Biomechanics:

Biomechanics is the science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement. Biomechanics is part of the larger field of kinesiology, specifically focusing on the mechanics of the movement.

Biomechanics includes not only the structure of bones and muscles and the movement they can produce, but also the mechanics of blood circulation, renal function, and other body functions. The American Society of Biomechanics says that biomechanics represents the broad interplay between mechanics and biological systems.

These are the key areas that biomechanics focuses on:

- **Dynamics**: Studying systems that are in motion with acceleration and deceleration
  - **Kinematics**: Describing the effect of forces on a system, motion patterns including linear and angular changes in velocity over time as well as position, displacement, velocity, and acceleration are studied.
  - **Kinetics**: Studying what causes motion, the forces, and moments at work
- **Statics**: Studying systems that are in equilibrium, either at rest or moving at a constant velocity.

Movement of body:

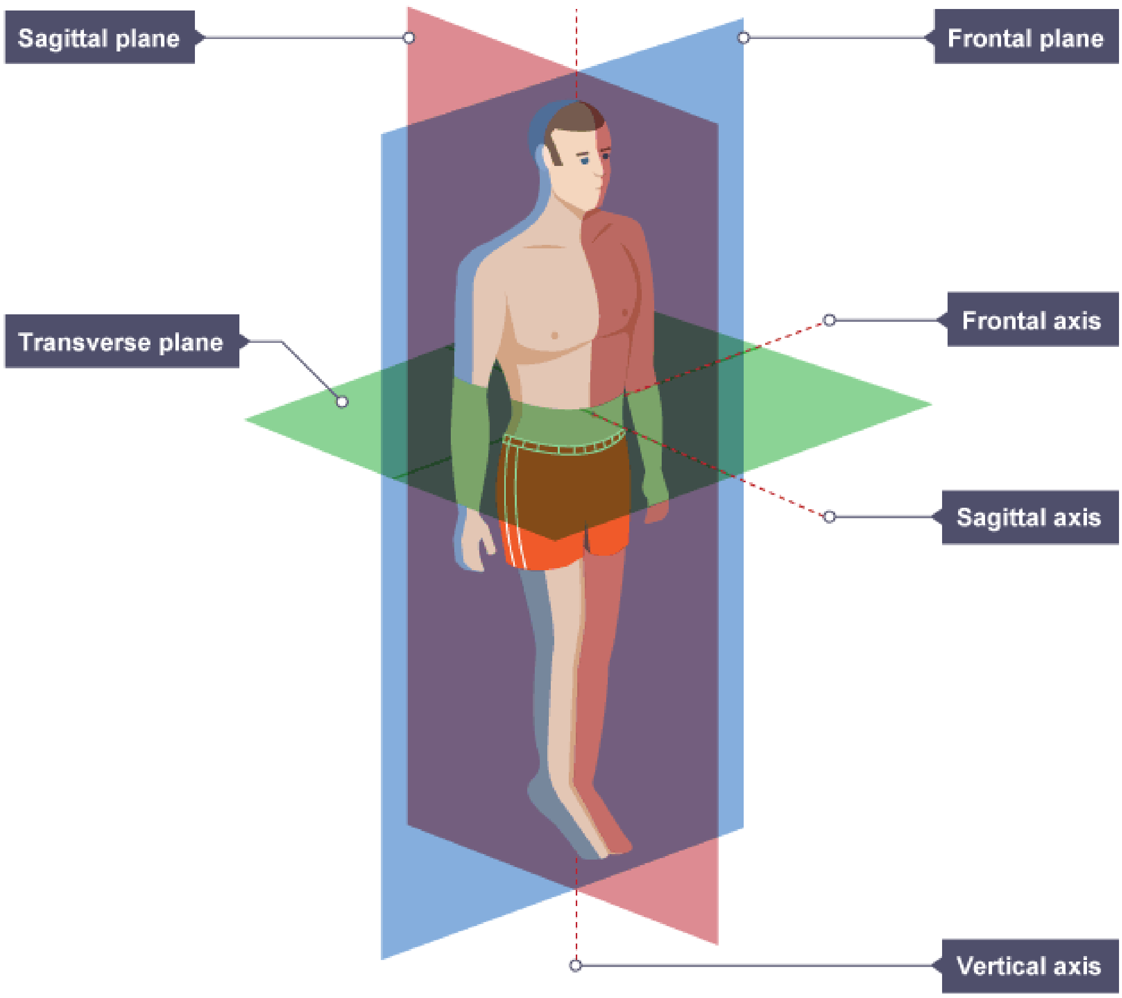
Planes of movement

- All body movements occur in different planes and around different axes.
- A plane is an imaginary flat surface running through the body.
- An axis is an imaginary line at right angles to the plane, about which the body rotates or spins.

There are three planes of movement:

1. **Sagittal plane** - a vertical plane that divides the body into left and right sides. Flexion and extension types of movement occur in this plane, eg kicking a football, chest pass in netball, walking, jumping, squatting.
2. **Frontal plane** - passes from side to side and divides the body into the front and back. Abduction and adduction movements occur in this plane, eg jumping jack exercises, raising and lowering arms and legs sideways, cartwheel.
3. **Transverse plane** - passes through the middle of the body and divides the body horizontally in an upper and lower half. Rotation types of movement occur in this plane, eg hip rotation in a golf swing, twisting in a discus throw, pivoting in netball, spinning in skating.

Movements are parallel to the plane in which they take place.

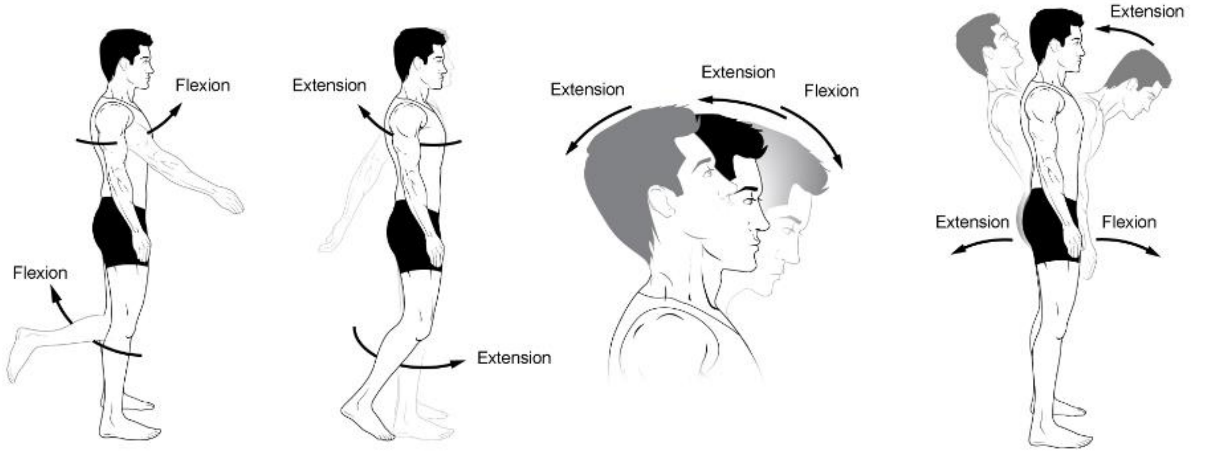


Types of joint movement

Hinge joints allow flexion and extension only.

Flexion and Extension

Flexion and **extension** are movements that take place within the sagittal plane and involve anterior or posterior movements of the body or limbs. For the vertebral column, flexion (anterior flexion) is an anterior (forward) bending of the neck or body, while extension involves a posterior-directed motion, such as straightening from a flexed position or bending backward. **Lateral flexion** is the bending of the neck or body toward the right or left side. These movements of the vertebral column involve both the symphysis joint formed by each intervertebral disc, as well as the plane type of synovial joint formed between the inferior articular processes of one vertebra and the superior articular processes of the next lower vertebra.



(a) and (b) Angular movements: flexion and extension at the shoulder and knees

(c) Angular movements: flexion and extension of the neck

(d) Angular movements: flexion and extension of the vertebral column

Abduction, Adduction, and Circumduction

Abduction and adduction are motions of the limbs, hand, fingers, or toes in the coronal (medial–lateral) plane of movement. Moving the limb or hand laterally away from the body, or spreading the fingers or toes, is abduction. Adduction brings the limb or hand toward or across the midline of the body, or brings the fingers or toes together. Circumduction is the movement of the limb, hand, or fingers in a circular pattern, using the sequential combination of flexion, adduction, extension, and abduction motions.

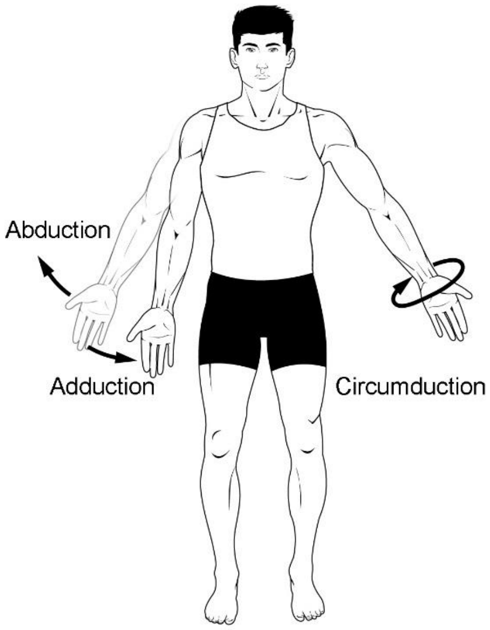
Adduction, abduction, and circumduction take place at the shoulder, hip, wrist, metacarpophalangeal, and metatarsophalangeal joints.

Abduction and Adduction

Abduction and **adduction** motions occur within the coronal plane and involve medial-lateral motions of the limbs, fingers, toes, or thumb. Abduction moves the limb laterally away from the midline of the body, while adduction is the opposing movement that brings the limb toward the body or across the midline. For example, abduction is raising the arm at the shoulder joint, moving it laterally away from the body, while adduction brings the arm down to the side of the body. Similarly, abduction and adduction at the wrist moves the hand away from or toward the midline of the body. Spreading the fingers or toes apart is also abduction, while bringing the fingers or toes together is adduction. For the thumb, abduction is the anterior movement that brings the thumb to a 90° perpendicular position, pointing straight out from the palm. Adduction moves the thumb back to the anatomical position, next to the index finger. Abduction and adduction movements are seen at condyloid, saddle, and ball-and-socket joints (see Figure 2).

Circumduction

Circumduction is the movement of a body region in a circular manner, in which one end of the body region being moved stays relatively stationary while the other end describes a circle. It involves the sequential combination of flexion, adduction, extension, and abduction at a joint. This type of motion is found at biaxial condyloid and saddle joints, and at multiaxial ball-and-sockets joints



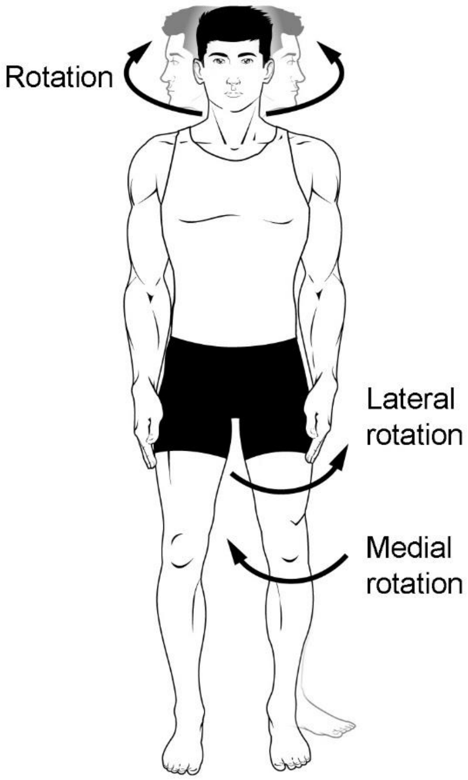
Angular movements: abduction, adduction, and circumduction of the upper limb at the shoulder

Rotation

Rotation can occur within the vertebral column, at a pivot joint, or at a ball-and-socket joint. Rotation of the neck or body is the twisting movement produced by the summation of the small rotational movements available between adjacent vertebrae. At a pivot joint, one bone rotates in relation to another bone. This is a uniaxial joint, and thus rotation is the only motion allowed at a pivot joint. For example, at the atlantoaxial joint, the first cervical (C1) vertebra (atlas) rotates around the dens, the upward projection from the second cervical (C2) vertebra (axis). This allows the head to rotate from side to side as when shaking the head "no." The proximal radioulnar joint is a pivot joint formed by the head of the radius and its articulation with the ulna. This joint allows for the radius to rotate along its length during pronation and supination movements of the forearm.

Rotation can also occur at the ball-and-socket joints of the shoulder and hip. Here, the humerus and femur rotate around their long axis, which moves the anterior surface of the arm or thigh either toward or away from the midline of the body. Movement that brings the anterior surface of the limb toward the midline of the body is called **medial (internal) rotation**. Conversely, rotation of the limb so that the anterior surface moves away from the midline is **lateral (external) rotation** (see Figure 3). Be sure to distinguish medial and lateral rotation, which can only occur at the multiaxial shoulder and hip joints, from circumduction, which can occur at either biaxial or multiaxial joints.

Turning of the head side to side or twisting of the body is rotation. Medial and lateral rotation of the upper limb at the shoulder or lower limb at the hip involves turning the anterior surface of the limb toward the midline of the body (medial or internal rotation) or away from the midline (lateral or external rotation).



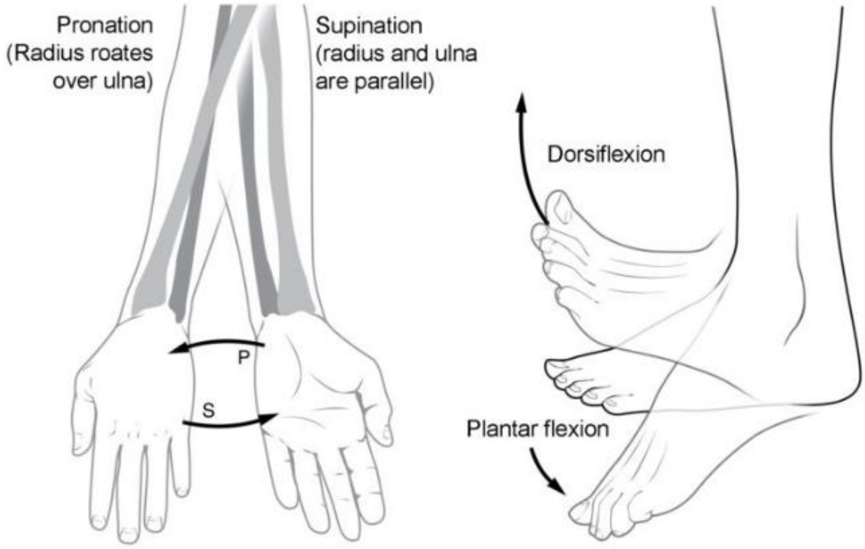
Rotation of the head, neck, and lower limb

Supination and Pronation

Supination and pronation are movements of the forearm. In the anatomical position, the upper limb is held next to the body with the palm facing forward. This is the **supinated position** of the forearm. In this position, the radius and ulna are parallel to each other. When the palm of the hand faces backward, the forearm is in the **pronated position**, and the radius and ulna form an X-shape.

Dorsiflexion and Plantar Flexion

Dorsiflexion and **plantar flexion** are movements at the ankle joint, which is a hinge joint. Lifting the front of the foot, so that the top of the foot moves toward the anterior leg is dorsiflexion, while lifting the heel of the foot from the ground or pointing the toes downward is plantar flexion. These are the only movements available at the ankle joint



(a) Pronation (P) and supination (S)

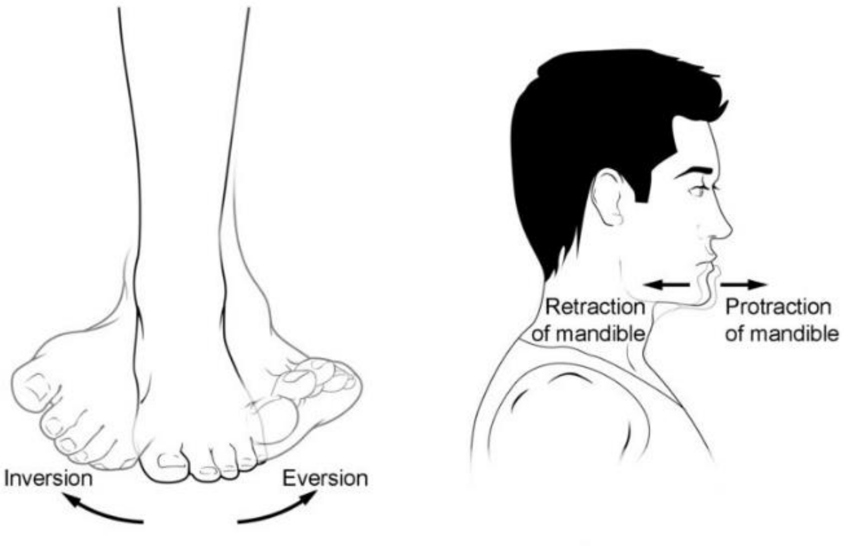
(b) Dorsiflexion and plantar flexion

Inversion and Eversion

Inversion and eversion are complex movements that involve the multiple plane joints among the tarsal bones of the posterior foot (intertarsal joints) and thus are not motions that take place at the ankle joint. **Inversion** is the turning of the foot to angle the bottom of the foot toward the midline, while **eversion** turns the bottom of the foot away from the midline. The foot has a greater range of inversion than eversion motion. These are important motions that help to stabilize the foot when walking or running on an uneven surface and aid in the quick side-to-side changes in direction used during active sports such as basketball, racquetball, or soccer .

Protraction and Retraction

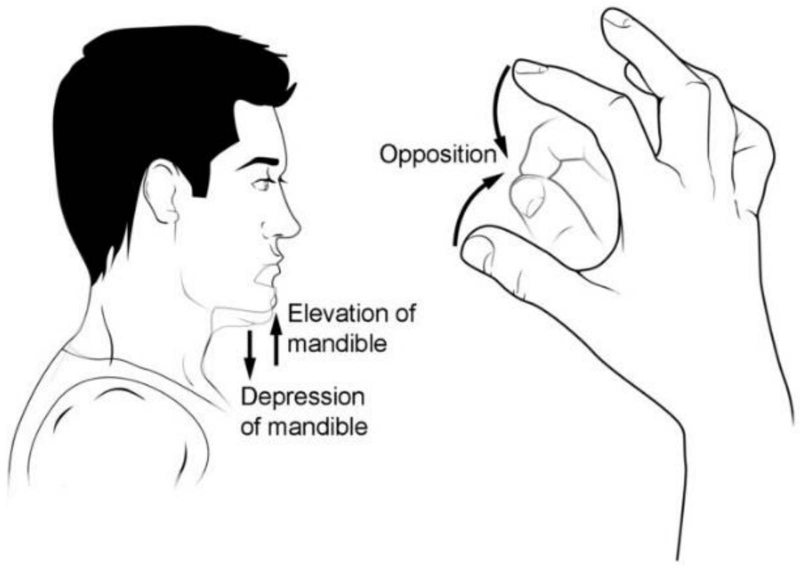
Protraction and **retraction** are anterior-posterior movements of the scapula or mandible. Protraction of the scapula occurs when the shoulder is moved forward, as when pushing against something or throwing a ball. Retraction is the opposite motion, with the scapula being pulled posteriorly and medially, toward the vertebral column. For the mandible, protraction occurs when the lower jaw is pushed forward, to stick out the chin, while retraction pulls the lower jaw backward.



(a) Inversion and eversion (b) Protraction and retraction

Depression and Elevation

Depression and **elevation** are downward and upward movements of the scapula or mandible. The upward movement of the scapula and shoulder is elevation, while a downward movement is depression. These movements are used to shrug your shoulders. Similarly, elevation of the mandible is the upward movement of the lower jaw used to close the mouth or bite on something, and depression is the downward movement that produces opening of the mouth



(a) Elevation and depression (b) Opposition

Gait cycle :

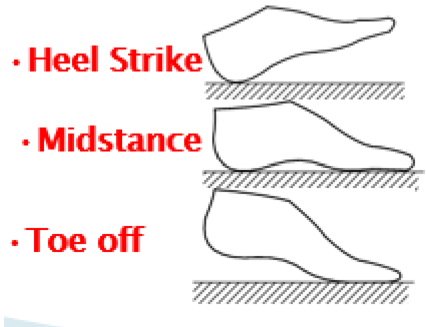
One gait cycle is measured from heel-strike to heel-strike ,consists of :

❖ **Stance phase**

- period of time that the foot is on the ground
- ~60% of one gait cycle is spent in stance
- during stance, the leg accepts body weight and provides single limb support

-Stance Phase

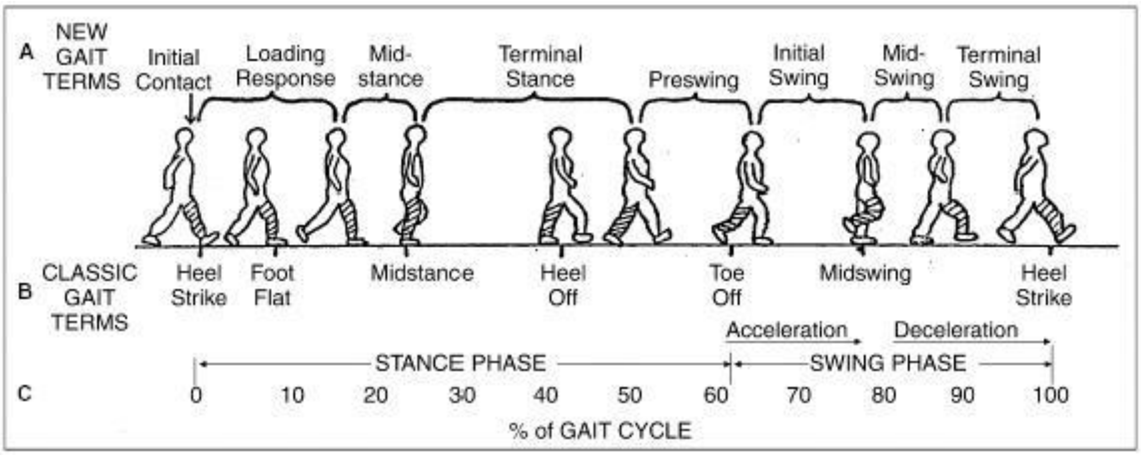
- Initial contact (heel strike)
- Mid stance
- Toe off (terminal stance)



❖ Swing phase

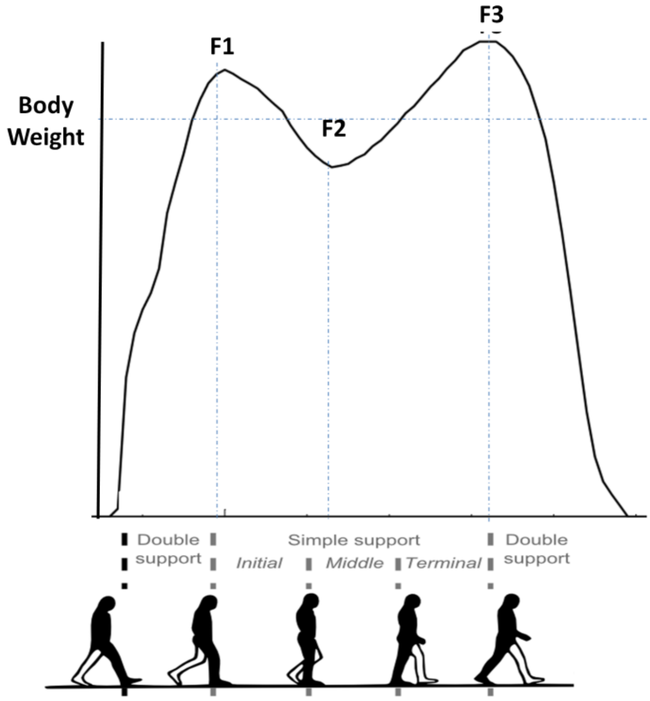
- period of time that the foot is off the ground moving forward
- ~40% of one gait cycle is spent in swing
- the limb advances

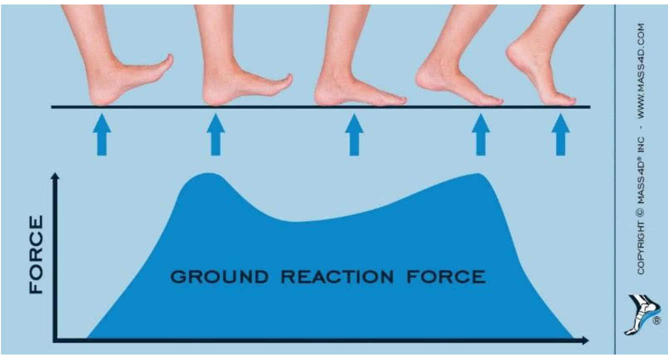
- Stride :is the distance between consecutive initial contacts of the same foot with the ground
- Step :is the distance between initial contacts of the alternating feet



Ground reaction force:

The ground reaction force (GRF) has three components: its point of application, its magnitude, and its line of action. In the stance phase of normal gait, the point of application progresses along the foot, and the magnitude and the line of action vary through the gait cycle.





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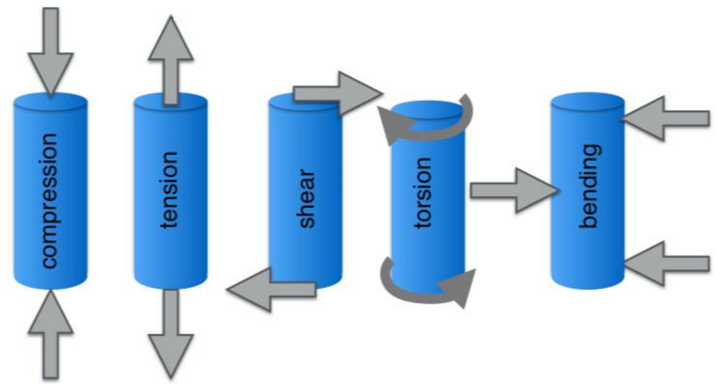
FORCE AND MOTION

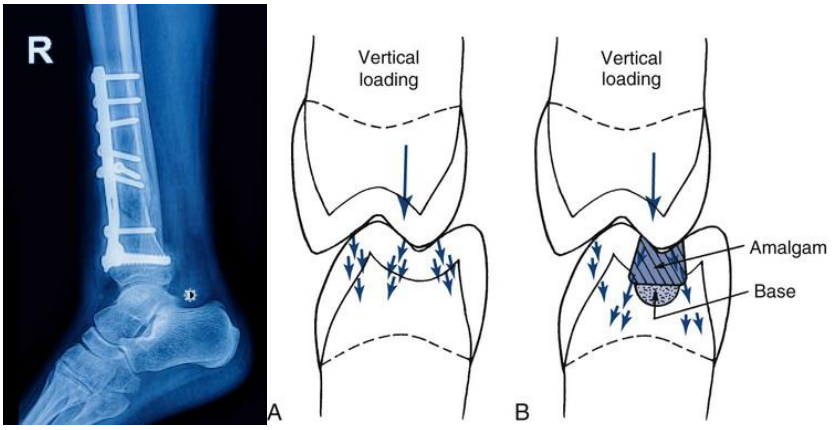
Note : vertical ground reaction force (F_z) increased linearly during walking and running from 1.2 BW to approximately 2.5 BW at 6.0 m /s remaining constant during forward lean sprinting at higher speeds.

Stress and forces of human structure:

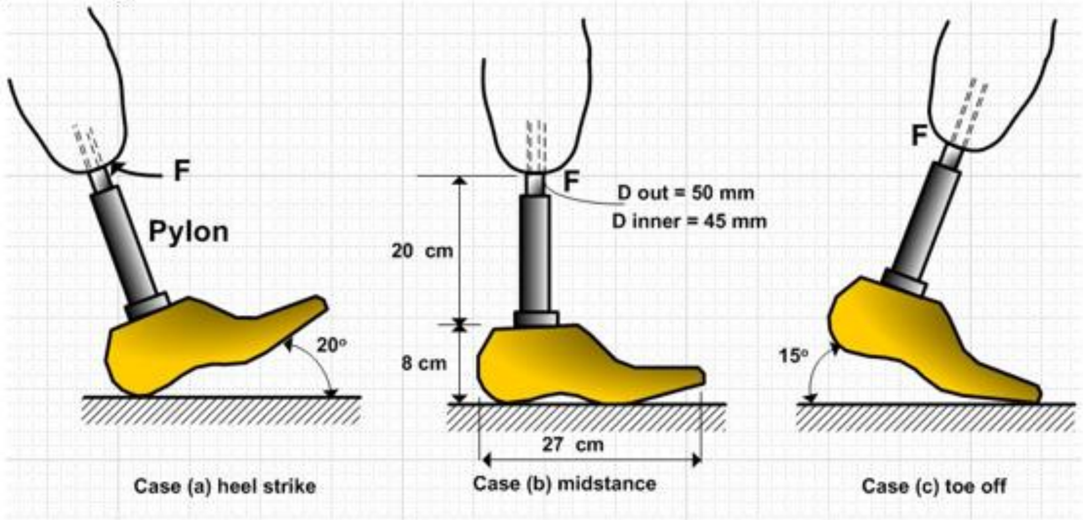
- Axial stress application
- Bending stress application
- Torsion stress application
- Combined stress
- Impact load
- Fatigue limit :

Fatigue Criterion	*Fatigue Formulas*
Goodman	$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{rt}} \cong \frac{1}{n}$ (1)
Soderberg	$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_y} \cong \frac{1}{n}$ (2)
Gerber	$\frac{n.\sigma_a}{S_e} + \left(\frac{n.\sigma_m}{S_{rt}}\right)^2 \cong 1$ (3)



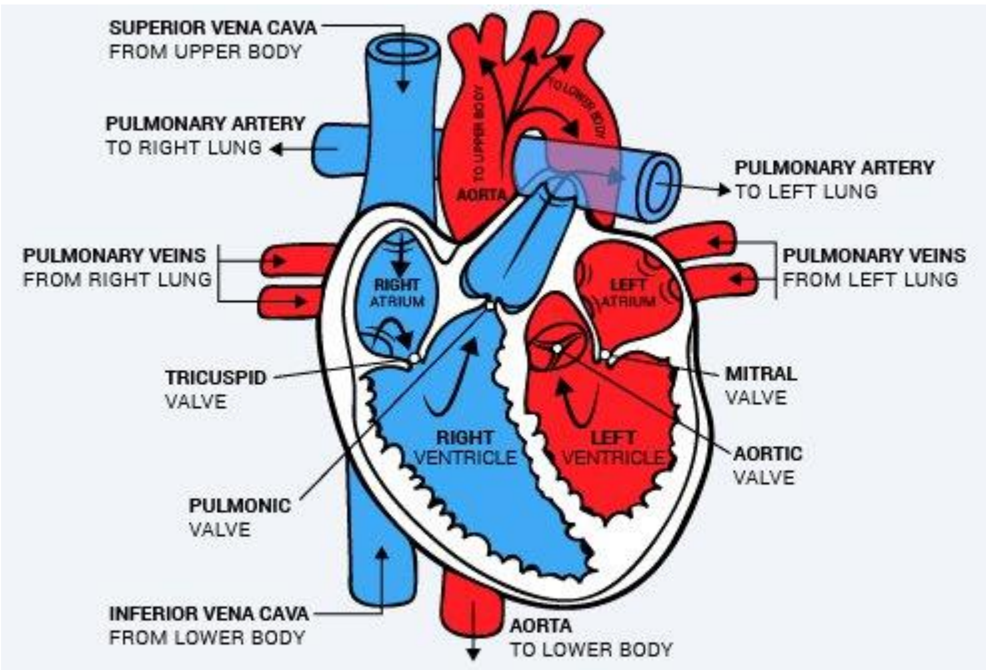


Q) Dr. Munjed Al Muderis was famous Professor in orthopaedic surgery. Al Muderis developed the new generation of implant, osseointegration prosthetic limb (OPL). In this method, Traditional and rigid socket based technology is now replaced with a surgery that inserts a titanium implant into the bone. The figure (Q) is represent the new method, what are the most dangerous case in the three figures (a, b and c) and determine the maximum stress at **point F** for this case. Note: Weight of total body is **80 kg.**



structure of heart and blood circulation :

https://www.youtube.com/watch?v=GMBSU-2GK3E



Blood pressure (BP) is the pressure exerted by blood on the walls of a blood vessel that helps to push blood through the body. Systolic blood pressure measures the amount of pressure that blood exerts on vessels while the heart is beating. The optimal systolic blood pressure is 120 mmHg. Diastolic blood pressure measures the pressure in the vessels between heartbeats. The optimal diastolic blood pressure is 80 mmHg. Many factors can affect blood pressure, such as hormones, stress, exercise, eating, sitting, and standing. Blood flow through the body is regulated by the size of blood vessels, by the action of smooth muscle, by one-way valves, and by the fluid pressure of the blood itself.

The pressure of the blood flow in the body is produced by the hydrostatic pressure of the fluid (blood) against the walls of the blood vessels. Fluid will move from areas of high to low hydrostatic pressures. In the arteries, the hydrostatic pressure near the heart is very high and blood flows to the arterioles where the rate of flow is slowed by the narrow openings of the arterioles. During systole, when new blood is entering the arteries, the artery walls stretch to accommodate the increase of pressure of the extra blood; during diastole, the walls return to normal because of their elastic properties.

Blood is a body fluid in humans and other animals that delivers necessary substances such as nutrients and oxygen to the cells and transports metabolic waste products away from those same cells.

It is composed of blood cells suspended in blood plasma. Plasma, which constitutes 55% of blood fluid, is mostly water (92% by volume), and contains proteins, glucose, mineral ions, hormones, carbon dioxide (plasma being the main medium for excretory product transportation), and blood cells themselves.

Viscosity: is the physical property that characterizes the flow resistance of simple fluids.

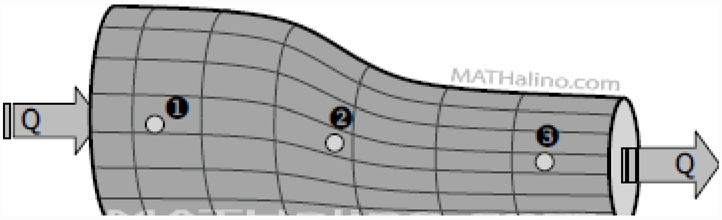
Newton's law: of viscosity defines the relationship between the shear stress and shear rate of a fluid subjected to a mechanical stress. The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the viscosity or coefficient of viscosity. Newtonian fluids obey Newton's law of viscosity. The viscosity is independent of the shear rate.

Non-Newtonian fluids: do not follow Newton's law and, thus, their viscosity (ratio of shear stress to shear rate) is not constant and is dependent on the shear rate. such as honey, toothpaste, , corn starch and blood .

https://www.youtube.com/watch?v=RIUEZ3AhrVE

❖ Discharge (also called flow rate) of fluid:

The amount of fluid passing a section of a stream in unit time is called the discharge. If *v* is the mean velocity and *A* is the cross sectional area, the discharge *Q* is defined by $Q = Av$ which is known as volume flow rate. Discharge is also expressed as mass flow rate and weight flow rate.



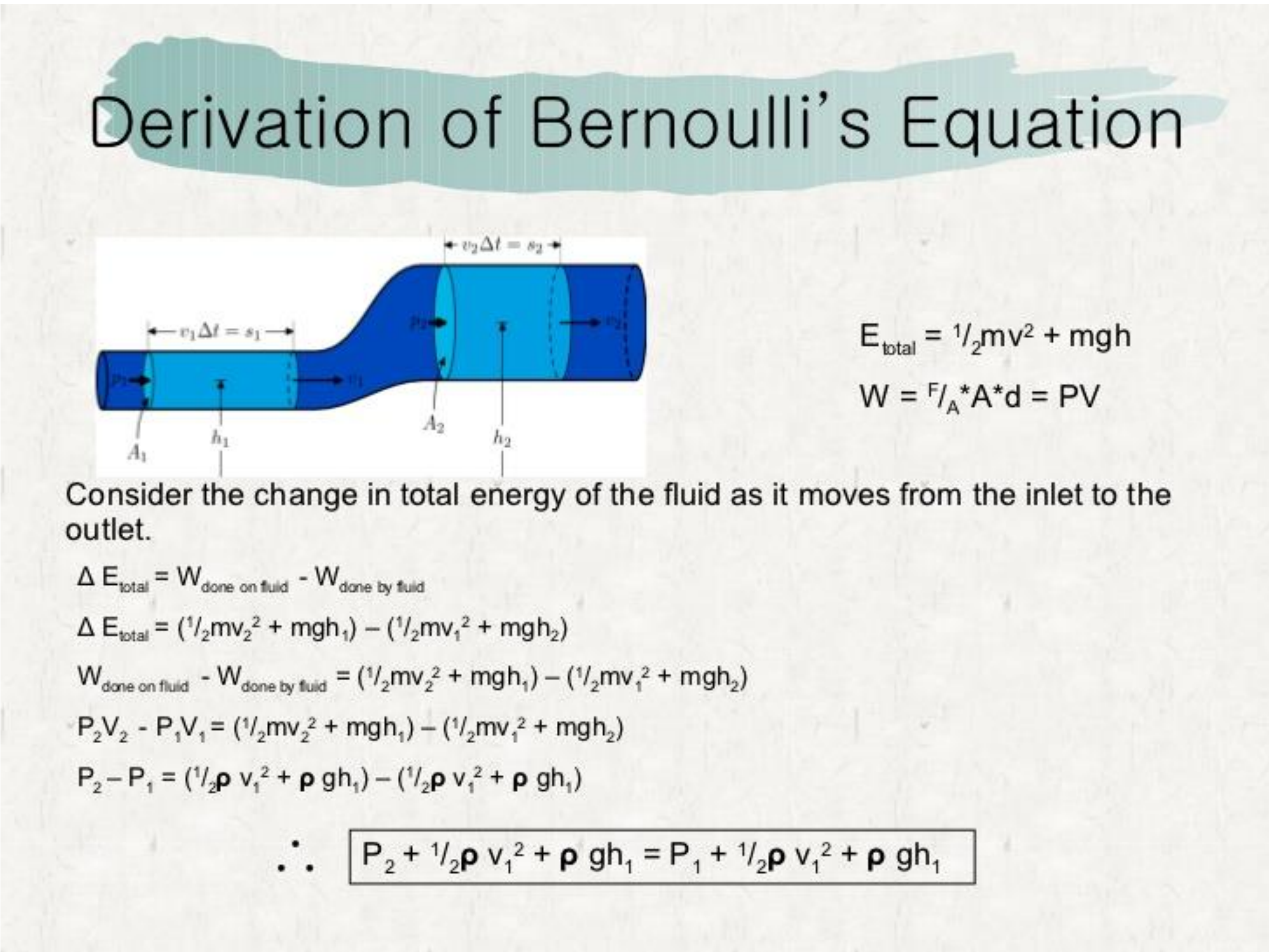
$$Q = \frac{Volume}{time} = v1 \times A1 = v2 \times A2 = v3 \times A3 = flow\ rate\ (\ m^3/\text{sec})$$

Where Q is discharge (m^3/sec)

$v1, v2\ , v3\ are\ velocity$ (m^3/sec)

A1, A2, A3 are cross section Area

⊠ Steady state of fluids (Bernoulli equation)



❖ Reynolds number and type of flow :

The Reynolds number is the ratio of inertial forces to viscous forces within a fluid which is subjected to relative internal movement due to different fluid velocities. A region where these forces change behavior is known as a boundary layer, such as the bounding surface in the interior of a pipe.

Newtonian Fluid Reynolds Number (Re) Formula

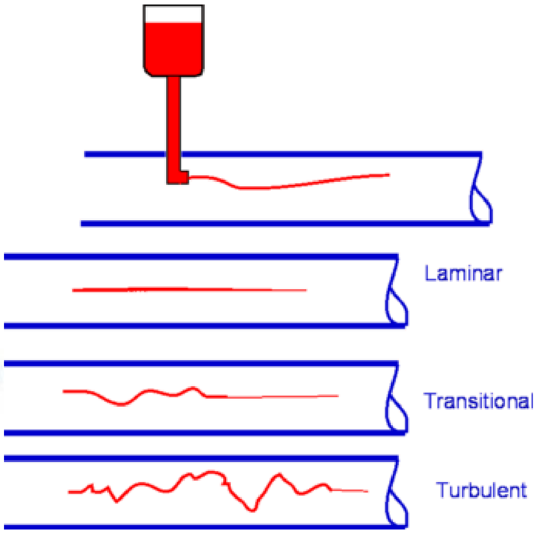
$$Re = \frac{\rho V D}{\mu}$$

$\mu - fluid\ dynamic\ viscosity\ in\ kg/(m.s)$

$\rho - fluid\ density\ in\ kg/m^3$

$V - fluid\ velocity\ in\ m/s$

$D - pipe\ diameter\ in\ m$



Re	Flow Regime
< 2000	Laminar
2000 – 4000	Transition
> 4000	Turbulent