



# Applied anatomy of the knee

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In nearly all circumstances, the knee works in axial compression under the action of gravity. It must therefore reconcile two opposed requirements, namely mobility and stability. This problem is resolved by an ingenious arrangement of ligaments, menisci and tendons: the ligaments and menisci provide static stability and the muscles and tendons dynamic stability. Nevertheless, the exposure of the knee to external forces makes it very vulnerable in many occupations and sports.

The main movement of the knee is flexion–extension; secondary movement – internal and external rotations of the tibia in relation to the femur – is possible only when the knee is flexed. To measure the extent of internal and external rotation, the knee must therefore be flexed to a right angle.

## Articular surfaces

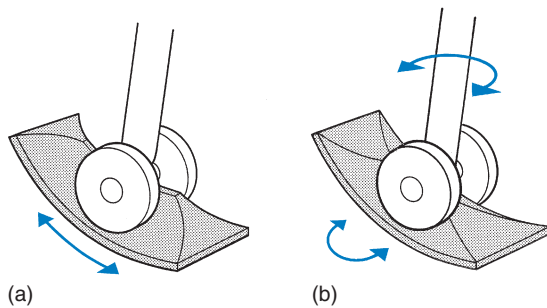
During flexion–extension, the knee acts as a hinge joint, whereby the articular surfaces of the femur roll (and glide) over the tibial surface.

The distal femur can be compared with a double wheel, in which the medial and lateral condyles are the components and the intercondylar notch the junction between them (Fig. 1). The condyles are convex in both planes. The medial condyle extends a little more distally than the lateral. The greater prominence of the lateral femoral condyle prevents the patella from sliding laterally.

The tibial aspect of the joint is two curved ‘gutters’, separated by an anteroposterior eminence. These gutters are not congruent with the corresponding condyles but this lack of compatibility is corrected by the menisci.

The anteroposterior elevation between the tibial condyles corresponds to the femoral intercondylar notch. If the surfaces of the tibial condyles are projected anteriorly, they coincide with the articular surface of the patella which corresponds to, and is almost congruent with, the anterior surfaces of the femoral condyles. If the intercondylar eminence of the tibia is projected anteriorly, its plane is continuous with the vertical ridge on the patella just as the intercondylar notch of the femur continues in the central groove of the patellar surface of the femur. This arrangement resembles a twin-wheel rolling on a central rail (Fig. 1a). During flexion and extension, tibia and patella act as one structure in relation to the femur.<sup>1</sup>

The rounded surfaces of the femoral condyles in relation to the flatter tibial ones might suggest that the former roll during flexion–extension. In fact this is not so. As long ago as 1836 the Weber brothers demonstrated that the femoral condyles roll and slide almost simultaneously, and that these movements are in opposite directions. During flexion, the femoral condyles roll backwards and slide forwards on the tibia, whereas during extension they roll forwards and slide backwards (see [Standing, Fig. 82.20](#)). The ratio of rolling to sliding differs with the degree of flexion or extension, which means that during the



**Fig 1** • (a) The knee as a hinge joint: the femoral condyles (twin wheel) in relation to the tibial and patellar surfaces ('rails'). (b) By flattening the anterior and posterior end of the 'rail', rotational movements become possible; the intercondylar spines act as the central pivot.

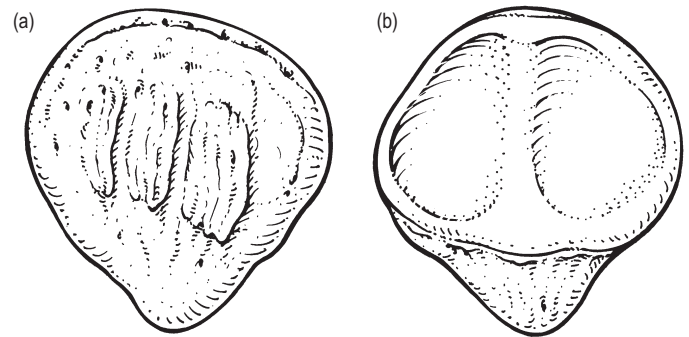
first 30° of flexion the movement is almost entirely rolling, whereas at nearly full flexion the condyles slip over the tibial plateau without rolling.<sup>2</sup>

The knee joint is thus primarily a hinge, with the wheel-shaped surfaces of the femoral condyles gliding and rolling in a twin set of concave curved gutters: the tibial and patellar surfaces. However, while this is a satisfactory concept in terms of flexion and extension, in reality the situation is more complex because the knee allows not only gliding and rotation around a horizontal axis but also rotation through a vertical axis, i.e. internal and external rotation of the tibia in relation to the femur. Were the knee to be only as so far described – a hinge joint with a long tibial intercondylar eminence gliding between the two femoral condyles – rotation would be precluded. However, if the anterior and posterior ends are flattened, rotation becomes possible (Fig. 1b). The remaining middle part of the eminence, forming the 'intercondylar spines', is then the central pivot about which the movements of axial rotation occur.

The knee joint is a hinge joint during flexion–extension but in a flexed position modifications enable axial rotation around a central pivot.

## The patella

The patella is a flat, triangular bone, situated on the front of the knee joint (Fig. 2). It is usually regarded as a sesamoid bone, developed in the quadriceps femoris tendon. Its convex anterior surface is covered by an expansion from the tendon of the quadriceps femoris which is continuous below with the superficial fibres of the ligamentum patellae. It is separated from the skin by a bursa (prepatellar bursa).



**Fig 2** • Surfaces of the patella: (a) anterior; (b) posterior.

The posterior surface presents above a smooth, oval, cartilaginous area, which is divided by a rounded vertical ridge into a larger, lateral portion, for articulation with the lateral condyle of the femur, and a smaller, medial portion, for articulation with the medial condyle of the femur. Below the articular surface is a rough, convex, non-articular area, the lower half of which gives attachment to the ligamentum patellae; the upper half is separated from the head of the tibia by adipose tissue.

The superior border of the patella is thick, and sloped from behind, downwards and forwards; it gives attachment to that portion of the quadriceps which is derived from the rectus femoris and the vastus intermedius muscles.

The medial and lateral borders are thinner and give attachment to those portions of the quadriceps femoris, which are derived from the vasti lateralis and medialis.

The apex is pointed and gives attachment to the ligamentum patellae.

The patella serves to protect the front of the joint and increases the leverage of the quadriceps femoris by making it act at a greater angle.

## The menisci

There are two menisci in the space between the femoral and tibial condyles. They are crescent-shaped lamellae, each with an anterior and a posterior horn, and are triangular in cross section. The superior and inferior surfaces are in contact with the femoral and tibial condyles, respectively, and the peripheral surfaces are adherent to the synovial membrane of the capsule. The anterior and posterior horns are anchored to the tibial condyle in the anterior and posterior intercondylar fossae, respectively. The horns of the medial meniscus are further apart than those of the lateral, which makes the former nearly semilunar and the latter almost circular. The menisci correct the lack of congruence between the articular surfaces of tibia and femur, increase the area of contact and improve weight distribution and shock absorption.<sup>3–6</sup> They also help to guide and coordinate knee motion, making them very important stabilizers of the knee.

Movement between the tibial surface and the menisci is limited by the coronary ligaments connecting the outer

meniscal borders with the tibial edge (Fig. 3, see Standing, Fig. 82.9). The coronary ligaments of the medial meniscus are shorter (4–55 mm) and stronger than those of the lateral meniscus (13–20 mm).<sup>7</sup> The medial collateral ligament of the knee is attached by its deep fibres to the outer border of the medial meniscus. In contrast, there is no connection between the lateral meniscus and the corresponding collateral ligament (Fig. 4). These anatomical differences between the medial and the lateral meniscus may explain the lesser mobility and the greater vulnerability of the former (see Fig. 3).<sup>8</sup>

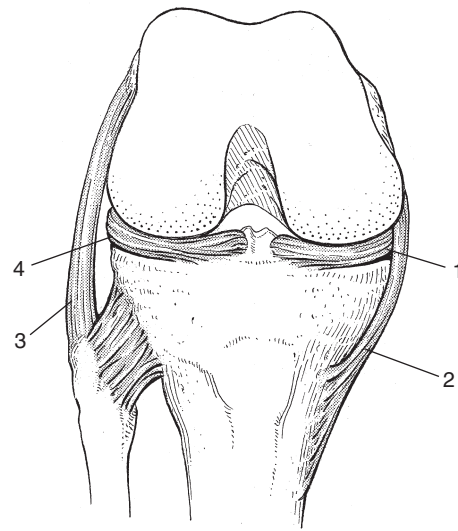
There are only a few muscle fibres attached to the menisci. The popliteus sends a fibrous expansion to the posterior border of the lateral meniscus and a few fibres of the semimembranosus tendon run to the posterior edge of the medial meniscus.

Menisci do not contain pain-sensitive structures and are consequently insensitive to trauma. Their outer third has some blood supply and therefore a slight ability to heal. The inner non-vascularized part receives nutrition through diffusion of synovial fluid.<sup>9,10</sup>

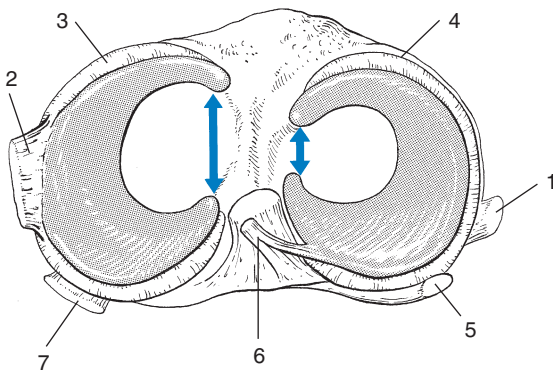
### Movements of the menisci

The inner sides of the menisci, attached by their horns to the tibial plateau, move with the tibia. The body of each meniscus is fixed around the femoral condyle and moves with the femur. Therefore, during movement between tibia and femur, distortion of the menisci is inevitable. Because the horns of the lateral meniscus are attached closer together and its body is more mobile, distortion is more marked in it.

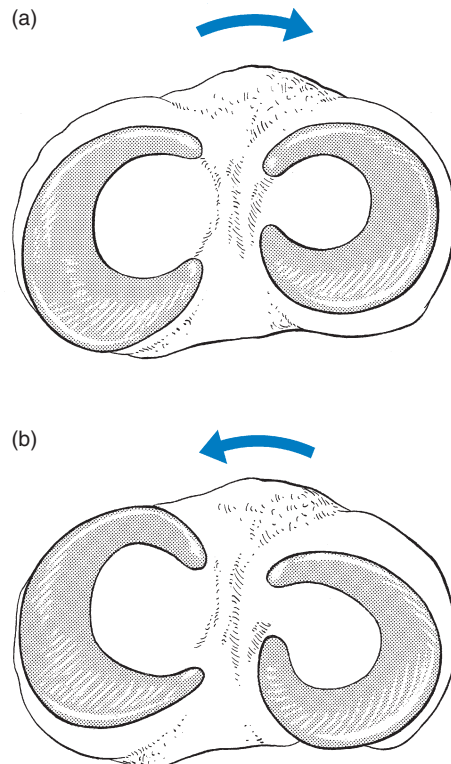
During flexion of the knee, the body of the meniscus moves posteriorly and during extension it moves anteriorly. In lateral (axial) rotation, the menisci will follow exactly the displacement of the femoral condyles, which means that the lateral meniscus will be pushed forwards on the tibia and the medial meniscus will be pulled backwards (Fig. 5a). On the medial aspect the anterior part of the medial coronary ligament then comes under tension. The same effect occurs in the medial rotation: the medial meniscus is pressed forwards and the



**Fig 4** • Anterior view of the menisci and their relations with the collateral ligaments: 1, medial meniscus; 2, medial collateral ligament; 3, lateral collateral ligament; 4, lateral meniscus.



**Fig 3** • Superior view of the menisci and their attachments (right knee). 1, lateral collateral ligament; 2, medial collateral ligament; 3, medial coronary ligament; 4, lateral coronary ligament; 5, popliteus tendon; 6, posterior cruciate ligament; 7, semimembranosus tendon.



**Fig 5** • Relative movement between tibia and menisci during rotation under 90° of flexion: (a) lateral rotation of the tibia; (b) medial rotation of the tibia.

lateral meniscus drawn backwards (Fig. 5b), which causes tension in the anterior part of the lateral coronary ligament.

## Joint capsule and ligaments

### Capsule

The capsule connects the distal end of the femur with the proximal border of the tibia. It consists of a fibrous sleeve and a synovial membrane, the attachments of which do not always coincide: only the synovial membrane is adherent to the peripheral surface of the menisci. Reinforcements in, or along the fibrous capsule keep the bones in contact, giving the joint passive stability.

The tibial attachment of the capsule (Fig. 6a) is attached to the borders of the articular surfaces of the tibia and therefore follows its anterior, medial and lateral edges. At the posterior border the synovial membrane follows the edges of the medial and lateral condyles, to form a loop around the insertion of the anterior cruciate ligament. At the anterior border the synovial membrane is projected backwards by a sizeable pad of adipose tissue – the infrapatellar pad.

The femoral attachment of the capsule also follows the articular surfaces of the femur, although there are some points to be noted:

- Anteriorly the capsule is attached proximal to the edge of the articular surface, thus forming the suprapatellar pouch (Fig. 6b).
- On the lateral condyle the attachment of the fibrous capsule lies above the insertion of the popliteus tendon, which makes the latter lie intra-articularly, covered only by the synovial membrane (Fig. 6c).
- Posteriorly and following the articular surfaces of the femoral condyles, the attachment of the synovial membrane dives into the intercondylar notch to form a loop around the femoral insertions of the cruciate

ligaments. The cruciate ligaments are thus kept outside the capsule by an invagination of the synovial membrane, which forms a partition in the sagittal plane of the joint space.

At the patella, the capsule follows the margins of the bone.

### Ligaments

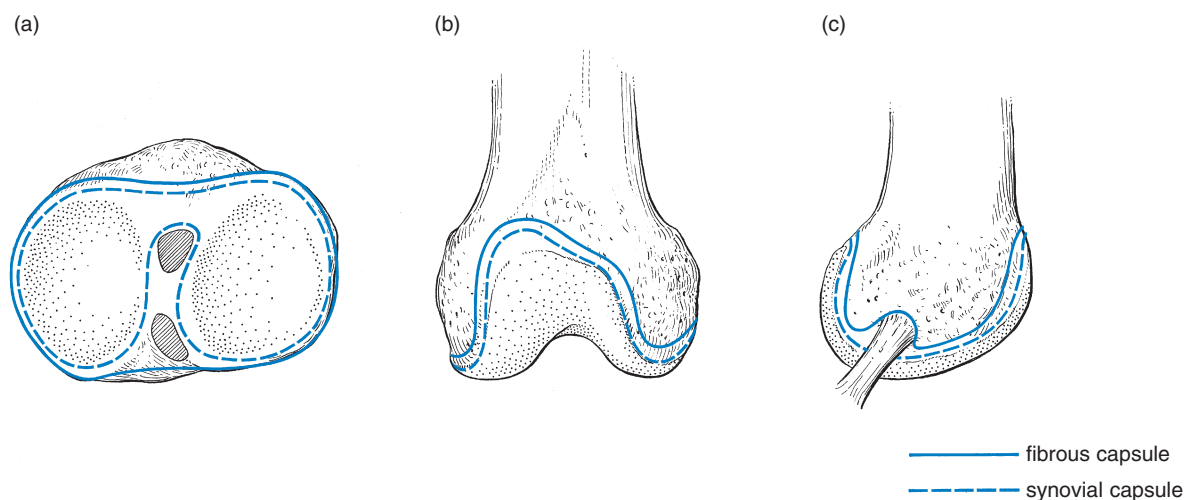
#### The medial ligamentous complex

The medial ligamentous complex has two layers: the deeply situated capsular reinforcements with an anterior, medial and posterior part, and the strong and more superficially localized medial collateral ligament (MCL). The MCL is the primary stabilizer of the medial side of the knee. It is a broad, flat and almost triangular band with a large femoral attachment on the posterosuperior aspect of the epicondyle. Its fibres run obliquely anteriorly and inferiorly to insert at the medial aspect of the tibia, just behind and slightly under the insertions of the semitendinosus muscle (see Gosling et al, Fig. 6.79). The anterior fibres of the ligament are separated from those of the deep capsular reinforcements and therefore the anterior border of the ligament can be palpated easily. The posterior fibres, however, blend intimately with the capsule and with the medial border of the medial meniscus (Fig. 7).<sup>11</sup>

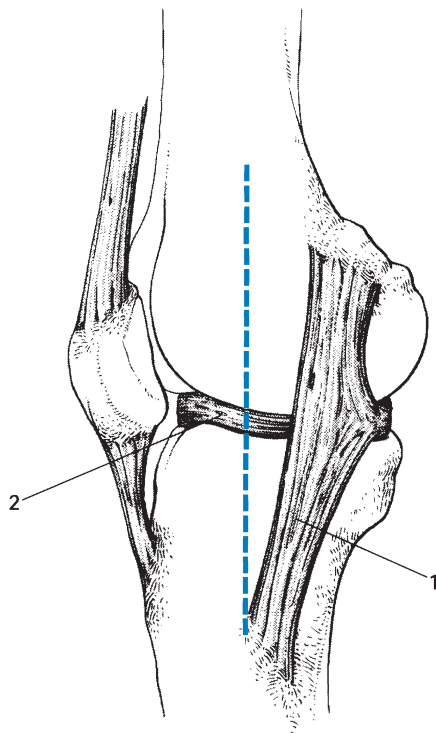
The strong MCL stabilizes the knee against excessive valgus forces and external rotation. Although it slackens during flexion, the posterior fibres attached to the meniscus remain taut, an observation that is important in the consideration of chronic ligamentous adhesions of the MCL (see p. 700).

#### The lateral collateral ligament

The lateral collateral ligament (LCL) is part of the so-called lateral quadruple complex (biceps tendon, iliotibial tract, popliteus and LCL), responsible for the lateral stability of the knee. It is round in cross-section and runs from the lateral epicondyle of the femur to the head of the fibula, deep to the



**Fig 6** • (a) Insertions of the capsule into the tibia, and its relations with the cruciate ligaments (shaded). (b) Anterior and medial insertions of the capsule into the femur. (c) Lateral insertion and relationship of the capsule and the popliteus tendon.



**Fig 7** • The medial collateral ligament (1) and medial meniscus (2).

insertion of the biceps. The ligament lies completely free, separated from the capsule and the lateral meniscus by the popliteus tendon (see Figs 3, 10, see Gosling et al, Fig. 6.78). It stabilizes the knee against excessive varus movement. A small bursa lies between the popliteus tendon and the LCL.

### The posterior capsular reinforcements

The posterior capsule is strengthened by two irregular ligamentous structures: the oblique popliteal and the arcuate popliteal ligaments. The former is an expansion of the semimembranosus tendon and reinforces the central posterior part of the joint capsule. The fibres of the latter run obliquely medially and upwards from the rear side of the fibular head to the posterior aspect of the femur.

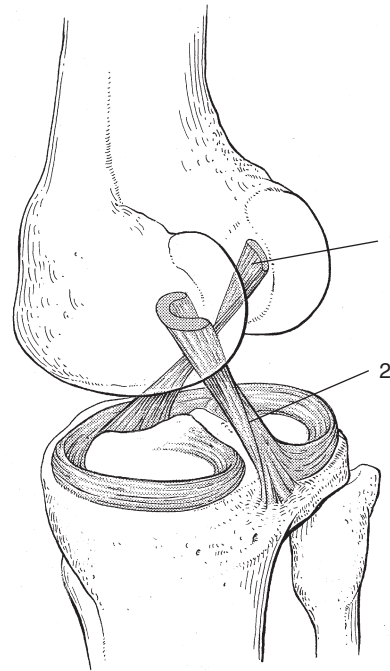
### The cruciate ligaments

Although the cruciate ligaments lie in the centre of the joint (Fig. 8), they remain extrasynovial because of the posterior invagination of the synovial membrane. They ensure the antero-posterior stability of the knee and, together with the collateral ligaments, prevent rotational movements during extension.

#### *The anterior cruciate ligament*

This is attached to the anterior intercondylar area of the tibia, between the anterior horns of the medial and lateral menisci. Its fibres run laterally and posteriorly to the internal aspect of the lateral condyle of the femur.

It has three coiled bundles (anteromedial, intermediate and anterolateral), which spiral from one insertion to the other. In extension, the anterior bundle is tight but in flexion the posterior fibres are stretched, which causes the anterior cruciate



**Fig 8** • Posteromedial view of the cruciate ligaments: 1, anterior; 2, posterior.

to be tightest at the extremes of range. During flexion, the femoral condyles tend to roll backwards over the tibia. This is checked by the anterior cruciate ligament, which induces a simultaneous anterior gliding of the femur. The anterior cruciate ligament also prevents excessive external rotation and varus movement of the tibia.

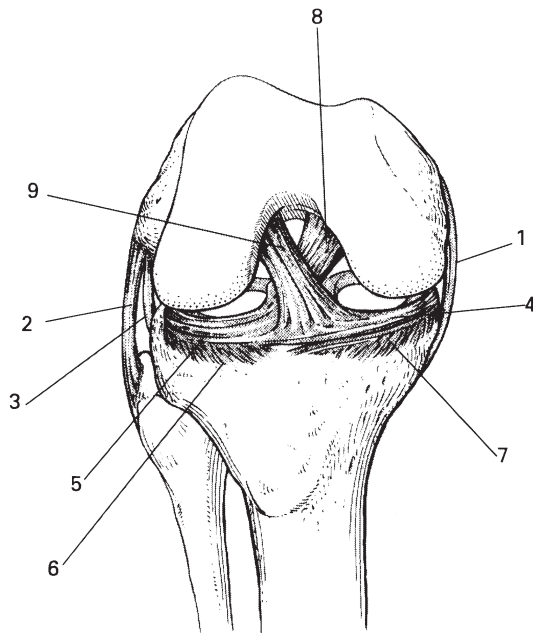
#### *The posterior cruciate ligament*

The tibial attachment of the posterior cruciate ligament is at the posterior intercondylar area, but fans out at the posterior border of the tibial plateau. The ligament runs in a medial and anterior direction and crosses the anterior cruciate ligament from medial and from behind to insert at the lateral surface of the medial condyle, deeply in the intercondylar fossa. Like the anterior cruciate, the posterior cruciate ligament has a complex architecture but is twice as strong. It is a basic knee stabilizer, tightest in mid-position. During extension, the posterior cruciate ligament pulls on the femur, causing backwards sliding during its anterior rolling. The posterior cruciate ligament also prevents anterior gliding of the femur during squatting, resists hyperextension and has an important role in the medial stability of the knee.<sup>12</sup>

### The coronary ligaments

The meniscotibial or coronary ligaments connect the periphery of the menisci with the edge of the tibial condyle (Fig. 9).<sup>13,14</sup> Some anatomists do not consider them to be true ligaments, but merely reinforcements in the synovial membrane.<sup>15</sup>

The fibres of the medial coronary ligament are 4–5 mm long, while those of the lateral coronary ligament are 2 cm long



**Fig 9** • Anterior view of the coronary ligaments, with the knee in flexion: 1, medial collateral ligament; 2, lateral collateral ligament; 3, popliteus tendon; 4, medial meniscus; 5, lateral meniscus; 6, lateral coronary ligament; 7, medial coronary ligament; 8, posterior cruciate ligament; 9, anterior cruciate ligament.

at the front and 1.3 cm at the back. The fibres of the lateral ligament are also looser than the medial ones.

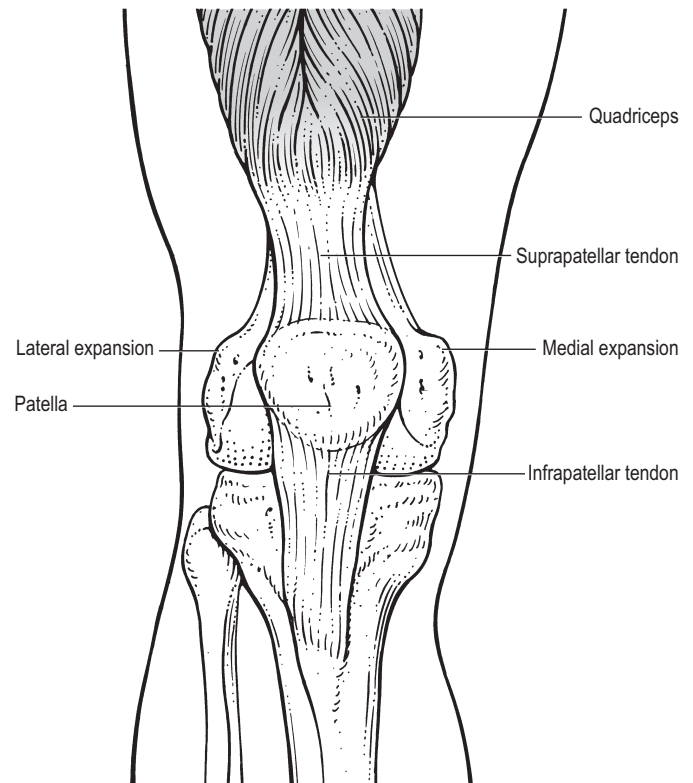
The medial coronary ligament is stretched during external rotation, while the lateral is stretched during internal rotation.

## Muscles and tendons

### The extensor mechanism (Fig. 10)

The extensor of the knee is the quadriceps; it consists of four muscle bellies. Three are monoarticular muscles – the vastus medialis, the vastus intermedius and the vastus lateralis. One is biarticular and spans knee and hip joints – the rectus femoris. These separate bellies have a common tendon, which inserts into the anterior tibial tuberosity. Imbedded in the tendon is the patella, a triangular sesamoid bone. The function of the patella is to increase the efficiency of the quadriceps contractions.

It is important to note that the patella lies fully within the tendon, which means there are tendon fibres all around the patellar edge. This has significant clinical consequences, since a tenoperiosteal tendinitis at the patella will occur not only at the distal but also at the proximal and sometimes even at the medial and lateral sides of the patella. For convenience, we call the part of the tendon above the patella the suprapatellar tendon (quadriceps tendon), the inferior part the infrapatellar tendon (or patellar ligament), and the medial and lateral fibres the medial and lateral quadriceps expansions; they are, nevertheless, only parts of a single tendon.



**Fig 10** • The extensor mechanism of the knee.

The biarticular nature of the rectus femoris and the fact that it runs anterior to the flexion–extension axis of the hip gives it the specific function of a hip flexor (see online chapter *Applied anatomy of the hip and buttock*).

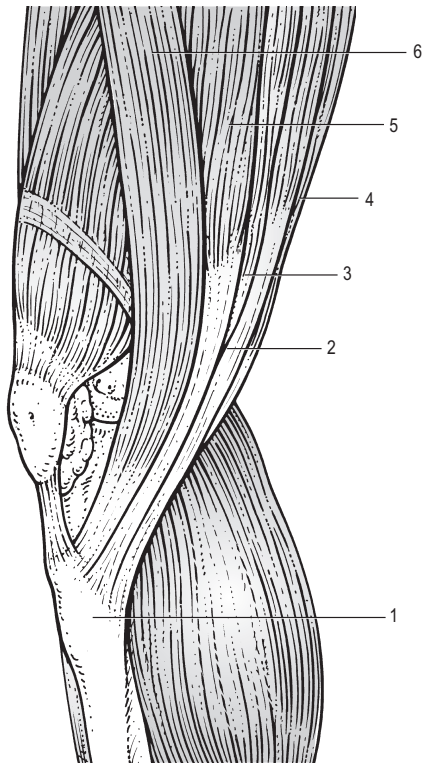
Some deeply situated fibres of the vastus intermedius run to the superior capsule of the knee joint, where they pull the loose capsule away from the joint and prevent the suprapatellar pouch from being pinched during knee motion.

Another, but weak, extensor of the knee is the tensor fasciae latae, which acts through the iliotibial tract, but only when the knee is extended. In flexion greater than 30°, the iliotibial tract becomes a weak knee flexor and an external rotator. The main function of the tract is to create static lateral stabilization of the knee.

### Flexors of the knee

The knee flexors are the hamstrings (semitendinosus, semimembranosus and biceps femoris), the sartorius and the gracilis, the popliteus and the gastrocnemii:

- *The gastrocnemii*, although strong plantiflexors and invertors of the heel, are only weak flexors of the knee (see *Standring, Fig. 82.3*). They also help in active stabilization of the joint. The medial head is a weak internal and the lateral head a weak external rotator.
- *The semitendinosus, gracilis and sartorius* insert under and in front of the medial condyle of the tibia in the so-called 'pes anserinus', just medial to the tibial tuberosity and

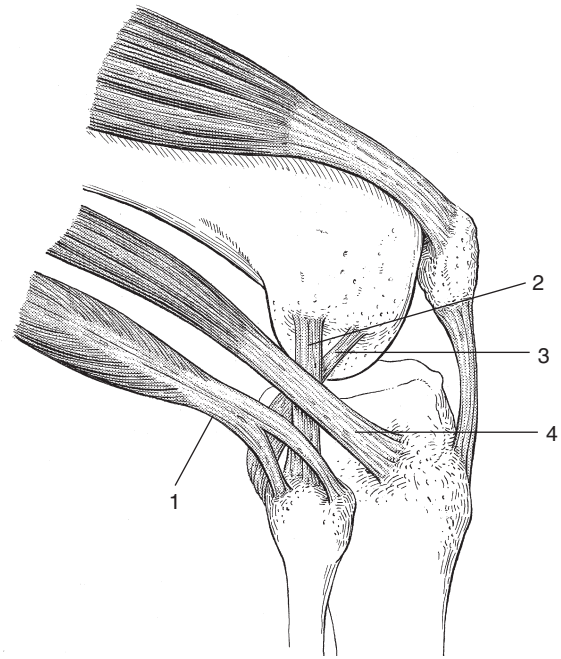


**Fig 11** • Medial view of the knee showing the relations between the tendons: 1, insertion of the pes anserinus; 2, semitendinosus; 3 and 4, semimembranosus; 5, gracilis; 6, sartorius.

anterior to the tibial insertion of the MCL. They are flexors and internal rotators of the knee (Fig. 11).

- *The semimembranosus* inserts at the medial condyle of the tibia but has some fascicles attaching to the oblique popliteal ligament and a few fibres attaching to the posterior edge of the medial meniscus. It is a flexor and an internal rotator.
- *The popliteus* muscle originates within the joint at the lateral epicondyle of the femur (Fig. 12, see [Standring, Fig. 83.11](#), see [Gosling et al, Fig. 6.77](#)). Other origins are situated at the dorsal aspect of the capsule and the lateral meniscus. The muscle belly lies deeply in the popliteal fossa under the lateral gastrocnemius and the plantaris. The broad insertion is at the upper and posterior aspect of the tibia. The popliteus is a flexor and an internal rotator of the knee. It also spans the posterior capsule of the knee and pulls the lateral meniscus in a posterior direction during flexion. Another important function of the muscle is to prevent the femur from slipping forwards on the tibia during squatting. This active function of the popliteus is very similar to the static role of the posterior cruciate ligament.
- *The biceps femoris or lateral hamstring* inserts at the top and posterior aspect of the fibular head in front of and behind the insertion of the lateral collateral ligament (see [Fig. 12](#)). Some fibres also attach to the posterolateral aspect of the tibia and the lateral part of the joint capsule. It is a strong flexor and external rotator of the knee.

Muscular function of the knee is summarized in [Box 1](#).



**Fig 12** • Lateral view of the knee, showing the relations between the lateral muscles and ligaments: 1, biceps femoris; 2, lateral collateral ligament; 3, popliteus; 4, iliotibial tract.

### Box 1

#### Summary of muscular function

##### Extension

Quadriceps femoris  
(Iliotibial tract)

External rotators  
Biceps femoris  
Iliotibial tract

##### Flexion

Internal rotators  
Gracilis  
Sartorius  
Semitendinosus  
Semimembranosus  
Popliteus

##### Stretching the capsule

Medial  
Semimembranosus  
Lateral  
Popliteus  
Anterior  
Vastus intermedius

#### Innervation of the muscles

This is detailed in [Table 1](#).

#### Nerve structures and blood vessels: the popliteal fossa

The lozenge-shaped popliteal fossa is an anatomical space of particular importance because it contains the vessels and nerves of the lower limb ([Fig. 13](#), see [Standring, Fig. 82.2](#)). Its lower borders are formed by the heads of the gastrocnemius. The upper lateral border is the biceps femoris and the upper medial border the semitendinosus and semimembranosus muscles. Its

**Table 1** Innervation of the muscles

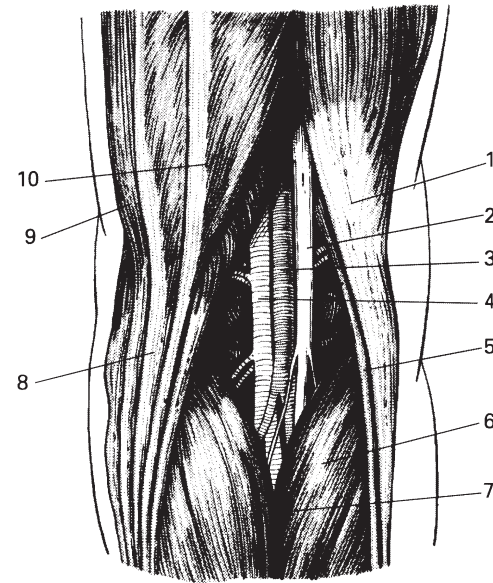
	Peripheral nerve	Spinal innervation
Extension		
Quadriceps	Femoral	L2, L3, L4
Flexion		
Semitendinosus	Tibial	L5, S1, S2
Semimembranosus	Tibial	L5, S1, S2
Gracilis	Obturator	L2, L3, L4
Sartorius	Femoral	L2, L3
Popliteus	Tibial	L4, L5, S1
Biceps femoris	Sciatic	L5, S1
Tensor fasciae latae	Superior gluteal	L4, L5
Gastrocnemius	Tibial	S1, S2

floor is the posterior capsule and the popliteus muscle. The popliteal fossa is bounded posteriorly by the deep popliteal fascia.

The lozenge is traversed vertically by (from lateral to medial) the tibial nerve, the popliteal vein and the popliteal artery. The common peroneal nerve descends along the inner border of the biceps. At the head of the fibula it splits into a deep peroneal branch, which curls around the fibular head to enter the anterior compartment of the leg, and a superficial peroneal branch, which supplies the peroneal muscles in the lateral compartment.

## The upper tibiofibular joint

This joint is separate from the knee. The capsule is reinforced in front and behind by two tibiofibular ligaments. Little



**Fig 13** • The popliteal fossa: 1, biceps femoris; 2, tibial nerve; 3, popliteal vein; 4, popliteal artery; 5, common peroneal nerve; 6, lateral gastrocnemius; 7, medial gastrocnemius; 8, semimembranosus; 9, gracilis; 10, semitendinosus.

movement takes place at the tibiofibular joint. The biceps femoris can pull the fibular head slightly backwards during active knee flexion, and slight passive upwards and downwards movements of the fibula may follow valgus and varus movements of the talus.

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