

The Cancer Chronicles

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I wonder now, though, if the steady presence of music around me didn't contribute importantly to my sense of the cancer as a thing with its own rights. Now it sounds a little cracked to describe, but then I often felt that the tumor was as much a part of me as my liver or lungs and could call for its needs of space and food. I only hoped that it wouldn't need all of me.

—REYNOLDS PRICE, *A Whole New Life*



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Tuberculosis used to be called “consumption” because it consumes. It dissolved a lung or bone. But cancer produces. It is a monster of productivity.

—JOHN GUNTHER, *Death Be Not Proud*

Jurassic Cancer

As I crossed a dry, lonesome stretch of the Dinosaur Diamond Prehistoric Highway, I tried to picture what western Colorado—a wilderness of sage-covered mesas and rocky canyons—looked like 150 million years ago, in Late Jurassic time. North America was breaking away from Europe and Asia—all three had formed a primordial supercontinent called Laurasia. The huge land mass, flatter than it is today, was drifting northward a few centimeters per year and was passing like a ship through the waters of what geographers would come to call the Tropic of Cancer. Mile-high Denver was near sea level and lay about as far south as where the Bahamas are today. Though the climate was fairly dry, webs of rivulets connecting shallow lakes and swamps covered part of the land, and vegetation abounded. There were no grasses or flowers—they had yet to evolve—just a weird mix of conifers commingling with ginkgos, tree ferns, cycads, and horsetails. Giant termite nests soared as much as thirty feet high. Splashing and stomping through this Seuss-like world were *Stegosaurus*, *Allosaurus*, *Brachiosaurus*, *Barosaurus*, *Seismosaurus*—their bones buried far below me as I made my way from Grand Junction to a town called Dinosaur.

Occasionally one can glimpse outcroppings of the Jurassic past, exposed by erosion, seismological uplift, or a highway department road cut—colorful bands of sediment that form a paleontological treasure house called the Morrison Formation. I knew what to look for from photographs: crumbling layers of reddish, grayish, purplish, sometimes greenish sediment—geological debris piled up over some 7 million years.

Just south of the town of Fruita on the Colorado River, I hiked to the top of Dinosaur Hill, stopping for a moment to pick up a pinch of purplish Morrison mudstone that had fallen near the trail. As I rolled it in my fingers it crumbled like dry cookie dough. On the far side of the hill, I came to a shaft where in 1901 a paleontologist named Elmer Riggs extracted 6 tons of bones that had belonged to an *Apatosaurus* (the proper name for what most of us call a *Brontosaurus*). Alive and fully hydrated, the 70-foot-long reptile would have weighed 30 tons. Riggs encased the bones in plaster of paris for protection, ferried them across the Colorado on a flat-bottom boat, and then shipped them by train to the Field Museum in Chicago, where they were reassembled and put on display.

After making my way north to Dinosaur (population 339), where Brontosaurus Boulevard intersects Stegosaurus Freeway, I stood at an overlook and watched Morrison stripes in a canyon reddening with the setting sun. But it was a little farther west, along the Green River in the western reaches of Dinosaur National Monument, that I saw the most beautiful example: a cliffside of greenish grays slumping into purples slumping into browns. It indeed resembled, as the woman at the park headquarters had told me, melted Neapolitan ice cream.

It was somewhere in these parts that a dinosaur bone was discovered that displays what may be the oldest known case of cancer. After the dinosaur died, whether from the tumor or something else, its organs were eaten by predators or rapidly decomposed. But the skeleton—at least a piece of it—gradually became buried by wind-blown dirt and sand. Later on, an expanding lake or a meandering

stream flowed over the debris, and the stage was set for fossilization. Molecule by molecule minerals in the bones were slowly replaced by minerals dissolved from the water. Tiny cavities were filled and petrified. Several epochs later dinosaurs were long extinct, their world overlaid by lakes and deserts and oceans, but this fossilized bone, encased in sedimentary rock, was preserved and carried through time.

That hardly ever happened. Most bones disintegrated before they could become fossilized. And of the fraction that survived long enough to petrify, all but a few remain buried. The specimen, now labeled CM 72656 and housed at the Carnegie Museum of Natural History in Pittsburgh, was a survivor. Unearthed by a rushing river or exposed by tectonic forces—somehow it was delivered to the surface of our world where, 150 million years after the animal died, it was discovered by some forgotten rockhound. A cross-section was cut with a rock saw, polished, and after passing through who knows how many human hands, the fossil found its way to a Colorado rock shop where it caught the eye of a doctor who thought he knew a case of bone cancer when he saw one.

His name was Raymond G. Bunge, a professor of urology at the University of Iowa College of Medicine. In the early 1990s, he telephoned the school's geology department to ask if someone would come evaluate a few prize specimens in his collection. The call made its way through the switchboard to Brian Witzke, who on a cold autumn day bicycled to the doctor's house and was presented with an attractive chunk, 5 inches thick, of mineralized dinosaur bone. Viewed head-on, the fossil measured 6.5 by 9.5 inches. Lodged inside its core was an intrusion, now crystallized, that had grown so large it had encroached into the outer bone. Bunge suspected osteosarcoma—he had seen the damage the cancer can do to human skeletons, particularly those of children. Oval in shape and the size of a slightly squashed softball, the tumor had been converted over the millennia into agate.

The fragment was too small for Witzke to identify the bone type

or the species of dinosaur, but he was able to provide a geological diagnosis: The reddish-brown color and the agatized center were clues that it came from the Morrison Formation. Bunge remembered buying the souvenir somewhere in western Colorado—burnished pieces of petrified dinosaur bone were a favorite among collectors—but he couldn't remember the precise location. He gave the rock to the geologist, asking that he seek an expert opinion.

Other projects intervened, and so the fossil sat almost forgotten atop a filing cabinet in Witzke's office, until the day he sent it to Bruce Rothschild, a rheumatologist at the Arthritis Center of Northeast Ohio who had expanded his practice to include dinosaur bone disease. He had never seen a clearer or more ancient example of prehistoric cancer. His next step was to determine just what kind of cancer it was.

The tumor, it turned out, didn't exhibit the ill-defined margins or the layered, onion-skin look of an osteosarcoma, the cancer Bunge had suspected, or of another malignancy called Ewing's sarcoma. Rothschild also felt confident in ruling out myeloma, a cancer of plasma cells that leaves bone with a "punched out" appearance. The fact that the tumor, gnawing its way outward, had left intact a thin shell of bone was reason to exclude the more invasive multiple myeloma. Every skeletal disease leaves a distinct engraving and, one by one, Rothschild eliminated the possibilities: "the superficial solitary and coalescing pits of leukaemia," "the expansile, soap bubble appearance of aneurysmal bone cysts," "the epiphyseal 'popcorn' calcifications characteristic of chondroblastomas," "the 'ground glass' appearance of fibrous dysplasia."

For an outsider reading Rothschild's observations, the medical jargon might be somewhere between translucent and opaque, words that gain a grim familiarity only as one strives to understand the sudden disruption of cancer. What is clear from the beginning is the confidence with which a specialist in the obscure discipline of dinosaur pathology can provide a likely diagnosis for a 150-million-year-old tumor. Rothschild went on to rule out the "sclerotic-rimmed lesions

of gout,” the “zones of resorption characteristic of tuberculosis,” and the “sclerotic features of gummatous lesions of treponemal disease.” Unicameral bone cysts, enchondromas, osteblastomas, chondromyxoid fibromas, osteoid osteoma, eosinophilic granuloma—who would have known that so much can go wrong inside what appears to be solid bone? None of these seemed like candidates. To Rothschild’s eye the lesion had the markings of a metastatic cancer, the deadliest kind—a cancer that had originated from cells elsewhere in the dinosaur’s body and migrated to establish a colony in the skeleton.

There had been scattered references in the journals to other dinosaur tumors—osteomas (clumps of overeager bone cells outgrowing their rightful bounds) and hemangiomas (abnormal effusions of blood vessels that can form within the spongy tissue inside bone). Like cancer, these benign tumors are a kind of neoplasm (from the Greek for “new growth”)—cells that have learned to elude the body’s checks and balances and exert a will of their own. The cells in a benign tumor are multiplying rather slowly and have not acquired the ability to invade surrounding tissue or to metastasize. They are not necessarily harmless. Occasionally a benign tumor can press dangerously against an organ or blood vessel or secrete destructive hormones. And some can become cancerous. These were rare enough. But sightings of malignant dinosaur tumors were especially scarce. A cauliflower-like growth in the forelimb of an *Allosaurus* was thought for a while to be a chondrosarcoma. But on close examination Rothschild decided that it was just a healed fracture that had become infected. Bunge’s fossil was the real thing. In a terse, five-hundred-word paper written with Witzke and another colleague and published in *The Lancet* in 1999, he came to a bold conclusion: “This observation extends recognition of metastatic cancer origins to at least the mid-Mesozoic [the Age of the Dinosaurs], and is the oldest known example from the fossil record.”

I’d first heard of Raymond Bunge’s fossil earlier that summer when I began working my way through the literature on the science of

cancer. There is something sickly fascinating about the way a single cell can break from the pack and start multiplying, creating something alien inside you—like a new organ suddenly sprouting in the wrong place or, even more gruesome, a vicious, misshapen embryo. Teratomas, rare tumors that arise from misguided germ cells (the ones that give rise to eggs and sperm), can contain the rudiments of hair, muscle, skin, teeth, and bone. Their name is from the Greek word *teras*, for “monster.” A young Japanese woman had an ovarian cyst with head, torso, limbs, organs, and a cyclopean eye. But these cases are very rare. Tumors almost always evolve according to their own impromptu plan. The most dangerous ones become mobile. Once they have established themselves in the immediate vicinity—your stomach, your colon, your uterus—they move on, metastasize, to new ground. A cancer that began in the prostate gland can end up in the lungs or the spinal column. There was no reason to believe that cancer hadn’t occurred in dinosaurs. But considering the tiny fraction of paleontological remains that humans have had the opportunity to examine, coming across an actual example seemed almost miraculous.

Consider the size of the field: From Dinosaur National Monument in Utah and Colorado, the Morrison Formation reaches north into Wyoming, Idaho, Montana, the Dakotas, and southern Canada. It spreads east to Nebraska and Kansas, and south to the panhandles of Texas and Oklahoma, and into New Mexico and Arizona. It covers approximately half a million square miles. Erosion and excavation, natural or man-made, have only nicked the edges, barely sampling the 7-million-year accumulation of dinosaur bones, and only those that happened to become fossilized. If it hadn’t been for Raymond Bunge’s sharp eye, the earliest solid evidence of prehistoric cancer would have been missed. How many other cases were crushed inside those lightless layers? And among the bones that have been retrieved, how many malignancies had been overlooked? Paleontologists were hardly ever looking for cancer—few would recognize it if they saw it—and the only tumors they had a chance of finding would be

those that had tunneled their way outward to a bone's surface or had been revealed by a random fracture or the blind cut of a lapidary saw.

One of the most elusive questions about cancer is how much is timeless and inevitable—arising spontaneously inside the body—and how much has been brought on by pollution, industrial chemicals, and other devices of man. Getting a rough sense of the frequency of cancer in earlier epochs might provide important clues, but only with a larger sample of data. His interest piqued by Bunge's fossilized tumor, Rothschild began looking for more.

With a portable fluoroscope, he began x-raying his way through the museums of North America. In people, cancers that metastasize to the skeleton most commonly lodge in the spine, so Rothschild concentrated on vertebrae. By the time he was done he had examined 10,312 vertebrae from about seven hundred dinosaurs collected by the American Museum of Natural History in New York, the Carnegie Museum in Pittsburgh, the Field Museum in Chicago, and other institutions throughout the United States and Canada—every specimen north of the Mexican border that he could get his hands on. He inspected loose vertebrae and, using ladders and a cherry picker, the soaring spines of whole skeletons. (There is a picture of him wearing a dinosaur T-shirt and leaning backward inside the rib cage of a *Tyrannosaurus rex*.) Bones that appeared abnormal under x-rays were scrutinized more closely with a CT scan.

In the end, his diligence paid off. He found another bone metastasis, and this time it was possible to identify the victim: an *Edmontosaurus*, a duck-billed titan (the family name is Hadrosauridae) that lived toward the end of the Cretaceous, right after the Jurassic, when dinosaurs began to go extinct. Other Hadrosauridae also had bone tumors, all of them benign: an osteoblastoma, a desmoplastic fibroma, and twenty-six hemangiomas, but there were none among the other beasts. That perhaps was the biggest surprise. Although Hadrosauridae vertebrae made up less than one-third of the bone pile—about 2,800 specimens from fewer than one hundred dinosaurs—they were the source of all the tumors. The approxi-

mately 7,400 vertebrae that were not hadrosaurs—*Apatosaurus*, *Barosaurus*, *Allosaurus*, and so forth—exhibited no neoplasms, either malignant or benign.

It was the kind of anomaly epidemiologists of human cancer confront all the time. Why do some people get more cancer than others? Some evolutionary twist may have left *Hadrosaurus* with a genetic predisposition for tumors. Or the reason might have been metabolic. These dinosaurs, Rothschild speculated, may have been more warm-blooded than other ones. Warm-blooded metabolisms run faster—it takes energy to maintain body heat—and that might accelerate the accumulation of the cellular damage that leads to malignancy.

Maybe the difference was not endemic but environmental—something about what *Hadrosaurus* ate. Plants in an ecosystem engage in endless chemical warfare, synthesizing herbicides and insecticides to fight off pests. Some of these chemicals are mutagens: they can change DNA. Modern descendants of the fernlike cycads that grew in Mesozoic times produce poisons that can induce liver and kidney tumors in laboratory rats. But why would *Hadrosaurus* eat more cycads than, say, *Apatosaurus*? Another possible source of carcinogens—needles from conifer trees—had been discovered in the stomachs of a couple of *Edmontosaurus* “mummies,” whose remains had been buried under the right environmental conditions to fossilize instead of rot. But that wasn’t much evidence to go on.

There were other curiosities to explain. When *Hadrosaurus* tumors did occur it was only among the caudal vertebrae—those nearest the tail of the spine. What was it about the bottom of the reptile that was more susceptible than the top? If only dinosaurs could be recreated from ancient DNA as they were in *Jurassic Park* and made available for medical research. At the great cancer centers—Dana-Farber in Boston, MD Anderson in Houston, and others around the world—a scientist can consume a career studying the role a single molecule plays in malignancy. Just the data from Rothschild’s survey suggested dissertations’ worth of questions. The overriding one was how to put his findings into perspective. Human bone cancer of

any kind—metastatic or originating in the skeleton—is a rarity. Was one case among seven hundred dinosaur skeletons a little or a lot?

In a third paper, Rothschild considered the odds. He had been approached by two astrophysicists who were hoping to support their theory that the end of the dinosaurs' earthly reign was hastened by a spike of radioactive cosmic rays. Ionizing radiation—the kind strong enough to damage DNA—can cause cancer, and bone marrow is particularly susceptible. If a cosmic event had unleashed unusually strong rays, the effect on the dinosaurs would have been like being x-rayed from outer space.

But how would you do the epidemiology? In an earlier study Rothschild and his wife, Christine, had x-rayed bones at the Hamann-Todd Human Osteological Collection at the Cleveland Museum of Natural History, a repository of three thousand skeletons from medical school cadavers—homeless souls who would otherwise be in pauper's graves. Thirty-three of them had metastatic bone tumors, which amounts to 1.14 percent. Autopsies at the San Diego Zoo suggested that reptiles have a bone cancer rate about one-eighth that of humans, or about 0.142 percent. One cancerous *Edmontosaurus* among seven hundred fluoroscoped dinosaurs yields almost precisely the same number. One would have to look elsewhere for evidence that cancer had been a factor in the extinction.

For months factoids like this had been accumulating in my notebook and metastasizing through my mind. Every question raised about cancer inevitably spawned more. How representative was the Hamann-Todd Collection of the overall cancer rate? The indigents whose bones were there may have suffered from poor nutrition and haphazard diets, possibly increasing their susceptibility. Yet many of them probably had comparatively short life spans, dying from violence or infectious diseases before there was time for a cancer to grow. Maybe it all balanced out. And maybe not. The study of the animals in the San Diego Zoo raised more questions. Animals in captivity tend to get more cancer than those in the wild, maybe because they are exposed to more pesticides or food additives, or

maybe just because they survive longer, get less exercise, and eat more. Of all the risk factors associated with human cancer two that are seldom disputed are obesity and old age.

The most troubling question was how much one can extrapolate about dinosaur cancer—and the ultimate origins of the disease—from what little evidence has survived. If you included in the sample only the one hundred tumor-prone *hadrosaurs*, their bone cancer rate would be 1 percent, about the same as for the human skeletons. But you have to wonder how many other specimens are waiting to be discovered. Just one more with a malignant tumor would double the cancer rate. Finally there was the question of how many cancers might have spread to unexamined parts of the skeleton or to softer organs—cancers that never reached bone. Once the tissues decomposed the evidence would be gone.

There are reports of a possible exception. In 2003, the year the Rothschild survey appeared, paleontologists in South Dakota announced the discovery of what might be a dinosaur brain tumor. They were preparing the skull of a 72-million-year-old *Gorgosaurus*, a close relative of *Tyrannosaurus rex*, when they found “a weird mass of black material in the brain case.” Analysis with x-rays and an electron microscope indicated that the rounded lump had consisted of bone cells, and veterinary pathologists diagnosed it as an “extraskelatal osteosarcoma,” a bone-cell-producing tumor that had taken up residence in the cerebellum and brainstem. Maybe that explains why the *Gorgosaurus* appeared to be so battered, as though the animal, suffering from a loss of motor control, had stumbled and fallen repeatedly. “It certainly would take a bizarre event to have created this appearance,” Rothschild speculated at the time. “The position and character may well be a tumor, but it still needs to be proven that this is not simply broken skull fragments that fell in.”

Continuing along the Dinosaur Diamond Highway, thinking about cancer, I made my own rare sighting: a Sinclair gasoline station with

its green dinosaur logo—another relic of earlier times. Along the road, rocking oil wells pumped the fossil fuels derived, as best we know, from prehistoric organic matter, a puree of tiny plant and animal life, perhaps with some oil of dinosaur splashed in.

It was almost dusk when I reached the Yampa Plateau in northern Colorado, a 300-million-year pile of geology. Eons of seismic turmoil—the thrusting and tilting, the slipping and sliding of great crustal masses—had made a mess of the timeline. For miles the road skimmed the surface of rock laid down in the Jurassic and Cretaceous, mid to late dinosaur time. Then without so much as a bump of the tires, the mesa top abruptly changed to Pennsylvanian—whole epochs sheared off to expose an older world, 150 million years before the Morrison dinosaurs, when primitive cockroaches crawled the land. Crushed a couple of strata beneath the Pennsylvanian would have been the Devonian, a 400-million-year-old countryside. In Devonian rock 1,600 miles east of the Yampa, a jawbone of a primitive armored fish was discovered near what became Cleveland, Ohio. It is pitted with what some scientists take to be a tumor and others dismiss as an old battle wound.

The road ended at Harpers Corner—the far tip of the plateau. I walked to the edge where deep below me the Green and Yampa Rivers come together, having sawed through all that hardened time. I stood there flummoxed by the thought of all that vanished past. After the disappearance of the dinosaurs came the Laramide orogeny, when the peaks that became the Rockies soared from the earth, reaching as high as 18,000 feet, only to become buried to their necks in their own debris. With the Exhumation of the Rockies (these names sound almost biblical), the infill began washing away. In early Pleistocene time, just 2 million years ago, the great glaciations followed, leaving behind the geography we know today. Throughout all of these cataclysms life kept evolving. Stowing away on the journey was this interloper called cancer.

Hints of benign neoplasms have been found in the fossilized bones of ancient elephants, mammoths, and horses. Hyperotosis, or

runaway bone growth, appears in fish from the genus *Pachylebias*, which seem to have put the tumors to good use. With the ballast provided by the increased bone mass, the fish could graze deeper in the salty Mediterranean waters, giving them an edge over their competitors. What began as a pathological growth may have been adopted as an evolutionary strategy.

Malignant tumors have been suspected in an ancient buffalo and an ancient ibex. There is even a report from 1908 of cancer in the mummy of an ancient Egyptian baboon. The examples are scant and sometimes controversial. But as with the dinosaurs, absence of evidence is not evidence of absence. Maybe cancer was a great rarity before man began messing with the earth. But a core amount of cancer must have existed all along. For a body to live, its cells must be constantly dividing—splitting into two cells, which split into four, then eight, doubling again and again. With each division the long threads of DNA—the repository of a creature's genetic information—must be duplicated and passed along. Over the course of time mechanisms have evolved to repair errors. But in a world awash with entropy that is naturally an imperfect process. When it goes wrong the result is usually just a dead cell. But under the right circumstances the errors give rise to cancer.

Even a lone single-celled bacterium can spawn a mutation that causes it to replicate more vigorously than its neighbors. When that happens to a cell within a tissue the result is a neoplasm. Plants and animals—two variations on the theme of multicellularity—ultimately sprang from the same primordial source. Plants are our very distant cousins, and they do get something resembling cancer. A bacterium called *Agrobacterium tumefaciens* can transfer a fragment of its own DNA into the genome of a plant cell, causing it to multiply into a tumor called crown gall. A remarkable paper published in 1942 demonstrates that in sunflowers these tumors can spawn secondary tumors—a primitive analog of metastasis. In the insect world larval cells can give rise to invasive tumors—the same phenomenon, perhaps, that carried over to the vertebrates.

Cancer (sarcomas, carcinomas, lymphomas, these clinically depressing names) has been described in carp, codfish, skate rays, pike, perch, and other fishes. Trout, like people, get liver cancer from a carcinogen, aflatoxin, produced by the fungus *Aspergillus flavus*. Rumors that sharks don't get cancer led to a mass slaughter by entrepreneurs hawking cancer-fighting shark cartilage pills. But sharks do get cancer. None of the classes of the animal kingdom are exempt. Among reptiles, there are cases of parathyroid adenoma in turtles and of sarcoma, melanoma, and lymphatic leukemia in snakes. Amphibians are also susceptible to neoplasms, but some offer a strange variation on the theme. When injected with carcinogens, newts rarely develop tumors. They are more likely to react by sprouting a new, misplaced limb. This ability to regenerate body parts has been all but lost by other animals over the course of evolution. Could this be another clue to the origins of cancer—damaged tissues trying frantically to regrow themselves, only to find that they no longer know how?

None of these creatures walk, swim, or slither to a clinic seeking care. But from the haphazard sightings of naturalists and zoologists, patterns have emerged. Mammals appear to get more cancer than reptiles or fish, which in turn get more cancer than amphibians. Domesticated animals seem to get more cancer than their cousins in the wild. And people get the most cancer of all.

One afternoon during my roadtrip, I stopped for a while at the Dinosaur Journey Museum. Given the current state of science museums—so much show biz—I expected the place to be infested with animatronic dinosaurs and hands-on exhibits resembling video games. But plenty of good science was there. I peeked through the picture windows of the Paleo Lab, where live men and women sat on display, leaning over worktables and chipping embedded fossils from surrounding stone. I walked among reconstructed skeletons towering toward the ceiling—*Allosaurus*, *Stegosaurus*. I saw a neck verte-

bra from an *Apatosaurus* so large that without the label I wouldn't have guessed the rocky mass had once been living tissue. It was all impressive, but over the years I had seen enough dinosaur skeletons to feel a little jaded. It wasn't until I stopped at a display with a full-size outline of a *Brachiosaur*'s heart standing as high as my chest that I really felt how enormous these beasts had been.

I thought again about Rothschild's survey of dinosaur tumors. There is a close relationship between size and life span. Though there are exceptions, larger species tend to live longer than smaller ones, and by some reckonings, the largest dinosaurs had very long life spans—so much time and space for mutations to collect. Wouldn't that have made them highly susceptible to neoplasms? At least in the mammalian world the issue is not clear-cut, an observation that goes by the name of Peto's paradox. It was named for Sir Richard Peto, an Oxford epidemiologist. He was puzzled that large long-lived creatures like elephants don't get more cancer than small short-lived creatures like mice. The mystery was succinctly posed in the title of a paper by a group of biologists and mathematicians in Arizona: "Why Don't All Whales Have Cancer?" Except for belugas in the polluted St. Lawrence estuary, whale cancer appears to be uncommon. For mice the cancer rate is high.

At first that didn't seem so strange. There is an inverse correlation between life span and pulse rate. During a typical lifetime an elephant and a mouse will each use up roughly a billion heartbeats. The mouse will just do it much faster. With a metabolism on so high a burn, it seems sensible that mice might get more cancer. But what is true for the mouse is not true for other tiny mammals. Birds, despite their frenzied metabolic rate (a hummingbird's heart can beat more than a thousand times a minute) appear to get very little cancer. If you graph mammalian size against cancer rate there is no telltale sloping line, just a scattering of dots. In our ignorance, each species seems like an exception.

Scientists have proposed several reasons for why cancer doesn't correlate smoothly with size. While larger animals may indeed get more mutations, they might also have evolved more effective means

for repairing DNA, or for warding off tumors in other ways. The authors of the Arizona paper suggested how that might occur: hypertumors. Cancer is a phenomenon in which a cell begins dividing out of control and accumulating genetic damage. Its children, grandchildren, and great-grandchildren go on to spawn broods of their own—subpopulations of competing cells, each with a different combination of traits. The stronger contenders—those that have evolved an ability to grow faster than the others or to poison their neighbors or to use energy more efficiently—will gain an upper hand. But before they can dominate, the authors proposed, they might become susceptible to “hypertumors”: clusters of weaker cancer cells opportunistically trying to latch on for a free ride. These parasites would sap energy continuously, destroying the tumor or at least keeping it in check. In large, long-lived animals cancer develops gradually enough for the leeches to form. They may indeed get more tumors, but they are much less likely to grow to a noticeable size. Cancer that can get cancer. For all the time I’d spent immersing myself in the literature, this was the first I had heard of that.

That still left me wondering about the hummingbirds, and a footnote in the paper about Peto’s paradox led me to yet another of cancer’s mysteries. It is well known to zoologists that virtually all mammals, no matter how tall or short, have precisely seven vertebrae in their necks: giraffes, camels, people, whales. (Manatees and sloths are exceptions.) Birds, amphibians, and reptiles are not bound by the rule—a swan can have twenty-two to twenty-five neck vertebrae. They also appear to get less cancer. Frietson Galis, a Dutch biologist, thought there must be some kind of connection. She considered what happens in rare instances when fetuses sprout an extra rib right where the seventh vertebra would normally be. As a result, children born with the defect have only six vertebrae in their necks. They are also more likely to die from brain tumors, leukemias, blastomas, and sarcomas. Galis suggests that it is why variation in the number of neck vertebrae is slowly being weeded out of the mammalian population.

I spent my last night on the road in Vernal, Utah, where a giant

pink *Brontosaurus* (I mean *Apatosaurus*) with long flirtatious eyelashes held up a sign welcoming visitors. It was about nine o'clock and the town was already shutting down. I found a restaurant with a Wild West theme barely open on Main Street. After a long day of driving I was looking forward to a glass of wine. I tried to keep up with the latest studies on how this vice, in moderation, might conceivably be good for the circulatory system, staving off heart attacks and strokes. The most wishful research even suggested that the anti-oxidizing effects of the elixir might help suppress tumors and extend life. But the longer you live the more likely you are to get cancer. Every meal presents a calculus of probabilities: Alcohol increases the risk for some cancers (mouth, esophageal) but may decrease the risk for kidney cancer.

In a file on my laptop I had been keeping a list of headlines from recent news:

“Natural Compounds in Pomegranates May Prevent Growth of Hormone-dependent Breast Cancer”

“Green Tea Could Modify the Effect of Cigarette Smoking on Lung Cancer Risk”

“Soft Drink Consumption May Increase Risk of Pancreatic Cancer”

“Bitter Melon Extract Decreased Breast Cancer Cell Growth”

“Seaweed Extract May Hold Promise for Non-Hodgkin’s Lymphoma Treatment”

“Coffee May Protect Against Head and Neck Cancers”

“Strawberries May Slow Precancerous Growth in Esophagus”

I knew by now that the effects, if real, would be minuscule. How can anyone sensibly weigh the trade-offs, based inevitably on imperfect information—on findings that could be overturned tomorrow?

The carcinogenic effects of red wine turned out not to be an issue that night. This was Utah and there was nothing alcoholic on the menu. My fried chicken cutlet sandwich was washed down with

lemonade made with powder from a jar and tap water. Back at my room at the Dinosaur Inn (guarded over by another smiling *Apatosaurus*), I thought again about those layers extending miles and millennia below me. Someday more layers would pile on top of us, and I wondered how much cancer would be there. It had been seven years almost to the day since Nancy, the woman I was married to, was diagnosed with a rabid cancer that sprouted for no good reason in her uterus and burned like a flame along a wick down the round ligament and into her groin. She lived to tell the tale, but ever since, I have been wondering how a single cell minding its own business can transmogrify into a science fiction alien, a monster growing within.

