Notes

TWO HOURS: MAY 6, 2017

1 **an estimated 13 million people:** Take all audience estimates with a grain of salt, but 13.1 million is Nike’s official tally of viewers tuned into the live stream on Twitter, Facebook, and YouTube during the race. Another 6.7 million watched the video over the following week, and that number doesn’t include China, where a substantial (but untracked) audience watched.


2 **A lot of people scratched their heads:** This and other details are from multiple conversations with Joyner, but he repeats this quote here: Michael Joyner, “Believe It: A Sub-2 Marathon Is Coming,” Runnersworld.com, May 6, 2017.


3 **Runner’s World magazine asked me:** “What Will It Take to Run a 2-Hour Marathon?,” *Runner’s World*, November 2014.

3 biggest sports brand in the world: The Forbes Fab 40 pegs Nike’s brand value at $15 billion, well ahead of ESPN in second place.

CHAPTER 1: THE UNFORGIVING MINUTE

7 **If you can fill the unforgiving minute:** From the poem “If—,” by Rudyard Kipling, in *Rewards and Fairies* (London: Macmillan, 1910).


7 “four-minute mile is beyond my capabilities”: As quoted in Neal Bascomb, *The Perfect Mile* (London: CollinsWillow, 2004). This definitive account is also the source of subsequent details about Landy’s races.


10 **the struggle to continue against a mounting desire to stop.**: Marcora cites this as the definition of an “effortful cognitive process,” drawing on a definition of stamina from Roy Baumeister et al. in “The Strength Model of Self-Control,” *Current Directions in Psychological Science* 16, no. 6 (2007).


10 Bolt’s 9.58-second world-record race: Bolt’s late-race surges can be partly explained by the fact that he reaches a higher top speed, which means that even if his relative deceleration in the final 20 meters is the same as everyone else’s, he’ll continue to pull away. But expert consensus is that he’s also uniquely good at late-race “speed maintenance.”


13 *Spanish star José Luis González became the three hundredth man:* According to the list maintained by the National Union of Track Statisticians, https://nuts.org.uk/sub-4/sub4-dat.htm.

14 *TV coverage of the 1996 Trials is on YouTube:* https://www.youtube.com/watch?v=8dSLUVmKI1k (but please don’t watch it; it wasn’t my finest hour).


CHAPTER 2: THE HUMAN MACHINE

17 *After fifty-six days of hard skiing:* Details of Worsley’s 2009 expedition and Shackleton’s 1909 expedition are from Worsley’s 2011 book, *In Shackleton’s Footsteps*, unless otherwise noted.

17 *just 112 miles from the South Pole:* the figure is often reported as “97 miles” because Shackleton (and Worsley) reported their distances in nautical miles, which are about 15 percent longer than the more familiar statute miles. All mile distances in this book are statute unless otherwise noted.

18 “The decision to turn back,”: From an archived interview broadcast on BBC Newsnight on January 26, 2016: https://www.youtube.com/watch?v=O3SMkxA08T8.


19 *what’s found inside the body is actually lactate:* L. B. Gladden, “Lactate Me-
Berzelius noticed that the muscles of hunted stags: This anecdote shows up in many modern textbooks (e.g., The History of Exercise Physiology, ed. Charles M. Tipton, 2014) but proved unexpectedly hard to trace. Berzelius first published the observation of lactic acid extracted from the muscles of slaughtered animals in 1808 (in his Swedish book Föreläsningar i Djurkemien, p. 176), but many chemists didn’t believe it. When the German chemist Justus von Liebig tried to claim credit for the discovery in 1846, Berzelius wrote an indignant response pegging the year of his own observation as 1807 (Jahresbericht über die Fortschritte der Chemie und Mineralogie, 1848, p. 586). But Berzelius himself never published the claim that the amount of lactic acid depended on the severity of pre-death exercise. Instead, this observation, attributed to Berzelius, first appears in the 1842 textbook Lehrbuch der physiologischen Chemie, by Carl Lehmann, on p. 285. In 1859, the physiologist Emil du Bois-Reymond wrote to Lehmann asking for the source of this statement; Lehmann replied that he had received a personal letter from Berzelius himself reporting that the muscles of hunted animals contained more lactic acid than normal, while animals whose legs were immobilized in splints before death had less lactic acid (reported in Journal für praktische Chemie, 1859, p. 240; reprinted in the 1877 book Gesammelte Abhandlungen zur allgemeinen Muskel- und Nervenphysik with a footnote describing the exchange of letters on p. 32.).

Chemists were still almost a century away: An oft-cited benchmark in the understanding of acids is Svante Arrhenius’s definition, an extension of work that earned him the 1903 Nobel Prize in Chemistry.

Berzelius himself subscribed to the idea of a “vital force”: Berzelius’s views on vitalism were actually quite nuanced and evolved over time, as discussed in Bent Søren Jørgensen, “More on Berzelius and the Vital Force,” Journal of Chemical Education 42, no. 7 (1965).

German scientists collected their own urine: Dorothy Needham, Machina Carnis (Cambridge: Cambridge University Press, 1972).


First to complete the 320-meter circuit: Christopher Thorne, “Trinity Great Court Run: The Facts,” Track Stats 27, no. 3 (1989). There are different schools of thought on the “correct” route around the courtyard, so Fletcher’s corner-cutting shouldn’t be taken as a mark against his character.

The importance of oxygen was confirmed: Leonard Hill, “Oxygen And Muscular Exercise as a Form of Treatment,” British Medical Journal 2, no. 2492 (1908).


23 In 1923, Hill: A. V. Hill and Hartley Lupton, “Muscular Exercise, Lactic Acid, and the Supply and Utilization of Oxygen,” Quarterly Journal of Medicine 16, no. 62 (1923). Details in subsequent paragraphs are also from this paper unless otherwise noted.

23 “it may well have been my struggles and failures”: A. V. Hill, Muscular Activity (Baltimore: Williams & Wilkins, 1925).

23 an eighty-five-meter grass loop in Hill’s garden: In Hill’s 1923 QMJ paper, he describes the experiments taking place “around a circular grass track 92½ yds. (84½ metres) in circumference.” Hugh Long, a coauthor and experimental subject in Hill’s Manchester studies, recalls “running up and down stairs, or round the professor’s garden while at intervals healthy samples of blood were withdrawn from my arms”; quoted in “Archibald Vivian Hill. 26 September 1886–3 June 1977,” Biographical Memoirs of Fellows of the Royal Society 24 (1978): 71–149.

23 “reaches a maximum beyond which no effort can drive it”: Hill, Muscular Activity, p. 98.


26 He rode a Harley, taught needlepoint to prison inmates.: Stefano Hatfield, “This Is the Side of Antarctic Explorer Henry Worsley That the Media Shies Away From,” Independent, January 31, 2016.

27 “As you probably are the first to reach this area”: Edward Evans, South with Scott (London: Collins, 1921).


28 On November 13, he set off on skis: Details of Henry Worsley’s Shackleton solo trip are from the daily audio dispatches he posted at https://soundcloud.com/shackletonsolo (the last five days have been removed). Further background details about his trip are at shackletonsolo.org.

29 “we don’t do it because it is useful . . .”: Hill, Muscular Movement in Man.


31 The most notorious of these wartime studies: Todd Tucker, *The Great Starvation Experiment* (Minneapolis: University of Minnesota Press, 2006).

32 “there is good reason for not trusting the subject’s . . .”: Henry Longstreet Taylor et al., “Maximal Oxygen Intake as an Objective Measure of Cardio-Respiratory Performance,” *Journal of Applied Physiology* 8, no. 1 (1955).


32 “. . . more in athletics than sheer chemistry,”: Hill, *Muscular Movement in Man*.


33 on the verge of dropping out: From interviews with Michael Joyner; see also Ed Caesar, *Two Hours* (New York: Penguin, 2015).


36 “I said, now hold on . . .”: Quotes are from my visit to Noakes’s lab in Cape Town in 2010.

CHAPTER 3: THE CENTRAL GOVERNOR


39 Noakes started out as a collegiate rower: most biographical details are from my interviews with him, with additional information from his 2012 memoir (with Michael Vlismas), *Challenging Beliefs*.


40 a handful of deaths: An exact count of deaths due to hyponatremia during endurance exercise is hard to pin down, but one 2007 study tallied eight confirmed and four suspected cases: Mitchell Rosner and Justin Kirven, “Exercise-Associated Hyponatremia,” Clinical Journal of the American Society of Nephrology 2, no. 1 (2007).


41 Gage was “no longer Gage.”: “Recovery from the Passage of an Iron Bar through the Head,” Publications of the Massachusetts Medical Society 2, no. 3 (1868).

42 “You must have just come through those tornadoes back there.”: Quoted in Hovey, “Running from the Seizures.”

42 “is the hardest thing I have ever done.”: Quoted in “900+ Miles Later, Diane Van Deren Reaches Jockey’s Ridge,” greatoutdoorprovision.com, 2012.

43 “Well, shit—I don’t feel pain?”: Quoted in Kotb, Ten Years Later.


43 largest, oldest, and most prestigious ultra-race: First run in 1921, Comrades earned a place in the Guinness record books in 2010 with 16,480 starters and 14,343 finishers within the twelve-hour time limit. In 2000, prior to Guinness certification, more than 20,000 people finished, according to the official results at www.comrades.com.

45 in a 1998 paper he coined the term “central governor,”: In “Maximal Oxygen Uptake: ‘Classical’ versus ‘Contemporary’ Viewpoints: A Rebuttal,” Medicine & Science in Sports & Exercise 30, no. 9 (1998), Noakes writes: “a new physiological model is proposed in which skeletal muscle recruitment is regulated by a central ‘governor’ specifically to prevent the development of a progressive myocardial ischemia that would precede the development of skeletal muscle anaerobiosis during maximum exercise.”


45 Frank Marino: See, for example, “Anticipatory Regulation and Avoidance of Catastrophe During Exercise-Induced Hyperthermia,” Comparative Biochemistry and Physiology—Part B 139, no. 4 (2004).


“If they caught you breaching, . . .”: This and other details from Micklewright’s talk at the Endurance Research Conference at the University of Kent in September 2015.


Other researchers have tried electroencephalography: L. Hilty et al., “Fatigue-Induced Increase in Intracortical Communication Between Mid/Anterior Insular and Motor Cortex During Cycling Exercise,” *European Journal of Neuroscience* 34, no. 12 (2011).

CHAPTER 4: THE CONSCIOUS QUITTER

Marcora’s thirteen-thousand-mile motorcycle ride: To hear Marcora himself spinning tales from this trip, check out his podcast appearance on the Adventure Rider Radio Motorcycle Podcast from May 15, 2015, https://adventureriderpodcast.libsyn.com/.

I drove 120 miles through Australia’s Blue Mountains: I wrote about this trip
and my subsequent experience with Marcora’s brain endurance training in the October 2013 issue of Runner’s World.


58 “…the single best indicator of the degree of physical strain;” Gunnar Borg, “Psychophysical Bases of Perceived Exertion,” Medicine & Science in Sports & Exercise 14, no. 5 (1982).


63 Mosso’s insights were mostly forgotten: Tim Noakes argues that Mosso’s ideas were supplanted by those of A. V. Hill: “Fatigue Is a Brain-Derived Emotion That Regulates the Exercise Behavior to Ensure the Protection of Whole Body Homeostasis,” Frontiers in Physiology, April 11, 2012.


professionals were significantly better at the Stroop task: K. Martin et al., “Superior Inhibitory Control and Resistance to Mental Fatigue in Professional Road Cyclists,” PLoS One 11, no. 7 (2016).

ushered through security into the Nike Sport Research Lab: My full account of the build-up to Nike's Breaking2 race, “Moonshot,” was published in the June 2017 issue of Runner's World. Further commentary and reporting is collected at www.runnersworld.com/2-hour-marathon.

tests secretly conducted at the University of Colorado: The study was performed in Rodger Kram's group: Wouter Hoogkamer et al., “New Running Shoe Reduces the Energetic Cost of Running,” presented at the American College of Sports Medicine annual meeting in Denver, May 31, 2017.


Shalane Flanagan, the second-fastest women’s marathoner: David Epstein noted Flanagan and Hall’s early exposure to high altitude in The Sports Gene (New York: Current, 2013).

aid tables every five kilometers: the IAAF Road Running Manual (www.iaaf.org) says “water shall be available at suitable intervals of approximately 5km.”

84 “. . . pain as a state of mind to be combated . . .”: Jens Voigt: The Man Behind the Hour Attempt,” Cycling Weekly, September 17, 2014.
85 The first official Hour record: Michael Hutchinson, “Hour Record: The Tangled History of an Iconic Feat,” Cycling Weekly, April 15, 2015. See also Michael Hutchinson, The Hour (London: Yellow Jersey, 2006), which recounts his own crack at the record.
89 “When I’m hurting like crazy,”: Jesse Thomas, “Damage Control,” Triathlete, August 12, 2015.
91 “Yes, whenever it was necessary.”: Quoted in The Economics of Professional Road Cycling, ed. Daam Van Reeth and Daniel Joseph Larson (Cham: Springer International, 2016).
91 Frenchman Roger Rivière: Various versions of Rivière’s tale circulate; see, for example, Nick Brownlee, Vive le Tour! Amazing Tales of the Tour de France (London: Portico, 2010).
92 took to the online journal Frontiers in Physiology: “Fatigue is a pain—the use of novel neurophysiological techniques to understand the fatigue-pain relationship” (May 13, 2013).
93 transcutaneous electric nerve stimulation (TENS), and interferential current (IFC): A. H. Astokorki et al., “Transcutaneous Electrical Nerve Stimulation Reduces Exercise-Induced Perceived Pain and Improves Endurance Exercise Performance,” European Journal of Applied Physiology 117, no. 3 (2017); A. H. Astokorki et al., “An Investigation into the Analgesic Effects of Transcutaneous Electrical Nerve Stimulation and
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Interferential Current on Exercise-Induced Pain and Performance,” presented at Endurance Research Conference 2015 at the University of Kent.

93 the primacy of effort: W. Staiano et al., “The Sensory Limit to Exercise Tolerance: Pain or Effort?” presented at Endurance Research Conference 2015 at the University of Kent.


96 wounded soldiers during the U.S. Civil War: Silas Weir Mitchell treated soldiers at a special hospital for “stumps and nervous diseases” and made important observations about phantom limb syndrome and nerve-related pain. See, for example, his American Physiological Society biography at http://www.the-aps.org/fm/presidents/SWMitchell.html.

CHAPTER 6: MUSCLE


105 to fill an awful lot of mousetraps.: You can (and should) watch the 1983 World’s Strongest Man competition on YouTube: https://www.youtube.com/watch?v=u8DECs72W4E.

105 records using standard bars and plates: There are many different record standards, depending on the use of equipment like lifting straps, to none of which Magee’s cheese lift conformed. The current International Powerlifting Federation record is 397.5 kg (876 pounds); Englishman Eddie Hall lifted 500 kg (1,102 pounds) at the World Deadlift Championships in 2016 before collapsing with burst blood vessels in his head.


109 By the time Stéphane Couleaud: Couleaud’s misadventures at the Tor des Géants are recounted on his blog, stephanecouleaud.blogspot.com: “Tor de Geants 2001–Edizione 2–11/14 sept,” October 4, 2011. Some of Couleaud’s data is presented in Guillaume Millet’s presentation, “Fatigue and Ultra-Endurance Performance,” at the Endurance Research Conference at the University of Kent in September 2015, along with Millet’s own Tor des Géants experience. The full results of the scientific study are published as Jonas Saugy et al., “Alterations of Neuromuscular Function after the World’s Most Challenging Mountain Ultra-Marathon,” PLoS One 8, no. 6 (2013).


116 events lasting between about one and ten minutes: Simeon P. Cairns, “Lactic Acid and Exercise Performance,” Sports Medicine 36, no. 4 (2006). In absolute terms, the highest levels of lactate may actually occur a few minutes after an all-out exercise bout of 30 to 120 seconds; see Matthew Goodwin et al., “Blood Lactate Measurements and Analysis During Exercise: A Guide for Clinicians,” Journal of Diabetes Science and Technology 1, no. 4 (2007). But from an athlete’s perspective, it doesn’t really matter what happens after the race is over.


CHAPTER 7: OXYGEN


120 "So I was brought up on the boat,: Quoted in One Breath–The Story of William Trubridge, a 2012 short film by Nicolas Rossier.
121 Rainmondo Bucher wagered 50,000 lire: Accounts vary about the details of Bucher’s dive; the details here are as reported by Nestor in Deep.
124 underwater for more than 45 minutes: Of the 87 dives observed in one study of Weddell seals, 86 were roughly 45 minutes or shorter and one was—apparently—82 minutes. Michael Castellini et al., “Metabolic Rates of Freely Diving Weddell Seals: Correlations with Oxygen Stores, Swim Velocity and Diving Duration,” Journal of Experimental Biology 165 (1992): 181–94.
124 Trubridge’s pulse drops into the 20s: He has recorded a pulse of 27 during dry-land training, though he hasn’t actually measured similar values during dives (personal communication).
124 sensors appear to be primarily around the nose: W. Michael Panneton, “The Mammalian Diving Response: An Enigmatic Reflex to Preserve Life?,” Physiology 28, no. 5 (2013).
125 heart rate begins to plummet just before it dives: See Panneton, “The Mammalian Diving Response.”
soldier-turned-mountaineer Edward Norton made it to 28,126 feet: Norton’s account is reproduced in Everest: Expedition to the Ultimate, Reinhold Messner’s 1979 book about his and Habeler’s ascent.


“No one cares for the prospect . . .”: Quoted in Messner, Everest.

“the rate of ascent must approach zero . . .”: Quoted in West, High Life.

he and his brother Günther: Brad Wetzler, “Reinhold Don’t Care What You Think,” Outside, October 2002.


the low-altitude control group lives at over 3,000 feet: For example, Christoph Siebenmann et al., “’Live High-Train Low’ Using Normobaric Hypoxia: A Double-Blinded, Placebo-Controlled Study,” Journal of Applied Physiology 112, no. 1 (2012).

no difference between sea level and Canberra: C. J. Gore et al., “Increased Arterial Desaturation in Trained Cyclists During Maximal Exercise at 580 m Altitude,” Journal of Applied Physiology 80, no. 6 (1996).

about 70 percent of male endurance athletes: K. Constantini et al., “Prevalence of Exercise-Induced Arterial Hypoxemia in Distance Runners at Sea Level,” Medicine & Science in Sports & Exercise 49, no. 5 (2017).

sustain an average of 85 percent of her VO_2max: Ben Londeree, “The Use of Laboratory Test Results with Long Distance Runners,” Sports Medicine 3 (1986): 201–13.


a manuscript called "New Records in Human Power": Thomas Haugen et al., International Journal of Sports Physiology and Performance, September 5, 2017.


A later study by AIS scientists: C. J. Gore et al., “Reduced Performance of Male and Female Athletes at 580 m Altitude,” European Journal of Applied Physiology and Occupational Physiology 75, no. 2 (1997).


139 mountain climbers who don’t adapt well: M. J. MacInnis and M. S. Koehle, “Evidence for and Against Genetic Predispositions to Acute and Chronic Altitude Illnesses,” High Altitude Medicine & Biology 17, no. 4 (2016).

CHAPTER 8: HEAT


141 “On the line”: As quoted in Lake.

141 “We’re gonna run”: As quoted in Lake.

141 “Ding, ding, ding”: as quoted in Daugherty.

143 more than a million boys: “2009–10 High School Athletics Participation Survey,” National Federation of State High School Associations.

143 invented sous-vide cooking, and introduced the potato: Joe Schwarcz, Monkeys, Myths, and Molecules (Toronto: ECW Press, 2015).

143 experiments on a professional cyclist named Melvin A. Mode: Francis Benedict and Edward Cathcart, Muscular Work: A Metabolic Study with Special Reference to the Efficiency of the Human Body as a Machine (Washington, DC, 1913).


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145 known anecdotally for centuries: For a historical review, see Charles Tipton, History of Exercise Physiology (Champaign, IL: Human Kinetics, 2014).


153 “so doped that he did not know . . .”: J. L. Manning, Daily Mail, July 31, 1967, as quoted by the Australian Associated Press in the Age, August 2, 1967.


154 “Their ‘safety brake’ didn’t work.”: Romain Meeusen at the Nestlé Nutrition Institute Sport Nutrition Conference, Canberra, Australia, 2010.


154 “I think you can almost take judicial notice . . .”: As quoted in Lake.

CHAPTER 9: THIRST


deaht of twenty-eight-year-old Cynthia Lucero: Noakes, Waterlogged.


“You will never be broken again.”: Alberto Salazar and John Brant, 14 Minutes: A Running Legend’s Life and Death and Life (Emmaus, PA: Rodale, 2013).


body temperature was measured as 88 degrees: Thomas Boswell, “Salazar Sets Record in Boston Marathon,” Washington Post, April 20, 1982.


your body monitors “plasma osmolality.”: Cheuvront, “Physiologic Basis.”

South African Special Forces soldiers: Heinrich Nolte et al., “Trained Humans
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\[170\] A Xo San Bushman hunter Karoha Langwane: Cited in Nolte, “Trained Humans.”


CHAPTER 10: FUEL


\[178\] “For 33 years I followed . . .”: Joe Friel, Fast After 50 (Boulder, CO: VeloPress, 2015).


180 researchers at the University of Minnesota: Tucker, The Great Starvation Experiment.


181 can store 400 or 500 calories: Benjamin Rapoport, “Metabolic Factors Limiting Performance in Marathon Runners,” PLoS Computational Biology 6, no. 10 (2010).

182 study found that Kenyan runners: “Food and Macronutrient Intake of Elite Kenyan Distance Runners,” International Journal of Sport Nutrition and Exercise Metabolism 14, no. 6 (2005).

182 Ethiopians; a similar study: Lukas Beis et al., “Food and Macronutrient Intake of Elite Ethiopian Distance Runners,” Journal of the International Society of Sports Nutrition 8, no. 7 (2011).


184 “And he possesses a very important adjunct, . . .”: Gilder, Schwatka’s Search.


imal Exercise Capability with Reduced Carbohydrate Oxidation,” *Metabolism* 32, no. 8 (1983).

186 *takes around 3,000 calories*: Rapoport, “Metabolic Factors.”


192 *fat-adapted runners were able to burn fat*: J. S. Volek et al., “Metabolic Characteristics of Keto-Adapted Ultra-Endurance Runners,” *Metabolism* 65, no. 3 (2016).


194 *The Supernova results*: Burke, “Low Carbohydrate.”

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199 “The cramps were fierce . . .”: “Have At It,” Mark Twight, press release issued after climbing Slovak Direct in 2000, https://www.marktwight.com/blogs/discourse/84295748-have-at-it.

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202 Tesla pace car: Alex Hutchinson, “Did the Tesla Pace Car Aid Eliud Kipchoge’s 2:00:25 Marathon?,” Runner’s World, May 24, 2017.
204 some expedition members felt its use was un-sporting: Reinhold Messner, Everest: Expedition to the Ultimate (New York: Oxford University Press, 1979).
206 “The verdict was that I’m ready . . .”: Peter Njenga, “Marathon King on a Mission to Break ‘Impossible’ Record,” Daily Nation, February 12, 2017.
207 “The difference only is thinking,”: “Kenyan Star Prepares ‘Crazy’ Sub-2 Marathon Bid,” Agence France-Presse, April 3, 2017.

CHAPTER 11: TRAINING THE BRAIN
211 the brain’s outgoing signals: This is a fascinating physiological question, but one that ends up making little practical difference to the research discussed in the book. Exercising with tired muscles may be challenging because the muscles send distress signals back to the brain, or it may be challenging because the brain has to send stronger outgoing signals to get the same muscle response. The net result, in most contexts, is the same. My guess is that there’s a little bit of both going on. For more, see M. Amann and N. H. Secher, “Point: Afferent feedback from fatigued locomotor muscles is an important determinant of endurance exercise performance,” Journal of Applied Physiology 108, no. 2 (2009); Helma de Morree and Samuele Marcora, “Psychobiology of Perceived Effort During Physical Tasks,” in Handbook of Biobehavioral Approaches to Self-Regulation (New York: Springer, 2015).
213 On my first day at the University of Kent’s: The visit and my experiences with brain endurance training were first described in “How to Build Mental Muscle,” Runner’s World, October 2013.


a 2016 analysis of virtually every brain-training study: Daniel Simons et al., “Do ‘Brain-Training’ Programs Work?,” *Psychological Science in the Public Interest* 17, no. 3 (2016).

“This is not happening! Why now?”: I first wrote about Isaković, and Paulus’s research, in “Cracking the Athlete’s Brain,” *Outside*, February 2014.


In the EEG study: “Fatigue-Induced Increase in Intracortical Communication


**CHAPTER 13: BELIEF**

246 Reid Coolsaet was wide awake: I wrote about Coolsaet’s marathon in “The Race Against Time,” *Walrus*, July/August 2012.


253 treat irritable bowel syndrome: Kathryn Hall et al., “Catechol-O-Methyltrans-


255 **doing a good deed:** Kurt Gray, “Moral Transformation: Good and Evil Turn the Weak into the Mighty,” *Social Psychological and Personality Science* 1, no. 3 (2010).

255 **fueled by “pure hate”:** As articulated in a classic thread on the Letsrun.com message boards, “Running the 800 on Pure Hate,” November 17, 2008.


257 **justified beliefs and true beliefs:** Edmund Gettier, “Is Justified True Belief Knowledge?,” *Analysis* 23, no. 6 (1963).

259 **Run a lot of miles:** Joyner sent me the haiku in an email on February 3, 2016, and has since been quoted on it elsewhere.

259 **Steve Magness has written:** “A Case for Running by Feel—Ditching Your GPS Because of Ecological Psychology,” scienceofrunning.com, February 8, 2016.


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266 **experimental Swedish sports drink:** Alex Hutchinson, “After a Near Sub-2 Marathon, What’s Next?,” *Runner’s World*, May 6, 2017.

266 **external testing of the Vaporfly:** Hoogkamer, “New Running Shoe.”