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Cryptographic City

Decoding the Smart Metropolis

By: Richard Coyne

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Notes

Introduction

1. I explored the role of acoustics signals in defining spaces in Coyne, *The Tuning of Place*.
2. Permissionjunkie, "What Secret Codes Are All around Us That Only People 'In the Know' Recognize?"
3. Baraniuk, "The Secret Codes You're Not Meant to Know."
4. This is the practice of runners in the "hare and hounds" activity of the global Hash House Harriers association, whose members adopt a particular set of waymarking signals. See <https://www.hashhouseharriers.com>.
5. Lessig, *Code and Other Laws of Cyberspace*.
6. Singh, *The Code Book*, 10–11.
7. Brown, *The Lost Symbol*, 274.
8. Kahn, *The Codebreakers*, "A Few Words," Kindle.
9. Sebeok, *Signs*.
10. I have expanded on the theme of interpretation in other texts. See Snodgrass and Coyne, *Interpretation in Architecture*, drawing on the theories of Gadamer, *Truth and Method*.
11. E.g., Freedom of Information Act (FOIA) requests.
12. For the variety of research on the smart city, see Aurigi, "No Need to Fix"; Cecco, "Google Affiliate Sidewalk Labs Abruptly Abandons Toronto Smart City Project"; de Lange, "The Smart City You Love to Hate"; Figueiredo, Krishnamurthy, and Schroeder, *Architecture and the Smart City*; Greenfield and Nurri, *The City Is Here for You to Use*; Hnilica, "The Metaphor of the City as a Thinking Machine"; McDermott, "New Sensorial Vehicles"; Penn and Al Sayed, "Spatial Information Models as the

Backbone of Smart Infrastructure”; van Ditmar, “The IdIoT in the Smart Home”; Willis and Aurigi, *Digital and Smart Cities*.

13. Degen and Rose, *The New Urban Aesthetic*, 77.

14. Berger and Iniewski, *Smart Grid Applications, Communications, and Security*.

15. Mattern, *A City Is Not a Computer*, 16.

16. Degen and Rose, *The New Urban Aesthetic*, 71.

17. Burgess, “What Is the Internet of Things? WIRED Explains.”

18. McDermott, “New Sensorial Vehicles”; Yoo, Eun, and Jung, “Drone Delivery.”

19. Alibasic et al., “Cybersecurity for Smart Cities.”

20. Alibasic et al., “Cybersecurity for Smart Cities.”

21. Gold and Shaw, “What Is Edge Computing and Why Does It Matter?”; Gusev and Dustdar, “Going Back to the Roots”; Hamilton, “What Is Edge Computing.”

22. Cerrudo, “An Emerging US (and World) Threat,” 9.

23. Cerrudo, 14.

24. Cerrudo, 14.

25. Graham, “Software-Sorted Geographies,” 564. Also see Graham and Marvin, *Splintering Urbanism*.

26. Mattern, *A City Is Not a Computer*, 16.

27. For an account of how narratives about economics inform citizens’ understandings of innovations such as cryptocurrency, see Shiller, “The Bitcoin Narratives.”

28. Lipman, Sugarman, and Cushman, *Teleports and the Intelligent City*.

29. See Joss et al., “The Smart City as Global Discourse.”

30. Lyons, “Getting Smart about Urban Mobility”; Deakin and Reid, “Smart Cities.”

31. Mattern, *A City Is Not a Computer*, 13.

32. Jung et al., *Man and His Symbols*, 236.

33. Zuboff, *The Age of Surveillance Capitalism*, 95.

34. Martin, *Cryptography*.

35. Martin, 7.

36. Ellison, *A Material History of Early Modern English Cryptography Manuals*, 8.

37. Ellison, 8.

38. Ellison, 8.
39. Ellison, 8.
40. Ellison, 8.
41. Ellison, 9.
42. Ellison, 8.
43. Hodges, *Alan Turing*.
44. Harari, *Sapiens*.
45. That's an interpretive enterprise, a hermeneutical process. See Gadamer, *Truth and Method*; Snodgrass and Coyne, *Interpretation in Architecture*.
46. Prominent Trump advocate R. W. Giuliani promoted conspiracy theories about the 1920 U.S. presidential election via his YouTube channel; see, for example, Giuliani, "Election Theft of the Century," since removed for violating YouTube Community Guidelines.
47. Gibson, *The Ecological Approach to Visual Perception*, 127; Gibson, *The Senses Considered as Perceptual Systems*. Note the broad reach of affordance theory to include "media affordances." See Rice et al., "Organizational Media Affordances."
48. Norman, *The Design of Everyday Things*. For the application of affordance theory to care facilities, see Topo, Kotilainen, and Eloniemi-Sulkava, "Affordances of the Care Environment for People with Dementia." Also see the application of Gibson's affordance theory to landscape architecture: Heft, "Affordances and the Perception of Landscape."
49. Gibson, *The Ecological Approach to Visual Perception*, 127–128.
50. Anon., "Affordances."
51. Mumford, *The Culture of Cities*, 3.
52. See my previous book on the pragmatic philosopher Charles Sanders Peirce: Coyne, *Peirce for Architects*.

Chapter 1

1. Lindon, *The Alchemy Reader*.
2. Hyde, *Trickster Makes This World*.
3. Underwood, *Numerology, or, What Pythagoras Wrought*, 2.
4. Scholem, *Major Trends in Jewish Mysticism*, 255.
5. Gaffarel, *Unheard-of Curiosities Concerning the Talismanical Sculpture of the Persians*.

6. Lebeuf, "The Alphabet and the Sky."
7. Lebeuf, 320.
8. Kamczycki, "The Kabbalistic Alphabet of Libeskind."
9. Oliver, *The Pythagorean Triangle*.
10. Based on the novel by Pullman, *Northern Lights*.
11. Brown, *The Lost Symbol*.
12. Curl, *The Art and Architecture of Freemasonry*. *Life* magazine from 1956 provides a set of colored images that highlight the spectacle of some of the Masonic rituals at that time. Anon., "Busy Brotherly World of Freemasonry."
13. For Jacques Derrida, that kind of reasoning would be "intertextual." See Coyne, *Derrida for Architects*.
14. Bogdan and Snoek, *Handbook of Freemasonry*.
15. Prescott, "The Old Charges," 33.
16. Stevenson, "The Origins of Freemasonry," 50.
17. Stevenson, 50.
18. Knoop, Jones, and Hamer, *The Early Masonic Catechisms*, 22.
19. Oliver, *The Pythagorean Triangle*.
20. Dickie, *The Craft*.
21. Dickie, "What the Freemasons Taught the World about the Power of Secrecy."
22. Dickie.
23. Knoop, Jones, and Hamer, *The Early Masonic Catechisms*, 197.
24. Curl, "Freemasonry and Architecture," 557.
25. Curl, 586.
26. Watkin, "Freemasonry and Sir John Soane," 402.
27. Watkin, 402.
28. Furjan, *Glorious Visions*.
29. Sir John Soane's Museum London, <https://www.soane.org>.
30. Furjan, *Glorious Visions*, 172.
31. Furjan, 172.
32. Furjan, 7.

33. Furjan, 61.
34. Furjan, 112. A translucent LiDAR scan of the building by scanlabprojects.co.uk further reveals its visual attributes. See Anon., "A New Way to Experience Sir John Soane's Museum."
35. Knoop, Jones, and Hamer, *The Early Masonic Catechisms*, 216.
36. Åhlén, "Pigpen Cipher (Decoder, Translator, History)."
37. Lakoff and Johnson, *Metaphors We Live By*. Lakoff and Johnson characterize metaphors in terms of *entailments* rather than *affordances*. I take these two terms to mean the same thing in this context.
38. Evans, "Figures, Doors and Passages," 90.
39. Knuth, "Two Thousand Years of Combinatorics." Also see Knuth, *The Art of Computer Programming*.
40. Singh, *The Code Book*, 30.
41. De Hoyos, "Masonic Rites and Systems," 355.
42. De Hoyos, 355–356.
43. Aristotle, *The Ethics of Aristotle*, 101.
44. Palladio, *The Four Books of Architecture*, 1.
45. Snoek, "Masonic Rituals of Initiation," 323.
46. Matthews, "Mazes and Labyrinths."
47. Thiel, "Processional Architecture."
48. Jones, *Design Methods*. Also see Fraser, "Design Research in Architecture, Revisited."
49. Vidler, *The Writing of the Walls*, 91.
50. We explored the theme of origins in architecture in Snodgrass and Coyne, *Interpretation in Architecture*.
51. Vidler, *The Writing of the Walls*.
52. Odgers, Samuel, and Sharr, *Primitive*.
53. Evans, "Figures, Doors and Passages," 90.
54. Knoop, Jones, and Hamer, *The Early Masonic Catechisms*, 178.
55. On the subject of thresholds, see Coyne, *Cornucopia Limited*.
56. Dickie, *The Craft*.

57. Gorlé, *Wittgenstein's Secret Diaries*.

58. The house was in the austere modernist style. He worked on the project with a trained architect, though by all accounts the design followed Wittgenstein's specifications and he obsessed over the details. See Sennett, *The Craftsman*; Wittgenstein, *Philosophical Investigations*.

59. Scholars have drawn similarities, and differences, with Heidegger's simple hut retreat in the German Black Forest. See Sharr, *Heidegger's Hut*.

60. Wittgenstein had intimate relations with fellow student Francis Skinner to whom he dictated some of his thoughts in philosophy and with whom he holidayed and cohabited for a period, a relationship made public only many years later. Gibson and O'Mahony, *Ludwig Wittgenstein*.

61. For an entry on "Mysticism," see Glock, *A Wittgenstein Dictionary*.

62. Weston, "The Lantern and the Glass."

63. Wittgenstein, *Tractatus*, 90.

64. Wittgenstein, *Philosophical Investigations*.

65. Wittgenstein, *Tractatus*, 25.

66. Wittgenstein, 87.

67. Wittgenstein, 54.

Chapter 2

1. The quote continues by referring to an epidemic in the city: "The pestilence doth still increase amongst us we shall not be able to hold out the siege without fresh and speedy supply." Wilkins, *Mercury*, 4.

2. Wilkins, 69.

3. Ellison, *A Material History*.

4. Ellison, 6.

5. The *Handbook of Semiotics* lists Wilkins among the progenitors of modern semiotics. See Nöth, *Handbook of Semiotics*.

6. Mitchell, *Placing Words*.

7. Mitchell, 11. *Intertextual* is a term used by Jacques Derrida as a tactic in argumentation where the reader is led along a circuit of interrelated terms. I elaborate on this approach in Coyne, *Derrida for Architects*.

8. Mitchell, 16.

9. For my own thinking on the application of Derrida's ideas about language and architecture, see Coyne, *Derrida for Architects*.
10. Mitchell, *Placing Words*, 17.
11. Mitchell, 17.
12. Mattern, *Code and Clay, Data and Dirt*, xi.
13. Mattern, xi.
14. Heyworth, "Monte Alban." On the theme of Monte Albán as an "information processing institution," see Marcus, "How Monte Albán Represented Itself."
15. The word in modern Hebrew is שיבולת.
16. Homer, *The Odyssey*.
17. Maria-Reina Bravo, "Doris Salcedo, Shibboleth."
18. "Shibboleth," *Monster Wiki*, <https://monster.fandom.com/wiki/Shibboleth>.
19. According to the shibboleth.net website: "With just one identity, a user can securely sign into a variety of systems while keeping management free from the burden of maintaining a collection of usernames and passwords."
20. Augoyard and Torgue, *Sonic Experience*, 62.
21. The OED politely defines the word *Ebonics* as "African-American English." The *Urban Dictionary* says less sympathetically: "A poor excuse for a failure to grasp the basics of english [sic]." The *Urban Dictionary* provides an example: "Don't be tellin' me dat I can't talk good cuz I speak ebonics."
22. Baker, *Polari*. Some minority languages started in fiction, films, or television series and have gathered a base of ardent practitioners. The putative alien language of Klingon from the *Star Trek* franchise is notable among them. Okrand, *The Klingon Dictionary*.
23. Stiny, "Kindergarten Grammars."
24. According to the OED, *to text* (someone) featured only since the 1990s as a verb in everyday usage: "transitive. Telecommunications. To send (a text message) to a person, mobile phone, etc.; to send a text message to. Also intransitive: to communicate by sending text messages." On the other hand, *writing* (to write) has served as a verb as well as a noun for much longer.
25. Poovey, *A History of the Modern Fact*.
26. Ong, *Rhetoric, Romance, and Technology*; Ong, *Orality and Literacy*.
27. Ong, *Rhetoric, Romance, and Technology*, 186.

28. Ong, 186.
29. Ong, 186.
30. Critical of this reductive accounting model, Alex Pazaitisa and colleagues describe double-entry bookkeeping as representing the way value is recorded in the depersonalized industrial economy. See Pazaitisa, De Filippib, and Kostakis, "Blockchain and Value Systems in the Sharing Economy."
31. Poovey, *A History of the Modern Fact*, 63.
32. Writing is also set in relationship to speaking, which recalls Jacques Derrida's account of the cultural and ontological priority of writing; he explains this in his book *Of Grammatology*. See Coyne, *Derrida for Architects*.
33. Huber, "How to Make GPS Art." For research into the city as networks of movement, see Hillier, *Space Is the Machine*; Turner and Penn, "Encoding Natural Movement as an Agent-Based System."
34. McLuhan, *The Gutenberg Galaxy*.
35. McLuhan, 95.
36. Knuth, "Two Thousand Years of Combinatorics."
37. DuPont, "The Printing Press and Cryptography," 101.
38. DuPont, 101.
39. DuPont, 100.
40. Priani, "Raymon Llull."
41. DuPont, "The Printing Press and Cryptography," 101.
42. Lowenthal, *The Past Is a Foreign Country*, 88.
43. DuPont, "The Printing Press and Cryptography," 95.
44. Alberti, *De componendis cifris*, 180.
45. Alberti, 180.
46. Ciphertown, "How to Use the Alberti Cipher Disk Device with Method 1."
47. Singh, *The Code Book*, 126–142.
48. Singh, 126.
49. Led by mathematician Alan Turing (1912–1954). Hodges, *Alan Turing*.
50. Williams, March, and Wassell, *The Mathematical Works of Leon Battista Alberti*, 193.

51. Williams, March, and Wassell, 193.
52. DuPont, "The Printing Press and Cryptography."
53. Vitruvius, *Vitruvius: The Ten Books on Architecture*, 13.
54. Carpo, *Architecture in the Age of Printing*.
55. Alberti, *On the Art of Building in Ten Books*, 204.
56. Alberti, 310.
57. Alberti, 310.
58. A key text on the cultural role of the carnivalesque is Bakhtin, *Rabelais and His World*.
59. Rescher, "Leibniz's *Machina Deciphtratoria*," 113.
60. Rescher, 110.
61. Ross, "Leibniz and the Nuremberg Alchemical Society," 223.
62. The philosopher Rene Descartes (1596–1650) was also familiar with Gaffarel. See Kirsanov, "Leibniz in Paris." I discuss this alphabet in chapter 1.
63. Look, "Gottfried Wilhelm Leibniz."
64. Leibniz, "Monadology," 7.
65. Deleuze, *The Fold*, 228.
66. This is a reference to Plato's famous cave analogy, in which the external reality of the *ideas* is perceived only fleetingly in the flickering firelight of the cave's interior; Plato, *The Republic of Plato*.
67. See, for example, Prominski and Koutroufinis, "Folded Landscapes."
68. The passage continues: "These folds, ropes, or springs set up on the opaque cloth represent innate knowledge, but an innate knowledge which passes into action when called upon by matter. For the latter unleashes the 'vibrations or oscillations' at the lower extremity of the ropes by means of 'small openings' which do exist on the lower level." Deleuze, *The Fold*, 228.
69. Look, "Gottfried Wilhelm Leibniz."

Chapter 3

1. Sebeok, *Signs*.
2. Nöth, *Handbook of Semiotics*.

3. Coyne, *Derrida for Architects*; Coyne, *Peirce for Architects*.
4. For example, see Windsor, "An Ecological Approach to Semiotics."
5. Shannon and Weaver, *The Mathematical Theory of Communication*; Reddy, "The Conduit Metaphor."
6. I am skirting past the findings of studies into language acquisition, but the view here accords with the pragmatism of Reddy, "The Conduit Metaphor." I return to this theme in chapter 13 in a discussion of languages for communicating with supposed extraterrestrial aliens.
7. Norman, *The Design of Everyday Things*.
8. Lynch and Hack, *Site Planning*, 218–219. Also see Lynch, *The Image of the City*.
9. For a critique of physical signs and how they turn places into non-places, see Augé, *Non-places*.
10. Unger and Grassl, "Insta-Holidays and Instagrammability," 92. Also see Degen and Rose, *The New Urban Aesthetic*.
11. Gehl, *Cities for People*.
12. In the *Handbook of Semiotics*, Nöth amplifies the role of "unwritten traditional rules of social conduct . . . for example the code of decorum or the fashion code." Nöth, *Handbook of Semiotics*, 206. Certain prescribed activities and conditions are mandated and presented as regulations. According to Nöth these are "sets of rules prescribing forms of social behaviour." These are typically written down and understood well in the urban context as ordinances, codes, regulations, laws, and instructions.
13. Lynch and Hack, *Site Planning*, 226.
14. In *The Image of the City*, he affirms: "A legible city would be one whose districts or landmarks or pathways are easily identifiable and are easily grouped into an overall pattern" (3).
15. Lynch and Hack, *Site Planning*, 226.
16. Lynch and Hack, 226.
17. "Yet certain elements will be crucial to all: the main system of circulation, the basic functional and social areas, the principal centers of activity and of symbolic value, the historic points, the natural site, the major open spaces." Lynch and Hack, 226.
18. Lynch and Hack, 226.
19. Lynch and Hack, 204–205.

20. Lynch and Hack, 193.
21. Lynch and Hack, 199.
22. See <https://www.airbnb.co.uk/s/experiences>.
23. Lynch, *The Image of the City*, 5–6.
24. Lynch, 5–6.
25. Lynch and Hack, *Site Planning*, 226.
26. Pullan, “Agon in Urban Conflict,” 222.
27. Hoffman, *Cybersecurity Bible*, 604.
28. McEwen, *Vitruvius*.
29. Singh, *The Code Book*, 257.
30. Coyne, Lee, and Parker, “Permeable Portals.”
31. More, *Utopia*, 65.
32. Jacobs, *The Death and Life of Great American Cities*, 32.
33. Schneier, *Beyond Fear*, 278.
34. Schneier, 278.
35. Schneier, 278.
36. OED.
37. See, for example, Lessig, *Code and Other Laws of Cyberspace*; Diver, *Digisprudence*.
38. Kitchin, “From a Single Line of Code to an Entire City,” 16.
39. Kitchin, 17.
40. Graham, “Software-Sorted Geographies,” 563.
41. Ben-Joseph, *The Code of the City*.
42. The philosopher Jacques Derrida makes much of concepts that revolve around *arche* and anarchy. Derrida, *Of Grammatology*. Also see Evans, “Towards Anarchitecture.”
43. May, “The Crypto Anarchist Manifesto.”
44. May.
45. May.
46. May.

47. Levy, "Crypto Rebels."
48. For example, the architect Bernard Tschumi's studio exercise of designing a nightclub in a graveyard: Tschumi, *Architecture and Disjunction*.
49. Mumford, *The Culture of Cities*, 288.
50. Mumford, 288.
51. Manaugh, *A Burglar's Guide to the City*.
52. Manaugh, 11–12.
53. Manaugh, 11–12.
54. Connor, *Beyond Words*, 48. Indeed, a search on my Apple music streaming service calls up many songs and albums simply titled "Whisper." There's George Michael's "Careless Whisper" sung in full voice. A rap song called "Wait (The Whisper Song)" by Ying Yang Twins starts, "Hey, how you doin' lil' mama? Let me whisper in your ear. Tell you somethin' that you might like to hear." That's a rap song delivered as a whisper—appropriate to its transgressive lyrics.
55. Known as ASMR (autonomic sensory meridian response) videos, designed to invoke a state of deep relaxation and sometimes euphoria through a putative psychophysical "auto sensory meridian response." For further explanation of ASMR, see my blog post: Coyne, "The Pleasures of the Mouth."
56. I review some of these considerations in Coyne, *The Tuning of Place*.
57. Connor, *Beyond Words*, 50.
58. Connor, 50–51.
59. Connor, 51.
60. See Tanizaki, *In Praise of Shadows*. Whispers belong in the half light of a private room, a building's eaves (where *eavesdroppers* hang out), in colonnades, doorways, and other thresholds.
61. See Crandall, "Invisible Commercials and Hidden Persuaders."
62. Packard, *The Hidden Persuaders*, 31.
63. Brean, "'Hidden Sell' Technique Is Almost Here."
64. In fact, that particular edition of *Life* magazine contains many other "subliminal messages." In keeping with the age, the edition purveys the good life, middle-class suburbia, a burgeoning consumer culture, gender stereotypes and the nuclear family—wash and wear shirts, lawn mowers, pasta sauce, washing machines, *South Pacific*, a Smith-Corona portable electric typewriter, a Keystone 8mm movie camera.

Chapter 4

1. Mumford, *The Culture of Cities*, 3.
2. That's $10 \times 9 \times 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$ orderings, or $10!$ (10 factorial).
3. Technically, some of these associations are "false cognates." According to the *Online Etymological Dictionary*, "hack" applied to labor derives from the pastureland in Hackney, England, where horses were kept for hire; <https://www.etymonline.com/search?q=hack>.
4. Shields, *Collage and Architecture*, 2.
5. Ellison, "Deciphering and the Exhaustion of Recombination," 181.
6. "A cabinet is redesigned so that visible drawers, already built to hide away documents, contain additional hidden compartments. Similarly, a book or a sentence can be restructured in ways that bend the conventions of their use, disguising messages in folds or between the lines." Ellison, 181.
7. Kurokawa, *Metabolism in Architecture*.
8. Anon., "TOOOL," <https://toool.nl/Toool>; Kurokawa, *Metabolism in Architecture*.
9. These are specialists who select locks from a catalogue and work out which locks share the same key, and master key.
10. Herbert Simon, theorist of decision-making, coined the term *satisficing* to account for the challenge of deciding between options in the face of multiple and conflicting criteria. See Simon, "The Structure of Ill-Structured Problems"; Newell and Simon, *Human Problem Solving*; Simon, *The Sciences of the Artificial*.
11. Conan Doyle, *The Sign of Four*, 42.
12. Descartes, *Discourse on Method and the Meditations*, 41.
13. Alexander, *Notes on the Synthesis of Form*; Jones, *Design Methods*.
14. Also see Steadman, *Architectural Morphology*.
15. Bloch and Krishnamurti, "The Counting of Rectangular Dissections."
16. Bloch and Krishnamurti.
17. Coyne, *Logic Models of Design*.
18. Designers don't design in this way. How designers might actually design, how elements get laid out in a city, and citizens organize space, is beyond the scope of this chapter. For an account of the difficulties with logical models of design and my retelling in the context of the pragmatic philosophy of Charles Sanders Peirce, see Coyne, *Peirce for Architects*.

19. Ong, *Ramus*.
20. See Lefebvre, *Rhythmanalysis*.
21. Descartes, *Discourse on Method and the Meditations*.
22. *Squid Game* (2021), Series 1, Episode 7: "VIPS."
23. A riddle falls within the purview of humor as a kind of joke. See Martin and Ford, *The Psychology of Humor*, 4.
24. That's close to a description of Salvador Dalí's painting *The Temptation of St Anthony*.
25. Topolinski and Reber, "Gaining Insight into the 'Aha' Experience."
26. Lyons, "English Letter Frequencies."
27. ETA, "Letter Frequencies."
28. Ohlman, "Subject-Word Letter Frequencies with Applications to Superimposed Coding."
29. Ohlman, "Subject-Word Letter Frequencies," 903.
30. Though it is likely a computer would produce a range of possible plain text messages from that short cryptogram. Mia Epner provides a helpful video explaining encryption keys. See Epner, "Encryption and Public Keys." For further explanation, see Lake, "What Is AES Encryption and How Does It Work?"; Watson, "Famous Codes and Ciphers through History."
31. Watson, "Famous Codes and Ciphers through History."
32. Sullivan, "A (Relatively Easy To Understand) Primer on Elliptic Curve Cryptography."
33. Mann, "The Science of Encryption."
34. I joined the cadre of bloggers who seek to explain and clarify cryptography with my own contribution; see R. Coyne, "RSA Public Key Encryption."
35. Seetharam, "RSA (Rivest, Shamir, Adleman) Algorithm Explained with Example."
36. Hughes, "How Elliptic Curve Cryptography Works." Diffie and Hellman were the computer scientists who identified the challenge of asymmetrical key encryption; see Diffie and Hellman, "New Directions in Cryptography."
37. Coyne, "Key Exchange"; Coyne, "Elliptic Trapdoors"; Coyne, "Elliptic Fields."
38. Here I follow the verdict of many linguists and theorists of metaphor that metaphors permeate every area of life and practice, including mathematics. See Black, *Models and Metaphors*; Lakoff and Johnson, *Metaphors We Live By*.

39. Aristotle introduced one of the main ideas about metaphor, that “a metaphor is the application of a noun that properly applies to something else.” See Aristotle, *Poetics*, 34.
40. Manaugh, *A Burglar’s Guide to the City*, 76.
41. Manaugh, 76.
42. Manaugh, 76.
43. Manaugh, 273.

Chapter 5

1. Langewiesche, “Welcome to the Dark Net.”
2. Langewiesche.
3. Dingleline, Syverson, and Mathewson, “Brows Privately. Explore Freely.”
4. Anderson, *Imaginary Cities*, 23.
5. Anderson, 19.
6. “In what might be termed a ‘vertical turn’, the politics of subterranea is a topic that a range of thinkers have turned increasing attention to.” Dobraszcyk, Galviz, and Garrett, *Global Undergrounds*, 15.
7. Manaugh, *A Burglar’s Guide to the City*, 274.
8. McCall Smith, *44 Scotland Street*.
9. Dobraszcyk, Galviz, and Garrett, *Global Undergrounds*, 11.
10. Anderson, *Imaginary Cities*, 21.
11. Negarestani, *Cyclonopedia*, 66.
12. Douglas, *Purity and Danger*.
13. Borges, “The Immortal,” 104.
14. Eco, *Reflections on the Name of the Rose*.
15. Eco, *The Name of the Rose*.
16. Eco, *Reflections on the Name of the Rose*, 57.
17. Such markets are usually in fact well organized, with sellers of produce allotted to their own areas. Proponents of unregulated software development in the sharing economy drew on the myth of the chaotic bazaar. See Raymond, *The Cathedral and the Bazaar*.

18. Eco, *Reflections on the Name of the Rose*, 58.
19. Pennick, *Mazes and Labyrinths*.
20. Pennick, 18.
21. Caillois, *Man, Play and Games*, 23.
22. Pennick, *Mazes and Labyrinths*, 39.
23. Examples include Daniel Libeskind and Cosentino's "Musical Labyrinth" project in Frankfurt, which is marked out as white lines and text on the ground plane of a public square. Libeskind's Jewish Museum in Berlin features a grid of obelisks described on the museum's website (<https://www.jmberlin.de>): "The labyrinthine 'Garden of Exile' tests the visitor's sense of balance and provides a metaphor for the loss of orientation in foreign countries." It is a 7×7 grid. The base and the rectilinear obelisks are at slight angles to the ground plane.
24. Douglas, *Purity and Danger*, 44.
25. To reinforce this connection, note how Negarestani refers to the Mesopotamian giant Humbaba, whose "labyrinthine face (with unicursal human entrails as the beard) recalls the early art of Haruspicy (divination using the liver or entrails) in ancient Mesopotamian cultures." Negarestani, *Cyclonopedia*, 115.
26. Negarestani, 43.
27. Falahat, *Re-imagining the City*.
28. Mumford, *The Culture of Cities*, 291–292.
29. Described in Negarestani, *Cyclonopedia*, 51.
30. He refers to the book as a work of philo-fiction. In a helpful explanation in a blog by Terence Blake the prefix philo- refers to the compulsory course in French schooling known casually as *philo*. The genre is also known as *theory-fiction*.
31. Borges, "The Aleph," 423.
32. The panopticon plan was championed by the nineteenth-century utilitarian social reformer Jeremy Bentham (Bentham, *The Works of Jeremy Bentham*, vol. 4) and critiqued as a model of social control by Michel Foucault (Foucault, *Discipline and Punish*), and many urban critics have adopted it as leitmotif for the surveillance society (e.g., Levin, Frohne, and Weibel, *CTRL [SPACE]*).
33. Borges, "The Aleph," 423.
34. Borges, "Library of Babel," 59.
35. Borges, 58.

36. Weinsheimer, *Gadamer's Hermeneutics*.
37. The repeated near-far experience also resonates with Freud's account of the uncanny. See Freud, "The 'Uncanny.'"
38. Batty and Hudson-Smith, "Imagining the Recursive City," 39.
39. Batty and Hudson-Smith.
40. Hofstadter and Dennett, *Gödel, Escher, Bach*, 135.
41. Hofstadter and Dennett, 136.
42. Hodge, "What Is Tor? A Beginner's Guide to Using the Private Browser."
43. Hofstadter and Dennett, *Gödel, Escher, Bach*.
44. Hofstadter and Dennett, 136.
45. For a political take on the concept of "the stack," see Bratton, *The Stack*.
46. Weinsheimer, *Gadamer's Hermeneutics*, 104.

Chapter 6

1. Baudrillard, *Simulacra and Simulation*. For many critical theorists, the reality of the city is capitalist hegemony and consumerism, and the inequalities and injustices they perpetuate. Contemporary critiques of the hidden biases of digital culture, as well as racial, gender, age, and other assumptions and discriminatory practices, include Williams, *Data Action*, and Benjamin, *Race After Technology*.
2. Caillois, *Man, Play and Games*, 19.
3. Caillois, 22.
4. For a critique of some UX design, see Gray et al., "The Dark (Patterns) Side of UX Design."
5. Whitson, "Gaming the Quantified Self."
6. Mac Sithigh and Siems, "The Chinese Social Credit System."
7. Huizinga, *Homo Ludens*.
8. "Emma Watson First Day in the Office," scene from the film *The Circle* (dir. James Ponsoldt, 2018), <https://www.youtube.com/watch?v=0ByQ35OLOMM>.
9. Nicholson, "A Recipe for Meaningful Gamification," 4.
10. Nicholson, 4.
11. The answer is "nothing."

12. For an account of the likely impact of quantum computing on cryptography, see Martin, *Cryptography*, 321.
13. Ellison, *A Material History*.
14. The film *Jumanji: Welcome to the Jungle* (dir. Jake Kasdan, 2017) uses this map scenario.
15. Brown, *The Lost Symbol*, 234.
16. <https://www.dyne.org>.
17. Shamir, "How to Share a Secret."
18. Anon., *Digital Government*.

Chapter 7

1. Mumford called this primal urban condition the "eopolis." See Mumford, *The Culture of Cities*; Geddes, *Cities in Evolution*. For related explanations of "social economics" and the gift society, see my own book on the subject: Coyne, *Cornucopia Limited*.
2. See Daniels Trading, "Bitcoin: Commodity or Currency"; Zuboff, *The Age of Surveillance Capitalism*.
3. Godbout, *The World of the Gift*.
4. Rivera, "Potential Negative Effects of a Cashless Society."
5. Jacobs, *The Death and Life of Great American Cities*, 421.
6. Nakamoto, "Bitcoin," 1.
7. Canellis, "Bitcoin Has Nearly 100,000 Nodes."
8. Anon., "SHA-256 Hash Calculator."
9. I alluded to the ubiquitous *block* idea in chapter 2 in relation to city blocks and printing blocks. The idea of the *blockchain* also bears some similarities to the *stack* described in chapter 5 in reference to keeping track of recursion and sequential data structures.
10. Anon., "Bitcoin Mining Guide." Also see Sutton, *Cryptocurrency Mining*.
11. Cannon and Tuwiner, "Is Bitcoin Mining Profitable or Worth It in 2020?"
12. These figures are frequently monitored and reported in the press; see, for example, Kharpal, "A Major Chinese Bitcoin Mining Hub Is Shutting Down Its Cryptocurrency Operations."

Chapter 8

1. Taylor, "The World's First Bitcoin Republic."
2. Elnagar, "IMF Executive Board Concludes 2021 Article IV Consultation with El Salvador."
3. For notes on the value of Bitcoin, see Edwards, "Bitcoin's Price History."
4. Remitly, <https://www.remitly.com/us/en>.
5. De Vries, "Bitcoin's Growing Energy Problem."
6. Naderzadeh, *Cryptocurrency Mining Using Renewable Energy*, 4. See also media accounts of "volcano-powered bitcoin mining" in El Salvador: Sigalos, "El Salvador Has Just Started Mining Bitcoin Using the Energy from Volcanoes." The president of El Salvador commissioned Mexican architect Fernando Romero (<https://fr-ee.org>) to design Bitcoin City adjacent to the volcano.
7. This is currently being challenged by increasingly centralized trading exchanges such as Coinbase and Jaxx, and Bitcoin's new status as a pseudo-commodity; see Daniels Trading, "Bitcoin: Commodity or Currency."
8. Saleh, "Blockchain without Waste," 1162. Also see Kiayias et al., "Ouroboros."
9. Saleh, 1176; Kiayias et al., "Ouroboros." See also <https://cardano.org>.
10. Bezek, "What Is Proof-of-Stake, and Why Is Ethereum Adopting It?"
11. Shiller, "The Bitcoin Narratives."
12. Szabo, "Formalizing and Securing Relationships on Public Networks"; Dewan and Singh, "Use of Blockchain in Designing Smart City."
13. Sundararajan, *The Sharing Economy*, 93.
14. Sundararajan. Contracts are verified with "zero knowledge" of content.
15. Sheldon, "Auditing the Blockchain Oracle Problem."
16. Oliva, Hassan, and Jiang, "An Exploratory Study of Smart Contracts."
17. Anon., "How Blockchain Technology and Smart Contracts Are Transforming the Real Estate Industry."
18. Shojaei et al., "An Implementation of Smart Contracts by Integrating BIM and Blockchain," 519. Colleagues and I have explored the application of smart contracts to 3D models in virtual reality (VR) environments; see Coyne, "Transactions in Virtual Places." For a different perspective, see Dounas, Lombardi, and Jabi, "Framework for Decentralised Architectural Design BIM and Blockchain Integration."

19. A smart contract could respond to triggers such as a transaction has been approved or completed, a certain amount of time has elapsed or a date is reached, the goods are at the optimal price for the purchaser, an item to be purchased is of a particular (approved) type (e.g., you can spend this cryptocurrency to buy an airline ticket but not on entertainment), or the item in the transaction has been resold. Here are some possible actions following such triggers: the smart contract prevents or enables further transactions, distributes funds to other parties, awards a refund, imposes a fee or penalty, sends an email, issues a private key to unlock a building, or switches on the heating.

20. For a discussion of big data in the urban context, see Engin et al., “Data-Driven Urban Management.”

21. In his *Utopia*, the Tudor scholar Thomas More said that people behave themselves as “everyone has his eye on you.” The ideal city was designed without places to hide.

22. Golumbia, “Bitcoin as Politics,” 119.

23. For the application of distributed ledgers in this context, see Townsend, *Distributed Ledgers*.

24. Naderzadeh, “Cryptocurrency Mining Using Renewable energy,” 5.

25. Reiff, “How to Identify Cryptocurrency and ICO Scams.”

26. For a further example, see Tavernise and Yaffe-Bellany, “Death of a Crypto Company.”

27. Frankel, “An Anonymous Left-wing Art Group Known in the 1990s as Luther Blissett.”

28. Kaminska, “From Bitcoin to QAnon.”

29. Kaminska.

Chapter 9

1. Degen and Rose, *The New Urban Aesthetic*, 41.

2. E.g., Base, *Animalia*.

3. Young Rival, “Black Is Good [Official] (Autostereogram Video).”

4. Roma N, “Animated Stereogram.”

5. Desmedt, Hou, and Quisquater, “Audio and Optical Cryptography.”

6. Bowen, “ASCII Stereograms.”

7. Naor and Shamir, "Visual Cryptography," 1.
8. To illustrate the method Naor and Shamir provided two images: "two random looking dot patterns. To decrypt the secret message, the reader should photocopy each pattern on a separate transparency, align them carefully, and project the result with an overhead projector." Naor and Shamir, "Visual Cryptography," 1.
9. Petrauskiene and Saunoriene, "Application of Dynamic Visual Cryptography."
10. Desmedt, Hou, and Quisquater, "Audio and Optical Cryptography."
11. Vitruvius, *Vitruvius: Ten Books on Architecture*.
12. Alberti, *On the Art of Building in Ten Books*.
13. Carpo, *Architecture in the Age of Printing*. For all his architectural inventiveness, some scholars describe Alberti as an iconophobe.
14. Maier, *Rome Measured and Imagined*.
15. I provide an illustration of pixel manipulation to blur and image on my blog: Coyne, "Urbanise Rasterise."
16. Rowe and Koetter, *Collage City*.
17. Anon., "AEC (UK) CAD Standard for Basic Layer Naming."
18. Tanna, *Codes, Ciphers, Steganography and Secret Messages*; Al-Mousaoui, *Image*; Bailey and Curran, *Steganography*.
19. Europol's European Cyber Crime Centre has an initiative to monitor and prevent the criminal use of information hiding techniques. See <https://cuing.org>.
20. Loos, *Ornament and Crime*.
21. I provide a worked example of such concealment in a blog post: Coyne, "Ornament and Crime."
22. In this sense, crypto art is no more a genre, subgenre, style, or movement in art than auction art, gallery art, or collectible art.
23. Hexeosis, "Why I Sell My Gifs as Crypto Art"; Hexiosis, "About Crypto Art." Also see Kim, "Mars House."
24. Abrahamson, "An NFT Just Sold for \$69,346,250."
25. Hall and Watkinson, "CryptoPunks."
26. Marx described this substitution as "a process of analysis—by subdivisions of labour, which transforms the worker's operations more and more into mechanical operations, so that, at a certain point, the mechanism can step into his place." Marx, *Karl Marx*, 379.

27. Mitchell, *The Reconfigured Eye*, 51.

28. There is scope for a crypto art that expands from its mode of transaction in cryptocurrency to the arena of cryptography, encryption, and cryptanalysis. Moving crypto art beyond the borders of the canvas and the flat screen to performance art would extend the crypto theme further.

29. Hollander, "Why NFTs Matter to Urban Planning."

Chapter 10

1. Bower and Green, "STIS Records a Black Hole's Signature."

2. Robinson, Boyd, and Fetterman, "An Emotional Signature of Political Ideology," 98. Such observations indicate that signatures can be as expansive and difficult to identify as emotional states. Here it's really a particular word that provides the signature: "fear" summarizes a conservative agenda, and "anger" accounts for liberals.

3. For a discussion of emotion in urban and digital contexts, see Coyne, "Melancholy Urbanism."

4. Furno et al., "A Tale of Ten Cities."

5. Degen and Rose, *The New Urban Aesthetic*, 77. Detecting flows is a bit like finding the rapid flow of material around a black hole to determine the black hole's presence and size, even though you can't see it.

6. To reduce an image to 1/16 its size on the screen, a reduction algorithm divides the image into 4×4 pixel squares and displays the average of the color value of each pixel in the 4×4 square as a single pixel in a new file to create the new reduced image.

7. The most common method uses an algorithm that creates a color table or palette of the colors that appear in an image.

8. One of the simplest ways to produce a hash of an image is to reduce its color range to a grayscale, then reduce its size repeatedly by the averaging process described previously to something as small as 8×8 pixels. See Anon., "Testing Different Image Hash Functions."

9. The ubiquitous hash symbol, the octothorp (#), has two pairs of lines that cut across each other, and as a hashtag has come to indicate a means of cross-referring to another part of a document.

10. Here I am using an online tool at <https://www.browserling.com/tools/all-hashes>.

11. Lawrence, "Graffiti Strategy for Edinburgh."

12. Ferguson and Schneier, *Practical Cryptography*, 83–95; Madeira, “How Does a Hashing Algorithm Work?”
13. Hall and Watkinson, “CryptoPunks.”
14. I used a drag and drop tool for this at GitHub: Anon., “SHA256 File Checksum.”
15. Douglass, “An Introduction to IPFS.”
16. Merkle, “A Digital Signature Based on a Conventional Encryption Function.”
17. Lewis, “A Gentle Introduction to Blockchain Technology”; Lewis, “A Gentle Introduction to Immutability of Blockchains”; Lewis, *The Basics of Bitcoins and Blockchains*.
18. Note the creation of the “permaweb” that deploys blockchain technology to render certain web content permanent. See <https://www.arweave.org>.
19. All Hash Generator, <https://www.browserling.com/tools/all-hashes>.
20. Lewis, “A Gentle Introduction to Immutability of Blockchains.” There are several other sophistications to the puzzle involving a range of terms such as *cryptographic nonce*. The nonce is the number appended to an encrypted block. Miners need to work out what that number is in order for the block to generate a hash that meets the criterion of the leading 0s.
21. Bispo, “Cryptocurrency, Graphics Card Shortage, and the Rise of Cloud GPU.”
22. Nakamoto, “Bitcoin,” 3.
23. Kiayias et al., “Ouroboros.”

Chapter 11

1. That’s my own example. I draw in this discussion on Brunton and Nissenbaum, *Obfuscation*. They give the example of the way spiders confuse predators.
2. What Friedrich Nietzsche describes as “the formless unformulable world of the chaos of sensations.” Nietzsche, *The Will to Power*, 307.
3. Brunton and Nissenbaum, *Obfuscation*. Also see Gray et al., “The Dark (Patterns) Side of UX Design.”
4. Brunton and Nissenbaum, *Obfuscation*, 7.
5. Brunton and Nissenbaum, 30.
6. Also see Gray et al., “The Dark (Patterns) Side of UX Design.”
7. Mueller, *Report on the Investigation into Russian Interference in the 2016 Presidential Election*.

8. Manchester, "Mueller Report Suggests Trump Intended to Obstruct Investigation, Says Ex-Watergate Prosecutor."
9. For a critique of Google's index and search, see Vaidhyanathan, *The Googization of Everything*.
10. See an account in the book by the chair of the United States House Permanent Select Committee on Intelligence: Schiff, *Midnight in Washington*.
11. Haines, *Foreign Threats to the 2020 US Federal Elections*.
12. DiResta et al., *The Tactics and Tropes of the Internet Research Agency*; Howard et al., *The IRA, Social Media and Political Polarization in the United States, 2012–2018*.
13. DiResta et al., *The Tactics and Tropes of the Internet Research Agency*, 8. Also see Schiff, *Midnight in Washington*.
14. Surowiec, "Post-truth Soft Power." For compelling accounts of Russian influence in U.S. politics, see Nance, *The Plot to Betray America*, and Nance, *They Want to Kill Americans*.
15. Surowiec, 25.
16. Surowiec, 24.
17. Nicole Perlroth outlines the parlous state of cybersecurity defenses in cities and states. See Perlroth, *This Is How They Tell Me the World Ends*.
18. Wicker, "The Ethics of Zero-Day Exploits," 99.
19. Wicker, 99.
20. Perlroth, *This Is How They Tell Me the World Ends*.
21. Suiche, "Shadow Brokers."
22. Snowden, *Permanent Record*.
23. For Snowden's own account, see *Permanent Record*. This was followed up by the 2016 film *Snowden*, directed by Oliver Stone.
24. Snowden, *Permanent Record*.
25. Greenwald, "Edward Snowden"; Greenwald, "NSA Collecting Phone Records of Millions of Verizon Customers Daily."
26. Bernal, "Does the UK Engage in 'Mass Surveillance'?"
27. Alerts to the issue of bulk data collection are also provided in Moody, "What's the Difference Between 'Mass Surveillance' and 'Bulk Collection'?"; MIS, "Introduction to Bulk Data."
28. Greenberg, "How Not to Prevent a Cyberwar with Russia."

29. Perloth and Shane, "In Baltimore and Beyond, a Stolen N.S.A. Tool Wreaks Havoc." Also see Perloth, *This Is How They Tell Me the World Ends*.

Chapter 12

1. See Popov et al., "Apply Magic Sauce." I fed this paragraph through the system and it inferred that I as the author am "liberal and artistic," contemplative, competitive, relaxed, etc.

2. Dang and Goller, "What They Said."

3. Dang and Goller.

4. Zuboff, *The Age of Surveillance Capitalism*.

5. Benjamin, *Race After Technology*, 16. For a reading of the relationship between ethics and digital systems, see Amoores, *Cloud Ethics*. I think the political and ethical challenges posed by machine learning algorithms extends to every kind of algorithm.

6. Sommerville, *Software Engineering*.

7. Benjamin, *Race After Technology*, 16.

8. The area of bias is addressed by studies into interpretation and hermeneutics. See, for example, Gadamer, *Truth and Method*; Snodgrass and Coyne, *Interpretation in Architecture*.

9. Accessibility is written into law in many countries. See, for example, the UK Equality Act 2010, <https://www.legislation.gov.uk/ukpga/2010/15/section/20>.

10. CDRC Mapmaker, <https://maps.cdrc.ac.uk/>.

11. Deas et al., "Measuring Neighbourhood Deprivation."

12. Amoores, *Cloud Ethics*, 6.

13. Amoores, 109.

14. Amoores, 8.

15. Howe, Zer-Aviv, and Nissenbaum, "AdNauseam."

16. Howe, Toubiana, and Nissenbaum, "TrackMeNot."

17. Brunton and Nissenbaum, *Obfuscation*. A low-tech method is to share SIM cards and loyalty cards to confound profilers. This is a bit like masking confidential in-person conversations by meeting in a noisy bar, or a place where there are many voices to drown out your own. In this section I have put the spotlight on algorithms, the design and implementation of which inevitably interact with developments in

legislation such as the highly consequential GDPR in Europe and similar in other parts of the world. See <https://gdpr.eu>.

18. See Rumelhart and McClelland, *Parallel Distributed Processing*. Using such methods, natural language processing (NLP) programs now seem able to take as input words and phrases provided by a human operator and generate coherent sentences in response, simulating a kind of dialogue that scholars such as David Chalmers think exhibit general intelligence. See Weinberg, "Philosophers on GPT-3 (updated with replies by GPT-3)." For my own experimentation with the GPT-3 based AI platform, see Coyne, "Benefits of Artificial Misinformation."

19. Vision AI, <https://cloud.google.com/vision>. Also see <https://openai.com/dall-e-2/>.

20. The latter includes Google's reCAPTCHA tool that supports login routines that ask you to prove you are a human user and not a malicious program by giving you a simple pattern-matching test. The data from that test feeds the training algorithm. See <https://www.google.com/recaptcha/about/>.

21. For a review of feature detection in the case of landscape assessment, see Wilkins et al., "Promises and Pitfalls of Using Computer Vision."

22. Amore, *Cloud Ethics*, 71.

23. Amore, 172.

24. Das et al., "Estimating Likelihood of Future Crashes for Crash-Prone Drivers."

25. Loo et al., "Applying the Hidden Markov Model"; Rabiner and Juang, "An Introduction to Hidden Markov Models."

26. Jeon, Jordan, and Krishnamoorthy, "On Modeling ASR Word Confidence." I also explain the approach at Coyne "Speech to Text." For a discussion of race differences and automated speech recognition, see Benjamin, *Race After Technology*, 15.

27. Ahmed, Natarajan, and Rao, "Discrete Cosine Transform," 93. I provide a worked example at Coyne, "COVID-19 Rhythmanalysis."

28. Lefebvre, *Rhythmanalysis*.

29. Coyne, *The Tuning of Place*.

30. Nevejan, Sefkatli, and Cunningham, *City Rhythm*.

31. Nevejan, Sefkatli, and Cunningham, 3.

32. Nevejan, Sefkatli, and Cunningham, 3.

33. Nevejan, Sefkatli, and Cunningham, 4.

34. Nevejan, Sefkatli, and Cunningham, 44.

35. The authors provide a diagram that shows “the rhythms of a fictional elderly persona (yellow), rhythms of a young fictional persona (red) and rhythms of the shopping centre (green).” Nevejan, Sefkatli, and Cunningham, 47.
36. Nevejan, Sefkatli, and Cunningham, 74.
37. Neuman, “Keeping Secrets.”
38. Karpel, “Family Secrets,” 2.
39. Manaugh, *A Burglar’s Guide to the City*, 263.
40. The website faketv.com bears the heading “Burglars Love Easy Targets.”

Chapter 13

1. Bosworth, “Building the Metaverse Responsibly.” The term *metaverse* was coined by Stephenson in the 1992 novel *Snow Crash*. For a discussion of the relationship between *metaverse* and *multiverse*, see Dallow, “The Media Multiverse and Adaptive Virtuality.”
2. Ito, Okabe, and, Matsuda, *Personal, Portable, Pedestrian*.
3. Hall, *The Hidden Dimension*, 53.
4. Hall, 53.
5. LaBelle, *Background Noise*.
6. LaBelle, 325.
7. Descartes, *Discourse on Method and the Meditations*. Axes xyz offer three dimensions.
8. Or interchange the axes to rotate the object so described.
9. See, for example, Anon., “The Hardest Trip.” Also see Gleick, *Chaos*.
10. I am quoting Wittgenstein again. See chapter 3.
11. Calvino, *Invisible Cities*.
12. Anderson, *Imaginary Cities*.
13. On the idea of a virtual reality metaverse, see Wright et al., “Augmented Duality.”
14. The sci-fi film *Valerian and the City of a Thousand Planets* (dir. Luc Besson, 2017) offers a compelling live action and CGI rendering of a multilayered city superimposed over a desert experienced by the occupants via head-mounted displays. The film *Ready Player One* (dir. Steven Spielberg, 2018) offers a similar scenario. For a

philosophical treatment of multiple worlds, virtual reality, and the simulation hypothesis, see Chalmers, *Reality+*.

15. Abbott and Ehlinger, "Flatland—the Film"; Abbott, *Flatland*.
16. A (magic) goose explains other worlds: "millions of other universes exist unaware of one another. . . . We are as close as a heartbeat, but we can never touch or see or hear these other worlds except in the Northern Lights." Pullman, *Northern Lights*, 187.
17. Kessler, "Trump's Day on Twitter."
18. Vilenkin and Tegmark, "The Case for Parallel Universes."
19. String theory is explained in many popular science publications, including Hawking, *A Brief History of Time*.
20. These are themes developed in theology, psychology, and anthropology. See Eliade, *The Two and the One*; Turner, *The Forest of Symbols*.
21. According to sound theorist Douglas Kahn. See Kittler, von Mücke, and Similon, "Gramophone, Film, Typewriter," 12; Kahn, *Noise, Water, Meat*.
22. This philosophy of disembodiment was embraced by Plotinus (203–270 AD). Plotinus, *The Essence of Plotinus*, 55.
23. Kittler, von Mücke, and Similon, "Gramophone, Film, Typewriter," 12.
24. Enns, "Spiritualist Writing Machines," 4.
25. Conan Doyle, *The History of Spiritualism*, vol. 1, 62–62.
26. Enns, "Spiritualist Writing Machines," 4.
27. See Relph, "Spirit of Place and Sense of Place in Virtual Realities."
28. Here I draw on explanations provided by Cui et al., "An Encryption Scheme Using DNA Technology"; Dey et al., "DNA Origami"; Zahid et al., "DNA Nanotechnology."
29. Dey et al., "DNA Origami," 12.
30. Dey et al., 14.
31. Dey et al., 15.
32. Anon., "Fact Check."
33. Zhang et al., "DNA Origami."
34. Zhang et al., 2.
35. Zhang et al., 7.

36. Kahn, *The Codebreakers*, chap. 26, Kindle. For insight into interplanetary communication, I draw on this chapter, which is titled “Messages from Outer Space.” Also see Oberhaus, *Extraterrestrial Languages*.
37. Freudenthal, *Lincos*.
38. Freudenthal, 145.
39. Kahn, *The Codebreakers*, chap. 26, Kindle.
40. The society website is at www.bis-space.com/.
41. Galton, “Intelligible Signals between Neighbouring Stars.”
42. Galton, 658.
43. Kahn, *The Codebreakers*, chap. 26, Kindle.
44. Kahn, *The Codebreakers*, chap. 26, Kindle. SETI, the Search for Terrestrial Life Institute, continues the search for extraterrestrials by other means; see <https://www.seti.org>.
45. Anon., “How to Build a Quantum Internet”; Castelveccchi, “The Quantum Internet Has Arrived (and It Hasn’t).”
46. For a history and examination of the two-slit experiment, see Barad, *Meeting the Universe Halfway*.
47. Gregory, *Inventing Reality*; Barad, *Meeting the Universe Halfway*.
48. For a helpful account, see Smith, “Quantum Instruction Set—Computerphile.”
49. Anon., “How to Build a Quantum Internet.”
50. Crane, “China’s Quantum Satellite Helps Send Secure Messages over 1200km.”
51. I draw on some of Robert Smith’s explanations of the mathematics here. See Smith, “Quantum Instruction Set—Computerphile.”
52. Crane, “China’s Quantum Satellite Helps Send Secure Messages over 1200km.”
53. Also see Bohm and Peat, *Science, Order and Creativity*; Gell-Mann, *The Quark and the Jaguar*; Schade, *Free Will and Consciousness in the Multiverse*.
54. Everett, “‘Relative State’ Formulation of Quantum Mechanics,” 459. Also see Rovelli, “Relational Quantum Mechanics.”
55. Everett, “‘Relative State’ Formulation of Quantum Mechanics,” 460.
56. Everett, 462.
57. Barad, *Meeting the Universe Halfway*.

58. Interactive films such as *Bandersnatch* (dir. David Slade, 2018) in the TV series *Black Mirror* present alternate storylines, as do many video games.

59. Gregory, *Inventing Reality*.

60. Bohr, "The Bohr-Einstein Dialogue," 139.

61. Heisenberg, *Physics and Philosophy*, 46.

62. Barad, *Meeting the Universe Halfway*, 335.

63. Barad, 335.

64. Barad, 154.

65. Barad, 138.

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