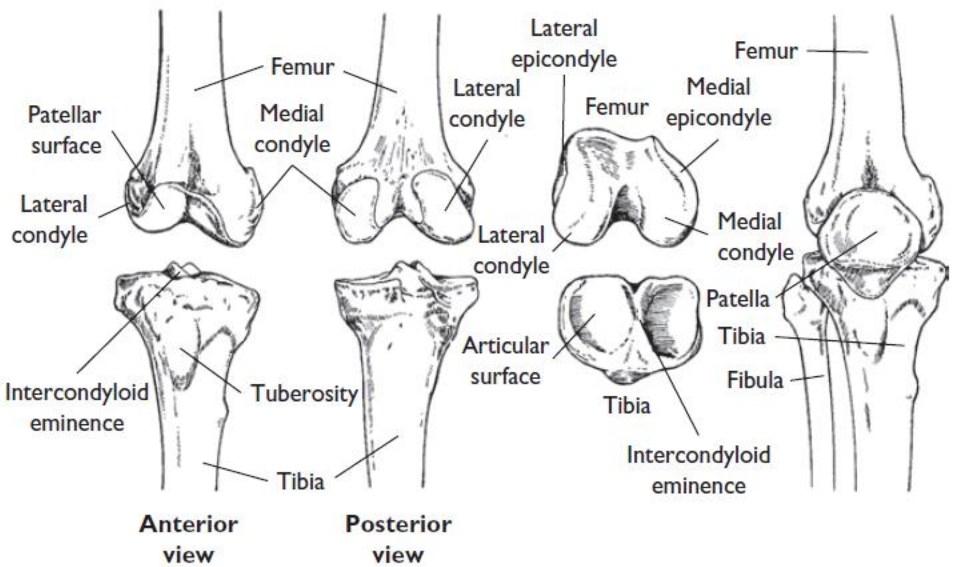
Biomechanics of the Knee Joint

1. Structure of the Knee

The **knee joint** is a **modified hinge joint** composed of two major articulations:

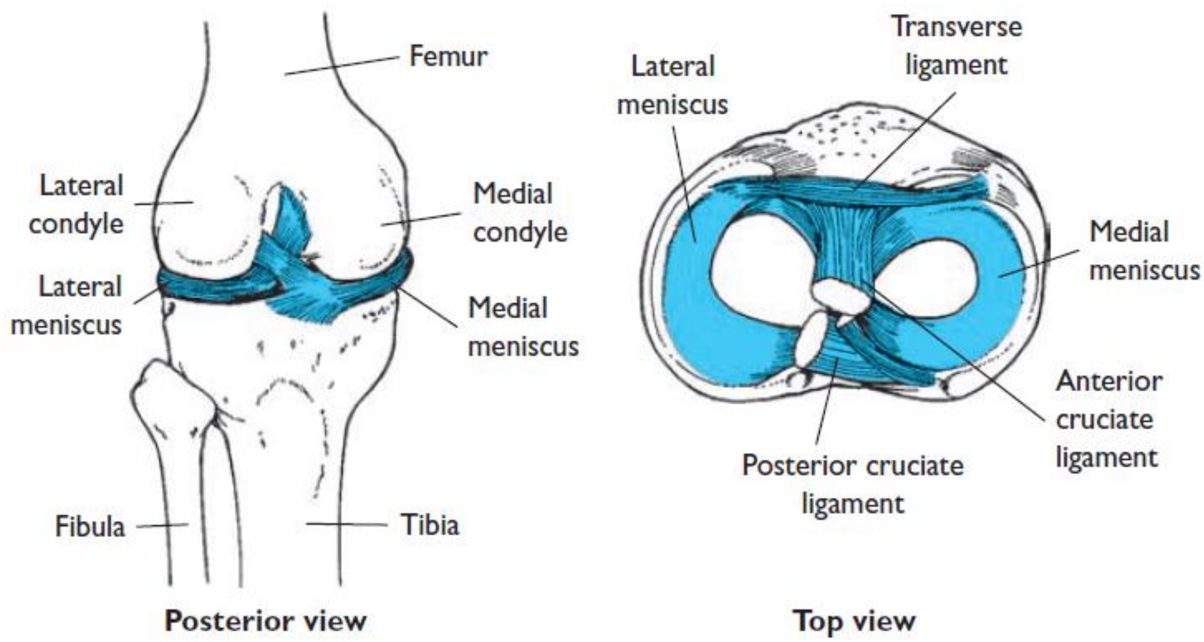
1. **Tibiofemoral Joint** – between the **femoral condyles** and **tibial plateaus**
2. **Patellofemoral Joint** – between the **patella** and the **trochlear groove** of the femur (Fig.5: Anatomical components of the knee.)



The knee is supported by:

- **Menisci**, which are fibrocartilaginous structures that increase joint congruency and absorb shock (Fig.6: Meniscal structure).
- The knee is stabilized by the major ligaments, including the **anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL)**, which collectively provide stability in all directions.
- Surrounding muscles such as the **quadriceps** and **hamstrings**, which contribute to dynamic stability.

Email (firas.thair.almaliky@uomus.edu.iq)



2. Joint Types of the Knee

2.1 Tibiofemoral Joint

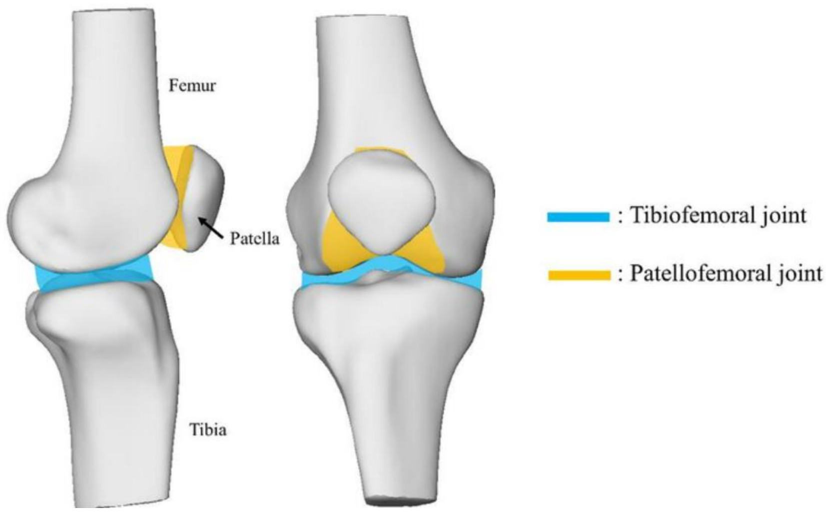
The tibiofemoral joint is a **modified hinge joint** (or **bicondylar synovial joint**). It primarily allows **flexion and extension**, with additional **internal and external rotation** when the knee is flexed.

Its motion includes both **rolling** and **gliding**, controlled by the shapes of the femoral condyles and tibial plateaus.

2.2 Patellofemoral Joint

The patellofemoral joint is a **gliding (plane) synovial joint**.

The **patella** glides superiorly and inferiorly along the femoral groove during knee extension and flexion. The patella functions to **increase the quadriceps moment arm**, improving the efficiency of knee extension. (Fig.7: Types of knee joint).



3. Movements of the Knee

The knee allows:

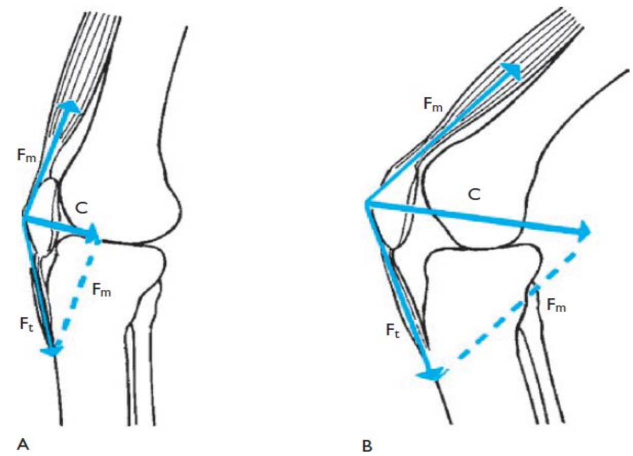
- **Flexion and Extension** as primary movements
- **Internal and External Rotation** when the knee is flexed
- **Small translations** and **glides** due to femoral-tibial surface geometry

The **screw-home mechanism** occurs at the end of extension, where the tibia externally rotates to lock the knee in a stable position.

4. Loads on the Knee

The knee experiences high mechanical loads during weight-bearing activities. During walking, forces reach nearly **three times body weight**. During stair ascent or descent, forces may increase to **four times body weight** (Fig.8: Knee joint forces).

The **patellofemoral joint** is subjected to high compressive forces during knee flexion, especially between **60° and 120°** when quadriceps tension is maximal. The **menisci** help distribute compressive forces and reduce stress on the tibial cartilage.



A. In extension, the compressive force is small because tension in the muscle group and tendon act nearly perpendicular to the joint. **B.** As flexion increases, compression increases because of changed orientation of the force vectors and increased tension requirement in the quadriceps to maintain body position.

SAMPLE PROBLEM.2

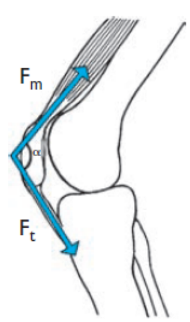
How much compression acts on the patellofemoral joint when the quadriceps exerts 300 N of tension and the angle between the quadriceps and the patellar tendon is (a) 160° and (b) 90°?

Known

$$F_m = 300 \text{ N}$$

Angle between F_m and F_t:

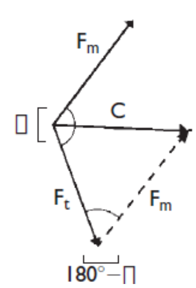
1. 160°
2. 90°



Graphic Solution

Vectors for F_m and F_t are drawn to scale (perhaps 1 cm: 100 N), with the angle between them first at 160° and then at 90°. The tip-to-tail method of vector composition is then used (see Chapter 3) to translate one of the vectors so that its tail is positioned on the tip of the other vector. The compression force is the resultant of F_m and F_t and is constructed with its tail on the tail of the original vector and its tip on the tip of the transposed vector.

The amount of joint compression can be approximated by measuring the length of vector C.



1. $C \approx 100$ N
2. $C \approx 420$ N

Mathematical Solution

The angle between F_t and transposed vector F_m is 180° minus the size of the angle between the two original vectors, or (a) 20° and (b) 90°. The law of cosines can be used to calculate the length of C.

1. $C^2 = {F_m}^2 + {F_t}^2 - 2(F_m)(F_t) \cos 20$

   $C^2 = 300\ N^2 + 300\ N^2 - 2(300\ N)(300\ N) \cos 20$

   $C = 104$ N

2. $C^2 = {F_m}^2 + {F_t}^2 - 2(F_m)(F_t) \cos 90$

   $C^2 = 300\ N^2 + 300\ N^2 - 2(300\ N)(300\ N) \cos 90$

   $C = 424$ N

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