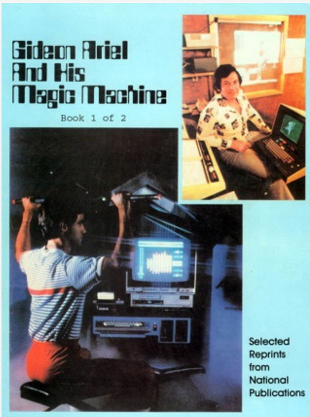
Gideon Ariel and his Magic Machine - Book 1

Selected Reprints from National Publication Book 1



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This article presents a collection of reprints from national publications presented to Gideon Ariel, a pioneer in the field of biomechanical analysis. Ariel's work involves simulating the performance of athletes on a specialized computer to determine their optimum potential. His findings have been used to correct performance flaws in athletes, leading to improved results and world records. The article also discusses Ariel's work in analyzing and improving athletic equipment, and his predictions for future athletic achievements based on his biomechanical analysis.

This article discusses the work of Gideon Ariel, a scientist and former Olympic discus thrower, who uses computerized biomechanical analysis to improve athletic performance. Ariel's technology uses high-speed motion picture cameras and sensors to analyze an athlete's movements and identify areas for improvement. His work has contributed to the training of Olympic athletes, the design of athletic equipment, and the development of new exercise machines. Ariel's research has also led to insights into optimal athletic techniques, such as the ideal launch angle for a long jump or the most effective pedaling stroke for cycling. His work is expected to continue influencing athletic training and performance in the future.

This article discusses the work of Gideon Ariel, a graduate student and assistant track coach at UMass, who used physics to optimize athletic performance. Ariel developed a system called Computerized Biomechanical Analysis (CBA) which uses computer technology to analyze the movements of athletes and suggest improvements. The system was initially used to help improve the performance of hockey players by identifying the optimum pressure point on the ice for the stick. The system was later used to analyze the performance of professional football players and Olympic athletes. The article also discusses how CBA has been used to improve sports equipment design, including shoes and tennis balls. Despite the success of CBA, Ariel acknowledges that the system can only offer ways to improve and it is up to the athlete to implement the advice.

The article discusses the work of Gideon Ariel, a pioneer in the field of biomechanical analysis. Ariel has spent over 10,000 hours over seven years creating programs that use computers to analyze the complex movements of athletes. His work has helped to understand the intricate relationships between an athlete's many moving parts, which cannot be assessed simply by looking at slow-motion pictures. Ariel's work has been used to analyze the movements of discus throwers, runners, and even high jumpers. His analysis has also been used in injury prevention and treatment, as well as in product development for sporting goods. Despite some resistance from traditional coaches and corporate executives, Ariel's work has the potential to revolutionize the field of sports science.

This article from Sports Illustrated, published in August 1977, discusses the work of Gideon Ariel, a scientist who uses technology to analyze and improve athletic performance. Ariel uses high-speed cameras and computers to break down and study the complex movements of athletes, providing insights that challenge traditional coaching methods. His work has led to significant improvements in performance for athletes such as discus thrower Mac Wilkins and shotputter Terry Albritton. Ariel's research has also debunked common beliefs about athletic performance, such as the importance of the forearm muscles in pitching and the role of the jumping leg in long jumps. Despite resistance from manufacturers and traditionalists, Ariel's work continues to revolutionize the field of sports science.

In a comprehensive study of tennis ball behavior, Gideon Ariel and his team discovered that a tennis ball is on the racket for approximately four milliseconds, far less than the human reaction time. This finding has implications for the design of tennis balls and rackets, and could potentially help reduce the incidence of tennis elbow. Ariel also studied the shock absorption of different athletic shoes, finding significant variations between brands. His research has led to the development of a $25,000 force plate that can measure four types of pressure exerted by the foot. Ariel's work has potential applications in injury prevention, treatment, and athletic performance optimization. His research has also led to the development of a computer program that can predict an athlete's optimum technique and coach them towards it.

The article discusses the work of Dr. Gideon Ariel, a scientist who is revolutionizing sports with his innovative use of technology. Ariel uses sonic pens, slow-motion cameras, and computer printouts to analyze and improve athletes' performance. He once proposed the use of electric strain gauges on ski-boot bindings for safety, but the idea was deemed too revolutionary. Despite setbacks, Ariel remains optimistic and continues his research. He recently collaborated with Al Oerter, a four-time Olympic discus champion, to improve his performance using scientific advancements. Ariel's work represents a new breed of sports training, combining science and technology to enhance athletic performance.

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Below find a reprint of the 40 relevant pages of the article "Gideon Ariel and his Magic Machine - Book 1" in "Collection of articles book 1":

Presented to

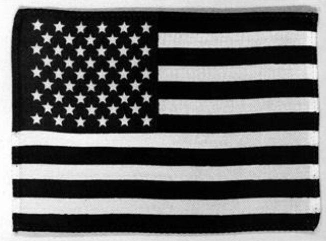
Gideon Ariel

Hope to have your work aboard soon.

W. Thornton, M.D.

Mission Specialist William Thornton

This flag and patch were flown aboard Challenger (STS-8), the first night launch and landing of the Space Shuttle. Aug. 30 - Sept. 5, 1983



Gideon Ariel And His Magic Machine

Selected Reprints from National Publication

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trends & trendsetters

Have you heard about the four-way Ford, or eating ruffage, or perfecting performance by computers? People are talking about them.

Programming performance

"If they perform to their optimum potential," says Dr. Gideon Ariel, "America's Mac Wilkins, Terry Albritton and Dwight Stones will win gold medals this month in Montreal." Such a prediction would be considered little more than conjecture, if Dr. Ariel were not himself a former Olympian from Israel, and a pioneer in the rapidly developing field of biomechanical analysis. Six months ago, neither Wilkins nor Albritton were considered serious contenders. However, on the eve of the Montreal Olympics, they are favored to win the discus and shot-put events, respectively.

Dr. Ariel's conclusions are the result of simulating the performance of these and other perspective Olympians on a specialized computer to determine what each of them could do if their timing, stride, delivery, and overall body motion were perfected. "The athletes corrected their performance flaws accordingly," says Dr. Ariel, "and within a month, world records began to fall."

The possibilities for using computers to perfect body motion are endless, says Dr. Ariel. He has already found that most people walk incorrectly, that most shoes will cause lower back pain because they are not constructed with the human foot in mind. He has also determined, as others of us have often claimed, that the tennis ball is made all wrong. His variety (recently put on the market by Spalding) provides the player for better control because it rests on the racquet strings some 20 percent longer.

Esquire
JULY, 1976 VOLUME 86 No. 1 WHOLE No. 512

Esquire's Olympics Preview: How To Know A Perfect Performance When You See One

by Gerald Astor

On July 17, to the accompaniment of booming cannons, flapping pigeons and assorted noise from the likes of the queen of England, a billion-dollar tribute to the pursuit of perfection opens at Montreal under the title of the Games of the XXI Olympiad. For the following fifteen days, ABC's TV cameras will long-lens, slow-motion, instant-replay, split-screen and stop-action the world's greatest athletes, who will run, jump, twist, heave, stroke, guide, steer and shoot in an orgy of excellence.

But perfection rarely holds still enough to be anatomized by a camera lens. Indeed, until commentator Jim McKay or his ilk advises us of the time, or a camera flashes on the scoreboard, we won't know whether a U.S. sprinter like Steve Williams has run a world record hundred meters or the Soviet Union's Olga Korbut has outdone Nadia Comaneci of Romania in the optional floor exercise for women gymnasts.

Even more significantly, the camera cannot show the mechanics employed by a body to produce a perfect shot put or a perfect Tsukahara vault. TV supplies a highly pleasurable caress to the visual sense—the same way Beethoven's Ninth Symphony provides an orgy of delight for the unschooled ear. But the enjoyment of athletics—as well as of music—increases with an intellectual knowledge of the dynamics, whether it is Beethoven's manipulation of notes or Terry Albritton's manipulation of muscle tissue to move the shot seventy-one feet.

In track and field, perfection rests upon the most efficient application of muscle force to segments of the body. Until recently, techniques for running, jumping and throwing improved haphazardly, mainly as a result of a challenger observing the style of a champion.

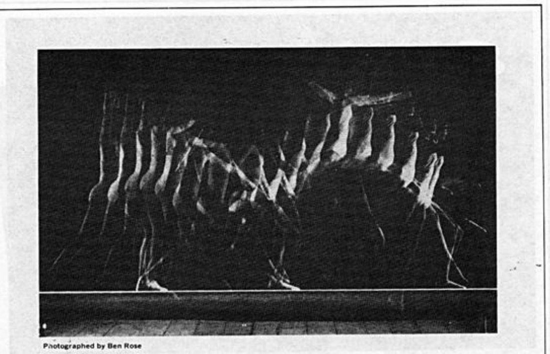
In track and field, perfection rests upon the most efficient application of muscle force to segments of the body.

Shot-putters adopted the ways of Parry O'Brien in the 1950's until the latest generation of iron-ball men discovered by trial and error that a martini is not the only thing that's improved by a twist. The Western roll sufficed for the high jump until the straddle leapers reached higher altitudes. And now the flop method, which benefited from a rule change that permits the head to lead, owns the world record.

But where these refinements have all come out of guesswork and experimentation, science is now on the case in the person of Israeli-born Gideon Ariel. As director of research for Computerized Biomechanical Analysis in Amherst, Massachusetts, Dr. Ariel's chief business is testing and designing athletic equipment that maximizes effective force. Since 1972, he has also been photographing athletes and feeding this visual data into a computer, which in turn spews out a graphic report in terms of force, direction of force, acceleration and velocity of body parts. The computer readouts give a quantitative measure of motion, from which Ariel sees what's necessary to perfect or optimize an athletic performance. The only limitations are those of muscle and ligament. Using data from medical science, Ariel knows at what point the forces exerted begin to tear human tissue.

What wins on paper, however, often runs out of the money at the track—except that Ariel has already astonished a number of expert skeptics. Last November he watched Mac Wilkins, a discus thrower (Ariel's own event as a 1964 Israeli Olympian). "Based on calculations I made," says the biomechanical engineer, "I could see Wilkins dissipated too much muscular force overcoming the friction between his shoe and the ground. I told him to pour water on the ground where his foot rested. He threw about two hundred thirty feet immediately. Until then, his best was two hundred fourteen feet. The water reduced the friction drag. A different shoe, one that lowered

Gerald Astor is currently working on a book about the F.B.I.



Photographed by Ben Rose

rotational friction, would have brought the same results.

"I also analyzed Bill Schmidt, the javelin thrower. The computer information indicated he lost force because he dropped his hip. After I pointed that out, Schmidt reached more than three hundred feet, much better than he had ever done."

Last year Ariel studied Kansas City Royals pitcher Steve Busby. "He's getting maximum velocity on the ball with his form," Ariel remarked to the Royals coaches. "But he's going to have trouble with his knee; there's too much stress on it." The K.C. coaches turned pale. They thought Busby's knee problems were a well-kept secret in Kansas City.

With his computations Ariel proves in the following pages that 1936 triple gold-medal winner Jesse Owens actually ran as fast as any current sprinter. Owens, however, was penalized by a slow track. Ariel shows that Soviet high jumper Valery Brumel could leap over eight feet if he'd just pay attention to Ariel's physical principles. According to Ariel's charts, one hundred feet is within reach of modern shot-putters. Finally, Ariel buries that hoary athletic maxim that perfection requires follow-through; he says it is actually counterproductive.

In one Olympic category, gymnastics, perfection is achievable, mainly because scores are rendered by judges, who may award, if they're so inclined, the highest possible marks to a performer. But when you watch these events on TV, you really can't tell why one exercise is worth a perfect ten while another one, equally amazing to the viewer, registers a less than perfect 9.75.

Muriel Grossfeld, herself a three-time member of the U.S. Olympic women's teams and now the coach for all entries at Montreal, notes some of the subtleties that escape the camera. "The body must look elastic; at times you must have the quality of dance. The suppleness cannot be just in the legs but in your entire appearance. Difficulty isn't all that counts. A gymnast must be able to move forward, backward and sideward."

When you watch gymnastics on TV, you can't tell why one exercise is worth a perfect ten while another registers a less than perfect 9.75.

She points out that perfection is not a relative quality; a routine movement executed properly scores a ten the same as a much trickier stunt done exactly right. Actually, in women's gymnastics, unlike the male competition, a flub during a movement of great difficulty is supposed to cost more than a similar error on an easier stunt. The principle is that a woman should not stretch beyond her competence.

Currently training a crop of gymnasts in a converted supermarket in New Haven, Grossfeld observes that there is a definite advantage for the ninety-pound Korbuts and Comanecis of the world. "Their tumbling radius is so much less than that of tall girls that they can do more in the limited space of a floor exercise. On the balance beam they also have more room to work since they cover less distance with each movement. On the uneven bars if you're tall you come closer to the floor and the bars can be adjusted to accommodate better someone under five feet." Even in training the flyweight females have an edge. They can begin vaults and balance-beam practice sooner than their heavier counterparts because "catchers" can protect them more easily when they miss.

"Tall or long-legged girls seem more graceful," says Grossfeld. On the other hand, the premium on the lower half of the body works against women with big shoulders—and a bosom is just excess baggage.

So let the Games begin, and for the perfections discovered by Gideon Ariel and explained by Muriel Grossfeld, the ones you won't see on the TV screen, read on.

Esquire's Olympics Preview:

THE PERFECT HUNDRED METERS
Current world record: 9.9 sec.
Projected outer limit: 9.6 sec.

Three factors determine speed in a sprint. The first is the condition of the track. If it's soft, or if it's slippery, horizontal force is absorbed or lost. If the track is hard and springy, none of the leg drive is dissipated. The second determinant is what Gideon Ariel calls "angular displacement of the leg joints." Whether it's an Olympic sprint or a slow walk to the bar, forward movement results from bending the three segments of the leg—hip to knee, knee to ankle, ankle to ball of the foot—from the horizontal plane. In mechanical terms, the total amount of angular displacement of these leg segments in a given period of time is a measure of how fast the leg is traveling.

The third element in sprint speed is the length of the leg segments. A sprinter with longer limbs covers more ground in each stride, although his angular displacement per moment in time may be the same as or even less than that of a shorter competitor.

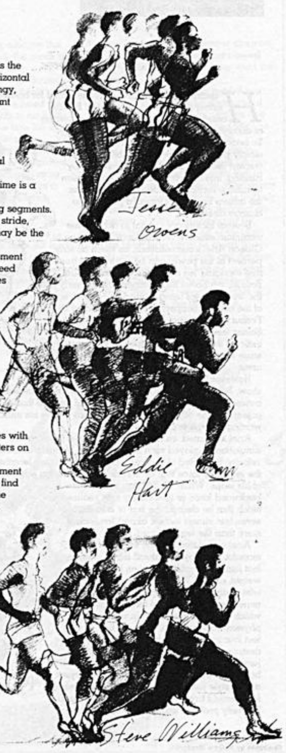
Thus, by measuring both angular displacement per moment in time and leg length, Gideon Ariel can calculate the speed of an athlete regardless of the effects of external influences such as track conditions or wind. He can thus project sprint perfection, beyond which a human can't go.

Eddie Hart and Steve Williams, two U.S. sprinters who have equaled the hundred-meter world record of 9.9 seconds, were compared on computers with Jesse Owens, whose best time was 10.2. Owens and Hart, both under six feet tall, showed an equal angular displacement. Williams, close to three inches taller than the others, moved his legs slower but covered more ground each step. Gideon Ariel's analysis: a triple dead heat of 9.9 if Owens—who ran on a slower track—faced Hart and Williams. "Comparing Owens' times with theirs is like matching a man who runs in sand with sprinters on a hard-surface road," says Ariel.

What makes the ultimate sprinter? Rapidity of leg movement is a function of the neuromuscular system. "A coach could find the most promising sprinters," remarks Ariel, "by timing the knee-jerk reflex of candidates." Other things being equal, longer legs with a smaller torso provides the optimum sprinter physique.

Although arm movement does add to the horizontal force, its primary function is the prevention of torque or wobble due to hip rotation. What does limit modern competitors are spiked shoes. These overcompensate for possible slippage. Every time those spiked shoes dig into the track, force is wasted pulling them out.

If all external conditions were ideal, Ariel figures that with a ten-percent increase in leg length over that of the best contemporary sprinters, and with ten percent more muscle power than shown to date, a 9.6 hundred meters or an 8.8 hundred yards is possible. Greater speed would probably tear muscles, even break bones.



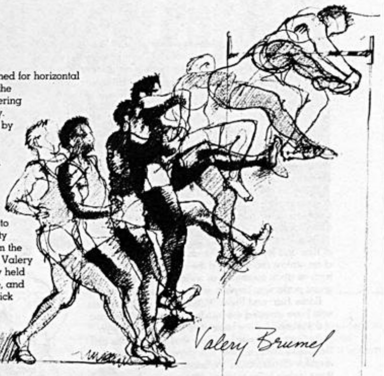
Illustrated by Andrew Moszynski

Esquire's Olympics Preview:

THE PERFECT HIGH JUMP
Current world record: 7 ft. 6½ in.
Projected outer limit: 8 ft. 10 in.

Humans appear to have been designed for horizontal rather than vertical movement. But the essence of the high jump is the mustering of enough vertical force to counteract gravity. To boost the limited upward thrust achieved by simply pushing off the ground, high jumpers convert their horizontal velocity, created by running, into a vertical force. The conversion technique requires sudden deceleration as the athlete brakes his forward progress to change direction.

Several factors are critical to achieve the maximum effective vertical force. According to Gideon Ariel's computations, as much as sixty percent of the power can be contributed from the free-swinging leg and arms. His analyses of Valery Brumel, the Soviet high jumper who formerly held the world record using a straddle jump style, and of the two top floppers, 1968 gold medalist Dick Fosbury and current record holder Dwight Stones (seven feet six and a half inches), indicate that all three produce roughly the same force by using their free legs and arms.



However, as the computer diagrams show, Brumel's straddle demands much more backward force in order for him to convert his horizontal drive into a vertical one. He thus wastes a considerable amount of power. On the other hand, Dwight Stones utilizes his muscular effort more efficiently, wasting much less in backward force.

Ariel simulated, on his computer, Brumel jumping flop style. The simulation employed such information as Brumel's horizontal velocity, the speed of segments of his body, his leg lengths, the muscular force that he had developed during some of his leaps. When Brumel flop jumped, his backward force or inefficiency was reduced so much that he cleared the bar at a fantastic seven feet eleven inches, almost five inches more than the world record.

Ariel calculated that the force manufactured by the takeoff leg in a seven-foot jump approximates seven times body weight, about 1330 pounds for an athlete who weighs 190. If Dwight Stones could generate 1750 pounds of force at takeoff, which is not unreasonable in view of his physical conformation, he could flop eight feet four inches. But what would totally destroy the accepted limits for the high jump would be a forward roll instead of the backward flop. According to Ariel's analyses, a dive-style jump with its minimum backward force would bring an eight-foot-ten-inch leap. The only problem might be the crash landing.

Illustrated by Andrew Moszynski

Esquire's Olympics Preview:

THE PERFECT LONG JUMP
Current world record: 29 ft. 2½ in.
Projected outer limit: 29 ft. 5 in.

The long or broad jump combines both the sprint and the high jump in a fusion of horizontal and vertical forces. The union of the two expressions of force optimizes at an angle somewhat less than thirty degrees from the horizontal. Theoretically the best ballistic angle would be forty-five degrees, but the angle must be cut down because an erect human starts his flight with his center of gravity already several feet off the ground. This principle, incidentally, holds true for the best angle of flight with the javelin.

Evidence of what makes near perfection in the long jump exists in the most incredible performance in the history of track and field. At Mexico City, in 1968, Bob Beamon of the U.S. jumped twenty-nine feet two and a half inches, more than a full foot beyond anything done before or since.

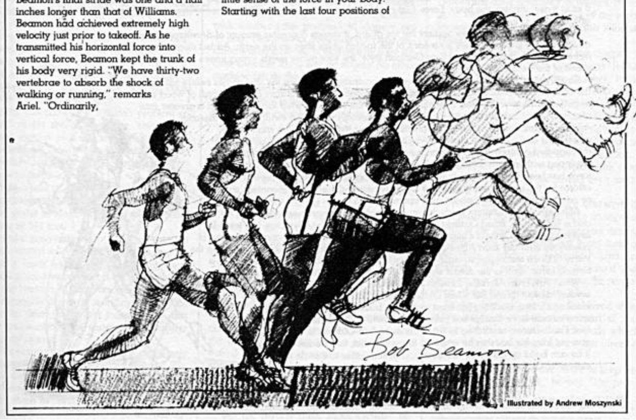
Using films of Beamon's jump, Ariel compared him on the computer with Randy Williams, the 1972 gold medalist. Beamon's final stride was one and a half inches longer than that of Williams. Beamon had achieved extremely high velocity just prior to takeoff. As he transmitted his horizontal force into vertical force, Beamon kept the trunk of his body very rigid. "We have thirty-two vertebrae to absorb the shock of walking or running," remarks Ariel. "Ordinarily, even the best long jumpers collapse the trunk slightly as they absorb the shock at takeoff in the vertebrae."

Beamon's ability to handle the forces without absorbing some in his joints is all the more remarkable since he fused the forces from various segments of his body within .075 seconds from the time his foot touched the board. Other jumpers required at least one tenth of a second or more. Thus, Beamon's linkage integrated a series of motions and combined more than one hundred sources of force in a near perfect piece of synchronization.

His free leg contributed as much as thirty-five percent to Beamon's performance because of the jumper's effective deceleration of the limb. As Isaac Newton proved, when a moving object suddenly slows, the force within it must go somewhere. For example, throw your fist in the air. Stop the punch abruptly and you will feel the force in other areas of your body. But if you simply permit the arm to extend fully, you will experience little sense of the force in your body. Starting with the last four positions of Beamon's free leg, the computer diagram of Beamon shows its movement slowed radically. The deceleration force went into the jump.

Beamon's swinging arms served two functions. Prior to lift-off he decelerated them to add more force, as with his free leg. During his flight, the arms added no power but helped retain balance.

Ariel's computer indicates Beamon rolled up 1700 pounds of force in his hip joint. Medical research suggests that at this level, the average muscle attachments to the hip will tear. Therefore, it is unlikely any human can significantly improve on the amount of force manufactured by Beamon. When Ariel put all of the data into the ideal long jump, he found that a twenty-seven-degree launch, one degree more than Beamon's, would be optimal. It still would add only a tiny increment to the jump. Beamon's record probably will be unsurpassed in the near future.



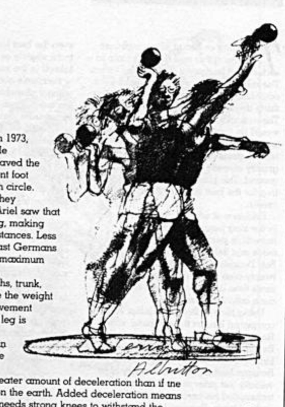
Illustrated by Andrew Moszynski

Esquire's Olympics Preview:

THE PERFECT SHOT PUT
Current world record: 71 ft. 8½ in.
Projected outer limit: 100 ft.

While wandering among the athletes at a meet in Spain in 1973, Ariel paused to watch some East Germans put the shot. He noticed that contrary to accepted practice, the Germans heaved the sixteen-pound weight with the back leg off the ground and the front foot coming all the way to the bucket or toe guard that rims the launch circle. Innocently, Ariel pointed out the flaws to East German coaches. They promised to initiate measures to reform their deviants. However, Ariel saw that for all the talk, the East Germans kept right on lifting that back leg, making sharp contact with the toe guard and throwing the shot goodly distances. Less blessed with sophisticated systems for biomechanical study, the East Germans had nevertheless discovered a precious asset for putting the shot: maximum deceleration.

The shot put involves a linkage of forces generated by legs, thighs, trunk, shoulders and arms into a united push against the ball. Just before the weight leaves the hand, the athlete suddenly decelerates. He halts his movement forward and applies the resultant force to the shot. When the rear leg is on the ground at the moment of deceleration, some of the force dissipates into the earth. But when the back leg lifts off, the forces in it must travel through the body. Force that might have gone into the ground goes to the shot.

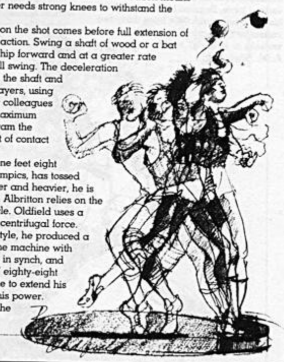


When the front foot smacks against the toe guard, it causes a greater amount of deceleration than if the athlete merely slowed himself by means of the friction of his shoe on the earth. Added deceleration means more force. One caution on the East German style: the shot-putter needs strong knees to withstand the shock of the deceleration.

Equally significant, Ariel's study shows that maximum force upon the shot comes before full extension of the arm, in the tradition of follow-through. It's analogous to whip action. Swing a shaft of wood or a bat or golf club. Stop your swing suddenly. The tip of the shaft will whip forward and at a greater rate of acceleration than if you had simply followed through with a full swing. The deceleration applied by arresting your arms is transmitted along the length of the shaft and manifested at the tip. That explains why slightly built baseball players, using thin-handled, whippy bats, hit home runs as well as their heavier colleagues equipped with massive bludgeons. Follow-through comes after maximum force has been brought to bear and it adds nothing. It may program the athlete for the proper swing or throw but it detracts if the moment of contact or release occurs after application of optimum force.

Although Terry Albritton holds the amateur record of seventy-one feet eight and a half inches, Brian Oldfield, a pro and ineligible for the Olympics, has tossed seventy-five feet. Oldfield's superiority rests on two features. Bigger and heavier, he is potentially stronger than Albritton. His second benefit lies in style. Albritton relies on the Parry O'Brien technique, straight-line steps across the launch circle. Oldfield uses a turning tactic, akin to the discus style, and it adds the potential of centrifugal force.

When Ariel ran Albritton through his computer with a turning style, he produced a seventy-six-foot throw. But when Oldfield was programmed into the machine with ideal conditions, back leg up, front foot to the bucket, the linkages in synch, and using muscle force that he has previously shown, Oldfield "threw" eighty-eight feet. Furthermore, according to Ariel, the more that Oldfield is able to extend his arm out from his body as he whirls to throw the shot, the greater his power. If he can build up his chest, shoulder and arm muscles to sustain the extension, Oldfield could reach a whiz bang one hundred feet.



Illustrated by Andrew Moszynski

Future Think

The Wizard and His Magical Machines

Gideon Ariel Puts the Computer to the Service of Sport

Kent K. Gordis

In the future, the work of Gideon Ariel will affect how we train.

Since 1971, when he first brought his high-tech visions to U.S. Olympic track and field training camps, Ariel, an expatriate Israeli who's now an American citizen, has played what many consider to be the leading role in a budding field called computerized biomechanical analysis.

More recently, his devices and insights have aided U.S. Olympic athletes, including Steve Hegg, 4000-meter pursuit gold medalist, and the 1984 women's volleyball team, which won a silver medal in Los Angeles. In the future, marathon runners, joggers and tennis players may also benefit from his contributions.

Adviser to Olympians

The year was 1975. American discus thrower Mac Wilkins felt confident he could perform well at the upcoming 1976 Montreal Olympics. Yet his throws always seemed to fall shy of the standard established by the East Germans. Coaches and advisers tried to help, but to no avail. This is when Gideon Ariel, a one-time Olympic discus thrower for Israel and a scientist dedicated to studying sport, stepped in. He was sure Mac Wilkins could easily beat the East Germans.

Ariel was convinced Wilkins's problem resided in his throwing motion. Using high-speed motion picture cameras and sensors that linked Wilkins's body to computers, Ariel established that the athlete was buckling his leg as he threw the disc.

Made aware of the power-robbing flaw, Wilkins changed his form and went on to win the gold medal at Montreal with a world record throw of 241 feet.

Ariel's contributions to training have not concentrated solely on the elite, however. He gave a boost to the weight training boom when he used his computers to design the cam on the Nautilus exercise machines. Ironically, he eventually drew on his findings to question Nautilus developer Arthur Jones's claims that the machines exercise muscles in a complete range of motion.

"We found that the design of the cam is only a compromise," Ariel explained from his Tarbuco Canyon, California, research center. "If you swing the weights too fast, the cam will make them fly away from you. Jones claims that because of this you have to use the machines slowly — but this is forcing the athlete to adapt to the machine and not vice versa."

Ultimate Exercise Machine

As a result Ariel, 46, took on a project to create the ultimate exercise machine. He knew from the start he was looking for a machine with a computerized brain that would adapt to each athlete's body form and range of motion instead of forcing the trainee to change style to fit the device.

He also knew that instant feedback would be a necessity and decided to incorporate a video monitor into the apparatus. Perhaps most importantly, he designed the machine to be free of inertia and gravity.

"What we have is basically a hydraulically operated system that's controlled by a computer," he explained. "And if I put an athlete like a shot-putter on the machine, it can start with a certain resistance (that permits a range of motion of) 10 degrees per second, and end with another (that permits) 30 degrees per second. This kind of computer-operated machine will adapt to the velocities which are the most favorable to his specific activity. No other machine can do this."

Lest he appear biased, Ariel was quick to add that his device is not the only computer-operated machine capable of such feats.

He also paid a lot of attention to the quality of feedback that the athlete could review. "We developed two ways to see your results," Ariel continued. "The first way is to see your output on colored graphs. Or you can create a split screen with your output on one side and the world champion's output on the other."

He added that when videotapes of both the subject and the world's best are available, the monitor can show split screen images of the two athletes. The complete unit retails for $16,500.

Now Ariel, a Ph.D. in exercise science from the University of Massachusetts, is delving into the field of cycling.

"It's a great, fascinating sport, because of the complex interactions between the bike and the rider," he explained. "The equations involved in cycling dynamics are extremely complicated." Ariel noted that the added inertia and aerodynamic factors created by the bicycle contribute to the difficulty of analyzing cycling motions.

"But the hardest thing about cycling," he continued, "is simply the fact that the motions are in so many planes. As the cyclist pedals, he tilts the bicycle back and forth and into an infinite series of planes." Only with stationary bicycles can Ariel's team begin to analyze cyclists. But he laments: "This is not a very realistic situation."

Computerized Bike

Using the technology of his exercise machine, Ariel has developed a computerized bike linked to a video monitor. "Both machines are resistance mechanisms," he noted. "For the bicycle machine we simply added a bike where there was a bench before. Our basic goal with the bicycle machine was to measure what is the basically isokinetic* force of cycling. And on this machine the cyclist will be able to determine the force he or she wants to reach. Let's say he wants 60 percent of his maximum (force) and more resistance in the first 10 degrees than in the last 10 degrees of the pedal stroke. All he has to do is enter this information in the computer."

Ariel first officially displayed this computerized bike at the Hilton Corporation Tennis Show in Los Angeles in late October, 1984. The bicycle machine, complete with computer, will retail for $9,500. The bicycle device alone will sell for $4,500, he said. Its cost is significantly less than the exercise machine because it doesn't require the expensive hydraulics of the general exercise device, he added.

"We've already received 62 orders for (the cycling machine) and we haven't even introduced it yet," Ariel said.

Prior to the summer Olympics, Ariel worked with Raleigh and Steve Hegg in an attempt to arrive at the most efficient equipment design. "Raleigh came to me with that funny looking bike Hegg used at the Olympics," Ariel explained. "We worked on its structural and aerodynamic characteristics within the parameters of the 4000-meter pursuit."

During his research, he discovered that, when Hegg accelerates at the start of the event, the bike's small 24-inch front wheel doesn't touch the ground for the first three or four pedal strokes.

"We told him to lean over more to keep his front wheel on the track," he said. "The prob-

**characterizing activity in which the speed of motion remains constant although the force may change* lem is, Steve's legs are so powerful, he could flip the bike over." Ariel added he has worked with Raleigh to design a new version of the "funny bike" that places more of the rider's weight over the front wheel, to hold it down.

Ariel's work has also brought him to study the question of saddle height. The generally accepted rule-of-thumb in the United States has been to place the heel on the pedal and raise the seat until the leg is fully extended. But when Cyrille Guimard, coach of the crack professional Renault racing team, took his riders thorugh a series of tests back in 1980, he found the optimal position to be 2.5 centimeters (about one inch) higher.

How does Ariel determine position?

"It is difficult to say," he conceded. "But it's true we've found a higher saddle usually results in more speed and force even if it's less comfortable." Ariel explained his findings metaphorically. "Everybody knows you can stand up with 500 pounds on your shoulders, but you can't squat with that much — it's a similar thing with saddle height."

The technique Ariel used to determine saddle height is straightforward. "At first we tried different heights at, say one-quarter inch increments. We measured the athlete's shank and thigh. Then we placed transducers on his legs and let him ride, with the computer calculating the data."

In these tests, close approximations of road riding were assured by placing the bicycle on rollers, rather than using a stationary bicycle, he added.

Pedal Power

The same tests have led to some interesting conclusions on the pedaling stroke. The most efficient stroke, he has found, involves keeping the ankle as perpendicular as possible to the primary range of motion. "But since this is a rotary motion, you really can't do that," he clarified. "You can't put your foot at a 90 degree angle to the primary motion when it's at the top or the bottom of the stroke — and to attempt it would be dangerous."

Ariel has determined that focusing force on the principal up and down strokes is usually the most effective method of pedaling. He also discovered that taping the ankles slightly can direct more of the cyclist's force into the vectors of the primary motion.

Ariel has also consulted with Shimano in their development of the aerodynamic pedals currently being sold on the American market.

Spying on the Soviets

Another major aspect of his work has involved comparing the dynamics of American athletes with that of Eastern Bloc stars. "But when, for example, we want to measure the dynamics of foreign athletes such as the Soviets, we can't wire them up because they obviously won't let us," he lamented. "So, we use the indirect method only."

Unlike laboratory tests that combine measurement of actual motion with computer transferred high-speed cinematography, Ariel uses only the second method with Iron Curtain athletes.

After filming the individuals under study, Ariel returns to his center where the film is isolated in one plane of motion and then projected onto a screen covered with a grid of hundreds of tiny microphones. Using a sonic pen linked to a computer, he pinpoints, frame by frame, the location of the athlete's limbs and other body parts. The computer then generates stick-figure representations of the athlete's motion.

Although he concedes the indirect method is not quite as exact, it has played a crucial role in bettering American performances in a number of sports, he said.

Fancy Footwork

In the past 18 months, Ariel has also expanded his fields of interest into footwear. He has been commissioned by the Pony shoe company, a subsidiary of Adidas, as a product researcher.

"We have developed a number of shoes for them," he noted, "including a computerized shoe that calculates stress points on the foot."

Ariel added that the shoe, currently used only for lab testing, might one day be marketed by Pony.

He has also developed a revolutionary marathon shoe. "Our tests showed that long-distance runners need a harder shoe. We are now developing a distance shoe with a two-part sole, one for the heel, one for the ball of the foot, for the best possible support."

In addition, Ariel has developed Pony's weightlifting shoe, which features a detachable sole that allows each competitor to add the appropriate height for his needs. Another shoe he's designed has an inflatable upper and would come in only three sizes, thus saving on inventory costs, he claims.

Feverishly Inventing

Meanwhile, Ariel is working with tennis instructor Vic Braden, chairman of the board at the center, to slow down the speed of tennis balls.

"The problem with tennis balls is that for the millions of average tennis players, the balls are too fast," Ariel emphasized. "For the average Joe who likes to play on weekends, the game is just too fast. So, at first we were involved in developing larger rackets. Now, we've been looking into slowing down the ball by making it larger and softer." Although illegal in competition, the slow ball has been a tremendous success with Braden's students, Ariel said.

He's also scrutinized the color of balls used in sports. "We've found that the color most people respond to is a dark orange or a light red. We've developed orange and red balls for tennis, volleyball, baseball and other sports."

From Mac Wilkins and the esoteric computerized research involved in improving his performance, to something as apparently mundane as determining the color of tennis balls, the two constants in Gideon Ariel's work have been his fascination with the human body and how it performs, and his refusal to take anything for granted. ○

New England
SPORTSGUIDE

By Milton Cole

The huge athlete cradled the 16-pound ball in his right hand poised just behind his right ear. He whirled in the power pirouette that provides a touch of grace to the brute sport, planted his right foot and took short, powerful steps forward and then lunged ahead, catapulting the steel ball up and away.

There were oohs and aahs and the measurement confirmed what most had thought — amateur hurler Terry Albritton had set a world record of 71 feet, five inches in the shot, fully two feet further than he had ever hurled the shot before.

If there were amazement and joy within the U.S. Olympic team (Albritton is competing in Montreal for U.S.), a former Israeli Olympian received the news in his office in the quiet college community of Amherst, Massachusetts without surprise.

"How can you be surprised," asked Gideon Ariel, "when you knew he could do it? The computer showed it was possible."

Indeed, Terry Albritton's record-breaking throw, the effort to improve Doug Bird as a pitcher for the Kansas City Royals, and the development of new athletic equipment — shoes, tennis balls, tennis rackets — and a new exercise machine, were designed by Gideon and his computer.

In fact, should the U.S. Olympic field events group establish all kinds of records at the July games and in other competition, officials might possibly cast a special gold medal for Gideon Ariel and his Computerized Biomechanical Analysis Inc. (CBA).

In the fall and winter of 1975-76, CBA did a study of U.S. Olympians and asked its computers how they could improve their performances. The result is a series of reports which show what the athlete is doing now, what is wrong with his or her form and how to improve.

It even offers suggestions on equipment changes.

For instance, in Albritton's case his steps were too long and he was losing force because his shoes were slipping on the lunge and release.

He took shorter steps, putting more power into each, straightened his walk, and then wearing a shoe modified to fit a design from CBA studies (one that enables the ball of the foot to turn in a lateral movement of the body, but stops the foot sho when it is planted for leverage) Albri ton hurled the ball a record distanc

Obviously Gideon Ariel is not tak ing all the credit. If Albritton were nc an outstanding athlete with the abilit to put the shot 69 feet, then all th computer studies in the worl wouldn't enable him to throw it 71 plus feet.

"But when you have an outstand ing athlete and then try to improve o his form you often can do goo things," said Gideon in his accente English.

Six years ago when CBA begar Gideon helped a friend discover wh his youth hockey team was havin trouble getting steam into its sla shots. Then graduate student Arie just beginning to design and improv on his computerized biomechanica system, took films of the boys shoot ing the puck. Then, tracing thei muscular and joint movements wit an electronic pencil attached to th computer, he got an electronic pic ture of what the arms, legs, etc. wer doing.

Using physics formulae h figured the optimum pressure point

The computer has its limits. You can chart what muscle and bone will do, but you can't chart what the brain will do.

on the ice for the stick and where the most power would be generated. He presented his findings to his friend and suggested that when the boys were preparing to take their shot, they put a little more pressure on the stick to give the shot more force. The advice worked and Computerized Biomechanical Analysis was off and running.

At the time Gideon was a graduate student and assistant track coach at UMass. The University of Wyoming graduate was able to film UMass and other athletes, chart their arm and leg action and help improve performance even as he was working to improve his system of plotting athletic endeavor. At about this time, 1972, Gideon's work came to the attention of Dartmouth College's track coach, Eric Wienbell, and the pair formed CBA.

But theirs was still a relatively unknown firm and the science that was evolving had not exactly swept the sports world. Still there were some who heard and sought help.

CBA filmed members of the Kansas City Chiefs professional football team and offered some advice on how some of the linemen in particular could improve performance.

No one knows just how much it helped because Kansas City, getting older, fell on some hard times. Gideon insists that his system can only offer the ways to help improve.

"After that it is up to the athlete to implement the advice," said Gideon. "For instance, we can chart athletes and determine what is possible from a muscle-and-bone standpoint. But you can't chart what the brain will do.

"We could check films of Joe Louis and Rocky Marciano and Muhammad Ali and tell what they are capable of from a point of view of their arms, legs, muscles, etc. But there is no way of knowing what a fighter will do if the other fighter drops his hand, or how quickly he is going to decide to throw the left hook or right cross.

"That's why those computer contests that show what would happen if one fighter met another, or one runner met another, or if Red Grange ran against O.J. Simpson, can't really tell an accurate story. The mind, the brain, the decision-making, when to cut back, when to follow the interference, etc. are not measurable."

Gideon and CBA have done readouts on what might appear to be optimum performances. For instance, before the National Football League's National Conference championship game last winter, CBS asked Gideon and CBA to figure out how the respective placekickers, Tom Dempsey of Los Angeles and Tony Fritsch of Dallas, would do.

The computer examined the joint and muscle movement of both, plotted trajectories and decided that Dempsey had the edge because his deformed foot with the square-toed shoe provided more impact force on the ball than did Fritsch.

But the computer could not decide how either would act under heavy pressure situations. As it turned out, the whole study was of little value. Neither kicker played a major role as Dallas creamed the Rams.

What the computer has found is the upper limit that the actual structure of bone and muscle can take and the figures: an 8-foot-4-inch high jump probably never will be attained because no one will ever be able to hit every facet of the optimum performance. Such studies provide Gideon and his firm with vital information to be used in other aspects of sports programs and improvement of performances and equipment.

For instance, CBA has been doing research on shoes. One study was done for the federal government to determine if shoes that we wear normally are improperly designed and if so how they can be improved.

The study which has been filed with the U.S. Department of Commerce indicates that shoes as currently made and designed are a prime cause of lower back problems.

This study was merged later with one done for Uniroyal on a better shoe for miler Jim Ryun to use when running. The government hasn't yet mandated a change in shoe design but Uniroyal has made a shoe for Ryun (since retired) to be used by other runners.

Its heel consists of energy-absorbing, rubber-like material that then helps push the energy back. The heel is designed to flow into the sole in a kind of rolling motion so the energy is constant. The shoe is meeting with success and being emulated by other manufacturers.

The design was pushed further when a study made on optimum performances by runners and jumpers focused on film Gideon took at the 1972 Olympics of Russia's Valery Borzov, gold medal winner in the 100 and 200 meters. That film plus other film taken of hurdlers showed that, contrary to popularly-held opinions, an expert runner does not land on the balls of his feet, the heels or the toes.

Rather, the films — taken at high speeds and then slowed down so they moved one frame at a time — showed that Borzov landed on the outside of his foot, rolled into the full width of the shoe, then landed again on the outside of the other shoe and rolled in.

So, reasoned Gideon and his team at CBA, a proper running shoe would have a shock absorbent heel and the heel and sole would extend out over the outside of both shoes. The shoes are already under design by another major maker of athletic shoes and may be used in the upcoming Olympics.

Similarly, a study was made for a large oil company whose products go into the manufacture of artificial turf, to see if the turf is as dangerous as pro football players claim and if a shoe could be designed to compensate for it.

"Our study showed that the turf is very dangerous. Its texture does not permit any sliding of shoes on its surface and when an athlete plants his foot and then cuts or turns sharply, the foot stays and the strain is all on the knee.

"What we did do, however, was to use all this data to plot a knee brace of light weight that will help to curb the accidents and their severity. We have tested it with the computer and it may be used widely on artificial surfaces in the future," notes Gideon.

CBA also conducted tests for Spalding on tennis balls to try to find a ball that would last longer and perhaps play better.

Using a baseball pitching machine, the CBA crew studied tennis balls as they hit the ground, the racket and otherwise bounced or boomed. From the data and the computer's readout, a new ball is coming onto the market with a different structure of materials and a different felt surface. The design, notes Dr. Ariel (he now has his Ph.D. in exercise science from UMass) provides for

If the U.S. field events group sets any records in July's Summer Olympics, officials should cast a special gold medal for Gideon Ariel.

more of the ball to be on the racket longer. It is only a millisecond longer, but it seems to provide the player with greater control of the ball, greater ability to return the shot or service.

"Those who have used the new ball in experiments are pleased with its performance and with their game without knowing why," said Gideon.

And while studying the action of the tennis ball, the CBA people viewed film of the human arm returning tennis shots and figured that the arm was asked to make more turning motions in returning the ball than it was equipped to do.

"That's where tennis elbow came from," said Ariel who doesn't play too much tennis himself.

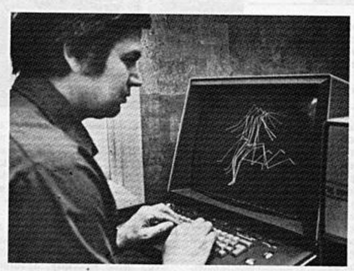
How then to get the racket turned so the face hits the ball properly without making the arm go through unnatural stresses?

The answer, CBA feels, may be an experimental racket it designed. It has a handle that turns. (The grip is on a shaft that lets the grip turn.) The tension is adjustable so that the amount of turn is controlled, permitting the full face of the racket to meet the ball.

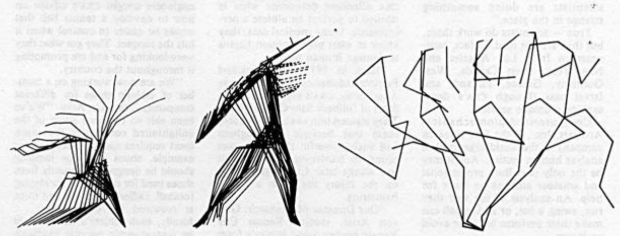
The computer, with the electronic pencil tracing how the sporting equipment or sportsman performs, can offer insight into what is being done wrong and how to do it right. But often doing it right is another matter, a matter of human frailty and inability to adjust. If all could follow the plan designed by the computer and its experts, we'd all be superstars!

In reality, Gideon doesn't contemplate Computerized Biomechanical Analysis as a means of turning out programmed superstars. Rather he sees it as a means of demonstrating what is best and letting the athlete strive toward it, with few achieving it.

Still, if those American-thrown discuses, shots and javelins go flying out of the Olympic Stadium at Montreal this July, Gideon Ariel and CBA may find athletes from all over the world beating a path to its door and its computers. □



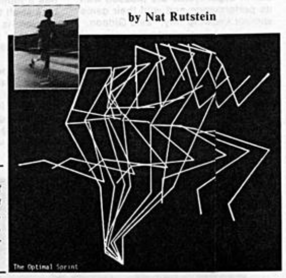
Left: Gideon Ariel computes the electronic pencil's tracings of a runner in action. **Below:** *These spider-web figures are the designs that help the computer and the biomechanical analysts determine the optimum performance of the athlete they are studying. The lines in the first figure belong to Terry Albritton who then set a world record with a 71-foot, 5-inch throw; the second figure traces a javelin thrower in action; and the third figure shows the stress points in a runner.*



IN SEARCH OF THE OPTIMAL SPRINT

CBA, Inc., not only tells Olympic athletes how to better their best marks, it helps design shoes for pregnant women.

by Nat Rutstein



CBA films sprinters in action, feeds it into a computer, and gets back a graphic measurement of motion, force, acceleration, and velocity. Analysis shows how to bring performance up to optimal levels.

Looking at the cluster of shops in Amherst, Mass., you would never think that a company based there had helped an Olympic gold medalist improve his performance. Its sign, COMPUTERIZED BIOMECHANICAL ANALYSIS, INC., even baffles the town's Ph.D.s, and there are hundreds of them around. Even the stores that flank it are mystified. A counterman at the adjacent sandwich shop thinks "a bunch of mad scientists are doing something strange in the place."

True — scientists do work there, but they are not mad. In fact, businessmen from Los Angeles and New York, from Canada, West Germany, Greece, Finland, and Israel pass through CBA's door, seeking a unique service.

Computerized Biomechanical Analysis, Inc., is the first research company in the world organized to analyze human motion. And it may be the only one. Both professional and amateur athletes go there for help. An analysis of the way they run, swing a bat, or kick a ball can make them perform better or avoid an injury.

Athletes are filmed in action. After the film passes through special tracing equipment, one frame at a time, it is fed into a high speed computer, which spews out a graphic report. The readouts give a quantitative measurement of motion, as well as the direction of force, acceleration, and velocity of specific parts of the body. In other words, the contribution of each body segment to the whole motion is measured. With this information, CBA scientists determine what is needed to perfect an athlete's performance. Using medical data, they know at what point motion begins to damage human tissue.

"Back in 1972, New England Patriots coaches came to us," says Ann Penny, CBA's president, "with films of fullback Sam Cunningham. They wanted him analyzed. We told them that because Cunningham had such powerful thighs, he was prone to hamstring pulls. About two weeks later Cunningham was on the injury list, with a pulled hamstring.

"Our Director of Research, Gideon Ariel, studied Kansas City Royals pitcher Steve Busby's form and discovered that though he was getting maximum velocity on the ball, he was going to have knee trouble because there was too much stress on it. Royals' management was flabbergasted because they were trying to keep Busby's knee trouble secret . . . they had him on the trading block."

Sports equipment outfits approached CBA for help with design of shoes, body-building devices, even balls. Recently, Spaulding engineers sought CBA's advice on how to develop a tennis ball that would be easier to control when it hits the racquet. They got what they were looking for and are promoting it throughout the country.

"We are now working on a number of athletic shoes for different companies," says Dr. Ariel. "We've been able to convince some of the enlightened companies that each sport requires special footwear. For example, shoes used for jumping should be designed differently from shoes used for running or for playing football. Different motion and force is required for each sport .... Ideally, each athlete's shoe should be custom-made because everyone is different."

In the back room of CBA's unassuming headquarters is more than $300,000 worth of equipment, including computer programming devices and special tracing equipment, all hooked to a network of computers in different cities. CBA also has a special arrangement with the University of Massachusetts Computer Center.

Beyond the operations area is the trophy room, where an assortment of chrome body-building machines stand out, all designed or refined by CBA. Dr. Ariel points with pride to a machine he designed for Universal Gym. "With this piece of equipment, an athlete is able to strengthen his muscles by lifting an increasing amount of weight — up to 1,010 pounds."

Gideon Ariel is the bedrock on which the company is built. He is not only a pioneer in human motion analysis, but is also committed to sharpening and refining human physical potential. For him, his work is a cause.

Ariel sets the tone and tempo at CBA headquarters, and his Israeli background has much to do with the working climate. Everyone is fastidious, aware of their goals, achievement oriented, yet relaxed. Studying computer readouts at 2 A.M. is not uncommon for them.

Ariel can appreciate an athlete's struggle for perfection. He hurled the discus for Israel in the 1960 and 1964 Olympics, starred for the University of Wyoming track team, and was an assistant track coach at the University of Massachusetts. The U.S. Olympic Committee has used his services, and so has Mac Wilkens, the 1976 Olympic gold medal discus thrower. Seven months before the Olympics, Ariel was observing Wilkens at a meet. And as a result of his biomechanical calculations, Wilkens was eventually able to throw the discus 16 feet further than his previous best.

Because of his dedication to amateur athletics, Ariel refuses to take money for analyzing a nonprofessional athlete's performance. Since receiving his Ph.D. in Exercise Science from the University of Massachusetts, he has developed an international reputation and has many friends in the sports world. Bill Toomey, the 1968 Olympic decathlon champion, is not only a friend but works for CBA as a market specialist, representing the company in the West.

Though involved in a flourishing business, Ariel remains a scholar. He is still involved in university research. Through a National Institute of Health grant, he and University of Massachusetts professor Michael Arbib are measuring cat coordination, trying to find out how the animal's brain controls its muscles. "Perhaps from this study," he says, "we might discover a clue as to how to improve human coordination." Some of the research work is taking place at CBA.

Graduate work in exercise science drew CBA President Ann Penny to Amherst. She expects to have her University of Massachusetts doctorate in June.

"Ann is steady; she knows every facet of our business," says Dr. Ariel. "Perhaps that's why the stockholders elected her president."

Determination and dedication best describe the North Carolinian, who admits to being swept up by Ariel's enthusiasm. "Biomechanics is an exciting field," she says. "And it's thrilling to be in the forefront of a science that can do so much good for people; not only athletes, but for the average person as well.

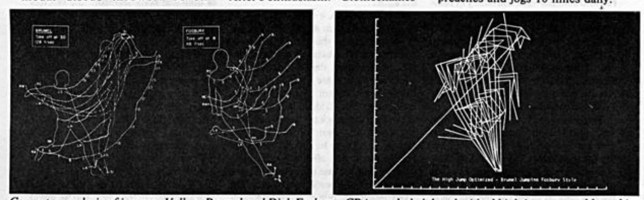
"Unfortunately very little thought is given to designing things like shoes that are biomechanically sound. More effort and money are devoted to the cosmetic aspect than to consideration of the bodily damage poorly designed shoes can generate. Back problems can result from bad footwear.

Penny has another deep concern. "Coaches seem threatened by what we can do for their athletes. They think we'll put them (the coaches) out of business, but the opposite is true. We can help them optimize their athlete's performance.

"Take the time we analyzed Bill Schmidt, the javelin thrower. The computer data showed that he lost force because he dropped his hip when executing. After pointing that out to Schmidt, he uncorked a throw of more than 300 feet, a record for him.

"We can help Los Angeles Rams kicker Tom Dempsey regain the form he had when he was booting longer field goals. Remember when he was with the Saints, and he kicked a 63-yarder? We analyzed pictures of that kick and discovered that he had more arm swing then than he has now. The coaches made Dempsey shorten his arm swing; consequently, shorter kicks."

A graduate of the University of North Carolina at Greensboro, Penny coached basketball and tennis at Princeton day school in New Jersey. She practices what she preaches and jogs 10 miles daily.



Computer analysis of jumpers Vallery Brumel and Dick Fosbury. CBA concluded that the ideal high jumper would combine Brumel's tremendous lift and acceleration with Fosbury's novel flop style.

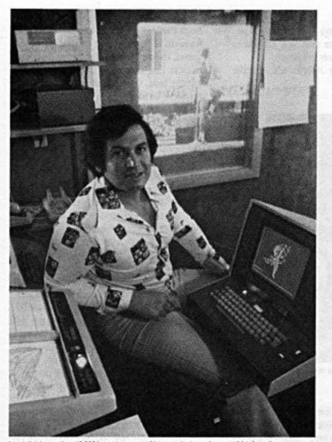
"Faith" is a fine invention
When Gentlemen can see—
But Microscopes are prudent
In an Emergency.
—EMILY DICKINSON

Around Amherst, Mass., colleges run into colleges—the University of Massachusetts, Hampshire, Amherst, Mount Holyoke, Smith—leaving little room for a real town. The population is incessantly changing, fresh ideas flowing through a setting that has a history of assisting clear thought, elegant patterns. Emily Dickinson wrote and is buried here, and Robert Frost's birches are still bending.

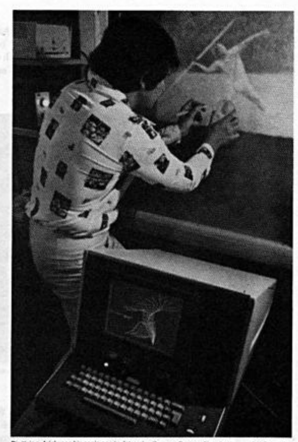
Working today in Amherst is a man who would hardly consider himself poetic, but Gideon Ariel has been a leading figure in taking the great raw minds of computers and bringing them to bear on movement. In so doing, he has for the first time let us see the line and meter of human motion. Sport can never be the same.

In the first place, it seems that we have been proceeding on a false assumption. We have believed that trained observers can discern the crucial elements of athletic performance, that coaches can see what their athletes are doing wrong. "The human eye cannot quantify human movement," says Gideon Ariel, ponderously, because he is a big man who threw the discus and shot for Israel in two Olympics, because he still struggles with his Hebrew accent after 14 years in this country, and because that sentence is the foundation of his revolutionary advance. "The important things in performance, the timing, the relative speeds of dozens of limb and body segments, the changes in centers of gravity—these all must be measured, weighed, compared to be of any use."

Ariel is a natural teacher, reaching always for images so vivid the dumbfounded or skeptical will be forced to see. "Compare coaches with bridge engineers," he says. "Suppose an engineer finishes the bridge and says, 'Wait, remove that beam.' You ask why, and he says, 'I took a survey of 100 drivers, and 75 said it looks better without the beam.' That is how coaches coach. What looks best. But if an engineer did that there would be a lot of cars in the river. And he would



It took Ariel more than 10,000 hours to program his computer to analyze an athlete's motions.



Digitizing, Ariel uses his sonic pen to determine the coordinates of javelin thrower Bill Schmidt.

find himself in the nuthouse, because he is required to measure the strength of his materials and design against the weight of his load."

People are subject to the same physical laws as bridges. Indeed, Leonardo da Vinci believed mechanical science the noblest, "seeing that by means of it, all animated bodies that have movement perform all their actions." Isaac Newton described the laws of motion in 1700, but not as vibrantly as does Gideon Ariel. "It doesn't matter if you lift a cow, or throw a chair, or punch your girl friend. Everything is according to Newtonian physics."

The problem, until now, has not been that we haven't believed this; it has been that too many things happen too fast for us. The sheer complexity and velocity of a javelin thrower's movement in the final quarter second before release, for example, preclude comprehension of what is going on.

Technology helps. One of the earliest uses of photography was to settle the turn-of-the-century question of whether all four hooves of a galloping horse ever were off the ground at once (they are). In the 1930s, high-speed cameras provided slow-motion photography to offer a clearer view of the action. Dozens of limb and body parts accelerating and decelerating could be seen and measured and charted against one another. Patterns of successful athletes began to appear.

"The better the athlete, the more sophisticated his timing," says Ariel. "The one basic principle of all sports—hitting or kicking balls, punching, throwing, jumping, breaking karate bricks—is a coordinated summation of forces."

But so delicate are the relationships between an athlete's many moving parts that they cannot be assessed simply by looking at the slowest of motion pictures. A process of frame-by-frame, body segment-by-body segment analysis is necessary to make optimum use of cinematography, work that is painstaking, dreary and absurdly time-consuming. Gideon Ariel gave that work to the computer and suddenly the maddening complexity of human motion could be matched by the awesome memory and speed of the machine. Well, not quite suddenly. It took Ariel some 10,000 hours over seven years to create the programs that instruct his computers. Now he offers the sporting world a chance to lift itself from, as he puts it, "the dark ages, a witchcraft business where everything is made of thin air." Over those years, Ariel transformed himself as well, from a carefree discus thrower to a compelling, caprizant figure, half academy lecturer, half medicine-show barker, a character entirely appropriate to spark the gap, to complete the circuit between science and sport.

Gideon Ariel is a fleshy man, with direct, hazel eyes and a shock of black curls graying at the temples as he enters his 39th year. His accent bears a resemblance to that of Alan Arkin playing Freud in *The Seven-Per-Cent Solution*, but he shouts more. Occasionally brilliant explications to visitors or students are followed by awkward silences because his Hebraic rhythms have made "quats" and "kets" of quartz and cats. Because photography is crucial to biomechanical analysis, Ariel speaks often of "fillums." But it is Ariel's work, not his speech, that has made him a hero to hundreds of athletes.

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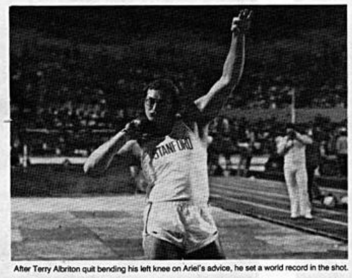
Shotputter Terry Albritton's mistake was similar to Wilkins'. "That front leg has to be the solid block you throw from," says Ariel. "What Terry was doing, bending that knee, was like trying to throw from a trampoline or shoot a cannon from a canoe." A year ago Ariel told Albritton he could be the next world-record holder if he'd stop doing that. A month later Albritton was the next world-record holder, with a put of 71′ 8½″.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No sport is immune to Ariel's iconoclastic examination. Not long ago, he and his staff spent 4,000 hours analyzing the behavior of tennis balls, filming them at 10,000 frames per second as they struck rackets and assorted surfaces,

"Tennis people think they can feel the ball on the racket. They talk as if they can do things to control it then," says Ariel, waving an imaginary racket. "We discovered that a tennis ball is on the racket approximately four milliseconds. Four one-thousandths of a second. Human reaction time is 120 milliseconds or more, so that ball is long gone before anybody feels it. It is off the racket even before the racket gives." Such a sharp jolt obviously packs a great deal of energy into the briefest of moments. "The muscles can't react to it, so the elbow, which is a single plane joint and can't pass any of the shock along, can briefly receive a hundred times the force it does when you throw something. No wonder people get tennis elbow."

The tennis ball study was commissioned by a manufacturer who will use the results to design balls that remain on the racket longer. But Ariel was most fascinated by having to devise a new equation to describe the behavior of elastic objects colliding at oblique angles, because these didn't seem to follow textbook physics. "The point of maximum compression is not the point of maximum force," he says excitedly. The commercial overtones of the research did not hold his interest. "They talk about light balls, heavy balls. Such craziness. All the brands were so much the same it was like they were made by the same machine."

Because so many of the body's reverberations end up in the feet, Ariel has long been interested in athletic shoes. "That is the witchcraft business, for sure," he says. "Shock absorption is the key to better distance running, no question, but look." He flips through a book of data. "Some brands absorb 2,300 newtons, some only 1,000. That range! And the manufacturers don't even know what their own shoes do."

Ariel, using an exquisitely sensitive $25,000 force plate, which transmits readings of four kinds of pressure—vertical, forward, sideways and twisting—to an oscilloscope, charted the forces of footstrike in different shoes at every

you want to be a discus thrower, you have to live with the discus. Carry it with you. Sleep with it."

That is what he did, with both shot and discus, throwing them as much as eight hours a day. "I threw from pictures. Coaches meant well, but one would say one thing, another would contradict him. It was all opinion. How did they know?"

One who knew a lot more than the rest was Dr. LeRoy Walker of North Carolina Central, who later became head coach of the 1976 U.S. Olympic men's track and field team. In the late '50s Walker coached Israel and Ariel. "He told us to do things we never did, like sprints and weight lifting, and we were all so sore after the first day we said, 'This guy is crazy.' But he had a method. He said, 'Go throw 500 times and we will talk. I can't tell you anything now because your variability is so great.' It worked. I got a pattern down and we could go from there. We talked about forces and angles. It was the beginning of a scientific approach."

They also talked about college scholarships, and after Ariel had taken part in the Rome Olympics and spent three years in the Army, he came to the University of Wyoming. "My life was just to throw the discus," he says.

When he graduated in 1966, it was found that Ariel had spent three years at Israel's Wingate Institute, earning a Diploma of Physical Education degree in 1960. He had never thought to tell anyone about it and had thus completed three years of U.S. college athletic competition without being eligible for it. "Wyoming was fun," he says now, "but the coach wasn't like Dr. Walker. It was back to opinion."

Ariel applied to the newly created School of Exercise Science at the University of Massachusetts, got his master's degree in nine months, became an assistant track coach and then plunged into an eclectic set of studies with all the fervor of his early years with the discus. "There had to be 20-hour days for him then," recalls University of Massachusetts Track Coach Ken O'Brien. "I'd find him sleeping at his desk in the mornings. A professor in one of his classes would mention some advance in an allied field, like calculus or cybernetics, and Gideon would go over and take the course."

One such suggestion came from the head of the computer science department. "He said, 'Why don't you apply computers to your mechanics?' " recalls Ariel, who was sick of laboriously tracing every joint on paper, limb by limb, frame by frame. But how? How to find a way of getting all this raw information into the computer? The answer was a device called a digitizer, a screen lined on two sides by 20,000 tiny directional microphones. The coordinates of any point on the screen touched with a sonic pen are automatically registered and fed into the computer. While visiting the Dartmouth Medical School, Ariel happened across one of these instruments, which looks not unlike a movie screen mounted in a console. "Then in 1968 Dartmouth started the computer time-sharing concept. The potential was unbelievable. All I needed was a $50-a-month rental to put a terminal in my house and I could do anything."

With his keyboard terminal installed, Ariel plunged into writing computer programs. "The whole idea is simple," he says. "Human beings are creative, but we have terrible memories. Computers are dumb, but their memories are perfect. You have to guide them, lead them step by step, channel your creativity through the software, the programs, till you have created a monster. It grows and you have to write more and more programs so it can do more and more things." What sustained those thousands of hours of labor? "It is fascinating work, and frustrating. For example, the equipment in our lab, which comes from 10 or 12 different companies, all had to be electronically interfaced. That was hard to figure out, how to get them working together without burning everything up. The exciting part is the conceiving, the finding out what you think you can do. Then it takes a long time to get the computers to actually do it." In other words, this is exactly like any other worthy craft.

In 1971 Ariel founded Computerized Biomechanical Analysis, or C.B.A., and landed a few contracts testing basketballs for Spaulding and shoes for Uniroyal. This allowed him to purchase more advanced equipment. Purdy predicts that Ariel is now about to reap rewards far above professional satisfaction. "If he's solved those problems of practical application, he'll find a ton of marketable uses. Look what digitizing analysis could do for the sports that are now judged subjectively, like diving or gymnastics. For the first time we could really measure how close a performer comes to perfection. Think of that, we wouldn't have those prejudiced Russian judges in there messing up results."

And there is always the lucrative world of product development. The key to opening it is the software, those valuable programs that are generally not copyrighted (one tiny change in a lengthy series of instructions to a computer obviously can cause drastically changed results). Add the fact that few scientists in the field are business oriented, least of all Ariel, and the situation seems ripe for corporate wrangling. Since receiving his Ph.D. in exercise science in 1972, Ariel has been involved in a train of legal skirmishes with an exercise-equipment company that couldn't stomach his analysis of its product (settled out of court with a public apology to Ariel), and with a colleague and one-time professor over some rights to C.B.A. Possessed of an unshakable faith in his own rectitude, Ariel will surely live out his life as one of those litigation-prone scientists—da Vinci was one—who feel somehow unclothed unless they have six lawsuits pending.

Gideon Ariel does not claim to be a true pioneer in biomechanical analysis. Sweden's Ingvar Fredricson has been studying the motion patterns of standardbred horses with a computer for 10 years, predicting lameness from minute stride irregularities, and discovering that most trotting tracks are banked too much on the straightaways and too little on the turns, placing dangerous stress on delicate forelegs. At Penn State, Peter Cavanagh is well along in a study of human stride patterns. But as Ed Burke, the U.S. record holder in the hammer throw and a close friend of Ariel's, says, "A lot of biomechanical people are contributing in their own quiet way. Gideon is contributing in his own, uh, inimitable way."

Ariel has had occasion to see what he might have ended up doing had he not harnessed the computer. "In 1972 I was in Spain and met with some East German coaches. I looked at the East German shotputters and saw that they all threw with exactly the same form, as if they had been molded that way. They all lifted their back legs before they re-

leased the shot. I mentioned this and a coach said, 'Oh really? We'll have to correct that.' I said, 'Don't give me that. It's good.' I knew we had something in common, a shared knowledge. Equations of motion are equations of motion. I saw notes from years before. Those men began long before I did. But they'd been doing it *by hand*. Imagine 15 engineers working a month to chart one shotput!"

There are times when Ariel becomes unabashedly sentimental about his U.S. experience, and this memory triggers a paean to the American system. "There was a time when we needed to know relative weights of body segments. We wrote to NASA research and they sent back books of data. No charge. That was a tremendous help. We couldn't have gone on without it. But in East Germany they would say, 'Confidential, classified.' Here, people are open-minded."

As if in recompense, Ariel has offered his services at cost to the U.S. Olympic Committee as it readies for the Moscow Olympics. "Until 1964," he says, "talent alone still worked. Since then sport has been a science, not an art. There is no way anyone is going to beat the talent in this country if it is properly prepared." Since May, Ariel has been spending half his time at the newly opened Olympic Training Camp at Squaw Valley, Calif. (*page 46*), working with field hockey players, soccer players, women's basketball players, kayakers and swimmers. As usual, he has doled out hours of fascinating advice. What is the optimum free throw? "The more limb segments you use, the more chance for error in coordination," he says. "The best players just use the knees for lift, and flip with the forearm. Simplest is best." In a skill as basic as jumping, Ariel brought about a two-inch improvement in one female basketball player whose coach had had her bending her knees too deeply before ascent.

The ice hockey coaches were reluctant to use Ariel's services until he explained to them, for the first time, just how it is that a slap shot by a small player can attain much greater velocity than a sweep shot by a monster. "The better shooters hit down on the ice behind the puck and bend the stick so it becomes loaded with energy. Then they flick the puck, like this," he said, flipping paper balls at the astonished and somewhat embarrassed coaches.

Indeed, Ariel's findings and progress in biomechanical research present a challenge to all coaches. After he stops calling them witches and predicting that a computer-monitored individual training system will do away with them, he backs down a bit, saying, "I can't coach the Dallas Cowboys, but I can give them more information. I can tell them where and how to hit the other players, how to create the greatest force in blocking, how to brace knees, improve helmets. People cry about removing the art from sport. But they started it. Why do you time a runner, or measure a jumper, or count goals? Maybe we shouldn't. But once you decide to use all those numbers, O.K., let's really use them." This has some added force, said as it is while Ariel dramatically unfolds a printout of thousands of multidigit measures of Offensive Tackle Rayfield Wright's center-of-gravity fluctuations, the paper spilling across his desk and onto the floor.

Ariel's old boss, Track Coach O'Brien, has thought about the threat he poses to old-school coaches. "Gideon assumes, rightly, that most coaches don't know biomechanics, physics or biology, and haven't got a burning desire to learn. Coaches just use what has seemed to work in the past. It's true that you can't see enough. We see positions, we see lines, but we don't see magnitude, how hard that foot is pushing. If we are willing to admit we're inadequate in those areas, we will use the techniques he has developed."

O'Brien sees a possible source of resentment in the necessity of coaches relinquishing athletes to outside analysts like Ariel. "Nobody likes to share the credit." O'Brien has observed Ariel's presentations to several coaching clinics. "He's a good entertainer. You pretty much have to respond to the force of his personality, so it is illuminating to watch the people when he's done. Some rush him for more and more. They're all saying the same thing. 'Where can I use it? How the heck can we make it available?' The others are turned off. They drift out shaking their heads, sullen."

One sees the same dark clouds on the brows of corporate sporting-goods executives that fogged the brains of Galileo's judges. Science is no respecter of tradition, and Gideon Ariel is a man of pure, almost innocent, science. In his lab is a scientifically designed shotput shoe. It has laces inside its laces and is twisted, as if a truck had run over it. "Did you ever see anyone put the shot while standing up straight? No. This shoe cocks the foot into position and the double laces save energy. It works." No manufacturer will touch it. "It wouldn't look so good on display," Ariel says. "And how many shotputters are there in this country?"

A maker of golf shoes wanted C.B.A. to prove its shoes were the most comfortable, comfort being the basis of its advertising. Science had other ideas. "What is 'comfortable'?" Ariel demanded. "Does that mean a man can swing better? What if the best shoes for golf shots make a man limp down the fairway? You cannot high-jump in comfortable shoes. You cannot shoot a cannon from a canoe because the canoe is going under the water. . . ." The golf-shoe people departed with pinched expressions. Later they retained Ariel's services, warily.

A ski-boot company once got Ariel up to Vermont to analyze the forces on the ankle joints of a downhill skier. He proposed, for safety, the use of electric strain gauges on the bindings. "It was as if someone said to General Motors, 'Make an electric car.' It was too revolutionary. There is one word that seems to paralyze these people—that is 'retool.' "

Yet Ariel does not brood over temporary setbacks. His company owns outright all of his equipment, so if contracts or grants should dry up, he could press on with research. And his own competitive juices still surge. Recently, he got a call from an old hero of his, Al Oerter, the 40-year-old, four-time Olympic discus champion. "We, he and I, are going to reenter the ring," Ariel says, his eyes gleaming. "We will put him in a more efficient position. We will cut down on shoe friction. We will overcome physiological deterioration with scientific advance!" Ariel listens to his own echoes in the lab. "He was so nice on the phone, I had to say yes. He told me, 'We competed in the same Games.' But I didn't ever make the final."

Ariel—the scientist who is revolutionizing sport with his sonic pens and slow-motion cameras and computer printouts—smiles, seeing, perhaps, a pattern. "I was always too emotional in the big meets." END

Want a better athlete? Now scientists can build one for you

By Gaylen Moore

"Give me a kid with natural abilities and nothing can stop us from making him the best in the world," says Dr. Marvin Clein, chairman of the department of sports sciences at Denver University.

"There are certain personality traits that successful athletes share," notes Dr. Bruce Ogilvie of San José State University in California. "My job is to isolate the psychological weaknesses, and to strengthen those traits required for competition."

Clein, Ogilvie and others represent a new breed of sports trainer. They're scientists who use the findings of their fields, from physics to psychology, to improve an athlete's performance. Results have been nothing short of sensational.

Leslie Covillo of Golden, Colo., is a 15-year-old runner who was brought to Dr. Clein after her parents had read about him in a magazine. She was gangly and awkward, and had trouble running a straight line. "I'd made the track team," she recalls, "but I wasn't anything great. I thought if I had a coach, I could run a lot better."

Dr. Clein put Leslie through a series of tests: psychological, physical and others. "From the study," Clein reported, "we decided that Leslie needed development in two areas. She had to build up her body strength, and she had to learn *how* to run."

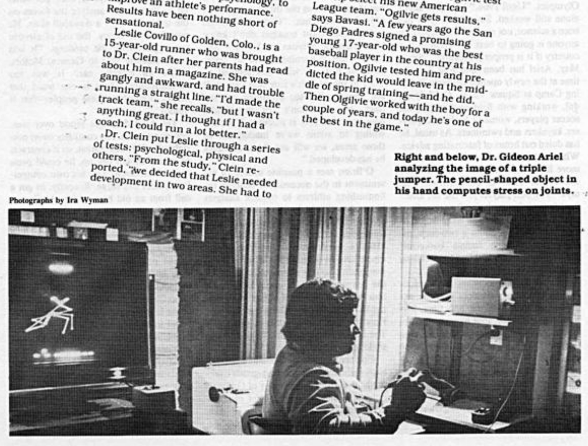
They worked together for five months. Then, the first time she went out on the track, Leslie came close to tying state high-school records.

Bruce Ogilvie, who works closely with Clein, specializes in the athlete's psyche, investigating such personality factors as motivation and commitment. He's worked with pro football, baseball and basketball teams and the last four U.S. Olympic teams. To some, his powers border on the prophetic.

Peter Bavasi, general manager of the Toronto Blue Jays, used an Ogilvie test to help select his new American League team. "Ogilvie gets results," says Bavasi. "A few years ago the San Diego Padres signed a promising young 17-year-old who was the best baseball player in the country at his position. Ogilvie tested him and predicted the kid would leave in the middle of spring training—and he did. Then Olgilvie worked with the boy for a couple of years, and today he's one of the best in the game."

Right and below, Dr. Gideon Ariel analyzing the image of a triple jumper. The pencil-shaped object in his hand computes stress on joints.

Photographs by Ira Wyman



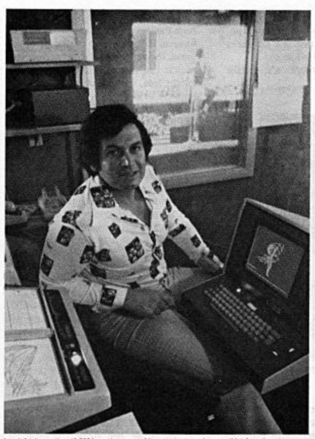
"Faith" is a fine invention
When Gentlemen can see—
But Microscopes are prudent
In an Emergency.
—EMILY DICKINSON

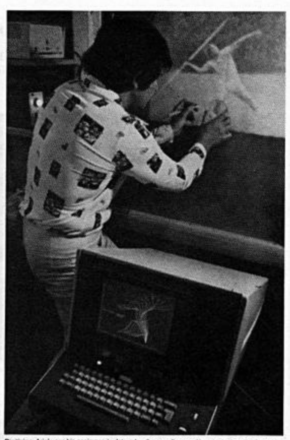
Around Amherst, Mass., colleges run into colleges—the University of Massachusetts, Hampshire, Amherst, Mount Holyoke, Smith—leaving little room for a real town. The population is incessantly changing, fresh ideas flowing through a setting that has a history of assisting clear thought, elegant patterns. Emily Dickinson wrote and is buried here, and Robert Frost's birches are still bending.

Working today in Amherst is a man who would hardly consider himself poetic, but Gideon Ariel has been a leading figure in taking the great raw minds of computers and bringing them to bear on movement. In so doing, he has for the first time let us see the line and meter of human motion. Sport can never be the same.

In the first place, it seems that we have been proceeding on a false assumption. We have believed that trained observers can discern the crucial elements of athletic performance, that coaches can see what their athletes are doing wrong. "The human eye cannot quantify human movement," says Gideon Ariel, ponderously, because he is a big man who threw the discus and shot for Israel in two Olympics, because he still struggles with his Hebrew accent after 14 years in this country, and because that sentence is the foundation of his revolutionary advance. "The important things in performance, the timing, the relative speeds of dozens of limb and body segments, the changes in centers of gravity—these all must be measured, weighed, compared to be of any use."

Ariel is a natural teacher, reaching always for images so vivid the dumbfounded or skeptical will be forced to see. "Compare coaches with bridge engineers," he says. "Suppose an engineer finishes the bridge and says, 'Wait, remove that beam.' You ask why, and he says, 'I took a survey of 100 drivers, and 75 said it looks better without the beam.' That is how coaches coach. What looks best. But if an engineer did that there would be a lot of cars in the river. And he would


It took Ariel more than 10,000 hours to program his computer to analyze an athlete's motions.


Digitizing, Ariel uses his sonic pen to determine the coordinates of javelin thrower Bill Schmidt.

find himself in the nuthouse, because he is required to measure the strength of his materials and design against the weight of his load."

People are subject to the same physical laws as bridges. Indeed, Leonardo da Vinci believed mechanical science the noblest, "seeing that by means of it, all animated bodies that have movement perform all their actions." Isaac Newton described the laws of motion in 1700, but not as vibrantly as does Gideon Ariel. "It doesn't matter if you lift a cow, or throw a chair, or punch your girl friend. Everything is according to Newtonian physics."

The problem, until now, has not been that we haven't believed this; it has been that too many things happen too fast for us. The sheer complexity and velocity of a javelin thrower's movement in the final quarter second before release, for example, preclude comprehension of what is going on.

Technology helps. One of the earliest uses of photography was to settle the turn-of-the-century question of whether all four hooves of a galloping horse ever were off the ground at once (they are). In the 1930s, high-speed cameras provided slow-motion photography to offer a clearer view of the action. Dozens of limb and body parts accelerating and decelerating could be seen and measured and charted against one another. Patterns of successful athletes began to appear.

"The better the athlete, the more sophisticated his timing," says Ariel. "The one basic principle of all sports—hitting or kicking balls, punching, throwing, jumping, breaking karate bricks—is a coordinated summation of forces."

But so delicate are the relationships between an athlete's many moving parts that they cannot be assessed simply by looking at the slowest of motion pictures. A process of frame-by-frame, body segment-by-body segment analysis is necessary to make optimum use of cinematography, work that is painstaking, dreary and absurdly time-consuming. Gideon Ariel gave that work to the computer and suddenly the maddening complexity of human motion could be matched by the awesome memory and speed of the machine. Well, not quite suddenly. It took Ariel some 10,000 hours over seven years to create the programs that instruct his computers. Now he offers the sporting world a chance to lift itself from, as he puts it, "the dark ages, a witchcraft business where everything is made of thin air." Over those years, Ariel transformed himself as well, from a carefree discus thrower to a compelling, caprizant figure, half academy lecturer, half medicine-show barker, a character entirely appropriate to spark the gap, to complete the circuit between science and sport.

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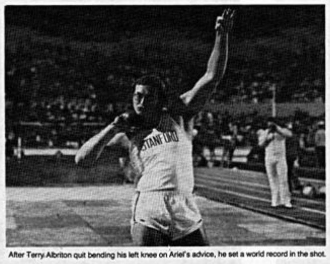
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"Tennis people think they can feel the ball on the racket. They talk as if they can do things to control it then," says Ariel, waving an imaginary racket. "We discovered that a tennis ball is on the racket approximately four milliseconds. Four one-thousandths of a second. Human reaction time is 120 milliseconds or more, so that ball is long gone before anybody feels it. It is off the racket even before the racket gives." Such a sharp jolt obviously packs a great deal of energy into the briefest of moments. "The muscles can't react to it, so the elbow, which is a single plane joint and can't pass any of the shock along, can briefly receive a hundred times the force it does when you throw something. No wonder people get tennis elbow."

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Because so many of the body's reverberations end up in the feet, Ariel has long been interested in athletic shoes. "That is the witchcraft business, for sure," he says. "Shock absorption is the key to better distance running, no question, but look." He flips through a book of data. "Some brands absorb 2,300 newtons, some only 1,000. That range! And the manufacturers don't even know what their own shoes do."

Ariel, using an exquisitely sensitive $25,000 force plate, which transmits readings of four kinds of pressure—vertical, forward, sideways and twisting—to an oscilloscope, charted the forces of footstrike in different shoes at every

back to California with the results, plopping 50-to-80-page computer print-outs into the bemused throwers' laps. One recipient was Mac Wilkins. The sheets of numbers meant little to him, but not Ariel's interpretation. "He pointed out that my front leg was absorbing energy that could go into the throw," says Wilkins. "I had to begin to change my whole conception of throwing. I used to think I had to put as much of my speed as I could in the direction of the throw."


After Terry Albriton quit bending his left knee on Ariel's advice, he set a world record in the shot.

Ariel, citing Newton's law about every action requiring an equal and opposite reaction, said no. "It's vital to have everything *stopping* in the discus. In the best throws, we found a pattern. It is like using a fly rod, or snapping a towel. You have to decelerate the heavy parts, the legs and the trunk, so you can accelerate the light parts, the arm and the discus." Ariel spoke to Wilkins with special care, because the analysis had shown him generating incredible speed in one section of his spin. "He was like 30% faster than the rest, even though he was dissipating it at the end. But if you see that, you know the potential is there." The computer found that with a perfectly timed summation of his forces, Wilkins could throw the discus 250 feet.

"It seemed a little far at the tim , says Wilkins, whose best was 219′ 1″. Indeed, the world record was 226′ 8″. But the second and third times Wilkins put Ariel's advice into practice, he broke the world record, eventually reaching 232′ 6″ and winning the Olympic gold medal at Montreal. He continues to throw, calmly maintaining he has not lived up to his potential, and for once that is a judgment supportable with clear evidence.

Shotputter Terry Albritton's mistake was similar to Wilkins'. "That front leg has to be the solid block you throw from," says Ariel. "What Terry was doing, bending that knee, was like trying to throw from a trampoline or shoot a cannon from a canoe." A year ago Ariel told Albritton he could be the next world-record holder if he'd stop doing that. A month later Albritton was the next world-record holder, with a put of 71′ 8½″.

Sometimes the camera and computer happen upon events that bluntly refute accepted theory. Long jumpers have all trained by rising to their toes under heavy weights, strengthening their calves for the last push from the board. Ariel's analysis showed, however, that the best jumpers don't point their toes until the pushing foot is already two feet off the ground. "Far more important than the jumping leg is the free leg," says Ariel. "It and the torso accelerate as the planted leg decelerates. Then the jumping leg is yanked off the ground. That leg isn't pushing, it's trying to catch up."

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point of foot placement. "You see pictures of runners, it looks like they're landing on their heels, but they're not. The good ones don't. They flick the foot down flat at the last instant. All these companies are making wonderful heels and the best runners are never coming down on them." One company, Pony, bowed to Ariel's advice and has brought out a shoe tested in his lab.

Visiting Ariel's office and laboratory, tucked away in a storefront between Erik's Giant Subs and Radio Shack, one sees wonders everywhere, like the electronic display on which he can call up the style of a shotputter or quarterback in the form of a sequence of glowing green stick figures. "You have to be very responsible to change the form of any good athlete," he says. "The better the athlete, the more it seems wrong to fool with him." So Ariel has programmed the computer to fool with an electronic copy of the athlete instead, changing angles, timing, even weight, and with each change he computes how performance would be affected. Seeing that, the imagination goes spinning off into a giddy future, where performance can be predicted years in advance, where technique and training can be fitted to individual talents. It turns out that Ariel is already disappearing into that future.

"We examined film of Dick Fosbury winning the Olympic high jump in 1968 and of Valery Brumel jumping his earlier world record of 7' 5¾". We found that of the total forces generated, the flop style has a higher vertical component. The computer that had Brumel use the flop. Had he known about it when he was jumping, Brumel could have cleared 7' 11". So we will one day see an eight-foot high jump."

Bud Greenspan, who produced *The Olympian* series on PBS television, provided Ariel with slow-motion film from 1936. He wanted to know who was the better sprinter, Jesse Owens or Eddie Hart, the present coholder of the world record for 100 meters at 9.9 seconds. Owens had run 10.2 on cinders, without starting blocks, Hart on polyurethane, with blocks, but Ariel saw no problem. "We knew the angular displacements, so we knew how many degrees per second their ankle, hip and knee joints displaced. We knew the length of the bones and the speed of the film frames, so we knew how much distance was covered per second. We let each man cover 100 meters and computed the time it took him." The winner? Jesse Owens.

When Mac Wilkins heeded the advice of Ariel's computer, he set a world record in the discus.

The precision with which Ariel's machines can trace movement patterns has widespread application in injury prevention and treatment. "Any little pain will change the pattern of locomotion," he says. Just now, Ariel has finished an analysis of film sent by the Dallas Cowboys, who wanted to find out if injured players were returning to normal patterns.

The possibilities for rehabilitation, or the teaching of any sort of muscular coordination, are enormous, especially now that Ariel has a little computer that can take instructions from a stick. Unlike the $8 million University of Massachusetts computer that Ariel dealt with through telephone connections and a Telex keyboard, his new one, the size of an electric stove and costing only $60,000, displays a set of functions on a screen and the operator selects the one he wants performed by directing a floating indicator light with a lever Ariel calls a joy stick. In a slot goes a black, magnetic insert that can hold nearly a million bits of information. The term for these is flexible diskettes—"floppy disks," in Ariel's argot. "In scientific training, a man will have his own floppy, containing his whole athletic history and an individual program computed for his needs. As he works in the gym or on the field, the computer will monitor him, giving him instant feedback directions . . . congratulations." Dr. Gerry Purdy, author of *Computerized Running Training Programs* and one of the few men in the field who share Ariel's dual expertise in computers and exercise science, says of this, "My first reaction is that he's bordering on artificial intelligence. Academically, it's not unreasonable, but from a practical standpoint, it's like *Star Wars.*"

Yet clearly the last obstacle to such an instant system is the fact that film takes time to be developed, and video tape is not yet a suitable replacement because of insufficient clarity and speed. But we are at a stage now where a computer can divine an athlete's optimum technique in an event and coach him toward it. "Of course, if a high jumper doesn't *want* to land on his back, that's another problem," says Ariel. "That's psychology. We can't do anything about that."

Gideon Ariel's own psychology is nearly as fascinating as his science. A clumsy, shy boy, he grew up in a boarding school near Natanya, about 20 miles north of Tel Aviv. Poor in sports, he nonetheless longed to be an athlete, and in 1956, when he was 17, he found that the best Israeli discus man had thrown less than 160 feet. Something clicked. "I can do better than that," he said and embarked upon four years of training, almost demented in his intensity. Speaking to a class at Amherst, he said, "If you want to be a discus thrower, you have to live with the discus. Carry it with you. Sleep with it."

That is what he did, with both shot and discus, throwing them as much as eight hours a day. "I threw from pictures. Coaches meant well, but one would say one thing, another would contradict him. It was all opinion. How did they know?"

One who knew a lot more than the rest was Dr. LeRoy Walker of North Carolina Central, who later became head coach of the 1976 U.S. Olympic men's track and field team. In the late '50s Walker coached Israel and Ariel. "He told us to do things we never did, like sprints and weight lifting, and we were all so sore after the first day we said, 'This guy is crazy.' But he had a method. He said, 'Go throw 500 times and we will talk. I can't tell you anything now because your variability is so great.' It worked. I got a pattern down and we could go from there. We talked about forces and angles. It was the beginning of a scientific approach."

They also talked about college scholarships, and after Ariel had taken part in the Rome Olympics and spent three years in the Army, he came to the University of Wyoming. "My life was just to throw the discus," he says.

When he graduated in 1966, it was found that Ariel had spent three years at Israel's Wingate Institute, earning a Diploma of Physical Education degree in 1960. He had never thought to tell anyone about it and had thus completed three years of U.S. college athletic competition without being eligible for it. "Wyoming was fun," he says now, "but the coach wasn't like Dr. Walker. It was back to opinion."

Ariel applied to the newly created School of Exercise Science at the University of Massachusetts, got his master's degree in nine months, became an assistant track coach and then plunged into an eclectic set of studies with all the fervor of his early years with the discus. "There had to be 20-hour days for him then," recalls University of Massachusetts Track Coach Ken O'Brien. "I'd find him sleeping at his desk in the mornings. A professor in one of his classes would mention some advance in an allied field, like calculus or cybernetics, and Gideon would go over and take the course."

One such suggestion came from the head of the computer science department. "He said, 'Why don't you apply computers to your mechanics?' " recalls Ariel, who was sick of laboriously tracing every joint on paper, limb by limb, frame by frame. But how? How to find a way of getting all this raw information into the computer? The answer was a device called a digitizer, a screen lined on two sides by 20,000 tiny directional microphones. The coordinates of any point on the screen touched with a sonic pen are automatically registered and fed into the computer. While visiting the Dartmouth Medical School, Ariel happened across one of these instruments, which looks not unlike a movie screen mounted in a console. "Then in 1968 Dartmouth started the computer time-sharing concept. The potential was unbelievable. All I needed was a $50-a-month rental to put a terminal in my house and I could do anything."

With his keyboard terminal installed, Ariel plunged into writing computer programs. "The whole idea is simple," he says. "Human beings are creative, but we have terrible memories. Computers are dumb, but their memories are perfect. You have to guide them, lead them step by step, channel your creativity through the software, the programs, till you have created a monster. It grows and you have to write more and more programs so it can do more and more things." What sustained those thousands of hours of labor? "It is fascinating work, and frustrating. For example, the equipment in our lab, which comes from 10 or 12 different companies, all had to be electronically interfaced. That was hard to figure out, how to get them working together without burning everything up. The exciting part is the conceiving, the finding out what you think you can do. Then it takes a long time to get the computers to actually do it." In other words, this is exactly like any other worthy craft.

In 1971 Ariel founded Computerized Biomechanical Analysis, or C.B.A., and landed a few contracts testing basketballs for Spaulding and shoes for Uniroyal. This allowed him to purchase more advanced equipment. Purdy predicts that Ariel is now about to reap rewards far above professional satisfaction. "If he's solved those problems of practical application, he'll find a ton of marketable uses. Look what digitizing analysis could do for the sports that are now judged subjectively, like diving or gymnastics. For the first time we could really measure how close a performer comes to perfection. Think of that, we wouldn't have those prejudiced Russian judges in there messing up results."

And there is always the lucrative world of product development. The key to opening it is the software, those valuable programs that are generally not copyrighted (one tiny change in a lengthy series of instructions to a computer obviously can cause drastically changed results). Add the fact that few scientists in the field are business oriented, least of all Ariel, and the situation seems ripe for corporate wrangling. Since receiving his Ph.D. in exercise science in 1972, Ariel has been involved in a train of legal skirmishes with an exercise-equipment company that couldn't stomach his analysis of its product (settled out of court with a public apology to Ariel), and with a colleague and one-time professor over some rights to C.B.A. Possessed of an unshakable faith in his own rectitude, Ariel will surely live out his life as one of those litigation-prone scientists—da Vinci was one—who feel somehow unclothed unless they have six lawsuits pending.

Gideon Ariel does not claim to be a true pioneer in biomechanical analysis. Sweden's Ingvar Fredricson has been studying the motion patterns of standardbred horses with a computer for 10 years, predicting lameness from minute stride irregularities, and discovering that most trotting tracks are banked too much on the straightaways and too little on the turns, placing dangerous stress on delicate forelegs. At Penn State, Peter Cavanagh is well along in a study of human stride patterns. But as Ed Burke, the U.S. record holder in the hammer throw and a close friend of Ariel's, says, "A lot of biomechanical people are contributing in their own quiet way. Gideon is contributing in his own, uh, inimitable way."

Ariel has had occasion to see what he might have ended up doing had he not harnessed the computer. "In 1972 I was in Spain and met with some East German coaches. I looked at the East German shotputters and saw that they all threw with exactly the same form, as if they had been molded that way. They all lifted their back legs before they re-

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COMPUTER

continued

leased the shot. I mentioned this and a coach said, 'Oh really? We'll have to correct that.' I said, 'Don't give me that. It's good.' I knew we had something in common, a shared knowledge. Equations of motion are equations of motion. I saw notes from years before. Those men began long before I did. But they'd been doing it *by hand.* Imagine 15 engineers working a month to chart one shotput!"

There are times when Ariel becomes unabashedly sentimental about his U.S. experience, and this memory triggers a paean to the American system. "There was a time when we needed to know relative weights of body segments. We wrote to NASA research and they sent back books of data. No charge. That was a tremendous help. We couldn't have gone on without it. But in East Germany they would say, 'Confidential, classified.' Here, people are open-minded."

As if in recompense, Ariel has offered his services at cost to the U.S. Olympic Committee as it readies for the Moscow Olympics. "Until 1964," he says, "talent alone still worked. Since then sport has been a science, not an art. There is no way anyone is going to beat the talent in this country if it is properly prepared." Since May, Ariel has been spending half his time at the newly opened Olympic Training Camp at Squaw Valley, Calif. (*page 46*), working with field hockey players, soccer players, women's basketball players, kayakers and swimmers. As usual, he has doled out hours of fascinating advice. What is the optimum free throw? "The more limb segments you use, the more chance for error in coordination," he says. "The best players just use the knees for lift, and flip with the forearm. Simplest is best." In a skill as basic as jumping, Ariel brought about a two-inch improvement in one female basketball player whose coach had had her bending her knees too deeply before ascent.

The ice hockey coaches were reluctant to use Ariel's services until he explained to them, for the first time, just how it is that a slap shot by a small player can attain much greater velocity than a sweep shot by a monster. "The better shooters hit down on the ice behind the puck and bend the stick so it becomes loaded with energy. Then they flick the puck, like this," he said, flipping paper balls at the astonished and somewhat embarrassed coaches.

Indeed, Ariel's findings and progress in biomechanical research present a challenge to all coaches. After he stops calling them witches and predicting that a computer-monitored individual training system will do away with them, he backs down a bit, saying, "I can't coach the Dallas Cowboys, but I can give them more information. I can tell them where and how to hit the other players, how to create the greatest force in blocking, how to brace knees, improve helmets. People cry about removing the art from sport. But they started it. Why do you time a runner, or measure a jumper, or count goals? Maybe we shouldn't. But once you decide to use all those numbers, O.K., let's really use them." This has some added force, said as it is while Ariel dramatically unfolds a printout of thousands of multidigit measures of Offensive Tackle Rayfield Wright's center-of-gravity fluctuations, the paper spilling across his desk and onto the floor.

Ariel's old boss, Track Coach O'Brien, has thought about the threat he poses to old-school coaches. "Gideon assumes, rightly, that most coaches don't know biomechanics, physics or biology, and haven't got a burning desire to learn. Coaches just use what has seemed to work in the past. It's true that you can't see enough. We see positions, we see lines, but we don't see magnitude, how hard that foot is pushing. If we are willing to admit we're inadequate in those areas, we will use the techniques he has developed."

O'Brien sees a possible source of resentment in the necessity of coaches relinquishing athletes to outside analysts like Ariel. "Nobody likes to share the credit." O'Brien has observed Ariel's presentations to several coaching clinics. "He's a good entertainer. You pretty much have to respond to the force of his personality, so it is illuminating to watch the people when he's done. Some rush him for more and more. They're all saying the same thing. 'Where can I use it? How the heck can we make it available?' The others are turned off. They drift out shaking their heads, sullen."

One sees the same dark clouds on the brows of corporate sporting-goods executives that fogged the brains of Galileo's judges. Science is no respecter of tradition, and Gideon Ariel is a man of pure, almost innocent, science. In his lab is a scientifically designed shotput shoe. It has laces inside its laces and is twisted, as if a truck had run over it. "Did you ever see anyone put the shot while standing up straight? No. This shoe cocks the foot into position and the double laces save energy. It works." No manufacturer will touch it. "It wouldn't look so good on display," Ariel says. "And how many shotputters are there in this country?"

A maker of golf shoes wanted C.B.A. to prove its shoes were the most comfortable, comfort being the basis of its advertising. Science had other ideas. "What is 'comfortable'?" Ariel demanded. "Does that mean a man can swing better? What if the best shoes for golf shots make a man limp down the fairway? You cannot high-jump in comfortable shoes. You cannot shoot a cannon from a canoe because the canoe is going under the water. . . ." The golf-shoe people departed with pinched expressions. Later they retained Ariel's services, warily.

A ski-boot company once got Ariel up to Vermont to analyze the forces on the ankle joints of a downhill skier. He proposed, for safety, the use of electric strain gauges on the bindings. "It was as if someone said to General Motors, 'Make an electric car.' It was too revolutionary. There is one word that seems to paralyze these people—that is 'retool.' "

Yet Ariel does not brood over temporary setbacks. His company owns outright all of his equipment, so if contracts or grants should dry up, he could press on with research. And his own competitive juices still surge. Recently, he got a call from an old hero of his, Al Oerter, the 40-year-old, four-time Olympic discus champion. "We, he and I, are going to reenter the ring," Ariel says, his eyes gleaming. "We will put him in a more efficient position. We will cut down on shoe friction. We will overcome physiological deterioration with scientific advance!" Ariel listens to his own echoes in the lab. "He was so nice on the phone, I had to say yes. He told me, 'We competed in the same Games.' But I didn't ever make the final."

Ariel—the scientist who is revolutionizing sport with his sonic pens and slow-motion cameras and computer printouts—smiles, seeing, perhaps, a pattern. "I was always too emotional in the big meets." END

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Want a better athlete? Now scientists can build one for you

By Gaylen Moore

"Give me a kid with natural abilities and nothing can stop us from making him the best in the world," says Dr. Marvin Clein, chairman of the department of sports sciences at Denver University.

"There are certain personality traits that successful athletes share," notes Dr. Bruce Ogilvie of San José State University in California. "My job is to isolate the psychological weaknesses, and to strengthen those traits required for competition."

Clein, Ogilvie and others represent a new breed of sports trainer. They're scientists who use the findings of their fields, from physics to psychology, to improve an athlete's performance. Results have been nothing short of sensational.

Leslie Covillo of Golden, Colo., is a 15-year-old runner who was brought to Dr. Clein after her parents had read about him in a magazine. She was gangly and awkward, and had trouble running a straight line. "I'd made the track team," she recalls, "but I wasn't anything great. I thought if I had a coach, I could run a lot better."

Dr. Clein put Leslie through a series of tests: psychological, physical and others. "From the study," Clein reported, "we decided that Leslie needed development in two areas. She had to build up her body strength, and she had to learn *how* to run."

They worked together for five months. Then, the first time she went out on the track, Leslie came close to tying state high-school records.

Bruce Ogilvie, who works closely with Clein, specializes in the athlete's psyche, investigating such personality factors as motivation and commitment. He's worked with pro football, baseball and basketball teams and the last four U.S. Olympic teams. To some, his powers border on the prophetic.

Peter Bavasi, general manager of the Toronto Blue Jays, used an Ogilvie test to help select his new American League team. "Ogilvie gets results," says Bavasi. "A few years ago the San Diego Padres signed a promising young 17-year-old who was the best baseball player in the country at his position. Ogilvie tested him and predicted the kid would leave in the middle of spring training—and he did. Then Olgilvie worked with the boy for a couple of years, and today he's one of the best in the game."

Photographs by Ira Wyman

Right and below, Dr. Gideon Ariel analyzing the image of a triple jumper. The pencil-shaped object in his hand computes stress on joints.

US May 1977

Dr. Gideon Ariel of the Computerized Biomechanical Analysis Center, in Amherst, Mass., turns to computers to help improve athletic performance. Dr. Ariel specializes in body movement—how an athlete should move in order to insure optimum performance. "We take high-speed film of the athlete in motion, then analyze it frame by frame. The data is fed into a computer to calculate the velocity and acceleration of each joint. Then we determine the forces acting on the joint. This tells us whether the total movement is efficient."

Besides testing athletes, Ariel tests equipment — like track shoes. Among his current "patients": Dallas Cowboy Rayfield Wright.

New York optometrist Dr. Richard Kavner is one of about 100 specialists in the country who are involved in improving athletes' eye-movement skills—aim, focusing, and eye and body coordination. These are the skills an athlete needs to locate a ball in space and know where it is in relation to himself, so that his body can be in the right place at the right time.

Dr. Kavner's exercises can also help improve peripheral vision. Other exercises require his clients to perform Chaplinesque-type feats by wearing glasses that distort normal spatial perception. Completely disoriented, the athletes must walk a narrow beam and touch a ball hanging nearby at the same time. The ball isn't where they think it is.

"By setting the eyes in conflict with what the body reports," explains Kavner, "you can teach athletes to form new associations with eye and body movement. These exercises show athletes that by changing their body posture, they can change how they see, and become more skillful at shooting fouls or returning a tennis serve."

Several weeks ago, Leslie Covillo beat everyone on her track team, including the boys. When asked about her future plans, she said, "Nothing special." But Dr. Marvin Clein chimed in, "Just look at her T-shirt—it says Moscow 1980."

Indeed, the next Olympiad will feature a host of Americans whose performances will be aided by sports science. Starting in May, the first U.S. Olympic Training Center in Squaw Valley, Calif., will provide Olympic hopefuls with the latest scientific advice from the experts. Tune in to the Moscow Olympiad for results.

US May 1977

American Medical

NEWS

An Informed Membership Is Our Greatest Strength

AUGUST 1, 1977

MD aims to improve nation's health using Olympic athletes as 'walking fitness labs'

Vascular surgeon Dardik (left) and computer scientist Ariel are collaborating at the Squaw Valley Sports Medicine Center to learn more about physical fitness using unique specimens—Olympic athletes.

Roy Petty/AMN

When Irving Dardik, MD, was a college kid in the mid Fifties, he was not only captain of the track team at th U. of Pennsylvania, but also a top-notch sprinter.

He almost made it to the 1956 Olympics in Melbourne in the 400-meter dash, and planned to try again the next time around, at the 1960 Rome Games.

But in 1958 he entered medical school, and that ended his dream of competing in the Olympics. "In those days, you couldn't just leave medical school for something like that," he says.

So instead of achieving fame as a quarter-miler, he achieved fame as a vascular surgeon. With his brother Herbert and Ibrahim Ibrahim, MD, he developed a coronary bypass graft technique using human umbilical cords.

That procedure has helped a lot of arteriosclerosis patients lead more active lives, but Dr. Dardik shrugs it off as "only palliative." He would rather prevent heart disease than treat it.

ALL OF WHICH explains what he's doing in Squaw Valley, Calif., helping to train young athletes for the 1980 Olympics. He's not just interested in helping the United States win more medals at the 1980 Moscow Games—he sees the young athletes as walking, talking laboratories of physical fitness who could help improve the nation's health.

The U.S. Olympic Committee appointed Dr. Dardik to set up the first of several Olympic Sports Medicine Institutes, on the grounds of the newly-opened Olympic Training Center in Squaw Valley, with two goals in mind: to help Olympic-caliber athletes learn more about their bodies and improve the physical fitness of the nation.

the three of them won the AMA's Hektoen Gold Medal last year.

"People ask me, why do you do this thing? As a vascular surgeon, how do you fit? An orthopod, yes, but a vascular surgeon?

"I treat people with coronary disease, and I work with bypass patients, which is sort of seeing the end of the spectrum of physical fitness. And here are these athletes, who are the best physiological specimens we can produce in this country, and I think somehow we can evaluate the process in physical fitness and use it to our advantage.

"THESE OLYMPIC athletes, these are ordinary people. Ordinary people who have talent. And they need to train and learn to live with that talent. We can learn so much from them."

Housed in the ghost town of dormitories and offices left over from the 1960 Winter Olympics at Squaw Valley, the Olympic Training Center is a busy and intense place, though it only opened for business two months ago, and all the equipment and facilities have not yet arrived and been set up.

An average of 200 Olympic-quality athletes and coaches (by invitation only) a day train in the center, some staying for only a few days, some for a few weeks. They represent an assortment of sports, from basketball to swimming to kayaking, and the atmosphere at the center, snuggled in one end of bowl-shaped Squaw Valley, 15 miles from Lake Tahoe, is that of a cross between a college campus and a monastery.

Sports medicine—sports science, as Dr. Dardik and others at the training center speak of it—has suddenly become a great deal more sophisticated, as have training methods.

Athletics as science

U.S. sports medicine neglected, MD says

INSTEAD OF pot-bellied men in sweatshirts and whistles telling everybody to run laps, there are people like Gideon Ariel, PhD, a computer scientist from Amherst, Mass., who competed in two Olympiads (1960 and 1964, as a discus thrower for Israel), and who now does amazing things in the field of biomechanics.

Dr. Ariel figured out a way of taking motion pictures of athletes performing typical sports maneuvers (a basketball player making a jump shot, for example), and translating the critical body motions onto a computer grid.

The computer analyzes the athlete's movements, step by step, and produces a thick printout that in essence compares how the athlete performed the maneuver with the theoretically "perfect" way to perform the maneuver—demonstrating exactly how, and where, the athlete should modify and improve his technique.

It works. Earlier this year, discus thrower Mac Wilkins came to Dr. Ariel's Amherst lab and went through the whirling, ballet-like motions of the discus throw for the benefit of Dr. Ariel's high-speed camera.

WILKINS HAD been throwing the 16-pound disc about 216 feet lately, but the computer said he should be throwing it 250 feet, and spotted a point where his left leg was working the wrong way, against the throwing motion instead of with it.

Wilkins corrected the error and, two days later, broke the world's discus record with a 232-foot throw.

Dr. Ariel's computer can be used for much more. He displayed an inch-thick printout analyzing the standard shooting and passing motions of four women basketball players bound for the Olympics.

He has a 10,000 frames-per-second camera that can analyze the way a tennic ball strikes the racket. In case you're interested, a tennis ball touches the strings of a racket for only .004 seconds, so that the "thump" you feel in the racket is not the ball—it's the reaction of the strings themselves, which is much longer lasting.

Biomechanics, like other phases of sports science, has applications outside athletes, too. Dr. Ariel used the same camera-computer technique to figure out how people with leg protheses can be made to walk without the limping, body-twisting motion common among those with artificial legs.

THE COMPUTER churned out a quick answer: for a person with an artificial left leg, put an eight-pound weight on the right arm. Then he'll walk easily and normally.

"There's so much we can learn from these kinds of applications. Things like that, about biomechanics, that coaches and athletes just aren't aware of. The use of the arms, for example.

"You can use your arms to lift your body off the floor. I weigh 220 pounds and, see, I can lift my feet off the floor, just by using my arms." He demonstrated, swinging his arms up sharply, lifting his muscular, fullback-sized body an inch or two off the ground.

Computer man Dr. Ariel and surgeon Dr. Dardik get along famously, each calling the other "a genius," falling into animated conversations about groundbreaking new research while watching films of sticklike figures on a computer grid, uncoiling in slow-motion jump shots.

"WHEN I WAS A physician at the last Olympic games, athletes would come up to me with questions about training, about nutrition, about drugs. That's what gave me the idea to talk to the U.S. Olympic Committee about setting up the institutes. There are so many things we don't know about."

Anabolic steroids, for example—the hottest question in Olympic sports right now. Both Dr. Dardik and Dr. Ariel testify that use of the strength-increasing hormones is widespread in this country, and universal in some other countries, though neither physicians nor athletes know how dangerous they might be.

"In the last Olympic trials," Dr. Ariel said, "if you were in the weight events (shot put, discus throw, and hammer throw), you wouldn't even make the trials if you weren't taking steroids. In the shot put, the difference between those on steroids and those not was as if one group was putting 16-pound shots, and the other was putting 40-pound shots."

Dr. DARDIK isn't sure steroid use is that widespread, but it is certainly a problem. "If an athlete asks me, should I take steroids, I would say no. But we don't really have enough information on it one way or the other. People are manipulating their bodies, and we don't know what the long-term effects are."

That's a result of the apparent lack of interest in sports medicine in the United States, he and Dr. Ariel believe.

"The technology is there," Dr. Ariel remarked. "This country has the talent, big corporations could provide all the equipment and funds we need just as a donation."

He pointed out that there were plenty of companies in the United States who make pulmonary function equipment like the one recently donated to the training center—but the one donated came from a West German firm, given to the U.S. Olympic Committee.

"People think athletics is an art. But it's really a science," Dr. Ariel said. "If nobody cared whether you won a gold medal or not, if you weren't competing against others, then maybe you could call it art.

"BUT THE MOMENT you put a stopwatch or a measuring tape to something, it becomes a science."

Dr. Dardik adds that the goal of the institute is a lot broader, and a lot more distant than merely the 1968 Moscow games.

"We're not just a bunch of jocks up here, training for the next Olympics," he declared, pointing out there had already been a spinoff from the program in his own backyard.

Dr. Dardik has set up a foundation in Englewood, N.J., using Olympic athletes to work "one on one" with juvenile diabetics. With the help of the American Diabetes Assn. and the Juvenile Diabetes Foundation, diabetic kids (along with children with other illnesses, including psychiatrically disturbed kids) were being taken through fitness training programs conducted by the Olympic athletes.

The point was to develop in the kids better cardiovascular condition, to reduce their otherwise elevated chances for arteriosclerosis later in life, he said.

BUT THE SIDE effects had been equally worthwhile: the youngsters' insulin needs were lowered sharply, for example, and all of them felt better, looked better, and displayed much greater self-confidence as a result of the Olympic fitness program.

Now he has bigger plans. He wants to expand the diabetic fitness program, and he's planning (with the assistance of the U.S. Olympic Committee) to set up as many as six sports medicine institutes around the country. One is now being developed in Colorado Springs, Colo., with the cooperation of the Air Force Academy, and another will be set up in the East next year.

—Roy Petty

AMERICAN MEDICAL NEWS August 1977

DAILY HAMPSHIRE GAZETTE

Computer helps design shoe that walks on air

By MILTON COLE

AMHERST — Walking on air.

The very thought is so pleasurable that the expression is used constantly to describe emotionally inspiring success.

But now a computer and a former Olympic athlete have merged knowledge and technology so they could make "walking on air" totally commonplace.

Dr. Gideon Ariel of Belchertown and his Computerized Biomechanical Analysis company in Amherst have designed shoes in which one does walk on air.

How efficient the shoe

They are the result of a survey on how efficient is the design of shoes in general, and how can they be made more efficient.

The result of that survey and study could be shoes that have one walking on air.

And if the air-shoes are the most unusual of the products of CBA, they are not the only ones.

For example, there is a new exercise machine that makes it unnecessary to have a large room to house it, and makes it possible to do all your exercises in half the average-size bathroom.

There is a tennis racket with a pivoting handle that enables a player to absorb the shock of a ball hit at him and return it with maximum force and accuracy.

And there is a study being made for the Department of Defense on how to make the foot soldier more efficient as far as equipment and uniform are concerned, and what is the most efficient way to hold and shoot a submachine gun.

These are some of the more unusual studies that have been or are being made. But there are others, enough others that the business started by Ariel six years ago has now grown into a multi-million-dollar firm that is expanding.

Take the air shoe.

Originally the U.S. Bureau of Standards contracted with CBA several years ago to do a survey on the efficiency of design of the common shoe.

The study, including filming of people walking and then slowing the film down to analyze frame-by-frame what happens when a person takes a step, showed that the common shoe is not an efficient design.

The protruding heel causes a person to step onto the heel of the foot first, putting the strain of each step on it, and then expanding that strain up through the leg into the lower back.

"It showed that the way we walk and the kind of shoes we walk with can be a cause of lower back trouble as well as the cause of foot and leg problems.

"The computer showed that the most efficient way to walk is the way we walk barefoot, with a rolling motion so that the force we generate as our foot hits the ground will cause a rolling motion, pushing the body forward on the foot, instead of jarring the force up the leg."

How to utilize knowledge

How to utilize that knowledge?

After the report was sent to the federal agency, Gideon and his compatriots at CBA worked on putting theory into reality.

One shoe was designed, aimed at providing the rolling motion, but still sending some of the jarring motion up the legs. Then came the idea of using that jarring action to provide forward motion.

The air shoe was born. The prototype is designed for athletes, and has been used successfully in practice by the members of the U.S. women's volleyball team.

They have found that they jump higher, and they end up with fewer leg problems, muscle pulls, etc. as a result of landing on their feet after a jump.

Basketball players are experimenting with them, along with runners.

The design is of a regular nylon-bodied running shoe, with the rubberized rippled or cleated sole.

But the inside has another rippled rubberized insert running the entire length of the shoe. In the outside of the heel of the shoe is a small air intake valve.

A rubber-bulb pump is inserted into the valve and the insert is filled with air, like filling an auto or bicycle tire or a football or basketball.

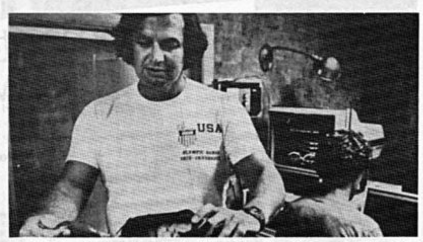
Then the shoe is put on, laced and tied. And when one walks on it, he or she is literally and actually walking on air.

Air forced out

Each step forces the air from one spot in the insert into another by use of computer-designed valves, and the result is a cushioned step whether walking or running or jumping, and a rolling effect when one walks or runs.

"They should end problems with leg muscles, shin splints, bone spurs, etc. And they should cut foot fatigue for runners," Ariel said.

Right now the design has been acquired by the Pony Shoe Company, which makes footwear for all kinds of sporting activities.



PUMPING UP the sole prepares the new "air shoe" for use. It was designed by Computerized Biomechanical Analysis in Amherst, and CBA president Dr. Gideon Ariel is getting the shoes ready. (Richard Carpenter Photo).

Ariel figures that the shoe will be used in Olympic and other national and international competition. He believes it will find a place in sports, particularly basketball, and perhaps football as well.

But it also should result in use in regular shoes worn by the general public, and could have the nation, if not the world, walking on air, and being healthier for it, if Ariel and his computers are correct.

"Imagine how great this would be for paratroopers or others jumping from considerable heights," enthused Ariel.

The graying but husky University of Massachusetts doctoral graduate also is enthusiastic about the exercise machine he has designed.

Originally used weights

Originally he designed one for the Universal firm, one of the top such companies in the U.S., using the established method of actual weights attached to pullies and handles.

It was different and easier to operate than others on the market at the time, but still quite bulky and space-consuming.

The latest design, made possible by the omniscient and omnipresent computer, is a simple large cylinder connected to a variety of bars or pedals or overhead handles.

The computer is hooked up on a shelf as part of the system. You press a button, and the computer asks if you want to exercise.

You press buttons that indicate that you want to do weight lifting, and how much force or poundage you want to lift.

The computer then sets the valve that controls the hydraulic fluid in the cylinder and thus the amount of force necessary to lift the piston in the cylinder.

It eliminates the need for the actual weights to be there.

One of the people involved with Ariel in his enterprises is former U.S. Treasury secretary William Simon. He is interested in forming their own manufacturing firm to turn out the new tennis rackets that CBA has designed.

Doing research on tennis racket efficiency and how the ailment, "tennis elbow," occurs, CBA and Dr. Ariel found that the impact of a ball on the racket, sends a jarring force through the racket handle up the arm and against the elbow joint.

The computer suggested a rotating handle that would use that force to twist the handle, making it so the face of the racket is directly against the ball each time it hits the racket.

This not only eliminated the jarring force going into the elbow, it also made possible the opportunity for a perfect return shot.

Using that racket, which Ariel says will be produced by someone within a year, either their own firm or one of the regular sporting goods manufacturers, with the tennis ball CBA designed for Spalding, could make for much improved tennis.

DR. GIDEON ARIEL demonstrates how the computerized exercise machine his Computerized Biomechanical Analysis firm of Amherst designed, with computer operating hydraulic piston to provide the same resistance as weights used on traditional exercise machines. (Richard Carpenter Photo).

DAILY HAMPSHIRE GAZETTE August 1978

TRACK & FIELD NEWS

WOMEN'S ANNUAL — EMBER 1977

TECH TALK

Dr. Ariel's Revolutionary Computerized Biomechanics

by Bob Hersh

R2D2 and C3PO will not represent the United States in the Moscow Olympics. But the technology that produced those robot heroes of *Star Wars* may be outdone by some of the scientific applications that will be available to American amateur athletes even before 1980.

That prospect was enhanced by the recent appointment of Dr. Gideon Ariel as the USOC's Director of Research in Biomechanics and Computer Sciences. Ariel brings to the USOC a method of biomechanical analysis that could revolutionize coaching and training in the technical aspects of track and field, and other sports as well.

The key to Ariel's innovative system is the "digitizer," a device that allows him to take films of athletes in competition or training and break them down into component parts, frame by frame.

With an electronic pen, he traces the position of key body points (wrists, elbows, shoulders, etc.) and transfers that data to a computer which produces stick drawings that show where each point is at each moment in time. Ariel has also developed computer programs that apply biomechanical principles to the position and velocity information obtained from the digitizer.

With his computer, Ariel can determine precisely all of the biomechanical forces bearing upon an athlete's performance. He can also compute the theoretical advantage that could result from a specific change in form.

"If it seems that a hammer thrower's elbow is in the wrong position at a certain time," he explained, "I can have the computer move it an inch or two and then recalculate the forces. That will tell me how much distance this particular thrower would have added if his elbow had been where I placed it. Once the computer is programmed, we can do all sorts of experiments in order to find the best results without wasting the time of the athlete or his coach."

Ariel has already shown that computer analysis can produce not only theoretical data, but also practical results. Terry Albritton and Mac Wilkins set world records in 1976 and both credited Ariel with helping them discover deficiencies in form that they corrected before their record efforts. "I changed my whole conception of throwing," said Wilkins, who set world discus records at the second and third meets in which he applied Ariel's advice. This must have given Ariel special satisfaction since he had been a thrower himself, having represented his native country, Israel, in the 1960 and '64 Olympics in the shot and discus.

Some coaches might see the computer as a threat to their profession, but Ariel thinks it can only help. "Most coaches recognize that field events happen too fast to analyze by sight, and that even conventional film analysis can't do what the computer can," says Ariel. "But you can't just give the athlete a lot of talk about vectors and kinetic forces. You have to know the individual athlete and how best to communicate with him. Only the coach can do that effectively."

Although field events would seem to lend themselves best to his refined biomechanics, Ariel has studied running as well. Using a sensitive force platform and high speed films, he has analyzed the forces that runners put on different parts of the foot. One shoe company, Pony Sports & Leisure, saw the possibility of capitalizing on the application of this analysis and retained Ariel to help design a shoe that would take account of his computer's findings. The result was a shoe whose virtues have been confirmed by independent laboratory testing.

Ariel has also applied his techniques to other sports, using the computer to determine the optimal method of taking a slap shot or a free throw. The Dallas Cowboys retained him to advise as to how the linemen can most effectively block and tackle.

All of this costs money, of course, and while the Cowboys may be able to afford individual player analysis at $500 per, the average amateur athlete cannot. "I haven't charged any of the amateurs I've done work for," says Ariel, "but I have been able to do things for only a limited number. This will be changed with what we have planned with the USOC.

"We are setting up satellite centers at USOC training facilities in Squaw Valley and Colorado Springs. We'll hire some athletes and train them to use the computer terminals so that we can provide our biomechanical analysis to amateur athletes who come to these facilities."

In another important way, Ariel may influence the course of amateur sports in the U.S. He and Dr. Irving Dardik, who has done much sports medicine work for the USOC, have formed a company which will be opening health centers. Among the facilities they will offer will be biomechanical testing that can be taken by children.

"By analyzing the child's abilities at basic speed and strength skills involving the various parts of the body, we can help determine where his talents lie," said Ariel. "A young boy may want to be a sprinter, but we may tell him that he will never be a great sprinter but he could be an Olympic caliber kayak racer."

It is not realistic to think that large numbers of young Americans will forsake football and baseball for kayak racing or javelin throwing, but for those who do dedicate themselves to amateur sports, the affiliation of Gideon Ariel and the U.S. Olympic Committee is very good news. It will give American athletes the advantage of sophisticated equipment that is at the frontier of the state of the art of biomechanical analysis. Many obstacles to Olympic success will remain, but one major element of the technological gap between the US and Eastern Europe is about to be closed. □

Ariel gives Al Feuerbach his "screen test."

Bible of the Sport

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Canadian Footwear Journal

Formerly Shoe and Leather Journal — A Southam Business Publication

Computerized Footwear

How one man's mind is thrusting athletic footwear design into areas which border on science fiction, but which are based on science fact.

by Steve Lloyd

Dr. Gideon Ariel, director of Computerized Biomechanical Analysis, Inc. and a consultant to the U.S. Olympic Committee, has been called the "Leonardo Da Vinci of sports." But while Da Vinci's studies of the human body were never fully appreciated by his contemporaries, Dr. Ariel is finding an increasingly receptive audience for his computerized analysis of human motion.

A pioneer at tying the science of motion into physical skills necessary to perform athletic feats, Dr. Ariel's studies are helping athletes perform better by revealing to them heretofore undeterminable deterents to optimum performance.

But Dr. Ariel's work isn't limited to helping athletes discover motion efficiency. His computer has been and can be applied to the improvement through redesign of athletic equipment, including, but not limited to shoes, racquets, clubs, bats and balls, and perhaps most importantly, injury preventive and rehabilitative articles and research in sports medicine.

The 39-year-old native of Israel combines the esoterica of computer science with the old athletic standby: high speed, slow-motion and stop-action photography applied with the century old principles of Newtonian physics.

"By analyzing high speed films (as fast as 10,000 frames per second) frame-by-frame, using equipment interfaced with our computer, we calculate velocity, acceleration, direction and angle of forces on all body joints. From that a whole new dimension of data becomes available to us," Ariel says.

Ariel combined science with sport following his own late-blooming career as a discus thrower on the Israeli teams in the 1960 and 1964 Olympics. During his gruelling eight-hour training sessions he heard one coaching theory after another. During his undergraduate years at the University of Wyoming and at Israel's Wingate Institute as a physical education major, his skepticism of countless — and contradictory — coaching theories grew. When he enrolled for master's courses at the newly-established School of Exercise Science at the University of Massachusetts, Ariel not only put his own thoughts to work there as the track coach, but also plunged himself into the study of calculus, cybernetics, physics, kinetics, medicine and computer technology.

It was at the suggestion of the head of computer sciences at U-Mass that Ariel first toyed with the idea of combining computer analysis with athletics. When he discovered the method of transferring data into computer banks via electronic pen ("source plates"), Ariel installed a keyboard terminal in his home and refined his aims. By 1971, he founded Computerized Biomechanical Analysis, Inc. and secured his first contracts for testing athletic equipment. It wasn't long afterward that athletes themselves came to Ariel for advice.

Ariel is by no means limited to giving advice on improving technique. Through biomechanics he has prescribed means of rehabilitation for injured athletes in many sports. He continues his association with the University of Massachusetts by further opening his computer banks to the study of animal behavior. He even talks of applying biomechanics to treatment for diabetics and weight watchers, or studies of concert musicians.

While Dr. Ariel uniquely brought together two sciences — biomechanics and computer sciences — it is important to state that his ability to do this was made possible by the collective efforts of many scholars and the technological advances of the past decade in the computer science.

Ariel's work in adapting the immense capabilities of the computer to bring biomechanical analysis into practical service has attracted increased attention in the sports and medical worlds.

Testimony to the tremendous potential of Ariel's work has been lauded by athletes including Mac Wilkins, Terry Albritton and Bill Schmidt; professional teams such as the Dallas Cowboys and the Seattle Super Sonics; the U.S. Olympic Committee, and the head of its medical staff.

Ariel's studies of the athlete in action have revealed that shoe designers unfortunately have overlooked the fact that shoe efficiency, safety and performance are inextricably tied to the biomechanics of the activity for which they are used. Too often, he has concluded, cosmetic features received consideration beyond that given the functional features of shoes.

"In essence," says Ariel, "all footwear, athletic specifically, cannot be evaluated separately from the 'athlete in the shoe.' Yet, this apparently is what has happened not only in shoe design, but in non-partisan evaluation and ranking of shoes by a major running publication."

Because Pony wanted a shoe for the runner, male and female, competitive racer or a recreational jogger, he was chosen to design the first anatomically, biomechanically developed and scientifically tested running shoe.

This shoe, as a result, is a radical departure from the norm in athletic shoe production.

"Usually bottom line dollars define product appearance and quality. However, Pony, a young and energetic sports shoe company, made a corporate commitment to quality of function rather than appearance through the unique science of Dr. Ariel," says Thom Gravelle, executive-vice president of Pony.

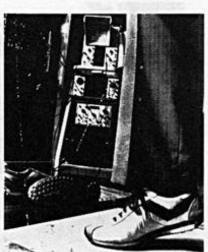
With this shoe, Pony, through Dr. Ariel's Massachusetts-based laboratory, has begun a directional change of sports shoe production forever.

How they did it is a fascinating story. →

BIRTH OF A WINNER: A SIX STEP SYSTEM

1 The Original: What do you do if you already have one of the best designed all-purpose training flats on the marketplace, a running shoe rated by Runner's World as the second best in mechanical performance? Well, if you are Pony Sporting Goods you do not stand back and pat your backs. This shoe, the Pony Runner, is now a distant ancestor in the rapidly changing world of athletic footwear. And the main reason is that for runners who are serious about their art — and how many are not these days? — there is a new generation of footwear in the marketplace. In their quest for the perfect sneaker, Pony, with the assistance of that ingenious New York scientist Gideon Ariel, is pushing the development of athletic footwear into areas previously only talked about. If that sounds far fetched, then maybe it will be more believable if you understand what happened when Pony took this shoe, along with others, to Ariel, one of the most brilliant minds in North American sport development. As director of Computerized Biomechanical Analysis Inc., and a consultant to the U.S. Olympic Committee, Ariel has been a pioneer at tying the science of motion into physical skills necessary to perform athletic feats. His efforts, however, are now being turned towards the improvement of athletic equipment, particularly footwear.

4 The Development: With this information, Pony's design and production engineers knew the structural requirements and materials critical to the creation of a running shoe which would most sufficiently provide the two qualities Ariel determined were absolutely necessary in an athletic shoe; *shock absorption* and *return of energy.* Ariel explains: "You see pictures of runners, it looks like they're landing on their heels, but they are not. The good ones don't. They flick the foot down flat at the last instant. Too many companies were making wonderful heels and the best runners weren't coming down on them." What Ariel knew from his studies was the slight, but powerful, rotation of the foot which occurred during each contact with the ground in an athlete's stride. Different areas of the sole were performing different functions, yet nearly all athletic footwear, including Pony's original Runner, had uniform soles with some type of grid pattern or nipple affect. Pony designers, working with Ariel, slowly developed a sole with two distinct features, each conceived to provide the shock absorption and the return of energy deemed invaluable for high performance. They changed the shoe's construction by using two sole materials, realigned the nipple pattern on most of the contact surface and added a "traction grid" on the inside of the sole, where motion study showed the runner used his power during each stride.



2 The Testing: The foot has a complex and highly efficient system of joints which helps give it tremendous flexibility, movement and weight-bearing capabilities. Moreover, 50 per cent of the bones in the human body are to be found in the feet, with each foot comprising 26 individual bones. During the act of running, the many movements of the body influence the position of forces on the foot and its parts, forces which are transferred to the shoe. Ariel decided that, since footwear must be designed to perform in stress conditions, it must therefore be analysed in realistic "action" conditions. Although this type of dynamic testing cannot be simulated in a laboratory, the use of a highly-sensitive force platform enabled actual running to be done in Ariel's test centre, where the forces were traced, measured and quantified immediately. High speed cameras producing slow motion cinematography were used in conjunction with the force plate to record the forces of "foot-strike" in different samples at every point of contact under actual performance conditions. The force platform, with the frame-by-frame evaluation of the motion picture film, fed data to a highly-sophisticated computer. When Ariel had all the information he felt was needed to begin his analysis, he moved to the next step in the complex process — the computer.

5 The finished product: With the addition of a lightweight, durable upper and the familiar Pony chevron symbol, the company has what they feel is the most sophisticated racing shoe on the market. The heart of these shoes, though, is that Ariel-conceived sole. There are two versions of the shoe, the training model (shown) and the racing model. The trainer is slightly heavier and more durable than the racer, because it will be needed for those long, gruelling practice sessions. The racer is expected to be used for exactly that — racing. The VSD sole (patent pending) is, by the way, endorsed by Jim Bush, the head track and field coach of the University of California at Los Angeles (UCLA). All of this research, presumably, cost money, but Thom Gravelle, executive vice-president of Pony, is adamant that athletic footwear prices will not skyrocket because of it. He said at the beginning of the year: "Our strategy is to market the finest athletic footwear at prices that will give the retailer a decent profit margin for a change, and yet give the consumer quality products at prices which are not outrageous." The Racer, he thinks, will fill that hope and then some. Reaction to the shoe has been favorable, but it will have to prove itself in the future.

3 The Analysis: So delicate are the relationships between an athlete's moving parts they cannot be accurately analysed simply by looking at the slowest of stop-action film. A process of frame-by-frame, body-part by body-part assessment is necessary to make optimum use of film, a process that is excruciatingly time-consuming. It took Ariel about 10,000 hours over seven years to create the programs that instruct his computer. This painstaking preliminary work, however, now meant that he could quickly quantify information pertaining to the entire running motion, including the effect it has on the shoe. The resultant data yielded the instantaneous forces on the shoe as a function of time, providing data not only on the biomechanical behavior of the runner, but the critical information on how the physical construction and material composition of the shoe performed during actual conditions. Without this highly-developed process, Ariel felt the construction of a truly efficient running shoe could not be done. What he found when testing the Pony Runner was that the shoe, as it was, could not be refined sufficiently to produce the desired "ultimate" product. Ariel decided, under exclusive contract to Pony, to work to develop a shoe based upon the motion of the foot in relation to the body, and the stresses placed upon the shoe materials during a race.

6 The future: While Pony and other companies struggle to keep their product at reasonable prices, the research and development continues. But where will it lead? What future refinements will athletic footwear undergo as producers scramble to come out with the most "modern" shoe? Well, the quest for the perfect sneaker may one day be over. Ariel, in his continuing work for Pony, is developing — are you ready? — an inflatable running shoe. Someday, an athlete will simply slip the limp casing of the shoe over each foot, fill it up with air and, presto, a perfect fit. He may not even have shoelaces to tie. More important, Pony points out, the shoe will be good for his feet, absorbing shock better and reducing the likelihood of shin splints and blisters. The research for this shoe has been going on for more than a year now, and company officials expect another year-and-a-half before they will be ready to take orders for the shoe. The inflatable shoe will be lighter than the conventional model and may only come in four sizes — small, medium, large and extra large — because the shoe will mold itself to the foot. Ariel envisions the shoe as having a valve that will accept the nozzle of a can of compressed air, and can be released to deflate the shoe. Laces will be replaced by an elastic band. If the shoe works, and sells, what will be the next step in footwear development? Ariel just might have some secret ideas on that subject — but he's not telling.