Basic Biomechanical Concepts

Kinesiology
RHS 341
Lecture **8**
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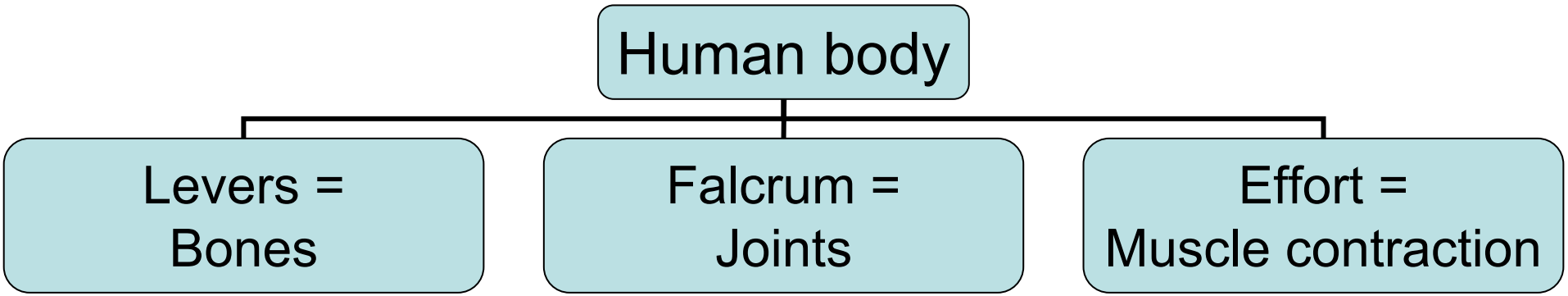
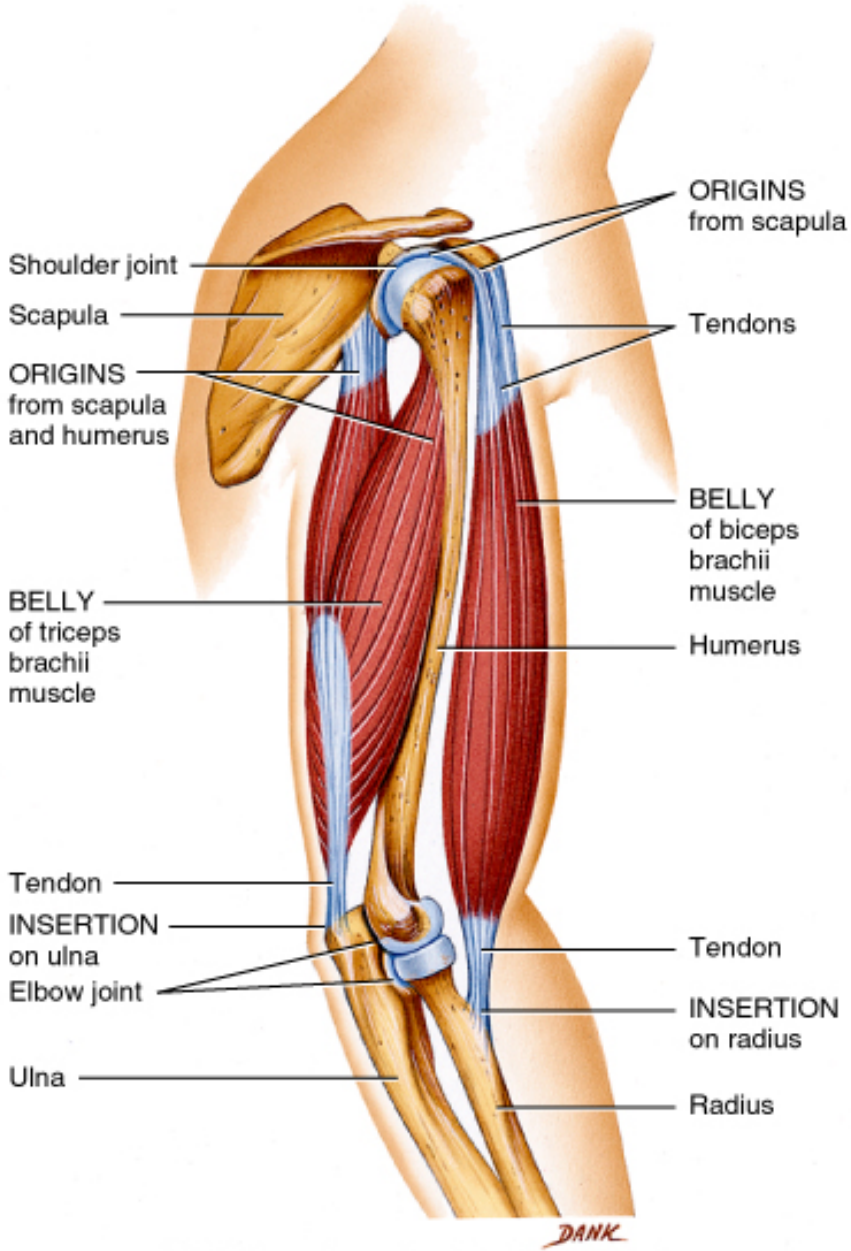
Laws of levers

- **Lever** = a rigid bar that moves on a fixed point (*falcrum*) when force is applied to it

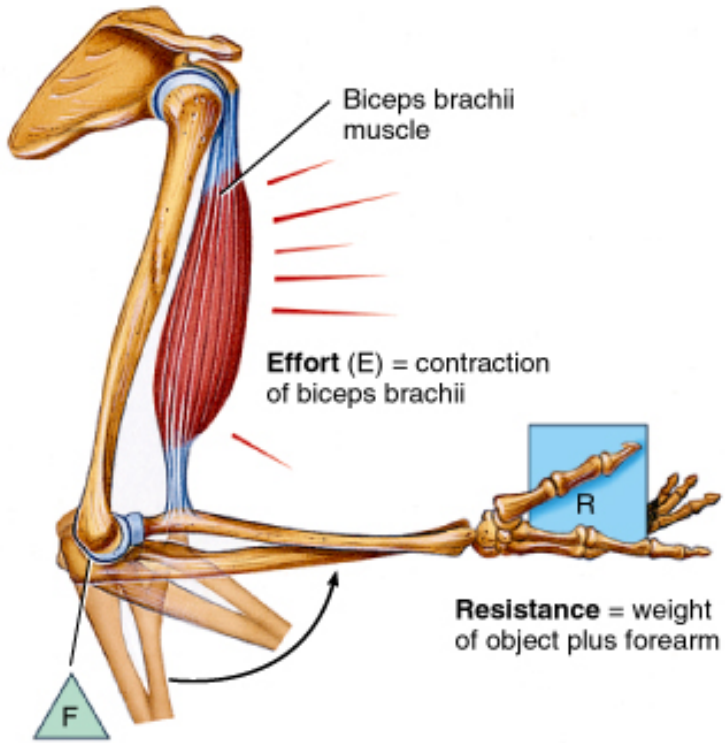
- The applied force (*effort*) is used to move or overcome a resistance (*load*)



Muscles apply force (effort) where the muscle attaches to the bone



(a) Origin and insertion of a skeletal muscle



(b) Movement of the forearm lifting a weight

Laws of levers

- **Effort arm** = the perpendicular distance from the line of action of the *effort force* to the falcrum

- **Resistance arm** = the perpendicular distance from the line of action of the *resistance force* (load) to the falcrum

Mechanical Advantage (MA)

- MA = the ratio of the effort arm to the resistance arm
- $$MA = \frac{\text{effort arm}}{\text{resistance arm}}$$
- MA is used to measure the efficiency of the lever

Mechanical Advantage (MA)

- When the effort arm equals the resistance arm: **MA = 1** ⟶

  the function of the lever is to alter the direction of motion or *balance* the lever, and NOT to magnify the effort

Mechanical Advantage (MA)

- When the effort arm is greater than the resistance arm: **MA > 1** ⟶

  the function of the lever is to magnify the *effort force*

  (Because the greater effort arm magnifies the torque created by the effort force)

Mechanical Advantage (MA)

- When the effort arm less than the resistance arm: **MA < 1** ⟶

  the function of the lever is to magnify the *velocity or speed* of movement

(Because a much greater force is required to overcome the resistance. But the effort force acts over a small distance, which moves the resistance force over greater distance in the same amount of time)

Laws of levers

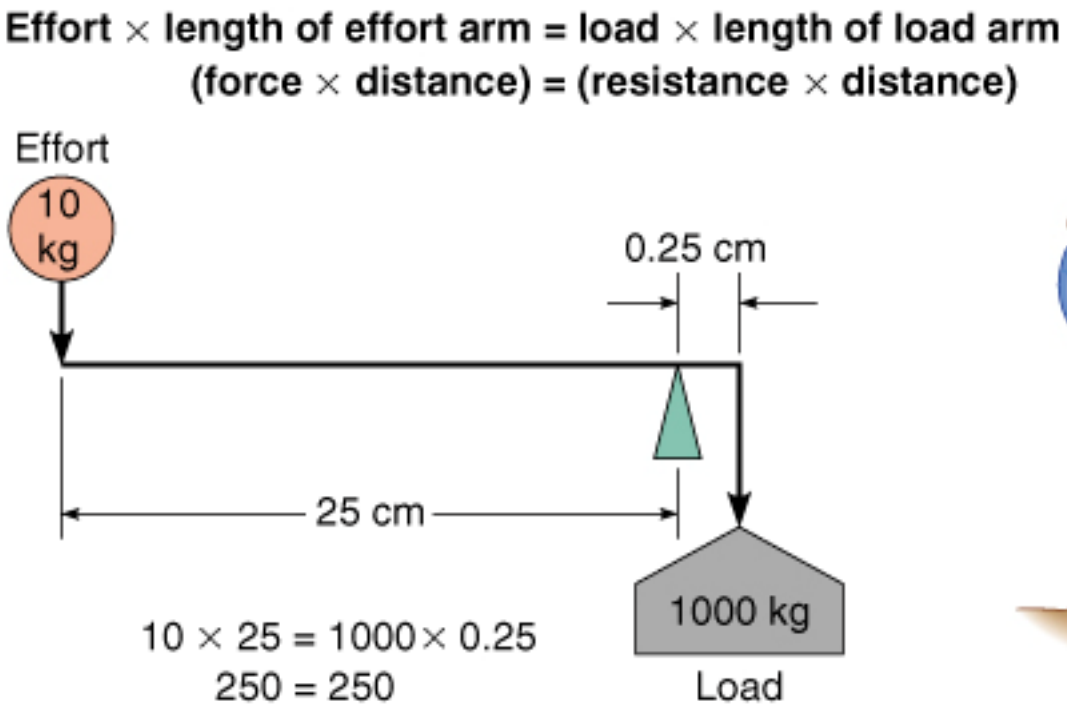
- A lever operates at a ***mechanical advantage*** when the effort is farther from the falcrum than the load

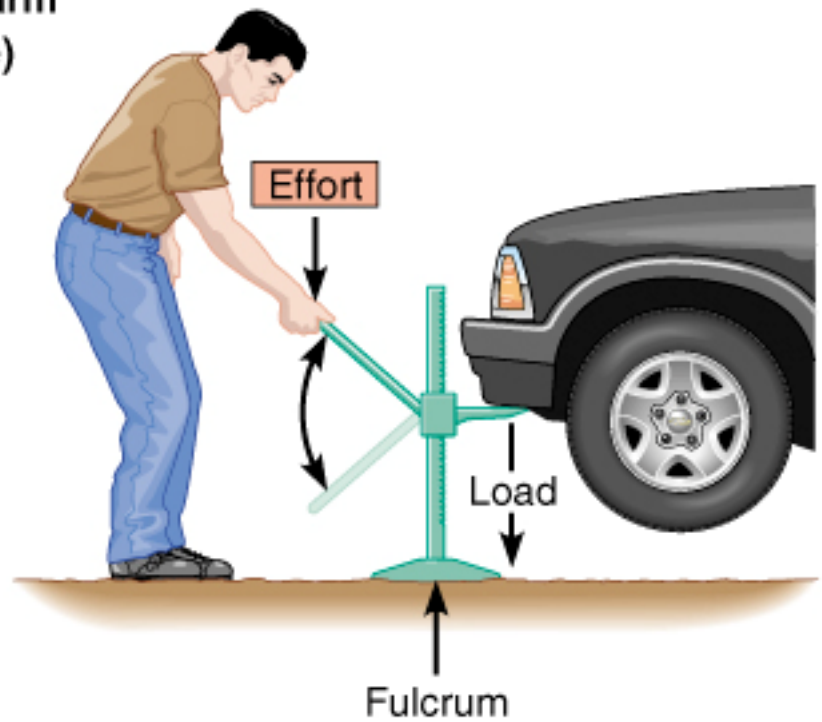
- A lever operates at a ***mechanical disadvantage*** when the effort is nearer to the falcrum than the load

Laws of levers

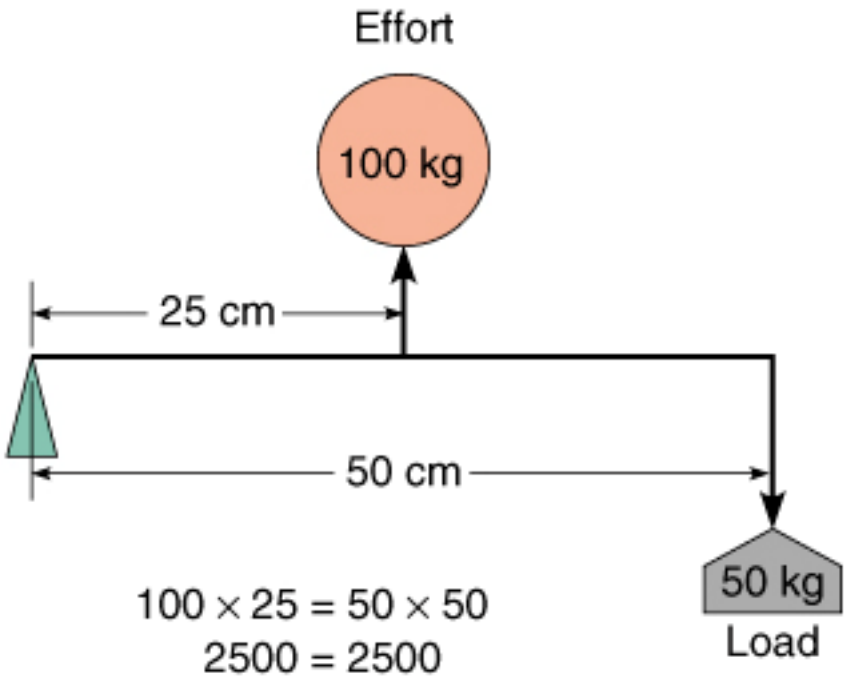
- A lever allows a given effort to move a heavier load, or to move a load farther or faster

- If the load is close to the falcrum and the effort is applied far from the falcrum, a small effort exerted over a large distance can move a heavy load over a small distance (Mechanical advantage)





Mechanical advantage



(b)

Mechanical disadvantage

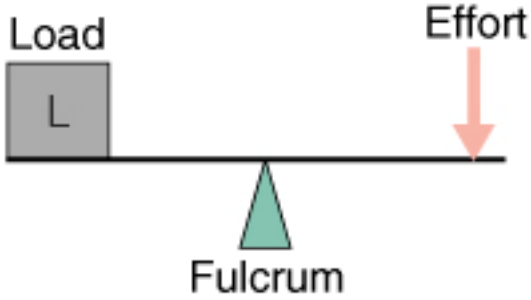
Classes of levers

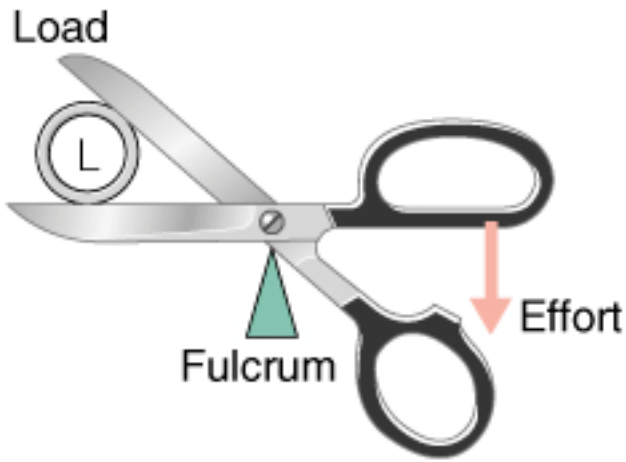
- Depending on the relative positions of the three elements:
  - Effort
  - Falcrum
  - Load

First-class levers

- *Effort* is applied at one end, and the *load* is at the other end, with the *falcrum* somewhere in between

- Example: seesaw (teeter-totter), scissors, neck extension





(a) First-class lever

First-class levers

- May have a mechanical advantage of 1, more than one, or less than one ($1 \leq MA \leq 1$)
- In most cases, first-class levers in the human body act with MA=1, so the lever acts to balance or change the direction of the effort force

First-class levers

- An example of first-class lever with an MA equal 1 is the splenius muscles acting to balance the head on the atlanto-occipital joint.

First-class levers

- The action of agonist and antagonist muscles on opposite sides of joint axis is considered first-class lever.

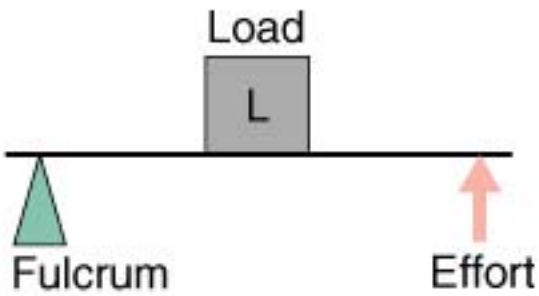
- The agonists provide the applied force and the antagonists provide the resistance force

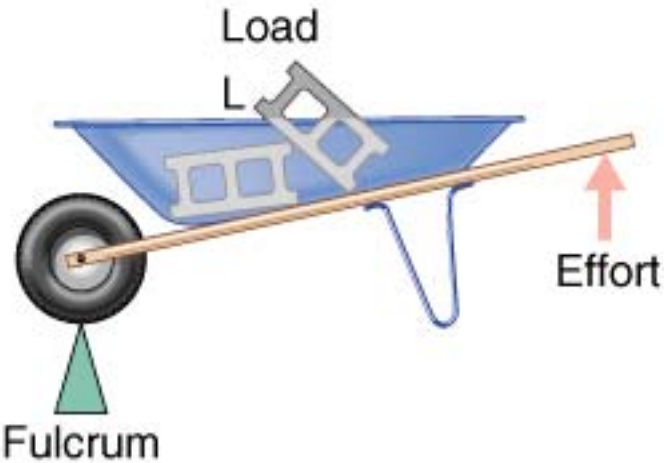
Second-class levers

- *Effort* is applied at one end, and the *falcrum* is at the other end, with the *load* somewhere in between

- Not common in the body

- Example: wheelbarrow, heel lift in standing (calf raise)





(b) Second-class lever

Second-class levers

- All work at a **mechanical advantage** (MA>1) because the muscle insertion (effort) is farther from the falcrum than the load

- Provide great ***strength***

- Does not provide speed and range of motion

Second-class levers

Masseter muscle during eating:

- the food acts as resistance when it is located at the posterior aspect of the mouth
- the falcrum is the tempromandibular joint
- the effort is at the insertion of the masseter muscle at the lower border of the mandible

Second-class levers

Calf raise (when you stand on your toes):

- the joints in the ball of the foot are the falcrum
- the load is the whole weight of the body
- the calf muscles exert the effort, pulling the heel superiorly

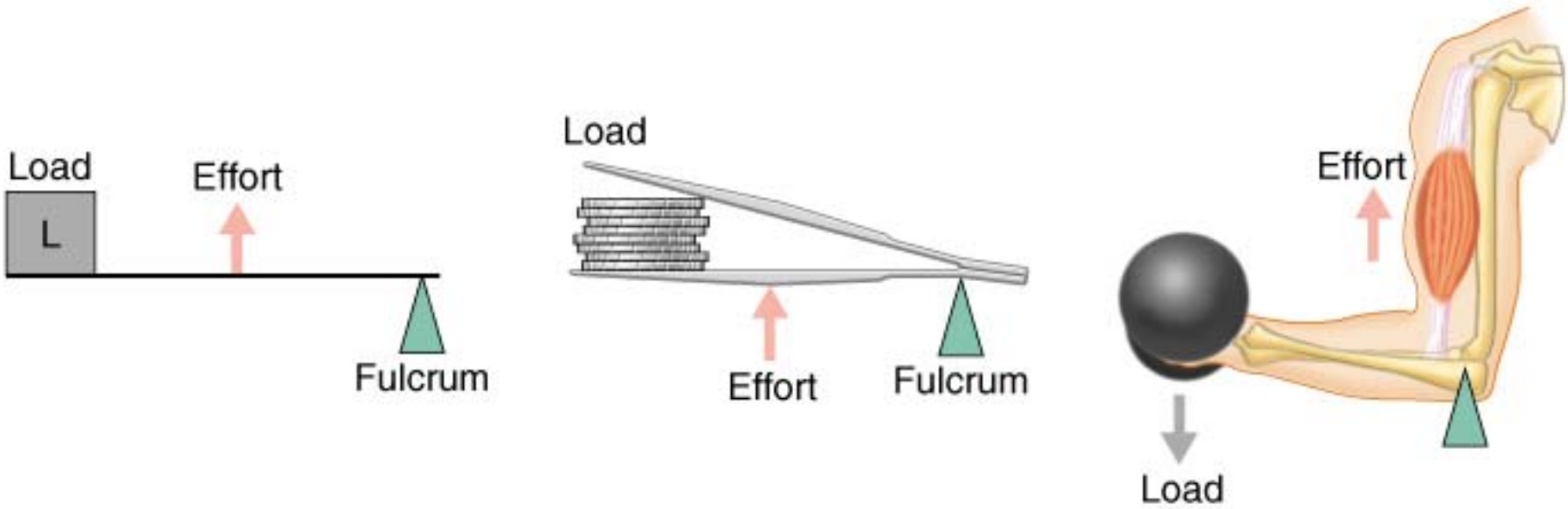
Second-class levers

Function:

- To magnify force
- To conserve energy (because muscles can use less amount of force with minimum energy to produce work)

Third-class levers

- *Effort* is applied between the *falcrum* and the *load*
- Common in the body (most skeletal muscles)
- Example: tweezers, biceps brachii



(c) Third-class lever

Third-class levers

In the **biceps** example:

- the falcrum is the elbow joint
- the force (effort) is exerted on the proximal end of the radius
- the load is the distal part of the forearm, plus anything carried in the hand

Third-class levers

- All work at a **mechanical disadvantage** (MA<1) because the muscle insertion (effort) is closer to the falcrum than the load

- A large effort is applied to overcome a moderate resistance
- Provide increased ***speed*** and ***range of motion***

Third-class levers

- Most skeletal muscles are inserted close to the joint around which movement occurs 

  allows fast movement with relatively little shortening of the muscle (humans are built for speed more than for strength)

- Permits us to move our limbs quickly, such as when we run or throw

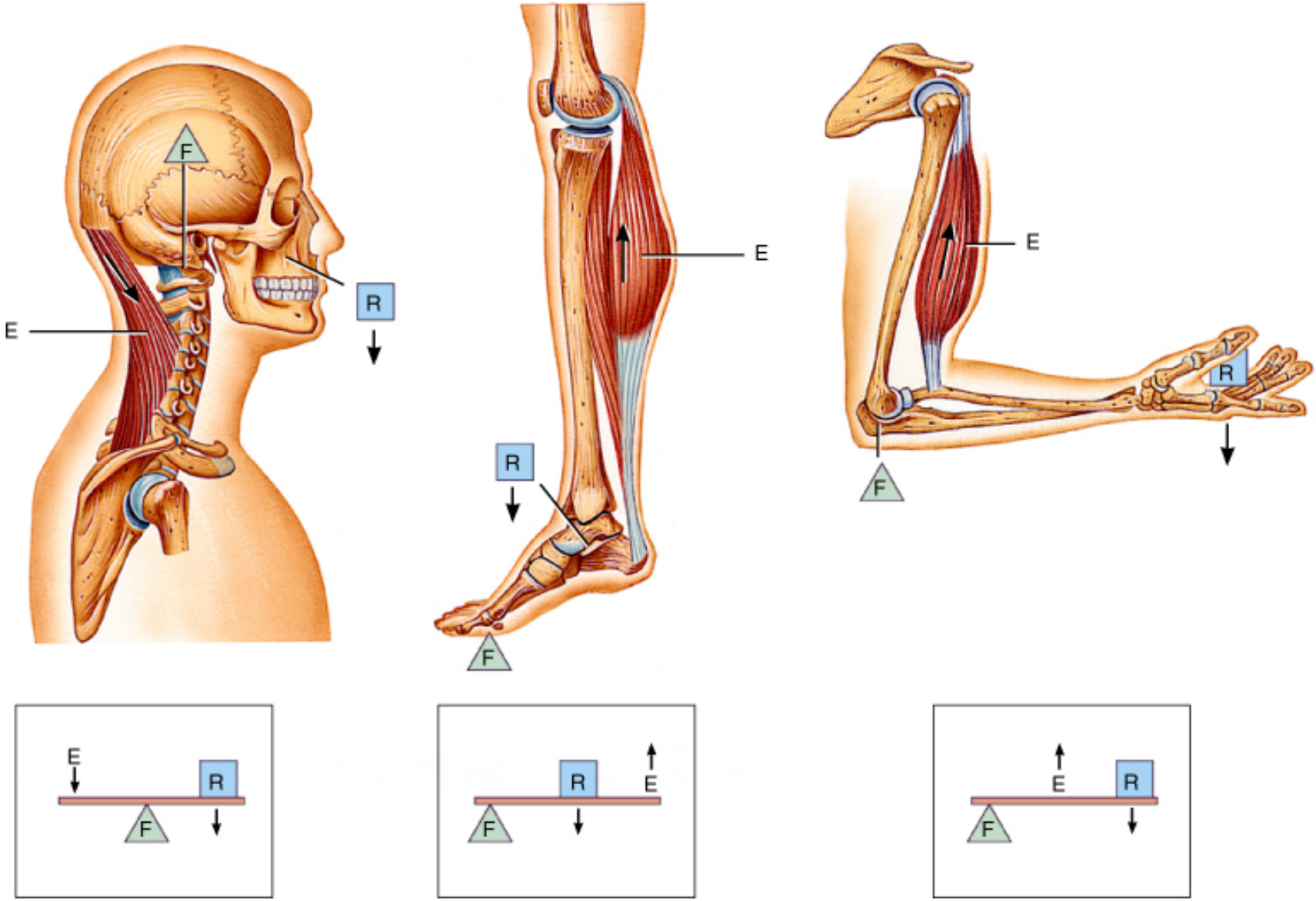
Difference between levers?

- Differences in positioning of the three lever-elements (effort, load, falcrum), modify the activity of muscles with respect to:
  - Speed of contraction
  - Range of movement
  - The weight of the load that can be lifted

Difference between levers?

- In lever systems that operate at a **mechanical disadvantage**:
  - force is lost
  - speed and range of motion are gained

- Lever systems that operate at a **mechanical advantage**:
  - used where strength is needed
  - tend to be slower and more stable



(a) First-class lever

(b) Second-class lever

(c) Third-class lever