How Cats Survive Falls from New York Skyscrapers

Science can progress even without controlled experiments

by Jared Diamond

I have never gone up the Empire State Building and never want to. I managed to get up the Eiffel Tower, barely, by closing my eyes in the elevator, holding my wife's hand tightly, and staying as far as possible from the edge when I reached the top. In Manhattan hotel rooms my legs lock when I look out the window to the street below.

All of you who share my fear of heights will understand these sensations. While my acrophobia is extreme, most people have some fear of falling, for good reason: falls are dangerous. With more than 13,000 fatalities each year, falls constitute one of the leading causes of traumatic death in the United States and are the most common such cause of death for children under fifteen. In New York City, falls account for one-fifth of all accidental deaths of children.

Even slips from a low stepladder often result in broken bones, but your chances of surviving a drop of fifty feet are only 50-50. Almost no one who falls off a six-story building onto a concrete sidewalk survives. Not surprisingly, jumping from buildings is a preferred means chosen by would-be suicides, and it's probably the most effective one. You might vomit the sleeping pills you swallowed, your hand may jerk as you pull the trigger, but nothing will save you once you've jumped off the ledge.

In all these respects, cats offer a startling contrast to Humans. They are as nonchalant about heights as most of us are frightened, and they regularly survive falls that would kill any person. The explanation isn't that they rarely fall. Instead, in Manhattan, with its abundance of high rises, cats are more prone to fall than humans because they fearlessly play and chase each other along ledges. Even in my hometown of Los Angeles, which has few skyscrapers, cats are still at risk of getting thrown off ledges of apartment buildings during earthquakes. Veterinarians see so many cats brought for treatment after a fall that there is now a technical term for the resultant pattern of injuries: "high-rise syndrome in cats."

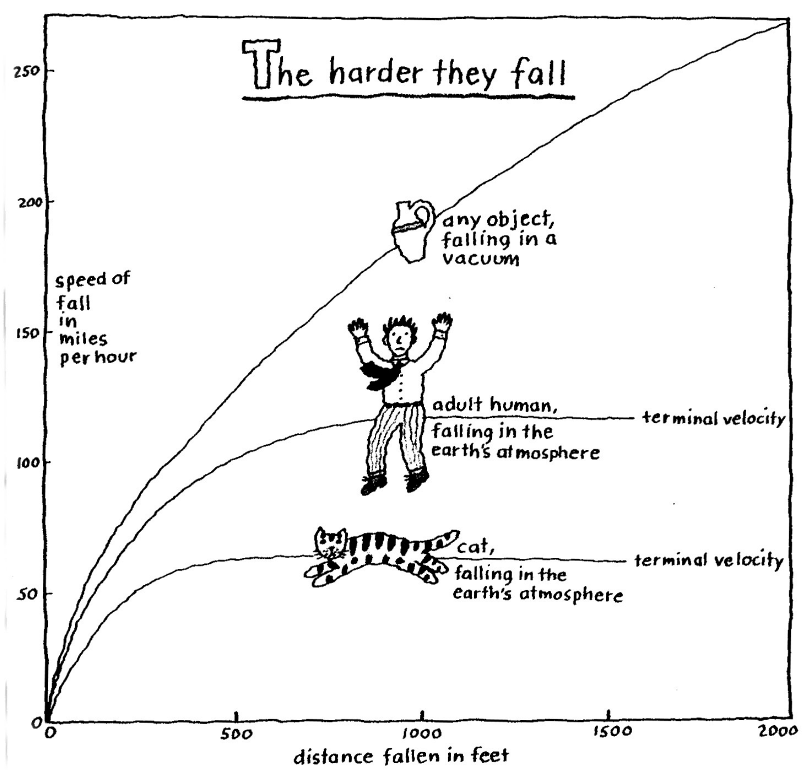
Despite cats' propensity to fall, the outcome is far less often fatal to them than it is to us. It's not just that cats, unlike humans, commonly survive plunges from mere six-story apartment buildings. What's more impressive is that cats hurtling out of skyscrapers onto asphalt usually don't die as a result. Apparently the record (at least for New York City) is held by a kitty named Sabrina, who fell thirty-two stories onto a sidewalk and suffered nothing worse than a chipped tooth and mild chest injuries. Paradoxically, the higher the building beyond a certain height, the less risk a falling cat has of being killed! This ability to survive seemingly appalling drops is the main fact behind the adage that cats have nine lives.

Feline pesematology (from the Greek pesema, for "fall"), the science of falling cats, may not strike you initially as the stuff for which Nobel Prizes are won. But it is undoubtedly of emotional importance, as any concerned felophile (cat lover) knows. It might be of importance to human medicine as well, if understanding cats' survival secrets helps us to reduce our own fall-related injuries. What's more, feline pesematology illustrates the interplay between physiology and evolutionary biology, while also teaching us how to gain knowledge in fields where intentional experiments would be utterly reprehensible. Thus, falling cats yield poignant insights into the scientific method.

As in any science, let's start with the raw data. Feline high-rise syndrome was described in 1976 by Dr. Gordon Robinson, a veterinarian at the ASPCA's Henry Bergh Memorial Hospital in New York, to which owners were then bringing about 150 fallen cats each year. Eleven years later the next major advance was made by two other veterinarians, Drs. Wayne Whitney and Cheryl Mehlhaff, at the Animal Medical Center in Manhattan. Within one five-month period in the summer and autumn, the lure of open windows generated a database of 132 cats admitted to the latter hospital after falls of at least 2 stories. Most falls were of 4 or more stories, with a mean value of 5.5 stories, standard error of plus or minus 0.3 stories, and maximum of 32 stories (the famous Sabrina). Most of the victims hit concrete pavement.

In their data analysis, Whitney and Melilhaff had to discount 17 cats put to sleep at their owners' request-usually not because of a poor outlook, but rather because the owners said they couldn't afford medical treatment. Of the remaining 132 minus 17, or 115 cats, only 3 were dead on arrival. Eight more died within the next twenty-four hours, and all the 104 other cats that pot through that first day survived. Thus, 90 percent of the falling cats available for analysis (104 out of 115) recovered, confirming the adage about cats' nine lives.

The commonest injuries suffered by falling cats differ drastically from hose of humans. Broken skulls and hemorrhage from internal injury are what kill falling people; broken backs and rib cages maim them. In contrast, one of the most frequent injuries to the cats was nosebleeds. That had not been among the risks on my mind as I stood with locked legs at the top of the Eiffel Tower, picturing myself splattered on the pavement far below. Falling felines also commonly suffered from facial lacerations, broken teeth, split palates or mandibles, and chest injuries.



Only three cats sustained the fractured vertebrae and four the broken ribs that are so common in humans. Like humans, cats often break limbs, but the pattern of limb breaks differs: adult humans most often break their legs, babies their arms, but cats break their forelimbs and hind limbs almost equally often. (Try to explain those differences now, without jumping to the end of this piece.)

Of course, falling cats differ most from falling people in their much lower death rate. Since fall injuries vary with the height of the fall, I've prepared a figure that plots mortality rate as a function of height in order to take the height factor into account. For any height, cats' mortality rate is far below that of human adults, while values for human babies are intermediate. Incredibly, cats' prospects for survival improve with height beyond seven stories: only 5 percent of cats that fell seven to thirty-two stories died, while relatively twice as many -10 percent - died from falls of only two to six stories. It's as if, confronted with someone threatening to throw you out a second-floor window, you could help yourself by begging him to throw you out a twenty-second-floor window instead.

So much for the raw data. To make sense of these puzzling results, let's turn to the deep theoretical insights that rigorous application 'of physical principles can offer us lowly biologists. Physics teaches that the outcome of a fall depends on impact velocity, compliance (softness) of the impacted surface, and five properties of the falling animal itself: its weight, surface area, surface compliance, bone parameters, and impact dissipation through joints and muscle.

As for impact velocity, your fall velocity accelerates by 22 mph with each second that you fall. For bodies falling in a vacuum, velocity increases as the square root of the distance fallen. By the time you've plunged thirty-two stories, you're going at a bullet-train speed of 120 mph, but after two stories you've only gotten up to a sedate 30 mph. That explains my intuitive sense, while at the top of the Eiffel Tower, that I would make a bigger splatter on the pavement below from that height than from the top of a stepladder.

However, distance fallen isn't everything. The force on impact depends on the impacted surface's compliance, which determines its stopping distance (the distance you penetrate into the surface before you come to a full stop). The greater the stopping distance, the less the impact force. That's why pole-vaulters place a thick foam cushion rather than a concrete slab below the crossbar. For a modest sum (say, $10 million), even I would agree to jump once from an apartment roof onto a suitably thick and wide foam pad. That's also why the stories of pilots who survived falls from planes without parachutes refer to the lucky pilots who landed in mud (with a stopping distance of about eight inches), rather than to the unlucky pilots who landed on asphalt (stopping distance a fraction of an inch). As an alternative to landing on a compliant surface, you can also wrap yourself in your own compliant surface. Part of the reason that human babies survive falls better than adults is the cushioning effect of a baby's subcutaneous fat.

Theory also teaches us that a falling body's mass in relation to its area is important in two ways. First, impact force is proportional to mass. It's a delightful game when my 27-pound son Joshua jumps on my stomach, but it won't be so delightful if he wants to continue the game after he grows up to be a 270-pound NFL tackle. More specifically, what counts is the falling body's mass divided by the area over which the impact is distributed.

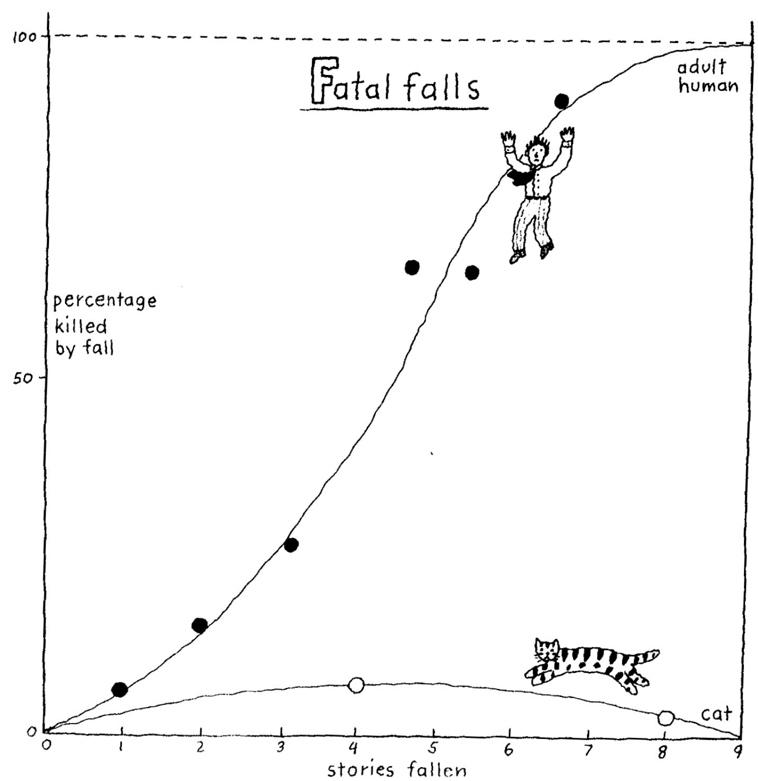
The other effect of mass and area involves air resistance as you fall. As we were all taught, Galileo supposedly proved that objects of different weights dropped from the Leaning Tower of Pisa strike the ground simultaneously. In fact, that result applies exactly only in a vacuum, where there is no air resistance to increase with velocity and to oppose the accelerating force of gravity. Eventually friction causes bodies falling in the

Earth's atmosphere to reach a certain terminal velocity, which they then maintain until they splatter on the ground below. The greater the body's area and the less its mass, the lower is that terminal velocity and the sooner it is reached. That's why paratroopers wear parachutes and why feathers hit the ground more gently than do cannonballs.

Now let's apply these physical principles to understanding the different injuries of falling human adults, babies, and cats. To begin with, humans are bigger than cats. Because mass increases with the cube power of linear dimensions, but area only as the square power, the mass-to-area ratio increases with body size. Hence we would hit the ground with more pounds per square inch than would a cat, even if our bodies were just a scaled-up cat's body and our landing positions were identical-which they are not.

You may object, correctly, that big animals have relatively stouter bones than do small animals, to absorb the greater impact. But the difference isn't enough to help. Elephants are much more at risk of a broken leg from a modest drop than are humans, just as adults are more at risk than babies, and babies more at risk than cats. Cats' lower ratio of mass to area also means that they reach a terminal velocity of a mere 60 mph within five stories of free fall, compared with our terminal velocity of 120 mph.

If cats were just scaled-down humans, that alone would make them less prone to injuries of falling than humans. But they have other unique advantages, beginning with a superb internal gyroscope located in the inner ear. If a cat starts to fall while upside down, it quickly detects its orientation, twists in midair, and has righted itself with all four legs pointing downward by the time it has fallen just two or three feet. The result is that it spreads the impact over all four limbs, not just two.

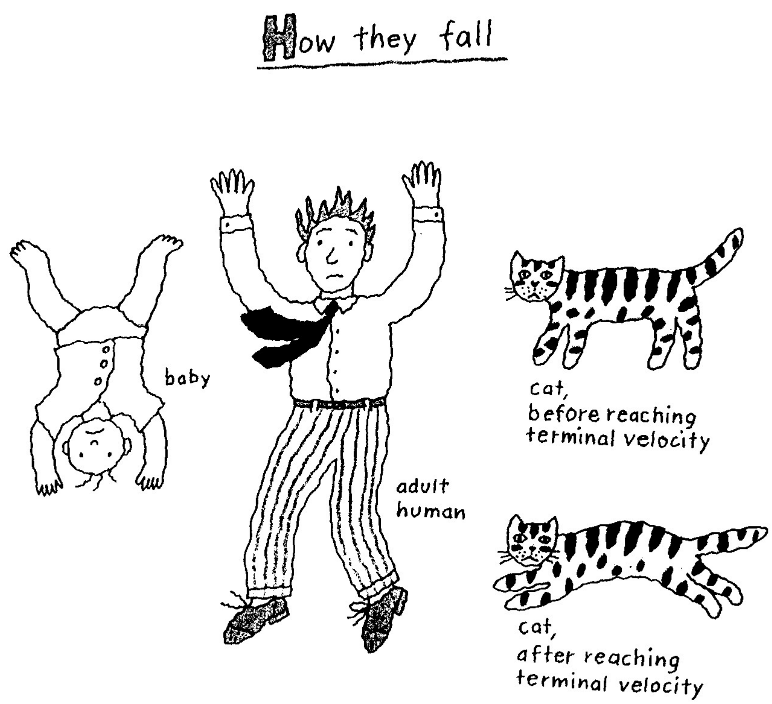


We adult humans, endowed with a much less efficient gyroscope, tend to tumble uncontrollably as we fall. We land most often on our (two) legs, next most often on our heads. Because babies have relatively large beads, they tend to fall head downward with their arms extended reflexly. These facts contribute not only to cats' better survival but also to their different injury pattern: equally frequent fractures of the forelimbs and hind limbs, as compared with the fractured skulls of humans of all ages, fractured arms of babies, and fractured legs of adults. (Did you guess that answer correctly?)

Another advantage of cats, apart from their small size, is that they land with their limbs flexed to distribute the impact force through their muscles and joints. While there's nothing we can do to acquire the feline gyroscope, their limb flexing on impact is something that we can indeed learn to imitate and thereby protect ourselves. Parachutists practice landing on their toes with their knees and hips flexed, then rolling successively onto their calves, thighs, buttocks, and back. In this way, they distribute the impact away from their rigid breakable bones, spread it over a large area of their body, and reduce the shock by thirty times or more.

None of these advantages of cats explains the most surprising result: their improved chances of survival if their fall exceeds seven stories. Recall that bodies falling in the earth's atmosphere accelerate up to a terminal velocity determined by their air friction (proportional to their area) and weight. Thereafter, their velocity remains constant-as long as their weight and area don't change. Weight of course can't change, but it's easy to change the area you present to the air rushing by. Free-falling parachutists decrease their area and increase their velocity by keeping a slim profile, and spread their arms and legs to increase area and brake their velocity.

Cats may be behaving like well-trained paratroopers. Until they reach terminal velocity, they reflexly extend their limbs, which are therefore prone to fracture on impact. After they reach terminal velocity and cease to feel gravity's acceleration forces, they may relax and spread their limbs horizontally, like a flying squirrel. This would increase their air resistance, decrease their velocity and impact force, and spread the impact over their whole body surface (not just over their four legs). Not only does this view of cats as skilled paratroopers account for their excellent survival of falls beyond seven stories but it also explains their greatly reduced risk of fractured limbs. Most cats that fell seven or eight stories suffered a fracture, but only one cat out of thirteen cats that fell nine or more stories did.



In short, falling cats are less at risk than falling humans for many reasons. Their small size means less impact force, less stress (force divided by area), and lower terminal velocity. All those features also favor other small animals besides cats, but falling cats are still less at risk than falling small dogs, because of further features unique to cats. These include their superb gyroscope, which lets them land legs first rather than headfirst; their flexed limbs, which spread the shock through their joints and muscles; and possibly their assumption of a flying squirrel configuration after they've reached terminal velocity.

Since we've now invoked physics, astronomy, and physiology to understand falling cats, it remains only to invoke evolutionary biology. I suggest that the unique features of cats resulted from natural selection. Most wild species in the cat family, but few in the dog family, climb trees. For millions of years, cats have been intentionally springing from trees onto their prey, as well as falling out of trees accidentally. All those cats whose gyroscopes, limb flexing, and flying squirrel posture weren't up to snuff broke their legs and rolled into evolution's garbage can. Only the best feline paratroopers survived. Thus, cats ultimately have their evolutionary history to thank for their nine lives.

For those of you who aren't really into falling cats themselves, I'll close with a coda about their broader significance. Our first association to "scientific method" is likely to be “experiments." Supposedly, science tests conclusions by experimentally controlling the variables, preferably indoors in a lab. Some areas of science, like molecular biology, chemistry, and physics, really do fit that stereotype. But in other areas of science you can't possibly manipulate the variables, perhaps the system is inaccessible or too big, as in astronomy or geology; perhaps it lies in the past, as in paleontology and archeology; or perhaps it would be unethical to manipulate variables, as in much of ecology and human research.

In these cases, scientists can still progress by searching for appropriate "natural experiments." That is, you don't manipulate the variables yourself; instead, you look for and compare existing situations where nature has already manipulated the variables for you. For instance, astronomers observe galaxies with different red shifts, epidemiologists compare human populations with different diets, and ecologists study islands with different sets of species. Scientists accustomed to manipulative experiments tend to be snooty about such research, but that attitude ignores the real difficulties of doing science on problems that don't fit in test tubes.

Injury patterns of falling animals provide a homely but clear example. We could gain insight rapidly by throwing various animals and people off buildings of various heights onto various surfaces. But laws and our consciences would block doing such experiments. Instead, we must rely on natural experiments and examine those unfortunate people and animals that fell naturally. The range of insights that Whitney and Mehlhaff were thereby able to extract illustrates how science progresses, even in those fields where controlled experiments would be immoral, illegal, or impossible.

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