CHAPTER

3

Fascial Science

Arjun

Good morning, Sir. I have done my homework. I read about fascial scientists, the prominent experts in movement analysis. They introduced the concept of fascial science and have shown the presence of interconnected fascial chains inside the human body, which have significant implications in therapeutic settings.[17,3]

Senior Therapist

Good morning, Arjun. I am sure you have also come across some significant researchers in the field of movement science who have expressed apprehension about the examination of the fascia in cadaveric specimens in controlled laboratory settings, and its subsequent implementation in the in-vivo behavior of human beings as controversial.

Arjun

Yes, there was a mention of the same.

Senior Therapist

Glad that you have read and come, as I want to continue with the valuable process of arriving at answers through dialogue. Do you know one of the reasons for the same is that, chemicals such as formaldehyde have been shown to alter the continuity and the biomechanical properties of several tissues of the body that include collagenous tissue, hyaluronic acid, and fascia. Moreover for analyzing movements, it is also essential to take into account the anatomical variations in the degree of connectivity and the interpretational analysis of histological variances of the connecting structures. To my surprise, all of that is lost in cadaveric specimens. It is thus suggested that future research on movement analysis should prioritize investigating the in vivo role of myofascial continuity, in isolated instances of active and/or passive tissue tensioning. These preconceptions led to the development of several clinical cues for K-CAT. But it is imperative to understand the fascial chains in the human body and its evolution, before the concept is used to draw clinical implications. So let me first describe fascial chain evolution before discussing additional subject matter (Fig. 3.1).

EVOLUTION OF FASCIA

An embryo undergoes development in a state of universal flexion inside the mother's womb and has a primary curve that is convex toward the posterior, an arc created by the divine or a curve formed by a natural process.

Following birth, as the infant's developmental milestones progress, he or she begin to exhibit slight neck control and over a period of time assumes a prone position. Gradually, the upward movement of the head in opposition to the force of gravity is initiated, which encourages the formation of the first human-made artificial curvature of the neck known as cervical lordosis.

Over a period of time the toddlers begin to sit, stand, and walk. The force of gravity has a vital role in the development of the concave lordotic curve of the lumbar spine as well as the extension of the knees. Additionally, development of the intrinsic muscles of the foot lead to formation of the plantar arch.

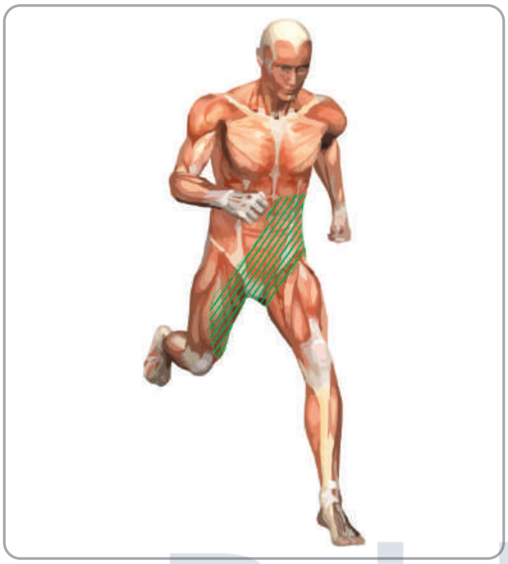


Figure 3.1: Autologous anterior/fascial sling: Proximal fascial tension pattern linking hip and core stability during gait

Therefore, the milestones through which an individual advances from infancy facilitate the development of God-made and evolutionary human-made arches on the dorsal aspect alternately. The vault of the cranium is a posteriorly convex God-made arch, cervical lordosis is evolutionary human-made, thoracic kyphosis is divine, and lumbar is created by regular interaction with gravity thus evolutionarily human-made. After the sacrum, the knee popliteal fossa (evolutionary human-made), calcaneum (natural), plantar arch (evolutionary human-made), the God-made base of the toes arch ensue alternately in the same fashion as seen in Figures 3.2A and B.

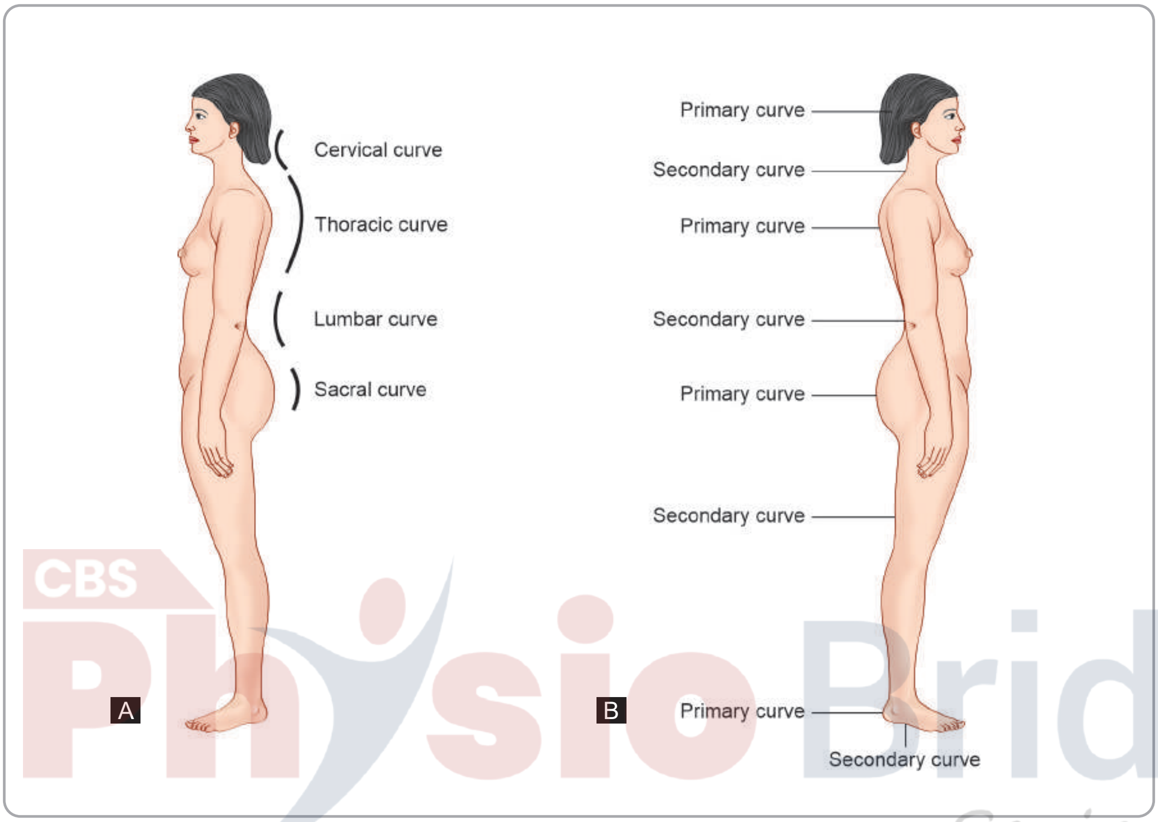
Arjun

So, what clinical implication does this have?

Senior Therapist

These primary and secondary curves are the secret to power, fluidity, and control of movement.

The primary and secondary curves in human body counterbalance one another and are essential for sustaining static posture throughout the dynamic motions with a continual interaction that integrates these elements, allowing for harmonious coordination. Furthermore, the line of gravity traverses the convex regions, rendering the concave sections susceptible to mechanical shear stresses, hence increasing the likelihood of development of length-tension disparity leading to distortion and stress, ultimately resulting in disorder or damage of overall neuromusculoskeletal integration. For example, anteroposterior fascial chain disturbances lead to development of kyphosis and lordosis, whereas lateral fascial chain disruption predisposes to scoliosis.



Figures 3.2A and B: A. Natural spinal curves in the human body; **B.** Secondary or evolutionary curves in the body

Unlike building construction, where stacked bricks are held together by compressive forces and cement, the human spine achieves stability or structural cohesion through a dynamic interplay of web tension and compression forces created by fascia. This allows for energy-efficient, graceful, agile, and subtle movements.

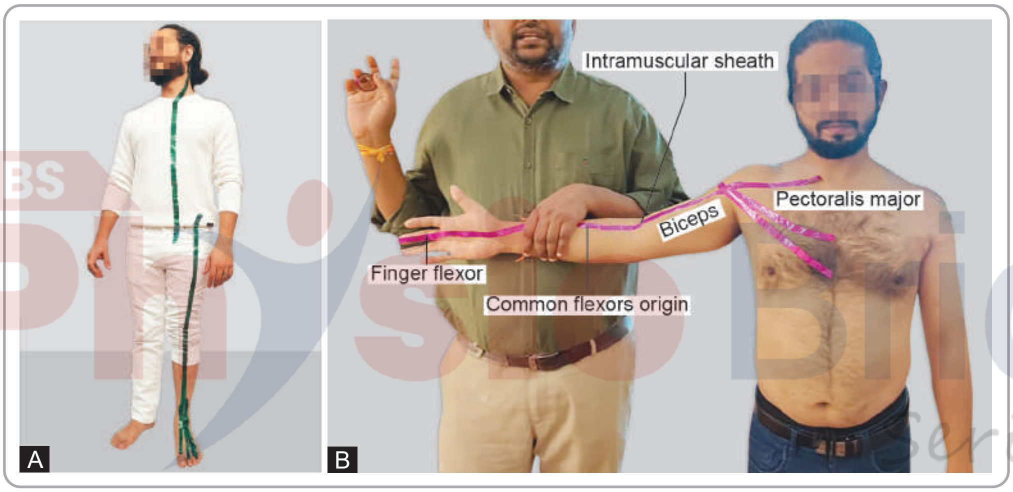
Food for Thought

A traditional spinal stabilization surgery relies on static compressive forces through screw fixation, prioritizing (hardware-based) bony structural stability over tissue length-tension relationships (e.g., fascial connections). This approach compromises mobility and leads to:
- Reduced flexibility
- Altered biomechanics
- Osteophyte formation at adjacent spinal levels

A more holistic approach would consider strategies that would combine the dynamic web of tension and compression forces within the body, leveraging restoration of:
- Fascial continuity
- Soft tissue relationships
- Multidirectional force distribution

FASCIAL CHAINS

To achieve optimal spinal stability, it is essential to balance stability and mobility, recognizing the intricate relationships between tissues and forces in the human body. According to fascial science, the posterior and anterior fascial chains function as interconnected rigging systems, similar to a sailboat's mast balance of tension and counter-tension. The anterior fascial chain, encompassing the chest, ribs, and abdomen, harmoniously counterbalances the posterior fascial chain, ensuring: (a) Optimal movement and stability: (b) Efficient force distribution and (c) Effective load transfer (Figs 3.3A and B). Having understood the crucial role of fascial interconnection, one can infer that when any part of this fascial network is injured or compromised, it disrupts the delicate balance, leading not only to altered movement patterns, compensatory mechanisms, and chronic pain or postural imbalances, but also to breathing difficulties. In such situations, K-CAT fascial strategies have proved to be beneficial without compromising either mobility or stability.



Figures 3.3A and B: A. Anterior fascial chain of the trunk; **B.** Superficial anterior fascial chain of the arm

A knowledge of the fascial connections, together with the interaction of curve development, is not only essential for abating manifestation of dysfunction but is also vital for the formulation of therapeutic programs for patients.

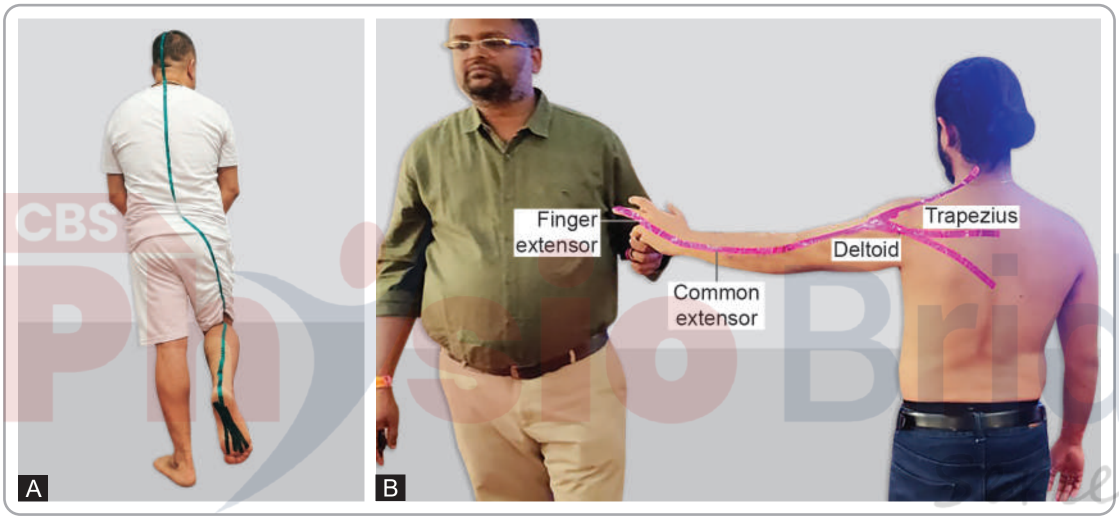
Therefore, comprehending the continuity of fascia in the human body is essential to comprehend the concept of power, fluidity, and control of movement. Let us examine the various superficial fascial chains individually.

Posterior Superficial Fascial Chain

The developmental milestones have facilitated the layout of the fascial interconnections that have grown posteriorly, which extends from the orbicularis oculi muscle at the apex of the human body to the base of the 1st and 5th metatarsal bones in the foot. Ascending from the bottom, it creates a triangular structure that links the balls of the toes to the calcaneus, also called the 'trampoline of the foot' as coined by K-CAT, due to its very function. It then continues through the achilles tendon, connects to the sacrotuberous ligament (STL) *via* the hamstrings, and further extends to the thoracolumbar fascia. From there, it reaches the paraspinal muscles and travels through the occipital protuberance to the cranial vault and joins the epicranial fascia. Finally, it ends at the orbicularis oculi muscle (Figs 3.4A and B).

Senior Therapist

The fascial linkages play a crucial role in both the occurrence of mechanical dysfunction and in designing the rehabilitation plan for patients. Activation of the posterior fascial chain in a case of non-specific mechanical backache is one of the techniques used for treatment. This includes percussion with cupped hands, administered to the superficial fascia of the posterior chain spanning from the gluteal line to the popliteal fossa (proximal to distal), encompassing the entire width of the posterior aspect of the thigh. Simultaneously, after each percussion maneuver, the other hand of the therapist shall apply two-finger mild resistance to the ankle for the patient to perform active knee flexion in the outer range (this has been dealt with elaborately in further chapters).



Figures 3.4A and B: A. Posterior fascial chain of the trunk; **B.** Superficial posterior fascial chain of the arm

Arjun

It is a harsh way of putting forth a question, but I am inquisitive to know whether this was actually helpful, sir, and why the strokes were taken only proximal to distal and not the other way around.

Senior Therapist

The upper thigh's anatomy, characterized by greater muscle mass and broader posterolateral dimensions, predisposes it to trigger-point development, which is exacerbated by sedentary lifestyles and prolonged chair-borne states.

The fascial characteristics vary along the thigh and are different in the proximal or upper thigh in comparison to the distal. The fascia in the upper thigh is softer, has more superficial fascia, a higher concentration of sensory nerve endings, and thus an increased susceptibility to trigger points. Whereas, the fascia in the distal or lower thigh is thicker, having more robust fascial structures like tendons, which are located superficially, and thus there is less incidence of trigger points. Understanding these factors is crucial to effective treatment strategies. Also, the embryological development of mesodermal tissues like fascia follows a proximal-to-distal budding pattern, influencing fiber orientation. Thus, the application of strokes from proximal to distal, during the maneuver, is vital.

Moreover, muscles such as hamstrings and quadriceps are just power generators. It is the fascia that augments the power generated by them, by conducting the forces (like high tension power lines) and allows the body to perform actions. It is generally presumed that the muscles like quadriceps or hamstrings may have gone weak, or the abdominals and back extensors are affected in cases of backache. However, it is invariably the posterior fascia which is not performing well enough, as it is not in resonance with other areas of the fascia due to mechanically disrupted sensory signals. The percussion of the fascia over muscle increases the sensory recruitment of the fascia, that in turn recruits a greater number of motor units in the muscle with each resisted knee flexion that the patient is made to do amidst the maneuver. This will in turn decrease the dysfunction and help the patient to walk out of the clinic joyfully where the outcome thus aligns with the goal of patient-centered, evidence-informed practices (EIP). A thorough discussion on the embryological development of different tissues of the body and the origin and relation of the muscles and the fascia will help to appreciate these facts all the more.

Arjun

Ok, that sounds interesting. So surely I will wait for the embryological discussion. I am assertive that you might have planned the right juncture to introduce me to this particular embryological theory in the further course of discussion. But as of now, can you please help me know how many such sessions of intervention are generally warranted for patients with back pain?

Senior Therapist

This treatment program includes patient-guided sessions, tailored to individual needs, until pain resolution or full recovery is achieved. The number of sessions varies based on patient presentation.

Arjun

And what about remedial advice at home to maintain and enhance recovery following this maneuver?

Senior Therapist

If an assistant is available, we can teach them the maneuver to support our treatment plan. Other tips to keep fascia healthy are staying hydrated by drinking enough water, avoiding prolonged static posture, and taking regular microbreaks. It is also recommended to ensure a good 7–9 hours of sleep during the night.

Arjun

Is that all about the posterior superficial chain?

Senior Therapist

Furthermore, the release of the sacrotuberous ligament, which also forms a part of the posterior superficial fascial chain, has shown significant therapeutic significance in K-CAT, and can be discussed at this point of time.

Arjun

I have not heard about this term! It looks like it was completely ignored by me during my study. Is it so relevant?

Senior Therapist

Yes, it is. Let us together uncover the role of sacrotuberous ligament (STL), a part of the posterior superficial fascial chain, in pelvic stability and pain management. A critical pelvic stabilizer, that is what I like to call this a 'bridge'.

Sacrotuberous Ligament

The sacrotuberous ligament (STL) is a fan-shaped connective tissue bridging the sacrum and ischial tuberosity, stabilizing the sacroiliac joint, and linking the vertebral column to the bony pelvis. It also forms a part of posterior chain.

Food for Thought

Functions of STL:
- Maintains pelvic stability
- Controls sacral nutation (anterior tipping)
- Supports erect posture

Innervation: Coccygeal plexus

Relations:
- **Anterior:** Pudendal nerve, internal pudendal artery
- **Posterior:** Gluteus maximus muscle
- **Inferior:** Coccyx, levator ani muscle

The sacrotuberous ligament forms a pivotal junction for the convergence of three muscles-gluteus maximus, piriformis, and the long head of the biceps femoris. Its anatomical relationship with the coccyx and levator ani maintains pelvic floor integrity. Thus, this ligament's functional significance extends to pelvic stability, musculoskeletal movement, and weight distribution.

Causes of injury or stress to the STL:
- Trauma (due to falls or, sports injuries)
- Repetitive strain (due to prolonged sitting or standing especially with anterior pelvic tilt)
- Biomechanical imbalances (due to poor posture, gait)
- Hormonal changes (in case of pregnancy, menopause)

Food for Thought

Pregnancy-induced laxity of STL enables pelvic accommodation of fetal growth and facilitates fetal delivery.

Consequences of injury or stress to the STL:

- Pelvic strain
- Low back pain with sacral joint dysfunction
- Thickening and tightening of the ligament (like a cord) due to sustained stress
- Ligament ossification (due to repetitive stress)
- Pudendal Nerve Entrapment Syndrome (PNES) (as a result of thickening and ossification)

There is an interdependent relationship as an affected STL can alter biomechanics, and vice versa. Thus, it is the posterior 'real core', essential for assuming an erect posture.

Arjun

How important is this ligament? Won't the structural cohesion ensure the stability of the pelvic region?

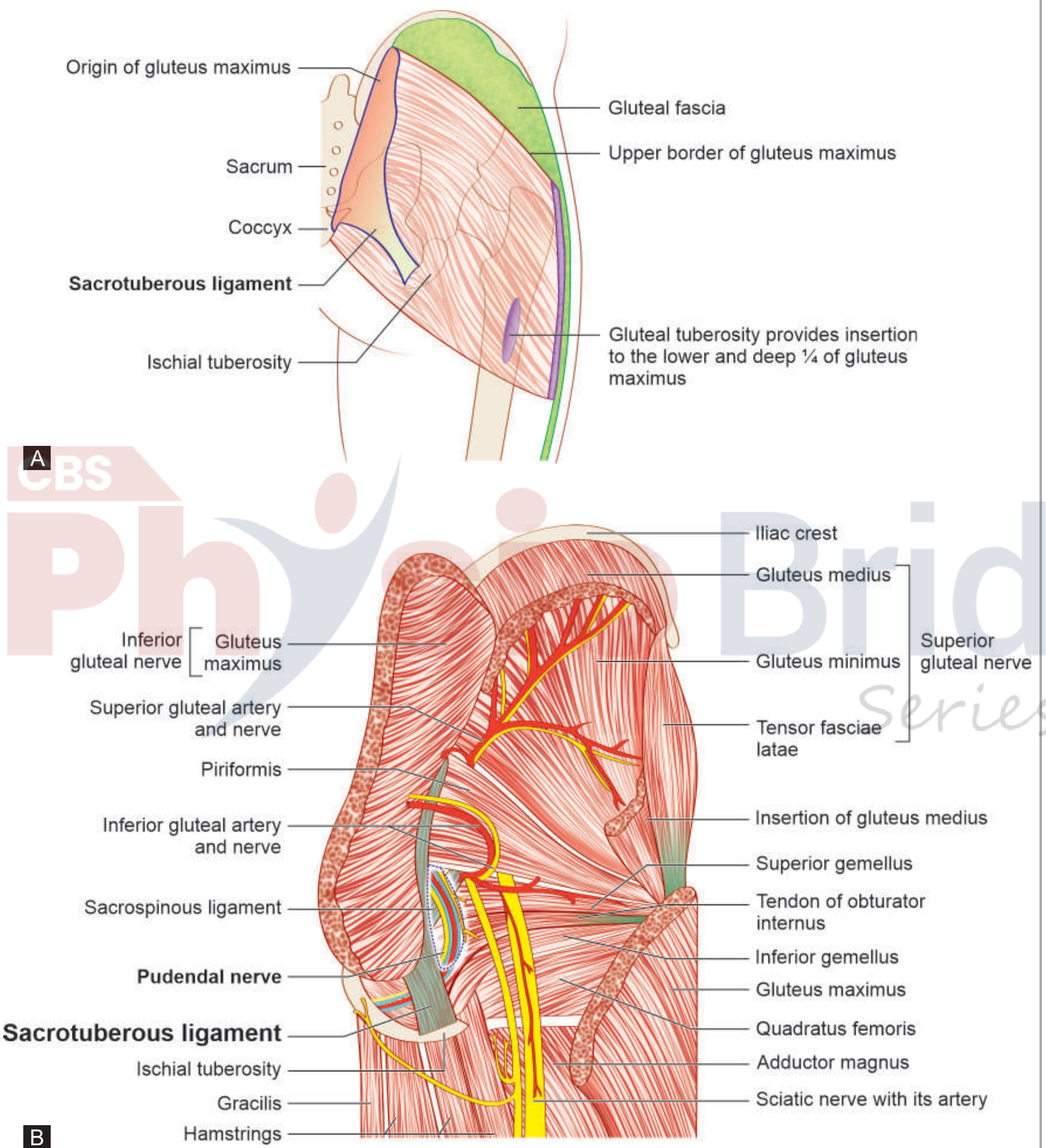
Senior Therapist

Actually, it would be quite a sight to imagine someone without a sacrotuberous ligament—every time they bend over, their tailbone would pop up like a jack-in-the-box (Fig. 3.5).

Figure 3.5: Absence of sacrotuberous ligament would make the tailbone pop out during forward bending

Arjun

It looks (Figs 3.6A and B) as though this ligament is quite deeply located. I wonder, how is it so approachable?



Figures 3.6A and B: A. Sacrotuberous ligament; **B.** Sacrotuberous ligament with the pudendal nerve (from the sacral plexus)

Senior Therapist

Certainly, it is deeply placed and we shall soon delve into the approach when we see the individual techniques at length. Nevertheless, here we should know that fascia has microstructures and is also divided macroscopically:

The microstructures (cellular) of fascia include:

- **Cells:** Fibroblasts, macrophages, and adipocytes
- **Ground substance:** Proteoglycans, hyaluronan, glycoproteins, and water
- **Fibers:** Collagen, elastin, and reticular fibers, which make the fascia malleable

The macrostructures (layered fascia) include:

- Superficial fascia consists of:
  - **Hypodermis:** Loose connective tissue
  - **Subcutaneous layer:** Adipose tissue and fibrous septa
- Deep fascia (muscular layer)
  - Surrounds muscles, and forms tendons, and ligaments
  - It is an aponeurotic (robust) fascia which is dense and has fibrous tissue
- Internal fascia (around visceral, vascular, and glandular systems):
  - Surrounds organs, glands, and blood vessels

A high density of the nerves responsible for sensory perception are located in close proximity to and harmonize with the subcutaneous fascia and thus superficial fascia directly influences skin sensations (sensorial resistance, pressure, temperature, and pain) and deep fascia indirectly has an impact on skin health and function (texture, tone, and mobility) and deep fascia affects the skin elasticity and firmness and provides architectural support. So, working from over the skin onto the deep fascia can have profound effects.

Arjun

And why do you always start with the anatomy of the fascia or the structures under discussion?

Senior Therapist

Understanding fascial anatomy and its interconnection with the skin is crucial for a holistic treatment approach and transcending medical specialties. Healthcare professionals, including physiotherapists, plastic surgeons, dermatologists, neurologists, and orthopedic surgeons, must integrate this knowledge into their fundamental treatment strategies.

Clinical Tip

In conditions such as Reflex Sympathetic Dystrophy (RSD), fascial anatomy plays a critical role. Irritation of sensory nerve endings through the autonomic nervous system (ANS), can lead to symptoms. Appreciation and recognition of this interplay between the structures and their relationship enhances clinical understanding, allowing healthcare providers to better comprehend patient experiences and develop effective treatment plans.

Notably, the therapeutic release of the STL can correct posture and alleviate symptoms of Peripheral Nerve Entrapment Syndrome (PNES) and related conditions. This underscores the STL's critical function as the posterior 'real core', enabling erect posture and optimal bodily alignment.

Senior Therapist

Now pull your reins, son, to make the matter more interesting we shall delve deeper into another clinical aspect of posterior superficial fascia. So here comes another clinical tip for a patient who presents with pain on the calcaneal aspect or the plantar aspect of the foot, which I do not generally like to call but is traditionally labeled as retrocalcaneal bursitis or plantar fasciitis.

Plantar Fascia: Trampoline of the Foot

The plantar fascia plays a vital role in supporting the arch of the foot, connecting the toes to the heel, and acting as a natural shock absorber during walking (due to its unique trampoline-like elastic and structural perspective at the base of the foot). This complex structure is part of the long posterior fascial chain, akin to a 'highway', which extends upward to the epicranial fascia and is hooked to the orbit. Patients labeled as having retrocalcaneal bursitis or plantar fasciitis often experience excruciating pain after rest or prolonged sitting, characterized by a distinctive 'moon walk' gait. This pain is frequently accompanied by difficulty in standing erect.

From an anatomical perspective, the calcaneus serves as a pulley, directing forces to the ascending posterior fascial chain, comprising that of the gastrocnemius and hamstring muscles on its way up. Alterations in this pathway can lead to stretching, microtears, and inflammation in the plantar fascia.

Three primary factors that disrupt the length-tension of the plantar fascia are: (i) Proximal traction from ascending structures, (ii) Local architectural barriers such as flat foot or high arch foot, and (iii) External causes, such as ill-fitting or improper, overly-padded and constricting footwear.

The plantar fascia is integral to the superficial posterior chain, and releasing tension in this area can alleviate pain not only in the foot (calcaneal and plantar regions) but also in the neck (cervical myalgia) and even migraines, by addressing the underlying root cause (Figs 3.7A to C). This comprehensive approach is integral to the K-CAT treatment maneuver.

Senior Therapist

By the way, Arjun, did you know quadrupeds do not even have a plantar fascia!

Arjun

Ah! That comes as a surprise, sir. What role does the plantar fascia play in supporting upright posture, and why is it absent in quadruped species?

Senior Therapist

Human bipedalism evolved through arboreal quadrupedal, knuckle-walking, leaping, and suspensory climbing stages. This progression led to the development of the plantar fascia for stability and mobility, distinct from quadruped species that rely on hooves (Fig. 3.8A to F).

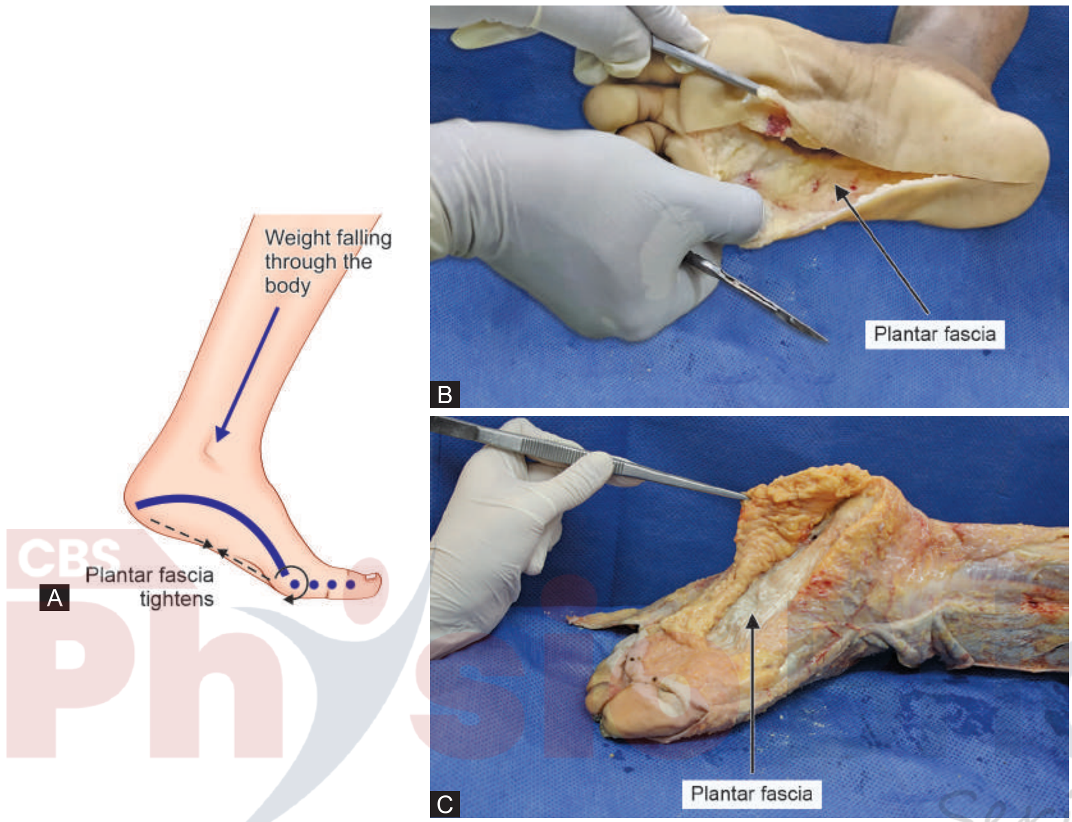
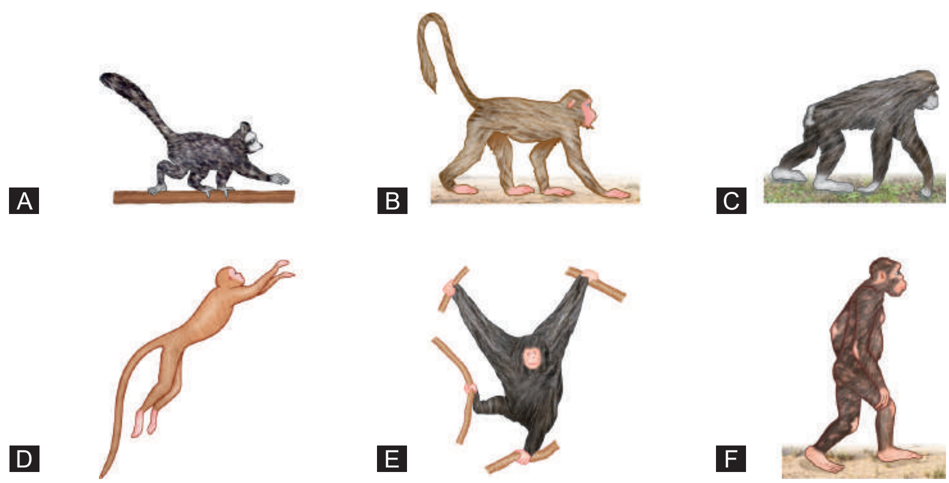


Image courtesy: Professor Andrzej Pilat

Figures 3.7A to C: Plantar fascia: **A.** Trampoline of the human foot; **B.** Plantar fascia trampoline in a cadaver; **C.** Dissected plantar fascia

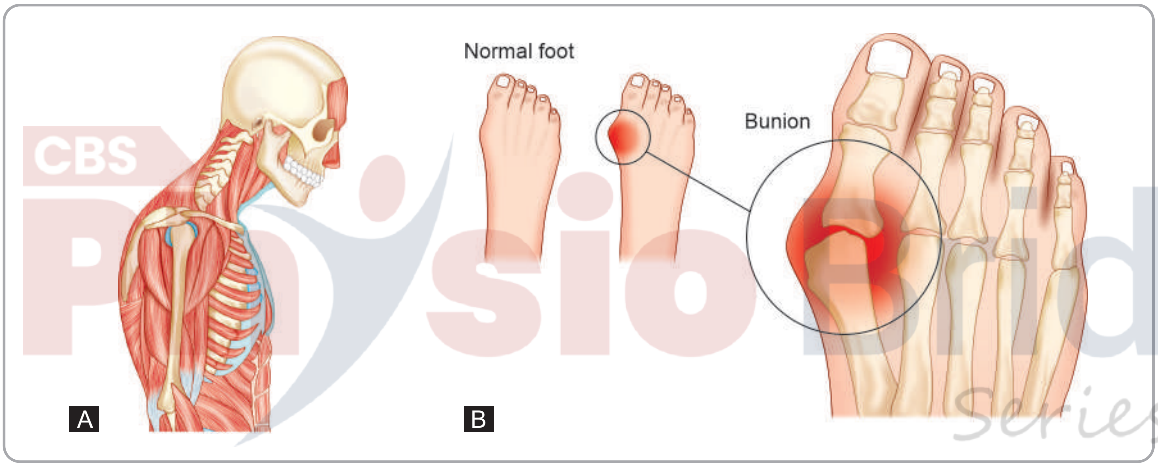


Figures 3.8A to F: From arboreal quadrupedalism to bipedalism[18]: **A.** Arboreal quadrupedalism; **B.** Terrestrial quadrupedalism; **C.** Knuckle-walking quadrupedalism; **D.** Leaping; **E.** Suspensory climbing; **F.** Bipedalism

Food for Thought

Text neck is a reason for bunion or plantar fasciitis.

A forward head posture (text neck) leads to shoulder roll inward, thoracic spine flexion, lumbar spine extension, and anterior pelvic tilt causing the whole-body to compensate and face the challenge of gravity to maintain balance. This leads to an increase in fascial tension in the back, hips, and legs. Due to this, there is further compensation in lower extremity (LE) and development of plantar fasciitis or bunion. It is due to the tibia leaning forward as a result of the pelvic tilt, which increases pressure on the arch of the foot and also causes continuous pressure on plantar fascia. This causes inflammation, swelling, and fluid accumulation, which becomes stagnant over a period of time. The body's reaction in turn calls for calcium deposition to stabilize the area and thus leads to the development of bunion. These are the long term consequences of fascial tension, postural compensation, biomechanical stress, inflammation, and fluid dynamics (Figs 3.9A and B).



Figures 3.9A and B: A. Forward head posture; **B.** Bunion

Senior Therapist

The aforesaid discussion also brings forth this fascinating comparison between bipedalism (two-legged) and quadrupedalism (four-legged), highlighting the role of fascia and biomechanics. As bipeds require balance and stability along with mobility, any disorder that leads to altered biomechanics affecting ankle dorsiflexion (DF), in turn increases the risk of repeated tugging of the plantar fascia, which can thus lead to its inflammation. This leads to anterior chain dysfunction and further to foot pronation.

The plantar fascia simulates an elastic trampoline, storing energy for efficient movement in bipeds. Bipedalism relies crucially on energy efficiency, where gravity facilitates momentum and rhythmic walking, providing a mechanical advantage that enhances locomotion. However, in quadrupeds as the center of gravity (COG) is lower, it reduces the effect of gravity on movement and offers stability.

Arjun

Why does the posterior chain extend all the way up to the superior orbit anteriorly?

Senior Therapist

It is a great question! To understand this, we need to look at the evolution of humans. When we study it deeply, we will soon realize how our anatomy changed from fish to humans, specifically the placement of our eyes and mouth. This helps us clearly understand why the posterior chain extends all the way up to the superior orbit anteriorly.

Arjun

Yes, I recall you mentioned embryological relevance earlier, as well. I am eagerly waiting to hear the same for other examples too. Can you please help me understand why any disorder that leads to altered biomechanics of ankle dorsiflexion have such significant consequences, and what is the root cause for it?

Senior Therapist

This, my son, brings us to the Anterior Superficial Fascial Chain. Understanding this chain sheds light on why limited dorsiflexion can have such far-reaching effects.

Anterior Fascial Chain

The anterior fascial system comprises two distinct chains: (i) A superficial chain, which is primarily involved in movement, and (ii) A deeper chain closely related to the peritoneum and visceral organs. Let us explore the superficial chain.

Anterior Superficial Fascial Chain

Anterior superficial fascial chain (Figs 3.3A and B) refers to a series of interconnected fascial structures located in the front part of the body. It begins at the first to fifth metatarsals on the dorsum of the foot, continues toward the tibia converging with the extensor retinaculum, and then follows the path of the tibialis anterior muscle, encompassing it. From there, it extends to the ligamentum patellae, the quadriceps rectus femoris, and finally reaches the anterior superior iliac spine (ASIS).

Arjun

Oh, so does it discontinue here?

Senior Therapist

No, Arjun, it does not. Instead, it continues as the periosteum of the pubic bone and converges at the pubic symphysis.

The anterior superficial fascial chain (ASFC) continues uninterrupted beyond the ASIS, transitioning into the periosteum of the pubic bone and converging at the pubic symphysis from both sides. From there, it extends along the rectus abdominis, sternalis, and sternocleidomastoid (SCM) muscles. Ultimately, the ASFC merges with the lateral fascial chain at the SCM.

Extensor Retinaculum

The superficial extensor retinaculum (ER) of the foot is the body's distal-most-apparatus, but it needs a special mention here, due to its crucial role in balance and coordination, mediated *via* the anterior superficial fascial chain.

The superior ER is found on the lateral side of lower leg, attached laterally to the lower end of fibula and medially to the tibia. Superiorly, it blends seamlessly with the anterior superficial fascial chain of the leg, forming a continuous layer. It stabilizes and supports anterior tendons at the foot, facilitates tendon gliding and movement, diverts forces to different parts of the leg, maintains tendon alignment, and prevents bowstringing of tendons at the foot. Without the ER, this alignment would be disturbed, and the tendons would simply float in the air, simulating a 'Devil's Foot'.

Food for Thought

Extensor Retinaculum

This fibrous band forms a lubricating sheath and wraps around the bulk of the anterior tendons, including:

- Tibialis anterior tendon
- Extensor digitorum longus tendon
- Extensor hallucis longus tendon
- Peroneus tertius tendon

It works as an anterior pulley that guides tendons through a fibro-osseous tunnel. The extensor retinacular fibers reinforce and stabilize the tendons, and the synovial sheath lubricates and reduces friction between tendons and surrounding tissues. This plays a crucial role in aiding the movement of the dorsiflexors as well as the antagonist action of the plantar flexors.

The tendons are generally rich in Golgi tendon organs (GTOs), which detect movement dynamics (speed, direction, length, tension, and proprioception) and trigger reflexes. Strategically located nearest to the gravitational forces, these tendons, along with the ER, form the body's distal-most 'apparatus', maintaining continuous communication with the cerebellum. This complex has been colloquially dubbed as the 'cerebellum of the foot' due to its crucial role in balance and coordination.

The ER, densely populated with proprioceptors, ensures optimal balance and stability during movement, particularly during anteropropulsion and ankle hinge movements. Constriction of this structure impairs balance, while releasing tension restores function, enhances proprioception, and boosts overall balance and stability.

Arjun

So, does that mean the anterior and posterior halves of the superficial fascial chains are associated? But then, why do not those two halves fall apart?

Senior Therapist

What an astute observation, you little brainy chap! Indeed, they are connected. I have started enjoying your company. Here comes the role of the lateral fascial chain.

Lateral Fascial Chain

The human body has not only the anterior and posterior chains, but also the lateral chain, which serves to connect and interweave the anterior and posterior chains in a crisscross pattern just like an interweaving mesh of a fruit basket (Fig. 3.10).

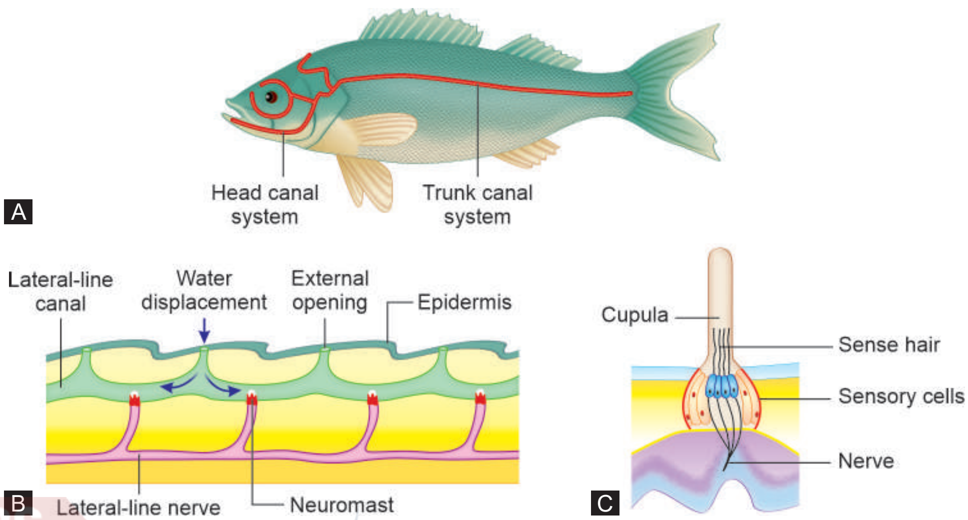
Figure 3.10: Fruit basket crisscross pattern

This arrangement enhances the body's ability to withstand falls and retain equilibrium.

Senior Therapist

Our evolutionary journey connects us deeply to our fish ancestors, and the genetic inheritance of those ancient fish still influences our bodies today.

Aquatic vertebrates, such as fish, possess the lateral line system, a complex network of tactile sensors that detect water movement and pressure changes in the surroundings. This system comprises a series of mechanoreceptors called neuromasts, forming a linear network traversing from head throughout the body and reaching the tail (Fig. 3.11A). Neuromast cells, resembling hair cells or cilia, are exposed on the skin surface (Figs 3.11B and C). Interestingly, in sharks, these neuromasts evolve into electroreceptors known as Ampullae of Lorenzini, enabling them to navigate and migrate.[19]



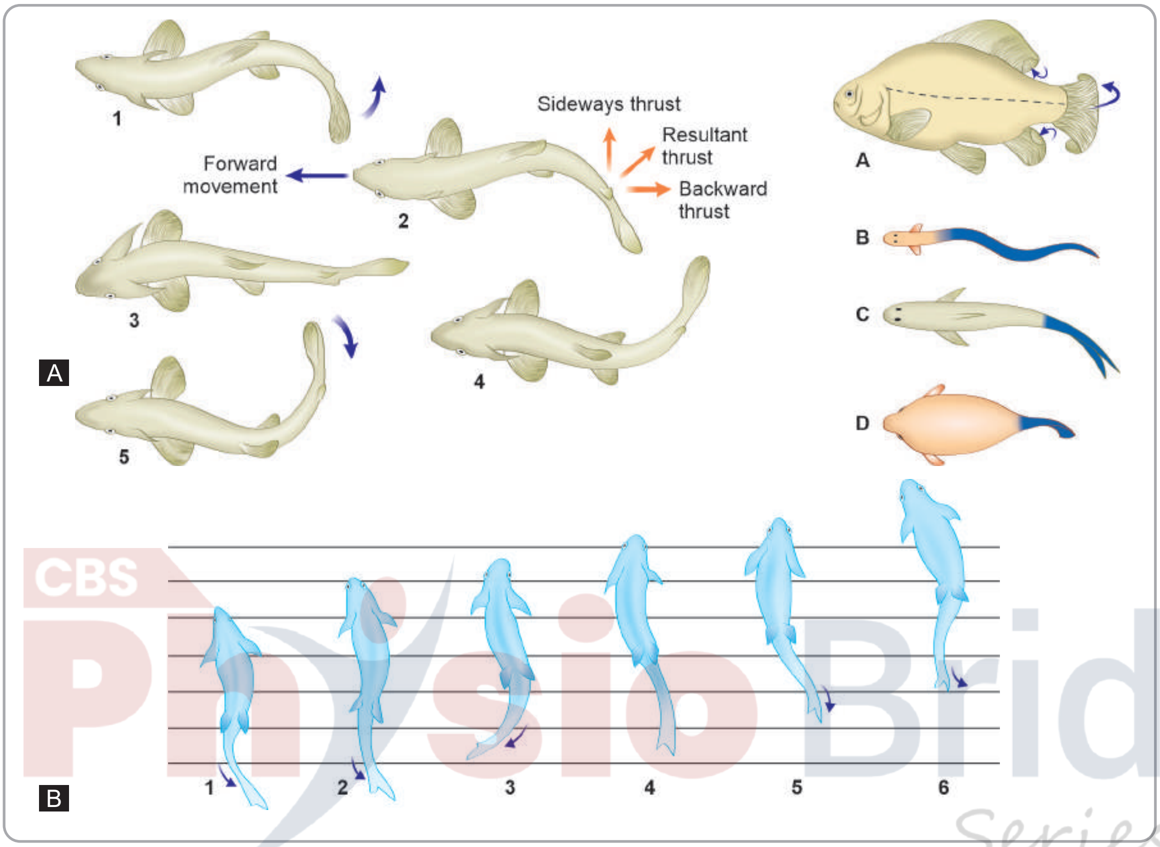
Figures 3.11A to C: Lateral line system of fish: **A.** Bodily location of lateral lines; **B.** Longitudinal section of a canal; **C.** Superficial neuromast

Senior Therapist

Therefore, it is not surprising to learn that one of the primitive movements in the human body, akin to the lateral movement of fish swimming in water, is the ability of the body to control lateral sways (Figs 3.12A and B). Ears, structurally placed along the same line of lateral fascial chain have, the vestibular system, which plays a crucial role in maintaining the body's balance and equilibrium. Thus, the lateral fascial chain along this line, controls the posture and regulates the gait of bipeds, just like the sensitive receptors on the lateral aspect of sharks guides its movement.

Any forward propulsion movement, be that of sperm or of human gait, uses an asymmetric force generation with coordinated counter-rotation to neutralize torque and produce linear forward propulsion (Fig. 3.13). It aids to push against fluid backward or against the ground to move forward. In sperm, the head rotates opposite to the tail torque and in humans arms and trunk rotate opposite to legs, whereas pelvis and trunk rotate in opposite directions and thus, help to generate an efficient forward motion (Fig. 3.14).

The lateral chain participates and assists in lateral and rotational movement of the trunk and also helps in creating lateral bending of the trunk on either side, as well as in abduction at the hip and eversion at the foot. It helps in forward propulsion. The lateral fascial chain extends from the inside edge of the first metatarsal head. The other part initiates from the inner edge of the fifth metatarsal. It crosses the dorsum of the metatarsal to reach behind the respective medial and lateral malleolus. (Fig. 3.15).



Figures 3.12A and B: Lateral chain in fish: **A.** Lateral view; **B.** Superior view

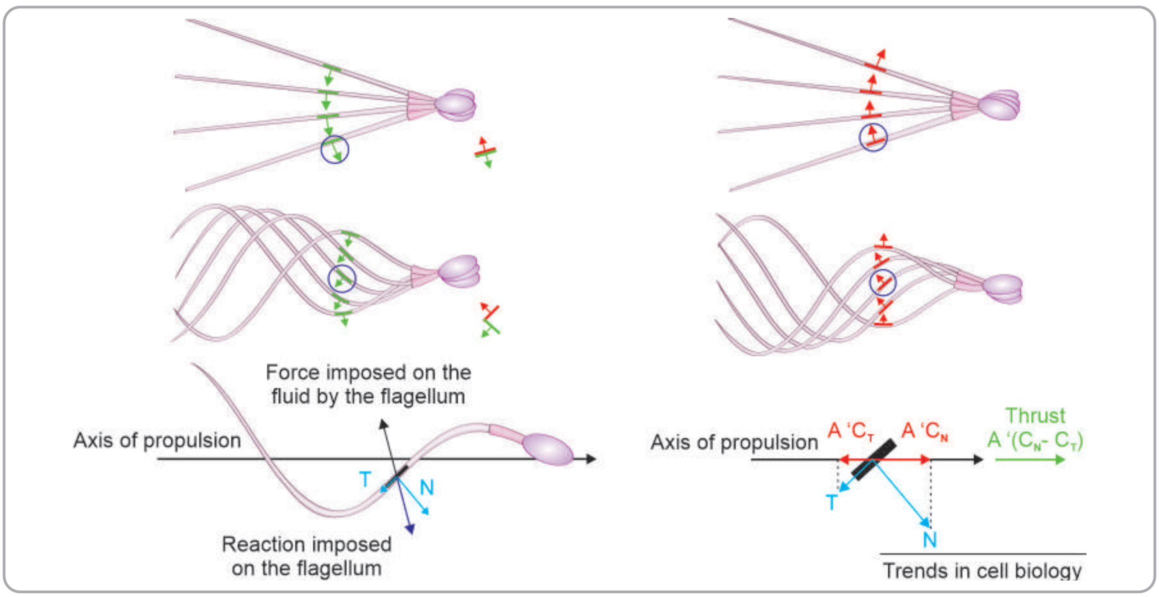


Figure 3.13: Sperm flagellar propulsion mechanism[20]

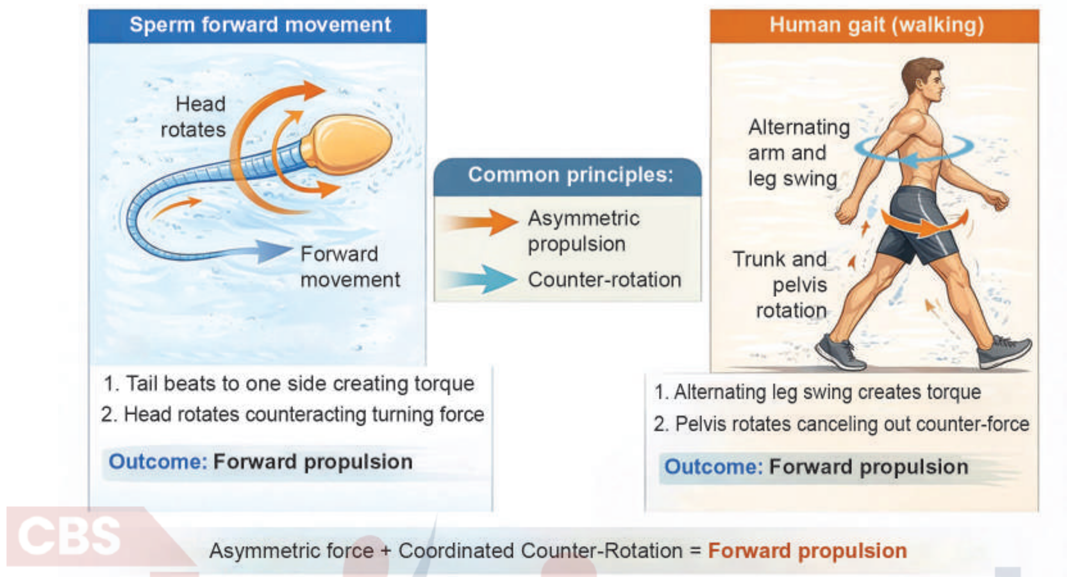


Figure 3.14: Correlation between sperm forward movement and human gait

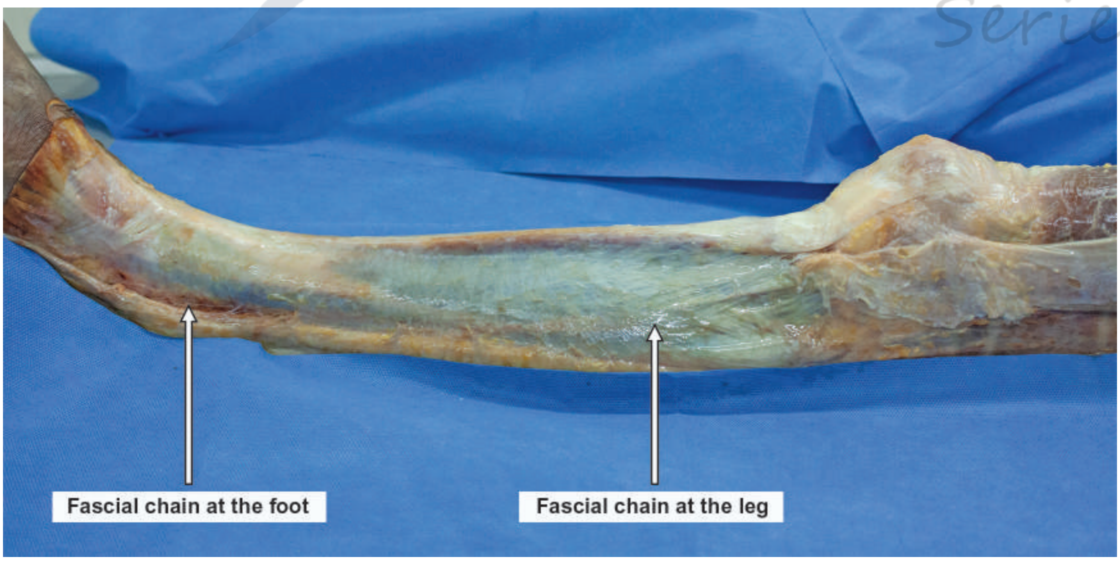


Image courtesy: Professor Andrzej Pilat

Figures 3.15: Lateral fascial chain at the foot and at the leg

Here on the medial side, fascia reaches the lateral malleolus from behind. It eventually joins the fascia from the fifth metatarsal. It encompasses the peroneus longus and brevis to continue as the iliotibial band. It then forms the fascia of the gluteus medius and maximus. It also interconnects with the tensor fascia lata on the way. Having reached the ASIS, it moves toward the internal oblique and external intercostals. From the posterior superior iliac spine (PSIS), the fascia extends further to the external oblique and internal intercostals. This forms the crisscross pattern similar to a 'fruit basket'. It also secures or joins the anterior and posterior halves of the fascia of the human body during movements (Fig. 3.16). The viscera are also thus well protected inside this fruit basket of fascia. The two sections of the lateral chain fascia connect with the anterior fascial chain at the SCM. They connect with the posterior fascial chain at the occipital protuberance and mastoid process. The lateral fascial chain along this line plays a vital role in affecting the balance of the body. In turn, it affects the posture and gait of the body.

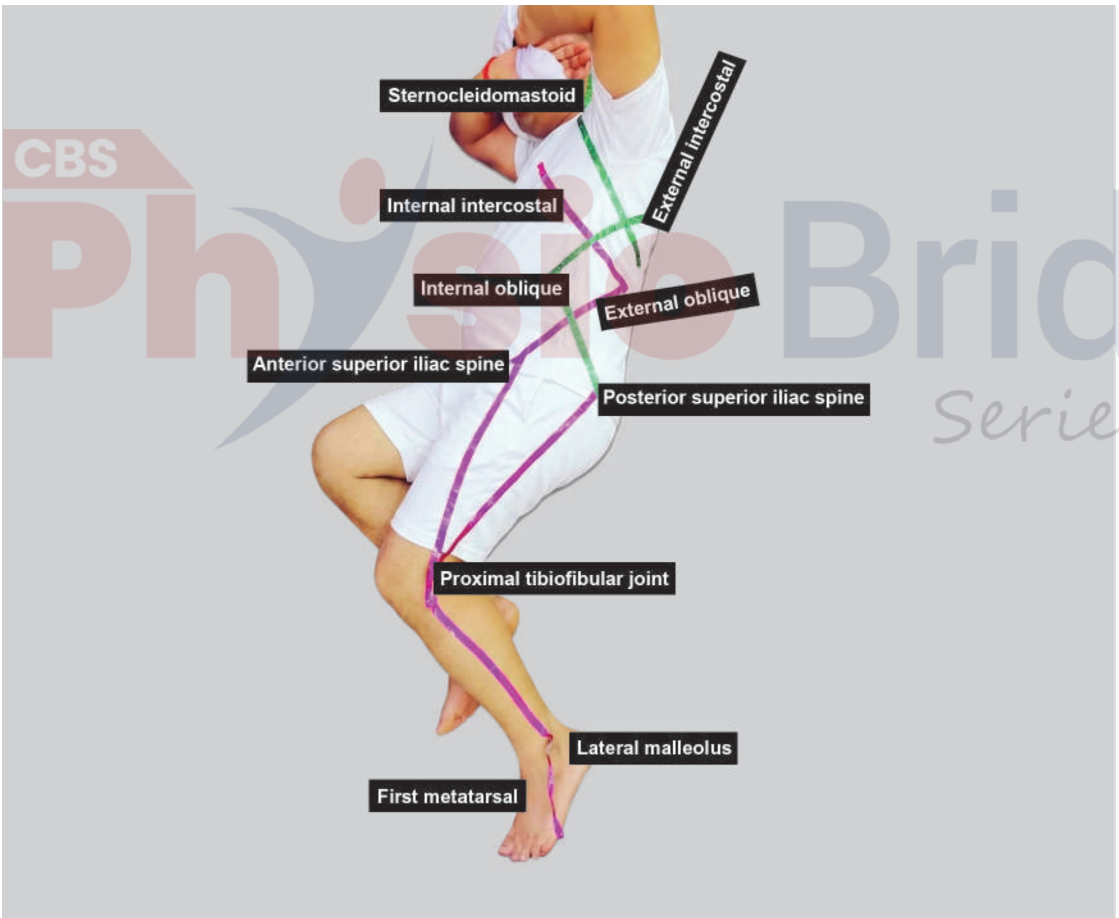


Figure 3.16: Lateral fascial chain

Food for Thought

The lateral fascial chain (LFC) often contributes to posture of the human body, and its disruption may affect the body's symmetrical alignment in the frontal plane and possibly result in postural abnormalities and anatomical malformations.

Abnormalities linked to LFC dysfunction are portrayed as *Pes cavus* (supinated foot) and *Pes planus* (pronated foot) at the level of the feet. Furthermore, alterations in the Q-angle may be induced at the knee and hip leading to *Genu varum* which depicts an elevated Q-angle and may manifest as *Coxa valga* or vice versa. Whereas, *Genu valgum* with reduced Q-angle and subsequent coxa vara or vice versa are also apparent in cases with LFC dysfunction.

The pelvis would be impacted too. The equilibrium between the length-tension relationship of the iliotibial (IT) band and consequently the adductors, abductors, and tensor fasciae latae (TFL) would further lead to lateral pelvic tilt/shift/list and a positive Trendelenburg sign during ambulation. It can also cause asymmetric compression at the lumbar spine and consequently, alter the kinematics at the rib cage in relation to the pelvis. The upper body may also exhibit asymmetry of the shoulders due to the development of scoliosis (curvature of the spine).

Lateral fascial chain dysfunction cascade

The LFC dysfunction can trigger a cascade of compensatory patterns, affecting:
- Compromised foot architecture
- Altered Q-angle
- Hip abnormalities
- Pelvic imbalances
- Spinal curvature disturbance
- Altered rib cage mechanics
- Shoulder imbalances
- Head postural variations

Iliotibial Band

An important structure of the lateral fascial chain is the IT band. It serves as a vital connective tissue, transmitting forces from the hip to the shinbone. Formed by the convergence of fascia from the tensor fasciae latae (TFL) anteriorly, the gluteus maximus posteriorly, and the gluteus medius laterally, this band acts as a sturdy stem. It channels forces through the intermuscular septum of the calf and the peroneal compartment, ultimately grounding them. Situated between the iliac crest (hip bone) and the lateral condyle of the tibia (Gerdy's tubercle), the IT band measures 2–3 cm in width and average 30–32 cm in length. One of its primary functions is stabilizing the knee, supporting the lateral collateral ligament, and reinforcing the posterolateral capsule, all of which are integral components of the lateral fascial chain (Fig. 3.17).

Food for Thought

Equally amazing is to find that there is a relation between iliotibial (IT) band and chest expansion. The IT band (IT tract) is a fascial structure connecting the hip to the knee. This tissue is also linked to the thoracolumbar fascia, the fascias that surround the abdominal cavity and also connects with the fascias of the internal and external intercostals through abdominal obliques.

This biomechanical chain, when disturbed as a result of a tight IT band, alters pelvic tilt and rotation. It causes lumbar lordosis and compensatory thoracic kyphosis, thus affecting breathing mechanics by altering the rib cage position. It therefore impairs chest expansion.

Releasing the IT band can thus:
- Reduce overall fascial tension
- Improve pelvic alignment
- Enhance lumbar flexibility
- Increase rib cage mobility
- Facilitate internal and external intercostal muscle activation, promoting chest expansion

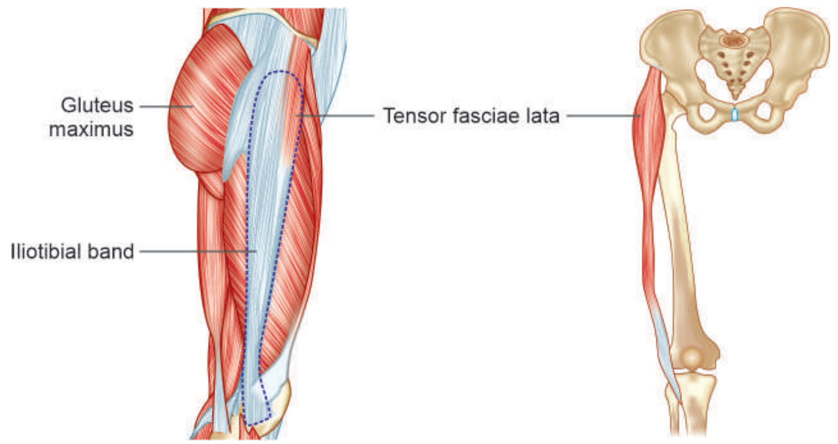


Figure 3.17: The sturdy stem: Iliotibial band

Additionally, altered IT band length–tension may result from friction and inflammation between the IT band and the lateral femoral condyle due to sudden overuse and unaccustomed activities (such as excessive running and cycling in non-athletic populations), increased training volumes, and biomechanical issues (e.g., leg length discrepancy, worn-out or inappropriate shoes). This condition can manifest with symptoms including lateral knee pain, swelling and erythema, a snapping or clicking sensation at the hip, and discomfort during activities such as running and squatting. It is also commonly termed runner's knee, as this condition is prevalent among runners, particularly those exhibiting excessive knee internal rotation and peak hip adduction during the stance phase of running. The abnormal joint posture and positioning increase stress on the IT band, leading to inflammation and pain[21].

Food for Thought

A common ailment, generally unheard of yet well labeled as External Snapping Hip Syndrome (ESHS), is also a consequence of the same. Symptomatically, it is perceived as an audible snap or click when the IT band moves over the greater trochanter (hip bone), caused by restriction of the IT band and limited hip mobility.

The IT band plays a crucial role, as it assists the lateral collateral ligament and the posterolateral capsule in stabilizing the knee. Therefore, the IT band needs to be flexible for the knee to function properly and effectively. In patients presenting with knee joint arthralgia, restoring the length–tension relationship of the IT band assists stability at the knee joint and helps reduce pain by aiding proper tracking and alignment of the patella, consequently reducing stress on the knee joint. Thus, flexibility of the IT band is extremely important for patients with osteoarthritic knees.

Food for Thought

Posterior capsulitis of the knee due to IT band involvement is commonly observed. Moreover, there is a strong connection between the IT band involvement and knee pains.

Arjun

In Concept 1 you said, 'Sensory input reflects motor output'. How do you connect this to the sensory input given while performing the techniques?

I have heard of the five senses of the human body, with the sixth sense often referred to as common sense. Skin is one of the five senses. However, you emphasized repeatedly in Concepts 1 and 2 that a high density of the nerves responsible for sensory perception are in harmony with the fascia. So how does this fascia network convey sensations?

Senior Therapist

There is also a highly concentrated network of the fascial microvacuole sliding system that connects the skin to the tissues underneath it. We have already discussed in Concept 2 that a high density of the nerves responsible for sensory perception are in concordance with the fascia. Thus, it is a major input source for all sensory nerves.

THE SEVENTH SENSE: FASCIAL SENSATION IN HUMAN BEINGS

Sensing and acting are fundamental components of animal behavior, including human beings. Sensing involves detecting and processing sensory information, creating a blueprint, and through this process generating a motor output, thereby creating a continuous cycle of interaction with the environment. When animals move, they probe their surroundings, sense changes, anticipate their next action, and keep adjusting their movements accordingly in a continuous fashion. This iterative process refines their actions in real time, blurring the distinction between sensing and acting (Fig. 3.18).

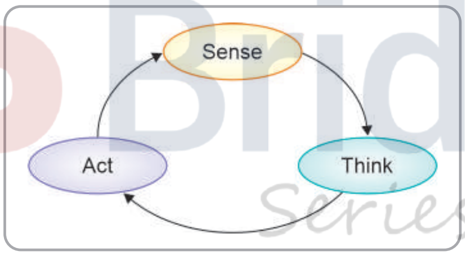
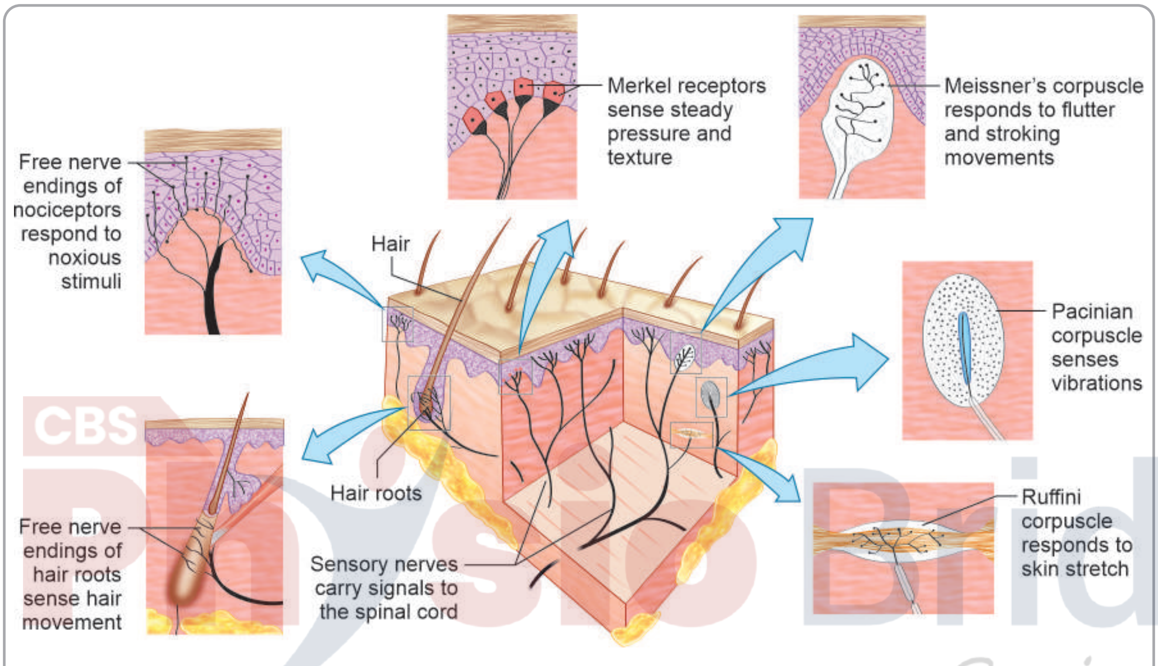


Figure 3.18: Sense-think-act cycle

This complex process relies on sensory receptors, which convert various forms of energy into neural signals. Sensory receptors perform four major functions: (i) Transduction, (ii) Amplification, (iii) Transmission, and (iv) Integration. There are several types of sensory receptors, each specialized to detect specific stimuli (Fig. 3.19). They are:

1. **Mechanoreceptors** respond to physical deformation caused by touch, stretch, motion, and pressure, including sound waves (compression and rarefaction).
2. **Chemoreceptors** transmit information about solute concentrations, with general receptors detecting overall levels, and specific receptors responding to individual molecules, such as oxygen, carbon dioxide, and hydrogen ions.
3. **Electromagnetic receptors** detect various forms of electromagnetic energy, including visible light, electricity, and magnetism.
4. **Photoreceptors** in the retina, which detect visible light, while some snakes possess infrared receptors that detect body heat.

5. **Thermoreceptors** respond to heat and cold, aiding temperature regulation, although as some of them are naked dendrites, their classification as modified pressure receptors is debated.
6. **Nociceptors**, naked dendrites in the epidermis and dermis, trigger defensive reactions to painful stimuli, with prostaglandins sensitizing these receptors to increase pain perception.



Receptor	Primary sensory	Secondary sensory	Synapse with	Adaptation
Free nerve endings	Temperature, noxious stimuli, hair movement	Around the hair roots and under the surface of the skin	Unmyelinated nerve endings	Variable
Meissner's corpuscles	Flutter, stroking	Superficial layers of the skin	Nerve endings encapsulated in connective tissue	Rapid
Pacinian corpuscles	Vibration	Deep layers of the skin	Single nerve ending surrounded by layers of connective tissue	Rapid
Ruffini corpuscles	Skin stretch	Deep layers of the skin	Nerve ending encapsulated in connective tissue	Slow
Merkel receptors	Steady pressure, texture	Superficial layers of the skin	Epidermal cell synapses with enlarged nerve ending	Slow

Figure 3.19: Sensory receptors in the skin

The sensory transduction process involves the conversion of stimulus energy into changes in membrane potential. This occurs through the opening and closing of ion channels in the plasma membrane, triggered by external forces such as bending and stretching. The resulting receptor potential generates neural signals that are transmitted to the central nervous system, where integration occurs. This integrated information guides motor output, influencing movement and behavior.

In motion, animals continuously interact with their environment, sensing and adapting to changes. This dynamic process underlies various behaviors, from predator-prey interactions to navigation and social interactions. Understanding sensory receptors and their functions provides insight into the intricate relationships between animals and their environments.

Senior Therapist

Dear Arjun, my study is right here, and it is going to be a long day. Let us catch up further tête-à-tête over a cup of coffee, as from this point forward I will need even more concentration. Let me fetch some for us!

As Arjun walked into the study, he noticed some interesting pictures displayed, as represented in Figures 3.20 and 3.21.

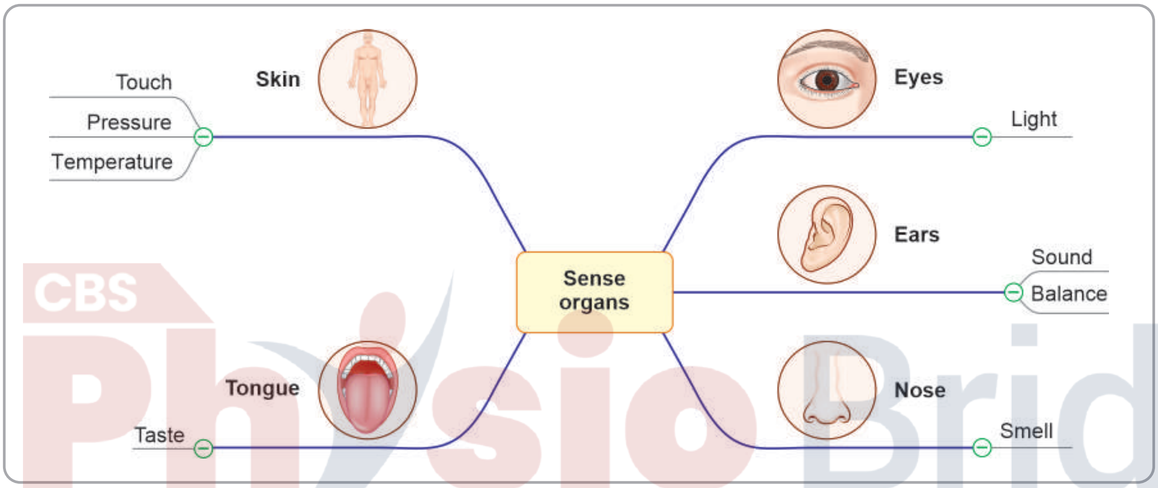


Figure 3.20: Sense organs

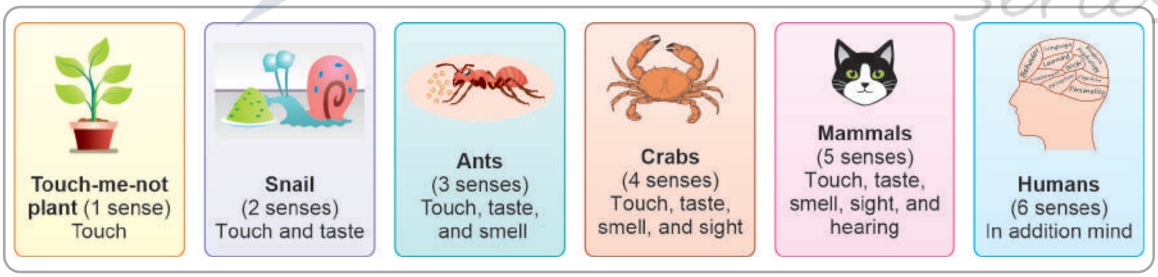


Figure 3.21: Diversity and complexity of sensory systems in different organisms

As the Senior Therapist walked in with two cups of coffee, Arjun cautiously took one from his hand.

Arjun

As I take the hot coffee from your hand, there is an expert execution of a seamless sensory–motor loop. Just by looking at the steam rising from the cup and feeling the warmth as I touched it, with precision, I was able to gauge each moment, integrating visual, proprioceptive, and tactile cues to guide the movement. The cautious approach exemplifies the cyclical process of sensing, acting, and adjusting, ensuring a smooth transition. This iterative process ensures precision and minimizes the risk of spills or accidents.

Senior Therapist

What a delightful example of the sensory-motor loop in action! Your cautious approach further exemplifies the cyclical process of:
Sense → Think → Act → Adjust → Sense → Think → Act, as depicted in Figure 3.22.

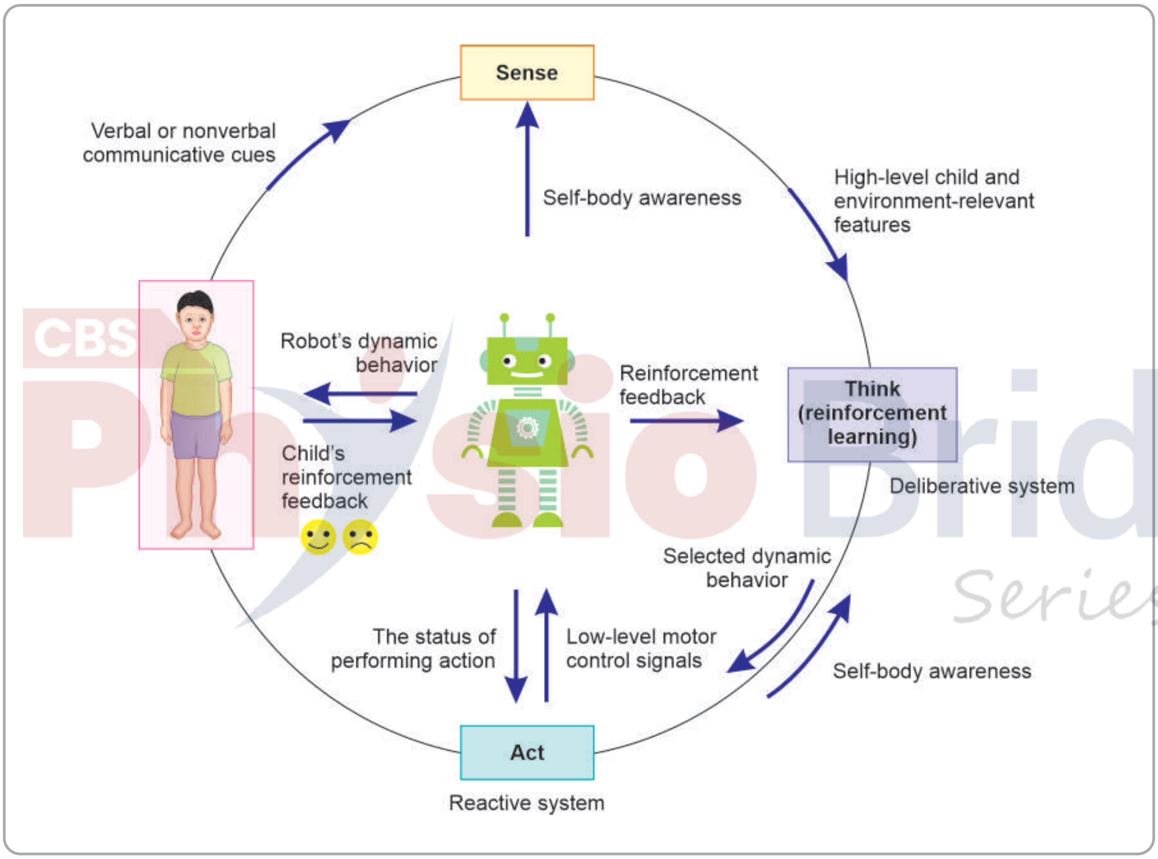


Figure 3.22: Sense–Think–Act cycle

Arjun

As I see, Figure 3.20 represents the same five senses that we have been discussing, but what is Figure 3.21 that you have presented in this frame on the wall? It looks quite interesting, and I appreciate how each box is presented, as if you want to convey something through it. I can also see that the sixth sense is acknowledged in humans. This looks very interesting, and I am all ears.

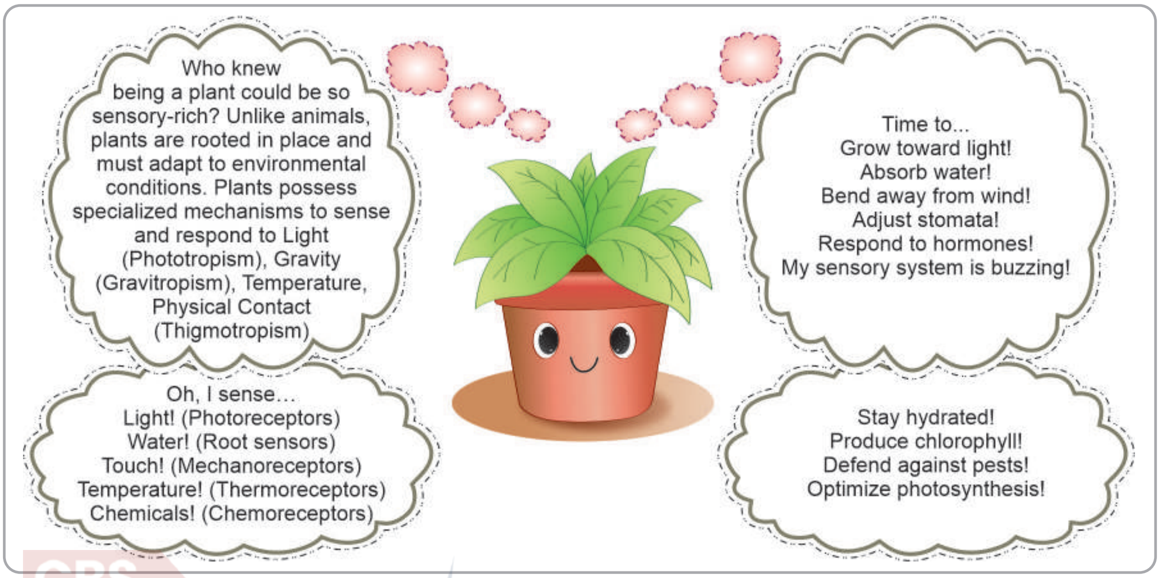


Figure 3.23: Plants embody life: Thought process and inner voice imagining its sensory system

Senior Therapist

Sensory evolution is equally important to discuss and realize the innate potential of human beings due to the presence of fascia.

In the process of sensory evolution, the fundamental sensation was touch, which originated in the earliest and simplest life forms, such as plants (Fig. 3.23).

Subsequently, the sense of taste emerged first in the animal world exemplified by creatures such as snails. This was followed by the sense of smell, seen in ants, and then by the sense of sight, found in crabs. Finally, mammals in the animal kingdom have developed the auditory sense additionally, which was the last to evolve.

In addition to the five senses in animals, humans possess a sixth sense that influences their behavior, perception, cognition, psycholinguistics, and learning. The proponents of K-CAT support the idea of the 7th sense, which is the fascial sense in these beings.

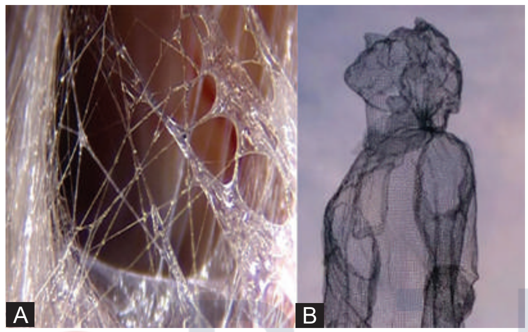
Senior Therapist

Arjun, appreciate my attention to detail in preparing my hands and applying pressure for each technique, ensuring they reach the optimal temperatures to effectively engage with the fascia when I demonstrate the maneuvers.

Every maneuver conducted by K-CAT experts is specifically designed to engage the fascia and modify the fascia's length-tension relationship. However, it is crucial to acknowledge that fascial response is not solely driven by tactile sensations, but also influenced by the patient's mindset. This is not only propagated by the

K-CAT experts but has also been mentioned in the book *The Endless Web: Facial Anatomy and Physical Reality*, in which R. Louis Schultz and Rosemary Feitis investigated the concept of emotional storage in the human body, with particular emphasis on connective tissue being well recognized[22]. "The soft tissue is the site of the physical response to emotion", they state. "The emotional body is the fascia." Ideally, emotions are experienced throughout the entire body, as they are transmitted through the fascial web. Subsequently, we interpret these physiological sensations as wrath, warmth, passion, concern, and so forth.

Certain conditions may present due to psychosomatic origin and may be partially resolved through physical release techniques unless it is acknowledged that it has an emotional root and thus treated accordingly. When a client is anxious, despondent, or apprehensive, their fascia may become less compliant and firmer[22]. One's posture, movement, and proprioception are all significantly influenced by their mood. The physical condition could conceivably be improved by enhancing mood, as it could impact the fascial web (Figs 3.24A and B).



Figures 3.24A and B: A. Fascia; **B.** Emotions[23]

Therefore, it is suggested that when there is any dysfunction, even at a remote region, it is crucial to take into account the tensegrity and structural integrity of the fascia (Fig. 3.25), as well as the sensitivity of these fascial network interconnections throughout its chain. By employing this concept, the healthcare professional can establish a comprehensive perspective on posture and movement, one that recognizes these professionals not only as physical but also as emotional and psychological experts.

In summary, it is important to note that as movement scientists, physiotherapists should be aware of the seventh sense, the sense of fascia, which maintains a normal individual's proportion of functional demand to motor response (Figs 2.12 and 2.13).

Vicious cycle of impairment can be broken at any step by applying K-CAT (Fig. 3.26).

Arjun

I now understand what fascial scientists have been wanting to convey through their studies. So, are we going to accept this theory as it stands?

Senior Therapist

Is this not good enough for you to understand?

Arjun

That is what I am hoping to discover! So let us take it as far as we can, until either you retract your theory or I am compelled by scientific evidence to accept it. I hope you refrain from feeling negatively about this, as I have been learning from the beginning, a different perspective conventionally. Therefore, perhaps I need stronger evidence to prove the facts, since the whole idea still does not hold water.

Senior Therapist

I understand why you are not yielding to your past beliefs. However, I am confident that when we meet tomorrow, I will systematically take this further with the embryological evidence, and then you will certainly acknowledge it.

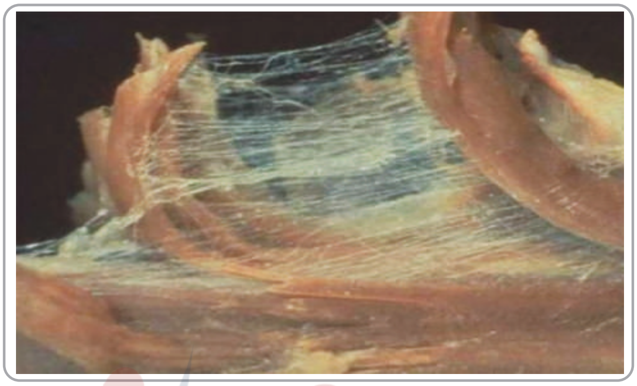


Figure 3.25: Structural integrity of the fascia

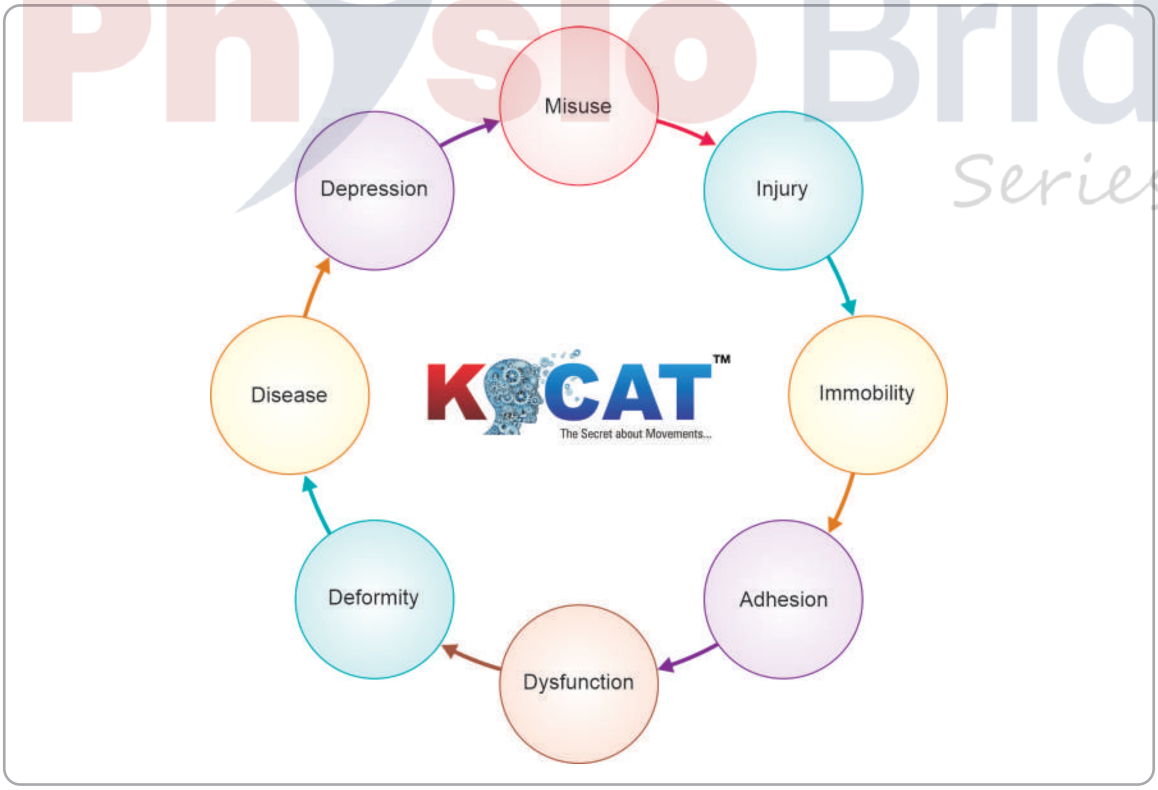


Figure 3.26: Application of K-CAT in breaking the vicious cycle of impairment

REFLECTIONS AND KEY TAKEAWAYS

- This chapter introduces readers to the structural organization of the body's three superficial fascial chains, highlighting their crucial role in maintaining body shape, posture, movement, and balance.
- The sacrotuberous ligament emerges as the 'posterior real core', vital for pelvic stability, postural alignment, and effective force transmission.
- The plantar fascia is portrayed as the 'trampoline of the foot', storing and releasing energy during gait, linking foot mechanics to cervical and cranial function through fascial continuity.
- The IT band connects hip to knee and indirectly influences rib cage expansion and respiratory efficiency, emphasizing fascia's role in global physiological and biomechanical integration.
- The fascial sensory system—encompassing mechanoreceptors, thermoreceptors, nociceptors, and proprioceptors—acts as a continuous sense-think-act-adjust feedback loop guiding motor behavior.
- In addition to the five senses in animals, humans possess a sixth sense that influences their behavior, perception, cognition, psycholinguistics, and learning. The proponents of K-CAT support the idea of the seventh sense, which is the fascial sense in these beings.