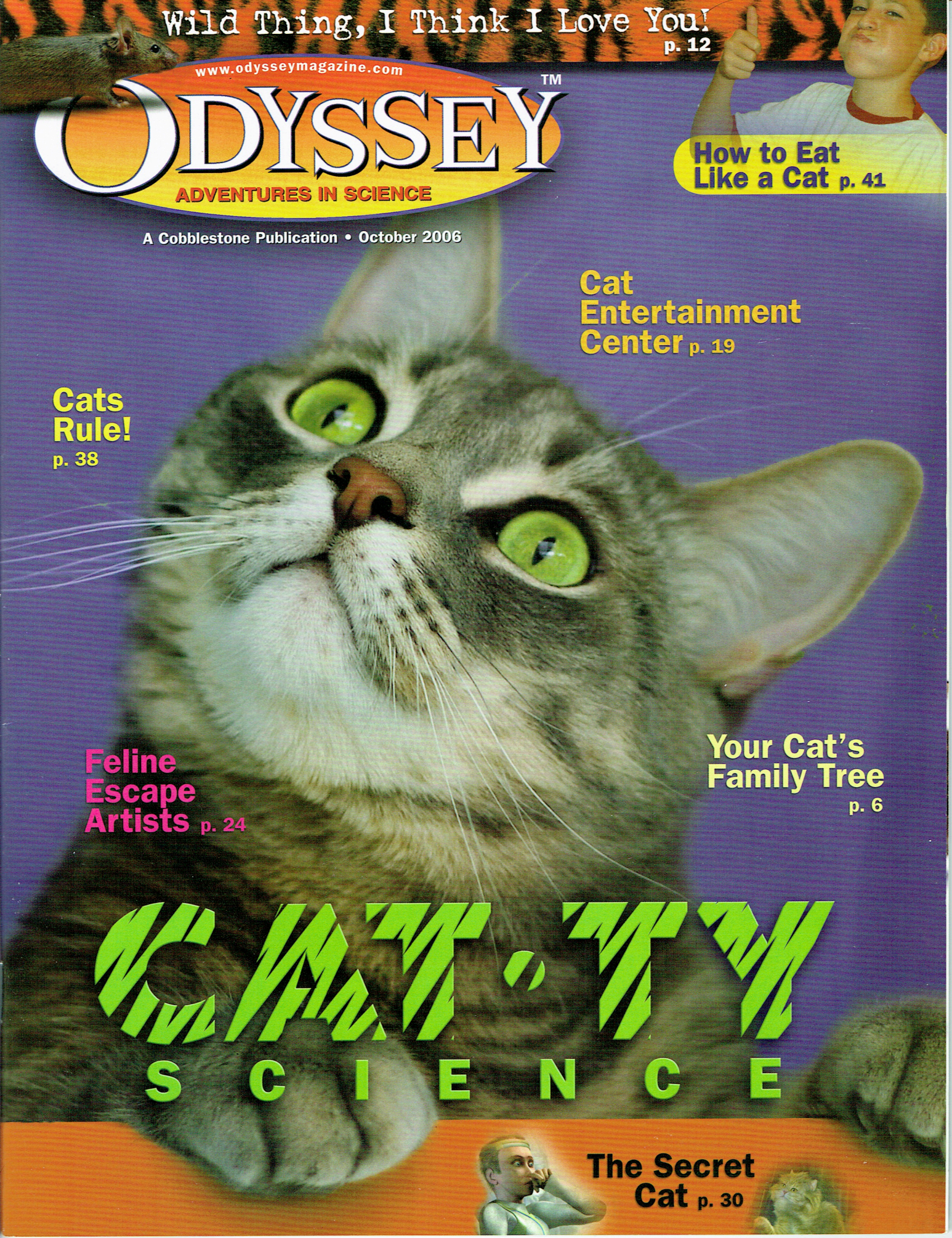
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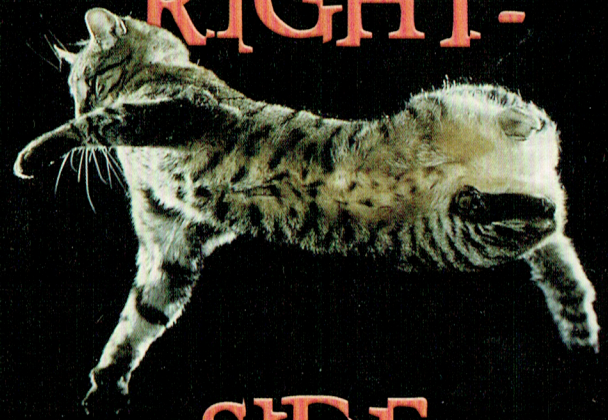
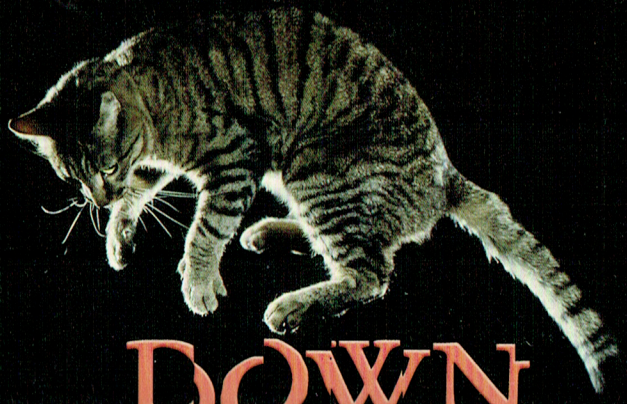
RIGHT-SIDE DOWN





Scientists have let the cat out of the bag when it comes to how felines land on their feet almost every time, even after long falls. This is feline physics at its very best, and it can boost human performance, too. In fact, what scientists have learned about cats' amazing ability to right themselves in a fall is already helping Olympic divers and gymnasts twist their ways to gold medals. One day, tumbling tabbies may even teach NASA new ways to right tumbling spacecraft and help astronauts walk in space.

IT'S ALL IN THE SPIN

Let's begin with an ordinary house cat, slipping from its high, comfortable perch yet rotating to a perfect landing. How does the cat right itself in midair — with nothing to grab on to? When viewed in slow motion, the maneuver seems unbelievable. It looks like a violation of Newton's laws.

The secret begins inside the cat's vestibular canals — the highly developed balance centers in its inner ears. Like the *gyroscopes* aboard an aircraft, this fluid-filled organ tells the falling cat which way is up. Next, the cat relies on its unique skeletal system. Cats have a clavicle, or collarbone, which is very small, and not attached to other bones, but embedded in muscle. This makes cats extremely flexible.

Physicists are still learning exactly how a cat performs its famous spin. One trick might be twisting the front and back parts of its body in opposite directions. Ordinarily, these opposite spins would cancel each other. (That's called "conservation of angular momentum.") However, the cat extends its front and back legs to different distances while twisting. (Like two

they have lots of surface area for their weight.) But there is one problem. After falling about five stories and reaching terminal velocity (over 60 mph!), the cat is falling too fast for its legs to withstand the landing. So, like a pilot ditching a crippled aircraft, the tumbling tabby doesn't deploy its landing gear (uh, feet). Instead, it lands on its belly, spreading the impact over the maximum area.

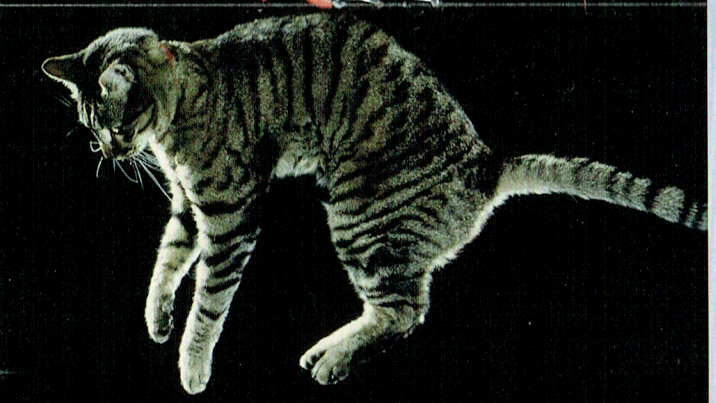
Such falls (often an accident or a last-ditch escape) can leave a cat badly injured, with a fractured jaw, broken pelvis, or other internal damage. Yet in a study published in the *Journal of the American Veterinary Medical Association* of 132 cats who suffered multistory falls, a remarkable 90 percent of them survived.

Credit surprising science, because a cat's landing technique turns out to be what physicists call a "zero-*torque* twist." This is a turn that happens without the help of any outside forces. (Remember, the cat has nothing to turn against, and it isn't turning when it starts to fall.) Even some experts didn't realize that this kind of turn was possible. In a test given during the 1970s, physics professors at a major university got a question about this kind of rotation wrong!

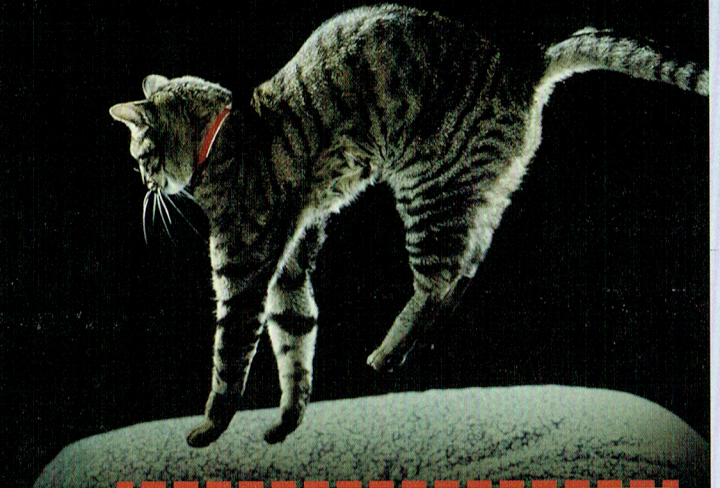
Yet if this twist seems familiar to you, it's because some people can do it, too. For example, extreme skateboarders use it to execute a Frontside 180, an incredible turn in midair. By swinging their arms and legs like a cat, expert gymnasts also can execute a cat twist off the uneven bars. The best springboard divers can use it to add rotations to their dive, even after their feet have left the board.

Still, perhaps the most far-out application of this cat science has come from a team of engi-

LOWN



by Nick D'Alto



PURR-FECT SAFETY

Although they usually land on their feet, many cats are hurt in falls — even relatively short falls. In fact, emergency room vets call the problem of fall-related cat injuries "high rise syndrome." If you have a cat, never drop it intentionally and always keep it away from open windows or other unsafe perches.

spins would cancel each other. (That's called "conservation of angular momentum.") However, the cat extends its front and back legs to different distances while twisting. (Like two spinning ice skaters, one pulling arms in, the other pushing arms out.) The spins still cancel, yet the cat swings to one side. Some scientists speculate that cats also spin their tails to improve the effect. And now, breaking science news (see sidebar, p. 26) reveals a whole new "cat spin," which may have finally solved this twisting riddle.

The turn itself is like poetry in motion. (To see it yourself, catch the video at www.pbs.org/wnet/nature/cats/html/body_falling.html.)

GIVE ME A BREAK

The spin is super-fast; cats can right themselves during a fall of just one meter. Using their remarkable balancing act, cats can save themselves in falls of up to seven stories.

Some cats have survived much higher falls, plunging from ledges up to 25 stories high. (That's a 300-foot drop!) And get this: Cats that fell extremely far actually sustained fewer injuries — falling farther was *safer*. The explanation? It's simple: Cats wear parachutes. Really!

Skydivers understand a phenomenon called "terminal velocity" — that's when a falling object stops picking up speed, owing to resistance from the oncoming air. Cats somehow understand this, too. During extreme falls, they splay their legs outward, using their fluffy underbellies to glide down, like flying squirrels. (This works for small animals, because their feet have left the board.

Still, perhaps the most far-out application of this cat science has come from a team of engineering students at Missouri's Drury University. Their physics professor, Dr. Gregory Ojakangas, reached the finals in NASA's astronaut selection program. Dr. Ojakangas was intrigued by cat landings because a falling cat is moving in almost exactly the same way a spaceship travels through space. That's right: A free-falling cat is weightless, like an astronaut during a spacewalk.

Students in Dr. Ojakangas's physics class test robo-Kitty in microgravity.

CAT SPINS IN SPACE

To Ojakangas, cat turns might solve a huge, space-related problem — steering. For example, scientists must "steer" or point the Hubble Space Telescope precisely toward different stars. But like a falling cat, a telescope in space has nothing to push against for turning. Could scientists borrow the cat-twisting secret and create a spacecraft with catlike balance?

To find out, the professor's students designed their own robotic cat. Its two halves can turn at

Gyroscope — A device made up of a fixed base and a moving wheel mounted on an axis that can turn freely in one or more directions, allowing it to maintain its orientation when the base is moved

Torque — The measure of a force's tendency to produce twisting and turning about an axis

different rates (like a real cat's body), while umbrella-like extensions vary the cat-bot's moment of inertia (like a real cat's legs). Hung from a long wire, robo-kitty rights itself. But would it balance in space? The student team found out during an adventurous flight aboard NASA's microgravity aircraft. The "Vomit Comet," as it is called, is a specially equipped DC-9 type of jet that can make sudden dives, which simulate brief periods of weightlessness. Flying in zero gravity, the team got their robot cat to turn over on command. (To see incredible pix and video, visit: www.drury.edu/multinl/story.cfm?nlid=133&id=10809 and http://robothaven.net/article.pl?sid=04/07/16/ 034211&mode=thread.)

Today's space vehicles are steered by cumbersome methods, such as firing small rockets or turning weights called momentum wheels. But by using a cat twist, future space explorers might steer using cat-robots built into their space station or even into their space suits.

From sports to space, it's the cat's uncanny landing skill that really has nine lives!

BREAKING SCIENCE: More Than One Way to Spin a Cat

While most theories about a cat's landing twist focus on the feline manipulating its legs (or tail), physicist Dr. J. Ronald Galli of Utah's Weber State University has spotted a key cat maneuver that no one else has ever noticed. According to Galli, the ultimate secret to the cat's spin is in its spine.

Galli has discovered that a cat falling upside down first arches its flexible back to form a shallow "U." Then, by suddenly contracting the powerful muscles along its spine, the cat sends a rotating movement through its curved back. This spin works almost like the flexible, rotating shaft that powers a dentist's drill. However owing to the "kink" in the cat's back (and because a falling cat invariably leans slightly to one side), the entire cat flips over. With no help from outside forces, Galli's cat turn is another zero-torque twist.

To prove his point, the physicist even constructed mechanical cats, first using rubber bands for muscles and springs for a spine. In his lab, the coil-cat rotates beautifully — so well that Galli believes that a real falling cat would rely mostly on its back twist, and use leg and tail maneuvers to amplify the effect. "Even humans can do this," says Galli. "However, it takes quite a bit of training. We lack the instinct to do what a cat can do naturally."

Want to see this remarkable effect yourself? A working model of Galli's invention, dubbed "The Galli Cat" (see below), is now available for science classrooms, along with a video of the cat in action. To learn more, visit www.teachersource.com.