
یادداشت‌های پایانی

بخش ۱: فیزیک یونان

۱. مادّه و شعر

1. Aristotle, *Metaphysics*, Book I, Chapter 3, 983b 6, 20 (Oxford trans.). Here and below I follow the standard practice of citing passages from Aristotle by referring to their location in I. Bekker's 1831 Greek edition. By "Oxford trans.," I mean that the English language version is taken from *The Complete Works of Aristotle – The Revised Oxford Translation*, ed. J. Barnes (Princeton University Press, Princeton, N.J., 1984), which uses this convention in citing passages from Aristotle.
2. Diogenes Laertius, *Lives of the Eminent Philosophers*, Book I, trans. R. D. Hicks (Loeb Classical Library, Harvard University Press, Cambridge, Mass., 1972), p. 27.
3. From J. Barnes, *The Presocratic Philosophers*, rev. ed. (Routledge and Kegan Paul, London, 1982), p. 29. The quotations in this work, hereafter cited as *Presocratic Philosophers*, are translations into English of the fragmentary quotations in the standard sourcebook by Hermann Diels and Walter Kranz, *Die Fragmente der Vorsokratiker* (10th ed., Berlin, 1952).
4. *Presocratic Philosophers*, p. 53.
5. From J. Barnes, *Early Greek Philosophy* (Penguin, London, 1987), p. 97. Hereafter cited as *Early Greek Philosophy*. As in *Presocratic Philosophers*, these quotations are taken from Diels and Kranz, 10th ed.
6. From K. Freeman, *The Ancilla to the Pre-Socratic Philosophers* (Harvard University Press, Cambridge, Mass., 1966), p. 26. Hereafter cited as *Ancilla*.

This is a translation into English of the quotations in Diels, *Fragmente der Vorsokratiker*, 5th ed.

7. *Ancilla*, p. 59.
8. *Early Greek Philosophy*, p. 166.
9. *Ibid.*, p. 243.
10. *Ancilla*, p. 93.
11. Aristotle, *Physics*, Book VI, Chapter 9, 239b 5 (Oxford trans.).
12. Plato, *Phaedo*, 97C–98C. Here and below I follow the standard practice of citing passages from Plato's works by giving page numbers in the 1578 Stephanos Greek edition.
13. Plato, *Timaeus*, 54 A–B, from Desmond Lee, trans., *Timaeus and Critias* (Penguin Books, London, 1965).
14. For instance, in the Oxford translation of Aristotle's *Physics*, Book IV, Chapter 6, 213b 1–2.
15. *Ancilla*, p. 24.
16. *Early Greek Philosophy*, p. 253.
17. I have written about this point at greater length in the chapter "Beautiful Theories" in *Dreams of a Final Theory* (Pantheon, New York, 1992; reprinted with a new afterword, Vintage, New York, 1994).

٢. موسيقى و رياضيات

1. For the provenance of these stories, see Alberto A. Martinez, *The Cult of Pythagoras—Man and Myth* (University of Pittsburgh Press, Pittsburgh, Pa., 2012).
2. Aristotle, *Metaphysics*, Book I, Chapter 5, 985b 23–26 (Oxford trans.).
3. *Ibid.*, 986a 2 (Oxford trans.).
4. Aristotle, *Prior Analytics*, Book I, Chapter 23, 41a 23–30.
5. Plato, *Theaetetus*, 147 D–E (Oxford trans.).
6. Aristotle, *Physics*, 215p 1–5 (Oxford trans.).
7. Plato, *The Republic*, 529E, trans. Robin Wakefield (Oxford University

Press, Oxford, 1993), p. 261.

8. E. P. Wigner, "The Unreasonable Effectiveness of Mathematics," *Communications in Pure and Applied Mathematics* 13 (1960): 1–14.

۳. حرکت و فلسفه

1. J. Barnes, in *The Complete Works of Aristotle—The Revised Oxford Translation* (Princeton University Press, Princeton, N.J., 1984).

2. R. J. Hankinson, in *The Cambridge Companion to Aristotle*, ed. J. Barnes (Cambridge University Press, Cambridge, 1995), p. 165.

3. Aristotle, *Physics*, Book II, Chapter 2, 194a 29–31 (Oxford trans., p. 331).

4. *Ibid.*, Chapter 1, 192a 9 (Oxford trans., p. 329).

5. Aristotle, *Meteorology*, Book II, Chapter 9, 396b 7–11 (Oxford trans., p. 596).

6. Aristotle, *On the Heavens*, Book I, Chapter 6, 273b 30–31, 274a, 1 (Oxford trans., p. 455).

7. Aristotle, *Physics*, Book IV, Chapter 8, 214b 12–13 (Oxford trans., p. 365).

8. *Ibid.*, 214b 32–34 (Oxford trans., p. 365).

9. *Ibid.*, Book VII, Chapter 1, 242a 50–54 (Oxford trans., p. 408).

10. Aristotle, *On the Heavens*, Book III, Chapter 3, 301b 25–26 (Oxford trans., p. 494).

11. Thomas Kuhn, "Remarks on Receiving the Laurea," in *L'Anno Galileiano* (Edizioni LINT, Trieste, 1995).

12. David C. Lindberg, in *The Beginnings of Western Science* (University of Chicago Press, Chicago, Ill., 1992), pp. 53–54.

13. David C. Lindberg, in *The Beginnings of Western Science*, 2nd ed. (University of Chicago Press, Chicago, Ill., 2007), p. 65.

14. Michael R. Matthews, in Introduction to *The Scientific Background to Modern Philosophy* (Hackett, Indianapolis, Ind., 1989).

۴. فیزیک و فنّ آوری هلنی

1. Here I borrow the title of the leading modern treatise on this age: Peter Green, *Alexander to Actium* (University of California Press, Berkeley, 1990).
2. I believe that this remark is originally due to George Sarton.
3. The description of Strato's work by Simplicius is presented in an English translation by M. R. Cohen and I. E. Drabkin, *A Source Book in Greek Science* (Harvard University Press, Cambridge, Mass., 1948), pp. 211–12.
4. H. Floris Cohen, *How Modern Science Came into the World* (Amsterdam University Press, Amsterdam, 2010), p. 17.
5. For the interaction of technology with physics research in modern times, see Bruce J. Hunt, *Pursuing Power and Light: Technology and Physics from James Watt to Albert Einstein* (Johns Hopkins University Press, Baltimore, Md., 2010).
6. Philo's experiments are described in a letter quoted by G. I. Ibry—Massie and P. T. Keyser, *Greek Science of the Hellenistic Era* (Routledge, London, 2002), pp. 216–19.
7. The standard translation into English is Euclid, *The Thirteen Books of the Elements*, 2nd ed., trans. Thomas L. Heath (Cambridge University Press, Cambridge, 1925).
8. This is quoted in a Greek manuscript of the sixth century AD, and given in an English translation in Ibry—Massie and Keyser, *Greek Science of the Hellenistic Era*.
9. See Table V.1, p. 233, of the translation of Ptolemy's *Optics* by A. Mark Smith in "Ptolemy's Theory of Visual Perception," *Transactions of the American Philosophical Society* 86, Part 2 (1996).
10. Quotes here are from T. L. Heath, trans., *The Works of Archimedes* (Cambridge University Press, Cambridge, 1897).

۵. علم و دین باستان

1. Plato, *Timaeus*, 30A, trans. R. G. Bury, in *Plato*, Volume 9 (Loeb Classical

- Library, Harvard University Press, Cambridge, Mass., 1929), p. 55.
2. Erwin Schrödinger, Shearman Lectures at University College London, May 1948, published as *Nature and the Greeks* (Cambridge University Press, Cambridge, 1954).
 3. Alexandre Koyré, *From the Closed World to the Infinite Universe* (Johns Hopkins University Press, Baltimore, Md., 1957), p. 159.
 4. *Ancilla*, p. 22.
 5. Thucydides, *History of the Peloponnesian War*, trans. Rex Warner (Penguin, New York, 1954, 1972), p. 511.
 6. S. Greenblatt, "The Answer Man: An Ancient Poem Was Rediscovered and the World Swerved," *New Yorker*, August 8, 2011, pp. 28–33.
 7. Edward Gibbon, *The Decline and Fall of the Roman Empire*, Chapter 23 (Everyman's Library, New York, 1991), p. 412. Hereafter cited as Gibbon, *Decline and Fall*.
 8. *Ibid.*, Chapter 2, p. 34.
 9. Nicolaus Copernicus, *On the Revolutions of Heavenly Spheres*, trans. Charles Glenn Wallis (Prometheus, Amherst, N.Y., 1995), p. 7.
 10. Lactantius, *Divine Institutes*, Book 3, Section 24, trans. A. Bowen and P. Garnsey (Liverpool University Press, Liverpool, 2003).
 11. Paul, *Epistle to the Colossians* 2:8 (King James translation).
 12. Augustine, *Confessions*, Book IV, trans. A. C. Outler (Dover, New York, 2002), p. 63.
 13. Augustine, *Retractions*, Book I, Chapter 1, trans. M. I. Bogan (Catholic University of America Press, Washington, D.C., 1968), p. 10.
 14. Gibbon, *Decline and Fall*, Chapter XL, p. 231.

بخش ۲: اخترشناسی یونان

۶. کاربرد اخترشناسی

1. This chapter is based in part on my article "The Missions of Astronomy," *New York Review of Books* 56, 16 (October 22, 2009): 19–22; reprinted in

The Best American Science and Nature Writing, ed. Freeman Dyson (Houghton Mifflin Harcourt, Boston, Mass., 2010), pp. 23–31, and in *The Best American Science Writing*, ed. Jerome Groopman (HarperCollins, New York, 2010), pp. 272–81.

2. Homer, *Iliad*, Book 22, 26–29. Quotation from Richmond Lattimore, trans., *The Iliad of Homer* (University of Chicago Press, Chicago, Ill., 1951), p. 458.

3. Homer, *Odyssey*, Book V, 280–87. Quotations from Robert Fitzgerald, trans., *The Odyssey* (Farrar, Straus and Giroux, New York, 1961), p. 89.

4. Diogenes Laertius, *Lives of the Eminent Philosophers*, Book I, 23.

5. This is the interpretation of some lines of Heraclitus argued by D. R. Dicks, *Early Greek Astronomy to Aristotle* (Cornell University Press, Ithaca, N.Y., 1970).

6. Plato's *Republic*, 527 D–E, trans. Robin Wakefield (Oxford University Press, Oxford, 1993).

7. Philo, *On the Eternity of the World*, I (1). Quotation from C. D. Yonge, trans., *The Works of Philo* (Hendrickson Peabody, Mass., 1993), 707.

۷. اندازه‌گیری خورشیدی، ماه، و زمین

1. The importance of Parmenides and Anaxagoras as founders of Greek scientific astronomy is emphasized by Daniel W. Graham, *Science Before Socrates—Parmenides, Anaxagoras, and the New Astronomy* (Oxford University Press, Oxford, 2013).

2. *Ancilla*, p. 18.

3. Aristotle, *On the Heavens*, Book II, Chapter 14, 297b 26–298a 5 (Oxford trans., pp. 488–89).

4. *Ancilla*, p. 23.

5. Aristotle, *On the Heavens*, Book II, Chapter 11.

6. Archimedes, *On Floating Bodies*, in T. L. Heath, trans., *The Works of Archimedes* (Cambridge University Press, Cambridge, 1897), p. 254. Hereafter cited as Archimedes, Heath trans.

7. A translation is given by Thomas Heath in *Aristarchus of Samos* (Clarendon, Oxford, 1923).
8. Archimedes, *The Sand Reckoner*, Heath trans., p. 222.
9. Aristotle, *On the Heavens*, Book II, 14, 296b 4–6 (Oxford trans.).
10. Aristotle, *On the Heavens*, Book II, 14, 296b 23–24 (Oxford trans.).
11. Cicero, *De Re Publica*, 1.xiv §21–22, in *Cicero, On the Republic and On the Laws*, trans. Clinton W. Keys (Loeb Classical Library, Harvard University Press, Cambridge, Mass., 1928), pp. 41, 43.
12. This work has been reconstructed by modern scholars; see Albert van Helden, *Measuring the Universe—Cosmic Dimensions from Aristarchus to Halley* (University of Chicago Press, Chicago, Ill., 1983), pp. 10–13.
13. *Ptolemy's Almagest*, trans. and annotated G. J. Toomer (Duckworth, London, 1984). The Ptolemy star catalog is on pages 341–99.
14. For a contrary view, see O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Springer—Verlag, New York, 1975), pp. 288, 577.
15. Ptolemy, *Almagest*, Book VII, Chapter 2.
16. Cleomedes, *Lectures on Astronomy*, ed. and trans. A. C. Bowen and R. B. Todd (University of California Press, Berkeley and Los Angeles, 2004).

۸. مسئله‌ی سیارات

1. G. W. Burch, “The Counter—Earth,” *Osiris* 11, 267 (1954).
2. Aristotle, *Metaphysics*, Book I, Part 5, 986a 1 (Oxford trans.). But in Book II of *On the Heavens*, 293b 23–25, Aristotle says that the counter—Earth was supposed to explain why lunar eclipses are more common than solar eclipses.
3. The paragraph quoted here is as given by Pierre Duhem in *To Save the Phenomena—An Essay on the Idea of Physical Theory from Plato to Galileo*, trans. E. Dolan and C. Machler (University of Chicago Press, Chicago, Ill., 1969), p. 5, hereafter cited as Duhem, *To Save the Phenomena*. A more recent translation of this passage from Simplicius is given by I. Mueller: see Simplicius, *On Aristotle's “On the Heavens 2,10–14”* (Cornell University Press,

Ithaca, N.Y., 2005), 492,31– 493,4, p. 33. We don't know if Plato ever actually proposed this problem. Simplicius was quoting Sosigenes the Peripatetic, a philosopher of the second century AD.

4. For very clear illustrations showing the model of Eudoxus, see James Evans, *The History and Practice of Ancient Astronomy* (Oxford University Press, Oxford, 1998), pp. 307–9.

5. Aristotle, *Metaphysics*, Book XII, Chapter 8, 1073b 1–1074a 1.

6. For a translation by I. Mueller, see Simplicius, *On Aristotle "On the Heavens 3,1–7"* (Cornell University Press, Ithaca, N.Y., 2005), 493,1–497,8, pp. 33–36.

7. This was the work, in 1956, of the physicists Tsung—Dao Lee and Chen—Ning Yang.

8. Aristotle, *Metaphysics*, Book XII, Section 8, 1073b 18–1074a 14 (Oxford trans.).

9. These references are given by D. R. Dicks, *Early Greek Astronomy to Aristotle* (Cornell University Press, Ithaca, N.Y., 1970), p. 202. Dicks takes a different view of what Aristotle was trying to accomplish.

10. Mueller, *Simplicius, On Aristotle's "On the Heavens 2,10–14,"* 519,9–11, p. 59.

11. *Ibid.*, 504,19–30, p. 43.

12. See Book I of Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (Springer—Verlag, New York, 1975).

13. G. Smith, private communication.

14. Ptolemy, *Almagest*, trans. G. J. Toomer (Duckworth, London, 1984), Book V, Chapter 13, pp. 247– 51. Also see O. Neugebauer, *A History of Ancient Mathematical Astronomy, Part One* (Springer— Verlag, Berlin, 1975), pp. 100–3.

15. Barrie Fleet, trans., *Simplicius on Aristotle "Physics 2"* (Duckworth, London, 1997), 291,23– 292,29, pp. 47–48.

16. Quoted by Duhem, *To Save the Phenomena*, pp. 20–21.

17. Ibid.

18. For comments on the meaning of explanation in science, and references to other articles on this subject, see S. Weinberg, “Can Science Explain Everything? Anything?” in *New York Review of Books* 48, 9 (May 31, 2001): 47–50. Reprints: *Australian Review* (2001); in Portuguese, *Folha da S. Paolo* (2001); in French, *La Recherche* (2001); *The Best American Science Writing*, ed. M. Ridley and A. Lightman (HarperCollins, New York, 2002); *The Norton Reader* (W. W. Norton, New York, December 2003); *Explanations—Styles of Explanation in Science*, ed. John Cornwell (Oxford University Press, London, 2004), 23–38; in Hungarian, *Akadeemia* 176, No. 8: 1734–49 (2005); S. Weinberg, *Lake Views—This World and the Universe* (Harvard University Press, Cambridge, Mass., 2009).

19. This is not from the *Almagest* but from the *Greek Anthology*, verses compiled in the Byzantine Empire around AD 900. This translation is from Thomas L. Heath, *Greek Astronomy* (Dover, Mineola, N.Y., 1991), p. lvii.

بخش ۳: قرون وسطا

۹. اعراب

1. This letter is quoted by Eutychius, then patriarch of Alexandria. The translation here is from E. M. Forster, *Pharos and Pharillon* (Knopf, New York, 1962), pp. 21–22. A less pithy translation is given by Gibbon, *Decline and Fall*, Chapter 51.

2. P. K. Hitti, *History of the Arabs* (Macmillan, London, 1937), p. 315.

3. D. Gutas, *Greek Thought, Arabic Culture—The Graeco—Arabic Translation Movement in Baghdad and Early ‘Abbāsīd Society* (Routledge, London, 1998), pp. 53–60.

4. Al—Biruni, *Book of the Determination at Coordinates of Localities*, Chapter 5, excerpted and trans. J. Lennart Berggren, in *The Mathematics of Egypt, Mesopotamia, China, India, and Islam*, ed. Victor Katz (Princeton University Press, Princeton, N.J., 2007).

5. Quoted in P. Duhem, *To Save the Phenomena*, p. 29.
6. Quoted by R. Arnaldez and A. Z. Iskandar in *The Dictionary of Scientific Biography* (Scribner, New York, 1975), Volume 12, p. 3.
7. G. J. Toomer, *Centaurus* 14, 306 (1969).
8. Moses ben Maimon, *Guide to the Perplexed*, Part 2, Chapter 24, trans. M. Friedländer, 2nd ed. (Routledge, London, 1919), pp. 196, 198.
9. Ben Maimon is here quoting Psalms 115:16.
10. See E. Masood, *Science and Islam* (Icon, London, 2009).
11. N. M. Swerdlow, *Proceedings of the American Philosophical Society* 117, 423 (1973).
12. The case that Copernicus learned of this device from Arab sources is made by F. J. Ragep, *History of Science* 14, 65 (2007).
13. This is documented by Toby E. Huff, *Intellectual Curiosity and the Scientific Revolution* (Cambridge University Press, Cambridge, 2011), Chapter 5.
14. These are verses 13, 29, and 30 of the second version of Fitzgerald's translation.
15. Quoted in Jim al-Khalili, *The House of Wisdom* (Penguin, New York, 2011), p. 188.
16. *Al-Ghazali's Tahafut al-Falasifah*, trans. Sabih Ahmad Kamali (Pakistan Philosophical Congress, Lahore, 1958).
17. Al-Ghazali, *Fatihah al-Ulum*, trans. I. Goldheizer, in *Studies on Islam*, ed. Merlin L. Swartz (Oxford University Press, 1981), quotation, p. 195.

۱۰. اروپای قرون وسطایی

1. See, e. g., Lynn White Jr., *Medieval Technology and Social Change* (Oxford University Press, Oxford, 1962), Chapter 2.
2. Peter Dear, *Revolutionizing the Sciences—European Knowledge and Its Ambitions, 1500–1700*, 2nd ed. (Princeton University Press, Princeton, N.J., and Oxford, 2009), p. 15.
3. The articles of the condemnation are given in a translation by Edward Grant

in *A Source Book in Medieval Science*, ed. E. Grant (Harvard University Press, Cambridge, Mass., 1974), pp. 48–50.

4. *Ibid.*, p. 47.

5. Quoted in David C. Lindberg, *The Beginnings of Western Science* (University of Chicago Press, Chicago, Ill., 1992), p. 241.

6. *Ibid.*

7. Nicole Oresme, *Le livre du ciel et du monde*, in French and trans. A. D. Menut and A. J. Denomy (University of Wisconsin Press, Madison, 1968), p. 369.

8. Quoted in “Buridan,” in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillespie (Scribner, New York, 1973), Volume 2, pp. 604–5.

9. See the article by Piaget in *The Voices of Time*, ed. J. T. Fraser (Braziller, New York, 1966).

10. Oresme, *Le livre*.

11. *Ibid.*, pp. 537–39.

12. A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science—1100–1700* (Clarendon, Oxford, 1953).

13. For instance, see T. C. R. McLeish, *Nature* 507, 161–63 (March 13, 2014).

14. Quoted in A. C. Crombie, *Medieval and Early Modern Science* (Doubleday Anchor, Garden City, N.Y., 1959), Volume 1, p. 53.

15. Translation by Ernest A. Moody, in *A Source Book in Medieval Science*, ed. E. Grant, p. 239. I have taken the liberty of changing the word “latitude” in Moody’s translation to “increment of velocity,” which I think more accurately indicates Heytesbury’s meaning.

16. De Soto is quoted in an English translation by W. A. Wallace, *Isis* 59, 384 (1968).

17. Quoted in Duhem, *To Save the Phenomena*, pp. 49–50.

1. Herbert Butterfield, *The Origins of Modern Science*, rev. ed. (Free Press, New York, 1957), p. 7.
2. For collections of essays on this theme, see *Reappraisals of the Scientific Revolution*, ed. D. C. Lindberg and R. S. Westfall (Cambridge University Press, Cambridge, 1990), and *Rethinking the Scientific Revolution*, ed. M. J. Osler (Cambridge University Press, Cambridge, 2000).
3. Steven Shapin, *The Scientific Revolution* (University of Chicago Press, Chicago, Ill., 1996), p. 1.
4. Pierre Duhem, *The System of the World: A History of Cosmological Doctrines from Plato to Copernicus* (Hermann, Paris, 1913).

۱۱. حل منظومه‌ی شمس‌ی

1. For an English translation, see Edward Rosen, *Three Copernican Treatises* (Farrar, Straus and Giroux, New York, 1939), or Noel M. Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the *Commentariolus* with Commentary," *Proceedings of the American Philosophical Society* 117, 423 (1973).
2. For a review, see N. Jardine, *Journal of the History of Astronomy* 13, 168 (1982).
3. O. Neugebauer, *Astronomy and History—Selected Essays* (Springer—Verlag, New York, 1983), essay 40.
4. The importance of this correlation for Copernicus is stressed by Bernard R. Goldstein, *Journal of the History of Astronomy* 33, 219 (2002).
5. For an English translation, see *Nicolas Copernicus On the Revolutions*, trans. Edward Rosen (Polish Scientific Publishers, Warsaw, 1978; reprint, Johns Hopkins University Press, Baltimore, Md., 1978); or *Copernicus—On the Revolutions of the Heavenly Spheres*, trans. A. M. Duncan (Barnes and Noble, New York, 1976). Quotations here are from Rosen.
6. A. D. White, *A History of the Warfare of Science with Theology in Christendom* (Appleton, New York, 1895), Volume 1, pp. 126–28. For a deflation

of White, see D. C. Lindberg and R. L. Numbers, “Beyond War and Peace: A Reappraisal of the Encounter Between Christianity and Science,” *Church History* 58, 3 (September 1986): 338.

7. This paragraph has been quoted by Lindberg and Numbers, “Beyond War and Peace,” and by T. Kuhn, *The Copernican Revolution* (Harvard University Press, Cambridge, Mass., 1957), p. 191. Kuhn’s source is White, *A History of the Warfare of Science with Theology*. The German original is *Sämtliche Schriften*, ed. J. G. Walch (J. J. Gebauer, Halle, 1743), Volume 22, p. 2260.

8. Joshua 10:12.

9. This English translation of Osiander’s preface is taken from Rosen, trans., *Nicolas Copernicus On the Revolutions*.

10. Quoted in R. Christianson, *Tycho’s Island* (Cambridge University Press, Cambridge, 2000), p. 17.

11. On the history of the idea of hard celestial spheres, see Edward Rosen, “The Dissolution of the Solid Celestial Spheres,” *Journal of the History of Ideas* 46, 13 (1985). Rosen argues that Tycho exaggerated the extent to which this idea had been accepted before his time.

12. For claims to Tycho’s system and for its variations, see C. Schofield, “The Tychonic and Semi—Tychonic World Systems,” in *Planetary Astronomy from the Renaissance to the Rise of Astrophysics —Part A: Tycho Brahe to Newton*, ed. R. Taton and C. Wilson (Cambridge University Press, Cambridge, 1989).

13. For a photograph of this statue, taken by Owen Gingerich, see the frontispiece of my essay collection *Facing Up—Science and Its Cultural Adversaries* (Harvard University Press, Cambridge, Mass., 2001).

14. S. Weinberg, “Anthropic Bound on the Cosmological Constant,” *Physical Review Letters* 59, 2607 (1987); H. Martel, P. Shapiro, and S. Weinberg, “Likely Values of the Cosmological Constant,” *Astrophysical Journal* 492, 29 (1998).

15. J. R. Voelkel and O. Gingerich, “Giovanni Antonio Magini’s ‘Keplerian’ Tables of 1614 and Their Implications for the Reception of Keplerian Astron-

omy in the Seventeenth Century,” *Journal for the History of Astronomy* 32, 237 (2001).

16. Quoted in Robert S. Westfall, *The Construction of Modern Science—Mechanism and Mechanics* (Cambridge University Press, Cambridge, 1977), p. 10.

17. This is the translation of William H. Donahue, in *Johannes Kepler—New Astronomy* (Cambridge University Press, Cambridge, 1992), p. 65.

18. Johannes Kepler, *Epitome of Copernican Astronomy and Harmonies of the World*, trans. Charles Glenn Wallis (Prometheus, Amherst, N.Y., 1995), p. 180.

19. Quoted by Owen Gingerich in *Tribute to Galileo in Padua, International Symposium a cura dell’Universita di Padova, 2–6 dicembre 1992, Volume 4* (Edizioni LINT, Trieste, 1995).

20. Quotations from Galileo Galilei, *Siderius Nuncius, or The Sidereal Messenger*, trans. Albert van Helden (University of Chicago Press, Chicago, Ill., 1989).

21. Galileo Galilei, *Discorse e Dimostrazione Matematiche*. For a facsimile of the 1663 translation by Thomas Salusbury, see Galileo Galilei, *Discourse on Bodies in Water*, with introduction and notes by Stillman Drake (University of Illinois Press, Urbana, 1960).

22. For a modern edition of a seventeenth—century translation, see Galileo, *Discourse on Bodies in Water*, trans. Thomas Salusbury, intro. and notes by Stillman Drake.

23. For details of this conflict, see J. L. Heilbron, *Galileo* (Oxford University Press, Oxford, 2010).

24. This letter is widely cited. The translation quoted here is from Duhem, *To Save the Phenomena*, p. 107. A fuller translation is given in Stillman Drake, *Discoveries and Opinions of Galileo* (Anchor, New York, 1957), pp. 162–64.

25. A translation of the entire letter is given in Drake, *Discoveries and Opinions of Galileo*, pp. 175–216.

26. Quoted in Stillman Drake, *Galileo* (Oxford University Press, Oxford, 1980), p. 64.
27. The letters of Maria Celeste to her father fortunately survive. Many are quoted in Dava Sobel, *Galileo's Daughter* (Walker, New York, 1999). Alas, Galileo's letters to his daughters are lost.
28. See Annibale Fantoli, *Galileo—For Copernicanism and for the Church*, 2nd ed., trans. G. V. Coyne (University of Notre Dame Press, South Bend, Ind., 1996); Maurice A. Finocchiaro, *Retrying Galileo, 1633–1992* (University of California Press, Berkeley and Los Angeles, 2005).
29. Quoted in Drake, *Galileo*, p. 90.
30. Quoted by Gingerich, *Tribute to Galileo*, p. 343.
31. I made a statement to this effect at the same meeting in Padua where Kuhn made the remarks about Aristotle cited in Chapter 4 and where Gingerich gave the talk about Galileo from which I have quoted here. See S. Weinberg, in *L'Anno Galileiano* (Edizioni LINT, Trieste, 1995), p. 129.

۱۲. آغاز آزمایش

1. See G. E. R. Lloyd, *Proceedings of the Cambridge Philosophical Society*, N.S. 10, 50 (1972), reprinted in *Methods and Problems in Greek Science* (Cambridge University Press, Cambridge, 1991).
2. Galileo Galilei, *Two New Sciences*, trans. Stillman Drake (University of Wisconsin Press, Madison, 1974), p. 68.
3. Stillman Drake, *Galileo* (Oxford University Press, Oxford, 1980), p. 33.
4. T. B. Settle, "An Experiment in the History of Science," *Science* 133, 19 (1961).
5. This is Drake's conclusion in the endnote to p. 259 of Galileo Galilei, *Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican*, trans. Stillman Drake (Modern Library, New York, 2001).
6. Our knowledge of this experiment is based on an unpublished document, folio 116v, in Biblioteca Nazionale Centrale, Florence. See Stillman Drake,

Galileo at Work—His Scientific Biography (University of Chicago Press, Chicago, Ill., 1978), pp. 128–32; A. J. Hahn, “The Pendulum Swings Again: A Mathematical Reassessment of Galileo’s Experiments with Inclined Planes,” *Archive for the History of the Exact Sciences* 56, 339 (2002), with a reproduction of the folio on p. 344.

7. Carlo M. Cipolla, *Clocks and Culture 1300–1700* (W. W. Norton, New York, 1978), pp. 59, 138.

8. Christiaan Huygens, *The Pendulum Clock or Geometrical Demonstrations Concerning the Motion of Pendula as Applied to Clocks*, trans. Richard J. Blackwell (Iowa State University Press, Ames, 1986), p. 171.

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12. Quoted by Steven Shapin in *The Scientific Revolution* (University of Chicago Press, Chicago, Ill., 1996), p. 105.

13. *Ibid.*, p. 185.

۱۳. بازنگری روش‌ها

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2. Quotations are from René Descartes, *Principles of Philosophy*, trans. V. R. Miller and R. P. Miller (D. Reidel, Dordrecht, 1983), p. 15.

3. Voltaire, *Philosophical Letters*, trans. E. Dilworth (Bobbs—Merrill Educational Publishing, Indianapolis, Ind., 1961), p. 64.

4. It is odd that many modern English language editions of *Discourse on Method* leave out these supplements, as if they would not be of interest to philosophers. For an edition that does include them, see René Descartes, *Discourse on Method, Optics, Geometry, and Meteorology*, trans. Paul J. Olscamp (Bobbs—Merrill, Indianapolis, Ind., 1965). The Descartes quote and the numerical results below are from this edition.
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۱۴. آثار نیوتون

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4. Peter Galison, *How Experiments End* (University of Chicago Press, Chicago, Ill., 1987).
5. Quoted in Westfall, *Never at Rest*, p. 143.
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7. Quoted in James Gleick, *Isaac Newton* (Pantheon, New York, 2003), p. 120.
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12. See Robert P. Crease, *World in the Balance—The Historic Quest for an Absolute System of Measurement* (W. W. Norton, New York, 2011).
13. See J. Z. Buchwald and M. Feingold, *Newton and the Origin of Civilization* (Princeton University Press, Princeton, N.J., 2014).
14. See S. Chandrasekhar, *Newton’s Principia for the Common Reader* (Clarendon, Oxford, 1995), pp. 472–76; Westfall, *Never at Rest*, pp. 736–39.

15. R. S. Westfall, "Newton and the Fudge Factor," *Science* 179, 751 (1973).
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۱۵. سخن پایانی: فروگاهی بزرگ

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6. To forestall accusations of plagiarism, I will acknowledge here that this last paragraph is a riff on the last paragraph of Darwin's *On the Origin of Species*.

کتاب‌شناسی

این کتاب‌شناسی فهرست منابع ثانویه‌ی مدرن پیرامون تاریخ علم است که آن‌ها را خوانده‌ام و نیز آثار اصلی دانشمندان روزگاران گذشته، از قطعه‌های به‌جا مانده از دوران پیش از سقراط گرفته تا کتاب اصول نیوتون، است که به آن‌ها رجوع کرده‌ام، و به منابع امروزی‌تر تنها نگاهی گذرا انداخته‌ام. آثاری که فهرست آن‌ها را در اینجا آورده‌ام، همه به زبان انگلیسی و یا ترجمه‌های انگلیسی هستند، چون از شانس بد، من نه لاتینی می‌دانم و نه یونانی، کجا برسد به عربی. قصدم از این فهرست این نیست که فهرست جامع‌ترین منابع، یا آخرین ویرایش هر منبع را آورده باشم، بلکه این‌ها ویرایش‌هایی از کتاب‌هایی بوده‌اند که هنگام نوشتن کتاب تاریخ علم به آن‌ها دسترسی داشتم.

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