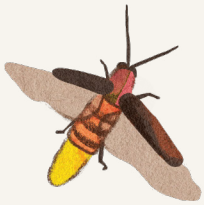
MEMOIR

A Son, a Scientist, and the Secret of Bioluminescence



My father spent a career decoding how fireflies make light. As dementia sets in, he is grappling with life's final mystery

BY ARNO KOPECKY
ILLUSTRATIONS BY JULIETA CABALLERO

There's a chemical reaction that occurs inside fireflies that allows them to flash without burning. It begins with a compound called luciferin, a name rooted in the Latin words for "light"—*lux*—and "bearing"—*ferre*—which also tells you something of the devil.

Fireflies make their own luciferin, along with an enzyme called luciferase. They fit together like a lock and key. The key turns when a firefly adds oxygen absorbed from the air. Internal combustion ensues. A flash of yellow-green light is released, along with a microscopic puff of carbon dioxide and far less heat than you might expect. So little heat, in fact, that when chemists decoded this reaction in the late 1800s, they were immediately bedevilled by a new mystery that took decades more to solve: in typical acts of combustion, most of the sundered fuel's energy is released as heat. But when oxygen tears the lucifers apart, energy escapes as light instead. Why?

My father wondered about that question for much of his life. As he approaches death at ninety-two, reluctant and afraid, I find I'm dwelling on it too. He doesn't have a terminal illness, but his body and mind are coming apart like so many molecules of oxygen. If this were one of his experiments, it might yield a flash of illumination. Instead, it seems, he's heading into darkness.

My father can't recall what he did yesterday. His hands are swollen and tremulous. It takes him two minutes to zip up a jacket. One day in February, he wandered over to a friend's house in search of food, but the friend was in Mexico; it was twenty degrees below zero, and my old man was knocking on the door wearing just his housecoat (no zippers). He became stranded on that doorstep, too weakened by the cold to walk home, and would have frozen to death if a neighbour hadn't walked their dog by right then. Shortly before that, he'd checked himself into the emergency room four times in two months, wracked each time with chest spasms, terrified he wouldn't wake up if he fell asleep.

A life of scientific inquiry has not prepared him for the final mystery.

The mystery in question: How do fireflies turn the energy of combustion into light instead of heat?

My father lives alone in Edmonton, 800 kilometres away from my brother and me in Vancouver. He's been there since 1960. His house is a few blocks from the University of Alberta, where he taught organic chemistry for thirty-five years. It was there, long before I was born, that he began tinkering with the photosensitive chemicals that became a gateway to the mysteries of fireflies and glow worms and marine plankton—the study of bioluminescence.

The job came with a personal laboratory that I can still smell from my own childhood visits—sulphurous, a bit rank. But the chemistry department was a perfume factory compared to the odours saturating the Iowa farm where my dad grew up. He left for college straight after high school, though he never stopped going back. When we were kids, my brother and I piled into his battered station wagon each summer for the two-day drive to visit our uncle, who's still working that same farm, and learned the value of intense physical labour. The pigsty stench was unforgettable. So were the fireflies. Each dusk, a chorus of cicadas and katydids would call them forth, faint pinpricks of light winking on, almost tentative at first—one here, one there, swelling in number as the air darkened, until they filled the night like so many shooting stars in the corn rows. I collected them in jars, fell asleep by the intermittent glow they put off from my nightstand.

The problem with bioluminescence, from a human-application perspective, is that it doesn't crank out lumens like a light bulb. Still, it has revolutionized everything from cancer research to gene therapy—you can inject firefly compounds into humans to make a tumour glow or light up DNA. But you'll never read a book by the shine of decomposing luciferin.

Who cares? Not I, nor Karl R. Kopecky. He was glad that his work contributed to "real-world" solutions, but happiest mucking about with the solutions he and his PhD students prepared in the lab. Theirs was a world apart, or rather a world within—a miniverse of atomic interactions manipulated by titanic hands to reveal the molecular structures operating far below our human scale of perception.

I still see those 3D models in his office: small solar systems made of Styrofoam balls connected by thin rods, like geodesic domes on acid. These are the molecules that everything—blood and plastic, air and granite—is made of. Ever wondered what benzene looks like to a proton? Arrange six balls (carbon) in a hexagon, attach a ball (hydrogen) four-fifths their size to each of those, and you've got yourself a hydrocarbon. Smash that for a great deal of heat without much light, the engine of modern civilization.

That engine provided my father with a good life, and for a long time, he didn't question it closely. He focused on work instead. Perhaps a bit too much. My parents split up when I was two, and my brother and I grew up in our mother's home. To stay connected with his sons, my dad threw himself into the strange sporting career we both chose: springboard diving. He didn't just drive us to the pool every day after school and become president of the club; he took lessons himself, learning front one-and-a-halfs, back layouts, reverse dive pikes. He was well into his fifties by then and about as emotive as you'd expect a man who grew up farming in the Great Depression to be. This, we'd say today, was his love language.

He paid glancing attention to current affairs but was so devoted to work during his career that he never realized America stopped being a global good guy five minutes after Hitler died. Half a century later, at the dawn of the internet era, he retired and turned his critical lens on the news. The George W. Bush administration was preparing to invade Iraq under patently false pretenses, and my father was shocked. He took his country's foreign policy as a personal betrayal and became, overnight, a born-again radical progressive. Suddenly vegan, environmentalist, and pacifist, he took to wearing a black armband every time he went out to represent the mounting death toll in Iraq. A lifelong atheist, he preached climate change and Republican corruption at every social encounter.

I share most of my dad's politics, but his communication style—demanding empathy, bestowing none—only

strengthened his opponents' world view. He was admirable and exasperating and remains so to this minute.

He refused to admit he was growing deaf over the past twenty years and rejected the hearing aids we kept urging him to wear. So the easiest way to communicate has been in writing. One day at the end of August, I texted to ask how he was doing. "I am in emergency with a heart attack," he wrote back.

A man who's having a real heart attack is unlikely to be texting about it, but that's still a disconcerting message to receive from your father. Turned out he was dehydrated. He forgets to drink water, among other things. A solitary figure, he's refused mounting entreaties to let my brother and me help him for well over a decade. His stubborn denial and continued survival felt like its own proof that he could manage—but contrary proofs have been accumulating, like dark energy, for some time.

At a Christmas party six years ago, a friend found him in the coat room, face down in a pool of blood. I was on the phone with him two hours later, listening to him slur from the hospital bed, both of us trying to work out what had happened. It took him months to admit he'd had a stroke, and he still avoids the word; he calls it "the faceplant" instead. He recovered, more or less, but was briefly weak enough to let his sons clean his house and hire someone to keep things tidy.

That didn't last long. He got his strength and speech back and chased the help away. He returned to his ways, at once unfathomable to me and terrifyingly prescient, a glimpse of one possible future: living alone in a condemned house that collapses in tandem with your body.

Let us help you, dad.

I'm fine.

People with parents who are hoarders can relate; anyone else would be shocked. A floor buried in papers dating back to the last century: junk mail, tax forms, letters from people he doesn't remember, chemistry reports he can no longer comprehend, a thousand magazines. Discarded clothing, empty oat milk cartons. Cardboard boxes full of rotting avocado skins and banana peels and apple cores—his version of composting.

The house still smells of smoke from the period when the furnace conked out and he burned wood inside for warmth. This in a city where winters reach forty degrees below. The windows are cracked, the plumbing is terminally screwed. For a while, the roof was leaking and he spread buckets around the kitchen to catch the water; then came the faceplant, and my brother put on a new roof. A new furnace arrived then too.

Let us help you, dad. He won't move out or let anyone in. I don't know how he's survived that place. The same way, I suppose, that he survived falling off the roof at eighty-four, or the faltering heartbeat that convinced him to walk to the hospital a year after the faceplant and get a pacemaker; his pulse was down to thirty. He's had several minor strokes since. He knows who we are, can tell you what day and year it is, but lives within a bubble of awareness that extends approximately half a day forward and back. I picture a man walking through a gathering storm, the snow getting deeper with every step, the wind blowing harder. He only hears me if I shout. He uses a magnifying glass to read his phone. He gets lost in his own neighbourhood.

I remember how it felt in the last few weeks of my wife's pregnancy, when we knew our daughter could

arrive at any moment. In that blend of certainty and uncertainty, time itself became pregnant. This is like that but in reverse. Same portal. He could die tomorrow or live another year. Maybe more. Every time he doesn't answer my call or respond promptly to a text, I wonder. It's been like this for years already.

Many lose their parents young or have parents who suffer dementia and other health catastrophes far earlier. People lose children, lovers, siblings. Those are tragedies. This, in a strange way, is something to celebrate: my dad has lived a long life, with a successful career. He got to see his two boys grow, develop careers, marry and have children. I got to have a father who loved me, taught me how to throw a ball and think a problem through. He's celebrated my victories like his own, all my life. We've both been lucky.

I've had to remind myself of that in moments when the tug of sadness combusts into anger, then settles into the ash of guilt. I'm angry at the man my father used to be for refusing to plan ahead, for letting it come to this. I feel guilty for the judgment. A phrase I can't stand keeps running through my head: he did the best he could with the tools he had. It's true. Now here we are. Should I let you live the way you want or force care upon you? Dignity or safety?

It turned out that my father, at this climactic moment of his career, had decided to stop for a haircut.

In September, I finally chose safety. Mice had moved in—a miracle it took this long—and squirrels were in the attic. He insisted a mouse trap would do. I showed him the mouse droppings on his pillow, in his food. He pulled out his magnifying glass. We called an exterminator. Got a social worker involved. I spent a week sorting, tossing, scrubbing, vacuuming. All against his will, but he was once again too weak to stop it. Maybe, I thought, he has been all along; maybe the weak one's been me.

I was vacuuming a path to his bedroom when a cut-out page of a stray magazine article got in the way. I picked it up, prepared to toss it into recycling, but a cursory glance revealed a title that made me pause: "Light of the first order." I dimly recognized the author's name, Cedric Mumford. I looked closer. The article was from the September 2001 issue of an obscure journal called *School Science Review*. I read the opening sentence: "Over thirty years ago, in the dusk of a Canadian evening, I was fortunate to take part in a unique experiment that linked chemistry with physics, and confirmed theories about one of the great unsolved mysteries of the living world."

I turned off the vacuum.

"In September 1965," Mumford wrote, "newly arrived in Edmonton, the capital of Alberta, I began research for my PhD…under Karl R. Kopecky, an American chemist." I rustled through the detritus spread around me, found the other two pages of the article, and read the whole thing twice.

Cedric Mumford, I now remembered, had been my father's greatest student. The mystery in question, of course, was that of bioluminescence: How do fireflies turn the energy of combustion into light instead of heat? Mumford's article described how he and my father discovered the answer.

By the 1960s, chemists had already theorized that another mysterious compound must be involved in a firefly's chemical reaction: dioxetane. When the lucifers are broken down by oxygen, the theory goes, their constituent parts form dioxetane for the most fleeting of instants; the dioxetane itself decomposes instantly, leaving no trace but a flash of light. Anyone could make a Styrofoam model of dioxetane—arrange four balls in a square, two each of carbon and oxygen, with two little hydrogens (or any number of substitutes) attached to each carbon—but the real thing was so unstable that it disintegrated the moment it formed. Isolating it in a lab was like trying to manufacture a snowflake in the desert.

Only far more dangerous. Dioxetane itself belongs to a highly explosive class of compounds called peroxides. Previous attempts to make it had destroyed many a chemist's apparatus.

"Explosions occur," Mumford wrote, "when an exothermic reaction generates heat at a faster rate than it can be lost to the surroundings." I thought of America when I read this. And I remembered how my dad, an otherwise calm man, would erupt in expletives every time we hit a red light when I was young; my parents' divorce was relatively recent then, but all my life, he never spoke a word about it.

In 1967, Mumford succeeded in isolating dioxetane. He'd created a chemical soup that held the compound steady. This was an enormous milestone, but it still didn't solve the fundamental mystery of bioluminescence. "The dioxetane never exploded during my research," Mumford recalled. "That in itself was strange."

It was my father, delighted by his student's success, who realized what was going on. Dioxetane's structure was almost identical to another compound that chemists knew could be assembled by shining ultraviolet light on two pairs of alkene molecules; the light's energy was sufficient to meld the two alkenes into a single unit. When dioxetane fell apart, my dad realized, the same process must be happening in reverse. "The excitement in his face, as he came striding up the lab, announced 'Eureka,'" Mumford wrote. "It therefore became our immediate priority to test the prediction."

Mumford spent the whole day preparing a fresh batch of dioxetane. "That evening I returned to the lab and awaited both Kopecky and the gathering dusk." The darkness came, but not my dad. Where was he? "I rang his wife and learned

that he had left their flat hours ago."

It turned out that my father, at this climactic moment of his career, had decided to stop for a haircut.

Mumford had a wife and two kids waiting for him at home. "I waited a while longer until the conflict of duties became unbearable, and then decided I would have to do the experiment alone." He immersed a test tube of his dioxetane solution in a beaker of hot water. "As a faint violet glow began to appear, I blinked to be sure."

When my dad finally arrived, the two men repeated the experiment together. "Kopecky's excitement on seeing the glow was electric. Having done much of his own research in the field of photochemistry he immediately saw a range of further experiments to try." To my father, this wasn't the end of a long journey but the beginning of a new one.

Fifty-six years later, standing in the hallway of his house, I wiped my cheeks dry. "Look what I found," I said to him later that day. It was a hot afternoon, and he was sitting at a shaded picnic table beside a splash park, watching my daughter and her two-year-old cousin dash about. I read Mumford's story out loud to him at the top of my lungs. The whole park could hear. He grinned the whole way through. He remembered.

By the end, his grandkids were listening too. They couldn't understand a word but were drawn in by our laughter.

Truth is, I've hit the limit of my own capacity to comprehend my dad's crowning achievement. As far as I can tell, the mystery hasn't been solved but has merely transferred from one compound to another. What's dioxetane's secret? Why does *it* dissolve into light instead of heat? What exactly is light, anyway? What's heat? What's energy?

What's life? The closer you look, the stranger it gets. Each revelation is a portal to a fresh mystery. I'm okay with that. I don't need every question answered. But I do find myself longing for some kind of lesson. All stories demand a resolution, all experiments a revelation. I know how this one ends, but I can't figure out what it means.

I'm sure my dad could relate. After all, the majority of his career wasn't spent grinning and shouting "Eureka!" It was spent in tedious, uncelebrated toil. That's a lot like writing. It's a lot like most working lives.

We operate largely in the dark, small specks in an incomprehensibly vast sea of atoms and stars, our lives punctuated by bursts of illumination—sometimes our own, usually someone else's. At the grand scale of existence, each life itself becomes one more flash of light. For a moment, it reveals something wonderful, by a glow so dim you need the dark to see it.

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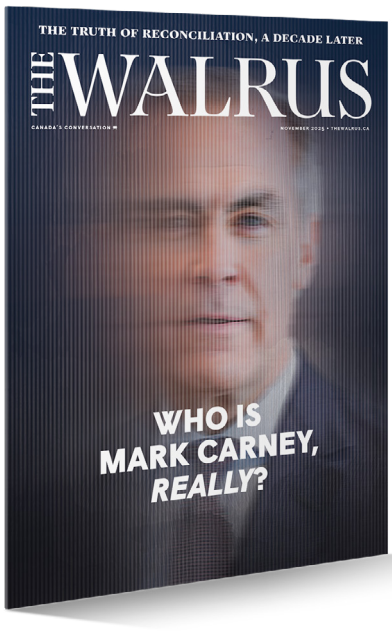

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