

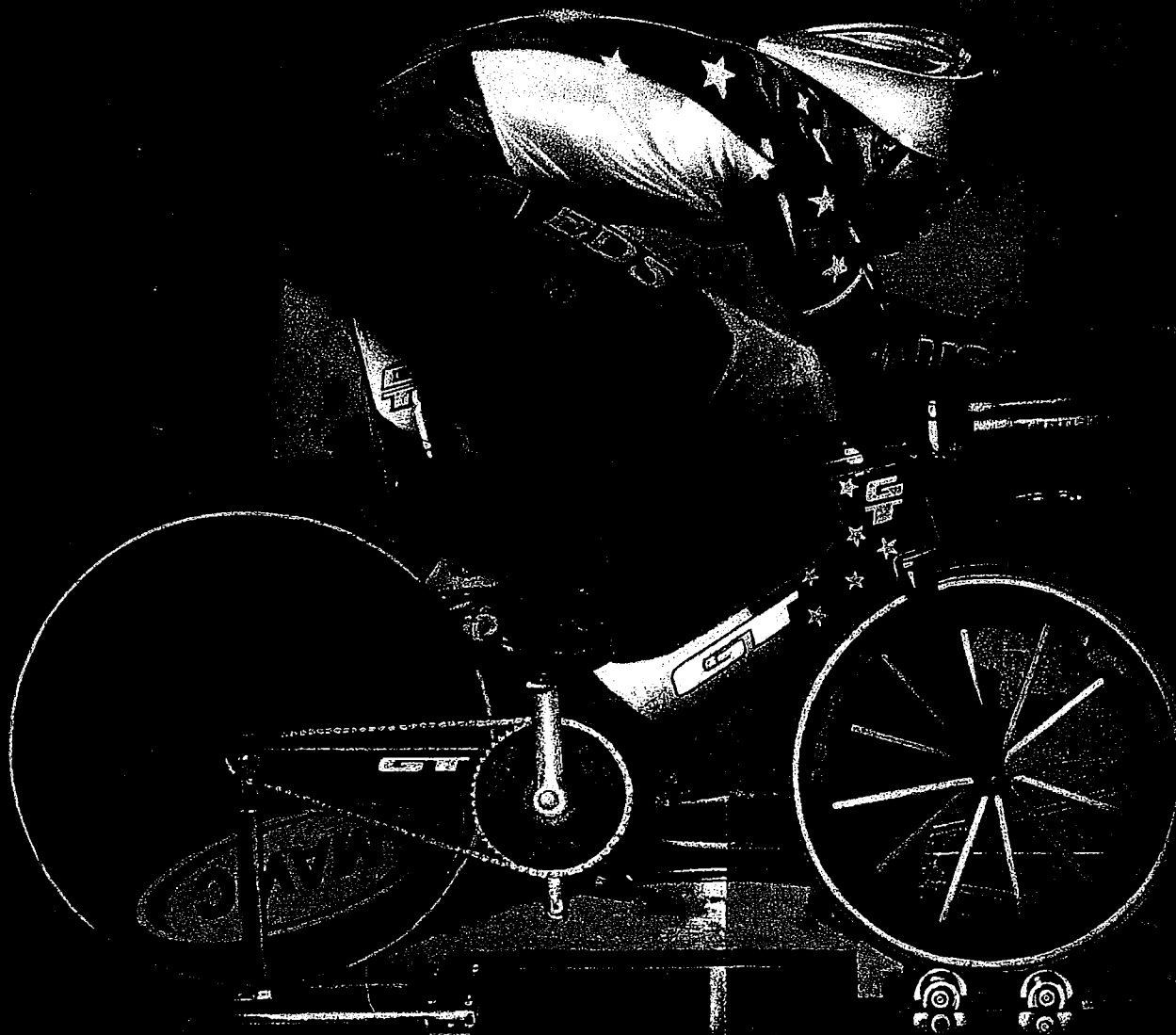
EINSTEIN AND BLACK HOLES MISMANAGED MICROCHIPS ANTICANCER DRUGS

SCIENTIFIC AMERICAN

JUNE 1996 \$4.95

THE SPACE STATION:
THIS ORBITING OUTPOST
PREPARES FOR LAUNCH
AMID MISGIVINGS
ABOUT ITS MISSION

*High-tech training methods
give Olympic athletes
their winning edge*



RESPONDENTS 56

Training the Olympic Athlete

Sports science and technology are today providing elite competitors with the tiny margins needed to win in world-class competition



CAMERA PHOTO-ARTE/ART-RESOURCE

by Jay T. Kearney

The lore of ancient Greece recalls an Olympic athlete who was determined to become the strongest person in the world. Every day Milon of Croton (*above*) would pick up a calf, raise it above his head and carry it around a stable. As the calf grew, so did Milon's strength, until eventually he was able to lift the full-grown cow.

Milon, who won the wrestling contest five times, intuitively grasped one of the basic tenets of contemporary sports science. Progressive resistance training—

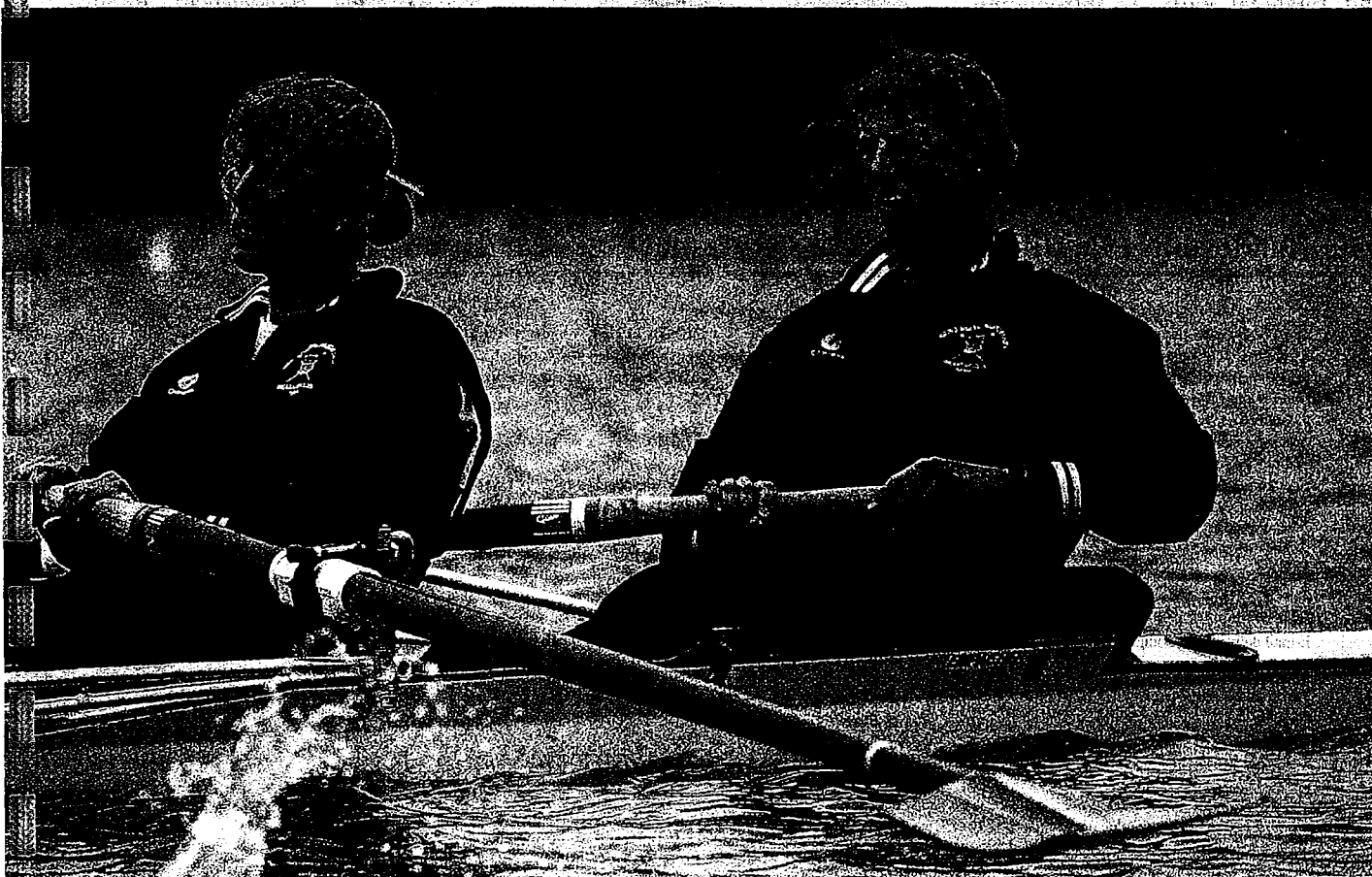
the stressing of muscles with steadily increasing loads—is something well understood by the more than 10,000 athletes from 197 countries who will go to Atlanta, Ga., next month for the centennial of the modern Olympic Games.

During the past half century, however, sports science has refined the basic principles of training beyond the understanding of the Greeks. Exercise physiologists and coaches draw on new scientific knowledge to help athletes develop a balance of muscular and metabolic fitness for each of the 29 sports in the Olympic Games. Biomechanical experts employ computers, video and specialized sensors to study the dynamics of movement. Design engineers incorporate ad-

vances in materials and aerodynamics to fashion streamlined bobsleds or racing bicycles. Sports psychologists build confidence through mental-training techniques. The integration of these approaches affords the small gains in performance that can translate into victory.

Working the Body

Understanding how training builds the strength and stamina needed for Olympic events requires basic knowledge of how the body produces energy. All human motion depends on the use and resynthesis of adenosine triphosphate (ATP), a high-energy molecule consisting of a base (adenine), a sugar



(ribose) and three phosphate groups. The breaking of the bond between two phosphate units releases energy that powers muscle contractions and other cellular reactions. Humans have a very limited capacity for storing ATP. At a maximum rate of work, the five millimoles of ATP available for each kilogram of muscle is completely depleted in a few seconds. To sustain activity, the body has three interrelated metabolic processes for continually resupplying the molecule. Which one predominates depends on the muscles' power requirements at a given moment and on the duration of the activity.

The most immediately available source for reconstructing ATP is phosphocreatine, itself a high-energy, phosphate-bearing molecule. The energy released by the breakdown of the phosphocreatine molecule is used to resynthesize ATP. The phosphocreatine system can recharge ATP for only a short while—just five to 10 seconds during a sprint. When the supply of this molecule is exhausted, the body must rely on two other ATP-generating processes—one that does not require oxygen (anaerobic) and one that does (aerobic).

The anaerobic process, also known as glycolysis, is usually the first to kick in. Cells break down specific carbohydrates (glucose or glycogen in muscle) to release the energy for resynthesizing ATP. Unfortunately for the athlete, the anaer-

obic metabolism of carbohydrates can yield a buildup of lactic acid, which accumulates in the muscles within two minutes. Lactic acid and associated hydrogen ions cause burning muscle pain. But lactic acid and its metabolite, lactate, which accumulates in muscle, do not always degrade performance. Through training, the muscles of elite competitors adapt so that they can tolerate the elevated levels of lactate produced during high-intensity exercise.

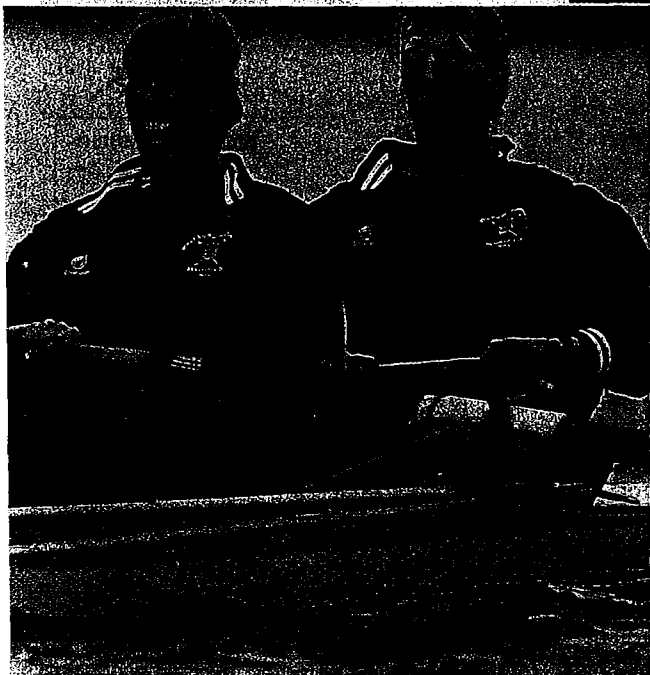
Even so, lactic acid and lactate eventually inhibit muscles from contracting. So anaerobic glycolysis can be relied on only for short bursts of exercise. It cannot supply the ATP needed for the sustained activity in endurance events. That task falls to aerobic metabolism—the

With the activation of the aerobic processes, these other systems function at a lower level. In the aerobic phase, for instance, lactic acid and lactate are still produced, but they are consumed by less active muscles or metabolized in the liver and so do not accumulate.

Although the aerobic system is highly efficient, its ability to supply the muscles with energy reaches an upper threshold. If still more ATP is needed, the muscles must step up the use of various other energy sources. A soccer player in the middle of a 45-minute half, for example, would depend mostly on aerobic metabolism. But if he needed to sprint briefly at full speed, his body would immediately call on stored ATP or ATP reconstituted by the phosphocreatine system to



PHOTOGRAPHS BY KEN REGAN CAMERA 5



Photography by Ken Regan

OLYMPIC HOPEFULS Betsy and Mary McCagg train together at the headquarters of the U.S. national rowing team in Chattanooga, Tenn. Although the twins often train and compete as a pair, they will participate in the Olympics as members of an eight-woman crew.

breakdown of carbohydrate, fat and protein in the presence of oxygen. In contrast with anaerobic glycolysis, the aerobic system cannot be switched on quickly. At least one to two minutes of hard exercise must pass until the increase in breathing and heart rate ensures delivery of oxygen to a muscle cell. During that interval, the athlete depends on a combination of stored ATP, the phosphocreatine system or anaerobic glycolysis to provide energy.

supplement the aerobic system. Similarly, if this high-intensity sprint continued for five to 15 seconds, the player would experience a rapid increase in the rate of anaerobic glycolysis. As the play ended, the body would return to its reliance on the aerobic metabolic system, while the capacities of the other energy systems regenerated themselves.

Coaches must understand the requirements of their sports and adjust the intensity or duration of training to improve an athlete's aerobic or anaerobic functioning. The fundamental principle of training is that sustained activity will result in adaptation of the muscles to

ever increasing levels of stress—an idea sometimes referred to as the stimulus-response model. Over time, training will induce physiological changes, which are adapted to the needs of a specific sport. The distance runner's training, for example, focuses on enhancing the capabilities of the aerobic system. In contrast, a weight lifter would concentrate on strength and power instead of the endurance requirements of the distance events.

Going the Distance

For the Olympic coach, training also becomes the judicious management of diminishing returns. During the first year, an athlete might invest 50 to 100 hours of training to improve 10 to 15 percent in a season. At the peak of his or her career, the same athlete might put in 1,000 hours of intense and concentrated effort to achieve an improvement of a single percentage point. Such a small gain appears to be a seemingly poor return on investment. But consider that the margin of victory in the track sprint events in the 1992 Olympics—the average difference between a gold and silver medal—was only 0.86 percent, little more than two tenths of a second.

The details of how coaches and athletes tailor training to specific sports are perhaps best illustrated by the examples of competitors in widely differing events. At the Atlanta Games, the longest competition will be the men's cycling race, which lasts about five hours. The 228-kilometer road race will bring together rivals whose training is optimized for sustained aerobic effort, while taking advantage of extraordinary advances in



MIKE POWELL/Alfport

LANCE ARMSTRONG, who will compete in the Olympics, won a stage (a day-long segment) of the Tour de France in 1995 (above and right).

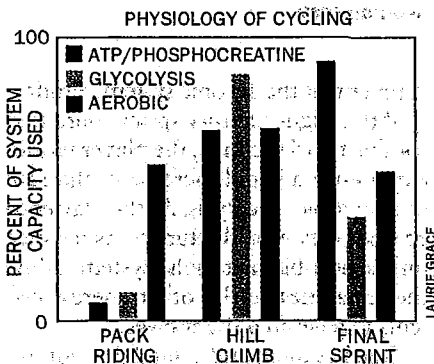
the aerodynamics of cycling technology. Lance Armstrong of Austin, Tex., is expected to be a strong contender for a medal. Although he did not bring home any medals in the 1992 Olympics, he won the world championship in 1993 and, in 1995, a day-long segment of the Tour de France.

Armstrong's innate ability was evident from an early age. At age 15, he demonstrated the aerobic capacity that places him among the upper 1 to 2 percent of athletes worldwide. A measure of overall cardiorespiratory fitness, aerobic capacity is the maximum amount of oxygen that can be taken up and delivered to muscle cells for use in making ATP. It also goes by the name of maximum oxygen uptake, or VO_2 max. Armstrong registered a maximum oxygen uptake of 80 milliliters of oxygen per kilogram of body weight per minute, a rate he continues to maintain at the age of 24. This measurement is almost double that of the average fit male.

As part of his preparation for the Olympics, Armstrong has made several trips to the U.S. Olympic Committee's largest training center, located at the committee's headquarters in Colorado Springs. I am part of the sports science team there that evaluates and advises athletes and their coaches on training improvements.

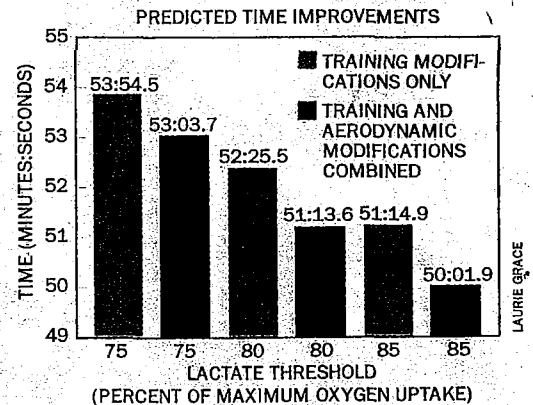


PASCAL RONDEAU/Alfport



LAURIE GRACE

PHYSIOLOGICAL DEMANDS for cycling vary throughout the event. A rider will tap stored ATP or the phosphocreatine system or will depend on anaerobic glycolysis to provide the additional energy needed for a hill climb or a final sprint.

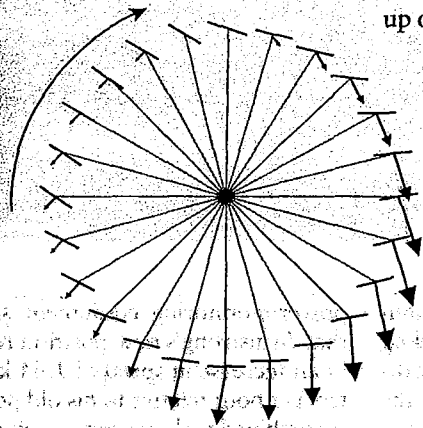


LAURIE GRACE

ANALYSIS of Armstrong's cycling was performed at the U.S. Olympic Training Center in Colorado Springs. Recommendations included changing his riding position to enhance aerodynamics and training so that he increased his lactate threshold, thereby delaying an accumulation of lactate. By following both suggestions, he could reduce his time in a race spanning 40 kilometers by nearly four minutes.

During one of his stays, Armstrong completed a metabolic assessment on a cycling ergometer, a machine in the sports physiology laboratory that precisely controls workload (how hard and fast an athlete pedals). Tests conducted while Armstrong labored on the ergometer measured VO_2 max, heart rate and lactic acid levels. Armstrong registered the highest

PEDAL MOTION of Armstrong was analyzed at the U.S. training center. The length and angle of the arrows indicate the magnitude and direction of forces applied by Armstrong's left foot. The diagram revealed that he needed to exert force on the pedal at both the top and bottom of the cycle in the direc-



VO_2 max of any U.S. cyclist. When performing at this peak level, he was able to marshal a world-class 525 watts of pedaling power.

Physiologists also assess two other benchmarks of performance—how efficiently the athlete uses oxygen and how quickly lactate builds up in the muscles. This latter measurement, the lactate threshold, is represented as a percentage of VO_2 max. It is at the threshold that lactate begins to accumulate, causing pain and burning.

At the training center, Armstrong's lactate threshold measured 75 percent, which was 10 percentage points less than the average for the best cyclists on the U.S. national team. The evaluation team recommended that he train more often at close to or slightly above his threshold. Training at this intensity produces changes in circulatory, nervous and enzymatic functions that can raise the lactate threshold, thereby delaying a build-up of lactate.

Training to improve physiological capacity is only one variable—and sometimes not even the most important one—in streamlining performance in a sport that relies

as much on technology as cycling does. During Armstrong's visits to Colorado Springs, we have also assessed his pedaling technique, riding position and bicycle design.

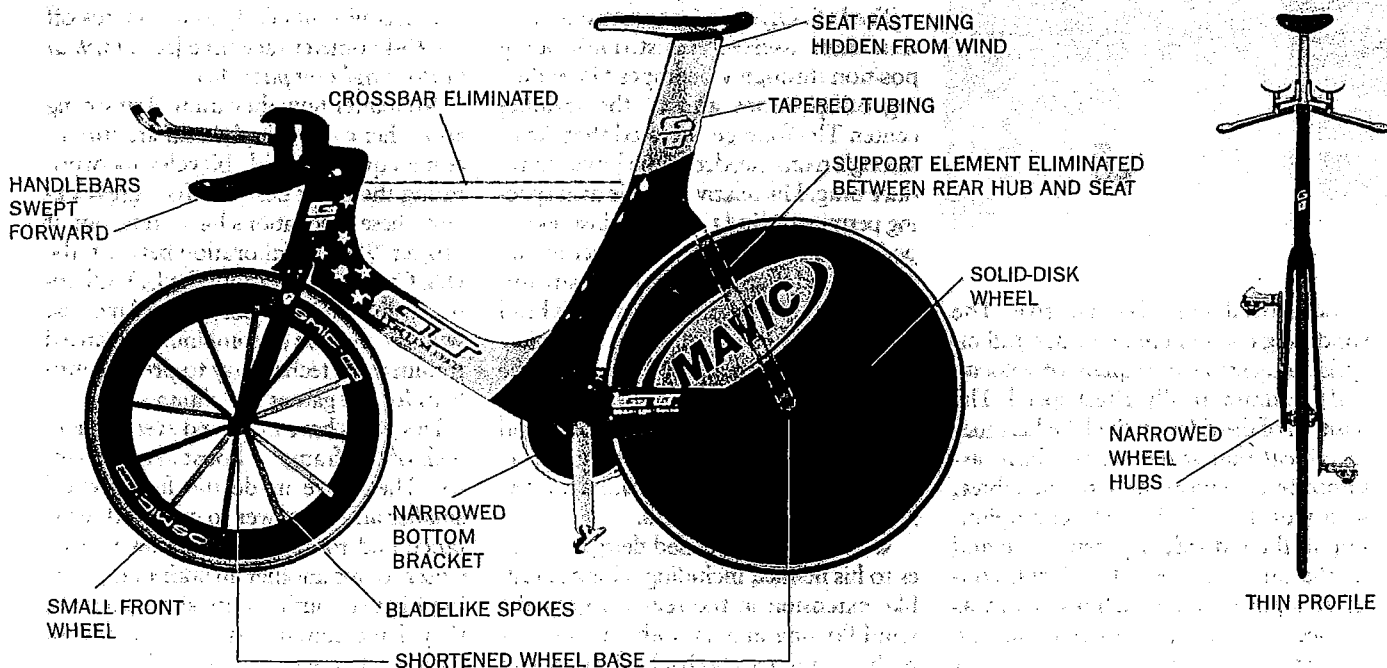
In our biomechanics laboratory Armstrong rode a stationary bicycle that measured the direction and magnitude of the forces on the pedals [see illustration at left]. Jeffrey P. Broker, a biomechanics specialist at the center, determined that Armstrong pedaled almost identically with the left and right leg. The only flaws identified were minor weaknesses in propulsive force at the top and bottom of the pedaling cycle.

An analysis of Armstrong's body po-

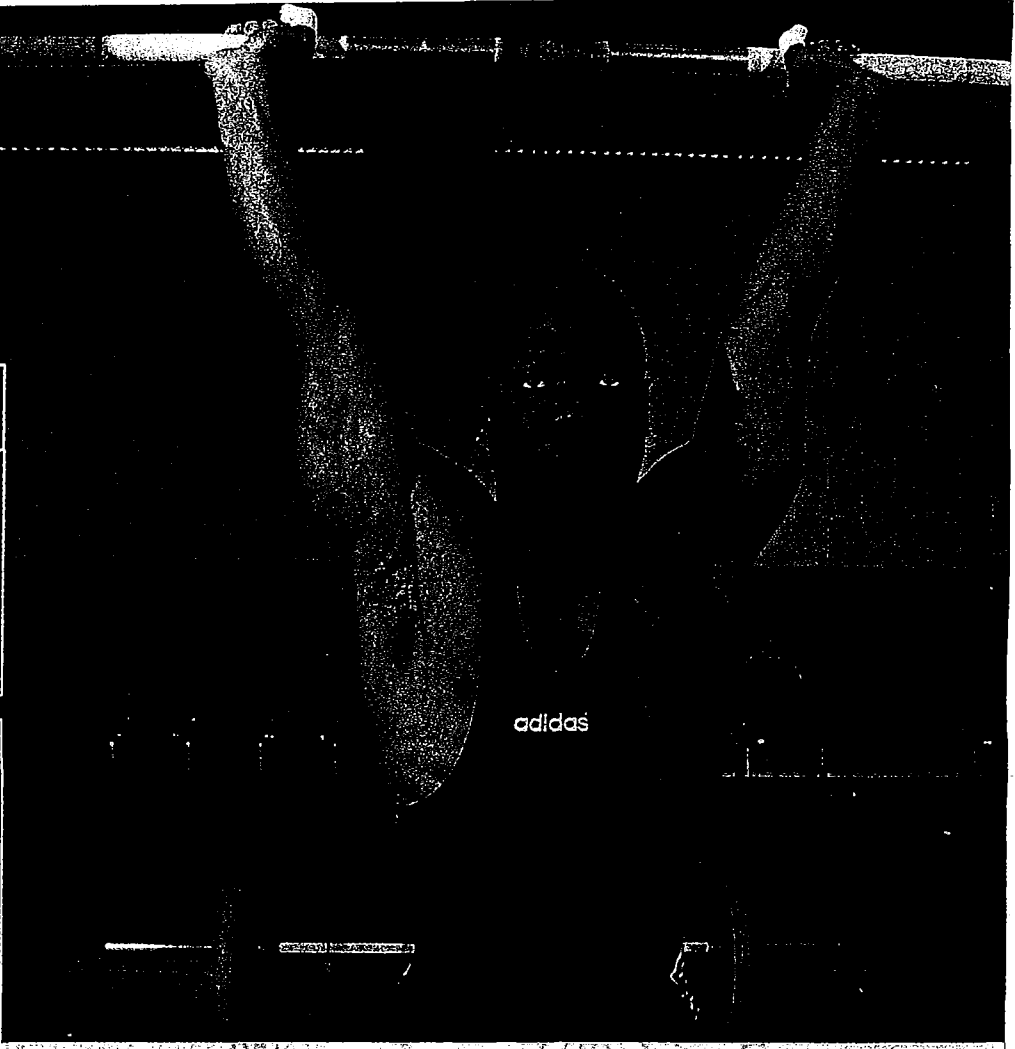
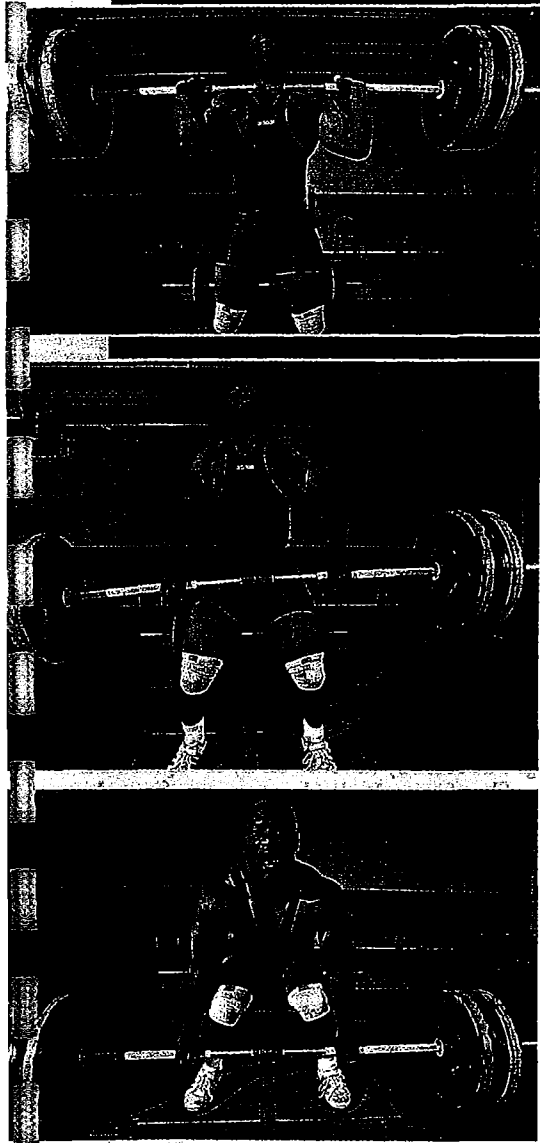


COURTESY OF JAY T. KEARNEY

AERODYNAMICS have preoccupied bicycle designers since the early part of this century, as is evident in early racing bicycles equipped with canopies, called fairings, that helped to reduce drag (above). The most advanced bicycles today are deployed in track racing. The recently unveiled SB II, or Superbike II (below), has a lightweight carbon-fiber frame. It also has a range of aerodynamic design elements. Similar features are incorporated into bicycles for some road-racing events in which Armstrong competes.



LAURIE GRACE



his chest, which was resting on the handlebars. Obree's unconventional riding position, one that was difficult for other cyclists to master, was banned by the International Cycling Union because it was unstable and dangerous.

The U.S. Olympic Committee evaluation team assessed Armstrong's riding position through videotapes taken during competitions and at the training center. The footage revealed that Armstrong's trunk needed to be lower to reduce drag. His relatively wide arm spacing permitted wind to stall against his upper torso, requiring more power at any given speed than a flatter, more streamlined position would. Moreover, his head position allowed his helmet to project up into the airstream. We suggested he move his seat forward and up slightly, his handlebars forward and down and his hands further forward on the "aero" bars—aerodynamic extensions of the standard drop handlebars.

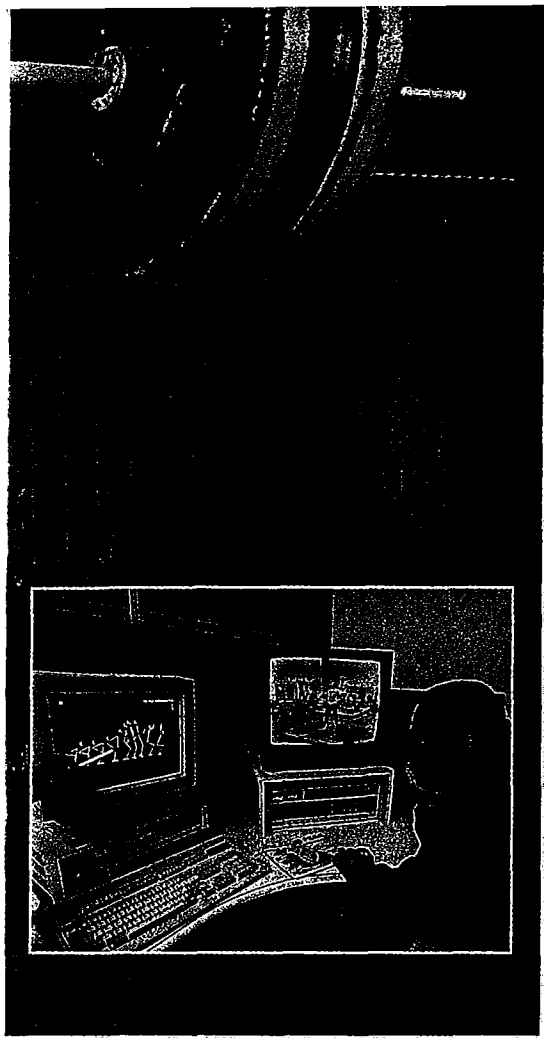
We also recommended design changes to his helmet, including a longer, tail-like extension in the rear (to keep the wind flowing in a smooth stream over his head and onto his back). Testing with

power-monitoring equipment showed that Armstrong's new position resulted in an increase in speed of 1.44 kilometers per hour relative to his old position. If combined with the various physiological improvements recommended, Armstrong could cut nearly four minutes off his 40-kilometer race time [see graph at bottom right on page 46].

No matter how they train, Armstrong and other cyclists in Atlanta are sure to come equipped with bicycles incorporating the latest designs. To a great extent, these innovations have come out of Project '96, a collaboration between the U.S. Cycling Federation, the U.S. Olympic Committee and corporate America, with the mission of combining advanced training and technology to prepare athletes for the games in Atlanta.

Designers have inspected every square inch of the frame to boost aerodynamics. They have made the front wheel smaller and narrower to cut wind resistance and to allow teammates to ride closer to one another. In addition, by using high-strength composite materials, they have minimized the amount of structural support needed. The tubing

position proved more constructive. The wind drag encountered by rider and bicycle increases as the square of velocity and can dramatically affect speed. The position of the rider on the bike becomes so critical that some cyclists have assumed bizarre postures. Graeme Obree, who won the 1995 world championship in the individual pursuit race and set the one-hour record in 1994, contrived a position in which his head was pitched far in front of the handlebars. His arms were completely tucked under



Weight lifting is at the opposite end of the physiological spectrum from cycling. Whereas cycling is the longest event in the Olympics, weight lifting is the shortest. Weight lifters require extreme muscular strength and power, as opposed to endurance. The act of lifting a 120- to 250-kilogram barbell demands up to 3,000 watts of power, enough to illuminate 50 lightbulbs, each 60 watts, for a second. For these events, the athlete relies on ATP stored in the muscles and the regeneration of ATP by the breakdown of phosphocreatine. During the long recovery period in training between each set of five or fewer lifts, these energy systems replenish themselves aerobically.

Eastern European Training

The U.S. has but a slight chance to win a medal in Atlanta, because the championship eastern European weight-lifting programs have endured in the newly independent countries that survived the fracturing of the Soviet bloc. Nevertheless, U.S. athletes have begun to adopt some of the same training methods embraced by their competition.

During the past five years, Dragomir Cioroslan, a Romanian-educated coach who won a bronze medal for that country in the 1984 Olympics, has taken over as the resident weight-lifting coach at the U.S. Olympic Training Center. Cioroslan has instituted a highly structured, year-round program based on his eastern European training. Tim McRae is one of the coach's protégés. With his anvil-like upper body, McRae might have been tapped for the National Football League instead of the U.S. national weight-lifting team if he had not stopped growing at 160 centimeters (five feet three inches). McRae, in fact, took up weight lifting because he hoped it would make him grow taller and more competitive in football.

McRae can lift more than twice his body weight, a feat that has helped make him national champion five times and the U.S. record holder in three weight classes for the two main competitive events—the snatch and the clean and jerk. In the snatch, an athlete grips the bar with hands placed two to three times shoulder width. He then pulls it to chest level. He squats under the bar, catching it overhead with straightened arms. Then he returns to a standing position with the bar above his head. The clean and jerk proceeds with hands at shoulder width. The athlete brings the bar to chest level, squatting underneath to secure it

on the shoulders before standing. After a pause, he finishes with the jerk, a full extension of the arms. An explosive vertical thrust from the legs aids him in lifting the bar.

McRae's stature—short limbs, long torso and muscular build—suits him well for weight lifting. For one, his height means that he need lift the bar only a relatively short distance. Perhaps McRae's most remarkable physical skill can be seen when he jumps straight up nearly a meter from a standing position, a demonstration of the kind of leg power needed in lifting.

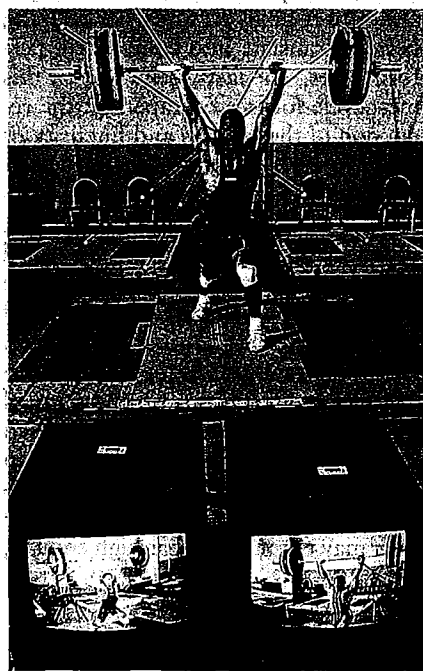
Weight lifting is the ideal sport to illustrate another fundamental concept of modern athletic training. Periodization, as it is known, is the structured, sequential development of athletic skill or physiological capacity through organizing training into blocks of time. The time periods involved range from an individual lesson to annual cycles. Weight lifters prepare two to four months for a competition through a macrocycle, a period that itself includes several shorter segments called mesocycles.

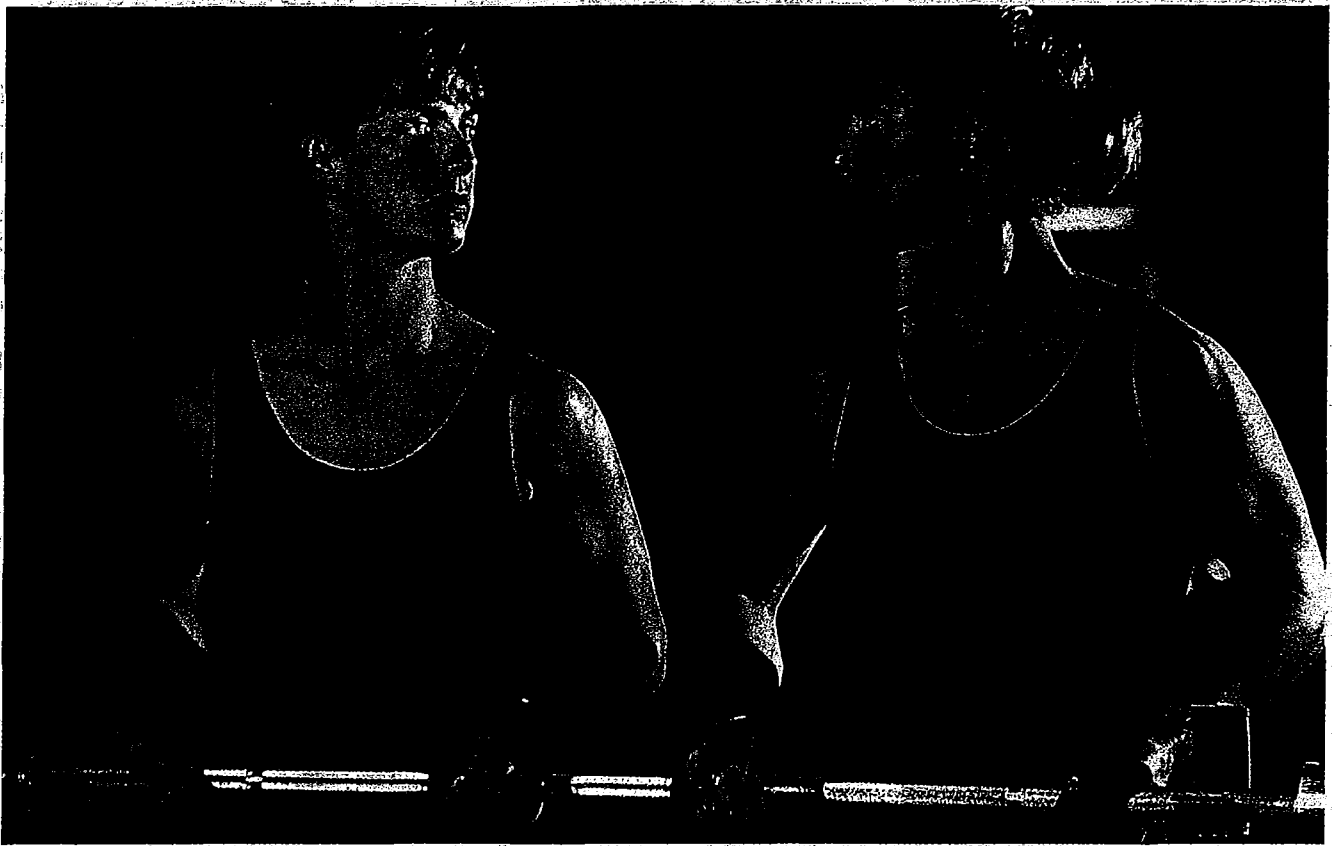
Cioroslan takes the athletes on the national team through three to four macrocycles during the year, each leading up to a major competition. A macrocycle begins with a preparatory phase, a mesocycle that lasts about eight to 10 weeks. Each week during this mesocycle, McRae and other athletes will perform 600 lifting repetitions at 80 to 90 percent of the maximum amount they are able to lift. The high-volume, medium-intensity workouts elicit changes in muscle, connective tissue, ligaments and other soft tissues. These changes enable the athletes

TIM MCRAE, a member of the U.S. national weight-lifting team, executes a 130-kilogram lift called the clean and jerk at the U.S. training center (bottom to top). Two high-speed cameras photograph the athlete to make an assessment of the pattern of motion (below right). Combining the videos provides a three-dimensional stick-figure image for analysis of lifting technique (inset).

found on an ordinary bicycle has been replaced by structural members that taper off from front to back in a teardrop shape, as does the wing of an airplane [see bottom illustration on page 47].

Examining every aspect of Armstrong's performance has improved his readiness for the Olympics. His lactate threshold has increased from 75 to 79 percent. He now practices or competes up to 40,000 kilometers every year. (This performance contrasts with the 1,600 kilometers or so he cycled at the age of 15.) Armstrong has also logged better results in recent races. In 1995 he won the U.S. Tour DuPont, and his training helps to explain why he scored an astonishing breakaway victory in a 167-kilometer stretch of the Tour de France, from Montpon-Menesterol to Limoges.





to tolerate heavier lifting in the next training phase.

In the second mesocycle, which lasts another four to five weeks, the team's training objective is to bolster strength and power by doing fewer repetitions (200 to 300 per week) but using heavier weights that require 90 to 100 percent of an athlete's lifting capacity. The strongest of Gioroslan's athletes might lift more than three million kilograms a year.

The final mesocycle includes two phases leading up to the event. During the first phase, the athlete works at maximum intensity to ensure that the strength and power gains from earlier training periods translate into competitive performances. The last week or so of this mesocycle focuses on tapering: the reduction of the volume and intensity of exercise to allow the athlete to recover from the stresses of training without losing the benefits of intensive preparation.

In addition to applying physiological principles to training, weight lifters, like cyclists, take advantage of an array of sophisticated monitoring equipment. Weight lifting is one of the most technically demanding sports, requiring use of a specific sequence of muscles. If each muscle group, from the knee and hip extensors to the shoulder and arm muscles, does not activate in sequence, the lifter may not raise the bar high enough,

or else it may sway precariously back and forth.

Sarah L. Smith, a biomechanical specialist at the Colorado Springs training center, tested McRae to track the smoothness of the S-shaped trajectory that the bar must trace from ground to full extension. The analysis involves two cameras and two platforms containing sensors that record the forces applied through each foot. If the load on each foot differs, the lifter may lose symmetry between his hands—that is, he may raise one side of the bar faster than the other. Testing showed that asymmetries in McRae's lifting made it difficult to catch and stabilize the bar during the snatch, a finding that led to several refinements in technique.

Choosing One's Parents

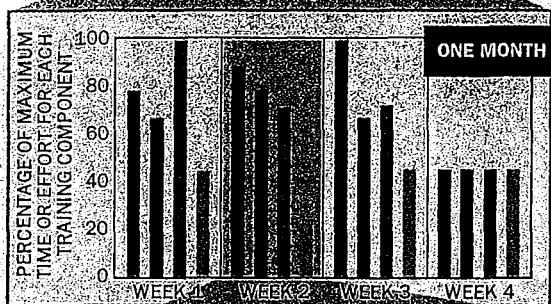
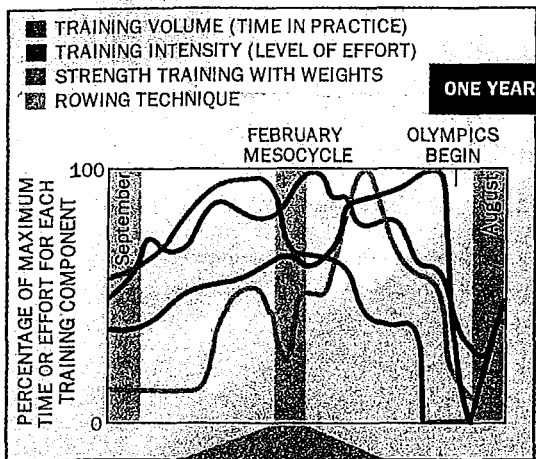
McRae's ability to lift more than twice his body weight may be a matter of birthright or his early exposure to the sport—or perhaps a little of both. Sports scientists often ponder the role of genes and environment in the make-up of the elite athlete.

The physiologist Per-Olof Astrand coined the often repeated maxim: to become an Olympic athlete, choose your parents well. That genetics probably plays at least some role has been demon-

STRENGTH TRAINING with weights is a critical part of the regimen of the McCagg sisters and the rest of the U.S. rowing team. But this type of training is just part of their periodization routine: the programmed scheduling of training by year, quarter (macrocycle, which is not shown), month (mesocycle), week and day (*graphs and table on opposite page*). The volume, intensity and type of training are carefully varied until the tapering-off period, just before the Olympic Games begin.

strated by Claude Bouchard, an anthropological geneticist and exercise physiologist at Laval University in Quebec. In the 1980s Bouchard studied paternal and identical twins. He found that some pairs of sedentary twins were able to nearly double their maximum oxygen uptake after 15 to 20 weeks of physical training, whereas others showed minimal gains in fitness. These findings suggested a genetic basis for the superior physiology of top-notch athletes. Bouchard is now looking for genetic markers that would distinguish between those with a high response to training and those who adapt less well.

As yet, no elite training programs seek out competitors with specific "athletic" genes. But they often do the next best thing. The physical typing of a prospective athlete—the systematic recruitment



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
MORNING	AEROBIC ENDURANCE TRAINING	AEROBIC ENDURANCE TRAINING		TRAINING AT LACTATE THRESHOLD	AEROBIC ENDURANCE TRAINING	TRAINING AT LACTATE THRESHOLD	INDIVIDUALIZED WORKOUTS
MIDDAY	STRENGTH TRAINING WITH WEIGHTS	HIGH INTENSITY ANAEROBIC TRAINING	STRENGTH TRAINING WITH WEIGHTS		AEROBIC ENDURANCE TRAINING		ONE WEEK
AFTER-NOON			SUSTAINED RUNNING	STRENGTH TRAINING WITH WEIGHTS	HIGH INTENSITY RUNNING		
	15 sets of 15 strokes at 100 percent effort		Five-mile run	15 sets of 400 meters			
	Four sets of 25 minutes each at a heart rate of 148 to 160 beats per minute		Three to five sets of up to 10 different lifting exercises each with five to 10 repetitions at 75 to 90 percent of maximum effort	Four sets of 10 minutes each at a heart rate of 190 beats per minute			

Laurie Grace

of youngsters based on traits under genetic control—has become a fixture of many national programs, particularly the now defunct East German sports machine. The Australians, in fact, have demonstrated that these principles can be applied in a country that does not exert heavy-handed control over its citizens' lives. The Australian rowing federation worked with coaches and sports scientists to develop a profile of women athletes who had the potential to become world-class rowers. Qualities such as height, body-fat composition, limb length and cardiovascular endurance were surveyed. Athletes without these characteristics are not excluded from consideration, however. The Australians showed through this program that they could field international athletes within two years.

If a comparable program existed in the U.S., two women who would have been targeted are the identical twins Mary and Betsy McCagg.

The McCagg sisters, stalwarts of the U.S. women's rowing team, are perfectly endowed for their sport. Both are 188 centimeters (six feet two inches) tall and weigh 79 kilograms (175 pounds). Both have body-fat compositions lower than that of the average college-age male (meaning most of that weight is muscle) as well as long legs that facilitate the execution of a long, powerful stroke.

The McCaggs also demonstrate that genes are only of value in an environment that permits development of one's natural physical assets through training. The family also had a multigenerational tradition of involvement in the sport. The McCaggs' father and grandfather—as well as many other family members—rowed competitively while attending Harvard University and other eastern establishment colleges.

After finishing their rowing careers in an exceptional high school program, the sisters attended Radcliffe College, with its long tradition in women's rowing. Expectations for the twins remained high from the outset: they joined the Radcliffe varsity team as freshmen. In their sophomore and junior years, the team went undefeated. Both sisters made the Olympic team in 1992; their crew of eight scored a sixth-place finish.

Improving the Best Rowers

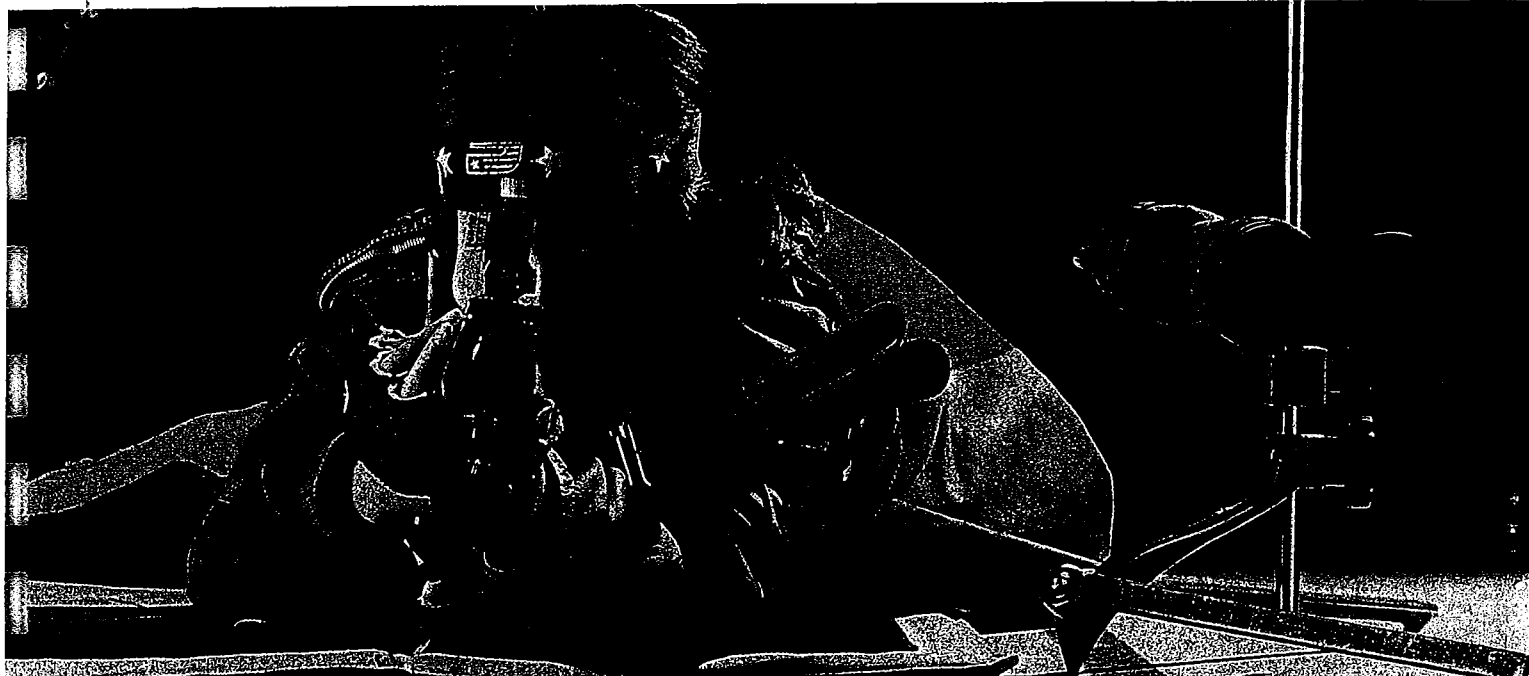
The McCaggs compete in either eight- or two-woman crews for sweep rowing, in which each crew member pulls one long oar with both arms. As much as any event, the 2,000-meter distance they traverse in six to seven minutes requires a balance of athletic physical capabilities: muscular power combined with a highly honed aerobic capacity, and an ability to tap into one's anaerobic pathway for more muscle power.

The McCaggs and the rest of the national team came to the training center in Colorado Springs in 1991 for a physiological and biomechanical assessment to determine why they encountered difficulties in the last 500 meters of a race. To their coaches, it appeared that they had failed to develop the requisite anaerobic capacity—and so were unable to achieve the increase in rowing power required in a final sprint.

Testing at the training center showed that, in actuality, the team had attained a level of anaerobic fitness matching that of the best rowers in the world. What the members lacked was sufficient aero-



MCCAGG SISTERS ready their oars for a daily training session on the Tennessee River; their coach, Hartmut Buschbacher, watches a video of the two women rowing.



TAMMY FORSTER prepared for the Olympic trials at the 50-meter shooting range at the U.S. training center. Forster did not qualify for the Olympic team.

bic capacity to carry them through the first 1,500 meters of a race without accumulating debilitating levels of lactate.

Later in 1991 someone with ideas about how to solve the problem of the anemic finishes arrived in the U.S. That year Hartmut Buschbacher, the former coach of the East German women rowers, took charge of the U.S. national team. Ironically, it was an East German junior women's team coached by Buschbacher that had beaten a U.S. team on which the McCaggs had rowed in 1985—an event that stiffened the sisters' resolve to become more competitive.

Buschbacher soon established a full-time resident athlete program in Chattanooga, Tenn., with a group of 15 carefully screened women. His philosophy of coaching borrows extensively from the systematic training principles for

which the East Germans were known. Buschbacher applied concepts of periodization, alternating different mixes of volume and intensity of training that helped to correct the aerobic deficit [see graphs and table on page 51].

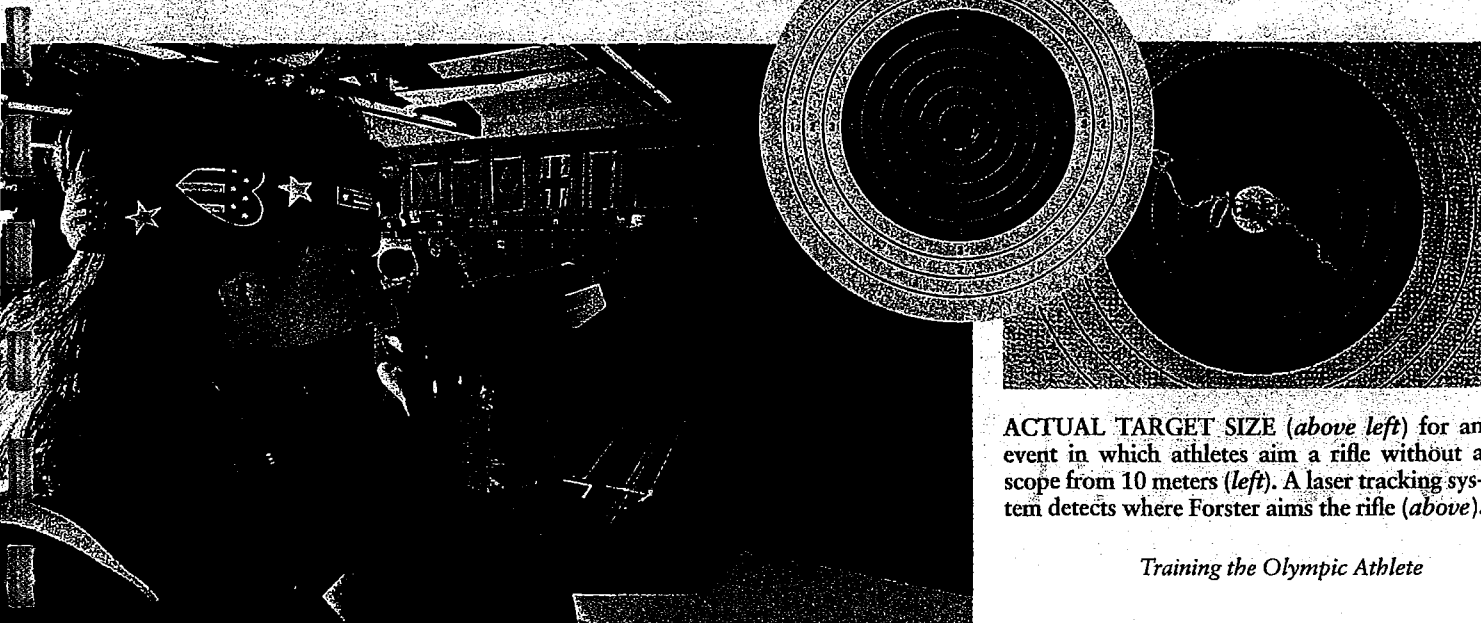
Evidence that Buschbacher's strategy may be helping came last summer when the McCaggs, racing in a team of eight, won the world championships in Tampere, Finland.

The Mental Game of Target Practice

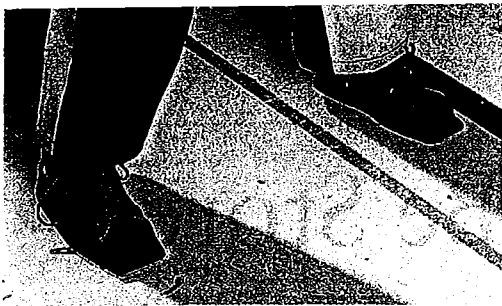
The Olympic events that rely less on brute strength and more on skill and mental conditioning than any other sport are the shooting and archery competitions, in which women can match or better the perfor-

mance of men. One female shooter, 27-year-old Tammy Forster, started down the path to becoming a national and international champion by watching television. At the age of four, seeing Olga Korbut's gold-medal-winning gymnastic feats made Forster vow to go to the Olympics. The opportunity to become an Olympic athlete presented itself in Forster's backyard, where her father, an expert rifleman and an occasional entrant in shooting contests, showed each family member how to use and take care of guns. Parental involvement in shaping the young athlete, a theme in the McCaggs' career, also encouraged Forster. Once her commitment became clear, her father decided to take classes in how to train shooters—and he now serves as one of her coaches.

By the time Forster was 15, she was training for 90 minutes a day with an air rifle or an unloaded small-bore (.22 cal-



ACTUAL TARGET SIZE (above left) for an event in which athletes aim a rifle without a scope from 10 meters (left). A laser tracking system detects where Forster aims the rifle (above).



SHOOTING SHOES provide a stable base to fire from a standing position.

iber) rifle indoors. She is a testament to the benefits of perseverance, showing that intensive training can in some sports make up for a lack of innate ability. Not a natural talent, Forster observed her sister shoot equally well while spending only a quarter of the time in practice. Forster nonetheless stayed with it. By 1985 she had won a silver medal at the junior national competition, and she chose to go to West Virginia University to train with Ed Etzel, an Olympic gold medalist in 1984.

In 1991 Forster took up residency at the Colorado Springs training center. Her stay has allowed her to devote full time to training for the 10-meter air-rifle contest and the three-position shooting event. The latter contest requires firing a small-bore rifle (one shooting a small-diameter bullet) at targets 50 meters away while lying, kneeling and standing. She has especially labored on the mental-rehearsal techniques she needs in order to muster the focused concentration essential to excelling in this event. Her efforts have improved her skills, although she fell short of winning one of the two open spots on the women's Olympic shooting team in the 10- and 50-meter events. Forster's training, however, provides an illustration of the benefits psychology brings to sports.

The roots of the sports psychology field that are the basis for Forster's skills extend back almost a century, when Norman Triplett discovered that athletes performed better when competing against one another than when compet-

ing against the clock. Sports psychology began to gain a broad appeal in the 1970s, when the profession started applying a set of cognitive and behavioral techniques to athletic training. At that time, new research showed that mental practice alone could improve motor performance.

As elements of her rehearsal training, she combines a number of techniques—among them, muscle relaxation exercises, mental visualization of a performance, and recording of her accomplishments and day-to-day emotions in a journal. She also sets out a series of realistic objectives that she can accomplish during each practice.

Relaxation exercises allow the shooter to heighten concentration and to recognize sources of muscle tension in the shoulders and back that can affect the accuracy of a shot. During visualization, Forster may picture herself aiming and shooting; at other times, she sees herself as a bystander watching the event from the sidelines. The more active imagery, when she actually imagines holding the rifle, seems to yield more of a performance gain.

Forster repeats a visualization routine before each shot she takes in competition. In her mind, she moves slowly through each step, from standing on the firing line to bringing the rifle into position to firing an actual shot. She goes through this mental exercise before each of the 60 shots in the three-position competition. Invoking this state of focused calm before each shot, a shooter may spend up to two and a half hours in preparation and firing, the time limit for a shooting event. The winner, who is gauged on accuracy, not speed, will hit the bull's-eye with more than 90 percent of the shots made in the two events.

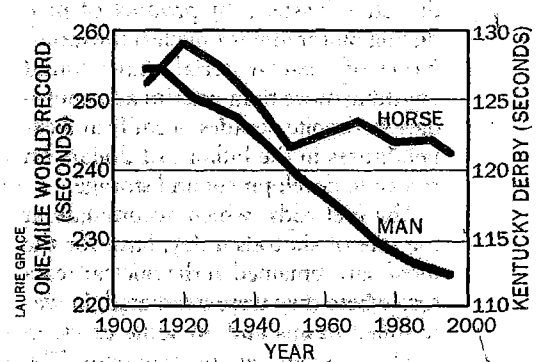
Forster has also worked directly with U.S. Olympic sports psychologist Sean McCann to allay the perfectionism that has sometimes caused her to lose confidence in the accuracy of her aim. To as-

sess her technique, she shot a rifle equipped with an infrared laser. An analysis of the placement of the beam on the target showed that her aim was nearly flawless. But she continually tried to make adjustments, and so her ability to remain steadily fixed on the target deteriorated after five or six seconds.

McCann helped Forster develop visualization routines that included a series of verbal cues to quell these fears—the repeating of simple words like “relax” or “ready.” Persistence has yielded some payoffs. During her residency, Forster has won two world cups, and last year she placed second at the national championships—a testament to the accomplishments that accrue from the slow, deliberate pace that characterizes this most cerebral of sporting events.

The combination of physical and mental training employed by the rower or shooter applies across the full range of the 29 Olympic sports, from swimming to baseball. Sports science and

RECORD RACE TIMES FOR MAN AND HORSE



technology have contributed to a trend in which world records in all sports keep falling. Winning times for horses in the Kentucky Derby have declined at a slower rate than records in the one-mile run have. It is certain, moreover, that the Olympic Games in Atlanta this summer will once again challenge the limits of human performance.

The Author

JAY T. KEARNEY, who holds a doctorate degree in exercise physiology from the University of Maryland, is a senior sports physiologist for the U.S. Olympic Committee. From 1974 to 1986 he was professor of physiology at the University of Kentucky, and from 1988 to 1992 he served as director of the sports science and technology division of the U.S. Olympic Training Center in Colorado Springs. He was on the flat-water canoeing team slated to go to the 1980 Olympic Games in Moscow, but the team stayed home because of the Carter administration's boycott protesting the Soviet invasion of Afghanistan. Professionals from the U.S. Olympic Committee's sports science and technology division contributed to this article—in particular, research assistant Susan Mulligan.

Further Reading

TRAINING FOR SPORT AND ACTIVITY: THE PHYSIOLOGICAL BASIS OF THE CONDITIONING PROCESS. Jack H. Wilmore and David L. Costill. Human Kinetics Publishers, 1988.

THEORY AND METHODOLOGY OF TRAINING: THE KEY TO ATHLETIC PERFORMANCE. Tudor O. Bompa. Kendall/Hunt Publishing, 1994.

THE OLYMPIC FACTBOOK: A SPECTATOR'S GUIDE TO THE SUMMER GAMES. Edited by Rebecca Nelson and Marie J. MacNee. Visible Ink, 1996.