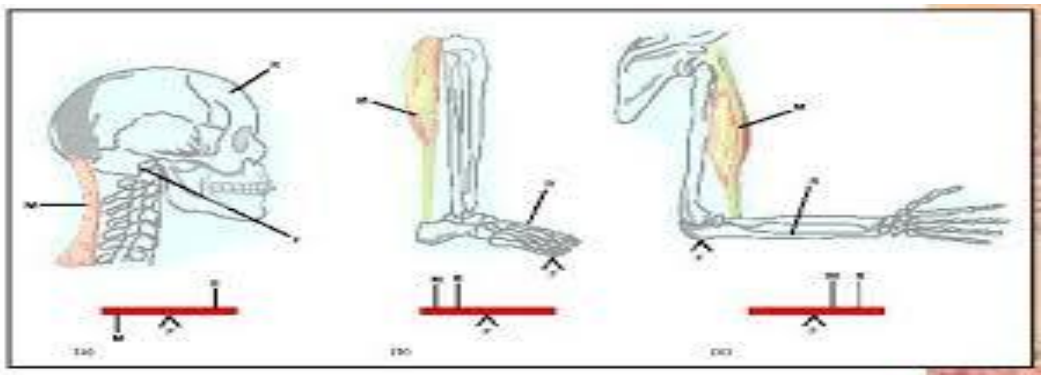
Levers in the Human Body

"Give me a lever long enough and a place to stand and I will move the Earth"

A lever is a simple machine that makes work easier for use; it involves moving a load around a pivot using a force.

In human body a lever is a rigid rod (usually a bone) that turns about a pivot (usually a joint). Levers can be used so that a small force can move a much bigger force. This is called ***mechanical advantage***.

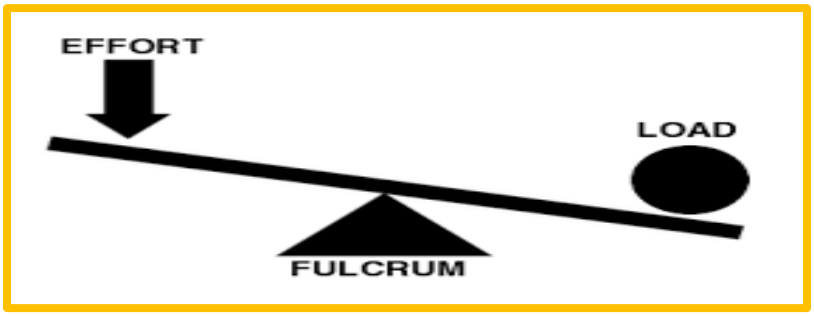
- Bones, ligaments, and muscles are the structures that form levers in the body to create human movement.



- There are **four parts to a lever** – lever arm, pivot, effort and load.

In our bodies:

1. Bones act as lever arms
2. Joints act as pivots (fulcrum)
3. Muscles provide the effort forces to move loads
4. Load forces are often the weights of the body parts that are moved or forces needed to lift, push or pull things outside our bodies.



- Levers are able to give us a strength advantage **or** a movement advantage but **not** both together.
- Levers can also be used to magnify movement, for example, when kicking a ball; small contractions of leg muscles produce a much larger movement at the end of the leg.

Mechanical advantage is a measure of the force amplification achieved by using a tool,

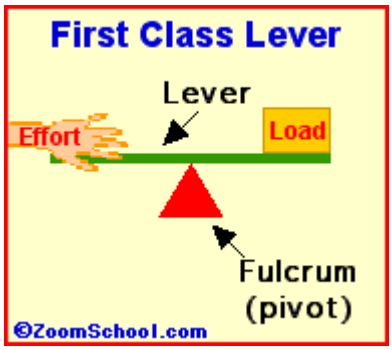
$$\textbf{Mechanical advantage} = \frac{\boldsymbol{Moment\ arm\ (force)}}{\boldsymbol{Moment\ arm\ (resistance)}}$$

Levers classification

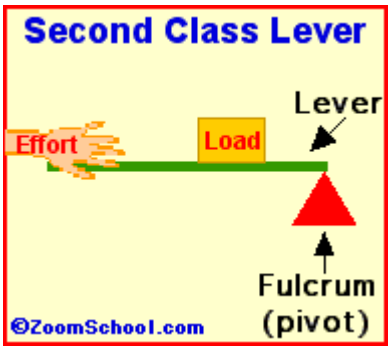
Levers are classified by the relative positions of the fulcrum, it is common to call the input force *the effort* and the output forces *the load* or *the resistance.* This allows the

identification of three classes of levers by the relative locations of the fulcrum, the resistance and the effort:

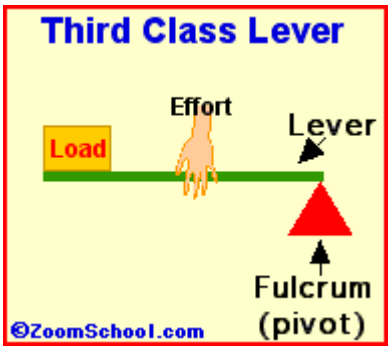
1. **Lever first class,** the pivot (fulcrum) is between the effort (force) and the load. Mechanical advantage may be greater than, less than, or equal to 1.
2. **Lever second class**, the load is between the pivot and the effort (force) Mechanical advantage is always greater than 1.
3. **Lever third class**, the effort is between the pivot and the loa Mechanical advantage is always less than 1.



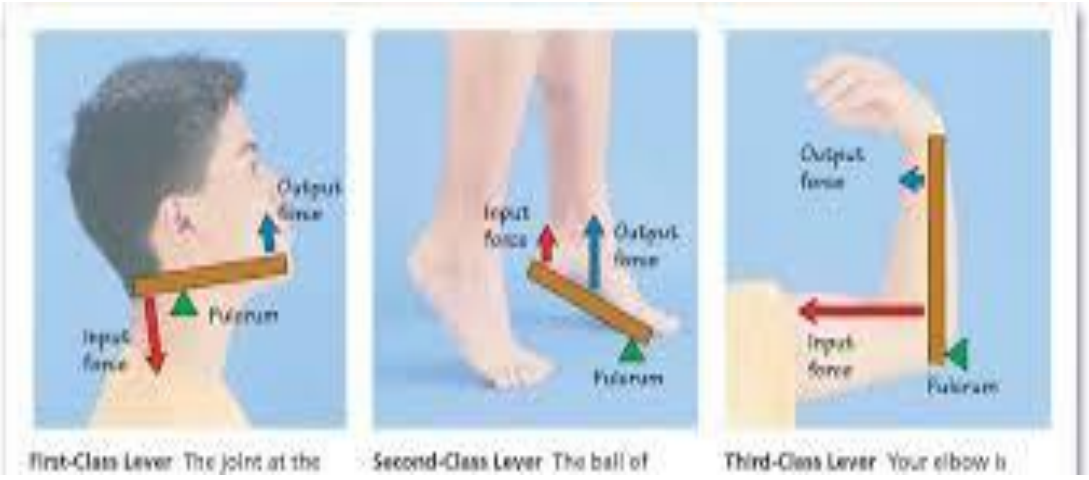
A Type 1 Lever.



A Type 2 Lever.

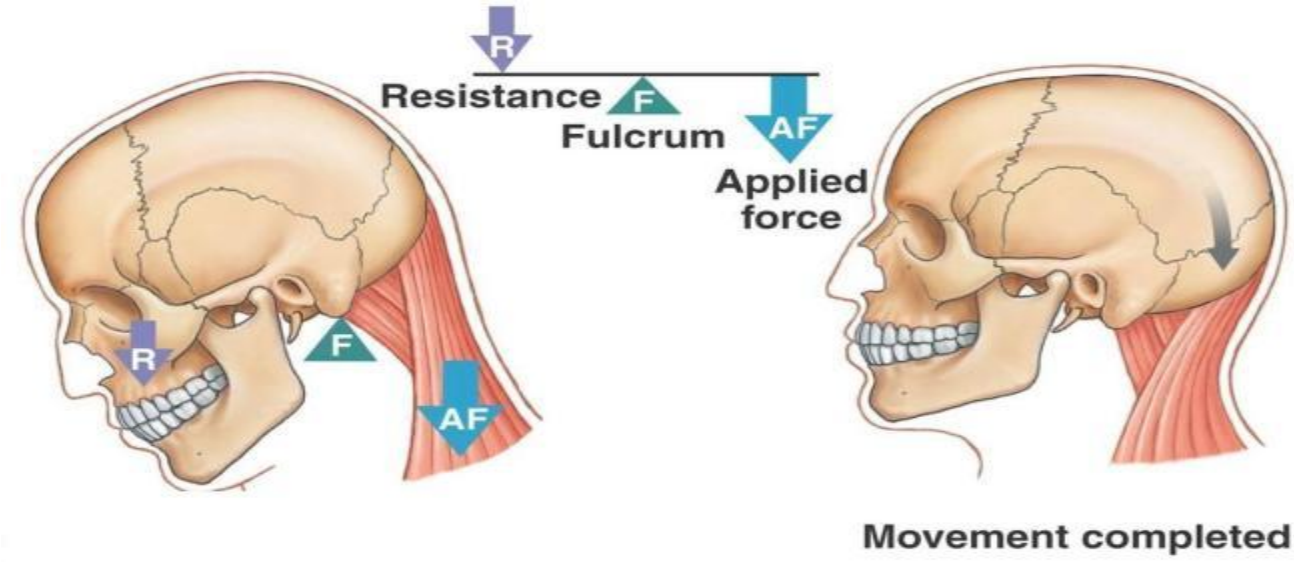


A Type 3 Lever.



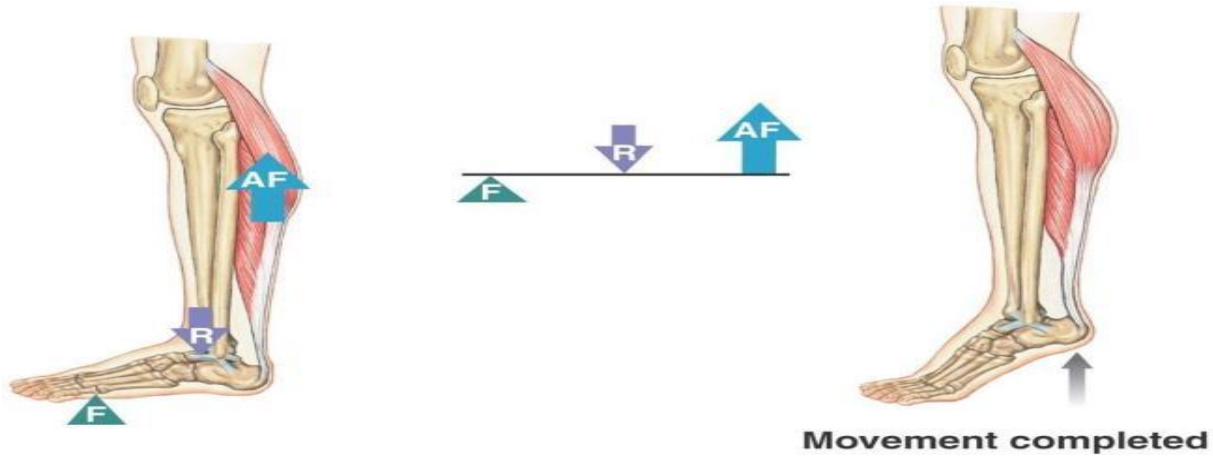
Levers classified by positions of the forces

First-class levers in the human body are rare. One example is the joint between the head and the first vertebra. The weight (resistance) is the head, the pivot is the joint, and the muscular action (force) comes from any of the posterior muscles attaching to the skull, such as the trapezius.



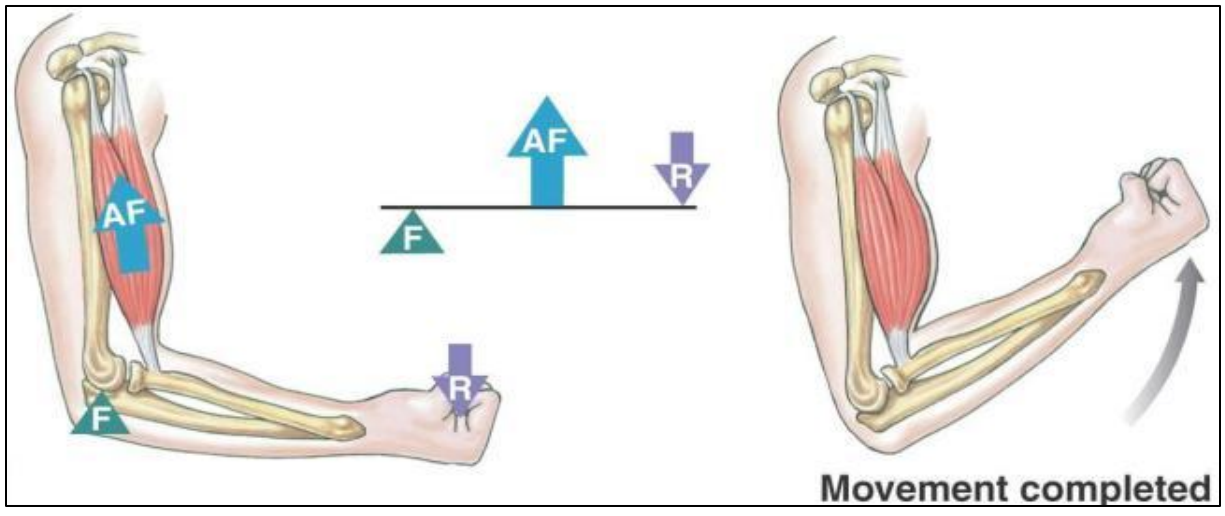
In the human body, an example of a **second-class lever** is found in the lower leg when someone stands on tiptoes the axis is formed by the metatarsophalangeal joints, the resistance is the weight of the body, and the force is applied to the calcaneus bone (heel) by the gastrocnemius and soleus muscles through the Achilles tendon.

There are numerous **third-class levers** in the human body; one example can be illustrated in the elbow joint the joint is the axis (fulcrum). The resistance (weight) is the forearm, wrist, and hand. The force is the biceps muscle when the elbow is flexed.



Function of lever in human body:

1. To balance multiple forces.
2. To enhance **force** in attempt to reduce the total force needed to overcome a resistance.
3. To enhance **range of motion** and speed of movement so that a resistance may be moved farther or faster.
4. To alter the resulting direction of the applied force.

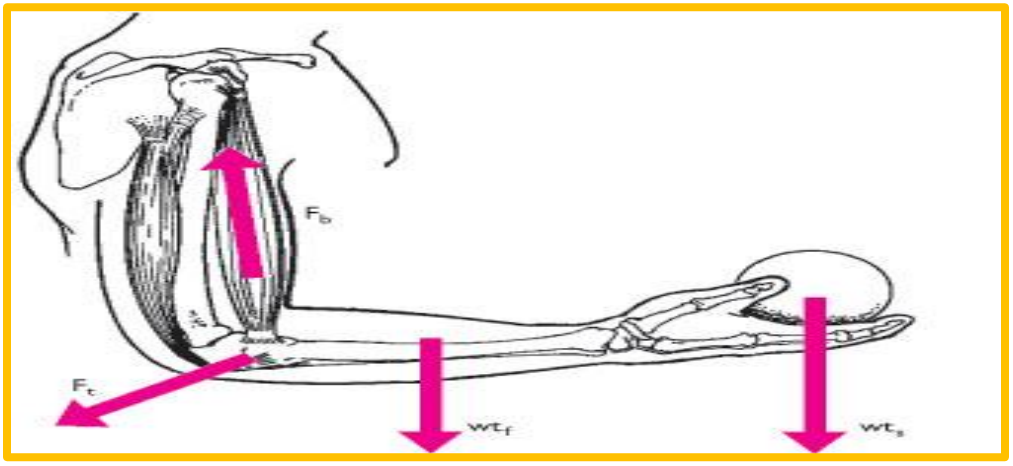


What is torque?

- Torque ($Fd_{\perp}$) is a vector quantity, has magnitude and direction
- counterclockwise (+) & clockwise (-)
- Product of muscle tension and muscle moment arm produces a torque at the joint crossed by the muscle
- Forces acting on a lever also have different effects depending how far they are away from the pivot. For example when pushing a door open it is easier to make the door move if you push at the door handle rather than near to the hinge (pivot). Pushing on the door produces a turning effect, which causes rotation.
- This turning effect is called torque (or leverage).
- The formula for calculating the amount of torque is:

torque = force x perpendicular distance to the pivot.

- The force is measured in newtons and the distance to the pivot is measured in meters or centimeters, so the unit for torque will be either newton meters (Nm) or newton centimeters (Ncm).
- You can increase the amount of torque by increasing the size of the force or increasing the distance that the force acts from the pivot. That's why the door handle is far away from the hinge.



Static Equilibrium:

- Three conditions for static equilibrium:
  - $\Sigma F_v = 0$, sum of vertical forces
  - $\Sigma F_h = 0$, sum of horizontal forces
  - $\Sigma T = 0$, sum of torques
- So, torques on one side (+) = torques on other (-)
- Force (+) x moment arm = Force (-) x moment arm