Lecture 1:

1.1 Forces On and In the Body

Gravitational force : Newton’s law: this law state that there is a force of attraction between any two objects, our weight is due to attraction between the earth and our body .

One important medical effect of gravitational force is the formation of varicose veins in the legs, as the venous blood travels against force of gravity on its way to the heart.
Another medical effect of gravity is on the bones. Gravitational force on the skeleton in some way contributes to healthy bones, if person becomes weight less such as in orbiting satellite, he may lose bone mineral and may be serious problem on very long journey.
Statics
Many of muscle and bone systems of the body acts as levers, levers are classified as, first, second, and third. The last are most common in the body, second are next common.

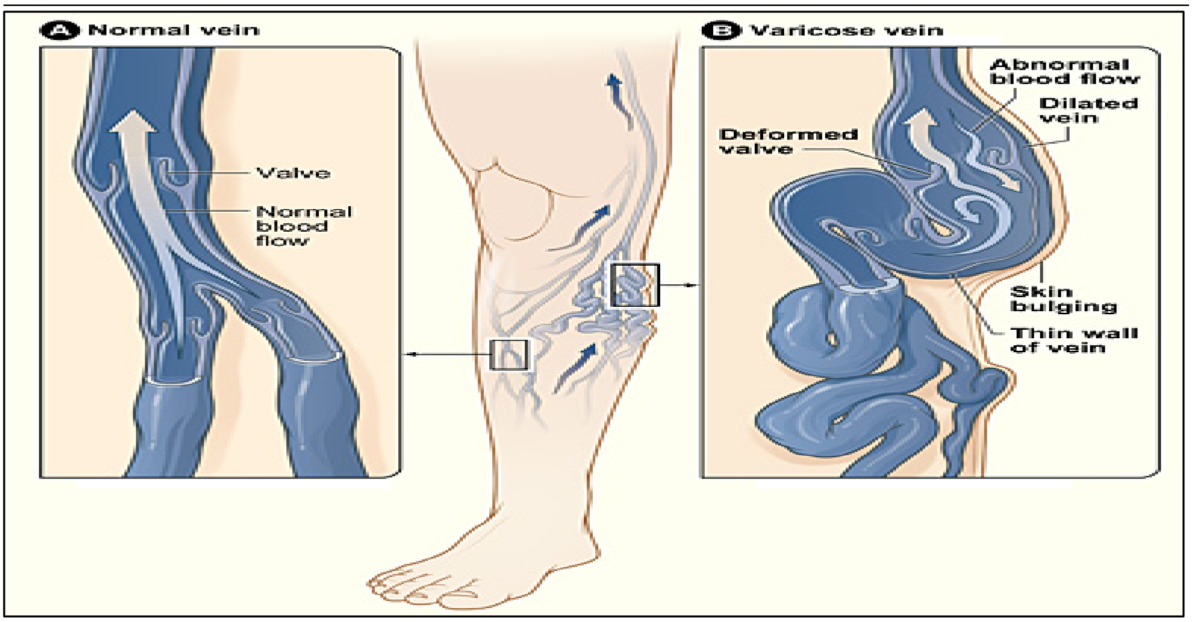
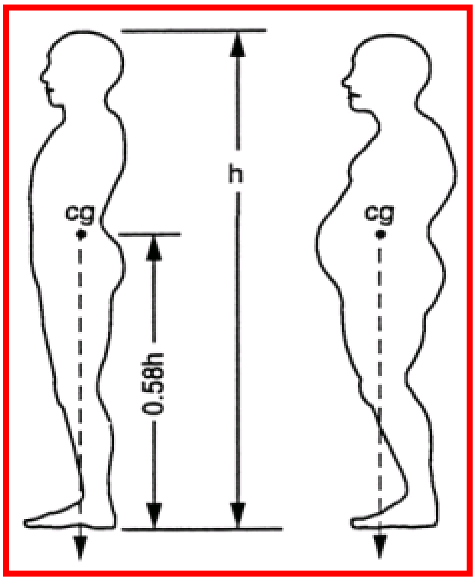


Figure 1: Gravitational force on the body

1.2 Equilibrium Considerations for the Human Body

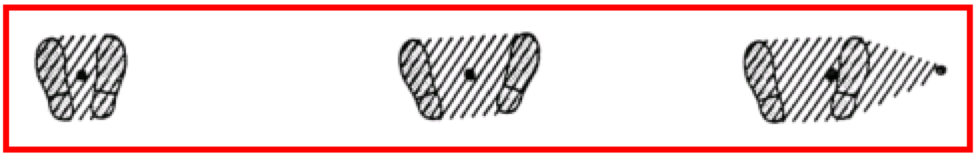


The center of gravity (c.g.) of an erect person with arms at the side is at approximately 56% of the person’s height measured from the soles of the feet . **The main force acting on the body is the gravitational force**

(W= weight!) → $W = m \cdot g$

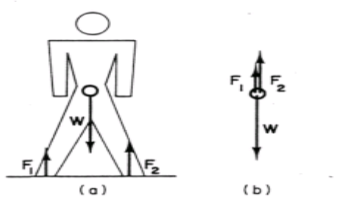
Stability of the body against the gravitational force is maintained by the bone structure of the skeleton

Gravitational force W applies at the center of gravity CG of the body



CG depends on body mass distribution to maintain stability **CG** must be located between feet, if feet are far apart forces in horizontal direction F_x have to be considered

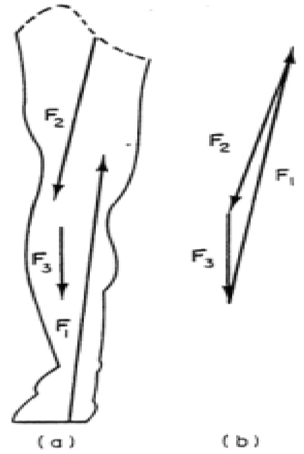
$$\sum \vec{F_i} = 0$$



$$\vec{F_1} + \vec{F_2} = W$$

$\vec{F_1}$, $\vec{F_2}$ are the forces the ground applies to the feet

To maintain stability the vector sum of all forces applying at the CG must be zero



in reality the forces applied to the leg are the vector sum of:
force of ground: $\vec{F}_1$
weight of body: $\vec{F}_2$
weight of leg: $\vec{F}_3$
in equilibrium: $\sum_i \vec{F}_i = 0$

1.3 Levers

A lever is a rigid bar free to rotate about a fixed point called the fulcrum. The position of the fulcrum is fixed so that it is not free to move with respect to the bar. Levers are used to lift loads in an advantageous way and to transfer movement from one point to another.

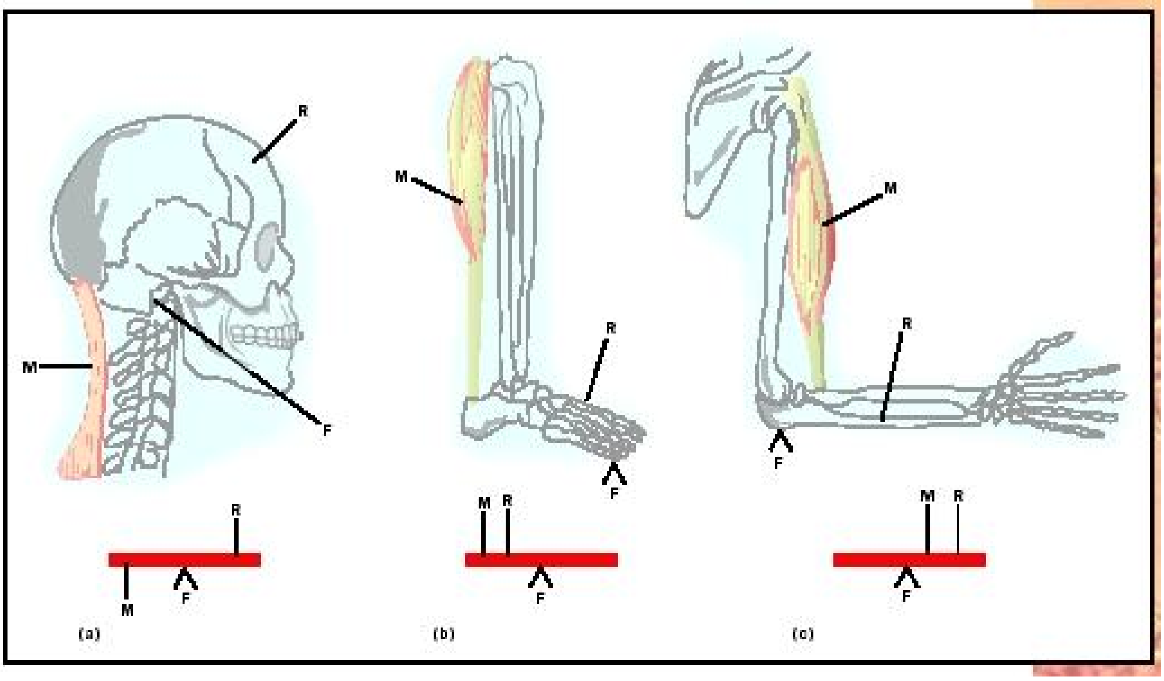


Figure 2 : lever system in the body

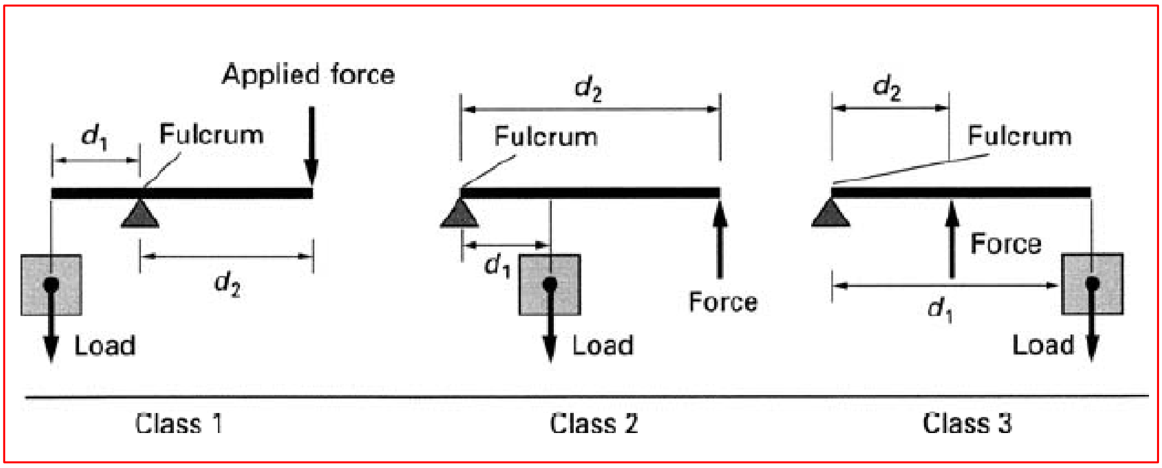


Figure 2 : lever system in the body

The situation is opposite in a Class 3 lever. Here d_1 is larger than d_2; therefore, the mechanical advantage is always less than one.

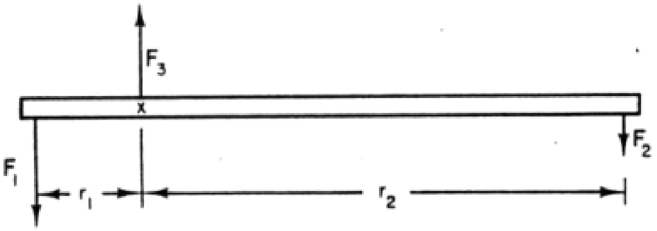
It can be shown from the conditions for equilibrium that, for all three types of levers, the force F required to balance a load of weight W is given by

$$F = \frac{Wd_1}{d_2},$$

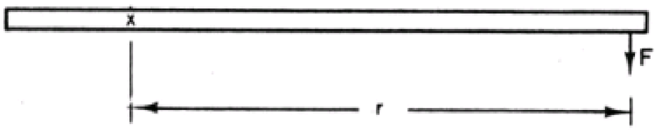
where d1 and d2 are the lengths of the lever arms, If d1 is less than d2, the force required to balance a load is smaller than the load. <u>The mechanical advantage M of the lever is defined as</u>

$$M = \frac{W}{F} = \frac{d_2}{d_1}.$$

Torque is defined by the force *F* applied at the distance *r* from the pivot point



$$\sum_i \vec{\tau}_i = \sum_i \vec{r}_i \times \vec{F}_i = 0$$



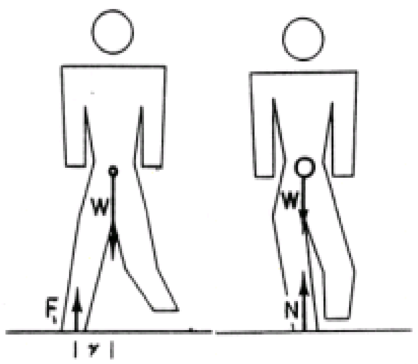
$$\vec{\tau} = \vec{r} \times \vec{F}$$

In rotational equilibrium (no rotation, constant rotation) to maintain stability for a person standing on one leg the torque requires to shift **CG** of body so, that:

$$\boxed{\sum_i \vec{\tau}_i = 0}$$

Example

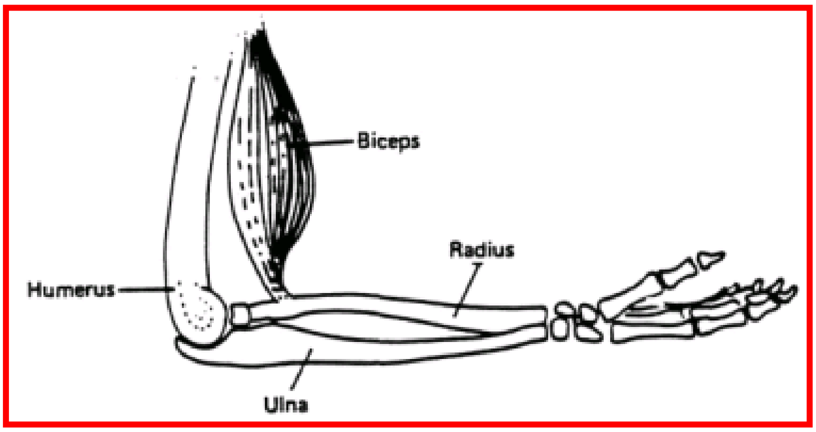
$$\boxed{\vec{F}_1 = \vec{W}}$$

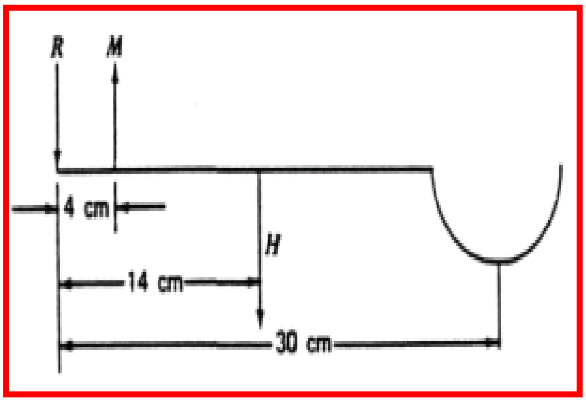


torque for an average person of weight $\vec{W}$=80 kg·9.81 m/s^2 and $\vec{r}$=20cm, $\vec{\tau} \approx$16 N·m

EXAMPLE: THE FOREARM AS LEVER SYSTEM

The biceps muscle pulls the arm upwards by muscle contraction with a force M the opposing force is the weight of the arm H at its center of gravity (CG)





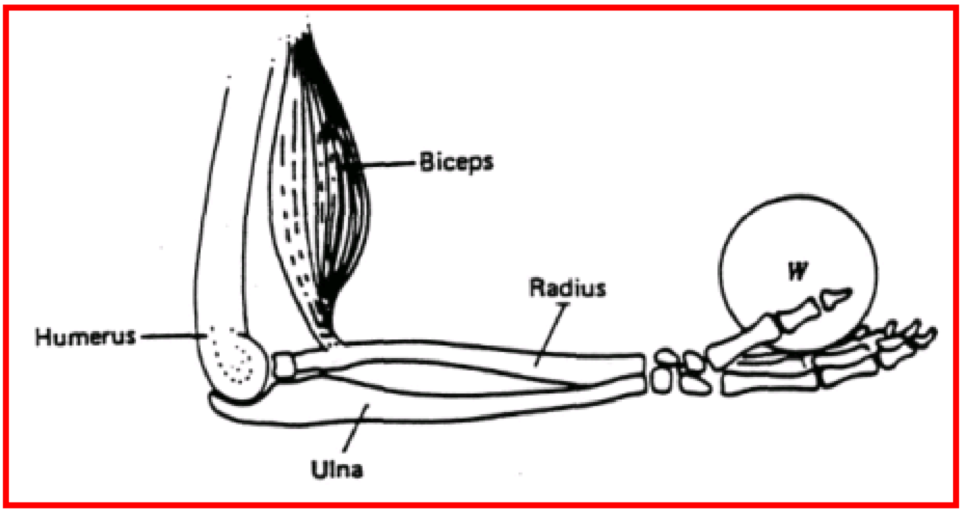
$$\sum_i \vec{\tau}_i = \vec{r}_1 \times \vec{M} + \vec{r}_2 \times \vec{H} = 0$$

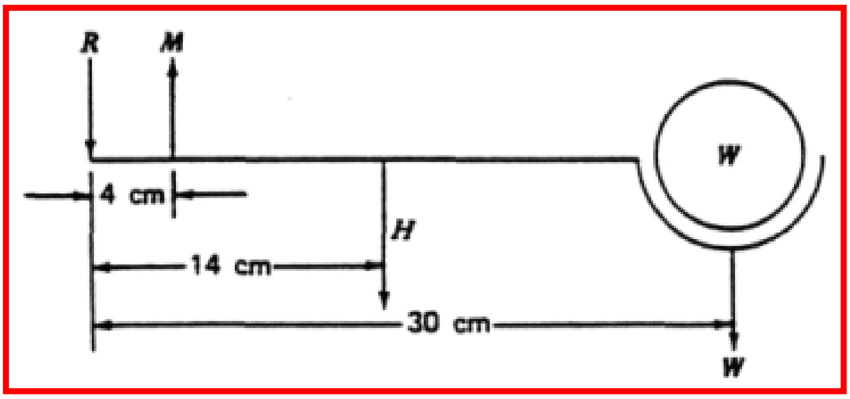
$$r_1 \cdot M - r_2 \cdot H = 4cm \cdot M - 14cm \cdot H = 0$$

(all forces apply perpendicular to the lever arm)
with $H \approx 15N$ (mass of the lower arm is approximately 3.3 lb)

$$M = 52.5\ N$$

Biceps can be strengthened by weight W lifting this adds another force which has to be compensated by the muscle force.





$$\sum_i \vec{\tau}_i = \vec{r}_1 \times \vec{M} + \vec{r}_2 \times \vec{H} + \vec{r}_3 \times \vec{W} = 0$$

$$r_1 \cdot M - r_2 \cdot H - r_3 \cdot W = 4cm \cdot M - 14cm \cdot H - 30cm \cdot W = 0$$

$$M = (14/4 \cdot H + 30/4 \cdot W) = 52.5\ N + 7.5\ W$$

muscle force increases linearly with weight

for $W = 100N$ (22lb); $M = 802.5\ N$