Injury-proof your body: Knees By Paul Scott

If you think a real knee is easily damaged, try taking out your frustrations on a fake one. A busted fake knee stands on my desk - a life-size prop of the kind that experts whip out to explain why this critical yet critically vulnerable joint can end up needing to be rested, rehabbed, restrung or replaced. It has moulded plastic bones and stretchy rubber tendons, one of which I severed by flexing the thing and bearing down hard on it to see what a knee looks like in a deep squat under a heavy barbell. Oops.

I became obsessed with what the human knee can and cannot do when one of mine shut down after a couple of days of modest runs over a nearby hill. The technical name for my injury was patellofemoral pain syndrome, otherwise known as PFPS or anterior knee pain. It felt as though I had hammered a steak knife deep beneath my kneecap, and was giving it a good twist on each step up the stairs.

Never before had so little running led to so much rueing. I therefore set out to prove that all knees are worthless. How could a joint that works perfectly well one day make you feel like a grizzled Chelsea Pensioner the next? What's wrong with these things?

I had my right knee X-rayed, examined and rehabbed. I spoke to an evolutionary biologist about the role of the knee on the Serengeti plain. I had my single-leg squat evaluated for valgus tendencies (I am a little knock-kneed, it turns out). I had a world-class orthopaedic surgeon (my father-in-law, conveniently) draw diagrams on napkins and bury me in research papers. I watched a surgeon complete one anterior cruciate ligament (ACL) reconstruction and two total knee replacements. I failed miserably to follow the rehab advice given to me by my physiotherapist.

It all started to make sense on the afternoon that I sat looking over the shoulder of Scott Dye, a professor of orthopaedic surgery at the University of California, as he dissected the left knee of a cadaver at a conference of physiotherapists. As I watched him demonstrate the way the donor's meniscus (knee cartilage) slid as his femur corkscrewed, I realised that not only is the human knee actually one of the most well-built force-transference mechanisms in all creation, but that the mysteries of patellofemoral pain are in fact the knee's gift to us.

Trauma, overuse and degeneration

"There tend to be three causes of injury to the knee; namely acute trauma, overuse or degeneration," says Dr Michael Stuart, an orthopaedic surgeon specialising in knee surgery and sports medicine at the Mayo Clinic in Rochester, Minnesota. The good news is that traumatic knee injuries like ACL tears and degenerative knee problems like osteoarthritis tend to strike the knees of everyday runners at rates no higher than those of everyone else. However, half to three-quarters of all running injuries are related to overuse, and knee problems, especially PFPS, dominate overuse injuries. According to a two-year study of more than 2,000 runners completed in 2002 by the University of British Columbia, USA, for example, most running injuries treated at the centre (42 per cent) occurred at the knee, with PFPS making up 46 per cent of them. The next most common knee injuries were iliotibial band friction syndrome, meniscal injuries and patella tendinitis.

Diagnostically, PFPS produces a nagging to howling pain that can begin after a short distance of running, while "under load" (climbing stairs or squatting) or while "unloaded" for an extended period of time in the bent position (for example, sitting at your desk). PFPS struck twice as many women as men in the British Columbia study, and women under 34 more frequently than those over.

According to conventional wisdom, PFPS happens when a kneecap has pulled to the side of its track and rubbed something where it should be gliding. There are various possible causes - the runner has bad biomechanics or bad bone structure; has followed bad training advice or owns bad shoes; has weak quads or tight hamstrings. Rehabilitation advice includes a programme of rest, icing, strengthening the quads and stretching the hamstrings, as well as using motion-control running shoes and reducing the amount of hill running you do as well as your overall mileage.

But the source of knee pain is still something of a mystery. "We don't understand the pain exactly," says Dr Robert D'Ambrosia, co-author of Prevention and Treatment of Running Injuries, who subscribes to the tight-hamstring-weak-quadriceps theory. "The knee is a hit taker," says Gary Gray, a physiotherapist who advocates a more holistic perspective on the nature of sports injury. "The runner will say, 'My knee is killing me when I run,' but it's usually the result of tightness in the hip, posterior fibula or pelvis." Your knee can even hurt, says Gray, from a dud ankle on the other side of your body. "If you can't explode off your left ankle, you can't rotate your right femur properly, and the right knee will take the impact," he says. "Often the cause of a runner's knee pain has nothing to do with the knee."

As he narrated his knee dissection, Dye said: "I challenge anybody to come up here, take this femur and try to tear this meniscus. You won't be able to do it." No one took him up on his offer.

A natural wonder

I first saw a meniscus only conceptually, drawn on a napkin by my father-in-law, Dr Franklin Sim, a Mayo Clinic joint specialist. He doesn't like to talk shop, especially over dinner, but the starters hadn't arrived so he gave me a crash course in all the delicate machinery needed to keep a knee healthy: the meniscus, the cruciate ligaments, medial and lateral tendons, articular cartilage, femur and tibia. Later, I would see an actual meniscus up close while watching Stuart replace a knee. It looked whitish and small, like a shrimp.

I had never seen one like this, however, a meniscus being used to redirect forces. Dye had been showing how the meniscus slides but now he had severed the upper and lower bones and was pushing the shiny top of the femur against the ring of cartilage to make the point that tearing your meniscus, a highly common athletic injury that can lead to degenerative problems down the road, was the result of no ordinary forces.

He held up the membrane-and-muscle-encased thigh and shin bones for all to see. "Do you understand how lubricated this is? How beautiful this system is? Think about it," he continued: "If you're 56 like I am, and as heavy as I am, and have put your knees through two or three million load cycles a year, and you don't have a torn meniscus and have never had any knee pain in your life, that's a pretty amazing design."

As Dye points out, the knee's amazing design is one that only the brilliant nonsense of nature could create: a curved femur end meeting a flat tibia; an inner ligament that is three times as long as the outer ligament; and a joint that rolls, glides and rotates. "It's a system full of asymmetries," he says. As he would explain later, the asymmetries of the human knee reflect the mathematically perfect placement required for something known as a "four-bar, stepless transmission", an elliptical figure of eight known as the Burmester curve.

Thanks to this "stepless transmission", we can use the large levers of the upper and lower legs to redirect forces that would be insurmountable by any other mechanism of the body. Simply climbing a flight of stairs, the human knee redirects as much as six times

your body weight. It is no simple hinge: for a 91kg man like me to run up those stairs, as I basically did in my hill climbs, you're talking about a system that is successfully redirecting into the ground 1,814kg of force with each and every step.

And the design has stood the test of time. While studying prehistoric knees at the American Museum of Natural History in New York, Dye discovered analogues to our knee bones in the pelvic fin of a fish 390 million years old, and noted our medial collateral ligaments and two menisci in a reptile from 320 million years ago. The 10,000-year-old knee of a sabre-toothed tiger is anatomically similar to that of Haile Gebrselassie.

Pinpointing pain

Dye, who has dedicated his career to the study of the knee and is a bit of a renegade, first posited that synovitis lay at the root of PFPS after having his knee probed without anaesthetic, to try to establish where the pain of PFPS comes from.When his assistant turned the barrel of his probe against Dye's synovium, a thin, highly enervated lining of tissue at the base of the kneecap, he discovered that just a light touch on the synovium can cause sharp pain, "eliciting involuntary vocalisations."

Dye titled his experiment "Conscious Neuromapping of the Interior Knee Without Anaesthesia" and published the results in the American Journal of Sports Medicine. PFPS, he argued, was not in general a problem with tracking or pronating. Rather, it was an inflammation of the synovium caused by activity that can be described as falling outside an optimal zone charted on a stress and frequency matrix, which puts you "outside your envelope of function".

"Synovial tissues can be easily pinched with certain activities, like running uphill," Dye says. "The tissues can swell up and never go back down, and are then vulnerable to repinching. Normal activities that were once in your envelope, like climbing stairs, fall out of your envelope."

Dye's discovery of how much synovium damage hurts was only a prelude to more questions about the etiology and management of knee pain. Reaction to his theory has been cautious. "Synovitis is a reasonable explanation for the pain," says D'Ambrosia. But he believes that PFPS could derive from what happens when muscular imbalances cause the patella to push inwards. "The cartilage becomes softer, and then you develop fissures leading to the subchondral bone." Which also hurts.

To back up his theory that biomechanics aren't the culprit in knee pain, Dye points to a host of studies dating back to 1985, including a military study that compared 104 patients with PFPS to 79 controls, and found no association between a larger quadriceps (Q) angle (the angle at which the femur meets the tibia) and patella pain. He cites studies that show how patients with well-functioning knees can show distinct mismatches between their patellas and patella tracks on X-ray.

What's more, while X-rays and MRIs rule in orthopaedics, Dye maintains that the only true yardstick of knee health is the rate of metabolic activity in the bone, information found in a less commonly collected and altogether different type of imaging - a bone scan, which reveals the rate of cellular turnover in the bone. A knee's bone alignment can look fine on an X-ray but a bone scan will show that its cellular processes remain in major repair mode.

Where orthopaedics traditionally looks at knee pain as a specific problem of mechanical cause and effect, Dye prefers a more holistic explanation: PFPS results from a mosaic of factors, including overload, synovitis and a loss of homeostasis. The system has essentially overheated and needs time to cool off.

Mindful Maintenance

What makes Dye's arguments more incendiary is his contention that when doctors rely on X-rays and don't use bone scans to determine whether an ACL repair has healed, they can send patients out too soon, and the result is an increased risk of arthritis. Dye points out that as many as 70 per cent of all ACL-repair patients go on to develop the symptoms of arthritis in seven years, and he believes these could have been arrested had the patient waited to use their repaired knees until after a negative bone scan. "This is a silent epidemic," he told the conference. "I'm afraid there are a huge number of patients at risk for arthritis and they don't know it, because their X-rays all look good."

Dye argues for slowing down our return to sport after injuries and taking much more seriously what it means to have a doctor slice into your knee. He is currently developing a formula using the bone scan and an X-ray to best predict which knees are likely to go on to develop arthritis.

So, while running six miles over a 91m hill, three times in one week, I managed to overtax a

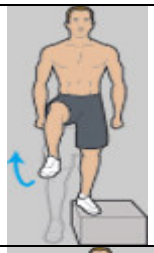
system created through half a billion years of evolution. An X-ray showed nothing to explain my having PFPS, even though, according to Dye, the chances are that my bone scan would have lit up like a Christmas tree. Which brings me to the most practical advice of the most visionary knee researcher in the United States: a bag of frozen peas for 20 minutes, twice a day, until pain subsides. Use bracing if necessary, rest, and gradually return to fewer miles and hills. Meanwhile, strengthen the core, quads and leg muscles.

I began thinking about my knee in connection to my entire capacity for balanced athleticism, running fewer miles and more bursts, training my hips to be stronger and more flexible, training my single-leg strength by using my own body weight, and strength-training in three planes of motion as much as possible. I haven't tried that hill run again yet. I can run a hard four miles, and an even harder mile, and for me, that feels like enough. According to Dye, the health of our knees today can predict their very viability tomorrow.

Build a Better Knee

Do these exercises independently of running

Four-Way Kick Attach your ankle to a cable machine (or use a resistance band). Face the machine. Kick your leg back 20 times. Rotate 90 degrees and kick to the side. Repeat in all four directions (when you're facing away from the machine, kick forwards). Start with two sets of 20 in each direction on each leg, and work up to three sets of 50 in each direction	

Lateral Step Up with Kick Stand with your left side next to a step eight to 12 inches high. Step up with your left foot, driving the right foot in the air so it's level with your waist. Step back down and repeat. This strengthens the lateral muscle of the quad to help protect the knee, Cummings says. Do two sets of eight to 12 repetitions on each side.	
Hip Lift Stand on your right foot (use a wall for balance). With your left knee bent, drop the left hip and lift it up. "Let the hip drop and try not to bend the left leg," says Dr Stephen Pribut, a sports podiatrist. "You'll feel it in the glutes." Do 15 to 20 times on each side.	
Step Down Stand on a step on your right foot. Lower your left leg towards the floor, making sure the knee of your right leg is centred over your foot. "With the step down, you're putting more focus on the glutes," says Matt Schneider, athletics trainer at the Boulder (Colorado) Centre for Sports Medicine, USA. Do two sets of 10 on each.	
Leg Lift Strong hip abductors help prevent strain of the ITB. "There's less torque on the band because you're decreasing the amount of hip abduction," says Flynn. Lie on your side with your elbow on the floor. Lift your upper leg about a foot and return to the starting position. Do 20 to 30 on each side. **Stretches: ITB** Lean into each stretch for 15 to 20 seconds, then switch sides	
Wall Banger Stand with your right side about six to 12 inches from a wall. Squat and lean your upper body to the left until your right hip touches the wall. "It stretches the ITB and strengthens the glutes," says Dr Nancy Cummings, the assistant professor at Florida Southern College.	
Side Stretch Stand with your left foot crossed in front of your right, and lean your upper body to the left with your hands overhead. Lean as far as you can without bending your knees	
Backward T Stretch Stand, feet together, facing a wall about six to 12 inches away. Hold your arms to your sides to form a T. Without bending your knees, reach down and back as far as you can with your right hand.