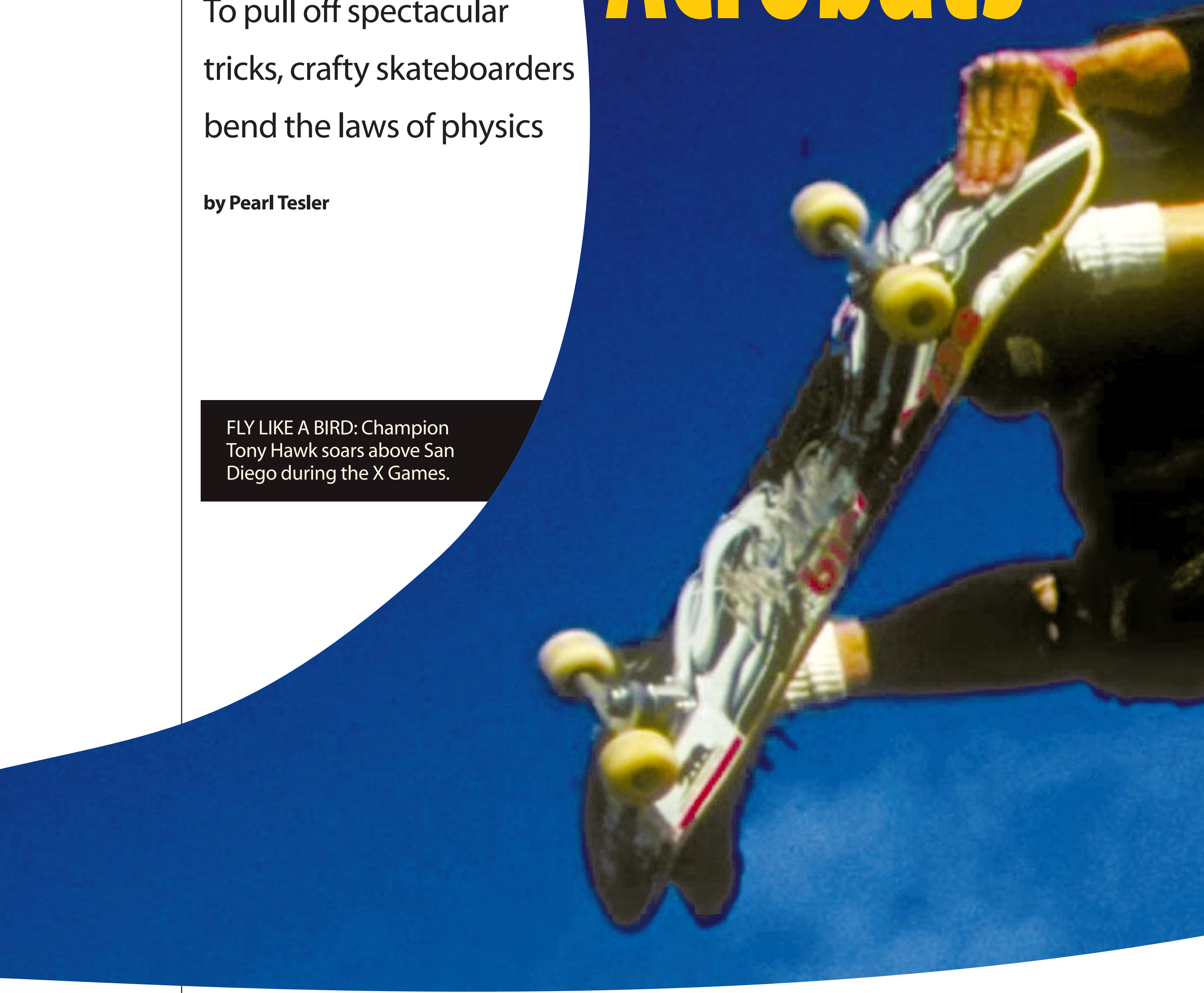
Asphalt Acrobats

To pull off spectacular tricks, crafty skateboarders bend the laws of physics

by Pearl Tesler



FLY LIKE A BIRD: Champion Tony Hawk soars above San Diego during the X Games.

TOM HAUCK *Allsport*

In June 1999 professional skateboarder Tony Hawk made history by performing the impossible. Egged on by a wildly enthusiastic crowd at San Francisco's X Games, he nailed the first recorded "900"—a horizontal midair twist of two and a half revolutions (900 degrees)—high above the huge U-shaped "half-pipe" that launched him toward the California sky.

Starting at the right-hand top of the U, Hawk plunged down inside the half-pipe to gain speed, then vaulted up and out of the opposite wall. Airborne and parallel to the ground, he immediately tucked his body, clutched the skateboard and spun two and a half rotations—finishing quickly enough that he could again extend his legs and push the board back against the left wall of the U before crashing down into the cement pipe's trough. To skateboard fanatics, the 900 was so difficult a maneuver that it seemed to be beyond an invisible barrier. It had eluded Hawk's efforts for 10 long years.

What made the 900 possible? Watching skaters like Hawk soar, twirl and swoop in a sophisticated blur of limbs, the real question seems to be: What makes any of it possible? Executed at top speeds, skateboard tricks can be difficult to follow, let alone understand.

It seems that skaters are defying the laws of physics. But the fact is, they're just cleverly exploiting the forces of nature. Every maneuver a skateboarder makes takes advantage of the fundamental physical principles that govern motion in virtually every sport: speed, momentum, rotation, gravity and good old muscle power. Analyzing skaters' brazen acrobatics unveils the scientific mysteries that allow an ice skater to spin, a diver to twist, a gymnast to tumble and a freestyle skier to catch "big air."

THE OLLIE

Before the 900 was even a glimmer in Tony Hawk's eye, there was the ollie. Invented in the late 1970s by Florida skater Alan "Ollie" Gelfand, the ollie is skateboarding's primordial trick, the foundation on which most other tricks are based. In its simplest form, the ollie is a jump that allows street skaters to skip up onto sidewalks, hop over obstacles and leap across urban chasms.

What amazes onlookers is that the board seems to lift magically with the skater's rising feet throughout the jump. Many people assume that the skateboard is somehow attached to the skater's shoes. It's not. Equally perplexing is that to make the skateboard soar up, a skater first stomps *down* on it. A step-by-step look at this paradoxical trick reveals the secret: skillfully controlled rotation of the skateboard.

The ollie begins explosively. A skater rolling along on flat ground places his front foot in the middle of the board and his rear foot on the tail. He drops into a crouch, which lowers his center of mass (the point where his weight is most concentrated). As the skater approaches the obstacle to be jumped, he throws up his arms and torso, accelerating his body upward before his feet begin to rise. (Starting with a lower center of mass gives the body more distance over which to accelerate before the skater's feet leave the ground. The height of any skateboard jump comes from this upward acceleration; the greater the acceleration, the higher the jump.)

As the skater's body streaks upward in launch, he stomps down hard on the skateboard's tail with his rear foot. The great force on the tail causes the front

THE OLLIE: A skater crouches down as he approaches the abyss, then accelerates himself upward by explosively raising his arms. He stomps his rear foot on the tail of the board while lifting his front foot, causing the board to pivot up. When the board's tail rebounds off the ground, the board pivots in the opposite direction. Once airborne, the skater slides his front foot forward, dragging the nose of the board upward, then levels out the board. If he times these motions just right, his feet and board rise, sail and fall in perfect unison, as if stuck together.

of the board to rear up. The board rotates backward around the rear wheel, nose lifting up into the air like a rising jet plane.

The downward stomp on the tail, however, causes it to strike the ground—hard—a fraction of a second later. The tail then bounces back up. Now the skateboard is fully in the air, rotating forward again; the front tip begins to come down while the back tip moves up. If left to its own devices, the skateboard would eventually flip tail over nose. But the airborne skater uses his feet to control the rotation, sliding his front foot forward to drag the nose of the board upward with his rising leap. Aided by the extra friction of sandpaperlike grip tape on the skateboard's top surface, this dragging motion keeps the skater's front foot in constant contact with the skateboard. Meanwhile the skater lifts his rear foot to get it out of the way of the rising tail. If he times these motions just right, his feet and the board will rise in perfect unison, seemingly stuck together.

At the top of the jump, the skater levels the board with his feet to stop its rotation. Now at their maximum height, skater and skateboard begin to fall together under the influence of gravity. To cushion the impact of landing, the skater drops his arms and bends his knees. In under a second, the ollie is over.

FRONTSIDE 180

After skaters master the ollie, they begin to add aerial maneuvers. One favorite is begun by speeding forward off a curb, or off the top of a short flight of stairs, and launching straight out into the air. Once in midflight, the skater rotates the board and his legs a full 180 degrees before touching down on the ground. Skaters call this a frontside 180; a physics student might call it impossible.

At first glance, the aerial turn seems to violate a basic law of physics, the conservation of angular momentum, which states that if you aren't rotating, the only way to start is with the help of a twisting force—a torque. But a skater already in the air has nothing to push against to create the needed torque. The only force that acts on someone in flight is gravity, and gravity can only make a person fall. It can't make you spin. So how does a skater create rotation out of thin air?

To generate the torque he needs, the skater borrows a trick from the amazing housecat. The lore that cats always land on their feet may not be strictly true, but it's also more than just talk. To right themselves while falling, cats do exactly what the stair-jumping skater must do: rotate while keeping their angular momentum constant at zero. Here's how it works: A cat falling with its back to the ground thrusts its back legs straight out behind its body. It simultaneously tucks its front legs. Extending the rear legs increases their rotational inertia—their tendency to stay straight and resist spinning. This shift of the hind legs creates a small torque that is transmitted through the cat's body. Because the front legs are tucked, their rotational inertia is relatively small; it takes only a small torque to rotate them. The result, very useful for the cat, is that the torque traveling through the cat's torso twists its front legs down toward the ground.

Using its muscles to stop the front legs' rotation when pointing closer toward the ground, the cat generates torque that can travel back through its body and help bring the hind legs around, too. With enough falling time, a cat can ratchet itself around by repeating these opposing twist motions, until both sets of feet are pointed down for the landing.

The torque needed for the frontside 180 is created in much the same way. Once airborne, the skater thrusts his arms out wide. This increases his upper

LUKE OGDEN *(top)*; MICHAEL BURNETT *(bottom)*; BOTH COURTESY OF *THRASHER* MAGAZINE

body's rotational inertia, making it harder to turn. He then throws his outspread arms in one direction, creating torque through the body that twists his legs (and skateboard) in the opposite direction. A nice sweep of the arms can cause a full 180-degree twist of the feet. Because the two rotations cancel each other out, the skater's total angular momentum stays the same—zero—and the law of conservation of momentum remains unbroken.

BIG AIR

Never is a skater's instinctive mastery of physics more apparent, or more necessary, than when she is skating in a big, foreboding half-pipe, a structure sometimes called a vert ramp. Lay a sheet of paper on the table, curl the edges so they point straight up, and you have a rough model of a vert ramp, so called because the topmost sections are perfectly vertical. Actual vert ramps are usually about 12 feet tall.

Once skaters learn how to dive and climb, traversing the trough of the ramp on each pass, they begin to contemplate an alluring daredevil move: getting enough momentum in the downswing to vault them up past the top of the far wall. Once in the air, they rotate a half-turn and skate back down the wall. Good skaters can roll down one side and up the other, return, and then do it again and again, while getting a little air at the top of each ascent.

It may seem that skaters in vert ramps are simply riding back and forth. But—although their parents may disagree—they're really working. Physics holds that when you're at a certain height above the ground—say, atop a vert ramp—you have a store of potential energy proportional to this height. You can convert this energy into kinetic energy, or motion, by rolling down the ramp and collect it back as potential energy when you roll back up the far side. But to make it back up to the top, a skater has to compensate for the energy lost to air resistance and the friction of the wheels on the cement half-pipe by adding energy. And if she wants to rise above the ramp—necessary for an airborne turn—she has to add even more energy. This means work.

On flat ground, the conventional skating method for adding energy is to push off the ground with one foot. But in vert ramps, skaters use a more elegant method called pumping. To pump, a skater crouches down while traversing the flat bottom of the ramp. Then, as she enters the upward curve, called the transition, she straightens her legs and rises. By repeating this motion each time she passes through the transition, a skater gives herself incremental boosts of speed that allow her to rise above the ramp wall.

Paul Doherty, a physicist at the Exploratorium museum in San Francisco, explains that this kind of pumping is identical to the pumping you do to go

FRONTSIDE 180: To rotate the board while in the air, a skater twists his upper and lower body in opposite directions to create torque, just as a falling cat twists to get its legs underneath itself before hitting the ground.

MICHAEL BURNETT (*above*); LUKE OGDEN (*right*); BOTH COURTESY OF *THRASHER* MAGAZINE

BIG AIR: To vault high above a half-pipe, or "vert ramp," skaters use a pumping technique similar to the one children use to soar high on a playground swing.

higher on a playground swing, in which you lift your ankles and feet up and forward as they pass through the bottom of the arc, then drop them at the top of the arc. "When you lift your legs at the bottom, your muscles have to work extra hard against the gravity force and the centrifugal force," Doherty says. "The energy you exert by lifting your legs against these forces makes you go higher and faster." The same principle, of course, applies to skaters in vert ramps, but instead of lifting their legs, they lift their whole bodies. So, if pumping makes skaters go higher, the next natural question is, Just how high can they go?

Skaters know that big air—rising high above the top edge of the ramp—is partly a function of ramp size. The current record holder, Danny Way, rose 16.5 feet out of an exceptionally tall, 18-foot ramp assembled by the DC Shoe Company at an airstrip near the California-Mexico border. Large ramps are more forgiving of the high-flying skater, because their larger transitions ease the shift from vertical to horizontal motion. And because the greater speeds they create mean greater centrifugal force to push against, the large ramps also make pumping even more fruitful. But at some point, the energy added with each pump can't compensate for the energy lost to wind resistance. The upshot? Height records will continue to climb, but each successive inch will come at a steeper price.

900 DEGREES . . . AND BEYOND?

By now it might be clear how legendary Tony Hawk manages to do the 900—and how stunning the maneuver is. Hawk must create a strong enough pump to launch himself sufficiently high above the vert ramp to have time to spin 900 degrees. And he must find a way to create the necessary catlike torque to twist his body two and a half times.

The truth is that to pull off a megatrick like the 900, Hawk also has to use a bit of catlike sneakiness. The two seconds he is airborne isn't quite enough time to fabricate the required rotation for 900 degrees of spin. Hawk has to leave the ramp already spinning. Then he must parlay this rotational energy into an even faster spin with a technique common to another form of skating—ice skating.

To accomplish their triple lutzes, ice skaters start with a wide sweeping spin, arms and legs extended. In the air, they pull their limbs in. This decreases rotational inertia, causing them to spin faster automatically.

Likewise, before he launches from the top of the ramp, Hawk gives himself a sizable amount of angular momentum. He approaches the top of the ramp with outstretched arms. As he nears the top, he tucks and begins to spin his body, pushing hard on the board to create an angular force. The angular momentum gained in this moment is all he'll have throughout the trick. After he leaves the ramp, he can't get any more.

The moment he is airborne, he speeds up the spin by jutting one outstretched arm high over his head, adding rotational torque. He drops the other arm to hold the skateboard (there's not enough friction between his feet and the board to drag it along during this superfast spin). Placing his arms in line with his body—his axis of rotation—speeds his spin, allowing him to squeeze in two and a half rotations in two seconds. These rotations are an act of faith. Hawk is no longer in control; at best, his control is limited. Turning quickly, body almost parallel to the ground, he twice completely loses sight of the ramp from which he has launched and onto which he must land. Only by throwing his arms wide after the second full spin can he slow his rotation enough to "spot" his landing. As the skateboard touches down, he absorbs his momentum by collapsing into a deep crouch, readying himself for a controlled yet jubilant landing at the bottom.

Hawk had hardly rolled to a stop after performing his miracle 900 when the buzz began: Could he do three full spins, a 1080? In an on-line chat room interview, Hawk unambiguously put the speculation to rest: "I don't have any desire to spin any further." Hawk describes each punishing attempt at the 900 as a potential trip to the hospital. Now 32 years old, he seems happy to leave the 1080 to younger, sprier disciples.

If you ask Jake Phelps, editor of *Thrasher* magazine, the skateboarder's bible, a 1080 is a definite, if delayed, possibility. "Someone may do it," he comments, "but not for a long time." Skateboarding, Phelps continues, is in a state of perpetual evolution, constantly consuming and reinventing itself as new tricks become old hat: "The greatest thing about skating is it changes every day. The first time I saw somebody ollie on the street I was like, 'No way!' But now every kid can get on a board and make an ollie. Today's impossible trick is just cannon fodder for the future."

THE 900: Tony Hawk goes where no skater has gone before, vaulting out of a vert ramp (*from bottom up*) and rotating two and a half times before landing back on the ramp.

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FURTHER INFORMATION

SKATEBOARDING TO THE EXTREME! by Bill Gutman, offers how-to instruction.

News and trick tips can be found on the Web at www.skateboarding.com and in *Thrasher* magazine.