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INTRODUCTION

THE TROUBLE WITH CHANCE

"When someone says everything happens for a reason, I push them down the stairs and say, 'Do you know why I did that?'"

—STEPHEN COLBERT

PLAYING IN HIS FIRST professional tournament at the Greater Milwaukee Open in 1996, Tiger Woods selected a 6-iron from his bag on the tee of the 188-yard par-3 14th hole. Although Woods was fifteen shots behind the tournament leader, a large gallery had assembled to get a glimpse of the heralded twenty-year-old phenom. Tiger launched the ball into the wind, it landed about six feet from the pin, bounced once to the left, and rolled straight into the hole. The crowd whooped and whistled for several minutes.

It was not, however, the most auspicious start in the history of the game.

Comrade General Kim Jong-Il, playing the very first round in his life, was reported to have scored five holes-in-one at Pyongyang Golf Club in 1994, while en route to a 38 under-par score in which the then-future Supreme Leader of North Korea shot no worse than birdie (one under par) on any hole.

There are only two possible conclusions here: 1) Tiger is not such a big deal; or 2) somebody is lying. It is not hard for any of us, except perhaps North Koreans, to figure out which is the case.

If we were inclined to investigate further, we would discover that Tiger has recorded three aces in his 24-year career (a span in which he has won more than eighty tournaments). We would also learn that based on a large body of golf statistics, the odds of a professional golfer making a hole-in-one on any given par-3 hole is about 1 in 2,500. Tiger has played about 5,000 par-3s in his pro career so two aces would be expected; his career total of three is not extraordinary. However, the odds of an amateur golfer making a hole-in-one on a given hole is about 1 in 12,500; the odds of shooting two holes-in-one in the same round is about 1 in 26 million; and of sinking four holes-in-one is about 1 in 24 quadrillion (that's 24 followed by 15 zeros).

What makes Jong-Il's five aces even more amazing is the fact that, like most 18-hole golf courses, Pyongyang has only four short, par-3 holes. All other holes are at least 340 yards long. So, to get that fifth "1" in his round, the diminutive dictator must have been, in the immortal words of *Caddyshack*'s Carl Spackler (played by Bill Murray), "a big hitter."

We do not need any sophisticated understanding of probability, statistics, or the game of golf to doubt the veracity of the Dear Leader's scorecard. Nor, for that matter, do we have difficulty determining the improbability of the claim that young Jong-Il wrote 1,500 books and six operas during his three years at Kim Il Sung University. And what's the chance that, as was said, he really did not defecate?

. . . *Even after that fifth hole in one!?*

FALLING FOR FALLACIES

Puncturing fables about Kim Jong-Il (or his successors) is easy, but in other realms it pays to have some grasp of probabilities and the game, such as when our hard-earned money is on the line.

We flock to casinos in droves. About 30 million people visit Las Vegas each year to try their luck at various games of chance, including roulette, keno, craps, and baccarat, as well as slot machines. The house advantage in these games ranges from about 1 percent (craps) to 30 percent (keno). That's how the casinos can afford pyramids, gondola rides, shark tanks, fireworks, cheap buffets, and to pay Britney Spears $500,000 a night.

Nevertheless, we wager our hard-earned cash knowing full well that the odds are against our winning. Perhaps that is because even in these games of pure chance with dice, wheels, or electronics, most players believe or at least behave as if they can do something to improve their odds—by playing their "lucky" number, or betting on a "hot" shooter, or wagering on a color or number that is "due."

How does that work? Say, for instance, one is playing roulette and a black number has come up five times in a row. Should one keep betting on black, because black is "hot"? Or should one bet on red, figuring that a red number is "due"?

Does the bet change if black has come up ten times in a row? Or fifteen times in a row?

These questions are not hypothetical. On August 18, 1913, at the Casino de Monte Carlo, a remarkable run of black numbers unfolded at the roulette table. On European wheels, there are eighteen black numbers, eighteen red numbers, and one green "0," so a red or black number is expected to come up almost half the time. By the time black had come up fifteen times in a row, gamblers started placing larger and larger bets on red, convinced that the streak was due to end. And yet black hit again, and again. Players

doubled and tripled their stakes, figuring that the chances were less than one in a million of a run of twenty consecutive black numbers. But the wheel kept hitting black until the streak ended at twenty-six. The Casino made a small fortune.

The incident in Monte Carlo is the textbook case for what has been dubbed the "Monte Carlo Fallacy" (or "Gambler's Fallacy")—the belief that when some event happens more or less frequently than expected over some period, then the opposite outcome will happen more frequently in the future. For *random* events such as rolls of dice or the spin of roulette wheels, this belief is false because each result is independent of the previous rolls or spins.

Our very powerful brains have trouble grasping this simple reality. If you think the incident in Monte Carlo is an isolated case from a less sophisticated, bygone age, consider the phenomenon that unfolded in Italy in 2004–2005. The Italian national SuperEnalotto worked at the time by selecting fifty numbers (from 1–90), five each from regional lotteries in ten cities. As more than a year passed without the number 53 being drawn in Venice, playing this *ritardatario* (delayed number) became a national obsession. Some citizens started betting so heavily that they exhausted family savings or ran up large debts. Despondent over her large losses, one woman drowned herself off Tuscany. A man near Florence shot his family and himself.

Finally, after almost two years, 152 draws, and more than 3.5 billion euros wagered on 53 alone (an average of more than 200 euros per family), the number was finally drawn in Venice, putting an end to what one group called the country's "collective psychosis."

Our problems with randomness in games spills over into real-life decisions. How many parents with children that are all of one sex opt to have another with the hope, if not the expectation, that the next child will be of the opposite sex? But, like the flip of a coin, the sex of a baby is pretty

close to a random event. I say "close" because there is a slight skew in the natural birth ratio of boys to girls of about 51:49.

The Monte Carlo Fallacy is an example of what psychologists call cognitive bias—errors in thinking that skew the way we see the world. When gambling, these biases distort our sense of control over random outcomes and cause us to overestimate our chances of winning. A large body of research has revealed that our cognitive biases and our responses to them are part of our normal brain wiring. Psychological studies on both laboratory subjects and in real field situations (casinos) have documented the Monte Carlo/Gambler's Fallacy concerning runs of numbers. They have also found that near misses of jackpots (non-wins that fall close to winning combinations) increase our motivation to play.

One explanation for our fallacious thinking is that our brains are adapted to working every day to perceive patterns and to connect events. We rely on those perceived connections both to explain sequences of events and to predict the future. We can easily be tricked then to believe that some sequence is a meaningful pattern, when in fact a string of randomly determined independent events is just that—random.

It is a matter of our biology, then, that humans have such a complex relationship with random chance. On the one hand, we sure do enjoy games of chance, even though we lose often. Of course, when we lose, we accept it as just a matter of "bad luck."

But on the other hand, when we win—and many people do win every day—that often gets an altogether different interpretation. Good fortune is often chalked up not to the mathematics of chance, nor even to mistaken confidence in gambling "strategies," but rather to other forces. For some it is a just reward for good character or deeds, to others it is a prayer answered.

Take California truck driver Timothy McDaniel. On Saturday March 22, 2014, McDaniel lost his wife to a heart attack. The next day, he bought three "Lucky for Life" lottery tickets. When he scratched them off, he discovered he had won $650,000. McDaniel said, "I think she just kind of sent me this money so I could continue taking care of the (grand) kids."

McDaniel's heartbreaking story reflects how in the larger game of life and death our relationship with chance is even more conflicted. Many people prefer to banish chance altogether, to believe that, as McDaniel told reporters, "everything happens for a reason."

But not everyone.

THE PRINCE OF CHANCE

Jacques Monod grew up just down the coast from Monte Carlo in Cannes, France, another town famous for its casinos and, later, its film festival. Graced with movie star looks—one prominent French journalist described him as a "prince" who resembled Hollywood icon Henry Fonda, as well as considerable musical talent, and an exceptional intellect, Monod struggled to decide on a career path through his twenties. After distinguishing himself in the French Resistance, Monod rose to fame not as an actor or musician, but as a brilliant biologist. He shared the 1965 Nobel Prize in Physiology or Medicine for seminal discoveries about how genes work.

A pioneer in the field of molecular biology, Monod was privy to the blizzard of discoveries in the 1950s and early 1960s about the molecules that determined the characteristics of living things—what Monod and others dubbed "the secrets of life." He kept close company with a relatively small international community of leading researchers. For example, when James Watson and Francis Crick cracked the struc-

ture of DNA (deoxyribonucleic acid) in 1953, Monod was one of the first with whom Watson shared the breakthrough.

But as a Frenchman steeped in his culture's deep philosophical traditions, Monod was interested in science for more than just science's sake. After the war, Monod befriended France's leading philosopher-writer Albert Camus, and the two men pondered questions of human existence in Left Bank cafés. Monod felt that the public misunderstood the principal purpose of science as being the creation of technology. Rather, Monod believed technology was merely a by-product. He said, "the most important results of science have been to change the relationship of man to the universe, or the way he sees himself in the universe"—a relationship of equally intense interest to his friend Camus.

Monod thought that there were profound philosophical implications of the new molecular biology, particularly in the realm of heredity, which had gone largely unnoted in the broader culture. Several years after his Nobel Prize and Camus' untimely death, he decided to write a book to try to bring the meaning of modern biology to laypersons.

"[T]he 'secret of life' . . . has been laid bare," he wrote. "This, a considerable event, ought certainly to make itself strongly felt in contemporary thinking."

Monod used several chapters to describe the insights that had very recently emerged from the study of DNA and the deciphering of the genetic code. He understood this knowledge would be unfamiliar to most readers, so he included an appendix with chemical structures of proteins and nucleic acids, and a primer on how the genetic code worked. In a matter-of-fact style, he explained genetic mutations as accidental alterations—substitutions, additions, deletions, or rearrangements—in the text of DNA, in the sequence of the long strings of chemical bases (ACGTTCGATAA, etc.) that make up genes.

Then, almost without warning, he turned to the broader implications of how mutations arise in DNA. It is worth

quoting him at length for after 111 pages of background, he delivered one of the most powerful ideas in five centuries of science (all *italics* are original):

"We call these events accidental; we say they are random occurrences. And since they constitute the *only* possible source of modifications in the genetic text, itself the *sole* repository of the organism's hereditary structure, it necessarily follows that chance *alone* is at the source of every innovation, of all creation in the biosphere.

"Pure chance, absolutely free but blind, at the very root of the stupendous edifice of evolution: this central concept of modern biology is no longer one among other possible or even conceivable hypotheses. It is today the *sole* conceivable hypothesis, the only one that squares with observed and tested fact. And nothing warrants the supposition—or the hope—that on this score our position is likely ever to be revised.

"There is no scientific concept, in any of the sciences, more destructive of anthropocentrism than this one."

In essence, heretofore obscure discoveries in biochemistry and genetics (largely studied at that time in simple bacteria) had upended two millennia of philosophy and religion that put humans at the center or apex of creation. "Man was the product of an incalculable number of fortuitous events," Monod wrote. "The result of a huge Monte Carlo game, where our number eventually did come out, when it might not well have appeared."

Le Hasard et la nécessité (Chance and Necessity) appeared in France in October 1970. It was a fairly technical book with several chapters on philosophy and genetics, and those appendices full of chemical diagrams. A first-time author, Monod did not know what reactions to expect.

The *merde* hit the fan.

The book received dozens of reviews across France and quickly became a bestseller—second only to the French translation of Erich Segal's *Love Story* (this was France

after all). After it was translated into English, reviews and interviews with Monod were featured in several of the most prominent British and American newspapers and magazines.

Many commentators immediately recognized the threat chance posed to traditional ideas of humanity's origins and purpose. To Arthur Peacocke, a British biochemist turned prominent theologian, Monod had put forth "one of the strongest and most influential attacks of the century on theism." A flurry of articles and books appeared with titles such as *Anti-Chance: A Reply to Monod's Chance and Necessity*, *Beyond Chance and Necessity*, and *God, Chance, and Necessity*. Monod was invited to debate philosophers and theologians both in France and abroad, on television, radio, and in print.

American Calvinist theologian and pastor R.C. Sproul summed up the high stakes posed by chance in the first page of his book *Not By Chance*:

"It is not necessary for chance to rule in order to supplant God. Indeed, chance requires little authority at all if it is to depose God; all it needs to do the job is to exist. The mere existence of chance is enough to rip God from his cosmic throne. Chance does not need to rule; it does not need to be sovereign. If it exists as a mere impotent, humble servant, it leaves God not only out of date, but out of a job."

More than two hundred pages later, Sproul concluded: "Chance as a real force is a myth. It has no basis in reality and no place in scientific inquiry. For science and philosophy to continue to advance in knowledge, chance must be demythologized once and for all."

Sproul and other critics argued that what scientists perceived as chance merely reflected a lack of knowledge of true causes. Perhaps that was the expression of hope to which Monod alluded—the hope that as scientists learned more, our position on the role of chance would somehow be revised.

A SECOND CHANCE

The ensuing fifty years have not played out as either Monod or his detractors hoped. The Frenchman thought that the new insights from molecular biology should be a turning point for modern society—away from traditional beliefs about causes in the natural world toward one that embraced randomness and our chance existence.

Ha! Fat chance. The excitement and fuss stirred by *Chance and Necessity* simmered down, and Monod passed away a few years later. Surveys reveal that the majority of Americans, for example, continue to believe that everything on earth happens for His reasons.

But Monod's critics should take no comfort. The province of chance in the biosphere and human life has been revised, although not at all in the scope or direction that they hoped. The domain of chance has expanded into realms neither Monod nor anyone else imagined.

As we have learned much more about the history and workings of the planet, we have been startled to discover how the course of life has been buffeted by a variety of cosmological and geological accidents—without which we would not be here. As we have explored human history, we have seen how pandemics, droughts, and other civilization-changing episodes have been triggered by random, singular events in nature that easily might not have happened. And as we have probed human biology and the factors that impact our individual lives, we have caught chance red-handed, reigning over the often-thin line between life and death.

This book tells the stories that Monod could not—of astonishing discoveries from the planetary to the molecular scale, from great upheavals across the globe to the machinery of chance that operates within every cell of every creature, including ourselves. And while these discoveries vaporize the comforts of anthropocentrism, the story of chance, I hope you will come to agree, is much more than

highfalutin philosophy or the refutation of theologians' wishful thinking.

I hope that you are awed—awed by the power and the drama of asteroids slamming into the planet, of continents colliding, and of the rapid rising and falling of ice and oceans; awed by the realization that we live on (and are at the mercy of) a planet that is far more unstable than our short lives perceive; awed by the knowledge of how random chance is at the source of all of the beautiful and wondrous creatures with whom we share the planet; awed by the unique invisible accidents that made each one of us; and awed by the fact that we humans, recent descendants of bands of hunter-gatherers who persevered through a period of exceptional chaos, have in just the last fifty years or so, figured all of this out!

My goal here is to be comprehensible without being comprehensive. It is almost trivial to claim that the world is the way it is or that we are here because of a long chain of chance, albeit fortunate, events. The explanatory power I seek comes from specificity. It is essential to unpack some of those events to appreciate how they shape the direction of life. The layout of the book follows a simple three-part logic. I'll begin with inanimate, external chance events that have shaped the conditions for life (Part One, "Stuff Happens"), and then turn to the internal random mechanism within every creature that generates the adaptations to those conditions (Part Two, "A World of Mistakes"). Then, I bring the story to the personal level (Part Three, "23 and You") and how chance impacts our natural lives, as well as our deaths. Our chance-driven existence shatters long-held beliefs about humanity's place and raises challenging questions about the meaning and purpose of our lives. In the Afterword, I'll offer some possible replies with the help of some special guests.

This is a relatively small book for a really big idea. Science has given us a handful of really big ideas over the centuries,

but they have been received in funny ways. Darwin had a huge idea that was very simple to understand, and even though the evidence is massive and everywhere, many refuse to believe it. Einstein had a brand new idea, and even though few understand it or the evidence for it, most everyone seems to believe it. Monod had a great idea, but these days most people (other than scholars) have not heard of it, or of him.

My greatest hope, then, is that this short book might be chance's second chance.

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