What Science Can Teach Us About Flexibility

In recent years, biomedical research has begun to investigate and appreciate what yogis have known for centuries: Stretching keeps us limber, youthful, and healthy. By Fernando Pagés Ruiz

If you're already practicing yoga, you don't need exercise scientists and physiologists to convince you of the benefits of stretching. Instead, you'd probably like them to tell you if there's anything in their flexibility research that can help you go deeper in your asanas. For example, when you fold into a forward bend and are brought up short by the tightness in the back of your legs, can science tell you what's going on? And can that knowledge help you go deeper?

The answer to both questions is "Yes." A knowledge of physiology can help you visualize the inner workings of your body and focus on the specific mechanisms that help you stretch. You can optimize your efforts if you know whether the tightness in your legs is due to poor skeletal alignment, stiff connective tissues, or nerve reflexes designed to keep you from hurting yourself. And if you know whether any uncomfortable sensations you feel are warnings that you're about to do damage, or whether they're just notices that you're entering exciting new territory, you can make an intelligent choice between pushing on or backing off—and avoid injuries.

In addition, new scientific research may even have the potential to extend the wisdom of yoga. If we understand more clearly the complex physiology involved in yogic practices, we may be able refine our techniques for opening our bodies.

Why Stretch?

Of course, yoga does far more than keep us limber. It releases tensions from our bodies and minds, allowing us to drop more deeply into meditation. In yoga, "flexibility" is an attitude that invests and transforms the mind as well as the body.

But in Western, physiological terms, "flexibility" is just the ability to move muscles and joints through their complete range. It's an ability we're born with, but that most of us lose. "Our lives are restricted and sedentary," explains Dr. Thomas Green, a chiropractor in Lincoln, Nebraska, "so our bodies get lazy, muscles atrophy, and our joints settle into a limited range."

Back when we were hunter-gatherers, we got the daily exercise we needed to keep our bodies flexible and healthy. But modern, sedentary life is not the only culprit that constricts muscles and joints. Even if you're active, your body will dehydrate and stiffen with age. By the time you become an adult, your tissues have lost about 15 percent of their moisture content, becoming less supple and more prone to injury. Your muscle fibers have begun to adhere to each other, developing cellular cross-links that prevent parallel fibers from moving independently. Slowly our elastic fibers get bound up with collagenous connective tissue and become more and more unyielding. This normal aging of tissues is distressingly similar to the process that turns animal hides into leather. Unless we stretch, we dry up and tan! Stretching slows this process of dehydration by stimulating the production of tissue lubricants. It pulls the interwoven cellular cross-links apart and helps muscles rebuild with healthy parallel cellular structure.

Remember the cheesy '70s sci-fi flick in which Raquel Welch and her miniaturized submarine crew get injected into someone's bloodstream? To really grasp how Western physiology can benefit asana practice, we need to go on our own internal odyssey, diving deep into the body to examine how muscles work.

Muscles are organs—biological units built from various specialized tissues that are integrated to perform a single function. (Physiologists divide muscles into three types: the smooth muscles of the viscera; the specialized cardiac muscles of the heart; and the striated muscles of the skeleton—but in this article we'll focus only on skeletal muscles, those familiar pulleys that move the bony levers of our bodies.)

The specific function of muscles, of course, is movement which is produced by muscle fibers, bundles of specialized cells that change shape by contracting or relaxing. Muscle groups operate in concert, alternately contracting and stretching in precise, coordinated sequences to produce the wide range of movements of which our bodies are capable.

In skeletal movements, the working muscles—the ones that contract to move your bones—are called the "agonists." The opposing groups of muscles—the ones that must release and elongate to allow movement—are called the "antagonists." Almost every movement of the skeleton involves the coordinated action of agonist and antagonist muscle groups: They're the yang and yin of our movement anatomy.

But although stretching—the lengthening of antagonist muscles—is half the equation in skeletal movement, most exercise physiologists believe that increasing the elasticity of healthy muscle fiber is not an important factor in improving flexibility. According to Michael Alter, author of Science of Flexibility (Human Kinetics, 1998), current research demonstrates that individual muscle fibers can be stretched to approximately 150 percent of their resting length before tearing. This extendibility enables muscles to move through a wide range of motion, sufficient for most stretches—even the most difficult asanas.

If your muscle fibers don't limit your ability to stretch, what does? There are two major schools of scientific thought on what actually most limits flexibility and what should be done to improve it. The first school focuses not on stretching muscle fiber itself but on increasing the elasticity of connective tissues, the cells that bind muscle fibers together, encapsulate them, and network them with other organs; the second addresses the "stretch reflex" and other functions of the autonomic (involuntary) nervous system. Yoga works on both. That's why it's such an effective method for increasing flexibility.

Your Internal Knitting

Connective tissues include a variety of cell groups that specialize in binding our anatomy into a cohesive whole. It is the most abundant tissue in the body, forming an intricate mesh that connects all our body parts and compartmentalizes them into discrete bundles of anatomical structure—bones, muscles, organs, etc. Almost every yoga asana exercises and improves the cellular quality of this varied and vital tissue, which transmits movement and provides our muscles with lubricants and healing agents. But in the study of flexibility we are concerned with only three types of connective tissue: tendons, ligaments, and muscle fascia. Let's explore each of them briefly.

Tendons transmit force by connecting bones to muscle. They are relatively stiff. If they weren't, fine motor coordination like playing piano or performing eye surgery would be impossible. While tendons have enormous tensile strength, they have very little tolerance to stretching. Beyond a 4 percent stretch, tendons can tear or lengthen beyond their ability to recoil, leaving us with lax and less responsive muscle-to-bone connections.

Ligaments can safely stretch a bit more than tendons—but not much. Ligaments bind bone to bone inside joint capsules. They play a useful role in limiting flexibility, and it is generally recommended that you avoid stretch-

ing them. Stretching ligaments can destabilize joints, compromising their efficiency and increasing your likelihood of injury. That's why you should flex your knees slightly—rather than hyperextending them—in Paschimottanasana (Seated Forward Bend), releasing tension on posterior knee ligaments (and also on the ligaments of the lower spine).

Muscle fascia is the third connective tissue that affects flexibility, and by far the most important. Fascia makes up as much as 30 percent of a muscle's total mass, and, according to studies cited in Science of Flexibility, it accounts for approximately 41 percent of a muscle's total resistance to movement. Fascia is the stuff that separates individual muscle fibers and bundles them into working units, providing structure and transmitting force.

Many of the benefits derived from stretching—joint lubrication, improved healing, better circulation, and enhanced mobility—are related to the healthy stimulation of fascia. Of all the structural components of your body which limit your flexibility, it is the only one that you can stretch safely. Anatomist David Coulter, author of Anatomy of Hatha Yoga, reflects this in his description of the asanas as "a careful tending to your internal knitting."

Now let's apply this physiology lesson to a basic but very powerful posture: Paschimottanasana. We'll begin with the anatomy of the asana.

The name of this pose combines three words: "Paschima," the Sanskrit word for "west"; "uttana," which means "intense stretch"; and "asana," or "posture." Since yogis traditionally practiced facing east toward the sun, "west" refers to the entire back of the human body.

This seated forward bend stretches a muscle chain that begins at the Achilles tendon, extends up the back of the legs and pelvis, then continues up along the spine to end at the base of your head. According to yoga lore, this asana rejuvenates the vertebral column and tones the internal organs, massaging the heart, kidneys, and abdomen.

Imagine you're lying on your back in yoga class, getting ready to fold up and over into Paschimottanasana. Your arms are relatively relaxed, palms on your thighs. Your head is resting comfortably on the floor; your cervical spine is soft, but awake. The instructor asks you to lift your trunk slowly, reaching out through your tailbone and up through the crown of your head, being careful not to overarch and strain your lower back as you move up and forward. She suggests that you picture an imaginary string attached to your chest, gently pulling you out and up—opening anahata chakra, the heart center—as you rotate through the hips into a seated position.

The image your teacher is using is not just poetic, it's also anatomically accurate. The primary muscles at work during this first phase of a forward bend are the rectus abdominis that run along the front of your trunk. Attached to your ribs just below your heart and anchored to your pubic bone, these muscles are the anatomical string that literally pulls you forward from the heart chakra.

The secondary muscles working to pull your torso up run through your pelvis and along the front of your legs: the psoas, linking torso and legs, the quadriceps on the front of your thighs, and the muscles adjacent to your shin bones.

In Paschimottanasana, the muscles running from heart to toe along the front of your body are the agonists. They're the muscles that contract to pull you forward. Along the back of your torso and legs are the opposing, or complementary, groups of muscles, which must elongate and release before you can move forward.

By now, you've stretched forward and settled into the pose completely, backing off slightly from your maximum stretch and breathing deeply and steadily. Your mind focuses on the subtle (or perhaps not so subtle) messages from your body. You feel a pleasant pull along the full length of your hamstrings. Your pelvis is tilted forward, your spinal column is lengthening, and you perceive a gentle increase in the spaces between each of your vertebrae.

Your instructor is quiet now, not pushing you to stretch further but allowing you to go deeper into the posture at your own pace. You're getting to know the posture and getting comfortable with it. Perhaps you even feel like a timelessly serene statue as you hold Paschimottanasana for several minutes.

In this kind of practice, you're maintaining the posture long enough to affect the plastic quality of your connective tissues. Prolonged stretches like this can produce healthful, permanent changes in the quality of the fascia that binds your muscles. Julie Gudmestad, a physical therapist and certified Iyengar instructor, uses prolonged asanas with patients at her clinic in Portland, Oregon. "If they hold the poses for shorter periods, people get a nice sense of release," Gudmestad explains, "but they aren't necessarily going to get the structural changes that add up to a permanent increase in flexibility."

According to Gudmestad, stretches should be held 90 to 120 seconds to change the "ground substance" of connective tissue. Ground substance is the nonfibrous, gel-like binding agent in which fibrous connective tissues like collagen and elastin are embedded. Ground substance stabilizes and lubricates connective tissue. And it is commonly believed that restrictions in this substance can limit flexibility, especially as we age.

By combining precise postural alignment with the use of props, Gudmestad positions her patients to relax into asanas so they can remain long enough to make lasting change. "We make sure people aren't in pain," Gudmestad says, "so they can breathe and hold a stretch longer."

Reciprocal Inhibition

Along with stretching connective tissue, much of the work we do in yoga aims to enlist the neurological mechanisms that allow our muscles to release and extend. One such mechanism is "reciprocal inhibition." Whenever one set of muscles (the agonists) contracts, this built-in feature of the autonomic nervous system causes the opposing muscles (the antagonists) to release. Yogis have been using this mechanism for millennia to facilitate stretching.

To experience reciprocal inhibition firsthand, sit down in front of a table and gently press the edge of your hand, karate-chop style, onto the tabletop. If you touch the back of your upper arm—your triceps muscle—you'll notice that it's firmly engaged. If you touch the opposing muscles, the biceps (the big muscles on the front of your upper arm), they should feel relaxed.

In Paschimottanasana the same mechanism is at play. Your hamstrings are released when you engage their opposing muscle group, the quadriceps.

David Sheer, an orthopedic manual therapist in Nashville, Tennessee, uses the principle of reciprocal inhibition to help patients safely improve their range of motion. If you went to Sheer to improve your hamstring flexibility, he would work the quadriceps, developing strength in the front thigh to help relax the hamstrings. Then, when the hamstrings have achieved their maximum range for the day, Sheer would strengthen them with weight-bearing, isometric, or isotonic exercises.

At the Yoga Room of Nashville, Betty Larson, a certified Iyengar instructor, uses the principles of reciprocal inhibition to help yoga students release their hamstrings in Paschimottanasana.

"I remind my students to contract their quads," says Larson, "lifting up the entire length of the front of the leg, so the back of the leg is loosened." Larson also includes backbends in her classes to strengthen her students' hamstrings and backs. She feels it's extremely important to develop strength in the muscles you are stretching. Like many teachers, Larson is using ancient yogic techniques that apply physiological principles only recently understood by modern science.

According to Sheer, she's doing the right thing. He claims the best type of flexibility combines improved range of motion with improved strength. "It's useful flexibility," says Sheer. "If you only increase your passive flexibility without developing the strength to control it, you make yourself more vulnerable to a serious joint injury."

Let's return to your Paschimottanasana. Imagine that this time, as you pivot from your pelvis and reach your trunk forward, your hamstrings are unusually tight. You can't seem to move as deeply into the pose as you would like, and the harder you try, the tighter your hamstrings feel. Then your instructor reminds you to continue breathing and relax every muscle that's not actively engaged in sustaining the pose.

You give up trying to match your personal best. You relax into the posture, without judgment, and slowly your hamstrings begin to release.

Why are you able to gradually bring your head toward your shins once you stop straining? According to science—and many ancient yogis—what was limiting your flexibility most wasn't your body, it was your mind—or, at least, your nervous system.

The Stretch Reflex

According to physiologists who view the nervous system as the major obstacle to increased flexibility, the key to overcoming one's limitations lies in another built-in feature of our neurology: the stretch reflex. Scientists who study flexibility think that the small, progressive steps that allow us to go a little deeper during the course of one session—and that dramatically improve our flexibility over a life of yoga practice—are in large part the result of retraining this reflex.

To get an understanding of the stretch reflex, picture yourself walking in a winter landscape. Suddenly you step on a patch of ice, and your feet start to splay apart. Immediately your muscles fire into action, tensing to draw your legs back together and regain control. What just happened in your nerves and muscles?

Every muscle fiber has a network of sensors called muscle spindles. They run perpendicular to the muscle fibers, sensing how far and fast the fibers are elongating. As muscle fibers extend, stress on these muscle spindles increases.

When this stress comes too fast, or goes too far, muscle spindles fire an urgent neurological "SOS," activating a reflex loop that triggers an immediate, protective contraction.

That's what happens when the doctor thumps with a small rubber mallet on the tendon just below your kneecap, stretching your quadriceps abruptly. This rapid stretch stimulates the muscle spindles in your quadriceps, signaling the spinal cord. An instant later the neurological loop ends with a brief contraction of your quadriceps, producing the well known "knee jerk reaction."

That's how the stretch reflex protects your muscles. And that's why most experts caution against bouncing while stretching. Bouncing in and out of a stretch causes the rapid stimulation of muscle spindles that triggers reflexive tightening, and can increase your chances of injury.

Slow, static stretching also triggers the stretch reflex, but not as abruptly. When you fold forward into Paschimottanasana, the muscle spindles in your hamstrings begin to call for resistance, producing tension in the very muscles you're trying to extend. That's why improving flexibility through static stretching takes a long time. The improvement comes through slow conditioning of your muscle spindles, training them to tolerate more tension before applying the neuro-brakes.

Proprioceptive Neuromuscular Facilitation...What?
Among the recent developments in Western flexibility training are neurological techniques that retrain the stretch reflex, promoting quick, dramatic gains in flexibility. One of these techniques is called—take a deep breath—proprioceptive neuromuscular facilitation. (Fortunately, it's usually just called PNF).

To apply PNF principles to Paschimottanasana, try this: While bending forward, just short of your maximum stretch, engage your hamstrings in an isometric contraction—as if you were trying to draw your heels down through the floor—lasting approximately five to 10 seconds. Then release this action, and see if you can move a little deeper into the forward bend.

The PNF method manipulates the stretch reflex by having you contract a muscle while it's at near-maximum length. When you engage your hamstrings, you actually ease the pressure on your muscle spindles, and they send signals that it's safe for the muscle to release further. In a seeming paradox, contracting the muscle actually allows it to lengthen. If you engage and then release your muscle fibers in this way, you will probably discover more comfort in a stretch that was near your maximum just seconds before. Now you're ready to open a little more, taking advantage of a momentary lull in neural activity, deepening the stretch. Your nervous system adjusts, affording you greater range of motion.

"PNF is as close as we've come to scientific stretching," physical therapist Michael Leslie says. Leslie uses combinations of modified PNF techniques to help members of the San Francisco Ballet improve their flexibility. "In my experience it can take weeks of static training to achieve the gains possible in one session of PNF," Leslie says.

As of yet, yoga has not focused systematically on PNF-type techniques. But vinyasa practices that emphasize careful sequencing of asanas and/or repetition of asanas—moving in and out of the same posture several times—tend to promote neurological conditioning.

Gray Kraftsow, founder of the American Viniyoga Institute and one of the most highly respected teachers in the Viniyoga lineage of T.K.V. Desikachar, likens Viniyoga to PNF. "Alternating between contracting and stretching is what changes the muscle," Kraftsow says. "Muscles relax and stretch further after contracting."

Prana & Flexibility
Kraftsow also emphasizes the importance of the breath in any kind of neurological work, pointing out that breathing is a link between our consciousness and our autonomic nervous system. "It's this quality of breathing," Kraftsow says, "that qualifies it as a primary tool in any science of self development."

Pranayama, or breath control, is the fourth limb in a yogi's path toward samadhi. One of the most important yogic practices, it helps the yogi gain control over the movement of prana (life energy) throughout the body. But whether viewed through esoteric yoga physiology or the scientific physiology of the West, the connection between relaxation, stretching, and breathing is well established. Physiologists describe this mechanical and neurological correlation of movement and breath as an instance of synkinesis, the involuntary movement of one part of the body that occurs with the movement of another part.

While you are holding Paschimottanasana, breathing deeply and steadily, you may notice an ebb and flow to your stretching that mirrors the tide of your breath. As you inhale, your muscles tighten slightly, reducing the stretch. As you exhale, slowly and completely, your abdomen moves back toward your spine, the muscles in your lower back seem to grow longer, and you can drop your chest toward your thighs.

It's obvious that exhalation deflates the lungs and lifts your diaphragm into the chest, thereby creating space in the abdominal cavity and making it easier to bend the lumbar spine forward. (Inhalation does the opposite, filling the abdominal cavity like an inflating balloon, making it difficult to fold your spine forward completely.) But you may not realize that exhalation also actually relaxes the muscles of your back and tilts your pelvis forward.

In Paschimottanasana, the musculature of the lower back is in passive tension. According to research cited in Science of Flexibility, every inhalation is accompanied by an active contraction of the lower back—a contraction in direct opposition to the desired forward bend. Then exhalation releases the lower back muscles, facilitating the stretch. If you place your palms on your back, just above the hips, and breathe deeply, you can feel the erector spinae on either side of your spinal column engage as you inhale and release as you exhale. If you pay close attention, you'll also notice that each inhalation engages the muscles around the coccyx, at the very tip of your spine, drawing the pelvis back slightly. Each exhalation relaxes these muscles and frees your pelvis, allowing it to rotate around the hip joints.

As your lungs empty and the diaphragm lifts into your chest, your back muscles release and you are able to fold into your ultimate stretch. Once there, you may experience a pleasant, seemingly eternal moment of inner peace, the pacifying of the nervous system traditionally considered one of the benefits of forward bends.

At this point, you may feel especially in touch with the spiritual element of yoga. But Western science also offers a material explanation for this experience. According to Alter's Science of Flexibility, during an exhalation the diaphragm pushes up against the heart, slowing down the heart rate. Blood pressure decreases, as does stress on the rib cage, abdominal walls, and intercostal muscles. Relaxation ensues, and your tolerance to stretching is enhanced—as well as your sense of well-being.

Short Cuts to Flexibility?

But not every moment in yoga is peaceful. At the extreme end of hatha yoga achievement, practitioners can experience breakthroughs that may involve a degree of pain, fear, and risk. (After all, hatha does mean "forceful.") You may have seen the photograph in Light on Yoga of B.K.S. Iyengar poised in Mayurasana (Peacock Pose) on the back of a student in Paschimottanasana, forcing her to fold more deeply. Or perhaps you've watched a teacher stand on the thighs of a student in Baddha Konasana (Bound Angle Pose). Such methods might appear dangerous or even cruel to an outsider, but in the hands of an experienced instructor they can be remarkably effective—and they bear a striking resemblance to cutting-edge techniques in Western flexibility training that focus on reconditioning neurological mechanisms.

As I researched this article, a friend told me about a time he accidentally engaged one of these mechanisms and experienced a surprising breakthrough after years of trying to master Hanumanasana (a pose better known in the West as "the splits"). One day, as my friend attempted the posture—left leg forward and right leg back, hands lightly supporting him on the floor—he stretched his legs farther apart than usual, allowing almost the full weight of his torso to rest down through his hips. Suddenly he felt an intense warmth in his pelvic region and a rapid, unexpected release that brought both his sitting bones to the floor.My friend had triggered a physiological reaction rarely encountered while stretching, a neurological "circuit breaker" that opposes and overrides the stretch reflex. While the stretch reflex tenses muscle tissue, this other reflex—technically, it's known as the "inverse myotatic (stretch) reflex"—completely releases muscular tension to protect the tendons.

How does it work? At the ends of every muscle, where fascia and tendons interweave, there are sensory bodies that monitor load. These are the Golgi tendon organs (GTOs). They react when either a muscular contraction or a stretch places too much stress on a tendon.

The huge, state-sponsored sports apparatus of the former Soviet Union developed a neurological flexibility training method based largely on manipulating this GTO reflex. "You already have all the muscle length you need," argues Russian flexibility expert Pavel Tsatsouline, "enough for full splits and most of the difficult asanas. But controlling flexibility requires control of an autonomic function." Tsatsouline makes the point by lifting his leg up on a chair back. "If you can do this," he says, "you've already got enough stretch to do the splits." According to Tsatsouline, it's not muscle or connective tissue that's stopping you. "Great flexibility," asserts Tsatsouline, "can be achieved by flicking a few switches in your spinal cord."

But exploiting the GTO mechanism to enhance flexibility entails certain risks, because muscles must be fully extended and under extreme tension to trigger a GTO reflex. Implementing enhanced methods of flexibility training—like the Russian system or advanced yoga techniques—requires an experienced teacher who can make sure your skeleton is correctly aligned and that your body is strong enough to handle the stresses involved. If you don't know what you're doing, it's easy to get hurt.

If used correctly, though, these methods can be extremely effective. Tsatsouline claims he can teach even stiff middle-aged men, with no prior flexibility training, how to do the splits in about six months.

Applied Physiology
By now you may be asking yourself, "What do these Western stretching techniques have to do with yoga?"

On the one hand, of course, stretching is an important component of building the yoga-deha, the yogic body that allows the practitioner to channel ever more prana. That's one reason why the major hatha yoga schools base their practice on the classic asanas, a series of postures that illustrate and encourage the ideal range of human movement.

But any good teacher will also tell you that yoga isn't just about stretching. "Yoga is a discipline that teaches us new ways of experiencing the world," Judith Lasater, Ph.D. and physical therapist, explains, "so that we can give up the attachments to our suffering." According to Lasater, there are only two asanas: conscious or unconscious. In other words, what distinguishes a particular position as an asana is our focus, not simply the outer conformation of the body.

It's certainly possible to get so caught up in pursuit of physical perfection that we lose sight of the "goal" of asana practice—the state of samadhi. At the same time, though, exploring the limits of the body's flexibility can be a perfect vehicle for developing the one-pointed concentration needed for the "inner limbs" of classical yoga.

And there is certainly nothing inherently contradictory about using the analytical insights of Western science to inform and enhance the empirical insights of millennia of asana practice. In fact, yoga teacher B.K.S. Iyengar, perhaps the most influential figure in the Western assimilation of hatha yoga, has always encouraged scientific inquiry, advocating the application of strict physiological principles to the cultivation of a refined asana practice.

Some yogis are already embracing this synthesis enthusiastically. At the Meridian Stretching Center in Boston, Massachusetts, Bob Cooley is developing and testing a computer program that can diagnose flexibility deficiencies and prescribe asanas. New clients at Cooley's stretching center are asked to assume 16 different yoga postures as Cooley records specific anatomical landmarks on their bodies with a digitizing wand, similar to the ones used in computer-aided drafting. These body-point readings are computed to make comparisons between the client and models of both maximum and average human flexibility. The computer program generates a report that benchmarks and guides the client's progress, spelling out any areas needing improvement and recommending specific asanas.

Cooley uses an amalgamation of what he sees as the best points of Eastern and Western knowledge, combining the classic yoga asana with techniques similar to PNF. (An eclectic experimenter, Cooley incorporates Western psychotherapeutic insights, the Enneagram, and Chinese meridian theory in his approach to yoga.).

If you're a yoga purist, you may not like the idea of a yoga potpourri that mixes new-fangled scientific insights with time-honed yoga practices. But "new and improved" has always been one of America's national mantras, and blending the best from Eastern experience-based wisdom and Western analytical science may be a principal contribution our country makes to the evolution of yoga.

Resources

Anatomy of Movement by Blandine Calais-Germain (Eastland Press, 1993).