Mechanics of human body

THE EFFECTS OF FORCE ON RIGID BODY

- translation or rotation

⬇

- the change of external energy (potential, kinetic)

- deformation

⬇

- the change of internal energy (potential)

Newton's Laws

- I $\Sigma \mathbf{F}_i = 0 \quad \Rightarrow \Delta \mathbf{v} = 0$

  a state of rest or a state of uniform motion - inertia

- II constant (unbalanced, resultant) force

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt}$$

Equation of motion; nonrelativistic approximation

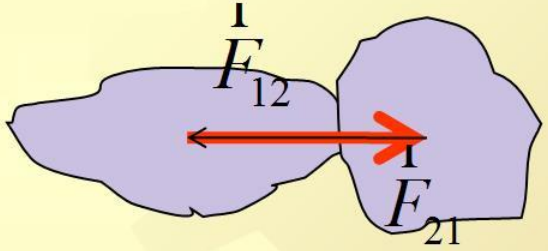
$$F = m\frac{d^2x}{dt^2} \quad \Rightarrow \quad x(t)$$

Newton's Laws

III forces of action and reaction

$$\vec{F}_{21} = -\vec{F}_{12}$$

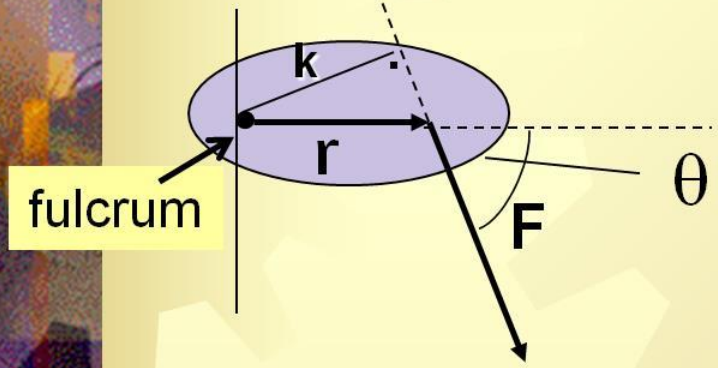
$$F_{21} = F_{12}$$

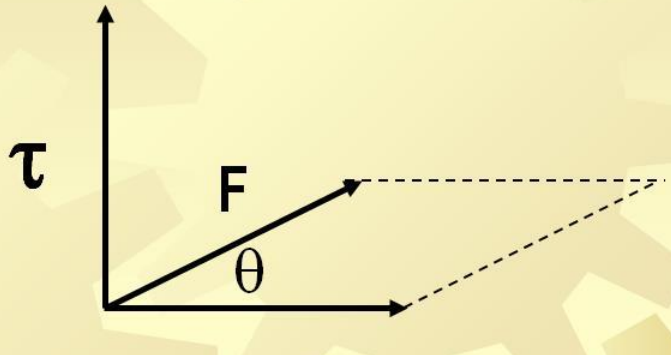


Forces of action and reaction act on different bodyes, but lie on the same streight line

Torque

- Action of a force on a body that can not freely move
- K – force arm – perpendicular distance from fulcrum to line of action of force

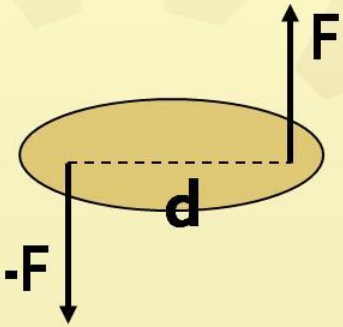




$\tau = r \times F$

$\tau = r F \sin \theta$

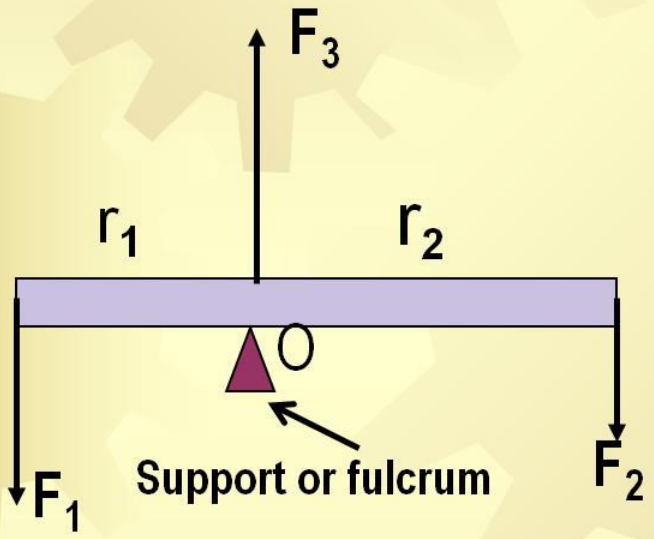
- **Force couple** – two equal opposite forces - rotation



M = d x F – the moment of the couple defines rotational ability

Example of implementation

Lever



- Translation equilibrium

$$\sum_i \vec{F}_i = 0$$

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$$

$$F_1 + F_2 = F_3$$

- Rotation equilibrium

$\Sigma\, \boldsymbol{\tau}_i = 0 \Rightarrow$

$\mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 + \mathbf{r}_3 \times \mathbf{F}_3 = 0$

$r_1 F_1 = r_2 F_2$

Lever in a Human Body

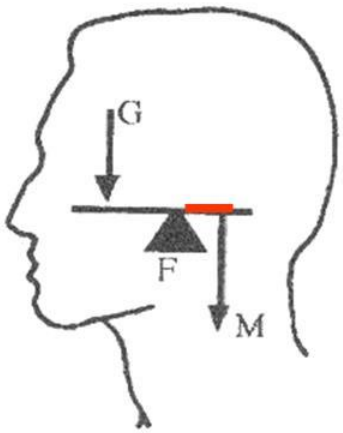
- Active force of muscles $\mathbf{F_M}$ **(M)** - lever arm $\mathbf{d_M}$
- Weight of load $\mathbf{F_W}$ **(W)** - lever arm $\mathbf{d_W}$

- Lever efficiency

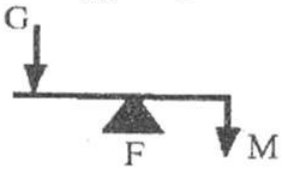
$$\eta = \frac{F_W}{F_M} = \frac{d_M}{d_W} = \frac{v_M}{v_W}$$

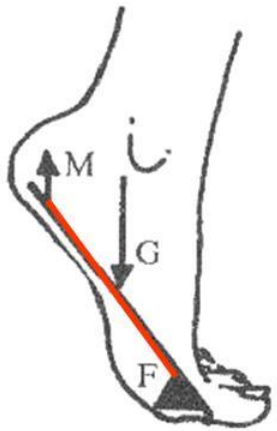
- $\eta < 1$ equilibrium lever (example: head)
- $\eta > 1$ power lever (example: foot)
- $\eta << 1$ speed lever (example: forearm)

Examples of Levers in a Body

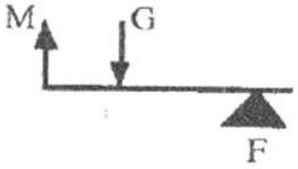


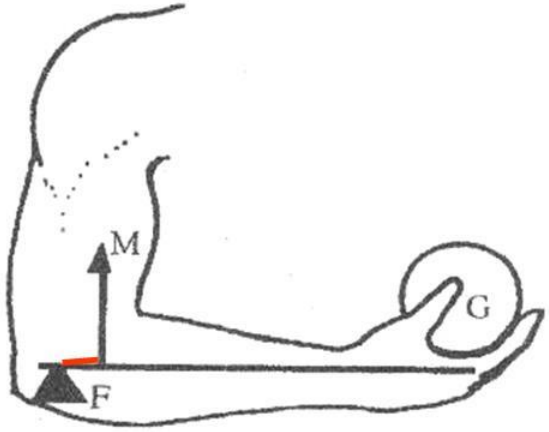
M > G





M < G





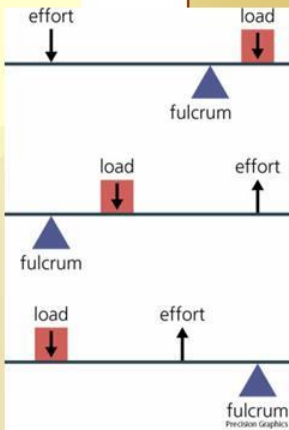
M >> G

First class lever or equilibrium lever

Second class lever or power lever

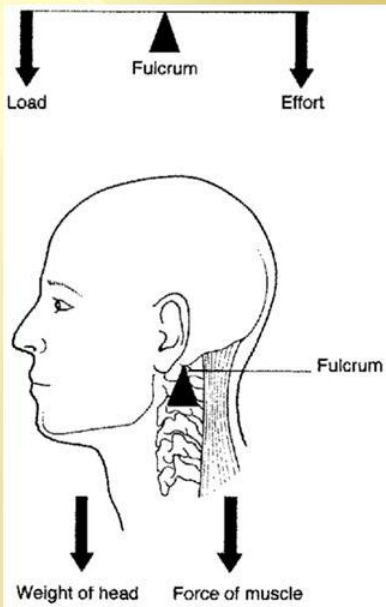
Third class lever or speed lever

Examples of lever



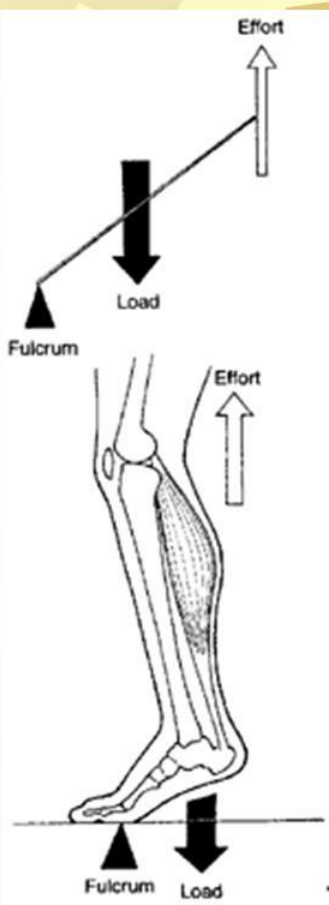
Model of Head

- The fulcrum is on a nose-ear junction, closer to an ear
- The center of masses (where a load force acts) is in a front part of head and muscles that lift head are attached in a back part
- The arm of muscle force is three times shorter than the arm of load force
- $\Rightarrow$ active muscle force if greater than the weight force
- **Head is a lever of the first class or an equilibrium lever**



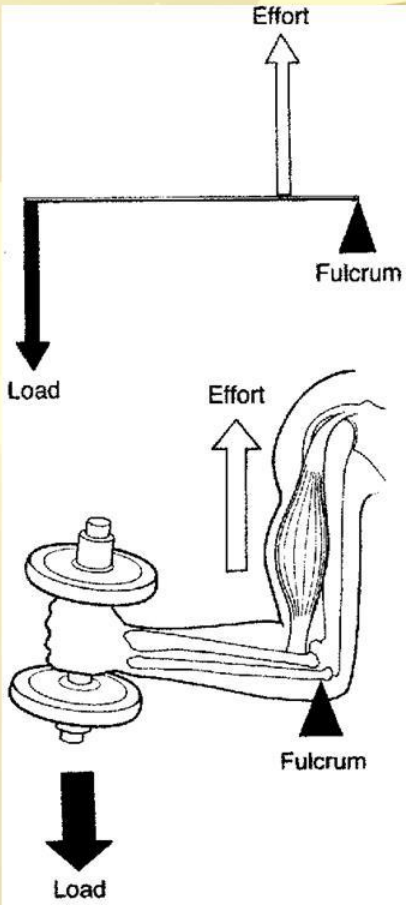
Model of Foot

- The fulcrum is in a root of fingers
- The load force acts almost in the middle of a foot
- The leg muscle which lifts the foot is attached close to the ankle – the arm of muscle force is at least two times longer than the arm of load force
- $\Rightarrow$ active muscle force is smaller than the load force
- **Foot is a lever of the second class or a power lever**

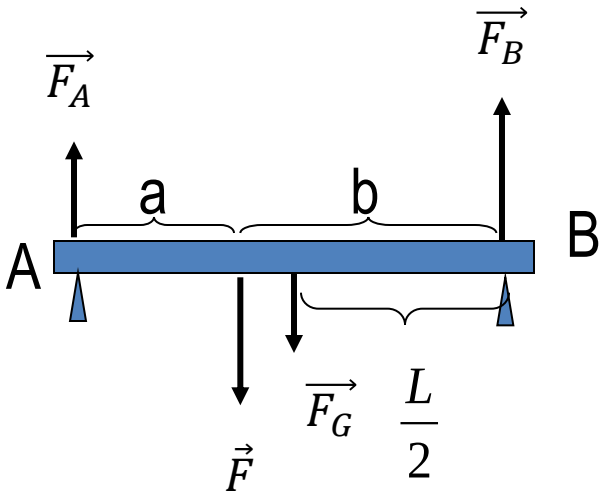


Model of Forearm

- The distance from fulcrum (elbow joint) to the point where the forearm muscle is attached is very small
- The length of the arm of load force, from elbow to wrist, is big
- $\Rightarrow$ active muscle force is greater than the load
- **Forearm is a lever of the third class or a speed lever**
- **In human development the speed was more important than the power**



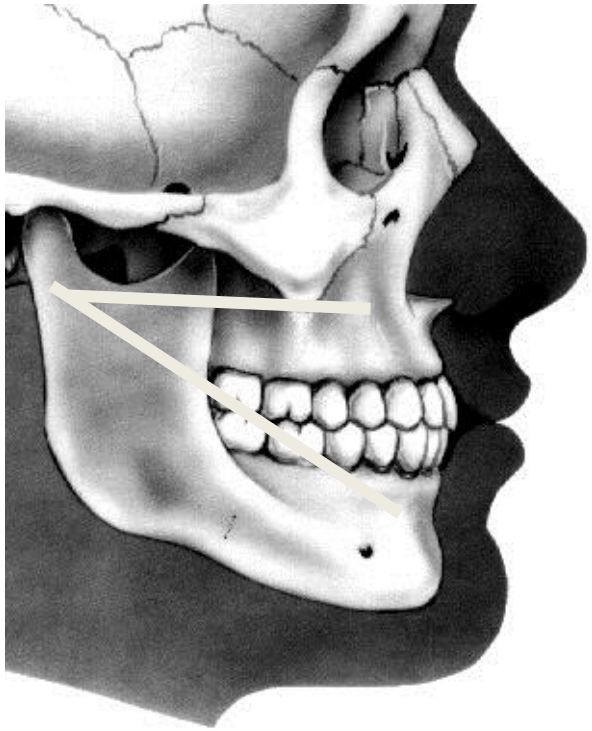
Dental bridge

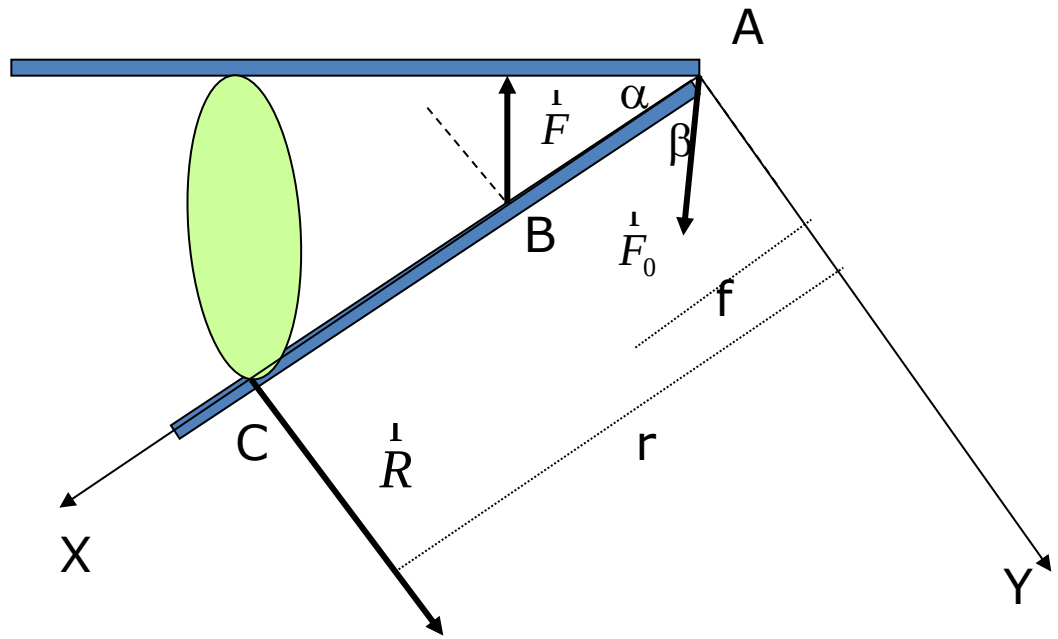


- Dental bridge - firm (solid) body is supported on two fulcrums (A i B).
- At the bridge there is an eternal force $\vec{F}$ and weight of the bridge $\overrightarrow{F_G}$.
- Forces on reactions are:
- $F_A = F\ b/L + ½\ F_G$
- $F_b = F\ a/L + ½\ F_G$

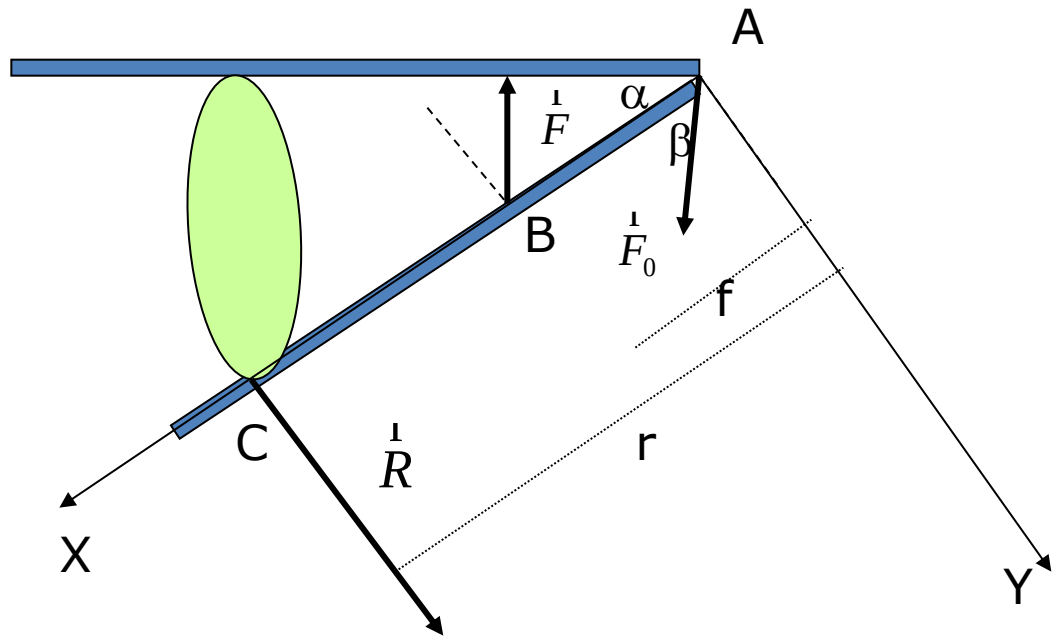
in point A: $F\ a + ½\ F_G\ L - F_b\ L = 0$
in point B: $-F_A\ L + ½\ F_G\ L + F\ b = 0$

Model: lower jaw as a lever





- rotation is in the jaw joint (point A)
- $\vec{F}$ – the force of the muscle – it closes the jaw
- $\vec{R}$ – the force of the bite of the object in the mouth;
- $\vec{F}_0$ – the force of the skull on the lower jaw



$$R = \frac{f\ F\ \cos\alpha}{r}$$

$$R \propto \frac{1}{r}$$

$$R \propto \frac{1}{\alpha}$$

$$F_0 = \sqrt{F^2 - 2F\,R\cos\alpha + R^2}$$