Movements of the knee

The knee is primarily a hinge joint.

**Flexion** decreases the angle formed by the posterior thigh and leg.

ROM for active flexion is limited by contact between the bodies of the contracting muscles.

ROM for passive flexion is greater (i.e., the heel can touch the buttock) since the flexor muscles are relaxed and more easily compressed. (The extensor muscles are passively stretched.)

In addition, ROM for flexion is greater when the hip joint is flexed and smaller when the hip is extended. Why?

Because position at the hip joint affects the degree of tension in the rectus femoris muscle (see p. 240).
Extension is an increase in the angle between the posterior thigh and leg, i.e., a return from flexion back to anatomical position.

Hyperextension, or "genu recurvatum" (an increase of this angle significantly beyond 180°), is uncommon.

ROM of knee extension is greater when the hip is extended...

...and limited when the hip is flexed. This reflects a degree of tension in the hamstring muscles (see p. 244).
To describe rotation, we will assume that the femur is fixed.

In lateral rotation, the tuberosity moves laterally.

In medial rotation, the tibial tuberosity moves medially.

It is also important not to confuse knee rotation with abduction/adduction of the foot. This is the reason for focusing on movement of the tibial tuberosity (see above) rather than the foot.

Rotation can occur to an appreciable extent only when the knee is flexed, and the ligaments are relaxed (see p. 222).

If the knee is extended and you see the tuberosity moving medially or laterally, this is rotation not at the knee but at the hip.

Note that these rotations occur automatically during knee flexion and extension, although ROM is small then and involves both bones (not just the mobile tibia below the femur, as shown above). These rotations are primarily due to the shape of the articular surfaces (see p. 223).
The knee joint consists of three bones

The femur articulates with the patella, which is called the femoropatellar joint.

The femur articulates with the tibia, which is called the femorotibial joint.

The patella does not articulate with the tibia. We will study it in detail on page 225. Here, we will just take a look at the femorotibial joint.

The shaft of the tibia is triangular in cross section.

The base of the femur:

The shaft of the femur is triangular in cross section (see p. 200).

At the bottom: the posterior edge of the femur's distal end bifurcates such that its shape in cross section changes to a square, which expands; thus, the base of the femur looks like the trunk of a pyramid.

The top of the tibia:

At the top: the anterior edge of the tibia's proximal end also bifurcates and changes to an expanding square shape. Its top looks like an upside-down pyramid.

Thus, the two bones are both expanded where they come together and form a massive structure, like the ends of two columns. This increases their stability and weight-bearing ability.

The fibers of the alveolar (spongy) tissue inside are oriented diagonally and vertically, as well as horizontally, which increases their strength.
Surfaces of knee joint

Above and posterior to the two condyles is a bony tuberosity.

The condyles are less curved anteriorly (good for weight-bearing function)...

Overall, the medial condyle is more curved than the lateral condyle, which helps explain the automatic rotations of the knee during flexion/extension (see p. 223).

Surfaces of femur

[INFEROANTERIOLATERAL VIEW]

The base of the pyramid is a rounded articular surface, shaped roughly like a pulley.

The anterior portion is called the intercondylar fossa of the femur, which articulates with the patella. Posteroinferiorly, the single-track pulley becomes double-track, and the shape of the surfaces is like the legs of a rocking chair.

These are the medial and lateral condyles of the femur, which articulate with the condyles of the tibia.

...and more curved posteriorly (good for flexion movement).

Prolonged standing with the knee in slightly flexed position puts stress on the small articular surface of the condyles, and can damage the cartilage.
Surfaces of tibia

The superior surface (base of the pyramid) of the tibia is called the **tibial plateau**.

The lateral and medial **condyles of the tibia**, protected by cartilage, are concave for articulation with the convex condyles of the femur.

The lateral surface of the tibial plateau has a tubercle, called **Gerdy’s tubercle**, where the fascia lata inserts.

Its anterior surface has a prominence, the **anterior tibial tuberosity**, where the quadriceps muscle inserts. You can feel this area when you kneel.

At the center of the tibial plateau, the edges of the condyles are raised and form the **intercondylar eminence**.

Anterior and posterior to the intercondylar eminence are two hollow surfaces, which do not articulate with the femur:

The sartorius, semitendinosus, and rectus femoris muscles attach to the upper medial shaft of the tibia. This is also where the tibial collateral ligament attaches.

The tibial condyles are concave transversely, but from front to back the lateral condyle is slightly convex while the medial one is concave.

The femorotibial articulation looks like a double-wheel structure fitting into a set of two tracks.
Displacement of condyles during movement of knee

There are two mechanisms associated with the movements of flexion and extension of the knee: rolling and gliding.

During flexion, if the femoral condyles were to simply roll backward, the femur would slip off the tibia.

The movement of the knee in the sagittal plane can therefore be described in the following way:

If they were to glide in one spot like a ball bearing, a single spot on the tibia would receive all the friction, and the cartilage there would be damaged.

In flexion, the femoral condyle first rolls (15-20°) on the tibial condyle, then glides... producing a combined "rolling-gliding" movement.

The opposite occurs in extension of the knee: first gliding, then rolling. During this movement, the lateral condyle rolls more than the medial condyle, which leads to automatic rotation of the knee (see also p. 223).
For the lower limb, in anatomical position, we can consider three different axes.

The first ("mechanical axis") passes through the middle of the femoral head above and the middle of the ankle joint below. In anatomical position, this axis is at an angle of about 3° from a vertical (sagittal) plane (shown as "V" in the diagram).

If you stand on one foot, this axis moves farther from the sagittal plane.

The second and third axes are those passing through the shafts of the femur and tibia, which form an angle that is usually between 170° and 175°.

The lateral angle formed by these two axes varies from person to person:

It can be less than 180° (genu valgum or "knock knees"), or greater than 180° (genu varum or "bow-legs").
Menisci

The menisci (singular: meniscus) are two croissant-shaped intra-articular discs made of fibrocartilage.

Their shallow central tips are attached to the intercondylar eminence of the tibia, and their thicker margins are attached to the peripheral edges of the medial and lateral tibial condyles.

They also have attachments to nearby structures such as the meniscopatellar ligaments, medial collateral ligament, and tendons of the popliteus and semimembranosus muscles.

The menisci are slightly mobile, and aid in spreading the synovial fluid during movements of the knee.
The menisci have several functions:

- As they move around, they increase the distribution of synovial fluid.
- They increase the weight-bearing surface, which results in a better distribution of pressure as they move around.
- Like wedges, they increase the concave shape of the tibial condyles and therefore provide better stability.

**How the menisci move during knee movements**

*In extension*, the menisci move forward because they are (1) pushed in that direction by the femoral condyles, and (2) pulled by the meniscopatellar ligaments, which are in turn pulled upward by movement of the patella.

*In flexion*, the menisci move backward because they are (1) pushed in that direction by the condyles...

...and (2) pulled by the tendons of the semimembranosus and popliteus muscles, and the medial collateral ligament.

*In rotation*, the ipsilateral meniscus moves forward because of pressure from the condyle and is held back by the meniscopatellar ligament.

These movements are all necessary for normal function of the knee joint. In some cases (particularly rapid extension movements, as in soccer),...

...the menisci may not move fast enough, and become crushed or torn.
Knee capsule

The knee joint is held by a thick capsule, which attaches just outside the articular surfaces of the three bones involved. The patella is contained in the anterior capsule. Thus the patella, femur, tibia, and capsule enclose a single synovial cavity within which synovial fluid circulates.

The capsule is very slack anteriorly...

...which allows good ROM for flexion.

In extension, therefore, the capsule forms deep folds at the front and sides. In cases of prolonged immobilization of the joint, these folds can develop adhesions which subsequently limit flexion.

In terms of bone morphology, the knee is not a very well-fitted joint. Therefore, its ligaments are essential to its stability.

The patella (see p. 224) is attached to the femoral condyles and the menisci by small ligaments (actually thickenings of the capsule).

The strong patellar ligament, which contains the patella and inserts on the tibial tuberosity, can be viewed as a continuation of the tendon of the quadriceps muscle, whose fibers cross over each other at the knee joint.

Posteriorly, the knee capsule is thicker and forms two strong bands connecting the femoral and tibial condyles. These resist hyperextension of the joint, and provide "passive stability" in the standing position (see p. 222).
The joint is also held in place by two **cruciate** ("crossed") **ligaments** located in the intercondylar fossa of the femur. They are named according to where they attach to the tibia. Anatomically, they are outside the joint capsule.

The **anterior cruciate ligament** is attached to the anterior intercondylar area of the tibia. It runs posterosuperolaterally and attaches to the medial aspect of the lateral femoral condyle.

The **posterior cruciate ligament** attaches to the posterior intercondylar area of the tibia. It runs anterosuperomedially and attaches to the lateral surface of the medial femoral condyle.

Their principal role is to prevent anteroposterior displacements of the two bones.

The anterior cruciate ligament tends to resist anterior displacement of the tibia on the femur... ...while the posterior cruciate ligament resists posterior displacement.

**Why have obliquely-oriented ligaments perform this braking action?**

In both flexion and extension, the cruciate ligaments remain fairly taut, and displacement of the tibia on the femur is minimal.

In lateral rotation, the cruciates slacken somewhat.

**Because simple anterior and posterior ligaments would not allow flexion.**

In medial rotation, they press against each other, and therefore become more taut.
On the sides, the joint capsule is reinforced by two collateral ligaments.

The **medial (tibial) collateral ligament** runs from the medial condyle of the femur to the medial condyle and upper medial shaft of the tibia. Its lower attachment is slightly anterior relative to its upper attachment.

The **lateral (fibular) collateral ligament** runs from the lateral condyle of the femur to the head of the fibula. Its lower attachment is slightly posterior relative to its upper attachment.

The principal function of the medial collateral is to stabilize the joint and prevent it from opening on the medial side. If this ligament is ruptured, the tibia will be able to move laterally.

The principal function of this ligament is to prevent the joint from opening on the lateral side. If it ruptures, the tibia will be able to move medially.
The medial collateral is considerably thicker and stronger than its lateral counterpart. Why?

In the average person, the lateral angle formed by the femur and tibia is slightly less than 180° (genu valgum, see p. 215). Since the joint "gapes" more on the medial side, there is a need for stronger stabilization on that side.

The collaterals tend to be taut in extension...

...and slack in flexion. Therefore, they resist hyperextension.

On leg bones, which have been "pulled apart" for illustrative purposes...

we see that the collaterals become slack in medial rotation of the tibia due to their orientation...

...and taut in lateral rotation. Thus, they resist excessive lateral rotation of the tibia.
How ligaments stabilize the knee

The knee ligaments act together to stabilize the joint. In extension, all the ligaments are taut, and the joint can be passively stabilized without any muscular action, e.g., when balancing on one foot.

Here, the joint is “locked” in slight hyperextension by the tautness of the ligaments (particularly the thickened posterior portion of the joint capsule).

In flexion, most of the ligaments are slack, and the joint therefore has some capacity for rotation.

As noted above, the collaterals and cruciates tend to limit lateral...

...and medial rotation, respectively.

But they are more restrictive in the extended than in the flexed position.

While balancing on one foot with the knee flexed, several muscles are used to stabilize the body:

- quadriceps to prevent the knee from flexing more
- rotator muscles to prevent or slow down excessive rotation
  - medially: vastus medialis, sartorius, gracilis, semitendinosus
  - laterally: vastus medialis, biceps femoris, tensor fascia latae (see also muscle actions on p. 254)
Some “automatic” rotation of the knee occurs during flexion/extension. Why is this?

The primary explanation involves the shape of the femoral and tibial condyles. The medial femoral condyle is more curved than the lateral one, i.e., its radius of curvature is smaller.

To understand the implications of this, visualize the two condyles as fitting inside a truncated cone, and the femoral shaft as a rectangular slab with a projection which we shall use as a reference landmark.

During extension, the shaft of the femur is directed forward.

During flexion, due to the shape of the cone, the landmark becomes directed somewhat laterally.

The tibial condyles are also not totally symmetric; both are concave transversely, but from front to back the lateral condyle is slightly convex while the medial one is concave. Therefore, the lateral tibial condyle allows more rolling than does the medial one.

During flexion, the lateral femoral condyle rolls backward more than the medial one does, which accentuates the lateral orientation of our landmark, i.e., the lateral rotation of the femur.

The secondary explanation for automatic rotation of the knee is that the medial collateral ligament is stronger than the lateral one (see p. 221). This reinforces the tendency of the medial femoral condyle to be less mobile than the lateral one.
Patella

This is a sesamoid bone, located anterior to the distal end of the femur, which develops within the tendon of the quadriceps muscle (right).

Its anterior surface sits directly beneath the skin and is easily palpable.

The two articular facets on its posterior surface fit against the patellar surface of the femur, and are separated by a vertical ridge.

The patella is both attached to the knee and is mobile on top of it.

It is connected:
- with the femoral condyles via the lateral and medial patellar ligaments
- with the menisci via the meniscopatellar ligaments.

It is connected with the tendon of the quadriceps femoris via the patellar ligament.
What exactly does the patella do? Its primary function is to protect the quadriceps tendon, in which it is contained. During movement, this tendon slides in the groove between the femoral condyles, like a rope in a pulley.

This causes intense strain on the patella:

- strain from being pressed against the groove during flexion due to the pulling action of the quadriceps muscles...
  
  ...this pressure can be 400 kg or more during squatting, and even more when carrying a heavy object

- strain from stretching (pulling forces from different directions)

- strain from constant usage.

The patella is not stable laterally.

The quadriceps follows the femoral shaft and its force is slightly oblique, but its tendon runs straight down to insert on the tibia. Thus, contraction of the quadriceps tends to pull the patella laterally...

...just as a pulley would move sideways if its rope came down at an angle.
The lateral instability of the patella is maximal during active extension or slight flexion when the patella is not firmly pressed against the patellar surface of the femur; during full flexion the patella is better "locked" in place.

This instability is accentuated during lateral rotation of the tibia when the lower as well as upper part of the tendon become obliquely oriented.

The tendency of the patella to move laterally is counteracted by two mechanisms:

- the projection of the lateral femoral condyle, which is more pronounced than that of the medial condyle

- the contraction of the vastus medialis muscle, which pulls the tendon medially.

As you can see, the articulation of the patella against the femur is subjected to major strains and stresses, particularly on the lateral side. This explains the frequency of arthritis here, which can compromise proper gliding of the patella and active extension of the knee.