technology." In: Heidegger, Martin, and William Lovit (ed.). *The Question Concerning Technology and Other Essays*. Translated by William Lovitt. New York: Harper Colophon Books.
- Heilbron, John L. 2001. "Introduction." In: Galilei, Galileo. 2001. *Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican*. Italian original 1632. Translated by Stillman Drake, 1953. New York: The Modern Library. xii–xxii.
- . 2003. "Scientist." In: Heilbron, John L. (ed.). *The Oxford Companion to the History of Modern Science*. Oxford: Oxford University Press. 744–745.
- Helsing, Daniel. 2013. "'Mitt i evigheten': Gestaltningen av den moderna naturvetenskapens kosmos i Peter Nilsons *Stjärnvägar*." *Sammlaren* 134: 198–221.
- . 2016. "Uses of Wonder in Popular Science: *Cosmos: A Personal Voyage* and the Origin of Life." *International Journal of Astrobiology* 15(4): 271–276.
- . 2017. "Blues for a Blue Planet: Narratives of Climate Change and the Anthropocene in Nonfiction Books." *Evolutionary Studies in Imaginative Culture* 1(2): 39–57.
- Hemmungs Wirtén, Eva. 2015. *Making Marie Curie: Intellectual Property and Celebrity Culture in an Age of Information*. Chicago and London: The University of Chicago Press.
- Henrich, Joseph. 2016. *The Secret of Our Success: How Culture Is Driving Human Evolution, Domesticating Our Species, and Making Us Smarter*. Princeton: Princeton University Press.
- Henrich, Joseph, Steven J. Heine, and Ara Norenzayan. 2010. "The Weirdest People in the World?" *Behavioral and Brain Sciences*, 33: 61–135.
- Heringman, Noah. 2003. "Introduction: The Commerce of Literature and Natural History." In: Heringman, Noah (ed.). *Romantic Science: The Literary Forms of Natural History*. Albany: State University of New York Press. 1–19.
- Heringman, Noah (ed.). 2003. *Romantic Science: The Literary Forms of Natural*

- History*. Albany: State University of New York Press.
- Hicks, Joshua A., and Clay Routledge. 2013. "Introduction." In: Hicks, Joshua A., and Clay Routledge (eds). *The Experience of Meaning in Life: Classical Perspectives, Emerging Themes, and Controversies*. Dordrecht: Springer. ix–xii.
- Hicks, Joshua A., and Clay Routledge (eds.). 2013. *The Experience of Meaning in Life: Classical Perspectives, Emerging Themes, and Controversies*. Dordrecht: Springer.
- Highfield, Roger. 2011. "The Brian Cox Effect is a Star Turn." *The Telegraph* September 6. <https://www.telegraph.co.uk/news/science/roger-highfield/8742949/The-Brian-Cox-effect-is-a-star-turn.html>.
- Hilgartner, Stephen. 1990. "The Dominant View of Popularization: Conceptual Problems, Political Uses." *Social Studies of Science* 20(3): 519–539.
- Hogan, Patrick Colm. 2016. *Beauty and Sublimity: A Cognitive Aesthetics of Literature and the Arts*. Cambridge: Cambridge University Press.
- . 2018. *Literature and Emotion*. London and New York: Routledge.
- Hogle, Jerrold E. 2010. "Romanticism and the 'schools' of criticisms and theory." In: Curran, Stuart (ed.). *The Cambridge Companion to British Romanticism*. Cambridge: Cambridge University Press. 1–33.
- Holdrege, Craig. 2014. "Goethe and the Evolution of Science." *In Context* 31(1): 10–23.
- Holmes, Richard. 2008. *The Age of Wonder: How the Romantic Generation Discovered the Beauty and Terror of Science*. London: Harper Press.
- . 2014. "In Retrospect: On the Connexion of the Physical Sciences." *Nature* 514: 432–433.
- Holwerda, Gus (dir.). 2014. *The Unbelievers*. London: Revelations Films. (DVD)
- Horkheimer, Max, and Theodor W. Adorno. 2002. *Dialectic of Enlightenment: Philosophical Fragments*. German original 1944. Translated by Edmund Jephcott. Stanford: Stanford University Press.
- Hornborg, Alf. 2001. *The Power of the Machine: Global Inequalities of Economy, Technology, and Environment*. Walnut Creek: AltaMira Press.
- . 2016. *Global Magic: Technologies of Appropriation from Ancient Rome to Wall Street*. Basingstoke and New York: Palgrave MacMillan.
- Hughes, Austin L. 2012. "The Folly of Scientism." *The New Atlantis* #37, Fall issue. 32–50.
- Hui, Andrew. 2013. "Horatio's Philosophy in *Hamlet*." *Renaissance Drama* 41(1/2): 151–171.
- Humes, Edward. 2007. *Monkey Girl: Evolution, Education, Religion, and the Battle for America's Soul*. New York: HarperCollins.
- Itzkoff, Dave. 2011. "'Family Guy' Creator Part of 'Cosmos' Update." *The New York*

- Times* August 5. <https://www.nytimes.com/2011/08/05/arts/television/fox-plans-new-cosmos-with-seth-macfarlane-as-a-producer.html>.
- Ivanova, Milena. 2017. "Poincaré's Aesthetics of Science." *Synthese* 194(7): 2581–2594.
- Jacobs, Arthur M. 2015. "Neurocognitive Poetics: Methods and Models for Investigating the Neuronal and Cognitive-Affective Bases of Literature Reception." *Frontiers in Human Neuroscience* 9: article 136: 22 pp.
- Jasanoff, Sheila. 2017. "Science and Democracy." In: Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (eds.). *The Handbook of Science and Technology Studies*. Fourth edition. Cambridge, MA, and London: The MIT Press. 259–287.
- Jean, James. (1930) 1931. *The Mysterious Universe*. Second edition. Cambridge: Cambridge University Press.
- Jensen, Derrick. 2006. *Endgame, Volume 1: The Problem of Civilization*. New York: Seven Stories Press.
- Johansson, Kaj. 2003. *Den torgförda biologin: Studier i populärvetenskapens problem och tematik*. Gothenburg: University of Gothenburg. Diss.
- Johnsson, Henrik. 2015. *Det oändliga sammanhanget: August Strindbergs ockulta vetenskap*. Stockholm: Malört.
- Jones III, John E. 2005. "Tammy Katzmilller, et al. Plaintiffs v. Dover Area School District, et al., Defendants. Memorandum Opinion December 20, 2005." Accessed at ACLUs (American Civil Liberties Union) website, www.aclu.org. Memorandum Opinion downloaded at <https://www.aclu.org/legal-document/kitzmiller-v-dover-memorandum-opinion>.
- Jonsson, Emelie. 2017. *Imagining a Place in Nature: Using Evolution to Explain the Early Evolutionary Imagination in Literature*. Gothenburg: University of Gothenburg. Diss.
- Josephson-Storm, Jason Å. 2017. *The Myth of Disenchantment: Magic, Modernity, and the Birth of the Human Sciences*. Chicago and London: The University of Chicago Press.
- Kafka, Alexander C. 2018. "'Sokal Squared: Is Huge Publishing Hoax 'Hilarious and Delightful' or an Ugly Example of Dishonesty and Bad Faith?'" *The Chronicle of Higher Education* October 3. <https://www.chronicle.com/article/Sokal-Squared-Is-Huge-244714>.
- Kamma, Harmke, and Geert Somson (eds.). 2016. *Pursuing the Unity of Science: Ideology and Scientific Practice from the Great War to the Cold War*. London and New York: Routledge.
- Kärnfelt, Johan. 2000. *Mellan nytta och nöje: Ett bidrag till populärvetenskapens historia i Sverige*. Stockholm/Stehag: Brutus Östlings Bokförlag Symposion. Diss.
- . 2004. *Till stjärnorna: Studier i populärastronomins vetenskapshistoria under*

- tidigt svenskt 1900-tal*. Göteborg: Folkuniversitets Akademiska Press.
- . 2009. *Allt mellan himmel och jord: Om Knut Lundmark, astronomin och den publika kunskapsbildningen*. Lund: Nordic Academic Press.
- Keats, John. 1820. "Ode on a Grecian Urn." In: Prickett, Stephen, and Simon Haines (eds.). 2010. *European Romanticism: A Reader*. London: Bloomsbury. 80–82.
- Keeny, Elizabeth. 2001. "Popularization of Science." In: Rothenberg, Marc (ed.). *The History of Science in the United States: An Encyclopedia*. New York and London: Garland Publishing. 448–449.
- Kelemen, Deborah, and Evelyn Rosset. 2009. "The Human Function Compunction: Teleological Explanations in Adults." *Cognition* 111(1): 138–143.
- Keller, Evelyn Fox. 1985. *Reflections on Gender and Science*. New Haven and London: Yale University Press.
- Keltner, Dacher, and Jonathan Haidt. 2003. "Approaching Awe, a Moral, Spiritual, and Aesthetic Emotion." *Cognition and Emotion* 17(2): 297–314.
- Kennedy, John F. (1961) 2004. "Excerpt from the 'Special Message to the Congress on Urgent National Needs.'" *NASA History* (website) May 24. https://www.nasa.gov/vision/space/features/jfk_speech_text.html.
- Kennefick, Daniel. 2009. "Testing Relativity from the 1919 Eclipse—A Question of Bias." *Physics Today* 62(3): 37–42.
- Kenny, Anthony. 2004. *A New History of Western Philosophy: Volume 1: Ancient Philosophy*. Oxford: Clarendon Press.
- Kern, Stephen. 2011. *The Modernist Novel: A Critical Introduction*. Cambridge: Cambridge University Press.
- Khalifa, Jean. 2003. "Pascal's Theory of Knowledge." In: Hammond, Nicholas (ed.). *The Cambridge Companion to Pascal*. Cambridge: Cambridge University Press. 122–143.
- Kidd, Celeste, and Benjamin Y. Hayden. 2015. "The Psychology and Neuroscience of Curiosity." *Neuron* 88(3): 449–460.
- King, John T. 2004. "Service-Learning as a Site for Critical Pedagogy: A Case for Collaboration, Caring, and Defamiliarization across Borders." *Journal of Experiential Education* 26(3): 121–137.
- King, Laura A., Samantha J. Heintzelman, and Sarah J. Ward. 2016. "Beyond the Search for Meaning: Contemporary Science of the Experience of Meaning in Life." *Current Directions in Psychological Science* 25(4): 211–216.
- Knight, David. 2009. *The Making of Modern Science: Science, Technology, Medicine, and Modernity: 1789–1914*. Cambridge: Polity Press.
- Knudsen, Susanne. 2005. "Communicating Novel and Conventional Scientific Metaphors: A Study of the Development of the Metaphor of Genetic Code." *Public Understanding of Science* 14(4): 373–392.
- Koopman, Eva Maria (Emy). 2016. "Effects of 'Literariness' on Emotions and

- Empathy and Reflection after Reading.” *Psychology of Aesthetics, Creativity, and the Arts* 10(1): 82–98.
- Koren, Marina. 2018. “Lawrence Krauss and the Legacy of Harassment in Science.” *The Atlantic* October 24. <https://www.theatlantic.com/science/archive/2018/10/lawrence-krauss-sexual-misconduct-me-too-arizona-state/573844/?fbclid=IwAR2ZjCaDUlzmrm9WgomUeA3J7eNtdWM-T3so-RyVpceqZJArhSs3LHsVw8rA>.
- Kraut, Richard. 2018. “Aristotle’s Ethics.” In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Summer 2018 edition. <https://plato.stanford.edu/entries/aristotle-ethics/#Aca>.
- Kuhn, Thomas. (1962) 1996. *The Structure of Scientific Revolutions*. Third edition. Chicago and London: The University of Chicago Press.
- Kuritz, Hyman. 1981. “The Popularization of Science in Nineteenth-Century America.” *History of Education Quarterly* 21(3): 259–274.
- Kuzmičová, Anežka, Anne Mangen, Hildegunn Støle, and Anne Charlotte Begnum. 2017. “Literature and Readers’ Empathy: A Qualitative Text Manipulation Study.” *Language and Literature* 26(2): 137–152.
- Ladyman, James, and Don Ross. 2013. “The World in the Data.” In: Ross, Don, James Ladyman, and Harold Kincaid (eds.). *Scientific Metaphysics*. Oxford: Oxford University Press. 108–150.
- LaFollette, Marcel Chotkowski. 2014. “Popularization of Science.” In: Slotten, Hugh Richard (ed.). *The Oxford Encyclopedia of the History of American Science, Medicine, and Technology. Volume 2: Machinery and Manufacturing—Zworykin, Vladimir Kosma*. Oxford: Oxford University Press. 267–282.
- Landy, Joshua, and Michael Saler (eds.). 2009. *The Re-Enchantment of the World: Secular Magic in a Rational Age*. Stanford: Stanford University Press.
- Latour, Bruno. 1999. *Pandora’s Hope: Essays on the Reality of Science Studies*. Cambridge, MA and London: Harvard University Press.
- Law, John. 2017. “STS as Method.” In: Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (eds.). *The Handbook of Science and Technology Studies*. Fourth edition. Cambridge, MA, and London: The MIT Press. 31–57.
- Leane, Elizabeth. 2007. *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies*. Aldershot: Ashgate.
- Leavis, F.R. (1962) 2013. *Two Cultures? The Significance of C.P. Snow*. Cambridge: Cambridge University Press.
- Leech, Geoffrey. 2008. *Language in Literature: Style and Foregrounding*. Harlow: Pearson Education Unlimited.
- Lenau, Nikolaus. (1840) 2017. *Faust: Ein Gedicht*. Berlin: Hofenberg Sonderausgabe.
- Leonard, Annie. 2010. *The Story of Stuff: How Our Obsession with Stuff Is Trashing the Planet, Our Communities, and Our Health—And a Vision for Change*. New

- York: The Free Press.
- Leslie, Ian. 2014. *Curious: The Desire to Know and Why Your Future Depends on It*. London: Quercus.
- Lessl, Thomas M. 1985. "Science and the Sacred Cosmos: The Ideological Rhetoric of Carl Sagan." *Quarterly Journal of Speech* 71(2): 175–187.
- . 1989. "The Priestly Voice." *Quarterly Journal of Speech* 75(2): 183–197.
- . 1996. "Naturalizing Science: Two Episodes in the Evolution of a Rhetoric of Scientism." *Western Journal of Communication (includes Communication Reports)* 60(4): 379–396.
- . 1999. "The Galileo Legend as Scientific Folklore." *Quarterly Journal of Speech* 85(2): 146–168.
- . 2007. "The Culture of Science and the Rhetoric of Scientism: From Francis Bacon to the Darwin Fish." *Quarterly Journal of Speech* 93(2): 123–149.
- Levin, Janna. 2006. *A Madman Dreams of Turing Machines*. New York: Knopf.
- Levine, George. 1988. *Darwin and the Novelists: Patterns of Science in Victorian Fiction*. Chicago and London: The University of Chicago Press.
- Lewenstein, Bruce V. 1987. "Was There Really a Popular Science 'Boom'?" *Science, Technology, & Human Values* 12(2): 29–41.
- . 1992. "The Meaning of 'Public Understanding of Science' in the United States after World War II." *Public Understanding of Science* 1(1): 45–68.
- . 1995. "From Fax to Facts: Communication in the Cold Fusion Saga." *Social Studie of Science* 25(3): 403–436.
- . 2002. "How Science Books Drive Public Discussion." In: Porter, G. (ed.). *Communicating the Future: Best Practices for Communication of Science and Technology to the Public*. Washington: GPO. 69–76.
- . 2003. "Popularization." In: Heilbron, John L. (ed.). *The Oxford Companion to the History of Modern Science*. Oxford: Oxford University Press. 667–668.
- . 2007. "Why should we care about science books?" *Journal of Science Communication* 6(1): C03.
- . 2009. "Science Books Since 1945." In: Nord, D.P.; Rubin, J.S. & Schudson, M. (eds.). *The Enduring Book: Print Culture in Postwar America*. Chapel Hill: University of North Carolina Press. 347–360.
- . 2013. "The 'Problem' of Public Understanding of Science: Public Knowledge of, Attitudes Towards, and Interests in Science." Symposium presentation at *US National Academy of Sciences Roundtable in Public Interfaces of the Life Sciences*, August, Washington, DC. Link to audio recording available at Bruce Lewenstein's website, <https://blogs.cornell.edu/lewenstein/watch-me-on-video/>. Accessed July 29, 2018.
- Lexico. 2019a. "mainstream. noun." *Lexico* (website). Accessed July 7. <https://www.lexico.com/en/definition/mainstream>.

- . 2019b. “mainstream media. noun.” *Lexico* (website). Accessed July 7. https://www.lexico.com/en/definition/mainstream_media.
- . 2019c. “science.” <https://www.lexico.com/en/definition/science>.
- Lightman, Bernard. 2007. *Victorian Popularizers of Science: Designing Nature for New Audiences*. Chicago and London: The University of Chicago Press.
- . 2010. “Darwin and the Popularization of Evolution.” *Notes and Records: The Royal Society Journal of the History of Science* 64(1): 5–24.
- . 2016. “Introduction.” In: Lightman, Bernard (ed.). *A Companion to the History of Science*. West Sussex: Wiley Blackwell. 1–6.
- Lindberg, David C. (1992) 2007. *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, Pre-history to A.D. 1450*. Second edition. Chicago and London: The University of Chicago Press.
- Llobera, Josep R. 2003. *An Invitation to Anthropology: The Structure, Evolution, and Cultural Identity of Human Societies*. New York and Oxford: Berghahn.
- Locke, Simon. 2011. *Re-crafting Rationalization: Enchanted Science and Mundane Mysteries*. Farnham: Ashgate.
- Loewenstein, George. 1994. “The Psychology of Curiosity: A Review and Reinterpretation.” *Psychological Bulletin* 116(1): 75–98.
- Lutz, Ashley. 2012. “These 6 Corporations Control 90% of the Media in America.” *Business Insider* June 14. <https://www.businessinsider.com/these-6-corporations-control-90-of-the-media-in-america-2012-6?r=US&IR=T>.
- Luzón, María José. 2013. “Public Communication of Science in Blogs: Recontextualizing Scientific Discourse for a Diversified Audience.” *Written Communication* 30(4): 428–457.
- Lyons, Sara. 2014. “The Disenchantment/Re-enchantment of the World: Aesthetics, Secularization, and the Gods of Greece from Friedrich Schiller to Walter Pater.” *The Modern Language Review* 109(4): 873–895.
- Lyotard, Jean-François. 1984. *The Postmodern Condition: A Report on Knowledge*. French original 1979. Translated by Geoff Bennington and Brian Massumi. Minneapolis: The University of Minnesota Press.
- Mahrt, Merja, and Cornelius Puschmann. 2014. “Science Blogging: An Exploratory Study of Motives, Styles, and Audience Reactions.” *Journal of Science Communication* 13(3): A05.
- Marchant, Jo. 2011. “Why are So Few Popular Science Books Written by Women?” *The Guardian* October 4. <https://www.theguardian.com/science/blog/2011/oct/04/popular-science-books-women>.
- Marsh, Oliver. 2016. “‘People Seem to Really Enjoy the Mix of Humour and Intelligence’: Science Humour in Online Settings.” *Journal of Science Communication* 15(2): C03.

- Masur, Louis P. 1993. "Stephen J. Gould's Vision of History." In: McRae, Murdo William (ed.). *The Literature of Science: Perspectives on Popular Scientific Writing*. Athens and London: The University of Georgia Press. 113–131.
- Mathavan, S., M.R. Jackson, and R.M. Parkin. 2010. "A Theoretical Analysis of Billiard Ball Dynamics under Cushion Impacts." *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science* 224(9): 1863–1873.
- McClellan, James E. 1985. *Science Reorganized: Scientific Societies in the Eighteenth Century*. New York: Columbia University Press.
- McCombs, Maxwell E., and Lei Gou. 2014. "Agenda-Setting Influence of the Media in the Public Sphere." In: Fortner, Robert S., and P. Mark Fackler (eds.). *The Handbook of Media and Mass Communication*. Chichester: John Wiley & Sons. 251–268.
- McCombs, Maxwell E., and Donald L. Shaw. 1972. "The Agenda-Setting Function of Mass Media." *The Public Opinion Quarterly* 36(2): 176–187.
- McMullin, Ernan. 2011. "Varieties of Methodological Naturalism." In: Gordon, Bruce L., and William A. Demski (eds.). *The Nature of Nature: Examining the Role of Naturalism in Science*. Wilmington: ISI Books. 82–94.
- McPherson, Guy. 2016. "Climate-Change Summary and Update." *Nature Bats Last* (blog) August 2. <https://guymperson.com/climate-chaos/climate-change-summary-and-update/>.
- McRae, Murdo William (ed.). 1993. *The Literature of Science: Perspectives on Popular Scientific Writing*. Athens and London: The University of Georgia Press.
- Mellor, Felicity. 2003. "Between Fact and Fiction: Demarcating Science from Non-Science in Popular Physics Books." *Social Studies of Science* 33(4): 509–538.
- Merchant, Carolyn. 1980. *The Death of Nature: Women, Ecology and the Scientific Revolution*. San Francisco: Harper & Row.
- Miall, David S. 2006. *Literary Reading: Empirical and Theoretical Studies*. New York: Peter Lang.
- Miall, David S., and Don Kuiken. 1994. "Foregrounding, Defamiliarization, and Effect: Response to Literary Stories." *Poetics* 22(5): 389–407.
- Midgley, Mary. 1992. *Science as Salvation: A Modern Myth and Its Meaning*. London: Routledge.
- Miller, Jon D. 1998. "The Measurement of Civic Scientific Literacy." *Public Understanding of Science* 7(3): 203–223.
- Milman, Oliver. 2017. "Bill Nye the Science Guy on Trump: 'We are in a Dangerous Place.'" *The Guardian* April 22. <https://www.theguardian.com/science/2017/apr/22/bill-nye-the-science-guy-donald-trump-march-washington>.
- Mirowski, Philip. 2011. *Science-Mart: Privatizing American Science*. Cambridge, MA, and London: Harvard University Press.

- MMD. 2019. "science." *MacMillan Dictionary* (website). Accessed July 12. <https://www.macmillandictionary.com/dictionary/british/science>.
- Morus, Iwan Rhys. 2005. *When Physics Became King*. Chicago and London: The University of Chicago Press.
- Mugglestone, Lynda. 2011. *Dictionaries: A Very Short Introduction*. Oxford: Oxford University Press.
- Munroe, Randall. 2008. "Purity." *xkcd: A Webcomic of Romance, Sarcasm, Math, and Language*, #435 June 11. www.xkcd.com. <https://xkcd.com/435/>.
- Murphy, Trevor. 2004. *Pliny the Elder's Natural History: The Empire in the Encyclopedia*. Oxford: Oxford University Press.
- MW. 2019. "science." *Merriam-Webster* (website). Accessed July 12. <https://www.merriam-webster.com/dictionary/science>.
- Myers, Greg. 1985. "Nineteenth-Century Popularizations of Thermodynamics and the Rhetoric of Social Prophecy." *Victorian Studies* 29(1): 35–66.
- . 2003. "Discourse Studies of Scientific Popularization: Questioning the Boundaries." *Discourse Studies* 5(2): 265–279.
- Naish, Darren. 2017. "The 'Birds Are Not Dinosaurs' Movement." *Scientific American: Blogs* November 15. <https://blogs.scientificamerican.com/tetrapod-zoology/the-birds-are-not-dinosaurs-movement/>.
- NASA. 2018. "What is Science?" *NASA Space Place: Explore Earth and Space!* (website). Accessed July 29. <https://spaceplace.nasa.gov/science/en/>.
- . 2019. "Cosmic Origins." *NASA* (website). Accessed July 12. <https://cor.gsfc.nasa.gov>.
- National Research Council. 1996. *National Science Education Standards*. Washington, DC: The National Academies Press. Published online at <https://www.nap.edu/catalog/4962/national-science-education-standards>.
- . 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: The National Academies Press. Published online at <https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states>.
- Nickles, Thomas. 2006. "Problem of Demarcation." In: Sarkar, Sahotra, and Jessica Pfeifer (eds.). *The Philosophy of Science: An Encyclopedia: 2-Volume Set*. New York and London: Routledge. 188–197.
- Nielsen, Henrik Skov. 2015. "Fiktion." In: Kjaeldgaard, Lasse Horne, Lis Møller, Dan Ringgard, Lilian Munk Rösing, and Peter Simonsen (eds.). *Litteratur: Introduktion till teori och analys*. Danish original 2012. Translated by Sven-Erik Thorell. Lund: Studentlitteratur. 185-196.
- Nieman, Adam. 2000. *The Popularisation of Physics: Boundaries of Authority and the Visual Culture of Science*. Bristol: University of the West of England. Diss.
- Nieto-Galan, Agustí. 2016. *Science in the Public Sphere: A History of Lay Knowledge*

- and Expertise*. Spanish original 2011. Translated by Fiona Kelso. London and New York: Routledge.
- Nightingale, Andrea Wilson. 2004. *Spectacles of Truth in Classical Greek Philosophy: Theoria in its Cultural Context*. Cambridge: Cambridge University Press.
- Nisbet, H. Barry. 1972. *Goethe and the Scientific Tradition*. London: Institute of Germanic Studies.
- Nixon, Rob. 2011. *Slow Violence and the Environmentalism of the Poor*. Cambridge, MA: Harvard University Press.
- North, Anna. 2019. "After Investigating Neil deGrasse Tyson for Sexual Misconduct, TV Networks Aren't Sharing Details." *Vox* March 20. <https://www.vox.com/identities/2019/3/20/18271509/neil-degrasse-tyson-investigation-2019-tchiya-amet>.
- NSB. 2018. *Science and Engineering Indicators 2018*. Produced by National Science Board. Published online at <https://www.nsf.gov/statistics/2018/nsb20181/>.
- NSF. 2019a. "About the National Science Foundation." *National Science Foundation* (website). Accessed July 12. <https://www.nsf.gov/about/>.
- . 2019b. "Research Areas." *National Science Foundation* (website). Accessed July 12. https://www.nsf.gov/about/research_areas.jsp.
- Oaksford, Mike, Nick Chater, and Neil Stewart. 2012. "Reasoning and Decision Making." In: Frankish, Keith, and William Ramsey (eds.). *The Cambridge Handbook of Cognitive Science*. 131–150.
- O'Brien, Conan. 2017. "Neil deGrasse Tyson Explains the Cosmic Perspective—Conan on TBS." *Team Coco on Youtube* (official Youtube channel for Conan) May 11. <https://www.youtube.com/watch?v=6dUEvT5XQjI>.
- O'Connor, Ralph. 2009. "Reflections on Popular Science in Britain: Genres, Categories, and Historians." *Isis* 100(2): 333–345.
- . 2013. "The Place of Myth in Modern Science: Some Theoretical Considerations." In: Roussillon-Constancy, Laurence, and Philippe Murillo (eds.). *Science, Fables and Chimeras: Cultural Encounters*. Newcastle upon Tyne: Cambridge Scholars Publishing.
- OD. 2019. "Lexico.com FAQs." *Oxford Dictionaries* (website). Accessed July 7. <https://languages.oup.com/lexico-faqs>.
- OED. 2018a. "Science, n. 5." *Oxford English Dictionary* (website). Accessed July 23. <http://www.oed.com/view/Entry/172672?redirectedFrom=science#eid>. 2018.
- OED. 2018b. "Propaganda, n. 2." *Oxford English Dictionary* (website). Accessed July 9. <http://www.oed.com/view/Entry/152605?rskey=nX848K&result=1&isAdvanced=false#eid>.
- Okasha, Samir. 2002. *Philosophy of Science: A Very Short Introduction*. Oxford: Oxford University Press.
- Olson, Richard G. 2016. *Scientism and Technology in the Twentieth Century: The*

- Legacy of Scientific Management*. Lanham: Lexington Books.
- Ortolano, Guy. 2009. *The Two Cultures Controversy: Science, Literature and Cultural Politics in Postwar Britain*. Cambridge: Cambridge University Press.
- O'Toole, Garson. 2013. "We Are Made of Star-Stuff." *Quote Investigator: Tracing Quotations* June 22. <https://quoteinvestigator.com/2013/06/22/starstuff/>.
- Pandora, Katherine. 2009. "Popular Science in National and Transnational Perspective: Suggestions from the American Context." *Isis* 100(2): 346–358.
- Papineau, David. (2007) 2016. "Naturalism." In: Zalta, Edward N. (ed.). *Stanford Encyclopedia of Philosophy* (website) Winter 2016 edition. <https://plato.stanford.edu/entries/naturalism/>.
- Pascal, Blaise. 1958. *Pensées*. French original 1670. Translated by W.F. Trotter. New York: E.P. Dutton & Co.
- Paul, Danette. 2004. "Spreading Chaos: The Role of Popularizations in the Diffusion of Scientific Ideas." *Written Communication* 21(1): 32–68.
- Payne, Darin. 2001. "Effacing Difference in the Royal Society: The Homogenizing Nature of Disciplinary Dialogue." *Rhetoric Review* 20(1/2): 94–112.
- PBS NOVA. 2007. *Judgement Day: Intelligent Design on Trial*. Aired November 13. Transcript available at <http://www.pbs.org/wgbh/nova/evolution/intelligent-design-trial.html>. Accessed July 29, 2018.
- Pennock, Robert T. 2011. "Can't Philosophers Tell the Difference Between Science and Religion? Demarcation Revisited." *Synthese* 178(2): 177–206.
- Peplow, David, and Ronald Carter. 2014 "Stylistics and Real Readers." In: Burke, Michael (ed.). *The Routledge Handbook of Stylistics*. London and New York: Routledge. 440–454.
- Perrault, Sarah Tinker. 2013. *Communicating Popular Science: From Deficit to Democracy*. Basingstoke: Palgrave MacMillan.
- Pfeifer, Jessica, and Sahotra Sarkar. 2006. "The Philosophy of Science: An Introduction." In: Sarkar, Sahotra, and Jessica Pfeifer (eds.). *The Philosophy of Science: An Encyclopedia: 2-Volume Set*. New York and London: Routledge. xi–xxvi.
- Pickett, Michael. 2013. "An Analysis of Narrative and Voice in Creative Nonfiction." *Journal of Arts and Humanities* 2(7): 1–14.
- Pidcock, Roz, Rosamund Pearce, and Robert McSweeney. 2019. "Mapped: How Climate Change Affects Extreme Weather around the World." *CarbonBrief* March 11. <https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world>.
- Pierre-Louis, Kendra. 2018. "Greenhouse Gas Emissions Accelerate Like a 'Speeding Freight Train' in 2018." *New York Times* December 5. <https://www.nytimes.com/2018/12/05/climate/greenhouse-gas-emissions-2018.html>.
- Piff, Paul K., Pia Dietze, Matthew Feinberg, Daniel M. Stancato, and Dacher Keltner. 2015. "Awe, the Small Self, and Prosocial Behavior." *Journal of Personality and*

Social Behavior 108(6): 883–899.

- Pigliucci, Massimo. 2018. “The Problem with Scientism.” *Blog of the APA* January 25. <https://blog.apaonline.org/2018/01/25/the-problem-with-scientism/>.
- Piketty, Thomas. 2014. *Capital in the Twenty-First Century*. French original 2013. Translated by Arthur Goldhammer. Cambridge, MA, and London: The Belknap Press of Harvard University Press.
- Plato. 1975. *Phaedo*. Translated by David Gallop. Oxford: Oxford University Press.
- Plumwood, Val. 2002. *Environmental Culture: The Ecological Crisis of Reason*. London and New York: Routledge.
- Popper, Karl. 1962. *Conjectures and Refutations: The Growth of Scientific Knowledge*. New York: Basic Books.
- Porush, David S. 1993. “Making Chaos: Two Views of a New Science.” In: McRae, Murdo William (ed.). *The Literature of Science: Perspectives on Popular Scientific Writing*. Athens and London: The University of Georgia Press. 152–168.
- Preston, Christopher J. 2018. *The Synthetic Age: Outdesigning Evolution, Resurrecting Species, and Engineering Our World*. Cambridge, MA: MIT Press.
- Principe, Lawrence M. 2011. *The Scientific Revolution: A Very Short Introduction*. Oxford: Oxford University Press.
- Pulitzer. 2018. “General Nonfiction.” *The Pulitzer Prize* (website). Accessed July 7. <http://www.pulitzer.org/prize-winners-by-category/223>.
- Radford, Tim. 2007. “Scheherazade: Telling Stories, Not Educating People.” In: Bauer, Martin W., and Massimiano Bucchi (eds.). *Journalism, Science and Society: Science Communication between News and Public Relations*. New York and London: Routledge. 95–99.
- Rapanut, Kimberly. 2018. “Lawrence Krauss Violated ASU Sexual Harassment Policies, Investigation Shows.” *The State Press* August 7. <http://www.statepress.com/article/2018/08/spscience-asu-investigation-states-lawrence-krauss-groped-woman-while-on-asu-funded-trip>.
- Resnik, David B. 2007. *The Price of Truth: How Money Affects the Norms of Science*. Oxford: Oxford University Press.
- Richards, Robert J. 2002. *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe*. Chicago and London: The University of Chicago Press.
- Ridder, Jeroen de. 2014. “Science and Scientism in Popular Science Writing.” *Social Epistemology Review and Reply Collective* 3(12): 23–39.
- Riesch, Hauke. 2008. *Scientists’ View of the Philosophy of Science*. London: University College London. Diss.
- Robbins, Brent Dean. 2006. “The Delicate Empiricism of Goethe: Phenomenology as a Rigorous Science of Nature.” *Indo-Pacific Journal of Phenomenology* 6(sup1): 13 pp.
- Robinson, Emerald. 2009. “What Is Science?” *MonkeySee* (website) June 16.

- <https://monkeysee.com/what-is-science/>. (Embedded video and transcript)
- Robinson, Kim Stanley. 1992. *Red Mars*. London: HarperCollins.
- Rockman et al. 1996. *Evaluation of the Bill Nye the Science Guy Television Series and Outreach*. Submitted to KCTS by Rockman et al., San Francisco, CA (no additional information on authors given). Available at *Informal Science* (website). <http://informalscience.org/evaluation-bill-nye-science-guy-television-series-and-outreach>.
- Rogers, Ben. 2003. "Pascal's Life and Times." In: Hammond, Nicholas (ed.). *The Cambridge Companion to Pascal*. Cambridge: Cambridge University Press. 4–19.
- Rosenberg, Alex. (2000) 2012. *Philosophy of Science: A Contemporary Introduction*. Third edition. New York and London: Routledge.
- Rosset, Evelyn. 2008. "It's No Accident: Our Bias for Intentional Explanations." *Cognition*, 108(3): 771–780.
- Rousseau, George S. 1982. "Science Books and their Readers in the Eighteenth Century." In: Rivers, Isabel (ed.). *Books and their Readers in the Eighteenth Century*. Leicester: Leicester University Press. 197–225.
- Rubenstein, Mary-Jane. 2008. *Strange Wonder: The Closure of Metaphysics and the Opening of Awe*. New York: Columbia University Press.
- Ruse, Michael. 2013. *The Gaia Hypothesis: Science on a Pagan Planet*. Chicago and London: The University of Chicago Press.
- Russell, Bertrand. 1945. *A History of Western Philosophy: And its Connection with Political and Social Circumstances from the Earliest Times to the Present Day*. New York: Simon & Schuster.
- Safranski, Rüdiger. 2014. *Romanticism: A German Affair*. German original 2007. Translated by Robert E. Goodwin. Evanston: Northwestern University Press.
- Sagan, Carl. 1985. *Contact: A Novel*. New York: Simon and Schuster.
- Salgaro, Massimo. 2015. "How Literary Can Literariness Be? Methodological Problems in the Study of Foregrounding." *Scientific Study of Literature* 5(2): 229–249.
- Sander, David, and Klaus R. Sherer (eds.). 2009. *The Oxford Companion to Emotion and the Affective Sciences*. Oxford: Oxford University Press.
- Saxifrage, Barry. 2017. "These 'Missing Charts' May Change the Way You Think about Fossil Fuel Addiction." *Canada's National Observer* July 13. <https://www.nationalobserver.com/2017/07/13/analysis/these-missing-charts-may-change-way-you-think-about-fossil-fuel-addiction>.
- Sayers, Janet, and Nanette Monin. 2012. "Blake's 'London': Diabolical Reading and Poetic Place in Organisational Theorising." *Culture and Organization* 18(1): 1–13.
- SC. 2018. "Our Definition of Science." *Science Council* (website). Accessed July 29.

- Published online, <https://sciencecouncil.org/about-science/our-definition-of-science/>.
- Schneider, Peter. (2006) 2015. *Extragalactic Astronomy and Cosmology: An Introduction*. Second edition. Berlin & Heidelberg: Springer.
- Schrempf, Gregory. 2012. *The Ancient Mythology of Modern Science: A Mythologist Looks (Seriously) at Popular Science Writing*. Montreal & Kingston: McGill-Queen's University Press.
- Schwartz, Richard A. 2003. *The 1950s: An Eyewitness History*. New York: Facts on File.
- Scott, David W. 2008. "The Transformation of Higher Education in the 1960s: Master Plans, Community Colleges, and Emerging Universities." *Journal of the Illinois State Historical Society* 101(2): 177–192.
- Seamon, David, and Arthur Zajonc (eds.). 1998. *Goethe's Way of Science: A Phenomenology of Nature*. Albany: State University of New York Press.
- Secord, James A. 2004. "Knowledge in Transit." *Isis*, 95(4): 654–672.
- . 2014. *Visions of Science: Books and Readers at the Dawn of the Victorian Age*. Chicago and London: The University of Chicago Press.
- Segerstråle, Ullica. 2000. "Science and Science Studies: Enemies or Allies?" In: Segerstråle, Ullica (ed.). *Beyond the Science Wars: The Missing Discourse about Science and Society*. Albany: State University of New York Press. 1–40.
- Segerstråle, Ullica (ed.). 2000. *Beyond the Science Wars: The Missing Discourse about Science and Society*. Albany: State University of New York Press.
- Segre, Michael. 1998. "The Never-Ending Galileo Story." In: Machamer, Peter. (ed.). *The Cambridge Companion to Galileo*. Cambridge: Cambridge University Press. 388–416.
- Shapin, Steven. 1996. *The Scientific Revolution*. Chicago and London: The University of Chicago Press.
- Sharot, Tali. 2017. *The Influential Mind: What the Brain Reveals about Our Power to Influence Others*. New York: Henry Holt and Company.
- Shea, Parker. 2018a. "ASU's Origins Project to Move under Interplanetary Initiative." *The State Press* September 29. <https://www.statepress.com/article/2018/09/spscience-asu-origins-project-to-move-under-interplanetary-initiative>.
- . 2018b. "Lawrence Krauss Replaced as Director of The Origins Project." *The State Press* August 2. <http://www.statepress.com/article/2018/08/sppolitics-lawrence-krauss-replaced-as-director-of-the-origins-project>.
- Shea, William. 1998. "Galileo's Copernicanism: The Science and the Rhetoric." In: Machamer, Peter. (ed.). *The Cambridge Companion to Galileo*. Cambridge: Cambridge University Press. 211–243.
- Shelley, Mary. (1818) 1981. *Frankenstein; Or, the Modern Prometheus*. New York:

Bantam Books.

- Sherrington, Charles. 1949. *Goethe on Nature and on Science*. Cambridge: Cambridge University Press.
- Shinn, Terry, and Richard Whitley (eds.). 1985. *Expository Science: Forms and Functions of Popularisation*. Dordrecht, Boston, and Lancaster: D. Reidel Publishing Company.
- Shiota, Michelle N., Dacher Keltner, and Amanda Mossman. 2007. "The Nature of Awe: Elicitors, Appraisals, and Effects on Self-Concept." *Cognition and Emotion* 21(5): 944–963.
- Shklovsky, Viktor. 2015. "Art, as Device." Russian original 1917. Translated by Alexandra Berlina. *Poetics Today* 36(3): 151–174.
- Shouse, Eric. 2005. "Feeling, Emotion, Affect." *M/C Journal* 8(6): neither page numbers nor number of pages specified.
- Shtulman, Andrew. 2017. *Scienceblind: Why Our Intuitive Theories About the World Are So Often Wrong*. New York: Basic Books.
- Sideris, Lisa H. 2017. *Consecrating Science: Wonder, Knowledge, and the Natural World*. Oakland: University of California Press.
- Sismondo, Sergio. (2004) 2010. *An Introduction to Science and Technology Studies*. Second edition. West Sussex: Wiley-Blackwell.
- Sleigh, Charlotte. 2010. *Literature and Science*. Basingstoke and New York: Palgrave MacMillan.
- Smallman, Melanie. 2018. "Science to the Rescue or Contingent Progress? Comparing 10 years of Public, Expert and Policy Discourses on New and Emerging Science and Technology in the United Kingdom." *Public Understanding of Science* 27(6): 655–673.
- Snow, C.P. (1959) 1998. *The Two Cultures*. Cambridge: Cambridge University Press.
- Somerville, Mary. (1834) 1849. *On the Connexion of the Physical Sciences*. Eight edition. London: John Murray, Albemarle Street.
- Sorensen, Karen Schroeder. 2017. *Cosmos and the Rhetoric of Popular Science*. Lanham: Lexington Books.
- Spangenburg, Ray, and Kit Moser. 2004. *Carl Sagan: A Biography*. New York: Prometheus Books.
- Stadler, Friedrich K. 2006. "Vienna Circle." In: Sarkar, Sahotra, and Jessica Pfeifer (eds.). *The Philosophy of Science: An Encyclopedia: 2-Volume Set*. New York and London: Routledge. 858–863.
- Steiner, Peter. 1984. *Russian Formalism: A Meta-poetics*. Ithaca and London: Cornell University Press.
- Stephenson, Roger H. 1995. *Goethe's Conception of Knowledge and Science*. Edinburgh: Edinburgh University Press.

- Stillman, Drake. (1980) 2001. *Galileo: A Very Short Introduction*. Oxford: Oxford University Press.
- Stockwell, Peter. 2002. *Cognitive Poetics: An Introduction*. London and New York: Routledge.
- . 2007. "Cognitive Poetics and Literary Theory." *Journal of Literary Theory* 1(1): 135–152.
- Suvin, Darko. 1972. "On the Poetics of the Science Fiction Genre." *College English* 34(3): 372–382.
- Taub, Liba. 2017. *Science Writing in Greco-Roman Antiquity*. Cambridge: Cambridge University Press.
- The Guardian Datablog. 2010. "NASA Budgets: US Spending on Space Travel since 1958." *The Guardian Datablog* February 1. <https://www.theguardian.com/news/datablog/2010/feb/01/nasa-budgets-us-spending-space-travel>.
- Thompson, Ann, and Neil Taylor (eds.). 2006. *The Arden Shakespeare: Hamlet*. London: Thomson Learning.
- Thompson, Carl. 2011. *Travel Writing*. New York: Routledge.
- Thornton, Stephen P. 2006. "Karl Raimund Popper." In: Sarkar, Sahotra, and Jessica Pfeifer (eds.). *The Philosophy of Science: An Encyclopedia: 2-Volume Set*. New York and London: Routledge. 571–578.
- Thurs, Daniel Patrick. 2007. *Science Talk: Changing Notions of Science in American Culture*. New Brunswick: Rutgers University Press.
- Tooby, John, and Leda Cosmides. 2015. "The Theoretical Foundations of Evolutionary Psychology." In: David M. Buss (ed.), *The Handbook of Evolutionary Psychology*. Second edition. Hoboken, NJ: John Wiley & Sons. 3–87.
- Topham, Jonathan R. 2007. "Publishing 'Popular Science' in Early Nineteenth-Century Britain." In: Fyfe, Aileen, and Bernard Lightman (eds.). *Science in the Marketplace: Nineteenth-Century Sites and Experiences*. Chicago and London: The University of Chicago Press. 135–168.
- . 2009. "Introduction." *Isis* 100(2): 310–318.
- Tresch, John. 2013. *The Romantic Machine: Utopian Science and Technology after Napoleon*. Chicago and London: The University of Chicago Press.
- . 2014. "Cosmologies Materialized: History of Science and History of Ideas." In: McMahon, Darrin M., and Samuel Moyn (eds.). *Rethinking Modern European Intellectual History*. Oxford: Oxford University Press. 153–172.
- Tsur, Reuven. (1992) 2008. *Toward A Theory of Cognitive Poetics*. Second, expanded and updated edition. Brighton and Portland: Sussex Academic Press.
- Turney, Jon. 2001. "Telling the Facts of Life: Cosmology and the Epic of Evolution." *Science and Culture* 10(2): 225–247.
- . 2004a. "Accounting for explanation in popular science—an analysis of popularized accounts of superstring theory." *Public Understanding of Science* 13:

- 331–346.
- . 2004b. “The Abstract Sublime: Life as Information Waiting to be Written.” *Science as Culture* 13(1): 89–103.
- . 2007. “Boom and bust in popular science.” *Journal of Science Communication* 6(1): C02.
- Tyrrell, Toby. 2013. *On Gaia: Critical Investigations of the Relationship Between Life and Earth*. Princeton and Oxford: Princeton University Press.
- UNESCO. 2018. “Women in Science.” *UNESCO* (website). Accessed July 7, 2018. <http://uis.unesco.org/en/topic/women-science..>
- Urquiza-Haas, Esmeralda G., and Kurt Kotrschal. 2015. “The Mind behind Anthropomorphic Thinking: Attribution of Mental States to Other Species.” *Animal Behaviour* 109: 167–176.
- Valdesolo, Piercarlo, and Jesse Graham. 2014. “Awe, Uncertainty, and Agency Detection.” *Psychological Science* 25(1): 170–178.
- Van Eperen, Laura, and Francesco M. Marincola. 2011. “How Scientists Use Social Media to Communicate their Research.” *Journal of Transnational Medicine*, 9:199: 3pp.
- Van Peer, Willie. 1986. *Stylistics and Psychology: Investigations of Foregrounding*. London: Croom Helm.
- Varghese, Susheela Abraham, and Sunita Anne Abraham. 2004. *Written Communication*, 21(2): 201–231.
- Vasalou, Sophia (ed). 2012. *Practices of Wonder: Cross-Disciplinary Perspectives*. Eugene: Pickwick Publications.
- Vasalou, Sophia. 2015. *Wonder: A Grammar*. Albany, NY: Suny Press.
- Von Platen, Magnus. 1996. *Skandalen på operakällaren och andra essayer*. Stockholm: Fischer.
- Walsh, Richard. 1997. “Who Is the Narrator?” *Poetics Today* 18(4): 495–513.
- Ward, Stephen J.A. 2014. “Classical Liberal Theory in a Digital World.” In: Fortner, Robert S., and P. Mark Fackler (eds.). *The Handbook of Media and Mass Communication*. Chichester: John Wiley & Sons. 3–21.
- Watson, Peter. 2010. *The German Genius: Europe’s Third Renaissance, the Second Scientific Revolution, and the Twentieth Century*. New York: HarperCollins.
- . 2016. *Convergence: The Idea at the Heart of Science*. New York: Simon & Schuster.
- Wedberg, Anders. 1982. *A History of Philosophy: Volume 1: Antiquity and the Middle Ages*. Swedish original 1958. Translated by Anders Wedberg. Oxford: Clarendon Press.
- Weiner, Norbert. 1948. *Cybernetics or control and communication in the animal and the machine*. Cambridge, MA: MIT Press.

- Weitkamp, Margaret A. 2017. "The Image of Scientists in *The Big Bang Theory*." *Physics Today* 70(1): 40–48.
- Welsh, Ian, and Brian Wynne. 2013. "Science, Scientism and Imaginaries of Publics in the UK: Passive Objects, Incipient Threats." *Science as Culture* 22(4): 540–566.
- Whewell, William. (1840) 1847. *The Philosophy of the Inductive Sciences, Based Upon Their History*. Second edition. London: John W. Parker.
- White, Hayden. 1987. *The Content of the Form: Narrative Discourse and Historical Representation*. Baltimore and London: The Johns Hopkins University Press.
- Whiteley, Sara, and Patricia Canning. 2017. "Reader Response Research in Stylistics." *Language and Literature* 26(2): 71–87.
- Whitley, Richard. 1985. "Knowledge Producers and Knowledge Acquirers: Popularisation as a Relation Between Scientific Fields and Their Publics." In: Shinn, Terry, and Richard Whitley (eds.). *Expository Science: Forms and Functions of Popularisation*. Dordrecht, Boston, and Lancaster: D. Reidel Publishing Company. 3–28.
- Wiki. 2019a. "Major English Dictionaries." *Wikipedia: The Free Dictionary* (website). Accessed June 6. https://en.wikipedia.org/wiki/Dictionary#Major_English_dictionaries.
- . 2019b. "Comparison of English Dictionaries." *Wikipedia: The Free Dictionary* (website). Accessed June 6. https://en.wikipedia.org/wiki/Comparison_of_English_dictionaries.
- . 2019c. "Science." *Wikipedia: The Free Dictionary* (website). Accessed July 12. <https://en.wikipedia.org/wiki/Science>.
- Williams, George C. 1966. *Adaptation and natural selection: A critique of some current evolutionary thought*. Princeton: Princeton University Press.
- Williams, Richard N. 2015. "Introduction." In: Williams, Richard N., and Daniel N. Robinson (eds.). *Scientism: The New Orthodoxy*. London: Bloomsbury. 1–21.
- Williams, Richard N., and Daniel N. Robinson (eds.). 2015. *Scientism: The New Orthodoxy*. London: Bloomsbury.
- Willis, Martin. 2006. *Mesmerists, Monsters, and Machines: Science Fiction and the Cultures of Science in the Nineteenth Century*. Kent, OH: The Kent State University Press.
- Wilson, Edward O. 1975. *Sociobiology: The New Synthesis*. Cambridge, MA: Belknap Press of Harvard University Press.
- Winston, Christine N. 2016. "Evaluating Media's Portrayal of an Eccentric-Genius: Dr. Sheldon Cooper." *Psychology of Popular Media Culture* 5(3): 290–306.
- Wolfe, Cary. 2010. *What is Posthumanism?* Minneapolis and London: University of Minnesota Press.
- Woolgar, Steve. 1988. *Science: The Very Idea*. London and New York: Tavistock

Publications.

- Wootton, David. 2010. *Galileo: Watcher of the Skies*. New Haven and London: Yale University Press.
- . 2015. *The Invention of Science: A New History of the Scientific Revolution*. London: Allen Lane.
- Wordsworth, William, and Samuel Tayler Coleridge. (1798, 1800, 1968) 1991. *Lyrical Ballads*. The text of the 1798 edition with the additional 1800 poems and the prefaces, edited with introduction, notes, and appendices by R.L. Brett and A.R. Jones. London and New York: Routledge.
- Wyatt, Sally, Staša Milojević, Han Woo Park, and Loet Leydesdorff. 2017. “Intellectual and Practical Contributions of Scientometrics to STS.” In: Felt, Ulrike, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (eds.). *The Handbook of Science and Technology Studies*. Fourth edition. Cambridge, MA, and London: The MIT Press. 87–112.
- Wynne, Brian. 1993. “Public Uptake of Science: A Case for Institutional Reflexivity.” *Public Understanding of Science* 2(4): 321–337.
- Zakai, Avihu. 2010. *Jonathan Edwards’s Philosophy of Nature: The Re-enchantment of the World in the Age of Scientific Reasoning*. London and New York: T&T Clark.
- Zakariya, Nasser. 2010. *Towards a Final Story: Time, Myth and the Origins of the Universe*. Cambridge, MA: Harvard University. Diss.
- . 2017. *A Final Story: Science, Myth, and Beginnings*. Chicago and London: The University of Chicago Press.
- Ziman, John. 2000. *Real Science: What it Is and What it Means*. Cambridge: Cambridge University Press.
- Zuba, Clayton. 2016. “Monstrosity and the Majority: Defamiliarizing Race in the University Classroom.” *Pedagogy* 16(2): 356–367.

Illustrations

Cover image: Rembrandt, *Faust in His Study*, c. 1652. Public domain.

Figure 3.1. p. 121. “Purity,” #435 in *xkcd* (Munroe 2008). Reprints allowed except for illegitimate merchandizing.

Figure 4.1. p. 136. The electromagnetic spectrum. Credit: Philip Ronan, Ginger. Creative Commons license.

Index

- Abraham, Sunita Anne, 47
Abrams, Meyer Howard, 29, 36, 81, 82
Ackerman, Diane, 75
Adams, John Couch, 132
Adorno, Theodor W., 248
Agar, Jon, 69, 70, 88, 120, 140
Agassi, Joseph, 200
Ait-Touati, Frédéricque, 17, 59–61
Aldhous, Peter, 46
Alexandrov, Vladimir E., 160
Alfieri, Lorenzo, 249
Alkestrand, Malin, 170
Alters, Brian, 117–119
Altmann, Ulrike, 160, 161
Amrine, Frederick, 86, 87
Anaxagoras, 99
Anaximander, 99
Anaximenes, 99
Anderson, Benedict, 195
Anderson, Hanne, 113, 120
Andrew, Elise, 74
Angier, Natalie, 44, 73
Aristotle, 21, 55, 58, 59, 99, 192, 193
Arnold, Matthew, 104
Asimov, Isaac, 71
Austen, Jane, 207
Bacon, Francis, 53, 62, 76, 87, 179, 180
Baker, Jennifer J., 64, 78, 80
Ball, Philip, 233, 234
Barad, Karen, 84
Bardeen, John, 203
Barthes, Roland, 187
Bartusiak, Marcia F., 75
Bathmaker, Ann-Mari, 70
Bauchspies, Wenda K., 34, 103, 104
Bauer, Henry H., 88, 111, 120
Bauer, Martin W., 35
Baumeister, Roy F., 123
Beagon, Mary, 57
Becker, Herbert, 176
Beer, Gillian, 16, 67
Bell, Alice R., 18, 37
Bennett, Brett M., 57
Bennett, Jane, 84
Bensaude-Vincent, Bernadette, 16, 18, 24,
51, 52, 61, 66, 67, 71, 170, 217
Berlin, Isaiah, 80
Berlina, Alexandra, 159
Bethe, Hans, 203
Betts, Richard A., 249
Blake, William, 81
Bloor, David, 34
Boghossian, Peter, 106
Bohr, Niels, 199, 203
Bohrn, Isabel C., 160

Bordo, Susan R., 25, 151
 Bornmann, Lutz, 70
 Bortoft, Henri, 16, 86, 87
 Bose, Satyendra Nath, 191
 Bothe, Walther, 176
 Bourdeau, Michel, 121
 Bowler, Peter J., 52–54, 58, 59, 66, 68
 Boyle, Robert, 53
 Bradshaw, Catherine, 249
 Brahe, Tycho, 53, 60, 138
 Brockman, John, 106
 Broks, Peter, 18, 32, 37, 42, 47, 51,
 65, 69, 70, 73, 130
 Bronowski, Jacob, 72
 Brown, Andrew, 106
 Brown, Dan, 135
 Brown, James Robert, 105, 106
 Brown, Kate, 258–260
 Brown, Marshall, 78, 80
 Bryson, Bill, 44, 73
 Bucchi, Massimiano, 47
 Burkeman, Oliver, 208
 Burnett, Thomas, 145, 146
 Burnham, John C., 67
 Burns, William E., 52, 62
 Butterfield, Herbert, 54
 Byrne, Richard W., 232

 Cadenas, Kerensa, 45
 Calsamiglia, Helena, 18, 32
 Camus, Albert, 13, 14, 163, 164
 Canning, Patricia, 160
 Carana, Sam (pseudonym), 249
 Carroll, Joseph, 207
 Carroll, Sean M., 15, 42, 44, 73
 Carruthers, Peter, 55, 236
 Carson, Johnny, 72
 Carson, Rachel, 29, 42, 69, 258
 Carter, Ronald, 160
 Cartwright, Nancy, 120
 Castiglione, Davide, 161
 Cat, Jordi, 120
 Cavaillé, Jean-Pierre, 52, 59
 Cavendish, Margaret, 88
 Champollion, Jean-François, 95
 Chandler, Daniel, 152
 Chandrasekhar, Subrahmanyam, 207
 Chapman, Matthew, 116
 Charney, Davida, 47
 Chater, Nick, 21
 Chatman, Seymour, 30, 48, 181, 187, 188
 Chico, Tita, 17, 59
 Chimba, Mwenya, 208
 Christianson, Gale E., 61
 Christie, Agatha, 200, 201
 Cicero, 56, 60
 Clarke, Arthur C., 71
 Clarke, Bruce, 47
 Clough, Patricia Ticineto, 215
 Cohen, Andrew, 42, 166
 Cohon, Rachel, 125
 Colbert, Stephen, 45
 Coleridge, Samuel Taylor, 81, 96, 157,
 158, 166, 172
 Collini, Stefan, 104, 105
 Collins, Harry, 88, 257, 260
 Comte, Auguste, 121, 148
 Cooper, Leon, 203
 Cooter, Roger, 18, 51
 Copernicus, Nikolaus, 53, 60, 115, 116
 Cosmides, Leda, 21, 23, 167
 Cox, Brian, 38, 41–43, 45, 74, 154, 166
 Cox, Virginia, 60
 Crescioni, A. Will, 123

Crichton, Michael, 19
 Critchley, Simon, 262, 263
 Croissant, Jennifer, 34, 103, 104
 Culler, Jonathan, 20, 28, 158
 Cummings, E.E., 162, 163
 Cunningham, Andrew, 55, 64, 82, 83,
 85
 Curd, Patricia, 99, 100
 Curie, Marie, 176, 210
 Curtis, Ron, 16, 18, 47, 200

 Da Vinci, Leonardo, 94
 Dahlstrom, Michael F., 47
 Darwin, Charles, 17, 23, 67, 150,
 205, 210
 Daston, Lorraine, 223, 233
 Daum, Andreas W., 18, 51
 Davidson, Hugh M., 78
 Davidson, Keay, 72, 73
 Davidson, Richard J., 215
 Davies, Paul, 42, 68, 72, 153
 Dawkins, Richard, 22, 41, 42, 44, 45,
 73, 106, 225
 Dear, Peter, 16, 55, 56, 62, 64
 Democritus, 94, 99
 Denzin, Norman K., 14
 Descartes, René, 53, 61, 79
 Deutsch, David, 42, 44, 73, 131
 Diels, Hermann, 99
 Dietze, Pia, 228, 229
 Dirac, Paul, 203, 209, 211
 Douthwaite, John, 159–161
 Doyle, Arthur Conan, 200, 201
 Drouin, Jean-Marc, 16
 Druyan, Ann, 15, 45, 72, 74, 91
 Dupré, John, 120, 125
 Dyball, Robert, 243

 Dylan, Bob, 15
 Dyson, Freeman, 203

 Economides, Louise, 157, 223, 226, 263
 Eddington, Arthur, 68
 Edford, Rachel, 42, 47, 177
 Eger, Martin, 25, 47, 48
 Ehrlich, Paul, 243
 Einstein, Albert, 30, 31, 68, 94, 103, 115,
 139, 154, 185, 186, 204, 210, 213,
 218, 223
 Eldelin, Emma, 16, 30, 105
 Empedocles, 99
 Epicurus, 57
 Eratosthenes, 94
 Eriksson, Gunnar, 18, 51, 52, 56
 Erlich, Viktor, 159, 160, 165

 Fackler, Mark P., 14
 Fahnestock, Jeanne, 36
 Fahy, Declan, 38, 41, 42, 45, 73, 75, 76,
 148
 Fairclough, Norman L., 152
 Faraday, Michael, 67, 199, 202, 207, 224
 Fausto-Sterling, Anne, 261
 Feinberg, Matthew, 228, 229
 Felt, Ulrike, 34, 102
 Ferguson, James, 238
 Fermi, Enrico, 203, 209
 Fernández-Armesto, Felipe, 243
 Feyerabend, Paul, 120
 Feynman, Richard, 38, 41, 71, 202, 203,
 207, 209, 211
 Fialho, Olívia da Costa, 175
 Field, J.V., 78
 Fine, Cordelia, 21
 Fisher, Philip, 83, 226

Fleck, Ludwik, 51, 102
 Fontenelle, Bernard le Bovier de, 61, 62
 Forrest, Barbara, 117
 Forshaw, Jeff, 42, 154
 Fortner, Robert S., 14
 Foucault, Michel, 234
 Fouché, Rayvon, 34, 102
 Fowler, Alastair, 18
 Frängsmyr, Tore, 61
 Freud, Sigmund, 210
 Friedrich, Caspar David, 15
 Frost, Samantha, 259, 260
 Fuller, Robert C., 223, 226–229
 Fuller, Steve, 117, 120, 217
 Fyfe, Aileen, 52, 65, 66

 Galilei, Galileo, 17, 53, 58–61, 199,
 205, 213, 221
 Galison, Peter, 70, 120
 Gamow, George, 71
 Gelbart, Nina Rattner, 61, 62
 Gell-Mann, Murray, 191
 Genette, Gérard, 30, 48, 181, 183, 189,
 190, 191
 Ghorayshi, Azeen, 46
 Gieryn, Thomas F., 15, 18, 33, 35, 39,
 47, 101, 110, 130, 141
 Gilovich, Thomas, 21
 Gladwell, Malcolm, 73
 Glashow, Sheldon, 203
 Gleick, James, 19, 42
 Goddard, Robert, 94, 95
 Gödel, Kurt, 256
 Godfrey-Smith, Peter, 100, 101
 Godhe, Michael, 52
 Goethe, Johann Wolfgang von, 16, 78,
 79, 85–87, 91

 Goldsmith, H. Hill, 215
 Golinski, Jan, 34
 Gorodeisky, Keren, 157
 Gottlieb, Jacqueline, 232
 Gottschall, Jonathan, 207
 Gou, Lei, 40
 Gould, Stephen Jay, 41, 42, 47
 Gouyon, Jean-Baptiste, 19, 32
 Graham, Jesse, 228
 Gramsci, Antonio, 51
 Greene, Brian, 13, 14, 17, 38, 39, 41,
 42, 44, 45, 73, 142, 153, 158,
 163–165, 167, 168
 Greenfield, Susan, 41, 75
 Gregg, Melissa, 215
 Gregory, Jane, 32, 35, 52, 56, 66
 Gribbin, John, 42, 166
 Gribbin, Mary, 42, 166
 Griffin, Andrew, 73
 Griffin, Dale, 21
 Gross, Alan G., 41, 42, 47, 85, 148, 227
 Gross, Paul, 105
 Grundmann, Reiner, 52, 59
 Guillory, John, 158
 Gunnarsson, Andreas, 130

 Habermas, Jürgen, 51
 Hadot, Pierre, 99
 Hadzigeorgiou, Yannis, 63, 85
 Haidt, Jonathan, 21, 215, 228
 Haines, Simon, 221
 Halley, Jean, 215
 Hammett, Dashiel, 201
 Hansen, Anders, 35
 Hansen, James, 42
 Haraway, Donna, 26, 35, 231, 261
 Harding, Sandra, 57, 151

Harris, Judith Rich, 75
 Harris, Sam, 127
 Harrison, Peter, 20, 53, 54, 64, 84, 85, 99, 100
 Harpham, Geoffrey Galt, 29, 36
 Harvey, David, 241
 Hættner Aurelius, Eva, 18
 Haught, John, 117, 118
 Hawking, Stephen, 15, 38, 41, 42, 44, 45, 73, 147, 154, 158, 231
 Hawkins, Mike, 67
 Hayden, Benjamin Y., 217, 232
 Haynes, Roslynn D., 79, 88–90, 200, 208, 212
 Heath, Joseph, 208
 Hegel, Georg Wilhelm Friedrich, 87
 Heidegger, Martin, 151
 Heilbron, John L., 59, 60, 64
 Heine, Steven J., 22, 124
 Heintzelman, Samantha J., 33, 123, 124,
 Helsing, Daniel, 24, 158, 223, 249
 Hemmungs Wirtén, Eva, 210
 Henrich, Joseph, 22, 124, 236
 Hepburn, Brian, 113, 120
 Heraclitus, 99
 Herder, Johann Gottfried, 87
 Heringman, Noah, 64, 78, 81
 Herschel, William, 136, 137
 Hevly, Bruce, 70
 Hicks, Joshua A., 33, 123
 Highfield, Roger, 74
 Higgs, Peter, 197, 198, 220, 224, 250
 Hilbert, David, 210
 Hilgartner, Stephen, 18, 19, 26, 32
 Hodge, Joseph M., 57
 Hofstadter, Douglas, 41
 Hogan, Patrick Colm, 215, 216, 218
 Hogle, Jerrold E., 80
 Holdrege, Craig, 86, 87
 Holmes, Richard, 24, 64, 65, 78, 79, 91, 93, 94, 96
 Holwerda, Gus, 45
 Horkheimer, Max, 248
 Hornborg, Alf, 151, 240, 243–246
 Hooke, Robert, 17
 Hoyle, Fred, 71
 Hubble, Edwin, 94
 Hughes, Austin L., 146
 Hughes, Virginia, 46
 Hui, Andrew, 137
 Humason, Milton, 94
 Hume, David, 125, 215
 Humes, Edward, 116
 Huxley, Aldous, 16, 89
 Huxley, Thomas Henry, 104
 Huygens, Christiaan, 17, 53, 79, 94, 202
 Hypatia, 94
 Itzkoff, Dave, 72
 Ivanova, Milena, 222
 Jackson, M.R., 177
 Jacobs, Arthur M., 160
 Jakobson, Roman, 159, 160
 James, William, 167
 Jardine, Nicholas, 64, 82, 83, 85
 Jasanoff, Sheila, 144
 Jeans, James, 68
 Jensen, Derrick, 243
 Johansson, Kaj, 18, 52
 Johnson, John A., 207
 Johnsson, Henrik, 16
 Joliot-Curie, Frédéric, 176
 Joliot-Curie, Irène, 176, 210

Jones III, John E., 116, 117, 119, 122,
 125, 126, 142, 143
 Jonsson, Emelie, 67
 Josephson-Storm, Jason Ā, 83, 84, 145
 Joyce, James, 191

 Kafka, Alexander C., 106
 Kahneman, Daniel, 21
 Kaku, Michio, 42, 44, 73, 141, 153, 158
 Kamminga, Harmke, 120
 Kärnfeldt, Johan, 18, 19, 52, 63, 217
 Keats, John, 82, 83, 221
 Keeny, Elizabeth, 66
 Kelemen, Deborah, 21
 Keller, Evelyn Fox, 25, 76, 127, 151,
 179
 Keltner, Dacher, 227, 228
 Kennedy, John F., 72
 Kennefick, Daniel, 68
 Kenny, Anthony, 99, 100
 Kepler, Johannes, 17, 53, 60, 61, 92, 94,
 95, 153
 Kern, Stephen, 30
 Keynes, John Maynard, 210
 Khalfā, Jean, 78
 Kidd, Celeste, 217, 232
 Kidder, Tracy, 75
 King, John T., 167
 King, Laura A., 33, 123, 124
 Kitzinger, Jenny, 208
 Knight, David, 55, 64
 Knudsen, Susanne, 47, 177
 Kolbert, Elizabeth, 42, 73, 75, 158,
 248
 Koopman, Eva Maria (Emy), 160
 Koren, Marina, 211
 Kotschal, Kurt, 21

 Koyré, Alexandre, 54
 Krauss, Lawrence, *passim*
 Kraut, Richard, 193
 Kubrick, Stanley, 89
 Kuhn, Thomas, 102
 Kuiken, Don, 160, 164, 175
 Kuritz, Hyman, 52
 Kuzmičová, Anežka, 160

 Ladyman, James, 130
 LaFollette, Marcel Chotkowski, 52, 66
 Landy, Joshua, 84
 Lang, Avis, 238
 Latour, Bruno, 28
 Law, John, 102
 Le Verrier, Urbain, 132
 Leane, Elizabeth, 16, 18, 25, 33, 37, 38,
 42, 47, 48, 52, 62, 63, 67, 68, 71–73,
 76, 104–106, 130, 141, 146, 170,
 177, 200, 201
 Leavis, F.R., 16, 104
 Leech, Geoffrey, 160
 Lenau, Nikolaus, 82
 Leonard, Annie, 244, 245
 Leslie, Ian, 217, 232, 233
 Lessl, Thomas M., 60, 146
 Leucippus, 99
 Levi, Primo, 47
 Levin, Janna, 43, 255–257, 260
 Levine, George, 67
 Levitt, Norman, 105
 Lewenstein, Bruce V., 24, 33, 37–39, 52,
 60, 71–73, 111, 148
 Lightman, Bernard, 47, 52, 62, 65–67, 75
 Lindsay, James A., 106
 Lindberg, David C., 54–56
 Llobera, Josep R., 243

Locke, John, 79
 Locke, Simon, 33, 39, 84, 130
 Loewenstein, George, 232
 Lovelock, James, 39–41, 150
 Lubric, Oliver, 160, 161
 Lucian, 61
 Lucretius, 56, 57, 186
 Lutz, Ashley, 40
 Luzón, María José, 40, 74
 Lynas, Mark, 42
 Lyons, Sara, 83
 Lyotard, Jean-François, 29

Maher, Bill, 45
 Mahrt, Merja, 40, 74
 Mangen, Anne, 160
 Marchant, Jo, 74, 75
 Margulis, Lynn, 39, 150
 Marincola, Francesco M., 40, 74
 Marsh, Oliver, 40, 74
 Marx, Karl, 246
 Massumi, Brian, 215
 Masur, Louis P., 47
 Mathavan, S., 177
 Maxwell, James Clerk, 199, 202–204,
 218, 224
 Mayr, Ernst, 131
 McClellan, James E., 63
 McCombs, Maxwell E., 40
 McMullin, Ernan, 142
 McPherson, Guy, 249
 McRae, Murdo William, 16, 47
 McSweeney, Robert, 249
 Mellor, Felicity, 15, 18, 29, 33, 34, 39,
 42, 43, 45–48, 130, 135, 141, 146,
 167
 Merchant, Carolyn, 25

Merton, Robert, 102, 103
 Miall, David S., 160, 161, 164, 175
 Midgley, Mary, 124
 Miller, Clark A., 34, 102
 Miller, Jon D., 112
 Miller, Kenneth R., 117–119
 Miller, Steve, 32, 52, 56, 66
 Mills, Robert, 219
 Milman, Oliver, 74
 Milojević, Staša, 102
 Mirowski, Philip, 140
 Mlodinow, Leonard, 42, 44, 73, 147, 154
 Monin, Nanette, 81
 Morus, Iwan Rhys, 20, 53–55, 58, 59
 Moser, Kit, 72
 Mossman, Amanda, 227
 Mugglestone, Lynda, 107
 Munday, Rod, 152
 Munroe, Randall, 44, 73, 120, 121
 Murphy, Trevor, 57
 Mutz, Rüdiger, 70
 Myers, Greg, 18, 52, 67

Naish, Darren, 188
 Newell, Barry, 243
 Newton, Isaac, 53, 55, 61, 79, 86, 87, 138,
 139, 150, 202, 205, 210, 213
 Nickles, Thomas, 33, 99, 101
 Nielsen, Henrik Skov, 31
 Nieman, Adam, 130, 131, 146
 Nieto-Galan, Agustí, 51
 Nightingale, Andrea Wilson, 223
 Nisbet, H. Barry, 87
 Nixon, Rob, 245
 Noether, Emmy, 210
 Norenzayan, Ara, 22, 124
 North, Anna, 45

Nye, Bill, 38, 45, 74
 Oaksford, Mike, 21
 Obama, Barack, 74
 O'Brien, Conan, 174, 228
 O'Connor, Ralph, 18, 25, 48, 51, 52
 Oerstad, Hans Christian, 223
 Okasha, Samir, 101, 133, 139, 144
 Olson, Richard G., 144
 Ortolano, Guy, 16, 104
 O'Toole, Garson, 95
 Oudeyer, Pierre-Yves, 232

Padian, Kevin, 117
 Pandora, Katherine, 18, 51, 52, 66
 Papineau, David, 142
 Park, Han Woo, 102
 Park, Katherine, 223, 233
 Parkin, R.M., 177
 Parmenides, 99
 Pascal, Blaise, 53, 77, 78
 Paul, Danette, 19
 Pauli, Wolfgang, 203, 208
 Payne, Darin, 62
 Pearce, Rosamund, 249
 Pennock, Robert T., 116–119, 126, 142
 Penrose, Roger, 41
 Peplow, David, 160
 Perrault, Sarah Tinker, 18, 33, 36, 43,
 47, 52, 62, 63, 146
 Pfeifer, Jessica, 98, 100
 Pickett, Michael, 30
 Pidcock, Roz, 249
 Pierre-Louis, Kendra, 249
 Piff, Paul K., 228, 229
 Pigliucci, Massimo, 146
 Piketty, Thomas, 241
 Pinch, Trevor, 88, 257, 260

Pinker, Steven, 41, 42, 44, 73
 Planck, Max, 131
 Plato, 60, 68, 76, 99, 100, 134, 135, 179,
 180, 199, 202, 205, 206, 213, 219,
 222, 223, 261, 262
 Pliny the Elder, 56, 57
 Pluckrose, Helen, 106
 Plumwood, Val, 151
 Plutarch, 61
 Porush, David S., 47
 Pope, Alexander, 88
 Popper, Karl, 33, 98, 100–102, 130, 132,
 134
 Posidonius, 56
 Preston, Christopher J., 263, 264
 Prickett, Stephen, 221
 Principe, Lawrence M., 54
 Protagoras, 99
 Proust, Marcel, 183, 191
 Pumfrey, Stephen, 18, 51
 Puschmann, Cornelius, 40, 74
 Pythagoras, 99, 134

Radford, Tim, 21, 22
 Randall, Lisa, 15, 41, 42, 44, 74, 142, 158
 Rapanut, Kimberly, 46
 Rees, Martin, 15, 42, 106, 154
 Resnik, David B., 140
 Restivo, Sal, 34, 103, 104
 Richards, Robert J., 85, 86
 Ridder, Jeroen de, 25, 143, 146
 Riesch, Hauke, 37, 130, 131, 133
 Robbins, Brent Dean, 87
 Robinson, Daniel N., 25, 144
 Robinson, Emerald, 113, 114
 Robinson, Kim Stanley, 30
 Rockman (et al.), 74

Rogers, Ben, 78
 Rosenberg, Alex, 100, 101
 Ross, Don, 130
 Rosset, Evelyn, 21
 Rovelli, Carlo, 42, 44, 73, 154, 166
 Rousseau, George S., 62
 Routledge, Clay, 33, 123
 Rubenstein, Mary-Jane, 223
 Ruse, Michael, 40, 85, 150, 151
 Russell, Bertrand, 68, 100

 Safranski, Rüdiger, 83
 Sagan, Carl, 14, 15, 17, 37, 38, 42, 43, 45
 61, 72–74, 91–96, 126, 134, 142,
 143, 145, 153, 158, 165, 166, 171,
 172, 196, 217, 218, 221–223, 262
 Saler, Michael, 84
 Salgaro, Massimo, 159
 Sander, David, 215
 Sarkar, Sahotra, 98, 100
 Saxifrage, Barry, 249
 Sayers, Janet, 81
 Schelling, Friedrich Wilhelm Joseph, 87
 Scheufele, Dietram A., 47
 Schiller, Friedrich, 78, 83, 85
 Schneider, Peter, 178
 Schopenhauer, Arthur, 215
 Schrempp, Gregory, 25, 47, 48, 106
 124, 146, 187
 Schrieffer, Robert, 203
 Schrödinger, Erwin, 200, 203, 211
 Schulz, Roland, 63, 85
 Schwartz, Richard A., 71
 Schwinger, Julian, 203, 219
 Scott, David W., 70
 Seamon, David, 87
 Secord, James A., 51, 65
 Segerstråle, Ullica, 105, 106

 Segre, Michael, 60
 Seigworth, Gregory J., 215
 Shakespeare, William, 104, 136
 Shapin, Steven, 53, 54, 120
 Sharot, Tali, 21, 170
 Shaw, Donald L., 40
 Shea, Parker, 46
 Shea, William, 59
 Shelley, Mary, 16, 22, 78, 79, 88, 90
 Sherer, Klaus R., 215
 Sherrington, Charles, 87
 Shetterly, Margot Lee, 45, 73
 Shinn, Terry, 16
 Shiota, Michelle, 227
 Shklovsky, Viktor, 157–162, 165, 166,
 172
 Shouse, Eric, 215
 Shtulman, Andrew, 21
 Sideris, Lisa H., 24, 25, 42, 48, 49, 85,
 124, 146, 148, 222–225, 227
 Siegal, Michael, 55, 236
 Singh, Simon, 44, 73
 Sismondo, Sergio, 101–103, 116
 Sleigh, Charlotte, 16
 Smallman, Melanie, 144
 Snow, C.P., 16, 104
 Sobel, Dava, 44, 73
 Socrates, 99
 Sokal, Alan, 105, 106
 Somerville, Mary, 64, 65, 121
 Sommerfeld, Arnold, 203
 Somson, Geert, 120
 Sorensen, Karen Schroeder, 72
 Soter, Steven, 15, 45, 72, 74, 91
 Spangenburg, Ray, 72
 Spinoza, Baruch, 204, 215, 223
 Stadler, Friedrich K., 100, 101
 Steinbeck, John, 15

Stephenson, Roger H., 87
 Stevenson, Robert Louis, 89
 Stewart, Jon, 45
 Stewart, Neil, 21
 Stich, Stephen, 55, 236
 Stillman, Drake, 59
 Stockwell, Peter, 30, 160
 Støle, Hildegunn, 160
 Strindberg, August, 16, 17
 Stump, David J., 120
 Susskind, Leonard, 44, 73
 Suvin, Darko, 170
 Svensson, Lena, 18, 51, 52,
 56
 Swift, Jonathan, 88

 't Hooft, Gerard, 204, 208
 Taub, Liba, 55–58
 Taylor, Neil, 137
 Tegmark, Max, 42, 44
 Thales, 99, 208
 Thompson, Ann, 137
 Thompson, Carl, 223
 Thornton, Stephen P., 101
 Thurs, Daniel Patrick, 63
 Tolkien, J.R.R., 170
 Tolstoy, Leo, 162, 163
 Tooby, John, 21, 23, 167
 Topham, Jonathan R., 18, 19, 51,
 63, 66
 Tresch, John, 20, 55, 78–80, 88,
 102, 151
 Tsur, Reuven, 160
 Turing, Alan, 256
 Turney, Jon, 18, 25, 37, 41, 44, 47,
 48, 146, 167
 Tyndall, John, 67
 Tynyanov, Yury, 165

 Tyrrell, Toby, 39
 Tyson, Neil deGrasse, *passim*

 Urquiza-Haas, Esmeralda G., 21

 Valdesolo, Piercarlo, 228
 Van Dijk, Teun A., 32
 Van Eperen, Laura, 40, 74
 Van Gogh, Vincent, 14, 18, 163, 164
 Van Peer, Willie, 159–163
 Vangelis, 92
 Varghese, Susheela Abraham, 47
 Varro, 56
 Vasalou, Sophia, 223
 Von Platen, Magnus, 167

 Wallace, Alfred Russel, 67
 Walsh, Richard, 189
 Ward, Sarah J., 33, 123, 124
 Ward, Stephen J.A., 14, 40
 Watson, Peter, 64–66, 147, 149, 150
 Wayne, John, 262, 264
 Weber, Max, 79, 83–85
 Wedberg, Anders, 100
 Weinberg, Steven, 38, 41, 42, 68, 106
 145, 147, 149, 150, 158, 204
 Weiner, Norbert, 23
 Weir, Andy, 16
 Weisskopf, Victor, 224
 Weitkamp, Margaret A., 209
 Welsh, Ian, 144
 Wheeler, Harvey, 87
 Whewell, William, 64, 65, 121, 148
 White, Hayden, 189
 Whiteley, Sara, 160
 Whitley, Richard, 16, 32
 Williams, George C., 23
 Williams, Perry, 55, 64

Williams, Richard N., 25, 144
Willis, Martin, 16
Wilson, Edward O., 41–43, 87, 106, 131, 145, 147–150, 223, 225, 261
Winston, Christine N., 208
Wolfe, Cary, 231
Wolpert, Lewis, 22
Woolgar, Steve, 103, 120
Wootton, David, 53, 54, 59, 78, 84, 138
Wordsworth, William, 81, 96, 157, 166, 171
Wu, Chien-Shiung, 209
Wyatt, Sally, 102
Wynne, Brian, 32, 144
Xenophanes, 99
Yang, Chen-Ning, 219
Young, Thomas, 203
Zajonc, Arthur, 87
Zakai, Avihu, 78
Zakariya, Nasser, 16, 25, 42, 47, 48, 52, 72, 121, 122, 146, 148, 196, 197
Zeno, 99
Ziman, John, 146
Zuba, Clayton, 167
Zucker, Francis J., 86, 87

CRITICA LITTERARUM LUNDENSIS

Skrifter utgivna av Avdelningen för litteraturvetenskap,
Språk- och litteraturcentrum, Lunds universitet.
Redaktionskommitté: Erik Hedling, Eva Hættner Aurelius,
Anders Ohlsson och Rikard Schönström.

1. Paul Tenngart, *Jag spelar er förväntan. Självdramatisering i Paul Anderssons diktverk Berättarna*, 2002.
2. Daniel Sandström, *Tvinga verkligheten till innebörd. Studier i Kjell Espmarks lyrik fram till och med Sent i Sverige*, 2002.
3. Helene Ehriander, *Humanism och historiesyn i Kai Söderhjelmns historiska barn- och ungdomsböcker*, 2003.
4. Eivor Persson, *C.J.L. Almqvists slottskrönika och det indirekta skrivsättet*, 2003.
5. Maria Nilsson, *Att förhålla sig till moderniteten. En studie i Gertrud Liljas författarskap*, 2003.
6. Wiveca Friman, *Växandets gestaltning i Peter Pohls romansvit om Micke*, 2003.
7. Anders Marklund, *Upplevelser av svensk film. En kartläggning av genrer inom svensk film under åren 1985-2000*, 2004.
8. Jon Helgason, *Hjärtats skrifter. En brevkulturs uttryck i korrespondensen mellan Anna Louisa Karsch och Johann Wilhelm Ludwig Gleim*, 2007.
9. Jonas Asklund, *Humor i romantisk text. Om Jean Pauls estetik i svensk romantik: C.F. Dahlgrens Mollbergs epistlar (1820), C.J.L. Almqvists Amorina (1822) och C. Livijns Spader Dame (1825)*, 2008.
10. Immi Lundin, *Att föra det egna till torgs. Berättande, stoff och samtid i Kerstin Strandbergs, Enel Melbergs och Eva Adolfssons debutromaner*, 2012.
11. Elisabet Björklund, *The Most Delicate Subject. A History of Sex Education Films in Sweden*, 2013.
12. Carolina Ignell, *Du och jag men inte vi. Om omöjliga möten och deras orsaker i J.M. Coetzees fiktion*, 2013.
13. Johan Edlund, *Modernitet och myt. Auförtrollning och återförtrollning i Knut Hamsuns Sult, Mysterier och Pan*, 2015.
14. Jimmie Svensson, *Versform & ikonicitet. Med exempel från svensk modernistisk lyrik*, 2016

15. Erik Erlanson, *Ordkonst och levnadskonst. Det skrivande subjektet i John Ashberys, Yves Bonneföys och Inger Christensens diktning*, 2017
16. Isak Hyltén-Cavallius, *Den ofärdiga vetenskapen. Om krisen i svensk litteraturforskning och litteraturtolkningens villkor*, 2018
17. Sanjin Pejković, *Det förflutna är ett främmande land. Medierade minnen av Jugoslavien i postjugoslavisk dokumentärfilm*, 2019