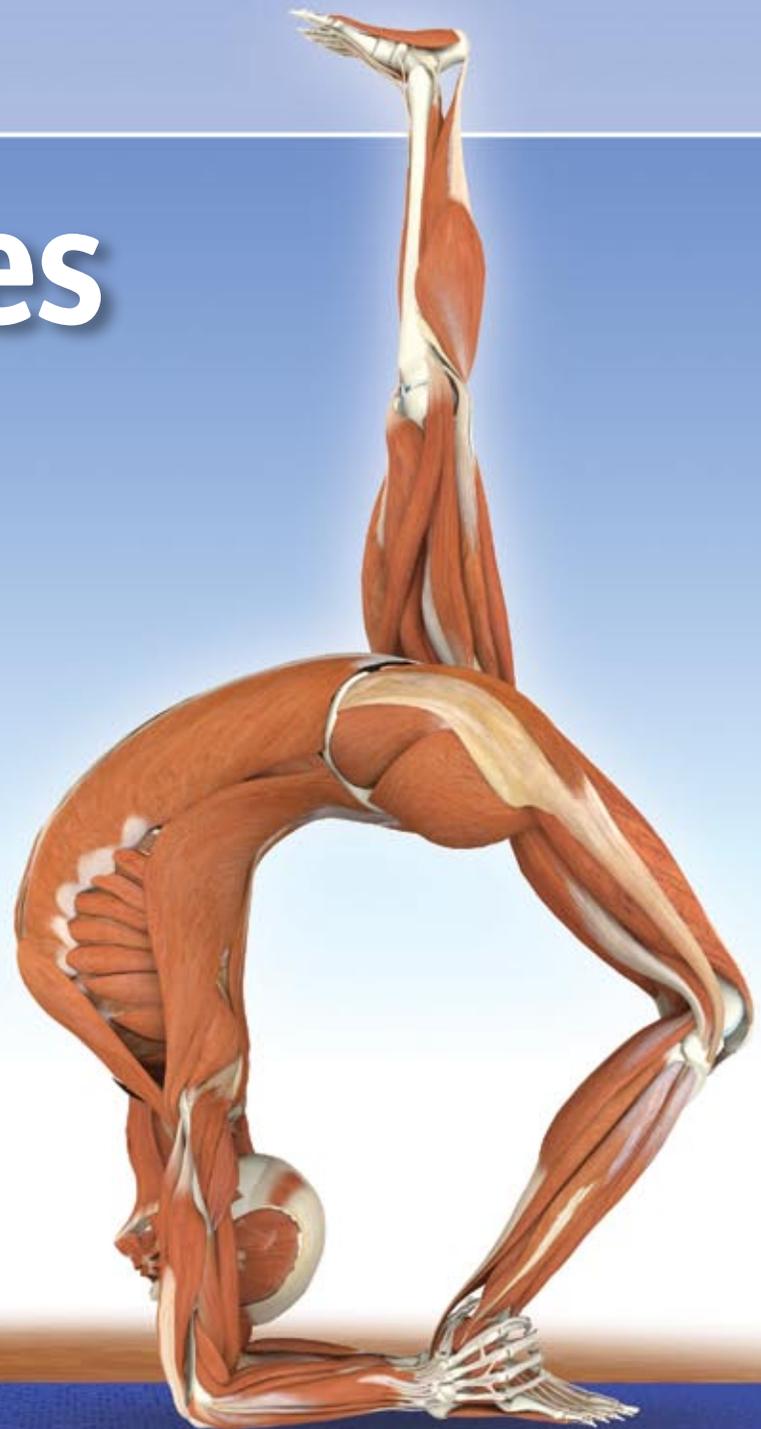
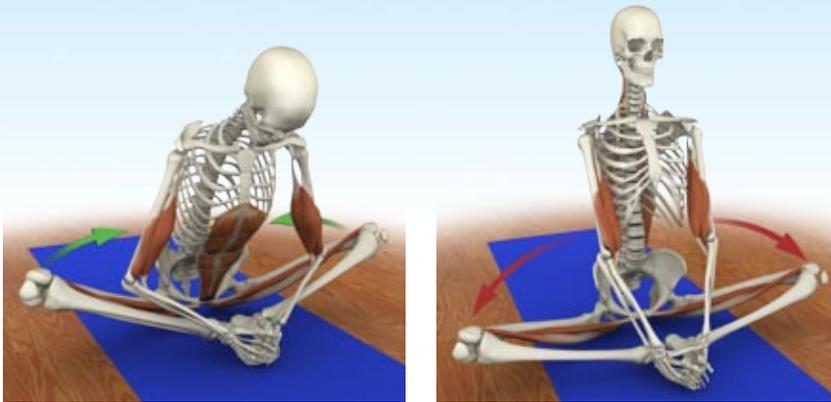


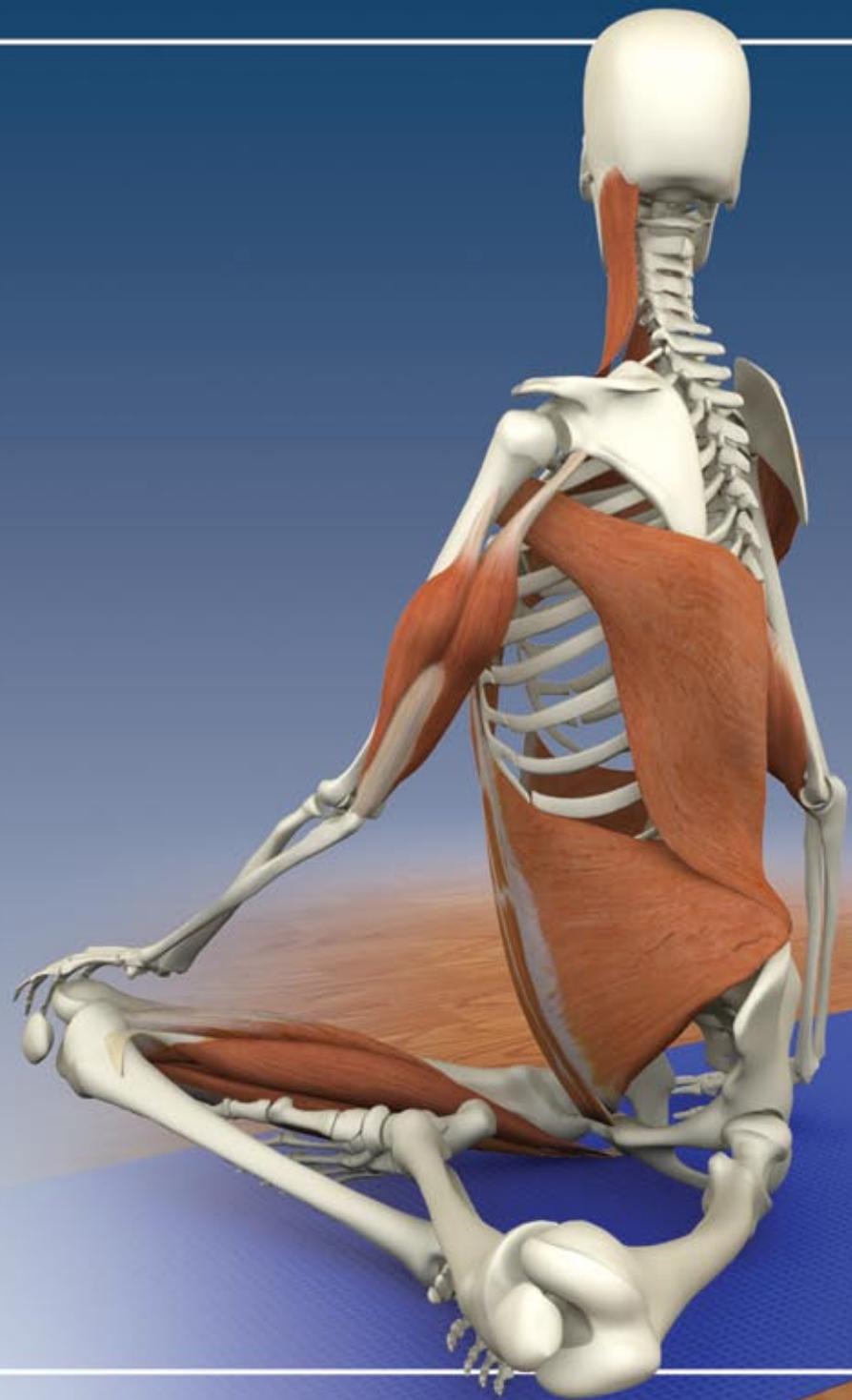
Scientific Keys Volume I

# The Key Muscles of Hatha Yoga

Ray Long MD FRCSC

With Illustrator Chris Macivor





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**Patanjali, the patron saint of yoga, said that mastery combines a balance of science and art. Knowledge of science is like the colors on an artist's palette – the greater the knowledge, the more colors available. The body is the canvas and the asanas are the art we create.**

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# Scientific Keys Volume I

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Always consult your healthcare provider before practicing yoga or any other exercise program.  
Yoga must always be practiced under the supervision of a qualified instructor.

The author assumes no responsibility for injuries that may occur as a result of the practice of yoga.

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Design: Ingrid Patricia Sanchez

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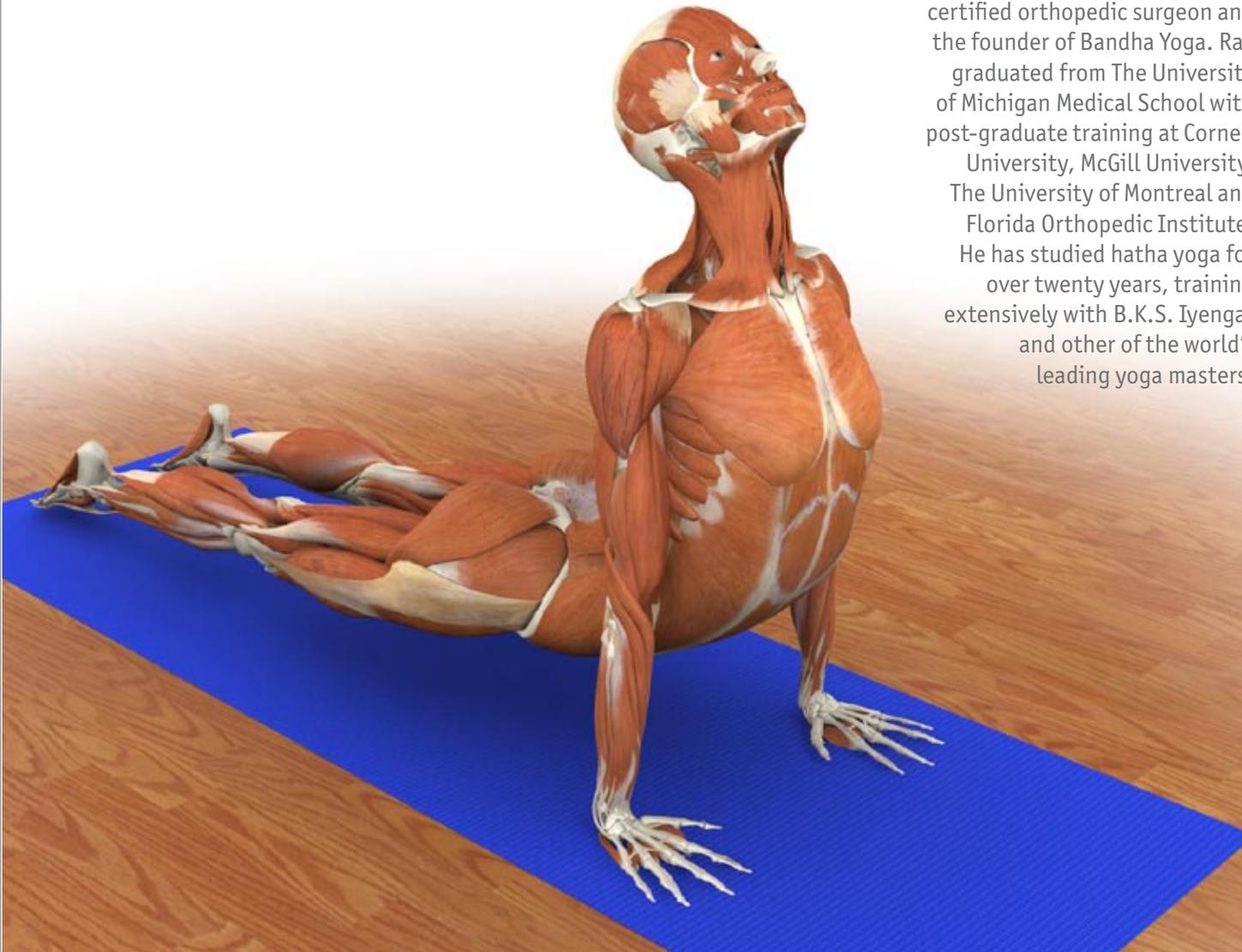
# About the Author

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*Ray Long* MD FRCS is a board certified orthopedic surgeon and the founder of Bandha Yoga. Ray graduated from The University of Michigan Medical School with post-graduate training at Cornell University, McGill University, The University of Montreal and Florida Orthopedic Institute. He has studied hatha yoga for over twenty years, training extensively with B.K.S. Iyengar and other of the world's leading yoga masters.

## Chris Macivor

*Chris Macivor* is a digital illustrator and the visual director of Bandha Yoga. Chris is a graduate of Etobicoke School of The Arts, Sheridan College and Seneca College. His work has spanned many genres from TV and film to videogames and underwater videography.



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# Scientific keys

## How to Use This Book

The images in this book are the keys. We present each muscle in the context of its function as an agonist, antagonist or synergist. Note the interrelated views of the muscle in each of its various representations.

Relax and study one muscle at a time. Actively apply what you have learned by visualizing the muscles as you perform the asanas. Consciously contract and relax them, as detailed in the images. This will consolidate your knowledge. Review each studied muscle, first at twenty four hours and then again at one week. In this way you will master the muscles and integrate them into your yoga practice.

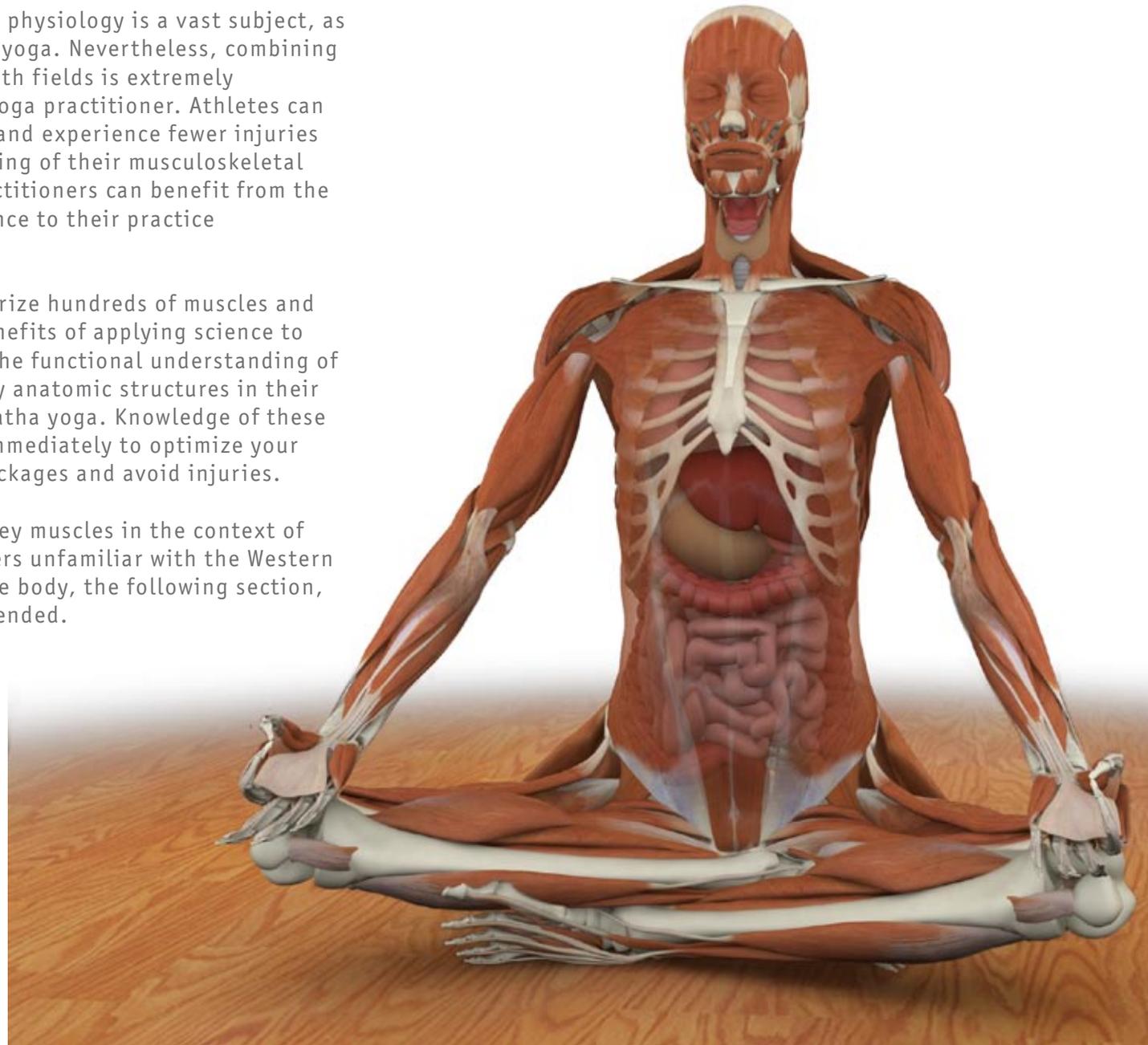


# Introduction

**H**uman anatomy and physiology is a vast subject, as is the art of hatha yoga. Nevertheless, combining knowledge from both fields is extremely beneficial to the yoga practitioner. Athletes can improve their performance and experience fewer injuries through a basic understanding of their musculoskeletal system. Similarly, yoga practitioners can benefit from the application of Western science to their practice development.

It is not necessary to memorize hundreds of muscles and bones to experience the benefits of applying science to yoga. What is necessary is the functional understanding of a manageable number of key anatomic structures in their settings as they relate to hatha yoga. Knowledge of these structures can be applied immediately to optimize your practice, break through blockages and avoid injuries.

This first volume presents key muscles in the context of hatha yoga. For practitioners unfamiliar with the Western scientific terminology of the body, the following section, “Fundamentals,” is recommended.



# Joints

As with the bones, the shape of the joints reflects their function (and their function reflects their shape). Joints come in a spectrum of shapes, depending on the mobility or stability they require. For example, the hip joint is a ball and socket while the knee joint is a hinge. A ball and socket type hip joint confers the greatest mobility in all planes and is useful for activities such as changing direction while walking and running (or reaching in various directions to grasp objects, as with the shoulder). A hinge type knee joint provides greater stability and is useful for propelling the body forward (or drawing an object towards the body, as with the elbow).

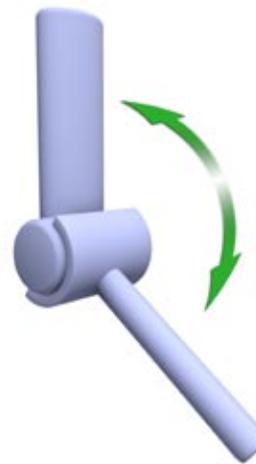
Other joints such as the intervertebral between the vertebrae allow for limited mobility between individual vertebrae but great stability to protect the spinal cord. Mobility of the spinal column comes from combining the limited movement of individual intervertebral joints as a whole.



*ball and socket*



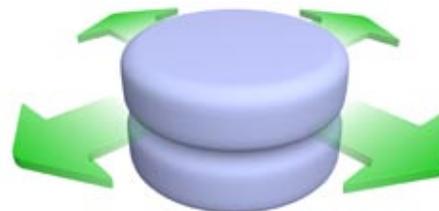
*hip*



*hinge*



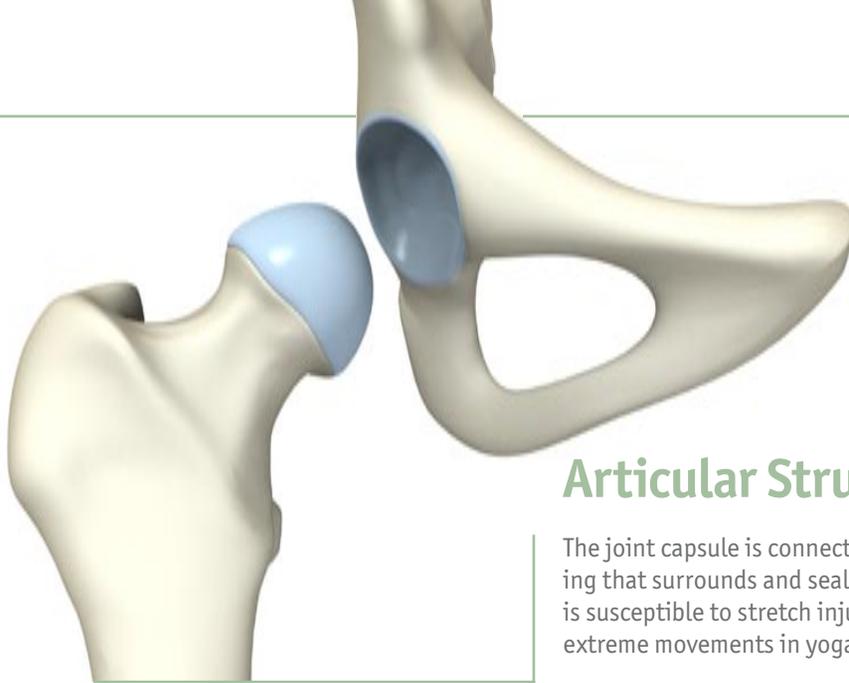
*knee*



*compressive*



*lumbar spine*



*hip articular cartilage*



*hip joint capsule with synovium (posterior view)*

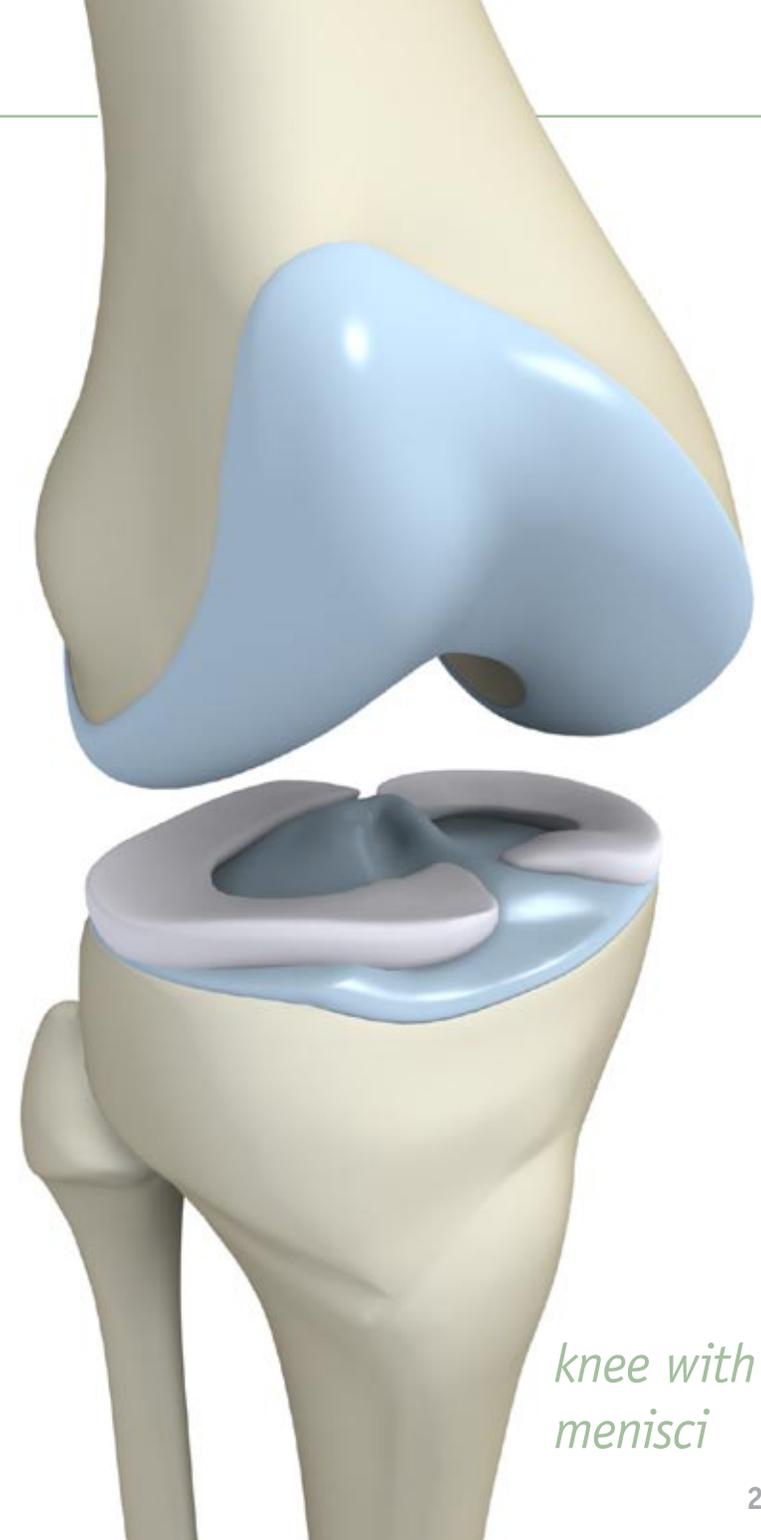
## Articular Structure

The joint capsule is connective tissue sheathing that surrounds and seals synovial joints. It is susceptible to stretch injury when executing extreme movements in yoga postures.

Synovial tissue lines the inside of the joint capsule. This tissue produces synovial fluid, a viscous lubricant for the joint surface that decreases friction during joint movement. Synovial fluid circulates throughout the joint, transporting nutrients to the articular cartilage and removing debris from the joint space. The various contortions resulting from yoga postures aid flex and expand the joint capsule, stimulating circulation of synovial fluid.

Articular cartilage covers the joint surfaces, allowing smooth gliding of one bone over the other. In fact, articular cartilage is one of the smoothest surfaces known to man. Applying excessive pressure to this fragile cartilage can injure it, ultimately resulting in arthritis.

The meniscus deepens the articular surface and broadens the contact area of the joint. This aids to stabilize the joint and distributes the force of gravity and muscular contraction over a greater surface area. The meniscus is composed of fibrocartilage, giving it a flexible rubbery consistency.



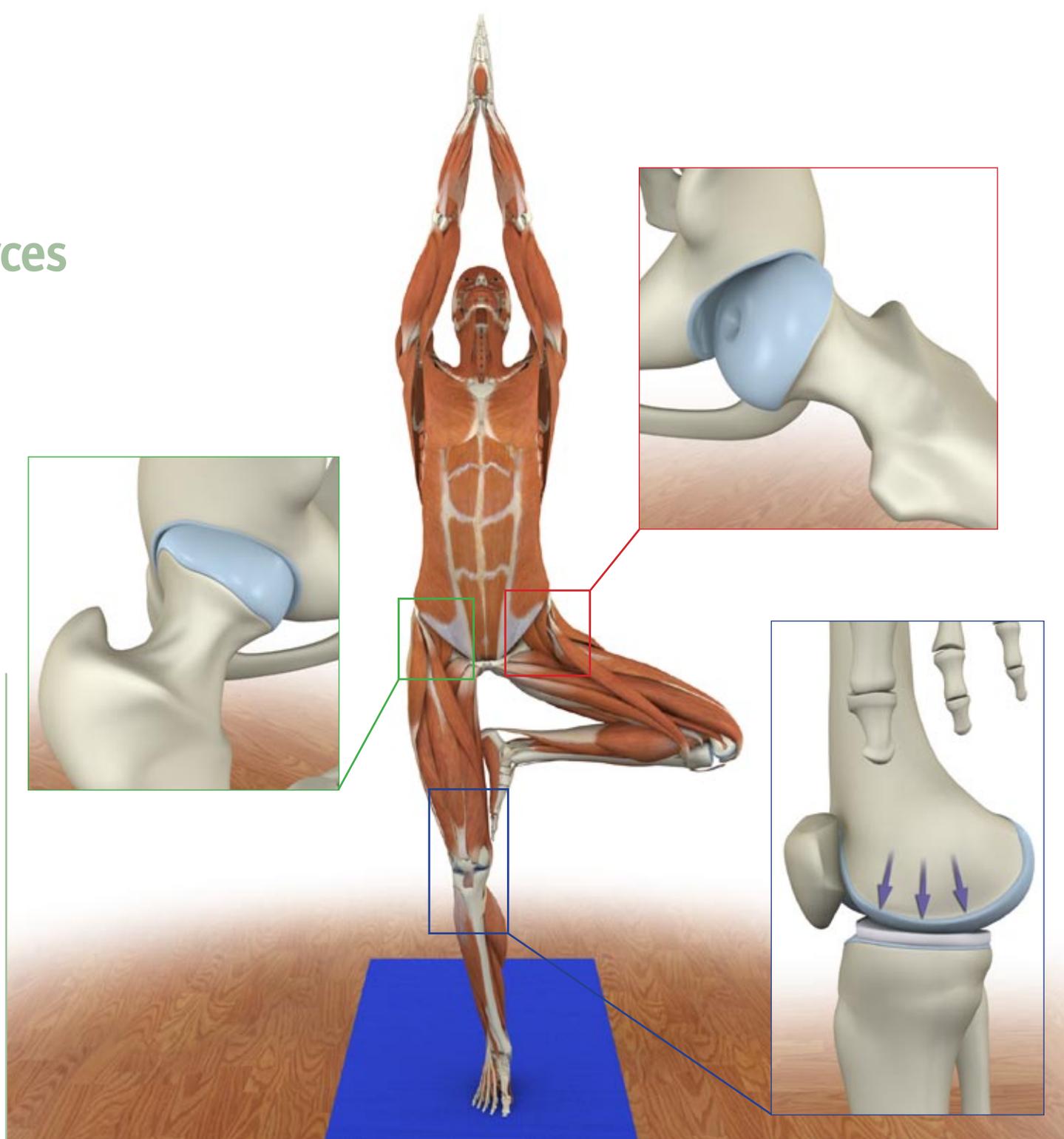
*knee with menisci*

# Joint reaction forces

Every action has an equal and opposite reaction. Muscular contraction and gravity create opposing forces across the joint surfaces, known as joint reaction forces. It is important to spread these forces over the greatest possible joint surface area.

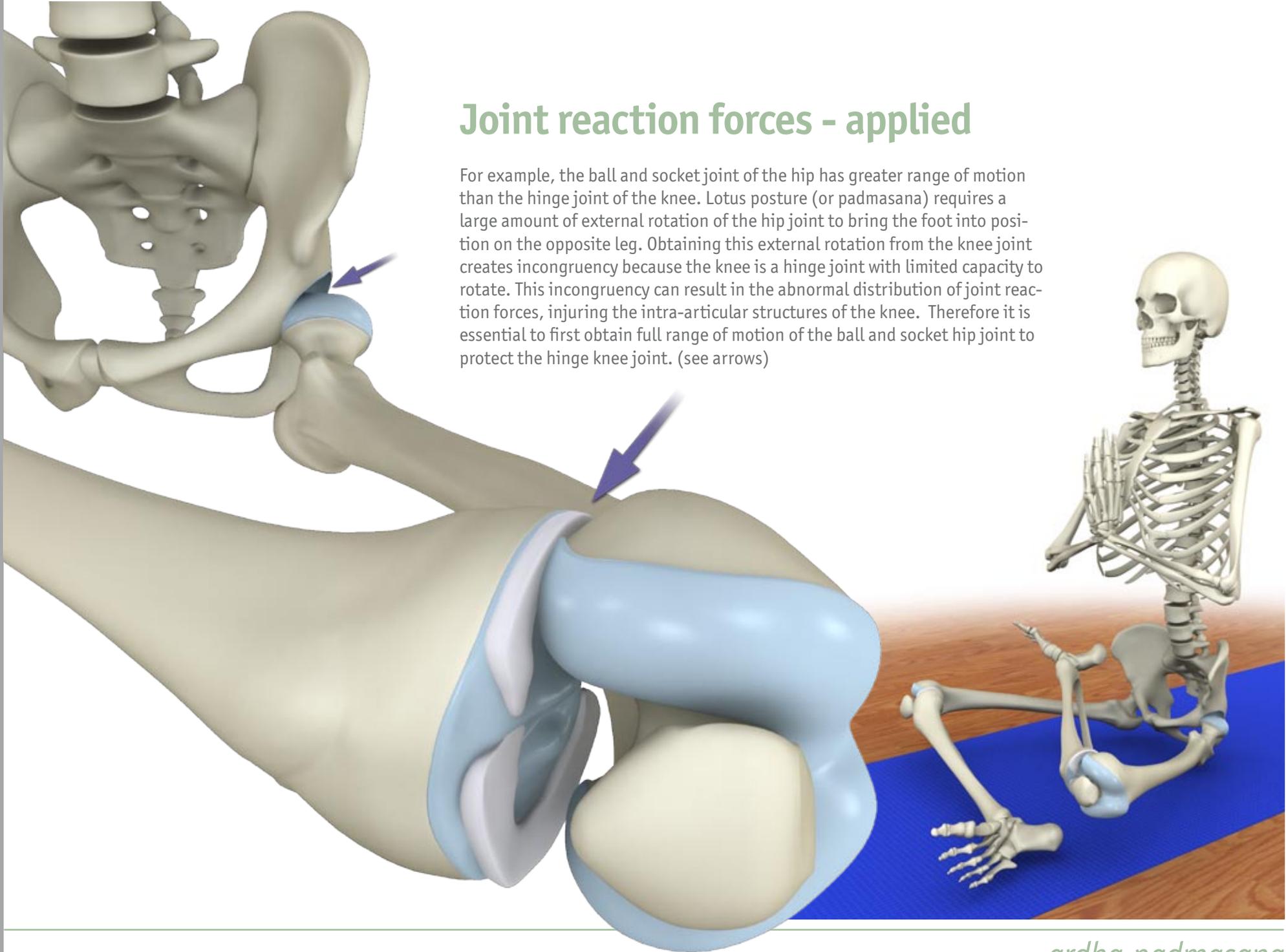
Joint congruency refers to the fit of a joint's articular surfaces. A joint is congruent when its surfaces fit together perfectly. Movement out of congruency focuses stress on a small surface area. A large force focused on a small area of articular cartilage can injure it, eventually causing degenerative changes.

Some yoga postures have the capacity to sublux or take a joint into an incongruent position. Avoid this by using the joints with a greater range of motion while protecting those joints with limited range of motion.



## Joint reaction forces - applied

For example, the ball and socket joint of the hip has greater range of motion than the hinge joint of the knee. Lotus posture (or padmasana) requires a large amount of external rotation of the hip joint to bring the foot into position on the opposite leg. Obtaining this external rotation from the knee joint creates incongruity because the knee is a hinge joint with limited capacity to rotate. This incongruity can result in the abnormal distribution of joint reaction forces, injuring the intra-articular structures of the knee. Therefore it is essential to first obtain full range of motion of the ball and socket hip joint to protect the hinge knee joint. (see arrows)



# Stretching Muscles

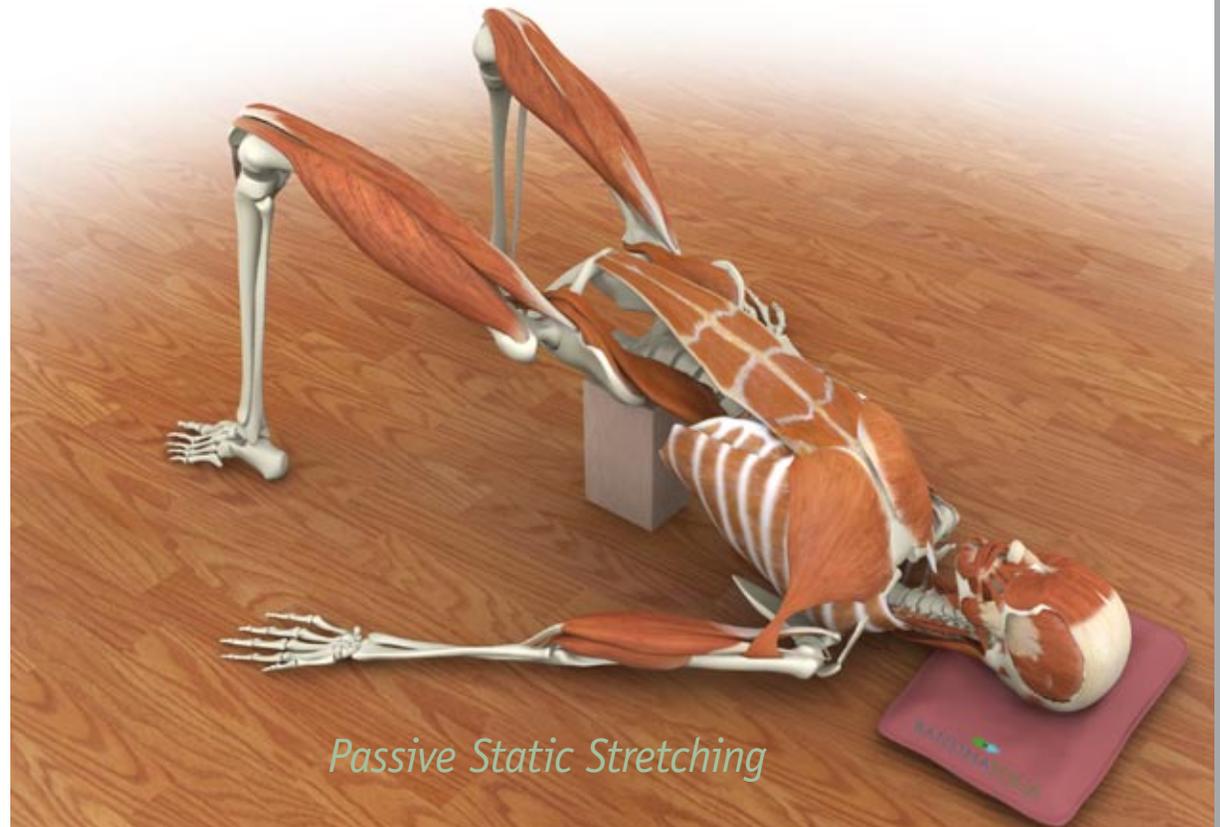
## Static Stretching

Static stretching is the most common technique used in hatha yoga. There are two categories of static stretching. The first is active static stretching. This involves contracting antagonist muscles to stretch a target muscle. Contracting the quadriceps, iliopsoas and biceps during the forward bend paschimottasana is a form of active static stretching of the hamstrings. Contracting antagonist muscles in active static stretching results in a phenomenon called "reciprocal inhibition." During reciprocal inhibition, the central nervous system signals the target muscle to relax.

Passive static stretching occurs when we relax into a stretch, using only the force of body weight (or an externally applied weight) to stretch muscles. The restorative pose setubandha is an example of passive static stretching of the iliopsoas muscle.



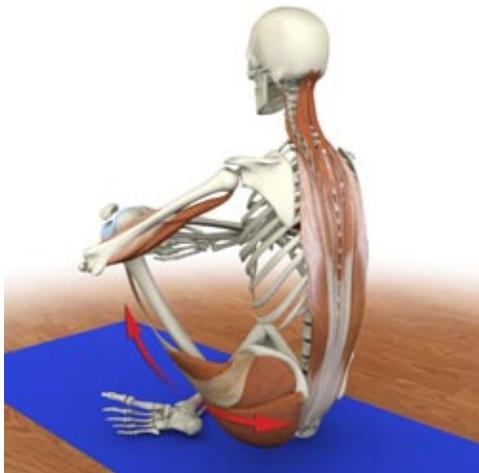
*Active Static Stretching*



*Passive Static Stretching*

## Facilitated Stretching

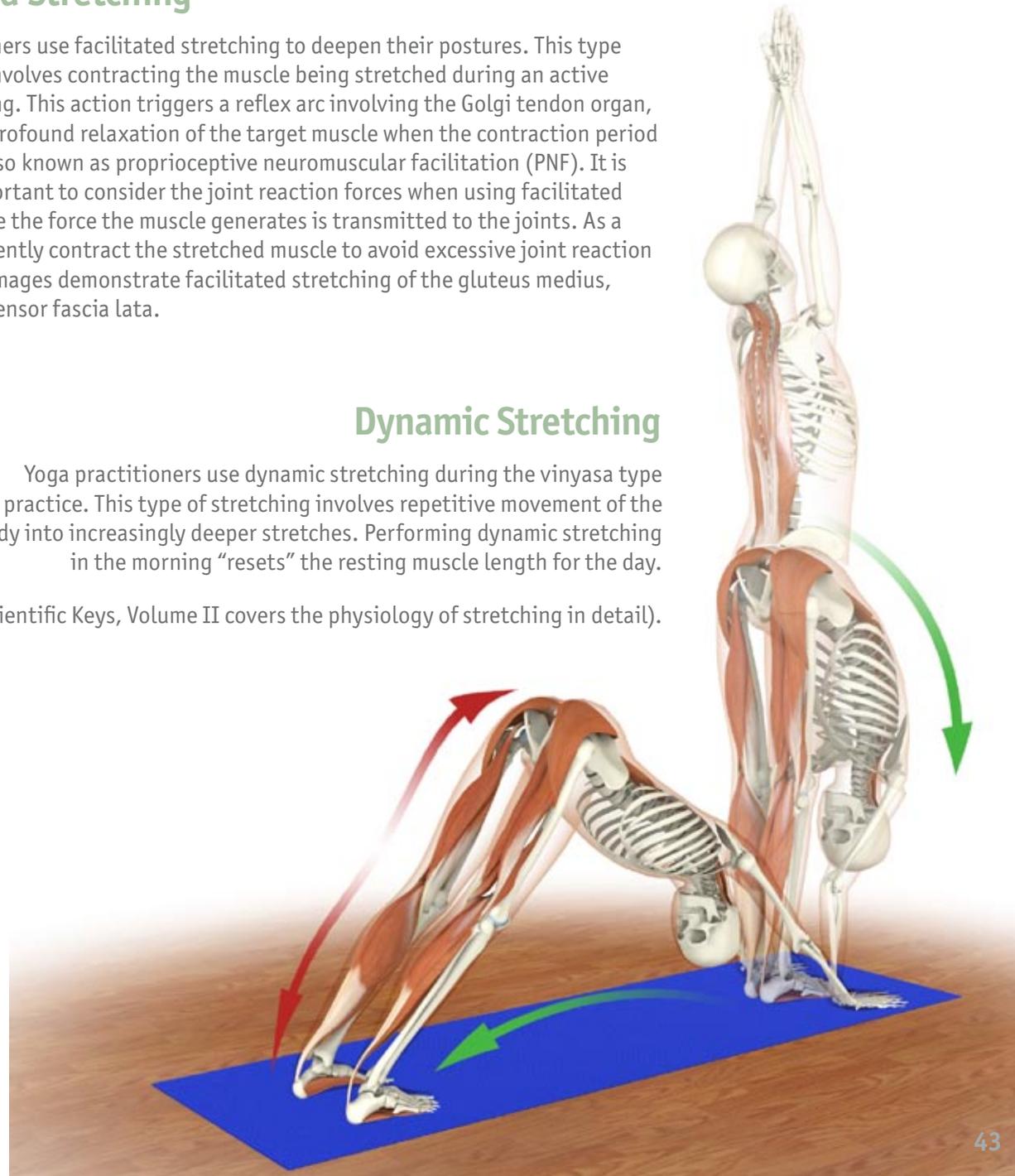
Yoga practitioners use facilitated stretching to deepen their postures. This type of stretching involves contracting the muscle being stretched during an active static stretching. This action triggers a reflex arc involving the Golgi tendon organ, resulting in a profound relaxation of the target muscle when the contraction period ends. This is also known as proprioceptive neuromuscular facilitation (PNF). It is extremely important to consider the joint reaction forces when using facilitated stretches, since the force the muscle generates is transmitted to the joints. As a general rule, gently contract the stretched muscle to avoid excessive joint reaction forces. These images demonstrate facilitated stretching of the gluteus medius, maximus and tensor fascia lata.



## Dynamic Stretching

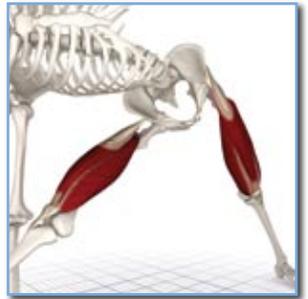
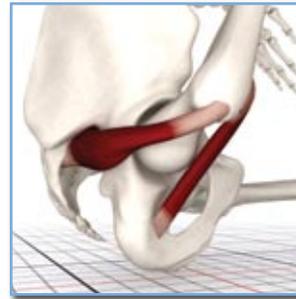
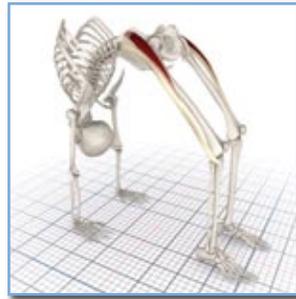
Yoga practitioners use dynamic stretching during the vinyasa type practice. This type of stretching involves repetitive movement of the body into increasingly deeper stretches. Performing dynamic stretching in the morning “resets” the resting muscle length for the day.

(Scientific Keys, Volume II covers the physiology of stretching in detail).



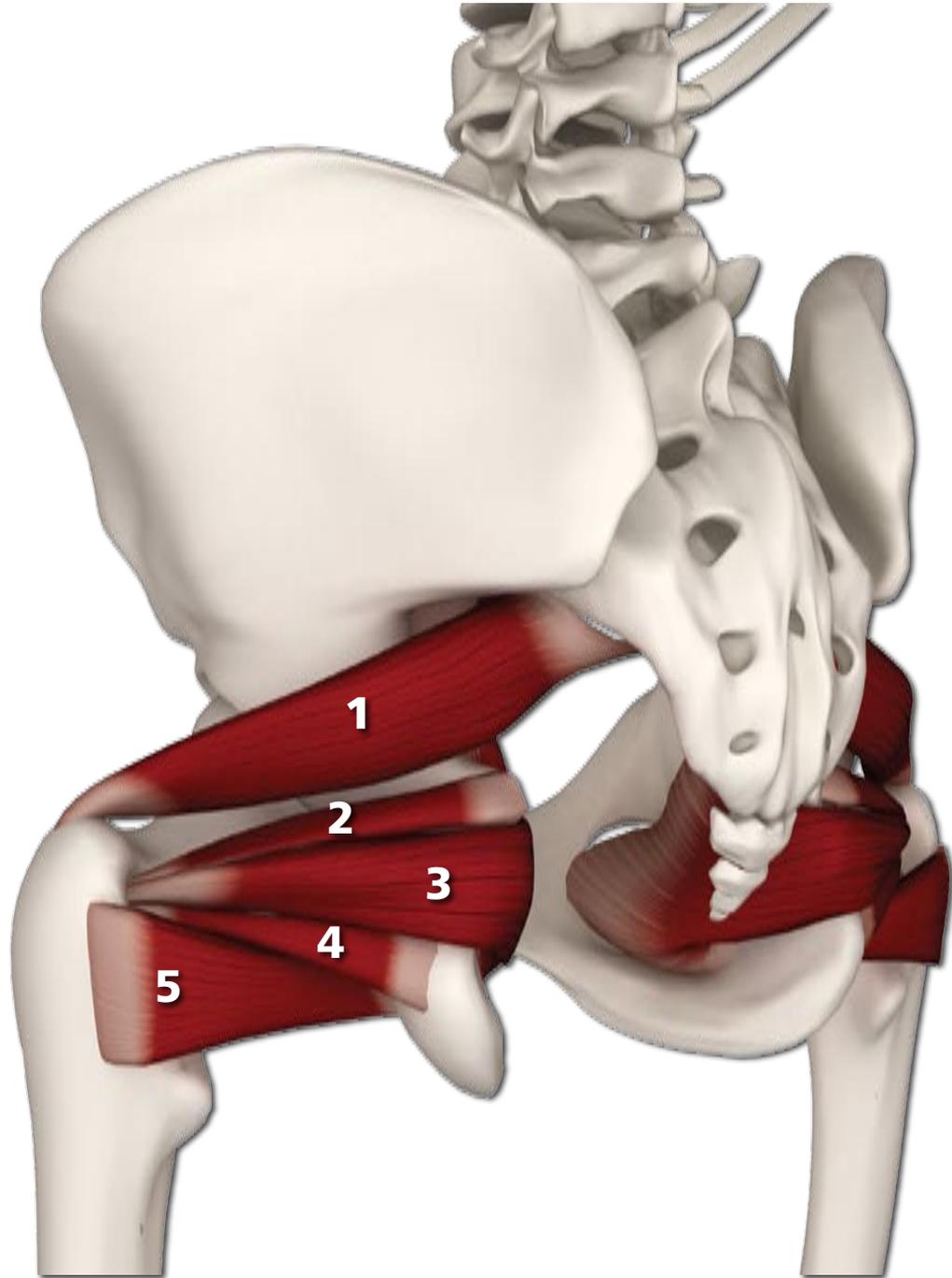
# Part One

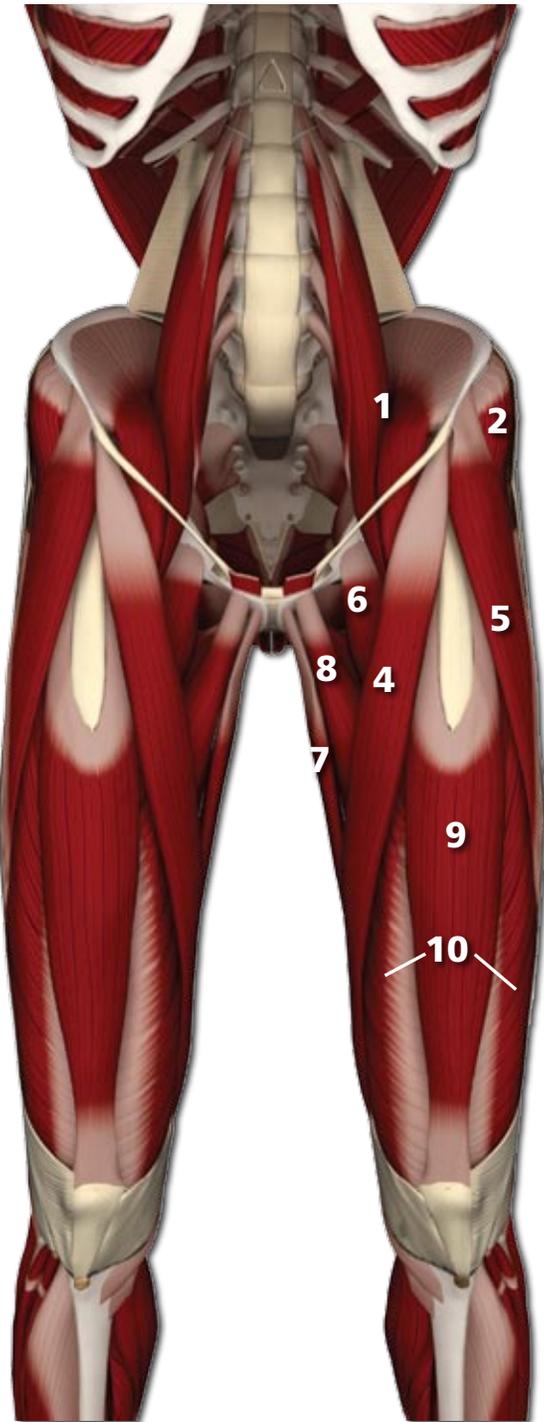
## Pelvic Girdle & Thighs



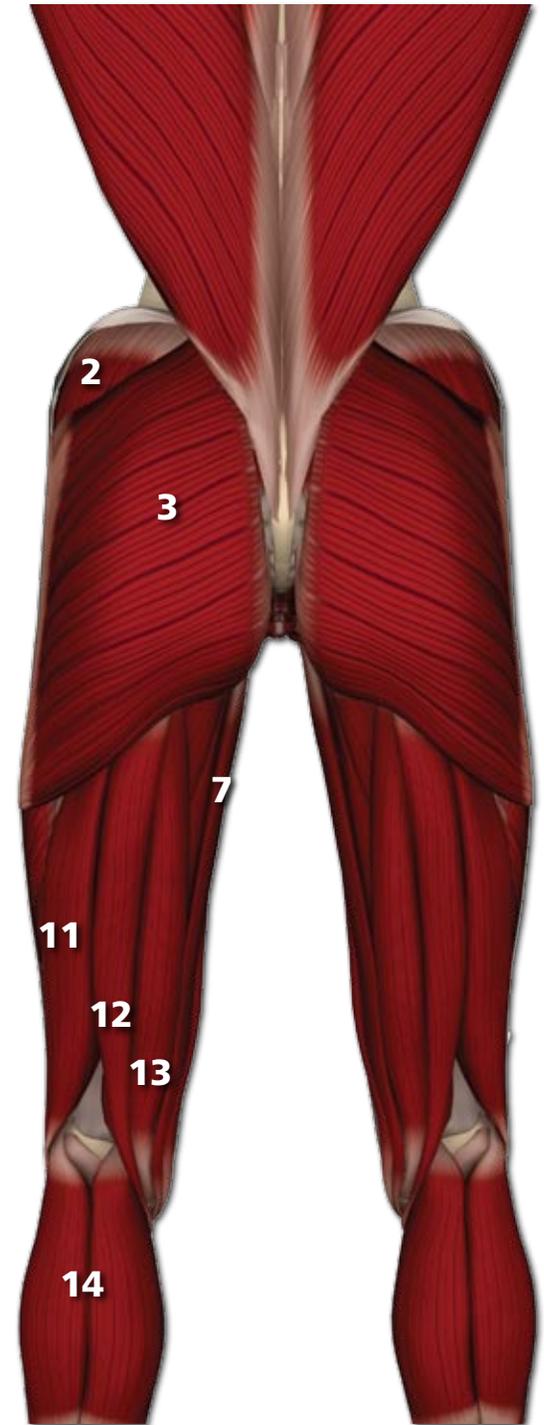
## External rotators of the hip

- 1 piriformis
- 2 gemellus
- 3 obturator internus
- 4 obturator externus
- 5 quadratus femoris





- 1**  
iliopsoas
- 2**  
gluteus medius
- 3**  
gluteus maximus
- 4**  
sartorius
- 5**  
tensor fascia lata
- 6**  
pectineus
- 7**  
gracilis
- 8**  
adductor longus
- 9**  
rectus femoris
- 10**  
quadriceps
- 11**  
biceps femoris
- 12**  
semitendinosus
- 13**  
semimembranosus
- 14**  
gastrocnemius



# Chapter 1

## Iliopsoas

Also known as the psoas muscle, the iliopsoas is actually a combination of two large muscles: the psoas major and the iliacus. The psoas major muscle originates in the lower back; the iliacus originates on the inside of the pelvis. Both muscles combine to form one tendon that attaches to the inside of the proximal femur bone.

### *psoas major*



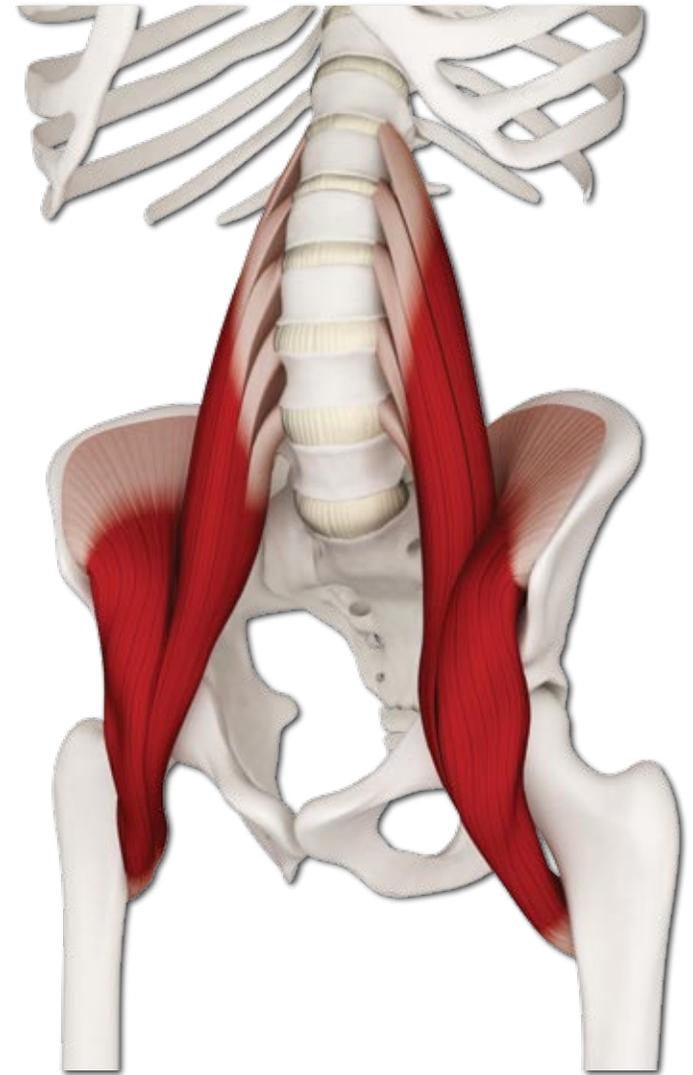
### *iliacus*



The iliopsoas is thus called polyarticular. This means that it crosses over (and moves) more than one joint. The iliopsoas also acts like a pulley as it curves over the front rim of the pelvis on its way to the femur. Like other pulley systems, this serves to multiply the force generated when the iliopsoas contracts. The iliopsoas thus moves the bones of the lower back, pelvis and hip in a coupled fashion. This means that when it contracts, a combination of movements across several joints is possible.

The iliopsoas first awakens during infancy when we are learning to sit up and then to walk. Once awakened, the iliopsoas becomes constantly active in activities such as standing and walking. In spite of this constant use, our awareness of the iliopsoas quickly becomes unconscious. (Imagine if we had to think every time we took a step!)

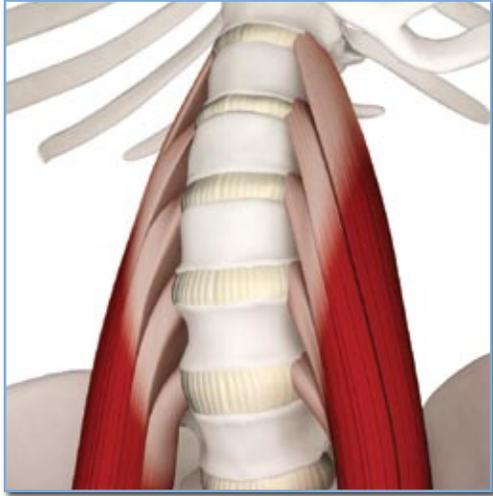
Hatha yoga can be used to reawaken our consciousness of this large and important muscle. Once you awaken the iliopsoas, contract or relax it to transform and deepen your asanas.



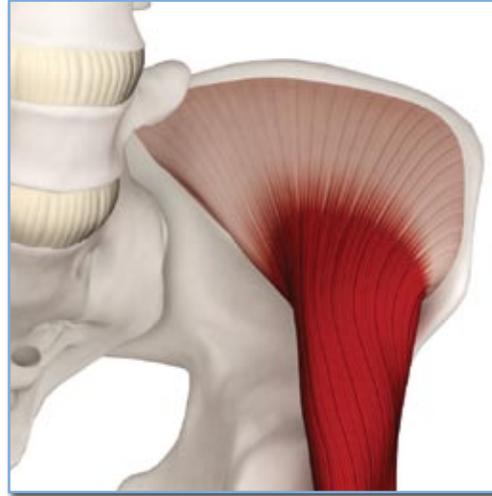
*iliopsoas*

## Origin

1) Psoas major: Transverse processes, discs and bodies of lumbar vertebrae one through five; body of twelfth thoracic vertebra.



2) Iliacus: Upper two thirds of the inside surface of the iliac bone up to the inner lip of the iliac crest and anterior sacroiliac joint.



## Insertion

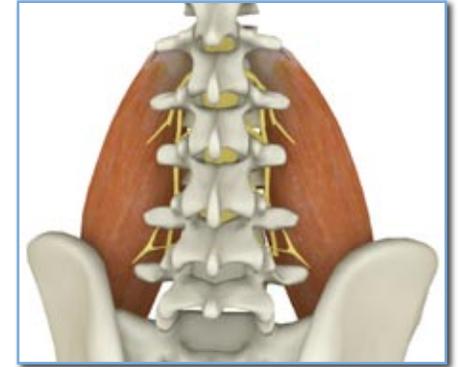
Lesser trochanter (the smaller prominence or knob) of the proximal femur.



## Innervation & chakra illuminated

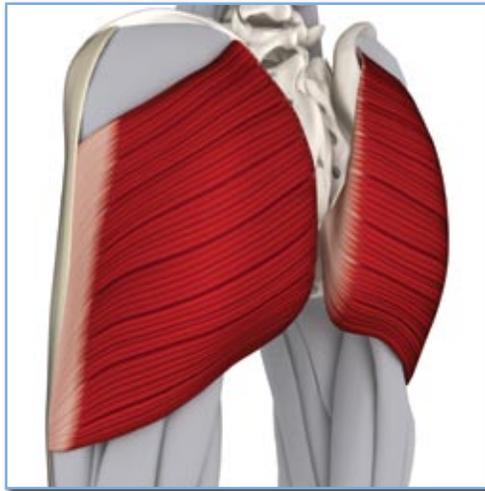
Lumbar nerves 1,2,3,4  
Chakra: Second

The second chakra is illuminated by contracting and lengthening the iliopsoas muscle. This is due to stimulation of the various sensory nerves at its origin and insertion, within the muscle itself, and the skin surrounding it.

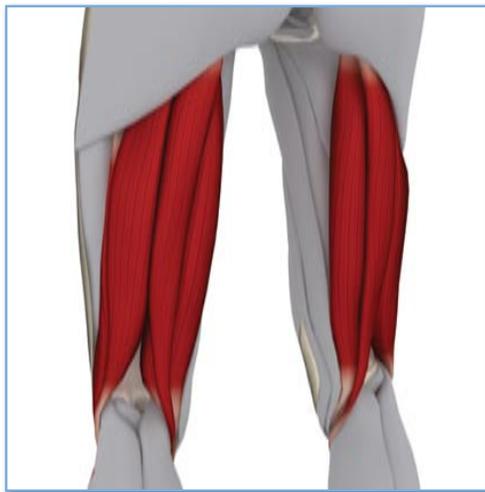


# Iliopsoas (il-e-o-SO-us)

## Antagonists



*Gluteus maximus:* extends hip and trunk resulting in lengthening and stretching of the Iliopsoas, particularly in backbends.



*Hamstrings:* extends the hip when initiating backbends, can be used to draw the opposite leg iliopsoas into a deeper stretch in lunging postures.

## Synergists



*Tensor fascia lata:* assists the iliopsoas in fine-tuning hip flexion.



*Sartorius:* assists the iliopsoas in fine-tuning hip flexion and external rotation.



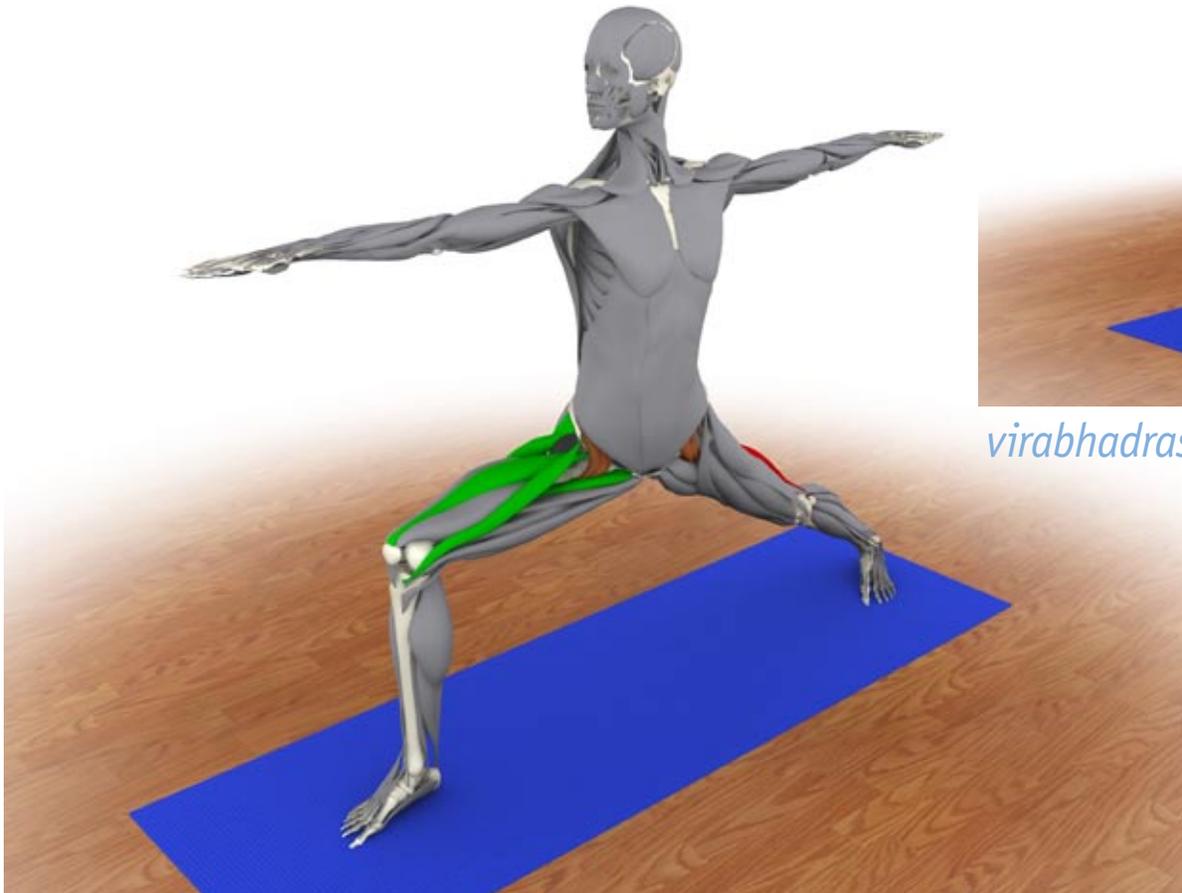
*Rectus femoris:* assists the iliopsoas in fine-tuning hip flexion, also assists the gluteus maximus in accentuating stretch of the iliopsoas during back-bending (by extending the knee).



*Pectineus:* assists the iliopsoas in fine-tuning hip flexion and provides adduction component to stabilize hip (also balances abduction action of sartorius).

# Synergy

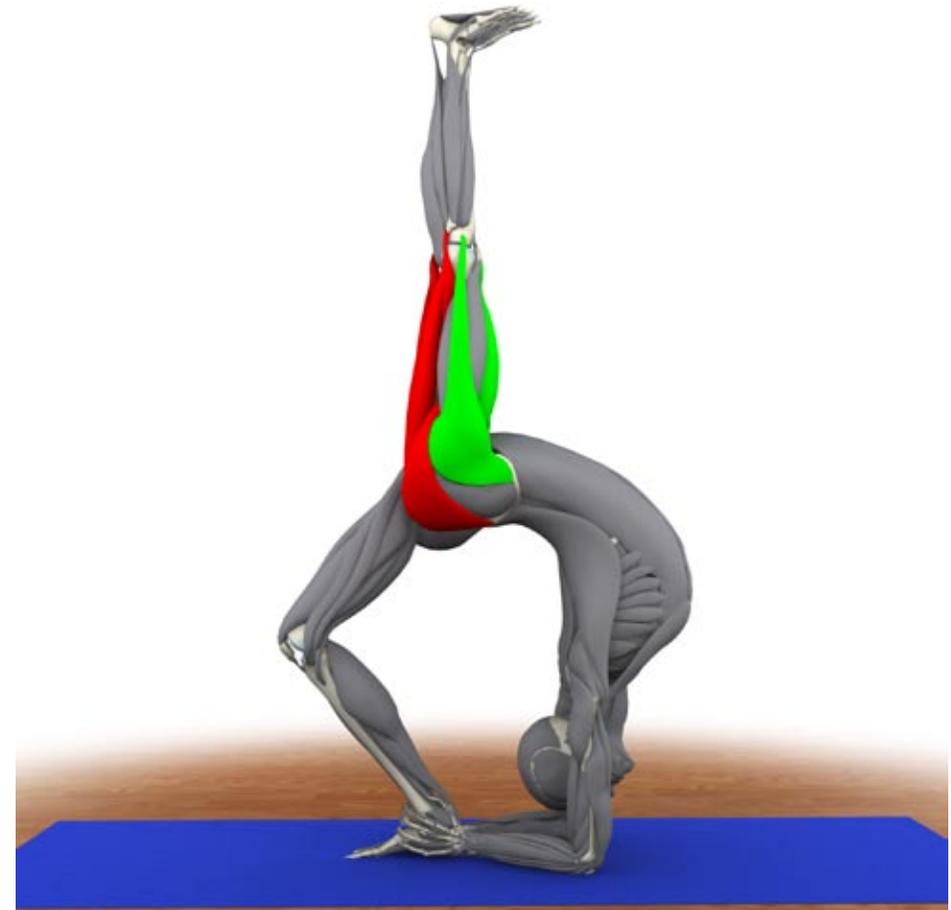
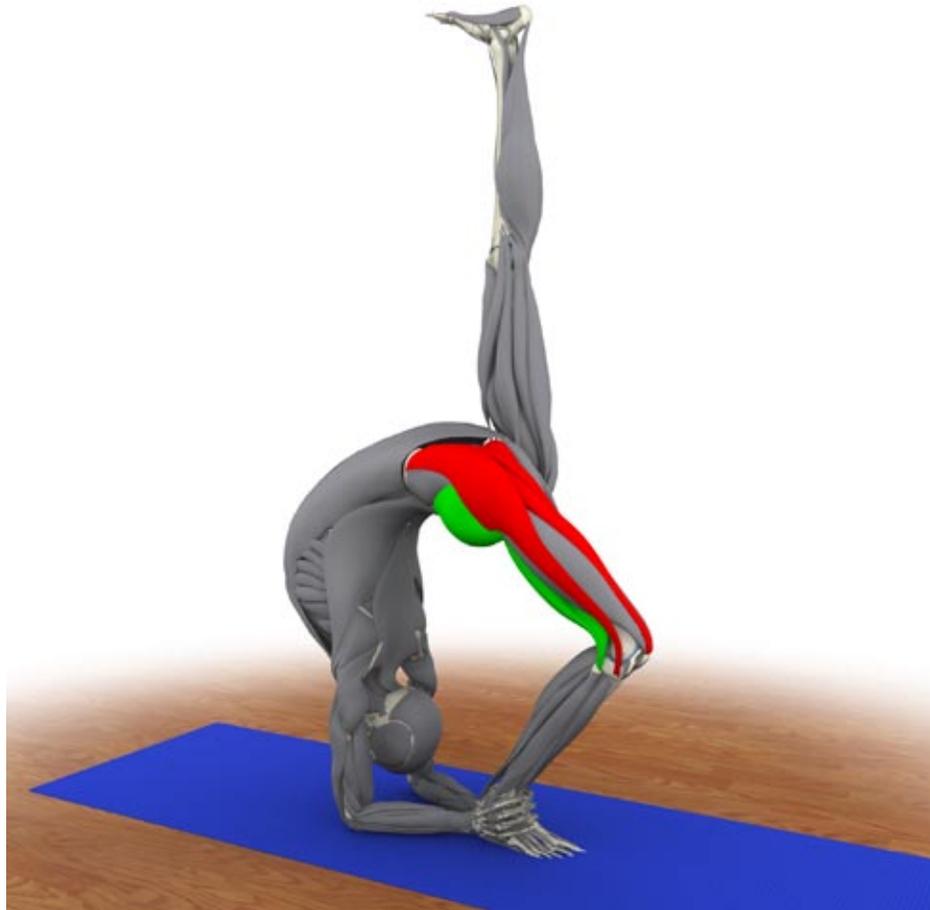
This illustration uses virabhadrasana II to demonstrate the tensor fascia lata, sartorius, rectus femoris, and pectineus as synergists of the psoas. Similarly, the extended back hip demonstrates how the gluteus maximus and hamstrings act as antagonists to the psoas.



*virabhadrasana II*

# Synergy

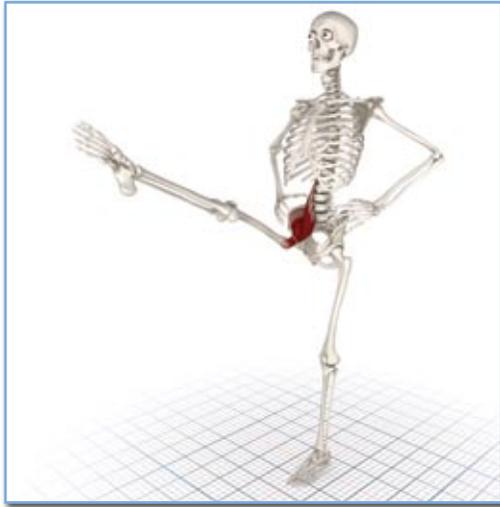
This illustration uses eka pada viparita dandasana to demonstrate the gluteus maximus and hamstrings stretching the psoas and the synergists of the psoas in the planted leg. Similarly, the flexed hip of the leg in the air demonstrates the tensor fascia lata, sartorius, rectus femoris and pectineus as synergists of the psoas.



*eka pada viparita dandasana*

# Iliopsoas (il-e-o-SO-us)

## Action



*Open chain*  
(Origin fixed, insertion moving):

Flexes and laterally rotates the femur at the hip. Ex. Padangusthasana D



*Closed chain*  
(Insertion fixed, origin moving):

Flexes the trunk, anteverts (tilts forward) the pelvis, straightens and supports the lumbar spine. Ex. Virabhadrasana B

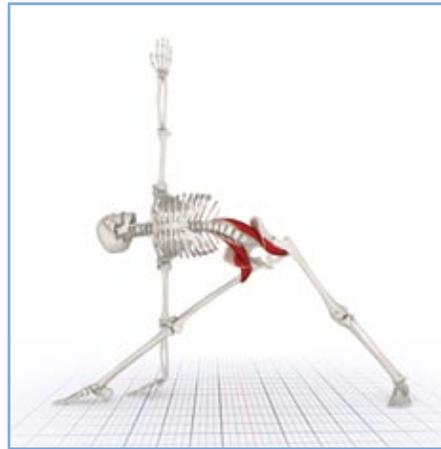
## Awakening



Open chain isometric resistance to femur flexing.



Closed chain isometric resistance to trunk flexing.



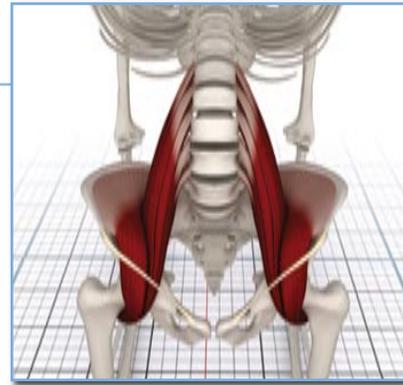
Conscious contraction in standing poses.



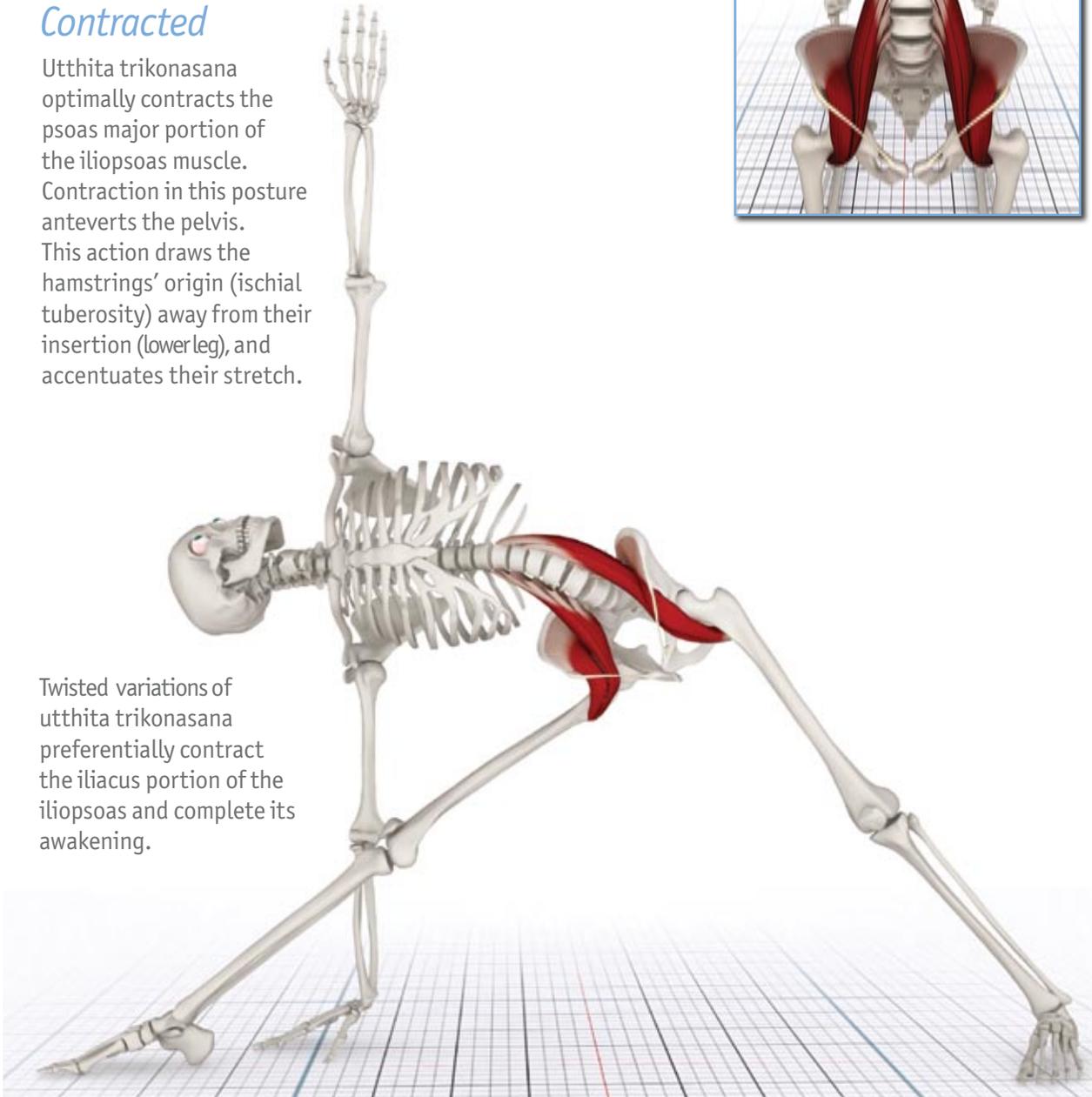
Eccentric contraction in lunging poses.

## Contracted

Utthita trikonasana optimally contracts the psoas major portion of the iliopsoas muscle. Contraction in this posture anteverts the pelvis. This action draws the hamstrings' origin (ischial tuberosity) away from their insertion (lower leg), and accentuates their stretch.

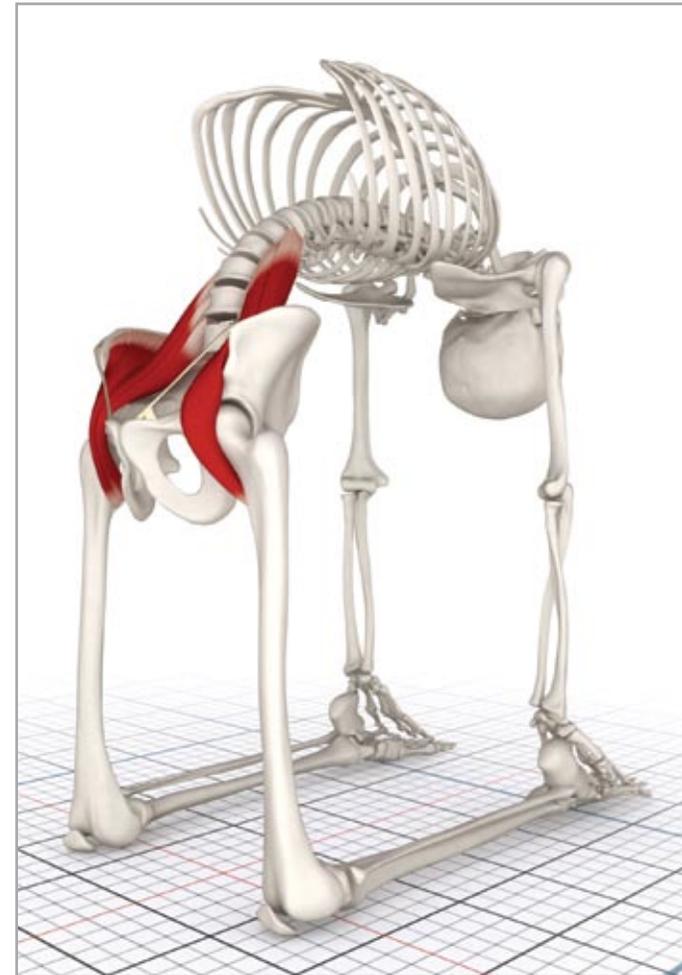


Twisted variations of utthita trikonasana preferentially contract the iliacus portion of the iliopsoas and complete its awakening.



## Stretched

Ushtrasana stretches the iliopsoas through contraction of the hip and trunk extensors, including the gluteus maximus. Stretch is accentuated by contraction of the quadriceps (including the rectus femoris, which is eccentrically contracted).

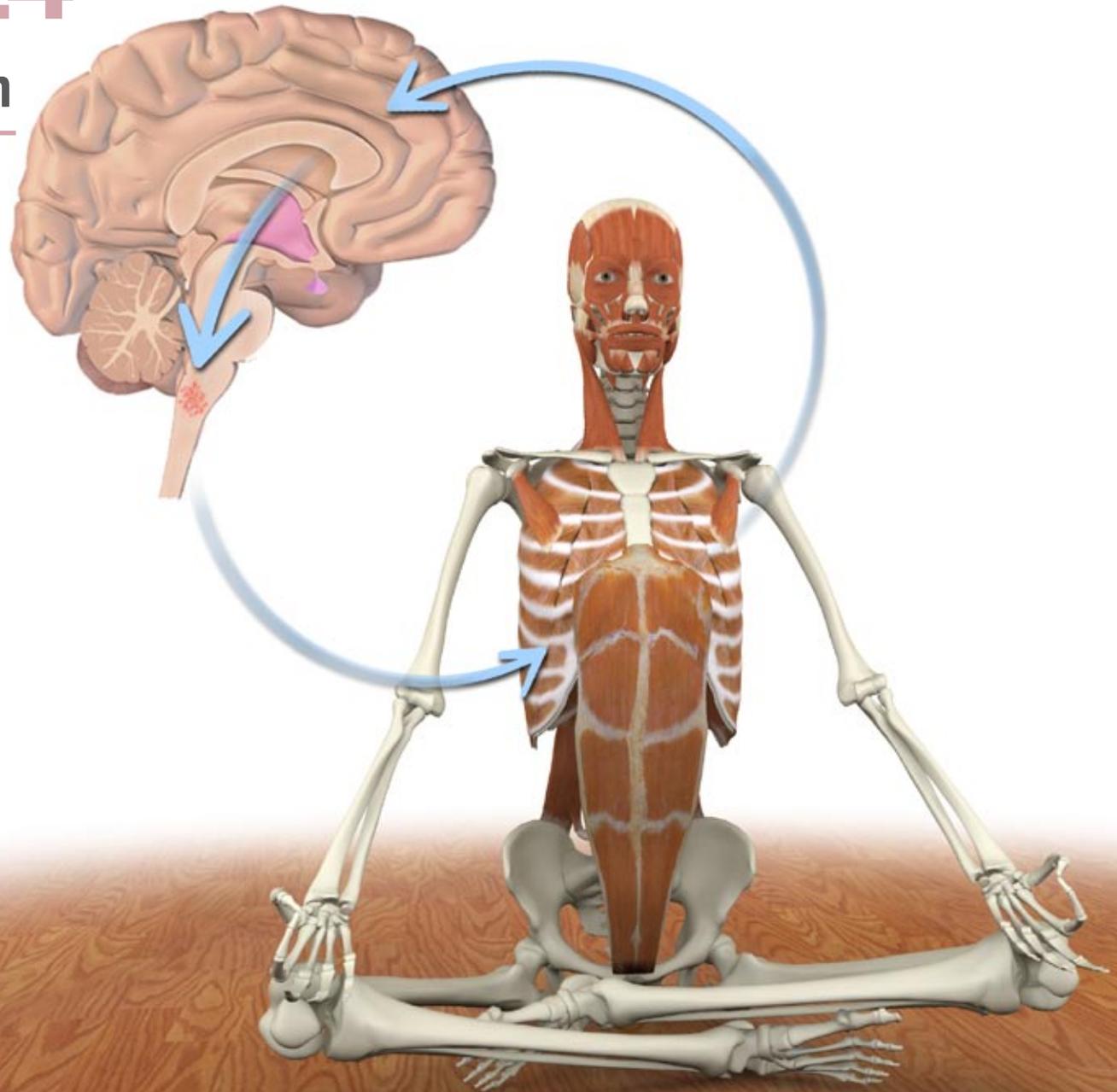


# Chapter 24

## The Breath Connection

Regions of the brain such as the brainstem are highly evolved for survival, controlling complex functions such as respiration with speed and precision that is far beyond the comprehension of the conscious mind. Great instinctive power is stored in these regions of the brain. Hatha Yogic breathing techniques “yoke” or connect the conscious mind to the primal instinctive regions of the brainstem.

Athletes and martial arts practitioners access the breath’s primal force by timing moments of exertion with forced exhalation. Yogis refine this by coordinating the rhythm of the breath with movements in the asanas, generally coupling inhalation with expansion and exhalation with deepening. Pranayama perfects this process.



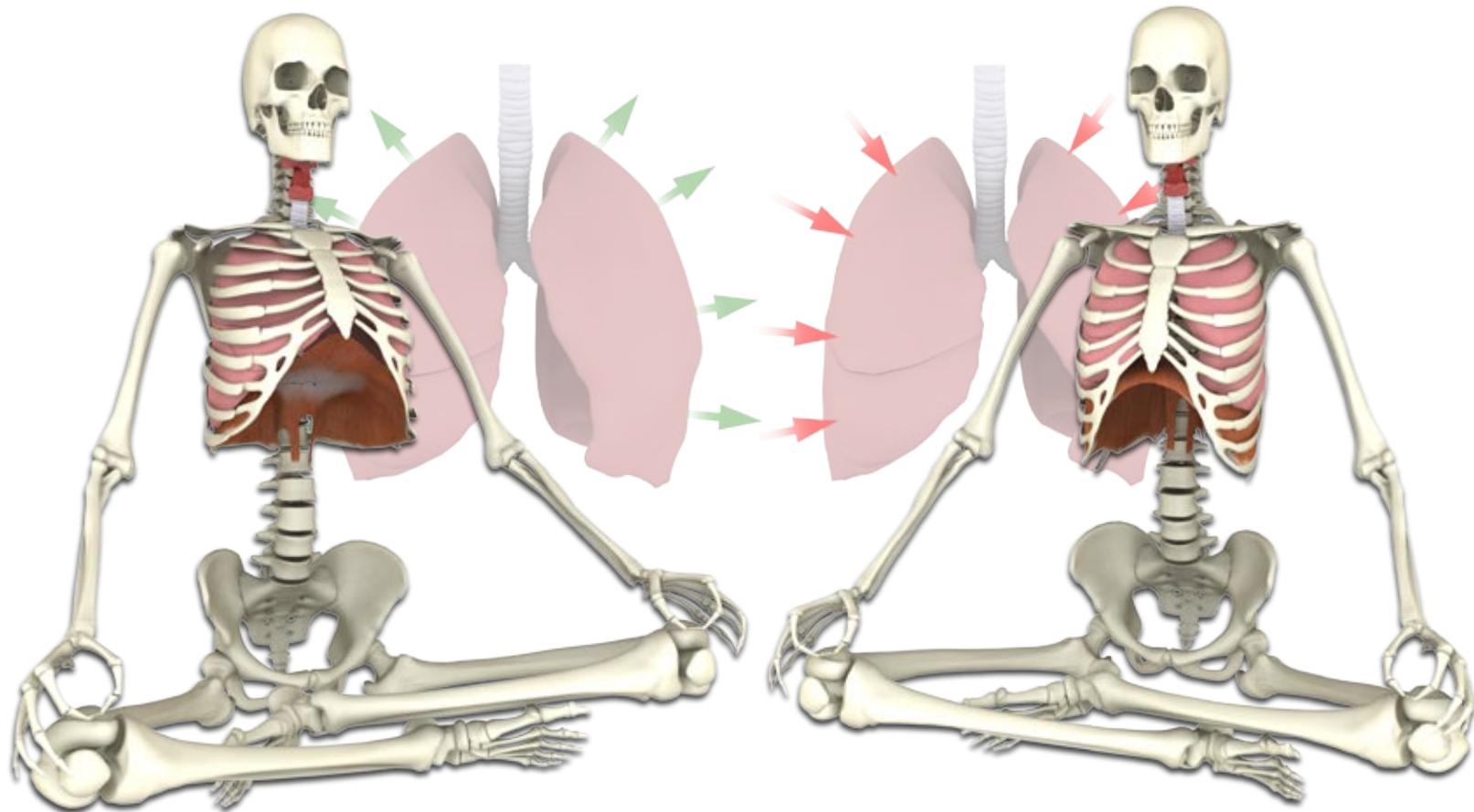
## *Inhalation and Exhalation*

The diaphragm is the prime mover for inhalation and exhalation. It is a thin half-dome shaped muscle that separates the thoracic abdominal cavities. Contracting the diaphragm expands the chest, creating a negative inspiratory pressure in the thorax, and drawing air into the lungs through the trachea. Contracting the diaphragm also gently massages the abdominal organs.

Unlike most other skeletal muscles, the diaphragm rhythmically contracts and relaxes under the control of the autonomic nervous system, via the phrenic nerve. We are unaware of the diaphragm, unless we consciously think about its function.

Yogic breathing techniques such as pranayama involve consciously contracting the diaphragm and controlling the breathing, thereby connecting the conscious and unconscious mind.

These images demonstrate the diaphragm contracting and relaxing. The lungs are elastic and expand when the diaphragm contracts during inhalation. Like a balloon the lungs passively empty during exhalation as the diaphragm relaxes.



# Ujayi Breath

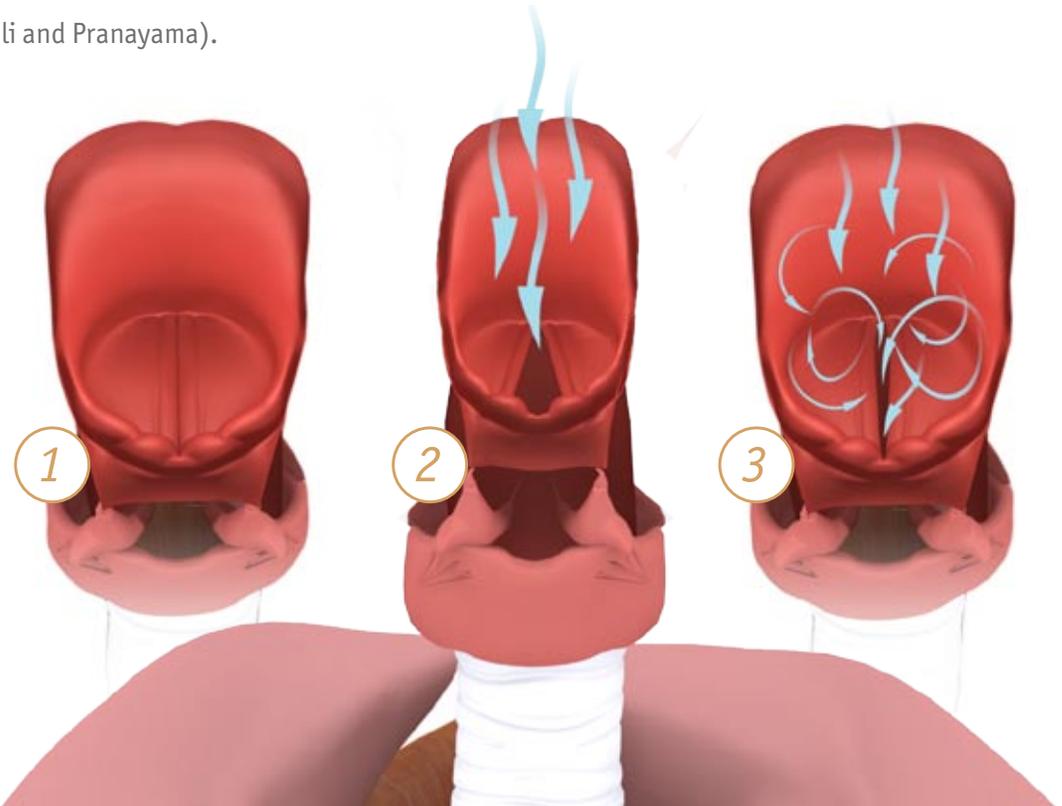
When we breathe, the air passes through the nasal sinuses and pharynx into the trachea and on to the lungs, oxygenating the blood and removing carbon dioxide. The pharynx and nasal passages are lined with blood-rich mucosa. The nasal sinuses create turbulence, increasing the amount of air contacting the mucosa. This process warms the air before it passes into the lower parts of the respiratory tract.

The glottis is a muscular aperture below the pharynx and nasal passages. Opening and closing the glottis regulates the flow of air into the lower respiratory tract. Normally we control the opening and closing of the glottis unconsciously.

Yogic breathing techniques involve consciously regulating airflow through the glottis. For example, we seal the glottis when performing Nali so that the negative inspiratory pressure generated by contracting the diaphragm draws the abdominal contents upward instead of drawing breath into the trachea.

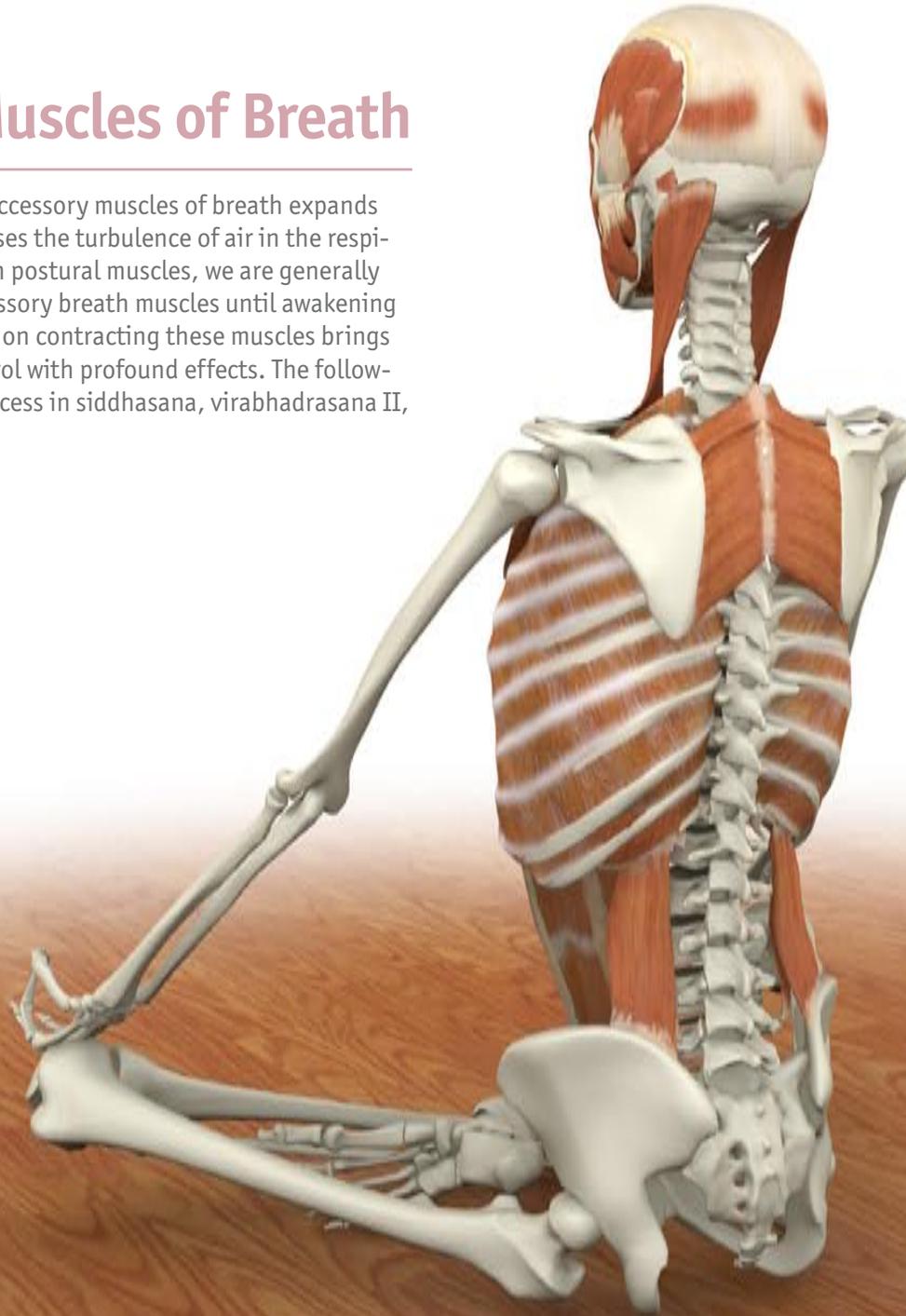
Consciously narrowing the opening of the glottis increases the turbulence of the air passing through the nasal and pharyngeal cavities. This action increases the transfer of heat to the air from the blood-rich mucosal lining, raising the temperature of the air above normal. Increasing air turbulence also creates an audible vibration similar to that of a flame leaping up from a fire. This process of increasing heat and creating vibration with the air is known as Ujayi breathing and is fundamental to the practice of Pranayama or “Breath of Fire.”

(See Scientific Keys, Volume II for details on Nali and Pranayama).



## Accessory Muscles of Breath

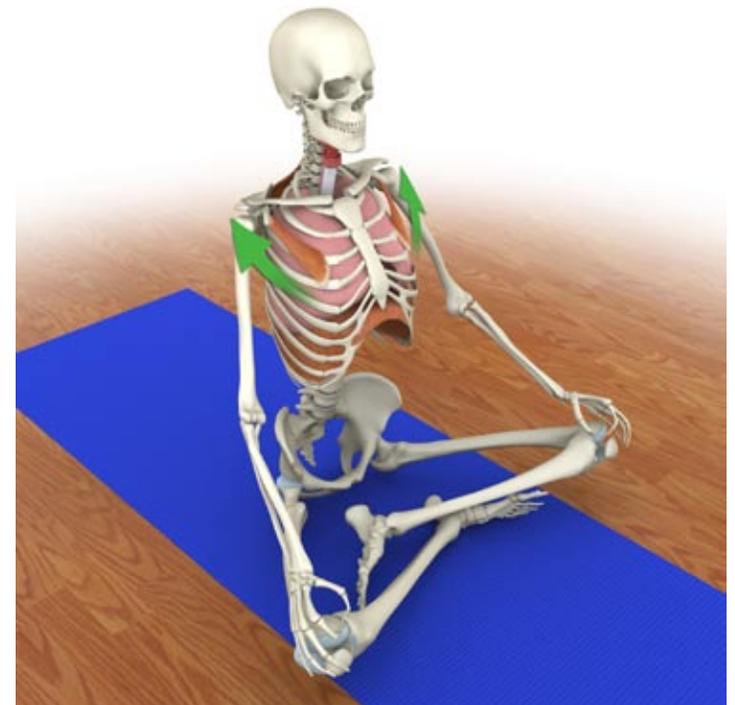
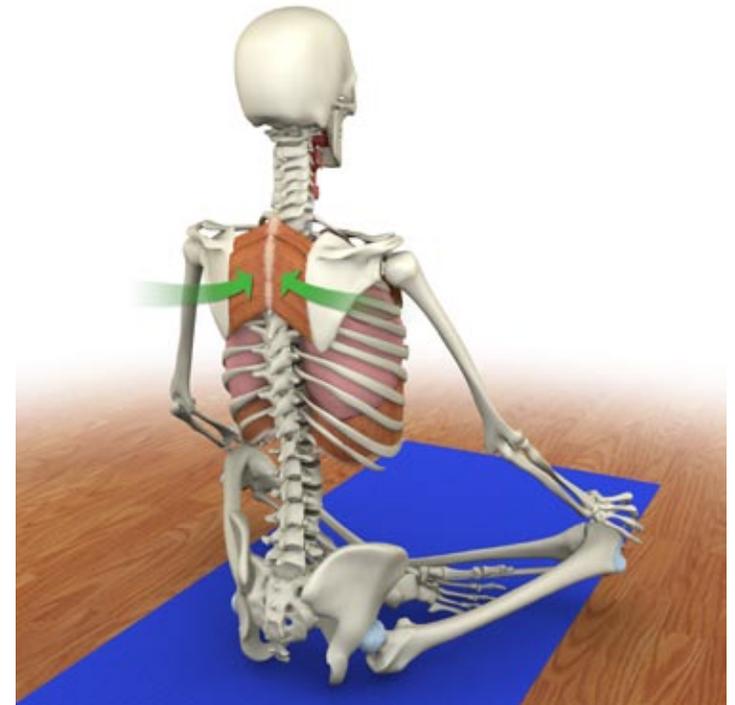
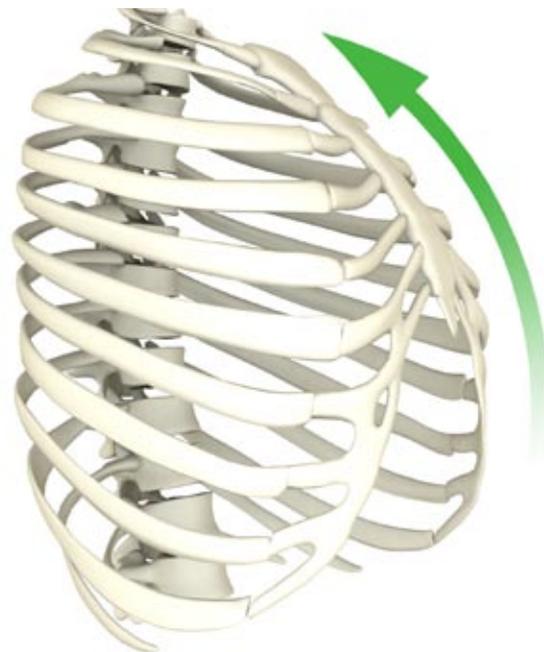
Accessing the force of the accessory muscles of breath expands the lung volume and increases the turbulence of air in the respiratory passageways. As with postural muscles, we are generally not conscious of these accessory breath muscles until awakening them consciously. Focusing on contracting these muscles brings them under conscious control with profound effects. The following pages illustrate this process in siddhasana, virabhadrasana II, tadasana and utthanasana.



## Thoracic Bellows

Begin awakening the accessory muscles of breath by drawing the scapula towards the midline. Hold this position and then attempt to roll the shoulders forward by contracting the pectoralis minor. This closed chain contraction lifts and opens the lower ribcage like a bellows and expands the lung volume.

Begin by practicing in siddhasana and then apply this technique to other postures such as twists that constrict the volume of the thoracic cavity.



# Accessory Muscles of Breath

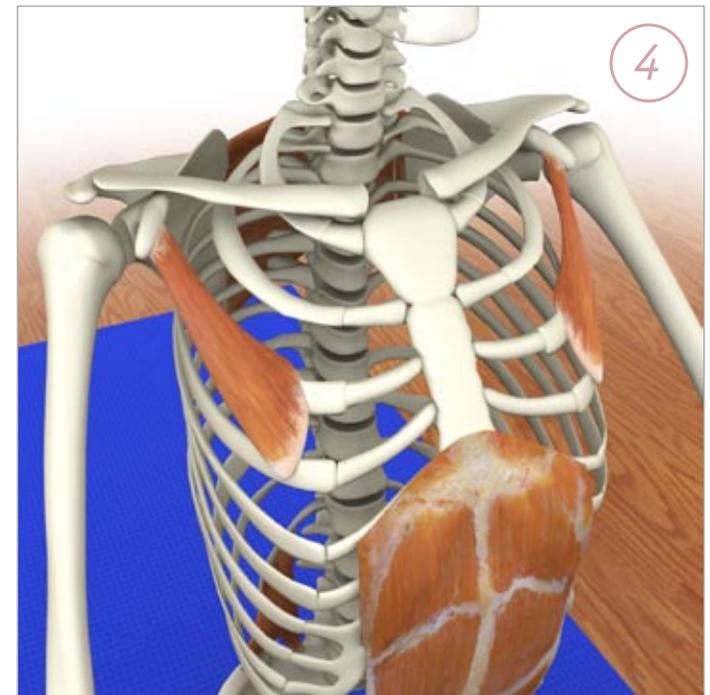
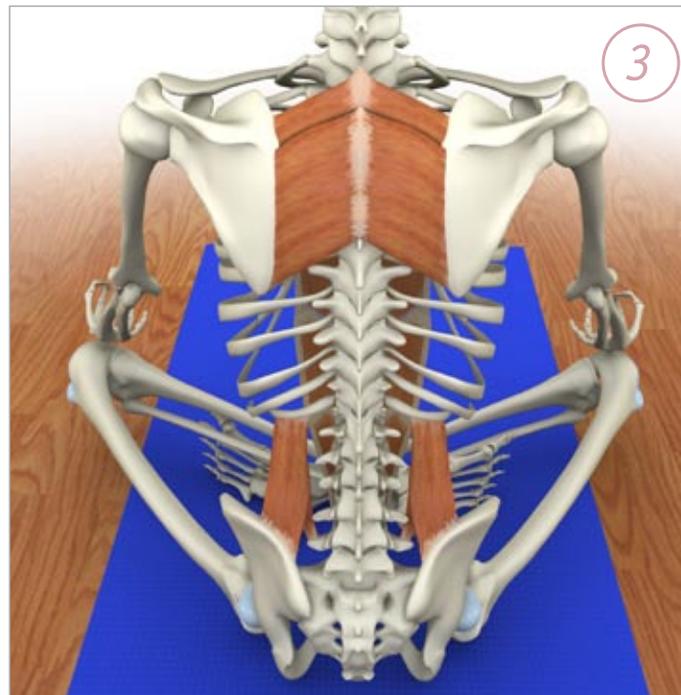
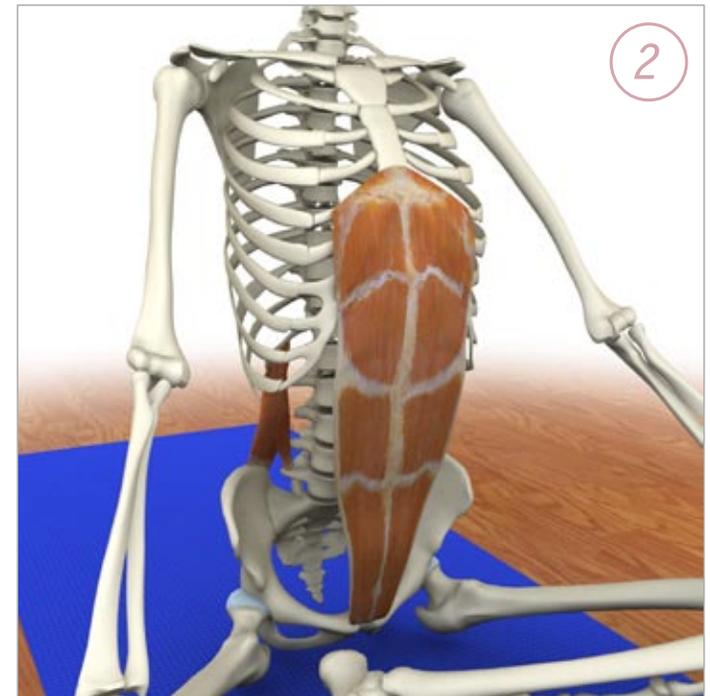
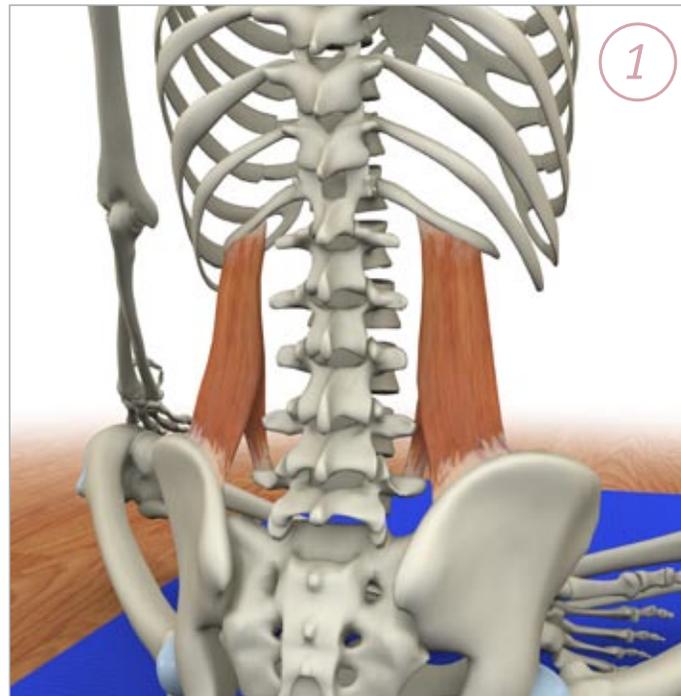
1) Straighten the lower back by contracting the erector spinae and quadratus lumborum. This draws the lower posterior ribcage downward.

2) Balance this action by gently contracting the rectus abdominus. This draws the lower anterior ribcage downward and compresses the abdominal organs against the diaphragm, dynamizing its contraction and strengthening it.

3) Draw the shoulder blades together by contracting the rhomboids. This opens the front of the chest.

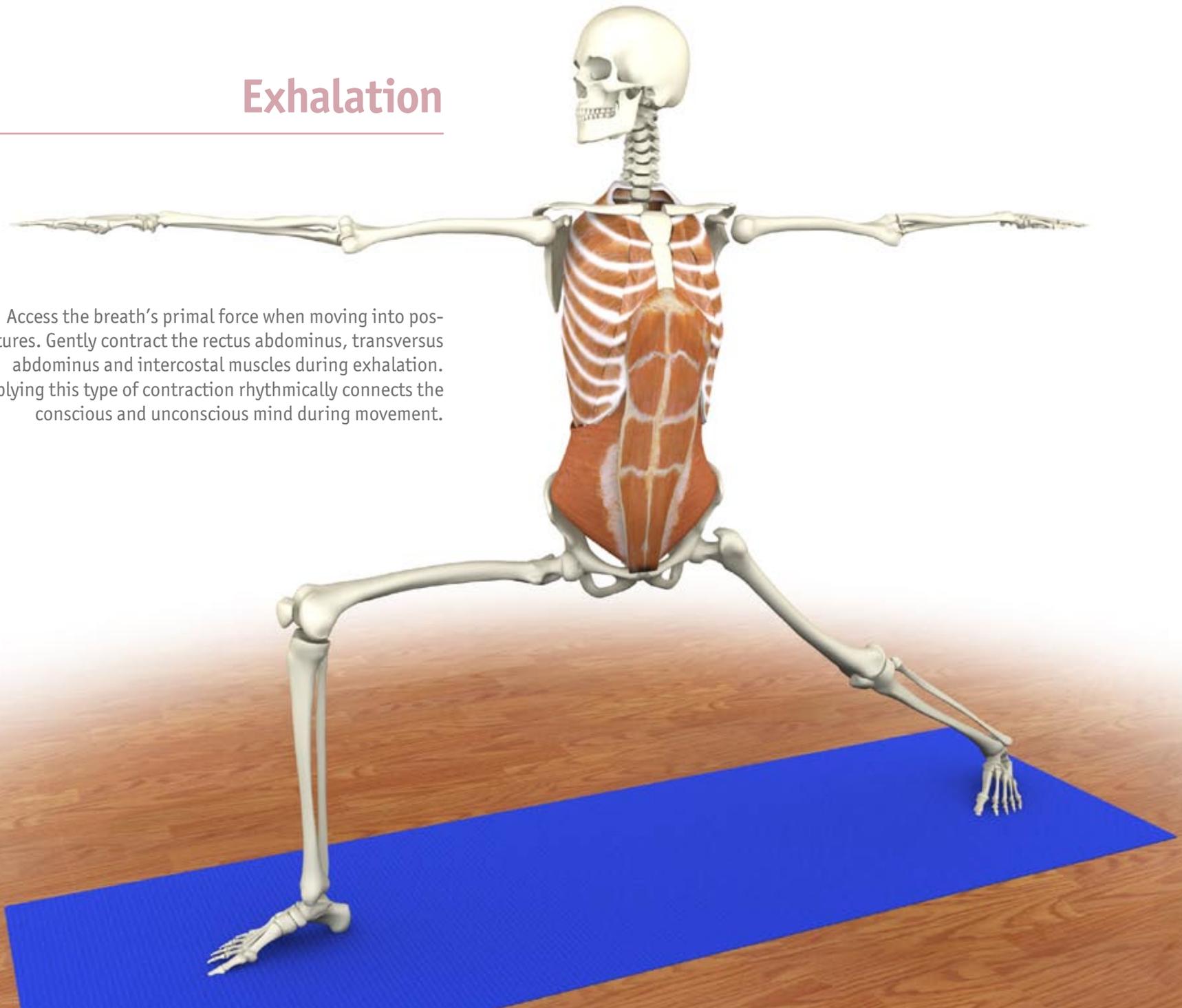
4) Maintain the contraction of the rhomboids and simultaneously contract the pectoralis minor and sternocleidomastoid. This lifts and opens the ribcage like a bellows.

Complete this process by pressing the hands down on the knees to fully open the chest (by contracting the latissimus dorsi).



# Exhalation

Access the breath's primal force when moving into postures. Gently contract the rectus abdominus, transversus abdominus and intercostal muscles during exhalation. Applying this type of contraction rhythmically connects the conscious and unconscious mind during movement.



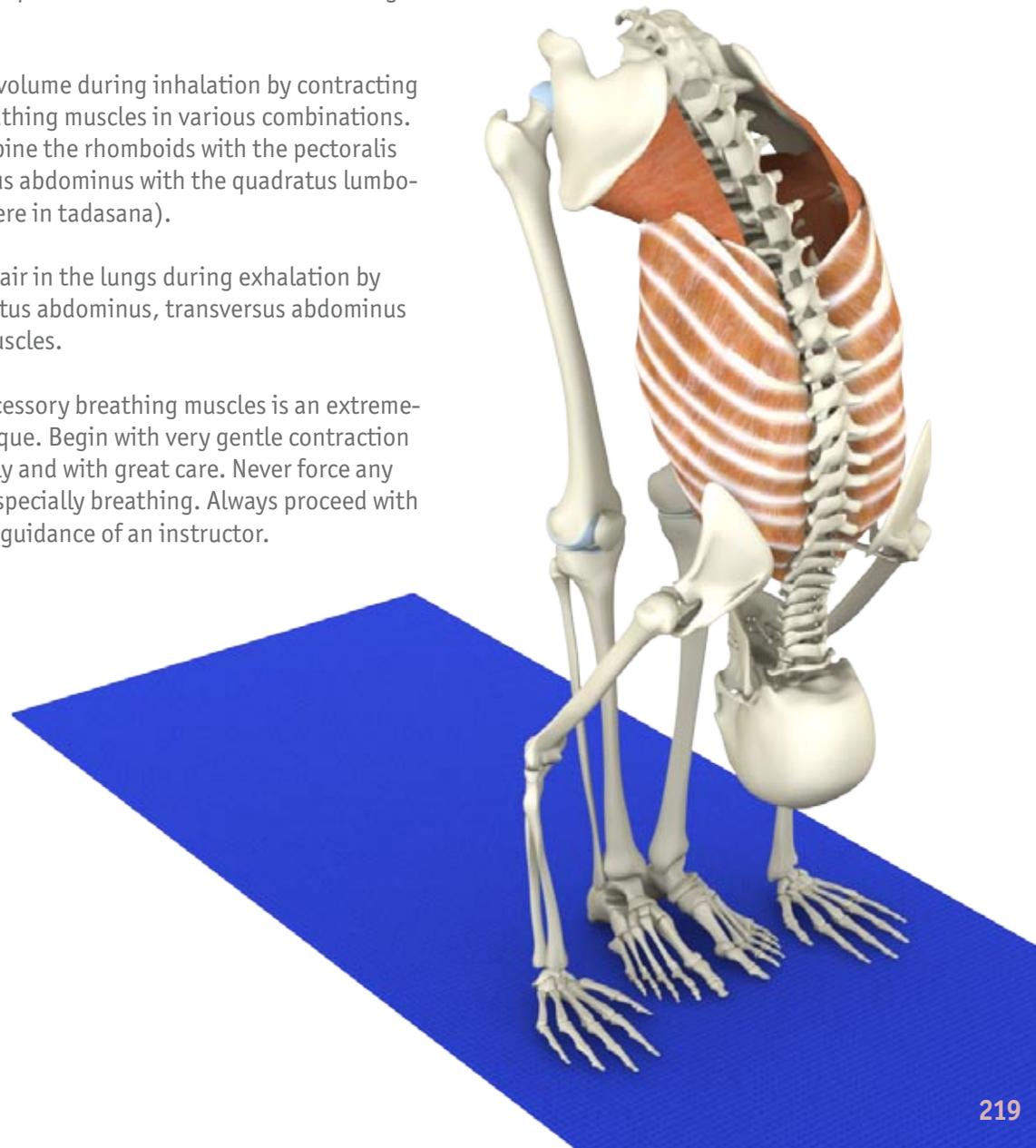
# Synergy

Train the accessory breathing muscles so that they work synergistically to expand and contract the thorax during movement.

Increase the lung volume during inhalation by contracting the accessory breathing muscles in various combinations. For example, combine the rhomboids with the pectoralis minor, or the rectus abdominus with the quadratus lumborum (illustrated here in tadasana).

Expel the residual air in the lungs during exhalation by contracting the rectus abdominus, transversus abdominus and intercostal muscles.

Awakening the accessory breathing muscles is an extremely powerful technique. Begin with very gentle contraction and progress slowly and with great care. Never force any yoga technique, especially breathing. Always proceed with caution under the guidance of an instructor.



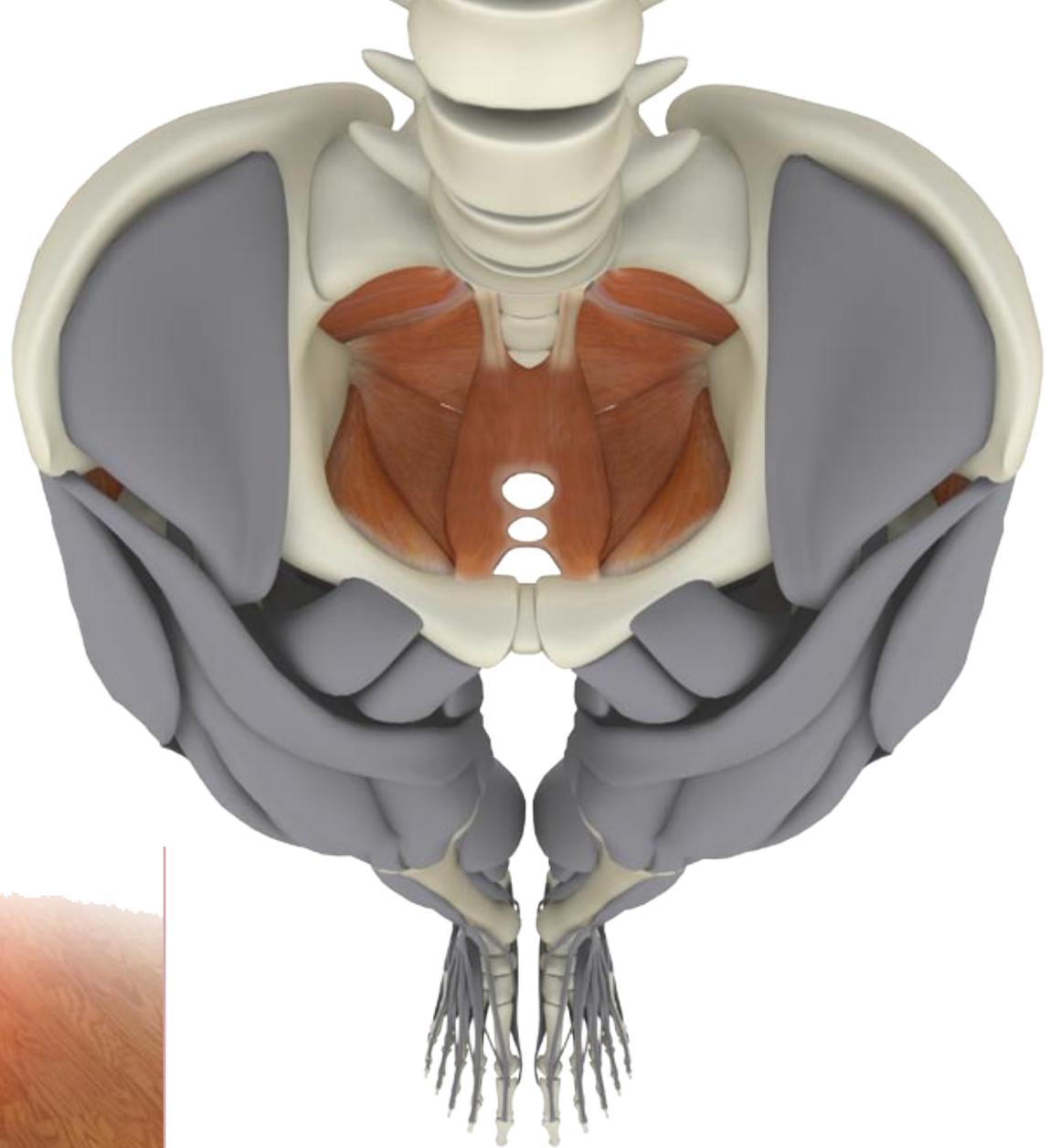
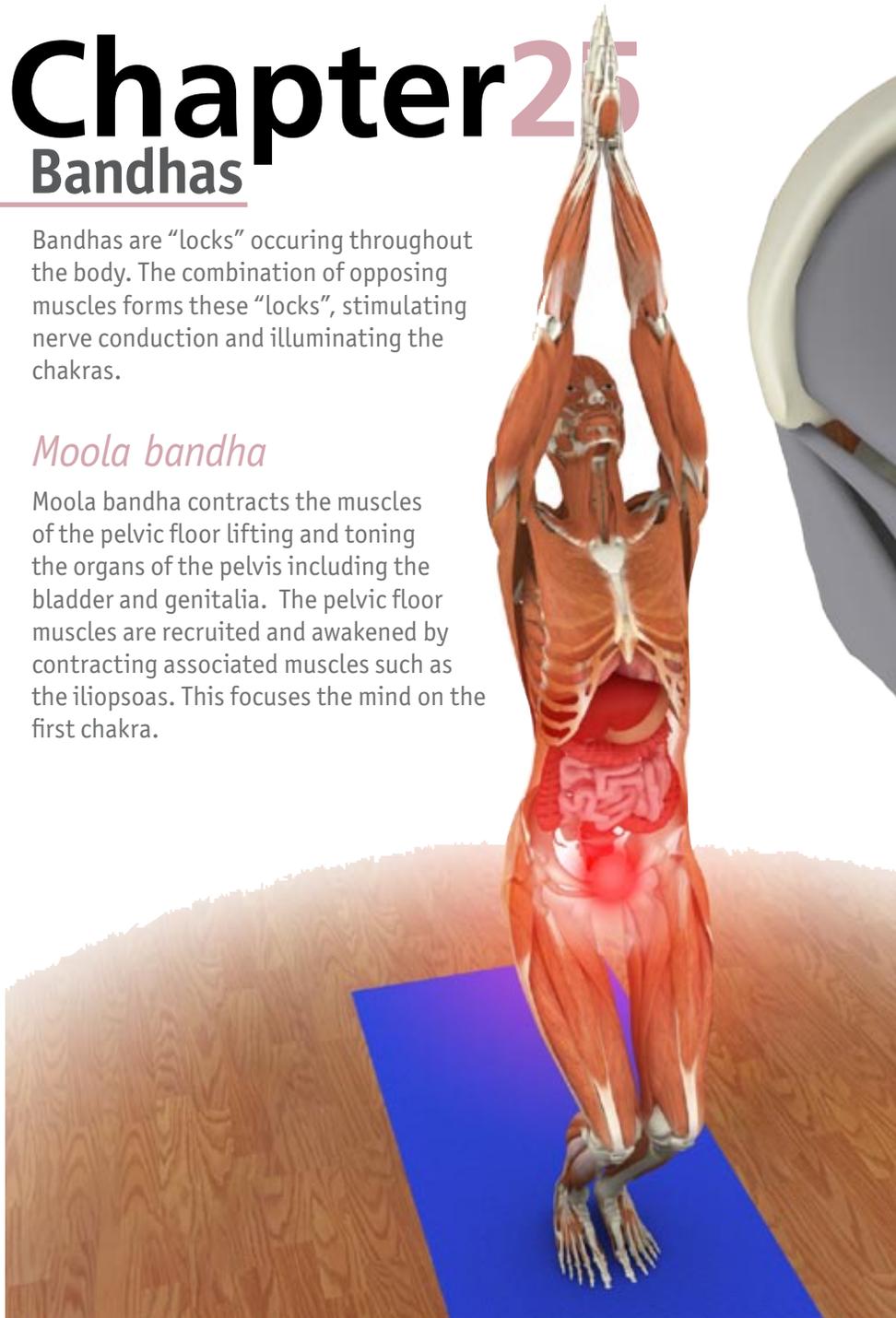
# Chapter 25

## Bandhas

Bandhas are “locks” occurring throughout the body. The combination of opposing muscles forms these “locks”, stimulating nerve conduction and illuminating the chakras.

### *Moola bandha*

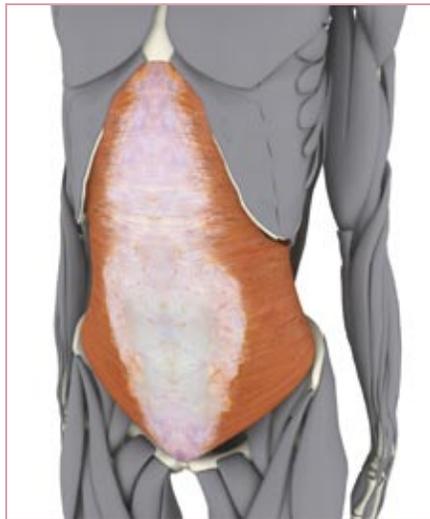
Moola bandha contracts the muscles of the pelvic floor lifting and toning the organs of the pelvis including the bladder and genitalia. The pelvic floor muscles are recruited and awakened by contracting associated muscles such as the iliopsoas. This focuses the mind on the first chakra.



Simultaneously contracting other muscle groups accentuates moola bandha. For example, gently squeezing the knees together (by contracting the adductors) increases contraction of the pelvic floor muscles. Pressing the hands together has the same effect. This phenomenon is known as “recruitment.”

## *Udyana bandha*

Udyana bandha contracts the upper abdominals in the region approximately two inches below the solar plexus and focuses the mind on the third chakra.



*transversus abdominus*



*rectus abdominus*

## *Jalandhara bandha*

Jalandhara bandha contracts the anterior neck muscles, flexing the neck and drawing the chin to the sternum. This focuses the mind on the fifth chakra.



# Chapter 26

## Chakras



The chakras are the subtle energy centers of the body. Like pinwheels, the chakras spin at the speed of light, emanating the colors of the spectrum, each resonating with a particular frequency. These colors combine to form the auras that surround each of us, connecting us with each other and with the cosmos.

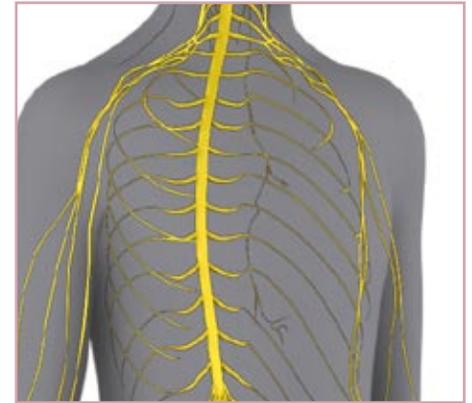
There are seven to eight major and numerous minor chakras in the body. Their locations correspond to regions of the body where nerves collect and electrical activity is high, such as the brachial and sacral plexi (major chakras) and the elbows and knees (minor chakras).

The flow of energy in the chakras can become blocked by life events through the activity of the autonomic nervous system. For example, when we habitually assume a defensive posture in response to negative stimuli, we block the flow of energy in the chakras. Hatha Yoga counteracts this and re-illuminates the chakras, stimulating them to spin freely.

Kundalini awakening refers to the “unblocking” of the flow of energy through and between the chakras. This process can occur instantaneously from contact with a master (inner or outer) who awakens the student’s awareness of his or her potential. Classically, this occurs through a touch but can occur with a glance or even through the mere presence of the master. This is known as Shaktipata (the transmission of psycho-spiritual energy). As human consciousness transitions from the Piscean to the Aquarian Age, more and more people are spontaneously experiencing varying degrees of Kundalini awakening.

Kundalini awakening is akin to tapping into a high voltage line and requires careful preparation. Hatha Yoga prepares the practitioner and awakens the Kundalini at the same time.

### *bracial plexus*



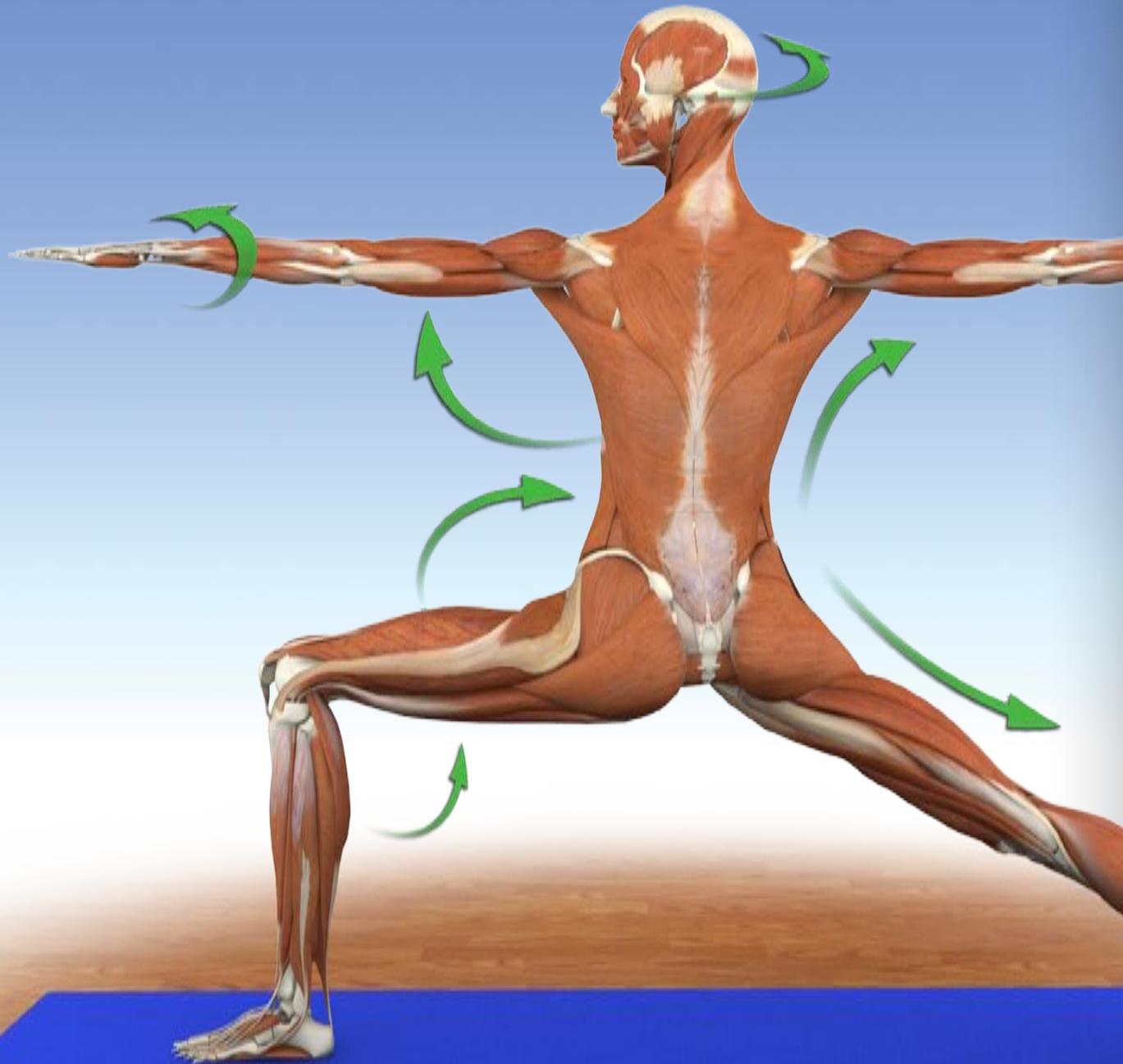
### *sacral plexus*



Asanas connect the body and mind. Breathing techniques connect the conscious and the unconscious. Chakra meditation connects the individual to the vibrational energy of the cosmos. Spend a few moments gazing at this image of the chakras and then meditate as you visualize them. The chakras will appear as a subtle but scintillating light within you.



# Scientific Keys Volume I



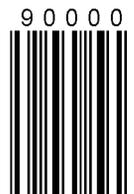
## The Key Muscles of Hatha Yoga

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