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In Memoriam

FICTION BY POUL ANDERSON

Against the inexorable forces of time, will humanity leave any lasting mark?

The last man on Earth knew not that he was. Nor would he have cared. He had met very few other humans in his life, and none since his woman coughed herself into silence. How long ago that happened, he did not know either. He kept no count of years, nor of anything else. She lay blurred in his memory, but so did most that was more than a few days past. Day-by-day survival took all his wits and strength, such as they were.

She had not been the last woman. That one had died in Novosibirsk. To her it was nameless; the crumbling buildings simply provided dens, and fuel against the winters, with a stock of rats and other small game for her to trap. Her family had laired there until, one by one, sickness or accident overtook each and they became food for the rest. A brother lived long enough that his feeble attentions got her pregnant, but it was a stillbirth and she ate it also. Nevertheless it left her weakened. When she fell and, broke a leg she was helpless and starved to death. The small creatures cleaned, liar bones

The last man was likewise born in what had been a city, in his case Atlanta. He fled it when gang of cannibals arrived and settled in to stalk its streets and hallways for meat. Several generations ago their sort had been common, but the prey dwindled fast. These few soon perished in various ways. By that time the last man was elsewhere, and thus missed the satisfaction of learning about their fates.

In his wanderings he came upon a girl, equally footloose. She fled, terrified. Having eaten more recently, he was able to run her down. But then he was not ungentle, and afterward she accompanied him willingly. He meant a slight added measure of food and protection.

She had no name and few words, which she seldom used, His childhood had been more fortunate, leaving him with some language and scraps of tradition. Those led him to grope east across sun seared barrens until, lurching and croaking, he and his mate found a swamp. Although risen sea level brought a salt tide upstream twice a day, the water was not too brackish to drink. In and around it, fish, frogs, snakes, insects, worms, roots, tubers, and leaves furnished a meager diet if the pair worked hard at their gathering and trapping. They were unaware of the lead, mercury, and organic toxins not yet broken down.

Indeed, had anyone spoken to them of contamination, they would have stared uncomprehending. Plankton, krill, soil requirements, ecological balance, the food chain, its broad and vulnerable base, ozone, greenhouse effect, famine, nuclear warheads, positive feedback, mass extinction were noises they had never heard. Their world was what it was, hot, harsh, mostly parched and bare, scoured by rains that turned the rivers to mudflows and uncovered bedrock to the sky. So had it been and always would be. Once upon a time children had heard their parents say, "Once upon a time," and related stories of a fabulous age; but as life grew harder and people scarcer, such tales seemed gibberish and were forgotten.

The girl became a woman before she really took sick-neither had ever been healthy-and died. Her infrequent couplings with the man had had no issue. He mourned in a mute fashion. Unsure what to do about the body, he finally dragged it behind a fallen tree at a distance from the brush shelter in which they had dwelt. Whenever he revisited the site, he would squat silent and shyly stroke her skull. In time, boggy ground and thorny overgrowth hid the skeleton, but he continued to eat the grubs he picked out of that log with a certain reverence.

Otherwise he lived dumb. His name and most else dropped out of memory. Gaunt, rachitic, rotten-toothed, plagued by recurrent fevers and jaw clattering chills, he endured for years. He made crude tools, traps, snares out of wood, bone, gut, what sharp stones he could find. Fire was a lost art, but on the rare cool nights he kept warm between layers of bracken. He paid no attention to the mosquitoes that beclouded and feasted on his nakedness; as for ticks and leeches, he plucked them off and swallowed them, ignoring the festering sores where their heads were stuck.

In due course his skin cancers shed their seed into his bloodstream and devoured him from within. All he knew was that he felt increasingly wretched, until he could not crawl more than a few of his own lengths in any one day.

Yet at the end a delirious yearning came upon him. Just outside the shelter was a small boulder. He had, in fact, chosen the location because this was a convenient surface on which to crack shells and crania or split reeds for their pith. Now he crept there on all fours. The sky burned pitiless blue overhead. A cypress, dead and bleached white, offered no shade. The edge of the swamp, which was shrinking, glimmered scummily, unreachable yards away. Rain had fallen during the night and a depression in the cracked red clay held a little water. The man sucked its siltiness dry. His thirst still smoldered, he was crusted and he stank, but his eyes cleared somewhat and he dragged his carcass onward to the rock. Several stones that he had collected lay around it. He took a wedge-shaped one in his left hand and a blunt one in his right. Blow by blow, he chiseled a mark into the boulder: as it happened, an X, unless it was a cross falling down. He could not have done this were the material not soft limestone, and even so, the mark was barely visible. For a spell he stared at it. The breath rattled in his lungs. He crumpled, sprawled, and breathed a while longer, then no more.
The undertakers sought to him, ants across the ground, insects from the air. They too had no way of knowing that this was the last man on Earth.
Life went on in vigor unabated. The continents were more brown than they were green; rare was the sight of silver slenderness cleaving the seas; but the desert appearance was deceptive. Only the least hardy animals and plants were extinct. They included the larger sorts and those that humans had considered beautiful, but this was of no serious biological consequence. Bacteria, protozoa, and other microscopic organisms had always outweighed as well as outnumbered everything else alive. Some parasites and disease germs died out with their hosts, but most species found the new conditions to their advantage and proliferated. Tough, scrubby grasses, shrubs, and trees made do. Freed of their warm-blooded predators, many invertebrates underwent population explosions. Amphibians had suffered badly, but various kinds of fish and reptiles survived and started to increase. The same was true of certain birds and lesser mammals, especially rodents. Conspicuous among these were the rats. They had declined after the civilization that nourished them ceased to be, but adapted well to the wild, for they were intelligent and tenacious and could eat practically anything.
Earth and moon wheeled on their ancient ways. Rain torrented, light blazed, oxygen and acids gnawed. In every crack or corner where a bit of dirt had drifted, seeds arrived, rootlets thrust forth, stalks lifted, and within a year masonry was breaking apart into finer and finer fragments. Termites and dry-rot fungi feasted for a century or more on wood, but when a house fell down it was lichen and moss, grass
and thistle that reduced the harder parts.
Of course, much resisted. Steel framed buildings reared as before, perhaps hollowed out but their exteriors merely blotched. The Pyramids of Egypt withstood the flood when the Aswan Dam broke and defied every weather. An explorer would have seen a few other such anomalies scattered around the planet. Small objects held on in large numbers, gemstones, gold work, ceramics, inert plastics.
Time passed. Within a century the bones of the last man were gone, dissolved, taken back into nature. The mark he scratched on his headstone had already blurred to nothing.
Time passed. Chemistry proceeded. Impurities were transformed or diluted to harmlessness. The ozone layer thickened again. Excess carbon dioxide reacted with exposed rock to form carbonates. Resurgent plant life took up more. Greenhouse effect diminished and Earth cooled.
This actually happened rather fast. High temperatures had evaporated vast quantities of ocean water. Much of this fell as snow on mountains and the polar regions. Not all of it melted in summer. The glaciers grew. They locked up most of the water vapor that is also an important greenhouse gas. Temperatures dropped further. Geologically speaking, the new Ice Age came overnight.
Glaciers penetrated Europe until they had buried what was left of Bordeaux, Berlin, Warsaw, and St. Petersburg. Local sheets in the Alps accounted for their share. In North America, ice engulfed the reaches once called Alaska and Canada; the Great Lakes froze to make a foundation for cliffs sheer above the sites of Detroit and Chicago. Except at high altitudes, Asia was too dry for this, though its northern half went bitterly cold. Africa stayed clear, like South America apart from the Andean heights. The Pacific experienced mainly a fall in sea level sufficient to rejoin Australia to the Indonesian islands; but icebergs often hove above the Tasmanian horizon.
At its mightiest, the glacier in Europe or North America bulked a mile thick.

Wind whistled over its wrinkled emptiness, driving snow or a glitter of crystals; crevasses shone a lovely mysterious blue, but the sun alone beheld. In summer at its edge, streams rushed down the cliffs and out of the caves, down to gurgle among stones, make the ground a bog, and lose themselves in the tundra that stretched on southward. Here grew lichens, mosses, now and then a tussock of grass or a
clump of dwarf willows. Mosquitoes bred their billions, darkened the air and sawed it with their whine. Then the brief season ended, pools stiffened, snow fell anew, starts crowded darkness out of utterly clear nights.
Interstadial periods occurred, when for millennia at a time the glacier retreated for hundreds of miles. The tundra lay warm, mist baked out of it, life swarmed in from the south, wildflowers, berry bushes, evergreens, seeding, growing, spreading, until a forest stood with its crowns like an ocean beneath the wind and flying creatures clamorous above. But the glaciers returned, froze the woods to death, crushed them underfoot, ground and scattered further the works of man.
This Ice Age lasted three million years.
They were by no means evil years for living things. On the contrary, Gaia flourished as she had not since the Pleistocene. Rain belts, forced equator ward, quickened the deserts. The erosion that washed soil down the rivers into the seas nourished them. Meanwhile its forces weathered rock and carried in organic matter to make loam, which roots anchored. Plants and animals multiplied, died, decayed, formed humus to support a life more rich. Volcanoes and ocean trenches brought minerals up from the depths; currents and winds spread them, microbes concentrated them, larger species used them. The waters filled with fins, the land with feet,
the sky with wings. Below the tundras and beneath the ranges, forests ran from shore to shore, save where grass billowed or marshes choked on their own abundance.
Evolution worked onward. Species diversified, more and more as increasing fertility opened opportunities. Those that were gone never came back, but new ones took their places. Sometimes, to some degree, they resembled the old. Broadleaf trees bore nuts and fruits, flowers bloomed like bits of rainbow, creatures had descendants bigger than themselves, such features as horns or fingers reappeared. However, an anatomist would have found essential differences; the likenesses were as superficial as those between fish, ichthyosaur, and whale had been.
After three million years, secular changes in Earth's orbit and axial inclination, together with geological and geochemical action, terminated the Ice Age. The glaciers withdrew to the poles and mountaintops. The woods advanced northward and southward over the tundras. They demolished the few shards of human artifacts above ground which the ice had not milled to powder. What roots and rain and frost did not finish yielded to natural acids or the microbes that had "learned"
to eat otherwise resistant synthetic materials.
The middle latitudes kept a little evidence of man.
The violence of earthquake, eruption, and tsunami had brought many works low, but this was as nothing compared to the patience of weather. There were hills, though, some quite big, where burrowing animals still came upon things that nature could not have made; in them, the soil usually had a high iron content. The Sphinx was long gone but identifiably artificial stumps of the Pyramids stood in the desolation that had encroached again after the rain belts moved back north. Early on, several tombs in the Valley of the Kings had filled with sand, which during the wet epoch hardened into stone. It preserved their contours and hints of their murals. Similar freaks of circumstance persisted in other corners of the world, far apart.
And then there were the fossils, not simply bones and teeth but manmade objects that by chance had been buried and petrified. They existed both ashore and at sea; countless minor items and several almost complete ships lay deep in the silt on ocean bottoms. Other remnants were not, strictly speaking, fossils. A coffee mug, a jade
ornament, a mutate, a faceted diamond, or the like could stay as it was, encysted in stone, indefinitely. Not every relic dated from historic times. Strata held fugitive memories of the Neolithic, the Paleolithic, or eras even older, a jawbone, a brainpan, a flint pounded to shape by Neanderthal or perhaps Pithecanthropus.
Beyond the clouds were clearer traces.
No artificial satellite or piece of debris had continued in orbit around Earth

past a century or two. Residual friction dragged them down, to flash as meteors or drift as dust. Whatever struck ground fell to the forces that gnawed at everything else. A few bits had escaped the planet, to course about the sun on eccentric tracks of their own, but collisions with asteroidal gravel annihilated them piecemeal.
Cosmic infall had also wiped footprints and wheel tracks off the moon. Crashed probes, abandoned vehicles, used-up robots, and discarded gear were left, untouched by air, water, or life. The stony rain wore them away, but slowly, slowly, perhaps one really damaging strike in a hundred thousand years.
Destruction went a little faster on Mars, which kept a wisp of atmosphere and was nearer the asteroid belt, but
maker looked at every part of the crater, identifying and mapping the strata as well as deformation in the crater wall. He found coesite, a type of silica that forms only under very high pressure. Deposits along the crater wall, he discovered, contained oxidized meteorites and glass impregnated with traces of meteorite in the form of melted iron and nickel. Shoemaker also showed that the crater was similar in structure to nuclear blast sites in Nevada. Judging from the evidence, he concluded that the mammoth crater was actually formed when a 45-meter-wide iron meteorite crashed to Earth at the incredible speed of as much as 50,000 miles an hour. The impact, which occurred 50,000 years ago, according to Shoemaker, sent 300 million tons of rock flying out of the crater; some of that rock formed the crater rim.
Today, of course, few scientists doubt that space rocks regularly plummet to Earth. Sometimes, although rarely, these visitors are very big rocks asteroids or comets. Both consist of material that never quite made it into planets when the solar system was created 4.5 billion years ago. Asteroids are solid, stony objects; comets are "dirty snowballs"-mixtures of dust, rocks, and ice. When one of these objects
crash-lands, it leaves behind a telltale crater and other signs of destruction.
In the past few decades, scientists have begun to appreciate the role impacts have played in shaping our planet. With this recognition has come a heightened awareness about the potential for mayhem and destruction, perhaps even extinction, from errant rocks in space. Even the powers that be on Capitol Hill have recently taken note. In 1990, Congress asked NASA to investigate the threat posed by "near Earth objects"-asteroids and comets flying in orbits that bring them perilously close to Earth. In response, two dozen astronomers and planetary scientists met throughout 1991 to devise a strategy for detecting the killer rocks among us. NASA assembled another panel of scientists, which met in 1992, to figure out ways of fending off or deflecting deadly extraterrestrial objects that might otherwise hit the earth.
Brian Marsden, astronomer at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and a member of the detection task force, finds some irony in the situation. "In ancient times, astronomers were supposed to protect the earth from danger. They had to predict things like eclipses, which were feared because no one
knew whether the sun would come back out again. The job really hasn't changed that much. Now we believe the earth may be in danger from a collision, and it's up to the astronomers to determine if and when such an event might happen and then suggest ameliorative measures."
That job is crucial, given the potential consequences of a direct hit. "It makes little difference whether we collide with a giant asteroid or a giant comet," says Clark Chapman from the Planetary Science Institute in Tucson, a member of both the detection and deflection committees. "The important point is that a very big, very-fast moving thing suddenly stops. That causes a rapid release of energy, about as rapid as the explosion of a bomb." If, for example, a 1.6 kilometer, or one-mile-wide, asteroid landed here, it would release nearly 100,000 megatons of energy, ten times as much as the explosion of the world's entire nuclear arsenal minus the radioactive fallout.
It's hard to contemplate such devastation. Yet it has happened before. Some 65 million years ago, a space rock 10 to 14 kilometers wide slammed into the earth, sparking a 100 million megaton blast 10,000 times more powerful than the explosion of all the nuclear weapons in the world. The dominant effect in the short run, scientists say, was cooling, mainly from the massive dust clouds thrown into the air. Over the long term, carbon dioxide, water vapor, and other gases entered the upper atmosphere, enhancing the greenhouse effect and raising temperatures almost 20 degrees Fahrenheit. The result of this climatic havoc: the demise of the dinosaurs and half the other species on Earth.
The notion that dinosaurs were wiped out by a colossal impact was first

articulated in 1979 by the Nobel Prize-winning physicist Luis Alvarez and his son Walter, a geologist. The Alvarezes based their claim on the presence of a thin layer of iridium -an element exceedingly rare in the earth's crust but abundant in extraterrestrial rocks deposited in clay throughout the world at the "K-T" (Cretaceous Tertiary) boundary. This layer, found beneath the ocean floor and in other erosion-free zones, marks the juncture between the Cretaceous and Tertiary geologic eras. It also correlates precisely with the date of mass extinctions.

"If you look back in time at the different layers of earth, fossils of critters are seen throughout the rock until they disappear at a specific point," explains University of Arizona geologist David Kring. "The K-T boundary is the point only a little. Jupiter had almost instantly reduced all that reached it, and Venus had done so within decades.

Time passed. Occasionally during the next thirty million years the ice advanced, but never very far, and each retreat went deeper back. At last none remained except on Antarctica and the tallest mountains. Swollen, ocean drowned many islands and coastal plains. Otherwise it was benign, the source and guardian of climates that held steady from tropical rain forests to the mild northern and southern fringes of the continents.

Life forms evolved, had their day, and yielded to successor breeds. Some lines of descent died out altogether, but some radiated into fresh kinds while some kept virtually unchanged for periods that ran into the hundreds of millions of years. From the rats arose creatures that grazed, creatures that preyed on them, creatures that took to the air and became raptors more fearsome than any bird. One branch of the rat family went into the trees and developed hands of a sort. Certain among these returned to the ground and grew large and brainy. None ever put fire to use nor any tool more complex than a carefully chosen stone or a stick sharpened with the teeth. Another branch became aquatic and gained flippers, but the truly gigantic sea beasts were originally birds. A variety of Octopodidae got to outliving their own procreation, and thence to caring for their young and a lifespan that lengthened as generation followed generation. Ultimately there were beings whose tentacles worked rock, shell, bone, and coral. They had language, although its symbols were gestures and color changes.

They hatched ignorant and weak, but learned from their elders and from experience as they matured. They created societies which practiced religious rites and subtle arts. Yet being confined to salt water, they never went technologically beyond their equivalent of the Stone Age. One by one, in different manners around the world, their cultures adapted so well to local conditions that innovation ceased; caste systems congealed; the biography of an individual was predetermined within narrow limits and in elaborate detail from the egg to the disposal. Having abolished natural selection for itself, intelligence atrophied. The species grew less and less able to cope with any change in environment. Twelve million years after it came into existence, it was extinct. To be sure, this was a considerably longer run than humankind had had.

As for the vestiges of that earlier race, geological vicissitudes pursued them. A river would change course, a land mass rise or sink, a fossil come to light and thus to erosion. For example, a set of footprints was once laid down in muddy ground that got covered over and lithified as shale. After fifty million years this was laid bare and broken open. Rain filled the prints, algae greened the puddles, the stone flaked and crumbled. In less than a century it had completely lost those traces left by the shoes of George Washington.

A few things stayed entombed and lasted immensely longer, fossilized tools or teeth, roadbeds or graves. But the planet queried. Crystal plate shifted ponderous about. When Africa sundered from Asia, the marks of the Pharaohs disintegrated. North America, colliding with northeastern Asia, raised a mountain chain and ground every token of man in those parts to molecules. Seabed relics slipped down subduction zones to be cycled through moltenness. So it went, while the years mounted into the billions.

No living things witnessed the end. Since first it condensed from primordial gas and dust, the sun had been brightening. Temperatures on Earth kept remarkably stable. In part this was due to chemistry and physics. More heat evaporated more water, much of which recondensed as clouds and deflected sunlight. Rock exposed by falling sea level or by geological uplift reacted with that other major greenhouse gas, carbon dioxide, and bound it. Life was a potent force too. Plants tied up

their own carbon, which often stayed in place when they died, were buried, and turned into peat or coal. Plankton exuded substances that contributed to cloud formation. Animals helped maintain the balance, cropping vegetable matter and each other lest one kind overrun the world.

Yet at last the input became overwhelming. The tropics steamed dry, wildfire consumed their jungles and savannahs, scorching winds blew the ashes off and left hardpan desert. Soon the higher latitudes went the selfsame way. Vertebrates died rapidly beside the vegetation that had sustained them; the toughest insects hung on for a span; finally the microbes succumbed.

Primitive, sorely depleted life lingered in the oceans, but not for long. The concentration of water vapor in the atmosphere passed a critical point, and a runaway greenhouse effect set in. The seas began to boil. It took a little time, but by one billion A.D. Earth was totally dead. Ascending, the water molecules encountered ultraviolet photons that split them apart. Their hydrogen escaped to space, the oxygen united with materials below. Carbon dioxide, roasted out of limestone, stoked the furnace further. The planet did not quite change into a twin of Venus, but the difference was trivial.

Volcanoes continued to vomit huge quantities of water from the mantle. It too was lost. Deprived of that lubricant, plate tectonics ground to a halt. Besides, the radioactive elements whose energy had driven the process were giving out. You could not say that continental drift ceased. Lacking oceans, Earth really had no more continents, just massifs in the basins. Unblocked by ozone, actinic radiation stalled them; wind sanded them; sometimes a large meteorite smote them. Without water, oxygen, and life, erosion went very slowly. Even after four billion added years, a few mesas stood above silicate wastes. A few rocks contained a few fossils, including bits of degraded organic matter that an observer who knew what to look for might have identified as of human origin.

When the seas departed, the sun and moon generated less tidal friction. Earth turned more leisurely than aforetime, but it did not go into locked rotation with either body. The distance of the moon varied according to the interplay of celestial mechanics, now greater, now lesser, but it neither crashed into the planet nor wandered free. By five billion A.D. meteoritic bombardment had completely, unrecognizably mingled all human-fashioned things on it and on Mars with their regoliths.

That was the approximate time when the sun left the main sequence and swelled to gigantic size. Surface temperature declined until it shone red, like a dying coal, but the whole output was monstrous. At its greatest radius, it ate Mercury and Venus and filled almost half the sky of Earth. The globe glowed, sand fused into glass, the last faint fossils melted and the last biotic molecules broke into their olden elements.

Now the sun collapsed. It ended as a white dwarf, hellish hot, its mass crushed into a volume scarcely larger than Earth's, gradually cooling toward oblivion. But this is epilogue and incidental. Nature had already erased from the Solar System every spoor of humanity. We might as well never have been.

Many light-years away, on widely divergent courses, Pioneer 10 and 11, Voyager 1 and 2, and perhaps some small sister spacecraft fared among the stars. DO

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