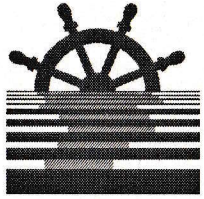

Stephen Graf

Hadamard's Billiards

Jacques Hadamard is considered by many to be the first discoverer of chaos. In 1898, Hadamard published an influential study entitled "Hadamard's Billiards" in which Hadamard was able to show that all trajectories are unstable, in that all particle trajectories diverge exponentially from one another.

MY EARS WOULDN'T STOP RINGING, that was the first thing I noticed. As I walked, I could barely control my gait; I'd lost all sense of balance. It reminded me of the feeling I used to get when I was a kid and would spin around until it made me so dizzy I had to drop to the ground. With each new step, I felt I would tumble face-first into the pavement, into the blackness. But I pressed forward, not understanding why, or even where I was going. I just knew I had to get away.

A meteorologist named Edward Lorenz was the first true experimenter in chaos theory. In 1960, he was working on the problem of weather prediction. Lorenz had a computer set up with a set of twelve equations to model the weather. The predictions could not be 100% accurate, but the program was able to theoretically predict what future weather might be.

Maria had told me before we vacationed there the first time that San Sebastian was the most beautiful city in the world. Her parents had taken her there as a kid when Franco was still in power and used to spend his summers there. There was something magical about it, she insisted, and

upon seeing it I had to agree. Nestled between a set of green mountains and the Bay of Biscay in the Basque region of northern Spain, when the sun shines there, which is usually, one can't help thinking that if there was a god, *this* was what he was thinking when he created the earth. The rest of the planet was just practice. The town itself was a cross between a quaint nineteenth century fishing village, and a more modern resort town. Maria and I had come here for our first official holiday as a couple, a few months after we'd started dating, so it held a special place in both of our hearts. When I decided to ask her to marry me, I knew it had to be here.

Like other small towns in Spain, the townspeople still turned out and promenaded the plazas every Saturday night. So as I staggered wildly down the sidewalk, couples in their finest clothes had to step aside to give me room. They stared at me as they did so, and some of them spoke to me, but I couldn't hear them because of the ringing in my ears. I felt like I was enclosed in one of those plastic bubbles, where nothing could touch me, and I could touch nothing. This feeling was put to the test by a stout woman with iron-gray hair and a brown shawl who refused to yield to some drunken foreigner weaving his way down the street. I thought I was going to ram her for sure, causing my bubble to burst and leaving the two of us sprawled on the dirty, cobblestone street. But at the last second, through a supreme effort, I was able to veer to the right, barely eluding her.

> *One day in 1961, Lorenz wanted to see a particular weather sequence again. In order to save time, he started the program in the middle of a sequence instead of at the very beginning. When he returned an hour later, the pattern had evolved differently, diverging from the earlier result, ending with a wildly different configuration from the original.*

Maria always said we were blessed, and I never argued with her. But I had my misgivings. When those bombs went off in the Madrid Metro a couple years back, I was supposed to be there. What I mean is the one bomb went off at my stop at the time when I normally would have been

there. I'd been at the Atocha station at exactly seven-thirty every weekday morning since I'd started work at a public relations firm in Madrid a year earlier. But that morning, I'd forgotten an important document I'd taken home to work on the previous night. Cursing my absentmindedness, I rushed back to my flat to get it. By the time I returned to the vicinity of the station, the three bombs had already detonated, leaving the surrounding area shrouded in smoke—blanketed in thick layers of dust, grief and turmoil. When I saw Maria that evening, she threw herself on me and wouldn't let go, as though she was trying to make sure I wasn't some sort of apparition that would evanesce the moment she released me. She kept saying it was a miracle. I preferred to think it was luck, because there was no miracle for those 191 people that did show up at their stops on time that day. It's difficult to accept that the only difference between a miracle and tragedy might be a little timing.

After that, Maria said we had to live each day like it might be our last. She always had anyway; she was so impulsive and full of life. And I tried to be like that, too. For a few weeks I tried, walking around filled with excitement and wonder, the way I had when I first moved to Madrid from the States. But it's hard to live that intensely for one month, let alone an entire lifetime. So gradually, as the city around me began to heal and fall into its old, regular patterns, I did the same. People have short memories. They have to. Otherwise, how could anyone ever get out of bed in the morning, knowing that everything around us is uncertain? Its existence in a constant state of flux, the entire human race is menaced with the possibility of sudden and unalterable change at every moment of every day; continually oppressed by the grim specters of pain and death. We are surrounded by chaos, so we make sense of it as best we can.

> *The phenomenon Lorenz discovered—one of two main components of what came to be known as chaos theory—was sensitive dependence on initial conditions, although it is more commonly referred to as the "butterfly effect."*

People who live through tragedies like the Madrid bombings, or the 9/11 attacks in New York—even if it is only tangentially like my experience—

become identified as survivors. But when I analyze this kind of categorization, taking it to its ultimate conclusion, then it seems to me it becomes reductive to the point of absurdity. After all, isn't everyone who is living a survivor in some sense? And if everyone is a survivor, then it basically splits human existence into two camps, both of which everyone will occupy eventually—those who survived, and those who didn't. Why, then, this urgency to live life differently?

Nevertheless, for a time we tried. One of the first things we did was to take that first trip together to San Sebastian. The day we arrived we took a tour in a taxi-cab and the driver had pointed out to us a splotch on the side of a cliff where—according to legend—an ETA terrorist had accidentally blown himself up while trying to plant a bomb years earlier. Maria was a pacifist to the point that she wouldn't kill a spider that was terrifying her in our apartment. And she wouldn't let me kill it either. Instead, I had to find a way to scoop it up in a newspaper, and take it outside to set it free. Which I did, with a resounding "splat" as soon as Maria was out of earshot. I remember Maria rhetorically asking the taxi driver why anyone would want to set off a bomb in the most beautiful place on earth. As though the beauty or ugliness of the setting made any difference.

Beauty means nothing to a bomb. A bomb accomplishes its work the same regardless of the aesthetic value of its surroundings. In a sense, a bomb operates much like chaos theory. The results are unpredictable and utterly chaotic, yet there is an underlying order to it. A bomb is utilitarian in nature; its job is simply to explode. The success or failure of the bomb itself is predicated on that and that alone. What causes a bomb to be considered good or bad is the use it is put to, and who is judging it. If it frees a group of trapped coal miners, the bomb is good. If it goes off in a crowded commuter bus, to most people it's bad—except to the terrorists who planted it. So it all depends on perspective.

> *The butterfly effect dictates that a very minor change in the initial conditions can drastically change the long-term behavior of a system. Therefore, as Lorenz later put it, just one flap of a butterfly's wings in Brazil could result in a tornado in Texas.*

When I first started dating Maria, I remember her asking me if I had ever heard of "la teoria de chaos." Because my Spanish still wasn't very good then, and because the way she pronounced the Spanish *chaos* sounded exactly like the English word *cows*, I thought she had asked me if I had ever heard of the *theory of cows*. I burst out laughing, and she couldn't understand why. All I could imagine was a group of cows, standing together in a field out in the country somewhere, lowing contentedly as they chewed their cuds and stared off blankly into space. I don't remember why she'd asked me about that—neither of us were scientists, or even scientifically inclined. All I remembered was the theory of cows. And in a sense, it wasn't a bad theory. Those cows in my mind's eye were contented, even happy in their way, oblivious to the fact that any day might end with them on the floor of a slaughterhouse. It wasn't really a theory, more of an image, but that was all right.

After that conversation, I looked the theory up on the Internet—the theory of chaos, that is, not cows. It seemed like a lot of it had already entered the common lexicon, as eventually happens with scientific discoveries. I read that many scientists believed that twentieth century science would be remembered for only three theories: relativity, quantum mechanics, and chaos. Aspects of chaos surround us: from the flow of blood through blood vessels, to a tree's branches, to the currents of the ocean, to the effects of turbulence. What surprised me was that the type of chaos which chaos theory dealt with was not the madness of the Madrid train bombings, or scenes like what I'd just lived through, but rather an orderly, even predictable kind of chaos.

But maybe the theory of chaos is simply another human construct that we try to lay over life in order to make some sense of it. Where I really think the chaos resides is inside of all of us. We are at all times consumed by contradictions—love, hate, happiness, sorrow, desire, revulsion—and these paradoxes are constantly at war with one another. What results is chaos. Not the orderly, predictable chaos of the chaos theory, but the unmitigated anarchy of the soul. How else can one explain someone setting off a bomb in a hotel in the most beautiful place on earth, randomly killing everything nearby?

The human heart has a chaotic pattern. The time between beats does not remain constant; it depends on how much activity a person is doing, among other things. The heartbeat can speed up under certain conditions. Under other conditions, the heart beats erratically. It has even been called a chaotic heartbeat.

This time it was Maria who'd forgotten something and had to go back, only this time it wasn't lucky. Standing on the wide veranda that ran along the front of the hotel, I watched her as she bounced through the glass doors and made her way across the lobby toward the elevators. Moments later I saw the lobby fill with flames. It was one of those unreal moments, where one sees clearly what is occurring, but one cannot believe it is truly happening, as though it were all part of some terrible dream. But this wasn't a dream. The sound came a split second later; it was a deafening roar that seemed to consume every other sound, like a black hole. This was followed immediately by a concussive blast that blew me from the porch, like a leaf caught in the wind. Landing on the sidewalk on the other side of the street, nearly ten meters from where I'd originally been standing, I was momentarily rendered unconscious.

When I came to, I couldn't hear anything, not a sound. Then the ringing gradually commenced, low at first but louder as it went. Turning to the hotel, I saw flames licking out of the ground floor windows, and dazed and bloody people beginning to stagger out. I watched for Maria, but she didn't come. In a haze, I ran my hands along my arms and legs to feel if there were any bones poking out. I wiped my face to feel for blood, but there was none. I pulled myself to my feet and limped toward the front door.

The analysis of a heartbeat can help medical researchers find ways to put an abnormal heartbeat back into a steady state, instead of uncontrolled chaos. It has been speculated that the human brain might also be organized somehow according to the laws of chaos.

The inside of the hotel was like a scene from Dante's *Inferno*. Acrid, black smoke billowed in the air, making it almost impossible to breathe. Half of the ceiling had collapsed. Broken furniture and bodies were strewn about the lobby floor. Along with the smoke and the dust, the air was filled with the moans and the shrieks of the survivors, which somehow pierced the ringing in my ears. I found Maria, what was left of her, in the back of the lobby near the elevators. She must have been close to the original blast, judging by the state of her. At least she went quickly—probably didn't even have time to realize what was happening. One second she's skipping through the lobby to retrieve her lipstick, and the next she finds herself launched into eternity.

I gathered up her body and carried it out to the street and lay it by a group of the wounded, huddled on the sidewalk in front of the hotel. I would have kissed her face goodbye, but there was nothing left to kiss. The bomb had taken care of that. I straightened up and began to stumble away from the scene. I thought I saw someone call to me, but I couldn't make out what he said, and didn't really care, either. At first I just fled. I had to get away and it didn't matter where. Then I noticed the chaos of my flight had an underlying order. I was heading for the beach at La Concha Bay. It was there I was going to propose to Maria that evening.

The chaos theory is paradoxical in nature. Although chaos is often thought to refer to randomness and lack of order, it is more accurate to think of it as an apparent *randomness that results from complex systems and interactions among systems. Thus, the chaos theory is really about finding the underlying order in apparently random data.*

As I got closer to the beach, my hearing began to gradually return. People dressed in their Sunday's best were rushing past me toward the columns of smoke that were rising from the hotel. I clearly heard the word, "sangre" from one onlooker, and a man with a concerned look on his face asked me in halting English, "Señor, are you okay?" I ignored all of this and kept walking.

The way a bomb works is it can't take away your memories of a person, and it can't rob you of your past. But it can wipe out your future in a matter of seconds. And not only your future, the futures of the children you would have had, and their children. The aftermath is exponential, like the butterfly effect—like chaos.

When I got to the bay, the tide was out. The sun was beginning to set and the water was so calm it looked like a deep blue sheet of glass. I could hear the wailing of police and ambulance sirens from the town center. Before me the beach was completely deserted; the commotion caused by the explosion had cleared off the last stragglers. I took a couple dozen wobbly steps onto the beach, and then dropped to my knees in the soft, white sand in front of a small pool of sea water that had been left behind by the receding tide. I wanted to cry or scream or do something to let out this emotion that was bottled up in me, but I couldn't. I was numb.

Digging in my jacket pocket, I produced the box containing Maria's ring. Removing the ring, I let the box drop into the sand in front of me. I tried to hold the ring up so I could look at it in the golden rays of the setting sun. But my hands were shaking so badly it slipped from my grip and dropped into the shallow pool in front of me without a ripple. Glancing down, I was able to make out my reflection on the surface of the pool.

I was covered in blood.

It wasn't mine.

Alexandria Marzano-Lesnevich

Stuck

ELLIE HAD HER FINGER STUCK UP HER NOSE when I met her. She was leaning over the adhesion tester so all I could see was blond hair and a lab coat, but I knew that stance. I'd done it before myself, twisting my finger like a corkscrew to work the glue in higher when a straight sniff didn't cut it anymore. "Careful you don't get stuck that way," I said, and she laughed, and wouldn't you know it, it did stick. Cyanoacrylate-54, a swift kick of a high but a pretty dumb move. Your nostril's lined with soft, delicate hairs and man, those fuckers hurt when you pull them.

Wasn't long after that we started messing around. The factory had been a hospital back in the days of bricks and ether, and had plenty of gloomy little rooms full of abandoned equipment, places no one would find us. I knew them all. I was an old-timer by glue factory standards. I'd started working there in high school, spending my summers testing samples on machines that looked like something Dr. Frankenstein would have used to squirt the elixir of life into his dear old monster, all syringes and metal springs. Six months of college in a pretty little town with a green in the middle, then my mom got sick and I moved back home to take care of her. The factory gave me back my old job, this time with the title of research technician, a fancy name for something a monkey in a lab coat could've done. Four years later I was still there, pushing the same levers and testing the same samples from the scientists, who were still trying and failing to find a knock-off for Post-It notes. It's the Holy Grail of adhesives. Everyone wants to be able to undo what they've just stuck.