Basic Biomechanics

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Basic Terms

- **Mechanics /**branch of physics dealing with the study of forces and the motion produced by their actions.
- **Biomechanics/**involves taking the principles and methods of mechanics and applying them to the structure and function of the human body.
- Mechanics can be divided into **two main areas**: statics and dynamics.
- **Statics :**deals with factors associated with nonmoving, or nearly nonmoving systems.
- **Dynamics:** involves factors associated with moving systems

- **Dynamics divided into kinetics and kinematics.**
- **Kinetics/**deals with forces causing movement in a system,
- **Kinematics/i**nvolves the time, space, and mass aspects of a moving system.
- **Kinematics can be divided** into osteokinematics and arthrokinematics.
- **Osteokinematics/**deals with the manner in which bones move in space without regard to the movement of joint surfaces, such as shoulder flexion/extension.
- **Arthrokinematics/**deals with the manner in which adjoining joint surfaces move in relation to each other, that is, in the same or opposite direction.

- **Force :** a push or pull action . A form of energy that causes movement and has direction and magnitude.
- **Vector :** a quantity having both magnitude and direction. Force is a vector
- **Scalar quantity** describes only magnitude.
- Common scalar terms: length, area, volume, and mass.
- **Mass:** amount of matter that a body contains.

- **Inertia:** the property of matter that causes it to resist any change of its motion in either speed or direction.
- Mass is a measure of inertia; its resistance to a change in motion.
- **Kinetics :**is a description of motion with regard to what causes motion.
- **Torque :** the tendency of force to produce rotation about an axis.
- **Velocity:** a vector that describes speed and is measured in units such as feet per second or miles per hour.

Friction

- A force developed by two surfaces, which tends to prevent motion of one surface across another.
- Friction is the relative resistance between two surfaces.
- It can be advantageous or deleterious, depending on the circumstances.
- A patient who is very weak may have difficulty abducting the thigh in supine because friction of the leg against the treatment table adds resistance. If the surface is made smoother by applying a friction-reducing agent such as talcum powder, the activity is easier.
- Sometimes we want to increase friction to obtain more traction and apply more force. Cleats on football shoes or tread on basketball shoes are good examples of this.
- When decreasing friction is desirable, such as on the uneven parallel bars in gymnastics, a substance such as chalk is used to reduce friction and minimize the risk of blisters.

Laws of Motion

Newton's Laws

- Motion is happening all around you—people walking, cars traveling on highways, airplanes flying in the air, water flowing in rivers, balls being thrown, and so on.
- Isaac Newton's three laws explain all types of motion.

Newton’s first law of motion

- An object at rest tends to stay at rest, and an object in motion tends to stay in motion.

- **=law of inertia,** because inertia is the tendency of an object to stay at rest or in motion.

Newton’s second law of motion

- **=law of acceleration:**
- the amount of acceleration depends on the strength of the force applied to an object.
- Acceleration is any change in the velocity of an object.
- Acceleration can also deal with a change in direction.
- Force is needed to change direction and, according to the law, the change in direction of an object depends on the force applied to it.
- Another part of Newton’s second law deals with the mass of an object.
- Acceleration is inversely proportional to the mass of an object.

Newton's third law of motion

- =**law of action reaction,**
- For every action there is an equal and opposite reaction.

- Can be demonstrated by jumping on a trampoline.

Newton's Three Laws of Motion

Here is a summary of Newton's first three laws:

1. **Newton's first law of motion: inertia.** A body remains at a state of rest or remains in uniform motion until a force acts on it.
2. **Newton's second law of motion: acceleration and momentum.** The acceleration of an object is directly proportional to the force causing motion and inversely proportional to the mass of the object being moved.
3. **Newton's third law of motion: action-reaction.** For every action there is an equal and opposite reaction.

Force

- No motion can occur without a force.
- There are basically two types of force that will cause the body to move.
- Internal: such as muscular contraction, ligamentous restraint, or bony support.
- External: gravity or any externally applied resistance such as weight, friction,

- To create a force, one object must act on another.
- Force can either be a push, which creates compression, or pull, which creates tension.

- Movement occurs if one side pushes or pulls harder than the other.

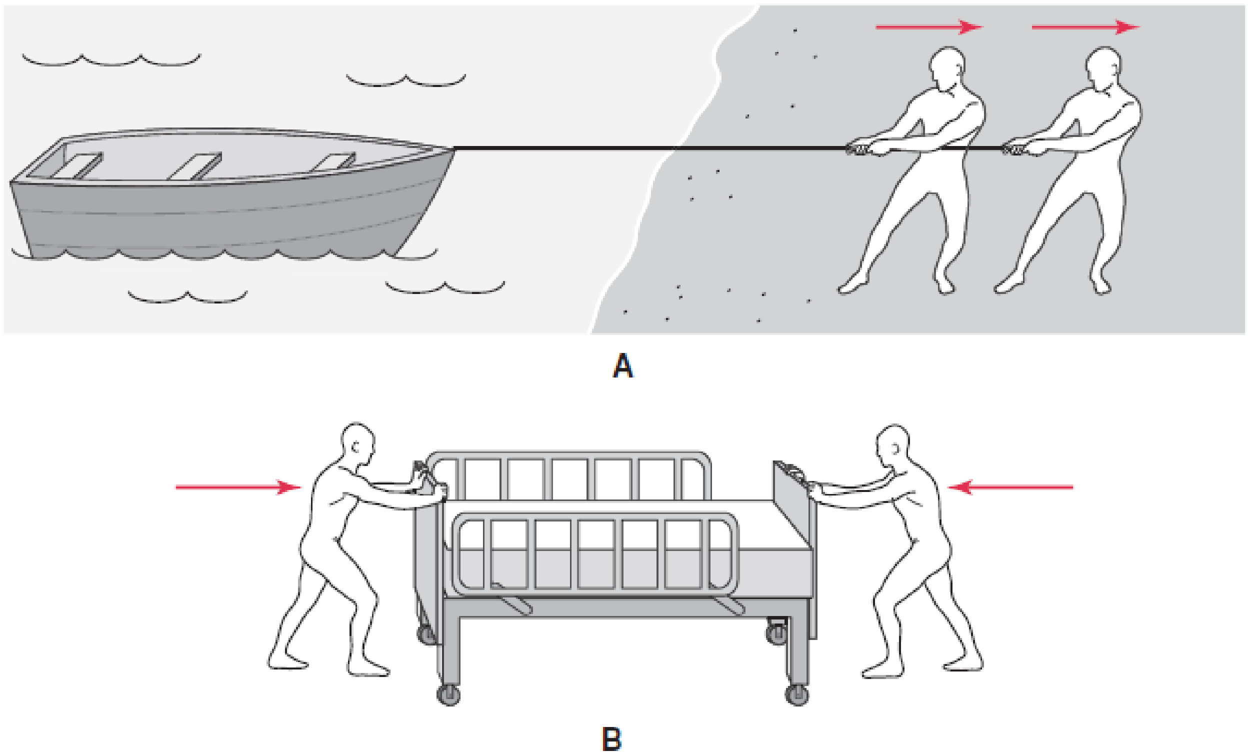
Force Vector

- Forces are vector quantities.
- A **vector quantity** describes both magnitude and direction.
- A vector force can be shown graphically by a straight line of appropriate length and direction.

- The characteristics of force include:
- 1. Magnitude
- 2. Direction
- 3. Point of application

Linear Force

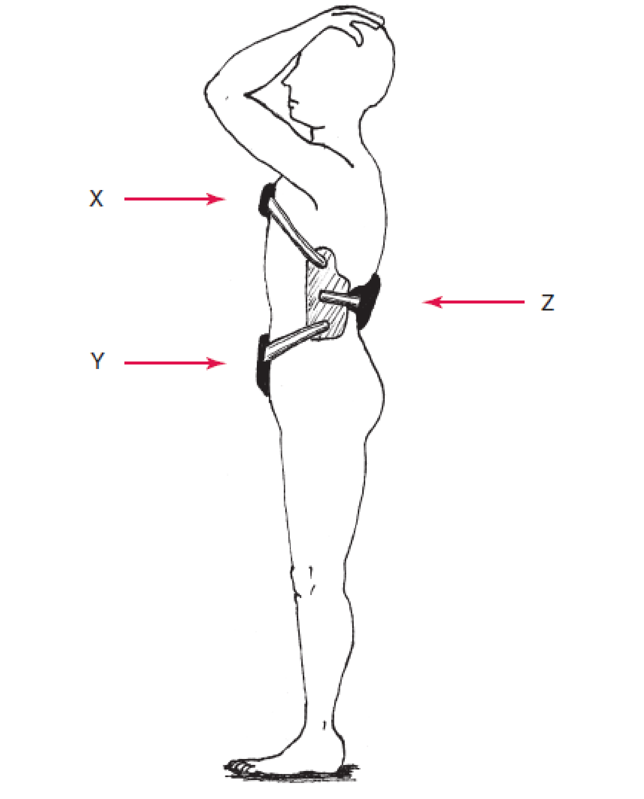
- Results when two or more forces are acting along the same line.



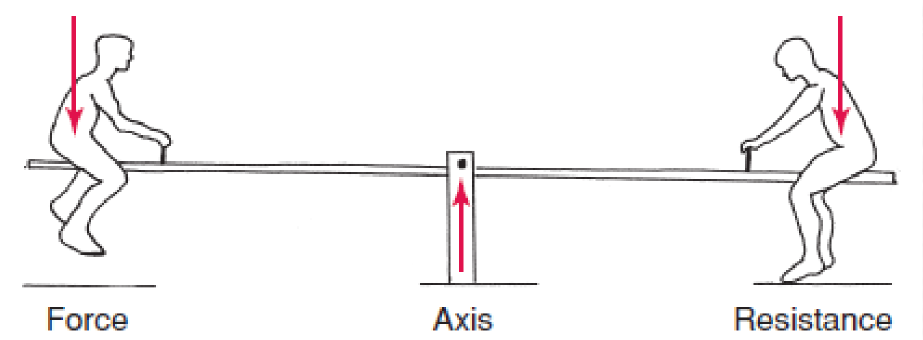
Linear forces. *(A)* Two people pulling in same direction. *(B)* Two people pushing with same force in opposite directions.

Parallel Forces

- Occur in the same plane and in the same or opposite direction
- As three-point pressures of bracing



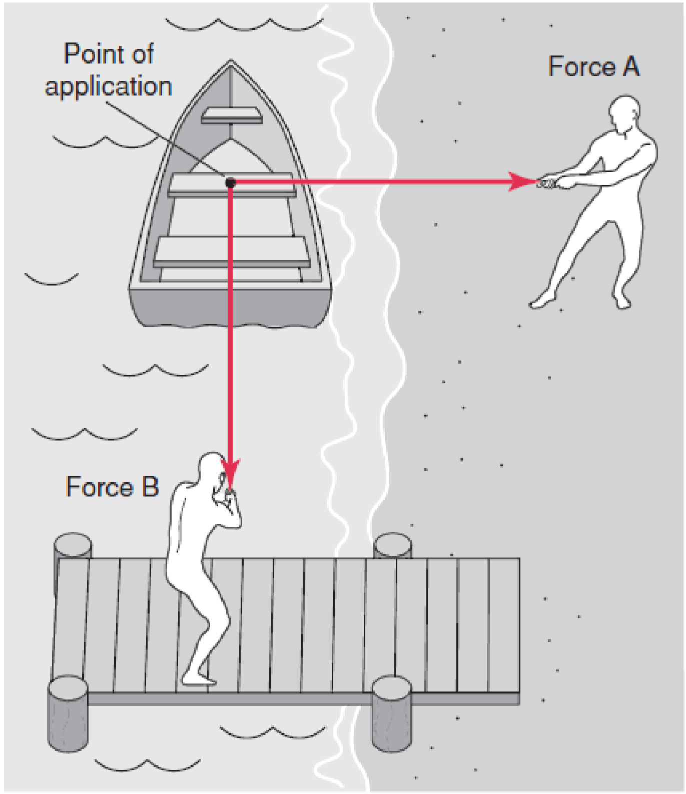
Parallel forces of body brace. Forces *x* and *y* are parallel in the same direction while force *z* is parallel, but in the opposite direction. Force *z* must be in between forces *x* and *y* to provide stability. If force *z* were at either end, instead of the middle, motion would occur.



Parallel forces of two children on seesaw with counterforce in the middle.

Concurrent Forces

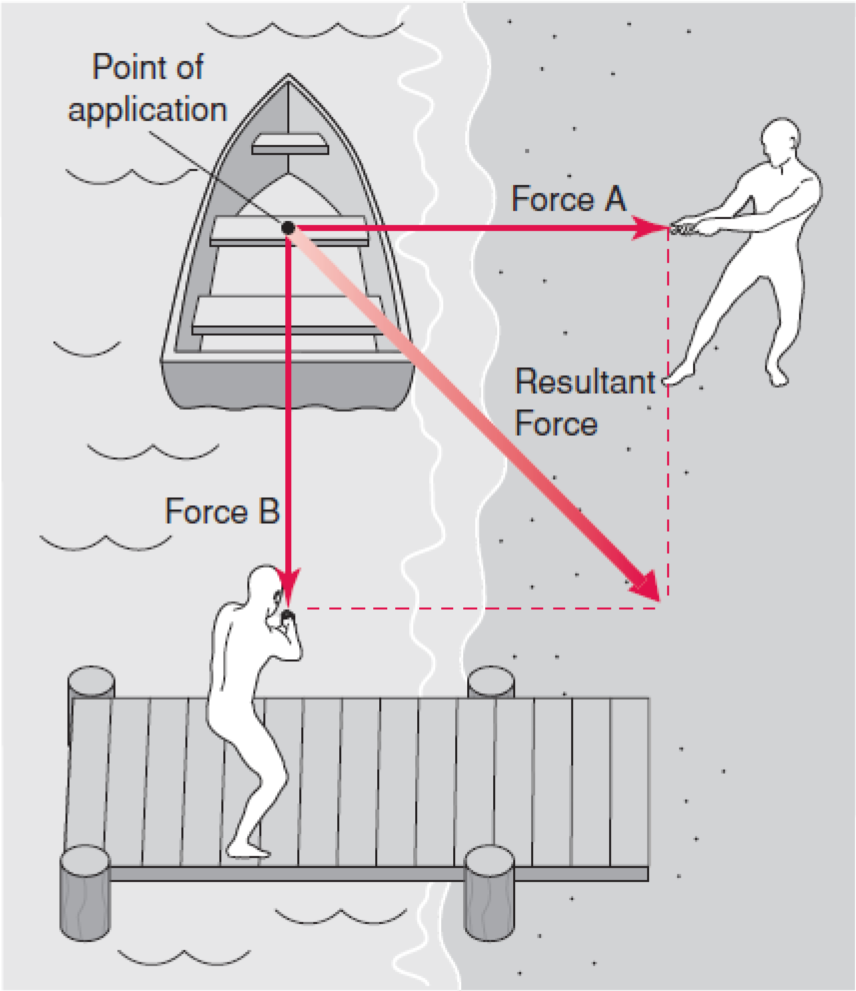
- Two or more forces must act from a common point but pull in different (divergent) directions,
- Such as the two people pulling on the boat /
- The net effect of these two divergent forces is called the resultant force



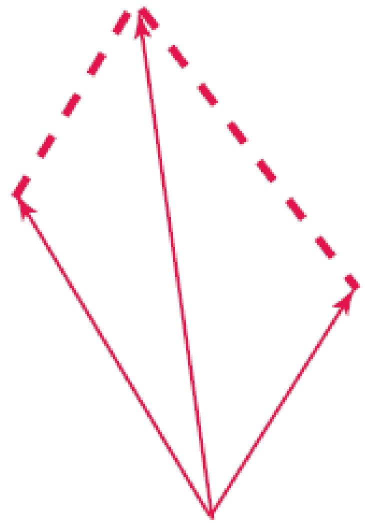
Concurrent force system. Two people pulling at different angles to each other through a common point of application.

Parallelogram

- Because forces are vectors, they can be shown graphically using what is called the parallelogram method.
- First draw in vectors for the two forces (solid lines).
- Secondly, complete the parallelogram using dotted lines.
- Lastly, draw in the diagonal of the parallelogram (middle line and arrow).
- This diagonal line represents the resultant force.



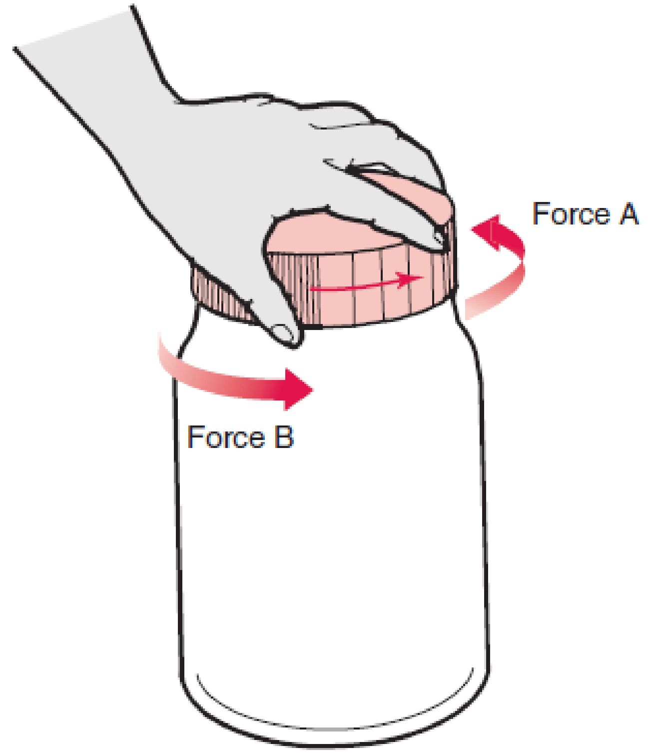
A parallelogram shows graphically the resultant force of two divergent forces pulling on the boat.



Resultant force of unequal forces moves toward the stronger force.

Force Couple

- A force couple occurs when two forces act in an equal but opposite direction resulting in a turning effect.

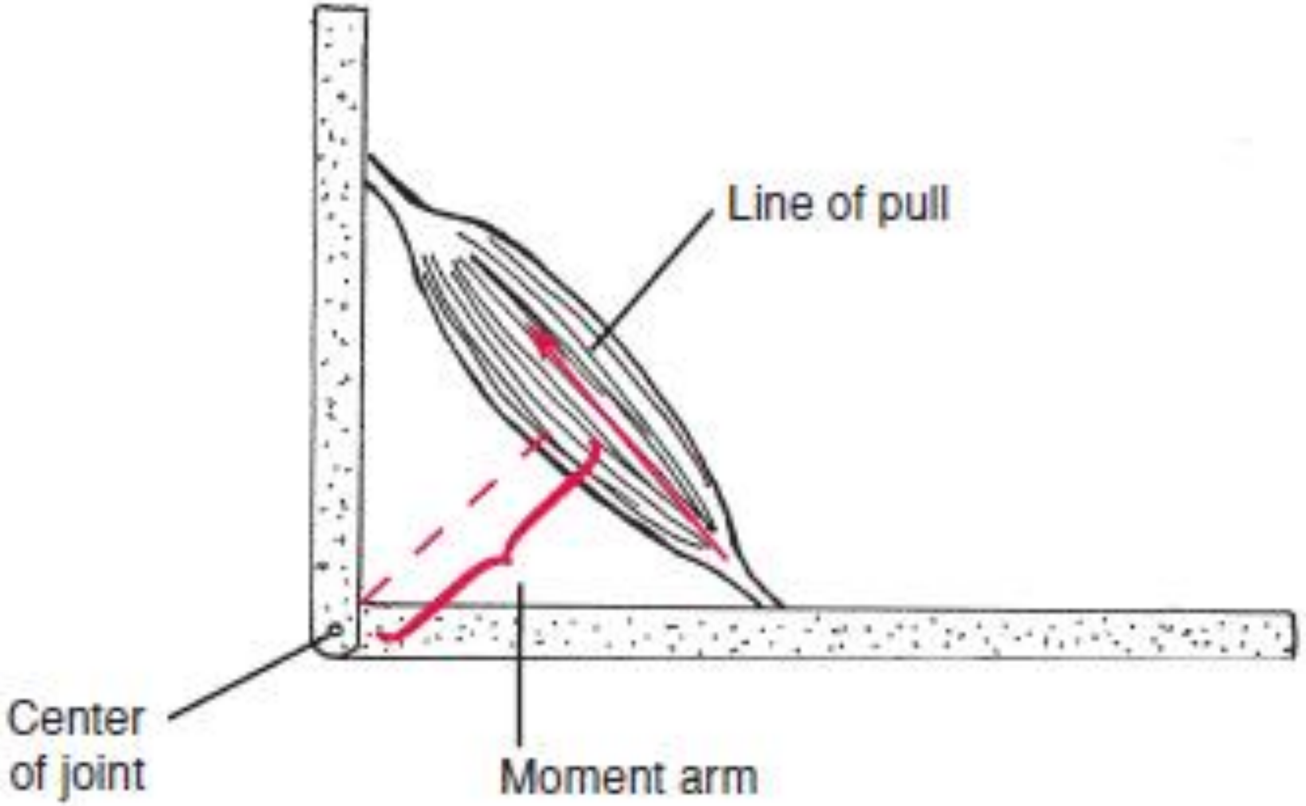


Force couple unscrewing lid.

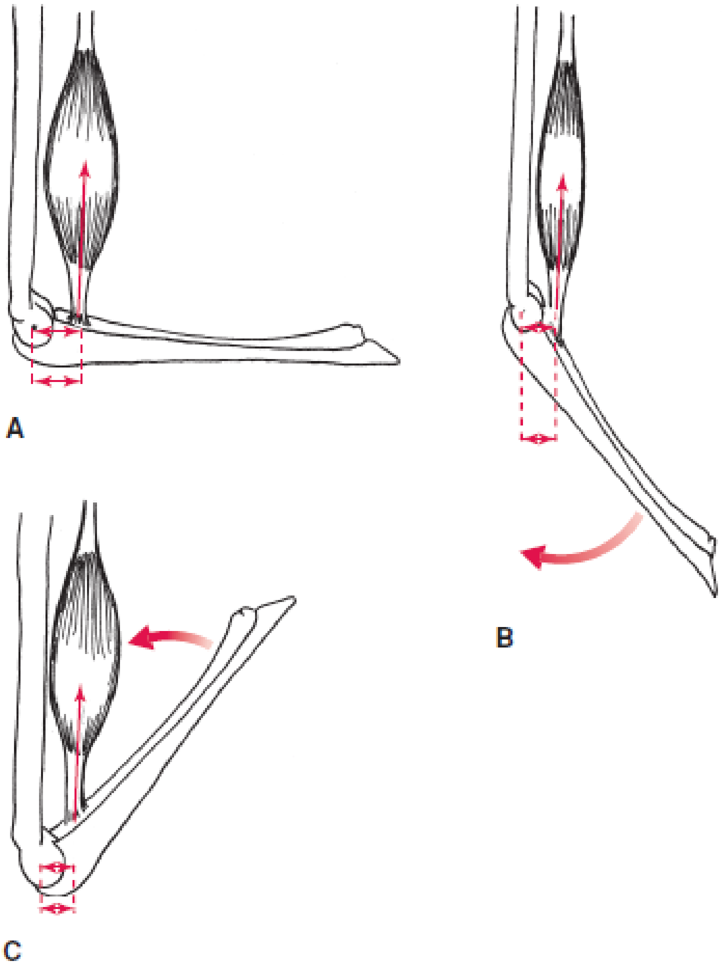
Torque

- Also known as moment of force,
- Ability of force to produce rotation about an axis
- Can be thought of as rotary force.
- The amount of torque a lever has depends on the amount of force exerted and the distance it is from the axis.
- Torque is also the amount of force needed by a muscle contraction to cause rotary joint motion.

- Torque about any point (axis) equals the product of the force magnitude and its perpendicular distance from the line of action of the force to the axis of rotation.
- The perpendicular distance is called the **moment arm or *torque arm***
- Therefore, the moment arm of a muscle is the perpendicular distance between the muscle’s line of pull and the center of the joint (axis of rotation).
- Torque is greatest when the angle of pull is at 90 degrees and decreases as the angle of pull either decreases or increases from that perpendicular position.



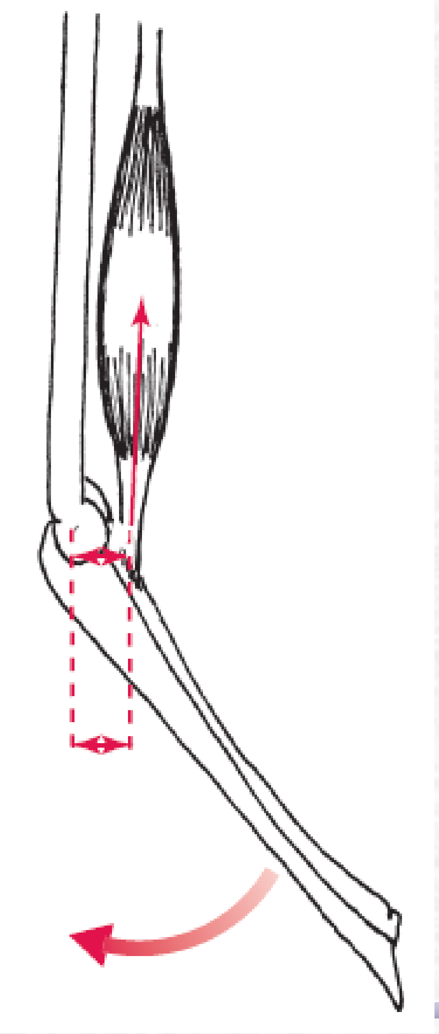
Moment arm of biceps is the perpendicular distance between the muscle's point of attachment and the center of the joint.



Effect of moment arm on torque. *(A)* Moment arm and angular force are greatest at 90 degrees. *(B)* Moment arm decreases as joint moves toward 0 degrees and stabilizing force increases. *(C)* Moment arm decreases as joint moves beyond 90 degrees toward 180 degrees and dislocating force increases. In both cases, when the stabilizing and dislocating forces are increasing, the angular force is decreasing. Stated another way, a muscle is most efficient at moving a joint or rotating when the joint is at 90 degrees. It becomes less efficient at moving or rotating when the joint angle is either increasing or decreasing.

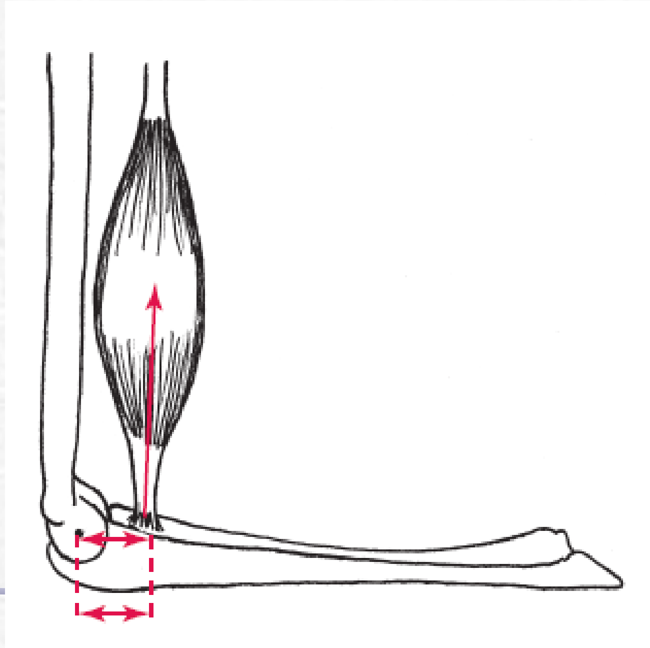
Stabilizing Force

- No torque is produced if the force is directed exactly through the axis of rotation.
- Although this is not quite possible for a muscle, it comes very close.
- For example, if the biceps contracts when the elbow is nearly or completely extended, there is very little torque produced
- The perpendicular distance between the joint axis and the line of pull is very small.
- Therefore, the force generated by the muscle is primarily a stabilizing force, in that nearly all of the force generated by the muscle is directed back into the joint, pulling the two bones together.



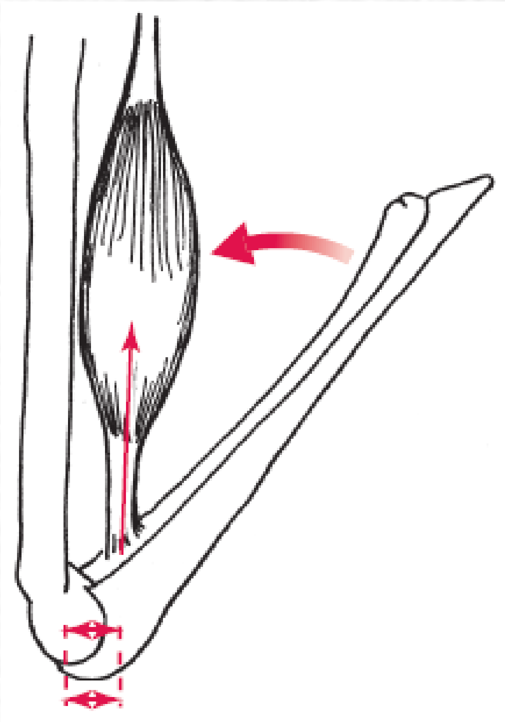
Angular Force

- When the angle of pull is at 90 Degrees the perpendicular distance between the joint axis and the line of pull is much larger.
- Therefore, the force generated by the muscle is primarily an angular force (or movement force), in that most of the force generated by the muscle is directed at rotating the joint and not stabilizing the joint.



Dislocating Force

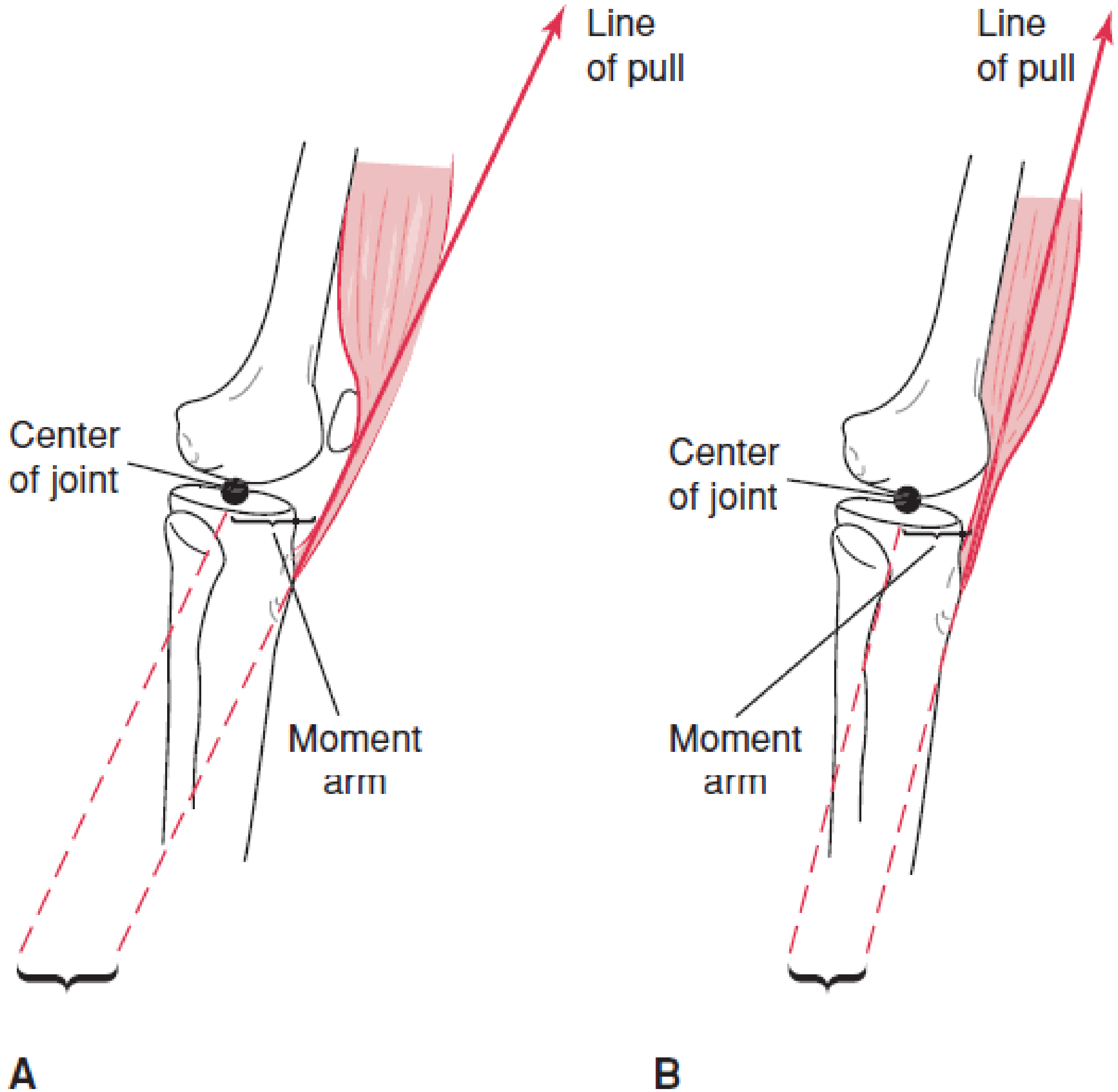
- As a muscle contracts through its range of motion (ROM), the amount of angular or stabilizing force changes.
- As the muscle increases its angular force, it decreases its stabilizing force and vice versa.
- At 90 degrees, or halfway through its range, the muscle has its greatest angular force.
- Past 90 degrees, the stabilizing force becomes a dislocating force because the force is directed away from the joint



Quadriceps & Patella

- The angular force of the quadriceps muscle is increased by the presence of the patella.

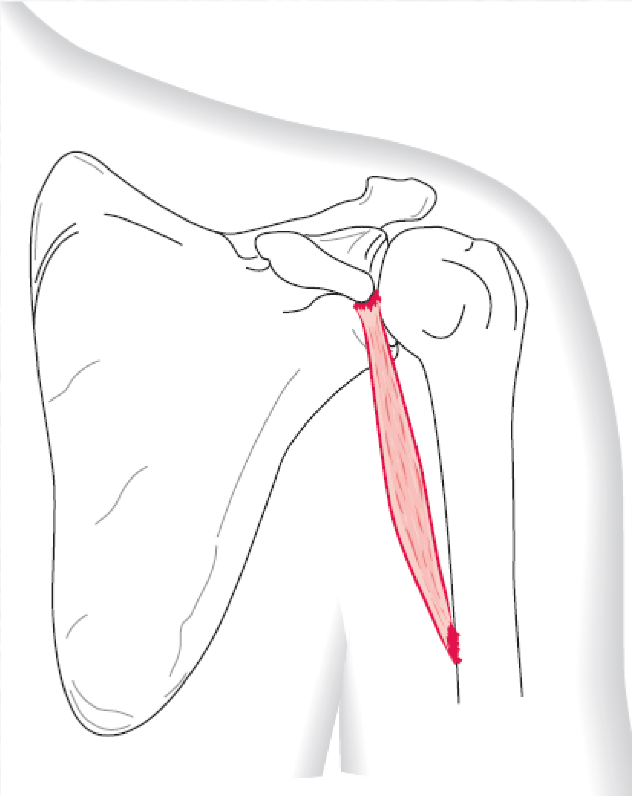
- The patella, increases the moment arm of the quadriceps muscle, allowing the muscle to have a greater angular force
- Without a patella, the moment arm is smaller and much of the force of the quadriceps is directed back into the joint . Although this is good for stability, it is not effective for motion.
- To have effective knee motion, it is vital that the quadriceps provide a strong angular force.



Moment arm of quadriceps muscle with a patella *(A)* and without a patella *(B)*.

Stabilizing force of coracobrachialis

- Some muscles have a much greater stabilizing force than angular force throughout the range, and therefore are more effective at stabilizing the joint than moving it.
- **Coracobrachialis**
- Its line of pull is mostly vertical and quite close to the axis of the shoulder joint.
- Therefore, it has a very short moment arm, which makes this muscle more effective at stabilizing than at flexing the shoulder joint.



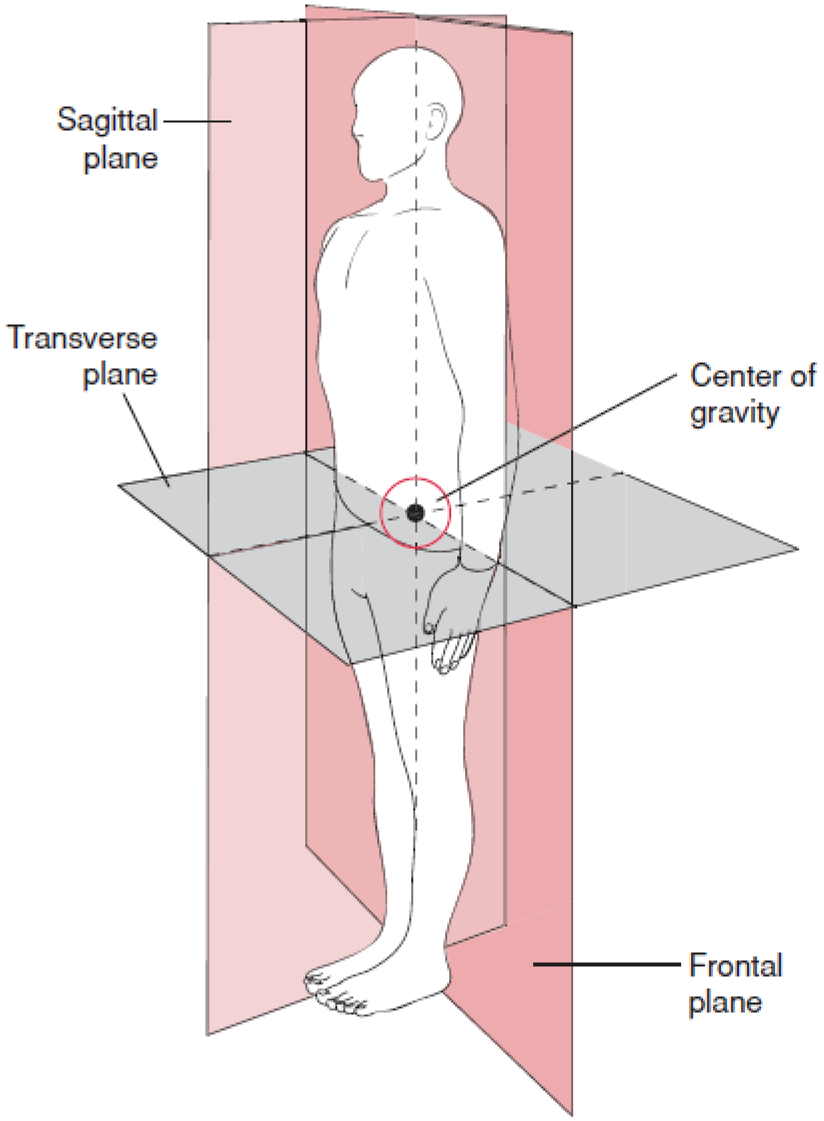
The coracobrachialis muscle.

Stability

- When an object is balanced, all torques acting on it are even, and it is in a **state of equilibrium.**
- State of equilibrium is depends primarily on the relationship between the object's center of gravity and base of support.

Gravity/Center of Gravity

- **Gravity** is the mutual attraction between the earth and an object.
- Gravitational force is always directed vertically downward toward the center of the earth.
- **Center of gravity (COG) :** the balance point of an object at which torque on all sides is equal.
- It is also the point at which the planes of the body intersect,



The center of gravity is the point at which the three cardinal planes intersect.

Human CoG

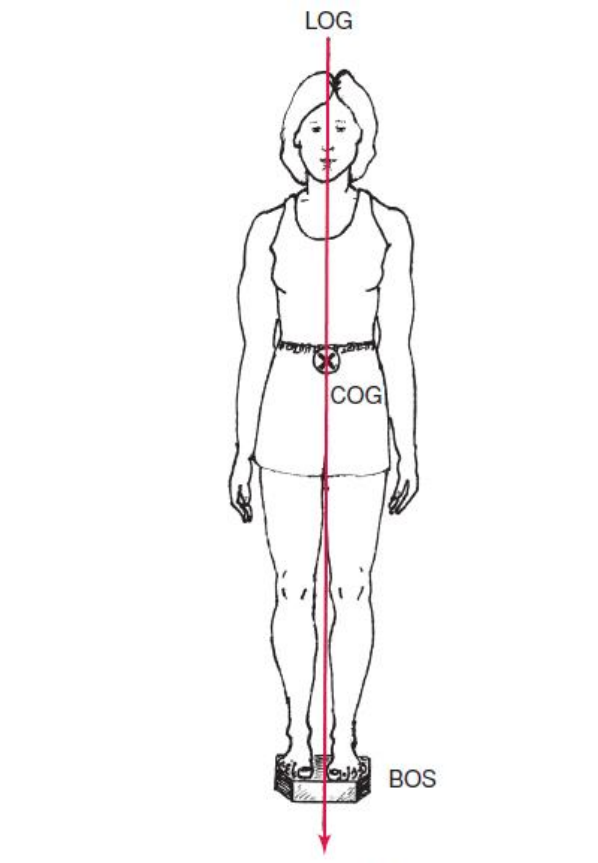
- In the human body, the COG is located in the midline at about the level of, though slightly anterior to, the second sacral vertebra of an adult.
- the COG of a child is higher than that of an adult.

Base of support (BOS)

- That part of a body that is in contact with the supporting surface.
- Outline the surface of the body in contact with the ground

Line of gravity (LOG)

- An imaginary vertical line passing through the COG toward the center of the earth.



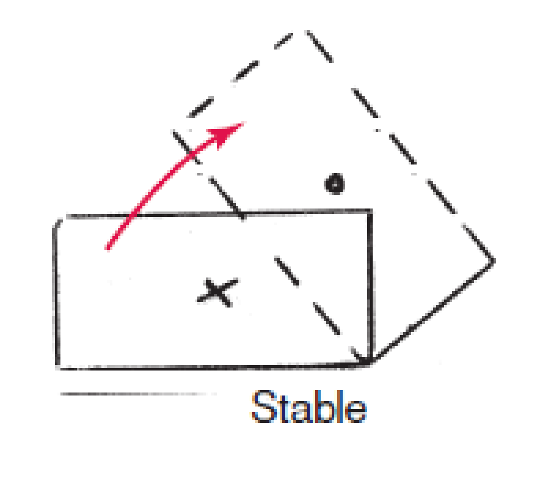
Center of gravity (COG), line of gravity (LOG), and base of support (BOS).

Three states of equilibrium

- Stable equilibrium
- Unstable equilibrium
- Neutral equilibrium

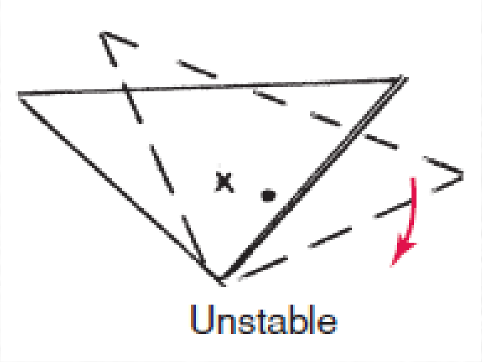
Stable equilibrium

- Occurs when an object is in a position that to disturb it would require its COG to be raised.
- A simple example is that of a brick.
- When the widest part of the brick is in contact with the surface (BOS), it is quite stable
- To disturb it, the brick would have to be tipped up in any direction, thus raising its COG.
- The same could be said of a person lying flat on the floor.



Unstable equilibrium

- When only a slight force is needed to disturb an object.
- Balancing a pencil on the pointed end is a good example.
- A similar example is that of a person standing on one leg.
- Once balanced, it takes very little force to knock the pencil over

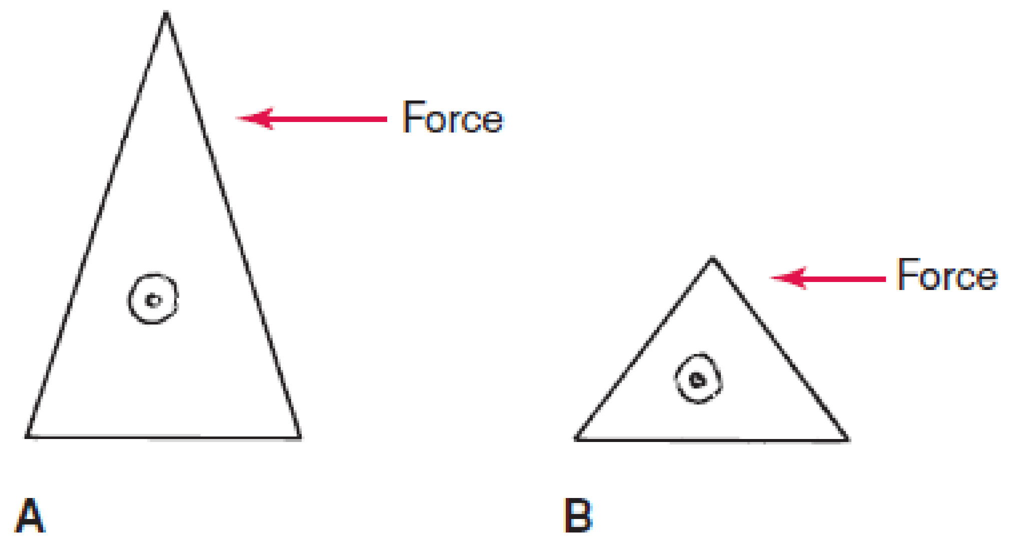


Neutral equilibrium

- Exists when an object’s COG is neither raised nor lowered when it is disturbed.
- A good example would be a ball.
- As the ball rolls across the floor, its COG remains the same

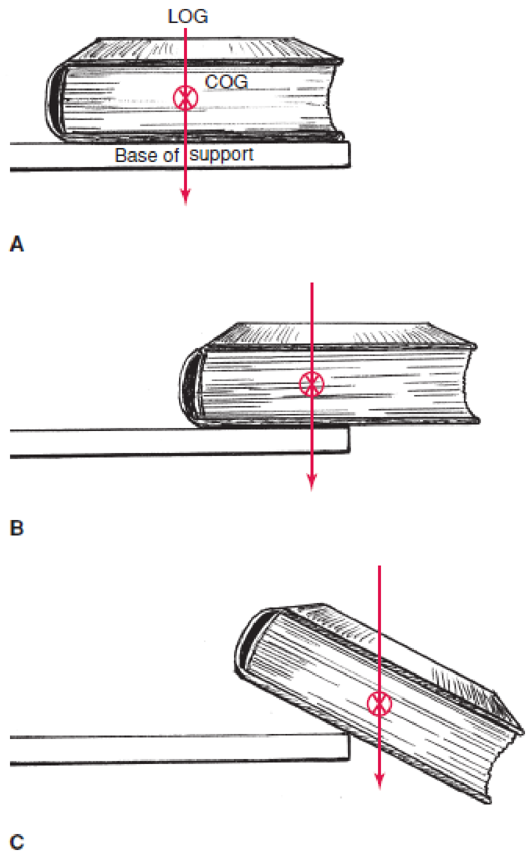
Principles of relationships between balance, stability, and motion

- The lower the COG, the more stable the object.

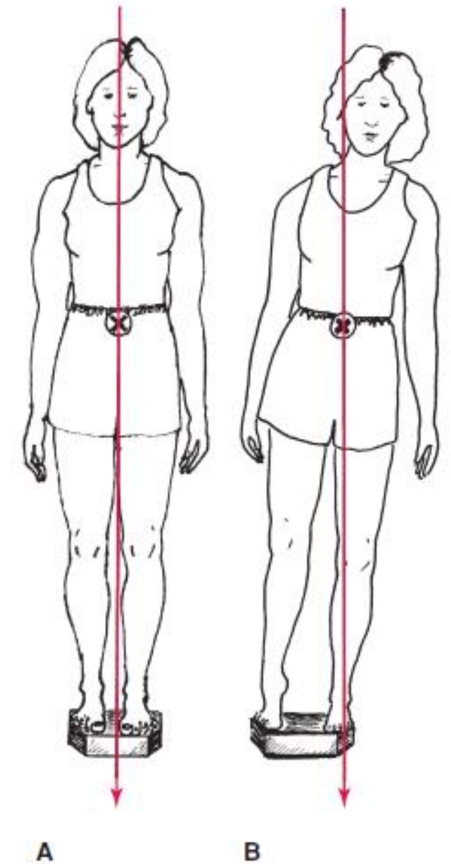


Relationship of height of center of gravity to stability. *(A)* is less stable because it has a higher COG. *(B)* Lower COG is more stable.

- The COG and LOG must remain within the BOS for an object to remain stable.
- Wider the BOS, the more stable the object.



Relationship of COG to BOS. *(A)* The book is very stable because its COG is in the middle of its BOS. *(B)* The book is less stable because its COG is near the edge of its BOS. *(C)* The book is unstable and will fall because its COG is beyond its BOS.



Relationship of COG to BOS. *(A)* She is stable—her COG is in the middle of her BOS. *(B)* She is less stable because her COG is near the edge of her BOS.

- Stability increases as the BOS is widened in the direction of the force.
- A person standing at a bus stop on a very windy day would be more stable when facing into the wind and placing one foot behind the other, thus widening the BOS in the direction of the wind

Wider base of support in direction of force increases stability.

- The greater the mass of an object, the greater its stability.
- The size of players on a football team. Linebackers are traditionally heavier, and thus harder to push over.
- Halfbacks, whose job is to run with the ball, are much lighter. It can be said that what is gained in stability is lost in speed and vice versa.

- The greater the friction between the supporting surface and the BOS, the more stable the body will be.
- Walking on an icy sidewalk is a slippery experience because there is essentially no friction between the ice and the shoe.
- Sanding the sidewalk increases the friction of the icy surface, thus improving traction.
- Pushing a wheelchair across a hardwood floor is much easier than pushing one across a carpeted floor. The carpet creates more friction, making it harder to push the wheelchair.

- People have better balance while moving if they focus on a stationary object rather than on a moving object.
- Therefore, people learning to walk with crutches would be more stable by focusing on an object down the hall than by looking down at their moving feet or crutches

Simple Machines

- Levers
- Pulleys
- Wheel and Axle
- Inclined Plane

Simple Machines

- In engineering, various machines are used to change the magnitude or direction of a force.
- The four simple machines are the lever, the pulley, the wheel and axle, and the inclined plane.
- Examples of each of these machines, except for the inclined plane, can be found in the human body.
- The lever, the wheel and axle, and the inclined plane allow a person to exert a force greater than could be exerted by using muscle power alone;
- The pulley allows force to be applied more efficiently.
- This increase in force is usually at the expense of speed and can be expressed in terms of mechanical advantage,

Levers

- There are three classes of levers, each with a different purpose and a different mechanical advantage.
- We use levers daily to help us accomplish various activities.
- Usually a lever will favor either power or distance (range of motion), but not both.
- However, the basic rule of all simple machines is that the advantage gained in power is lost in distance.
- Sometimes, a great deal of power is needed, such as moving a heavy rock.
- Other times, distance (range of motion) is needed, such as swinging a tennis racket.
- Wheelbarrows, crowbars, manual can openers, scissors, golf clubs, and playground seesaws are but a few examples of levers.

Terms

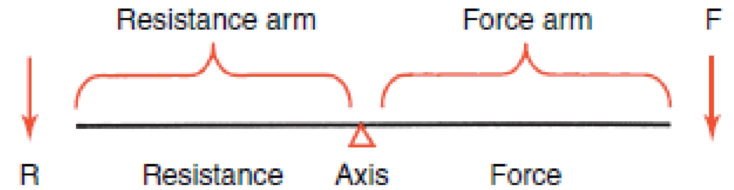
- A **lever** is rigid and can rotate around a fixed point when a force is applied. A bone is an example of a lever in the human body.
- The fixed point around which the lever rotates is the **axis** (A), sometimes referred to as the **fulcrum**. In the body, the joint is the axis.
- The **force** (F), sometimes called the effort, that causes the lever to move is usually muscular.
- The **resistance** (R), sometimes called the **load**, that must be overcome for motion to occur can include the weight of the part being moved (arm, leg, etc.), the pull of gravity on the part, or an external weight being moved by the body part.
- When determining a muscle's role (force or resistance), it is important to use the point of attachment to the bone, not the muscle belly, as the point of reference.
- When determining the resistance of the part, use its COG

- The **force arm** (FA) is the distance between the force and the axis,
- The **resistance arm** (RA) is the distance between the resistance and the axis
- The arrangement of the axis (A) in relation to the force (F) and the resistance (R) determines the type of lever.
- The longer the FA, the easier it is to move the part.
- The longer the RA, the harder it is to move the part.
- With the longer FA, the part will be easier to move, but the FA will have to move a greater distance.
- When the RA is longer, it won’t have to move as far, but it will be harder to move.

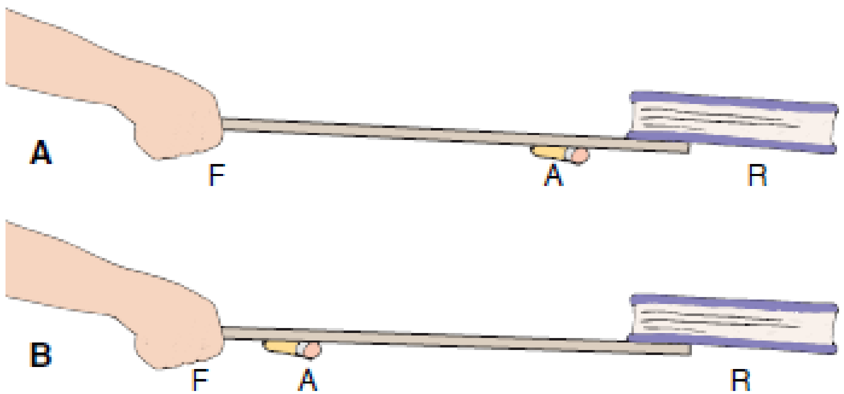
Classes of Levers

First-class lever

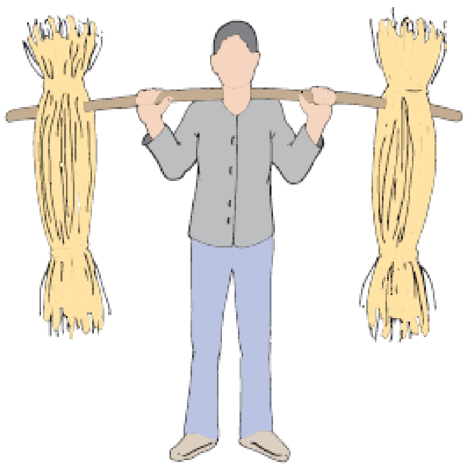
- The axis is located between the force and the resistance:
- If the axis is close to the resistance, the RA will be shorter and the FA will be longer. Therefore, it will be easy to move the resistance.
- If the axis is close to the force, just the opposite will occur; it will be hard to move the resistance.
- By placing the axis close to the resistance, you have a lever that favors force.
- By placing the axis close to the force, you have a lever that favors distance (range of motion) and speed.
- If you place the axis midway between the force and the resistance (assuming they are the same weight), the lever favors balance.



Components of a lever.

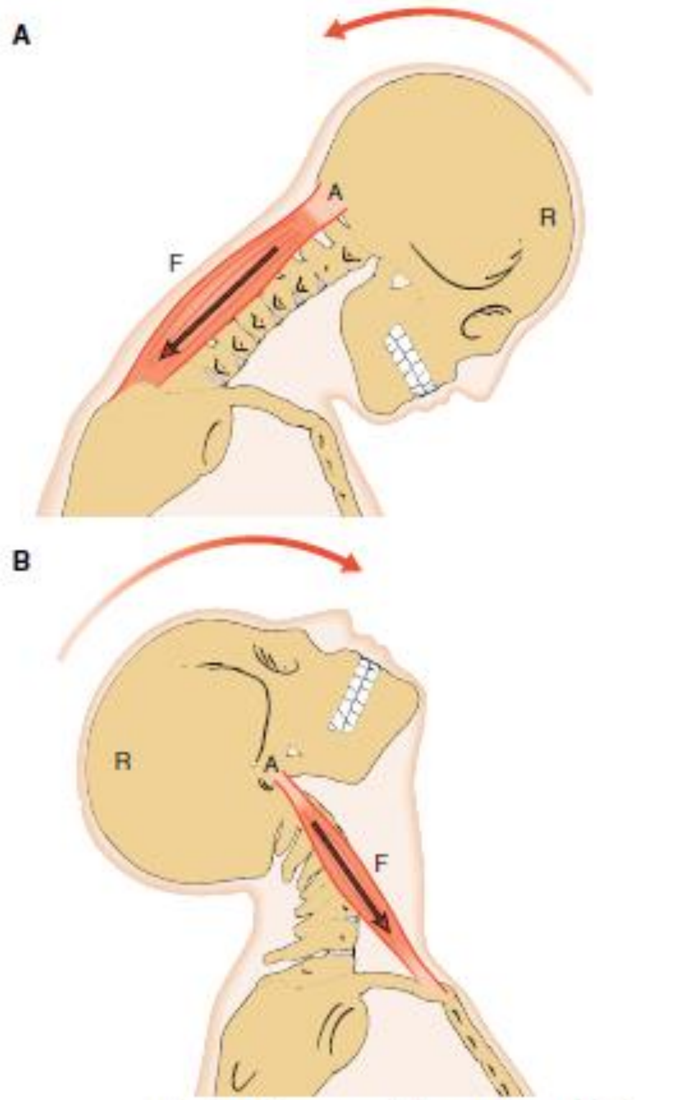


First-class lever. FAR (F = force; A = axis; R = resistance). **(A)** A is closer to R. **(B)** A is closer to F.


First-class lever. The two loads (F and R) are balanced on the shoulders.

First-class lever in the human body

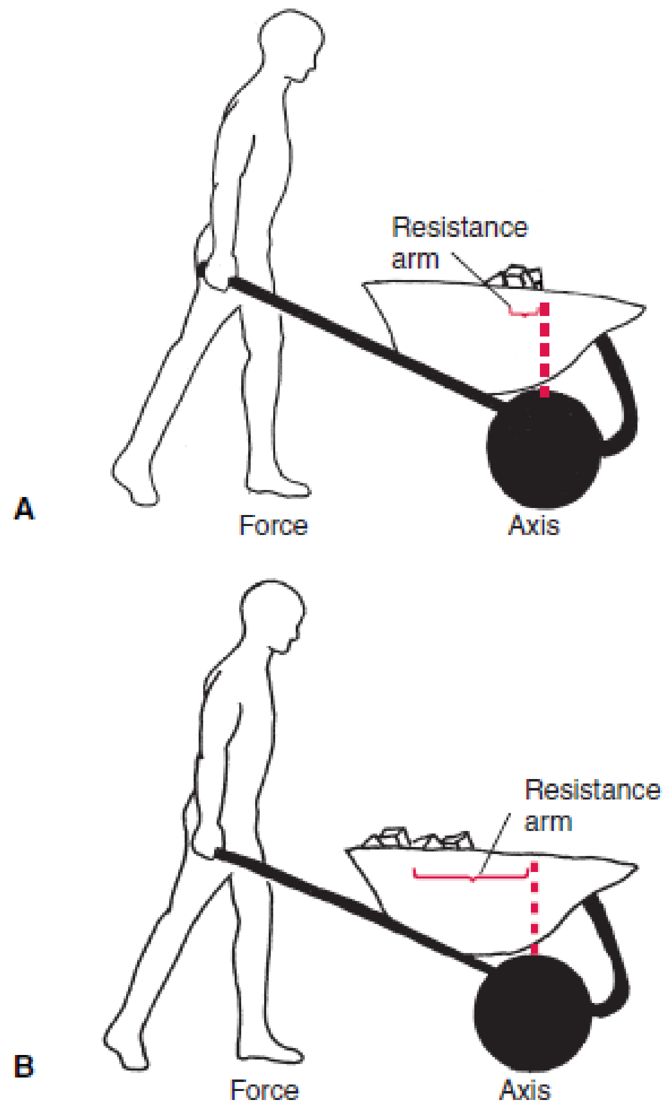
- The head sitting on the first cervical vertebra, moving up and down in cervical flexion and hyperextension.
- The vertebra is the axis, the resistance is the weight on one side of the head, and the force is the muscle pulling down on the opposite side of the head.
- The force and resistance will change places, depending on which way the head is tipped.



Head moving on neck demonstrates a first-class lever. In **(A)**, the axis is the head posteriorly moving on the vertebral column and is located between force (the extensor muscles), and resistance (weight of the head itself). In **(B)**, the axis is the head moving anteriorly on the vertebral column and is located between the force (flexor muscles) and the resistance (weight of head).

Second-class lever

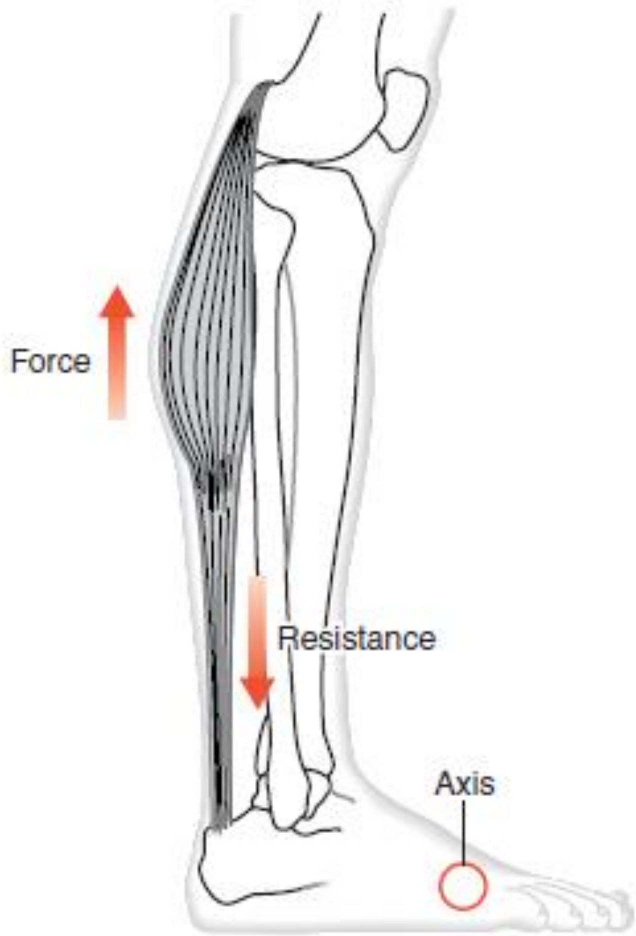
- the resistance is in the middle, with the axis at one end and the force at the other end
- The wheelbarrow is an example of a second-class lever
- The wheel at the front end is the axis, the wheelbarrow contents are the resistance, and the person pushing the wheelbarrow is the force.
- If we assume that the wheelbarrow is carrying a load of heavy bricks, we can apply the earlier statement that the longer the FA, the easier it is to move the part and the longer the RA, the harder it is to move the part.
- If we put all the bricks as close to the wheel as possible, we now have a long FA and a short RA. The wheelbarrow should be fairly easy to move.
- If we move the bricks to the other end of the wheelbarrow the FA remains the same length, but the RA is longer. The wheelbarrow is now harder to move because we have lengthened the RA.



Second-class lever. (A) RA is shorter. (B) RA is longer.

Second-class levers in the body

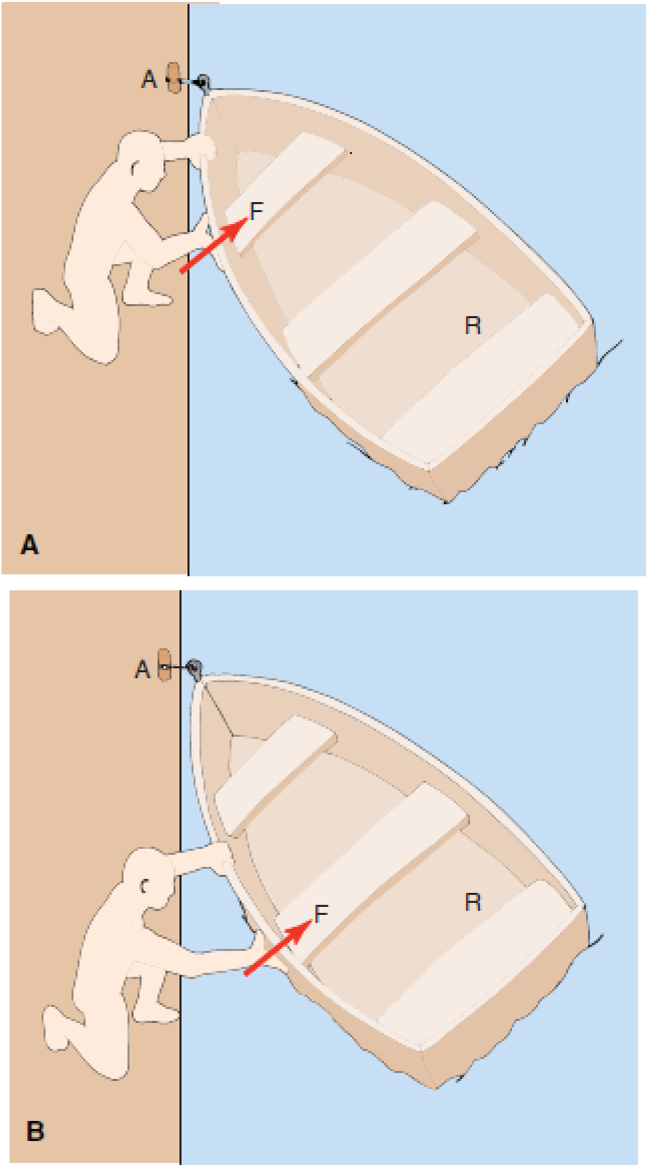
- the action of the ankle plantar flexor muscles when a person stands on tiptoe
- the axis is the metatarsophalangeal (MTP) joints in the foot, the resistance is the tibia and the rest of the body weight above it, and the force is provided by the ankle plantar flexors.
- The resistance (body weight) is between the axis (MTP joint) and the force (plantar flexors).
- The RA is only slightly shorter than the FA.
- This lever favors power because a relatively small force (the muscle) can move a large resistance (the body).
- However, the body can be raised only a fairly short distance. This again proves the basic rule of simple machines—what is gained in power (raising the body weight) is lost in distance (the body can't be raised very far).



Plantar flexors lifting body weight demonstrates a second-class lever.

Third-class lever

- Has force in the middle, with resistance and the axis at the opposite ends

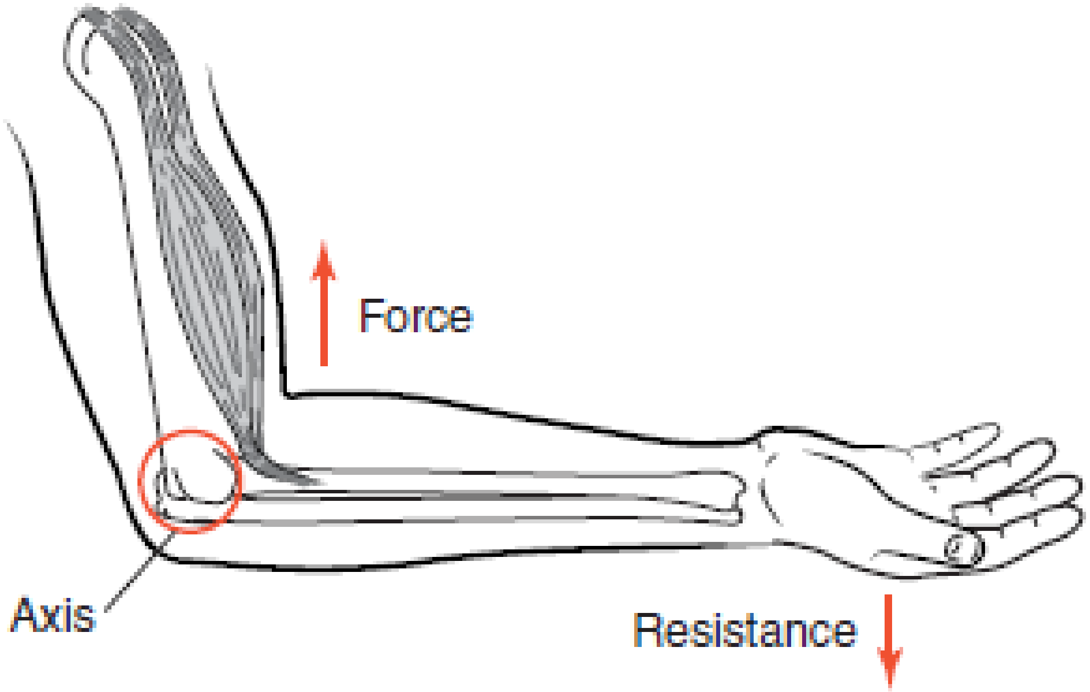


Moving boat tied to dock demonstrates a third-class lever (axis, force, resistance). A is the point where the boat is held against the dock. F is where the person pushes (or pulls) the boat away (toward) the dock, and R is the weight of the boat. In **(A)**, it will be easier to move the boat, while in **(B)** it will be harder.

- Example : a person moving one end of a boat either toward or away from a dock
- The axis is the front of the boat tied to the dock. The force is the person pushing on the boat, and the resistance is the weight of the boat.
- If the person pushes close to the front of the boat, it will be harder to move the boat but the back of the boat will swing farther away from the dock.
- Conversely, if the person pushes farther back on the boat, the boat stern won’t swing away from the dock as far, but it will be easier to move. In this case, the RA doesn’t change, but the FA does.
- When the FA is shorter, the boat is hard to push but moves a greater distance.
- When the FA is lengthened, the boat is easier to push but doesn’t move as far.
- The advantage of the third-class lever is speed and
- distance.

Third-class levers in the body

- The most common lever in the body
- Example: elbow flexion
- The axis is the elbow joint, the biceps muscle exerts the force, and the resistance is the weight of the forearm and hand.
- For the hand to be truly functional, it must be able to move through a wide range of motion. The resistance, in this case, will vary depending on what, if anything, is in the hand.
- Why are there so many third-class levers (which favor speed and distance) and so few second-class levers (which favor power) in the body? Probably because the advantage gained from increased speed and distance is more important than the advantage gained from increased power.

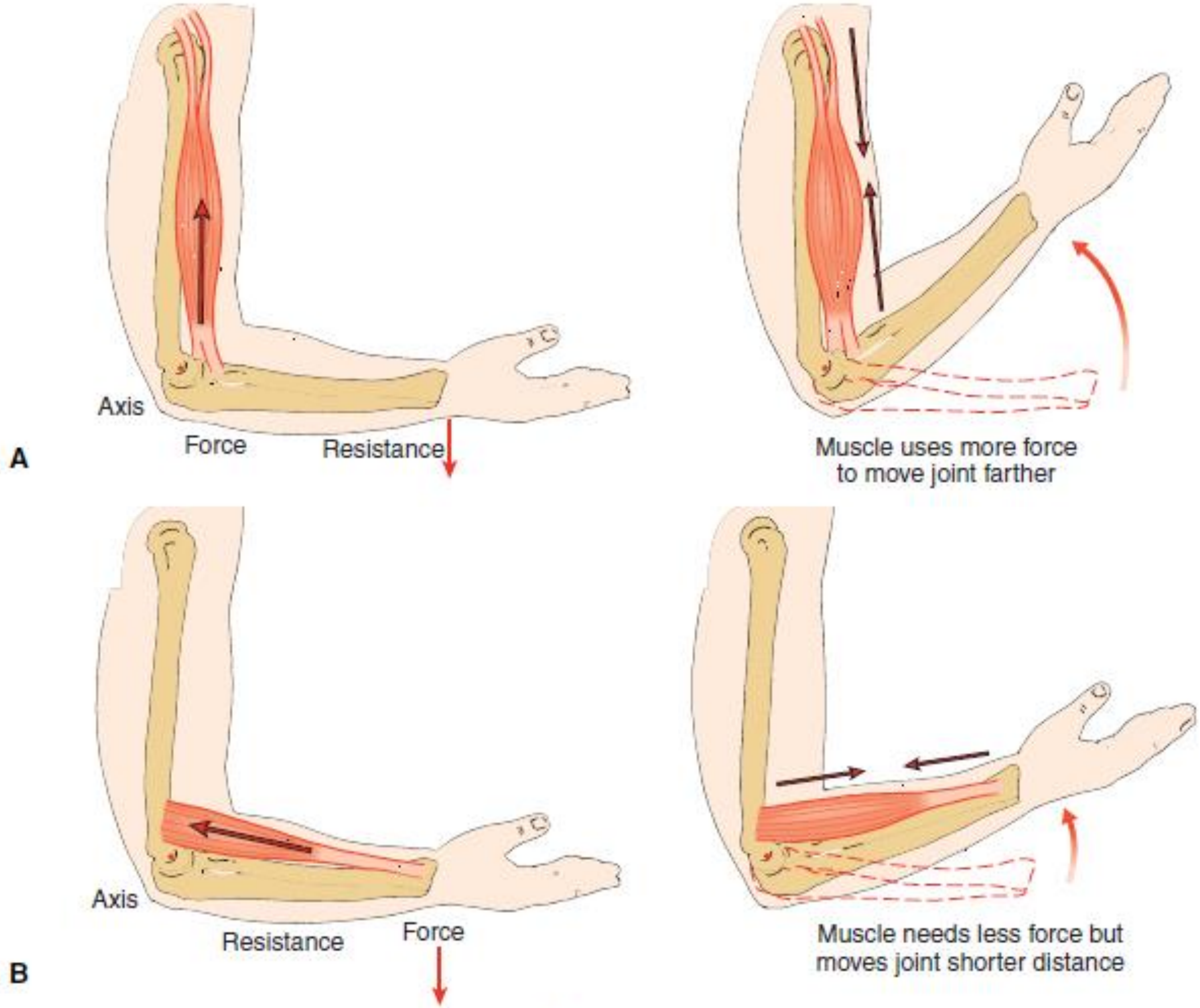


The biceps demonstrating a third-class lever.

Roles of the biceps and the brachioradialis muscles in elbow flexion

- They both cross the elbow but attach to the radius at very different places.
- The biceps muscle attaches to the proximal end of the radius, while the brachioradialis muscle attaches to the distal end.
- The biceps muscle acts as the force in a third-class lever because it attaches between the axis (elbow) and the resistance (COG of forearm/hand).
- The brachioradialis muscle is the force in a second-class lever because it attaches at the end of the forearm, putting the resistance (COG of forearm/hand) in the middle.

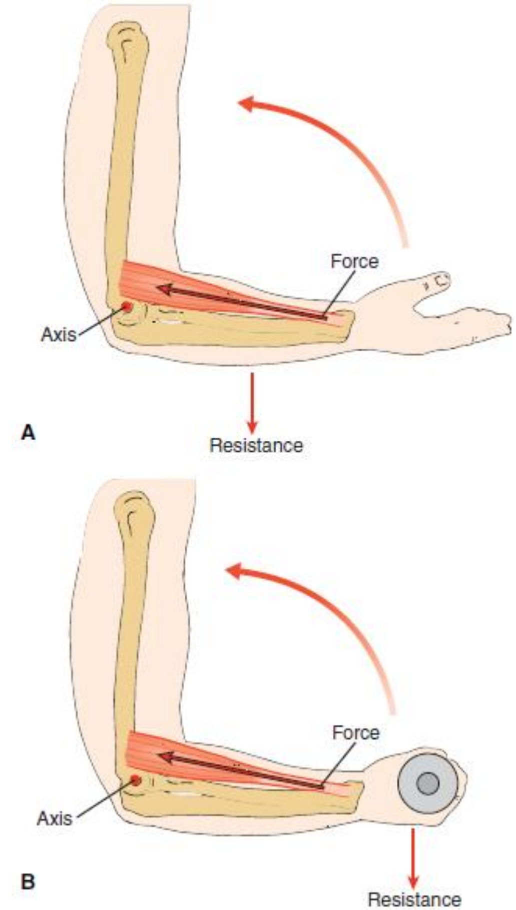
- Because the main function of the upper extremity is to allow the hand to move through a wide range, it makes sense that most muscles act as third-class levers, favoring range of motion.



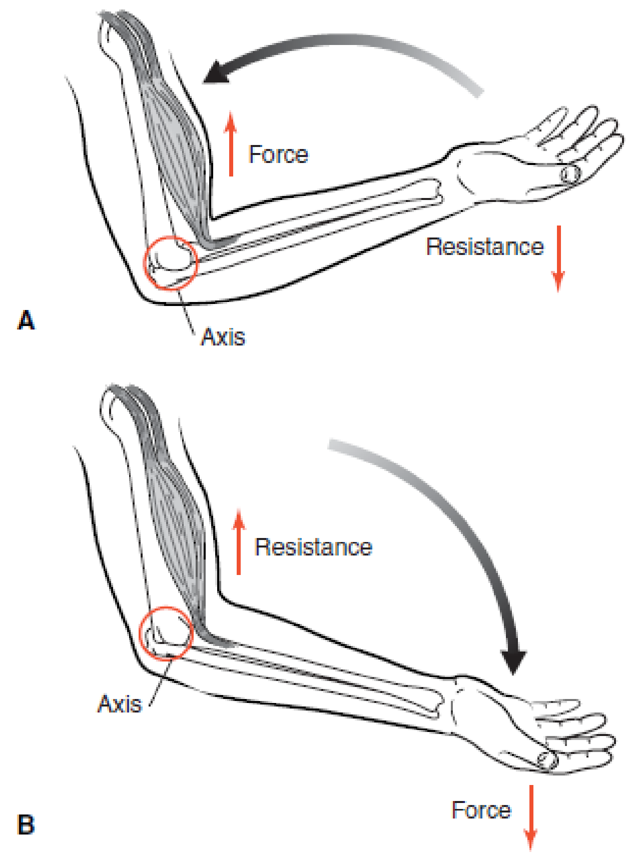
Third-class levers favor distance **(A)**, and second-class levers favor force **(B)**.

Change Class of levers

- Under certain conditions, a muscle may change from a second-class (axis-resistance-force) to a third-class lever (axis-force-resistance), and vice versa.



(A) The brachioradialis as a second-class lever. **(B)** It becomes a third-class lever when a weight is placed in the hand.



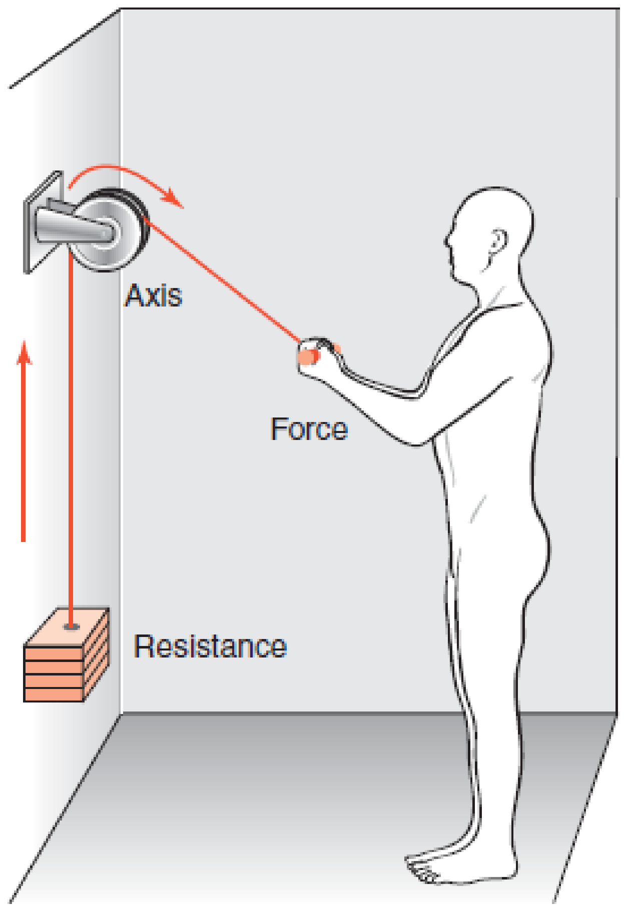
The biceps acts as a third-class lever when contracting concentrically **(A)**, and a second-class lever when contracting eccentrically **(B)**.

Pulleys

- A pulley consists of a grooved wheel that turns on an axle with a rope or cable riding in the groove.
- Its purpose is to either change the direction of a force or to increase or decrease its magnitude.

Fixed Pulley

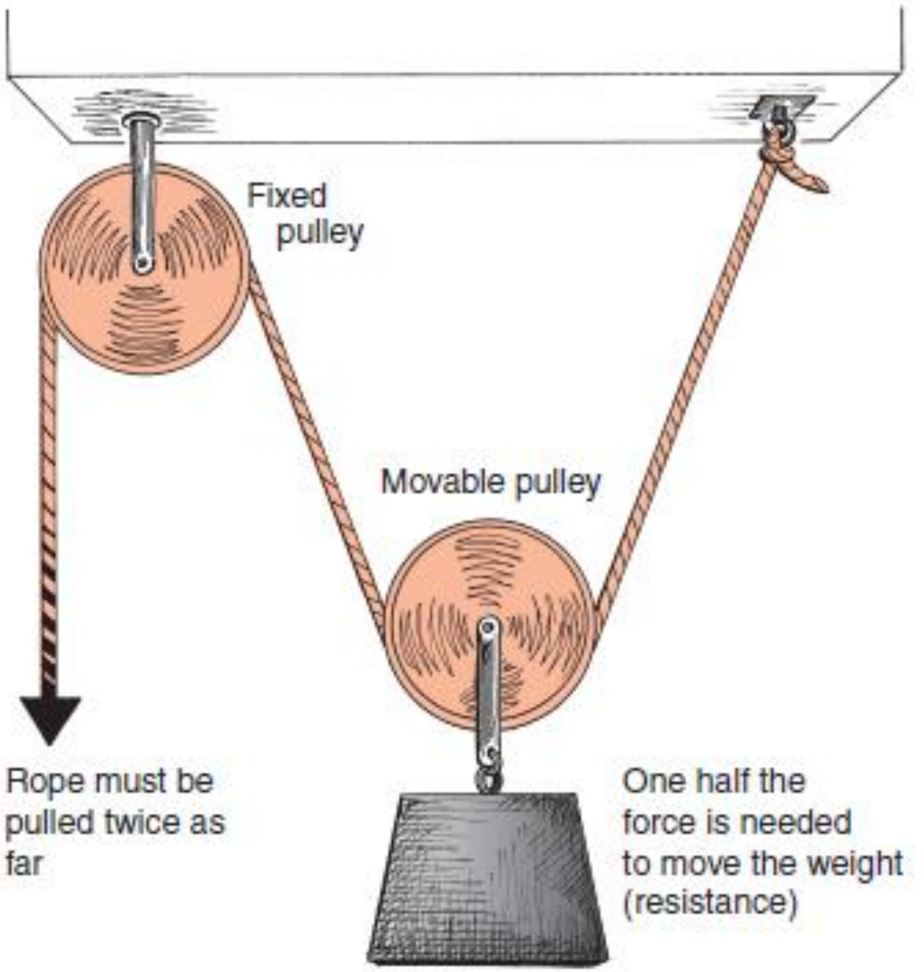
- Is a simple pulley attached to a beam.
- It acts as a first-class lever with F on one side of the pulley (axis) and R on the other.
- Used only to change direction.
- Clinical examples:
- can be found in overhead and wall pulleys
- in home cervical traction units.
- In the body, the lateral malleolus of the fibula acts as a pulley for the tendon of the peroneus longus and changes its direction of pull
- A Velcro strap on a shoe. The strap passes through a slot and folds over on itself.



Fixed pulley. Its purpose is to change direction.

Movable Pulley

- Has one end of the rope attached to a beam; the rope runs through the pulley to the other end where the force is applied.
- The load (resistance) is suspended from the movable pulley
- The purpose of this type of pulley is to increase the mechanical advantage of force.
- Mechanical advantage is the number of times a machine multiplies the force.
- The load is supported by both segments of the rope on either side of the pulley so it has a mechanical advantage of 2
- It will require only half as much force to lift the load because the amount of force gained has doubled.
- Although only half of the force is needed to lift the load, the rope must be pulled twice as far.
- In other words, it is easier to pull the rope, but the rope must be pulled a much farther distance.
- The human body has no examples of a movable pulley.

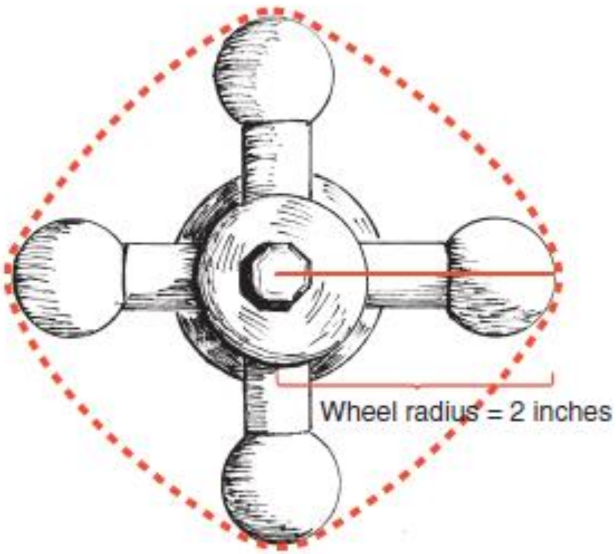


A movable pulley has a mechanical advantage for force.

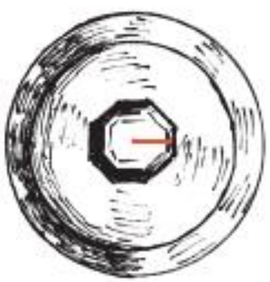
Wheel and Axle

- Another type of simple machine.
- It is actually a lever in disguise.
- The wheel and axle consists of a wheel, or crank, attached to and turning together with an axle.
- In other words, it is a large wheel connected to a smaller wheel and typically is used to increase the force exerted.
- Turning around a larger wheel or handle requires less force, whereas turning around a smaller axle requires a greater force.

- An example of a wheel and axle is a **faucet handle**
- The handle is the wheel and the stem is the axle. Turning the faucet requires a certain amount of force made easier by a longer force arm (wheel radius).
- However, take off the handle and you are left with only the axle Try turning it and you will realize that a great deal more strength is needed to do so.
- Simply stated, the larger the wheel (handle) in relation to the axle, the easier it is to turn the object.
- Just like the lever—in which the longer the FA, the greater the force—the wheel and axle provides greater force with a larger wheel.



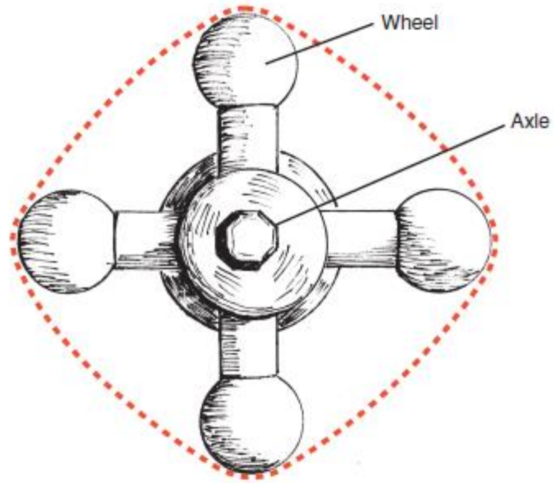
A



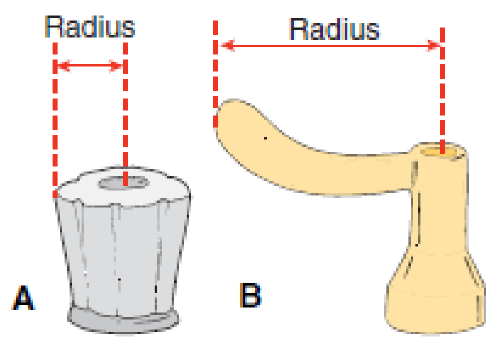
Axle radius = $\frac{1}{8}$ inch

B

The wheel of the faucet handle (A) has a longer radius than the axle (B). Therefore, the larger wheel is easier to turn than the smaller axle.



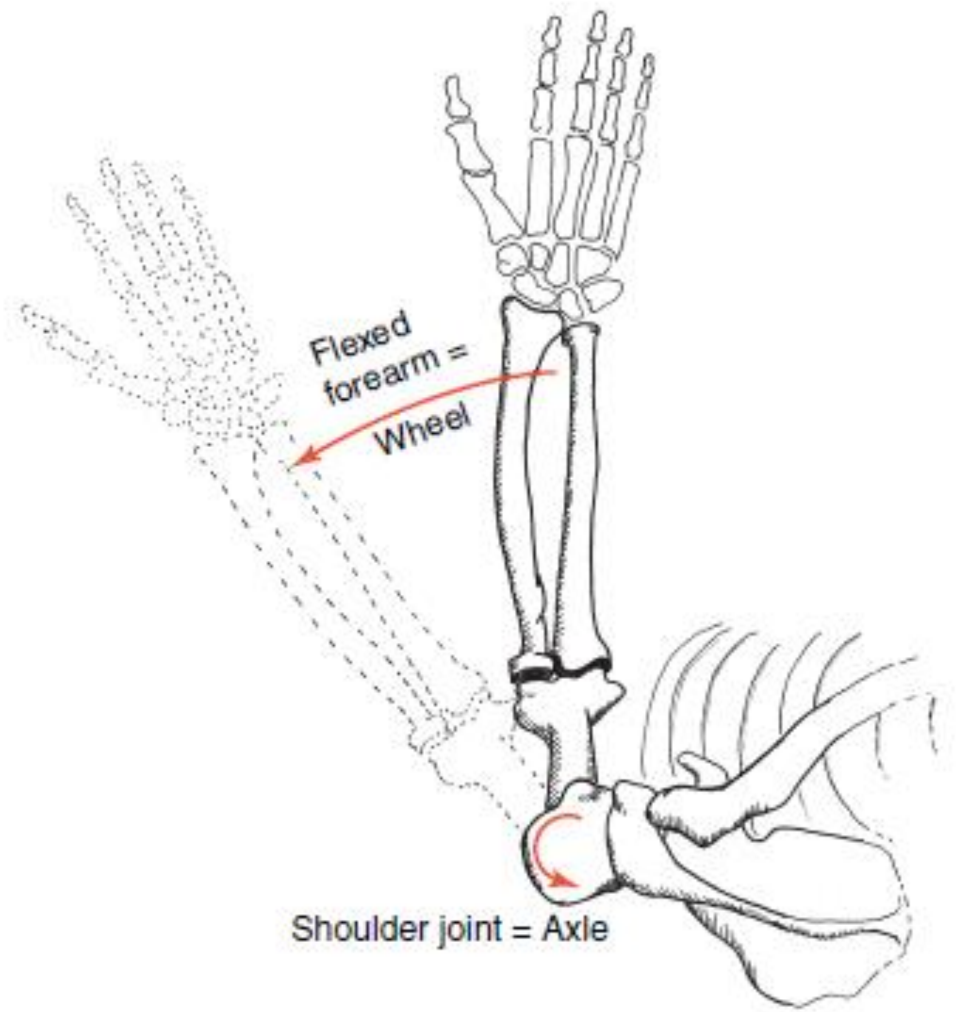
A faucet handle demonstrates a wheel and axle.



Typical faucet handles. Note that (A) has a shorter radius and requires more force to turn the wheel than (B).

Example of a wheel and axle in the human

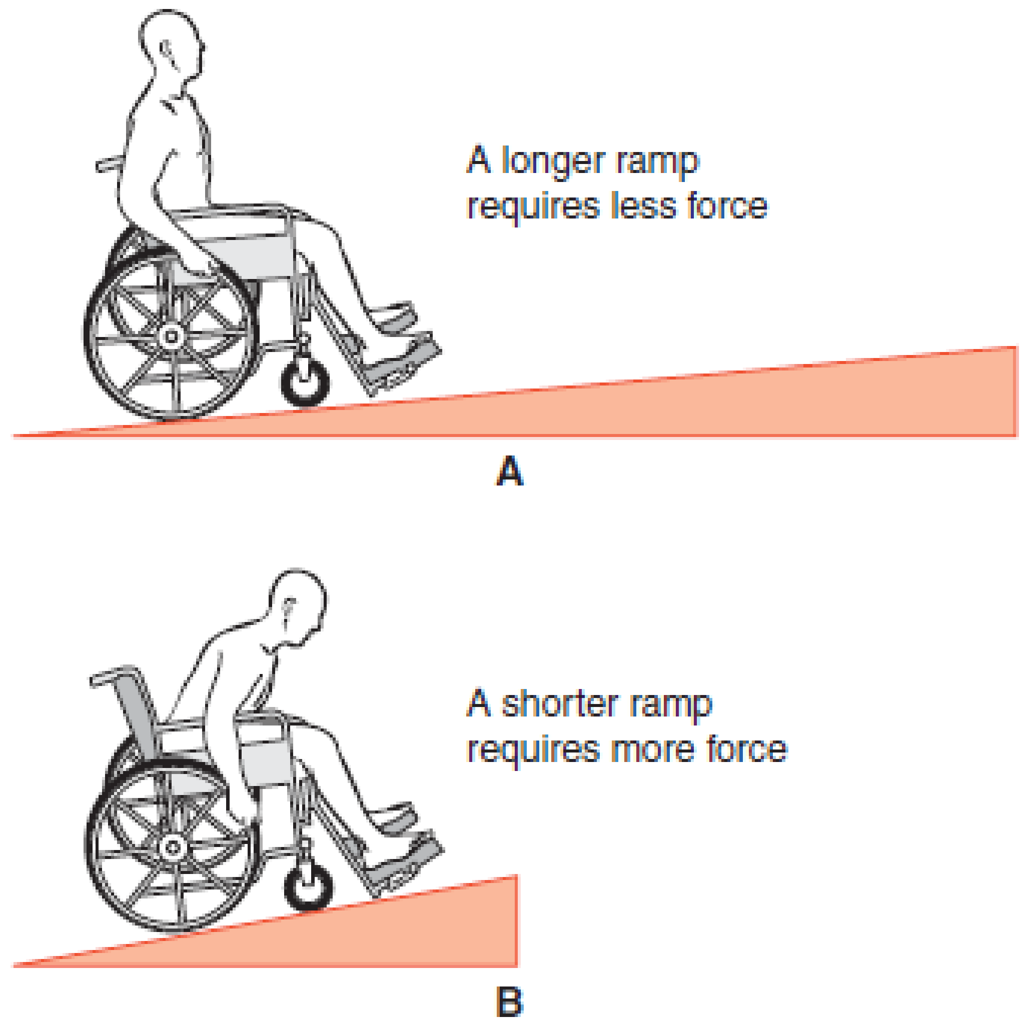
- Think of performing passive shoulder rotation on a patient.
- It can best be visualized by looking down on the shoulder from a superior view .
- The shoulder joint serves as the axle, and the forearm serves as the wheel.
- With the elbow flexed, the wheel is much longer than the axle and thus much easier to turn.



The upper extremity acting as a wheel and axle.

Inclined Plane

- Although there are no examples of an inclined plane in the human body, the concept of wheelchair accessibility often depends on this type of simple machine.
- Is a flat surface that slants.
- It exchanges increased distance for less effort.
- The longer the length of a wheelchair ramp, the greater the distance the wheelchair must travel; however, it requires less effort to propel the chair up the ramp, because the ramp’s incline is less.
- Repeating the basic rule of simple machines: the advantage gained in force (decreased effort needed) is lost in distance (longer ramp needed).



Inclined plane as a wheelchair ramp. A longer ramp (A) requires less force but greater distance to reach a certain height. A shorter ramp (B) requires more force but less distance to reach same height.

Other Physical Concepts

Strength

- A muscle’s relative ability to resist or produce a force.
- Factors that determine a muscle’s strength:
- the muscle’s angle of pull,
- the angle of the resisting force,
- the muscle’s length,
- the speed of contraction and movement

Work

- The product of the amount of force (F) and the distance (d) through which the force
- $W = F \times d$
- Work is measured in foot-pounds (ft-lb) in the English system and joules (1 J = 1 N·m) in the metric system.
- If you lift a 20 lb (89 N) weight from the floor to a shelf 6 ft (1.8 m) above the floor, you would do 120 ft-lb (about 160 J) of work (6 ft 3 20 lb, or 89 N 3 1.8 m).

Power

- Power is the work per unit of time, or how fast the work is produced:
- P = Fd / t
- Work is done regardless of how much time it takes to perform the work.
- Power is a measure of the work done in a specific amount of time.
- In the English system it is measured in foot-pounds per second or in horsepower (1 horsepower = 550 ft-lb/s).
- In the metric system it is measured in joules per second or Newton-meters per second.

Energy

- Energy is the capacity to do work.
- There are different types of energy.
- The law of conservation of energy states that energy can neither be created nor destroyed.
- Energy can, however, be converted from one form to another.

Two energy classifications

- Potential energy :
- The capacity to do work that is stored in a body.
- Kinetic energy:
- The energy a body has because of its motion.

- Potential energy and kinetic energy are often converted from one to the other.
- When a moving body stops, kinetic energy is all converted to potential energy. It is important to absorb this energy in a way that prevents injury.

Velocity

- Velocity is the rate of change of position.
- It is expressed in miles per hour (mph), feet per second (ft/s), or meters per second (m/s).

- Velocity is often interchanged with speed, which is not entirely accurate, but in most instances the difference is inconsequential.

Acceleration

- The rate at which velocity changes.
- It is expressed in feet per second per second (ft/s2) or meters per second per second (m/s2).
- A sprinter coming out of the blocks at the start of a race accelerates, increasing velocity as she continues.
- **Gravity** provides a constant acceleration of 9.8 m/s2 or 9.8 m/s/s (32 ft/s2 or 32 ft/s/s).
- In other words, every second that an object falls, it moves 9.8 m/s (32 ft/s) faster than it did during the previous second.

Deceleration

- **Negative acceleration** is called deceleration, the process of an object's slowing down rather than speeding up.
- After a baseball is pitched, the pitcher's arm goes from sudden acceleration to deceleration until the arm stops moving.

Elasticity

- The ability of an object to resume its former shape after a deforming or distorting force is applied then released.
- A muscle has elasticity because it can be stretched but returns to its normal length when the deforming force is discontinued.
- All substances have some degree of elasticity.
- Rubber tubing or bands used in therapeutic exercise have a lot of elasticity.
- Steel has elasticity but less than asphalt.
- Ligaments have more elasticity than bone but less than muscles.

Stiffness

- The ability of an object to resist deformation when a stress is applied to it.
- When a force is applied quickly to connective tissue, the connective tissue has more stiffness to resist the force than if the force is applied slowly over time.

- Tissue's tensile strength is related to its stiffness.
- Elasticity and stiffness are at opposite ends of the spectrum, so tissue that is more elastic doesn't have as much stiffness as tissue that is less elastic.
- Most human structures have a combination of elasticity and stiffness to provide them with both an ability to return to their former shape but also resist outside forces.

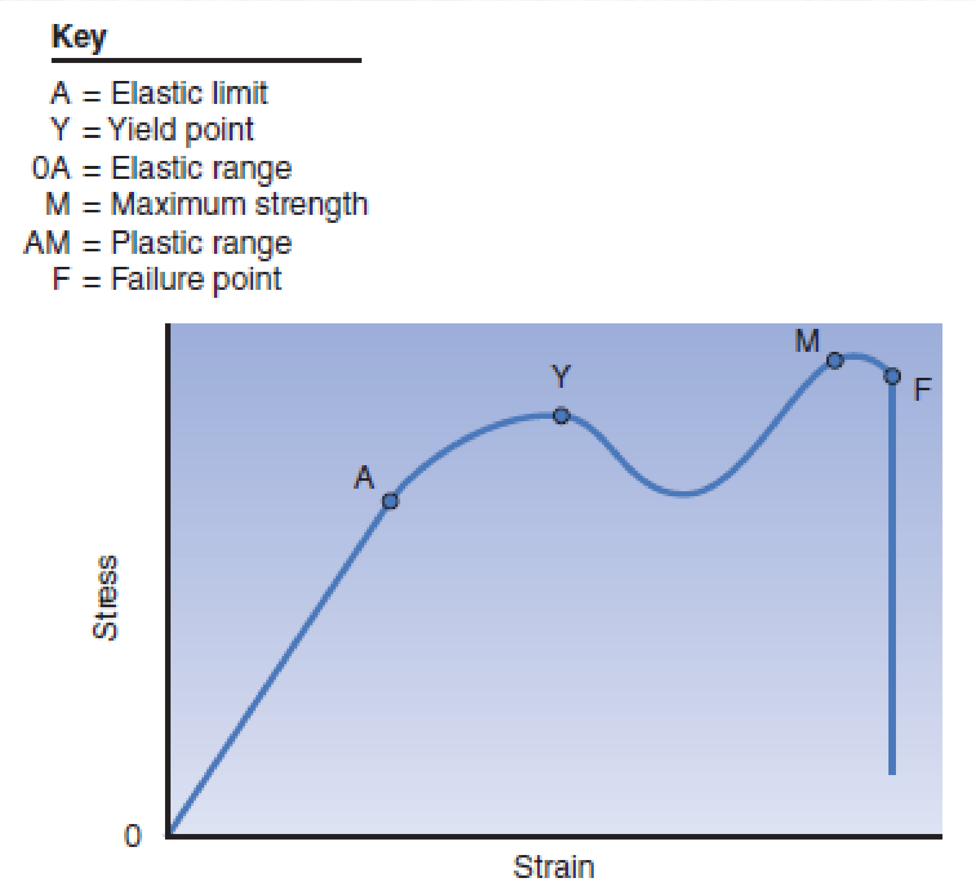
Stress and Strain

- **Stress** is a force that changes the form or shape of a body.
- **Strain** is the amount of change in the size or shape of the object caused by the stress.

- Hooke's Law, deals with the relationship of stress and strain to elasticity:
- The strain is proportional to the stress producing it (so long as the strain is not too great—once the elastic limit is exceeded, permanent deformation occurs).

Stress Strain Curve

- The OA curve segment represents the elastic range.
- If a load is released in this range of the stress-strain curve, the object returns to its normal length.
- A is called the elastic limit, beyond which Hooke's law is no longer valid.
- Beyond the elastic range is the plastic range AM. When a load stresses an object into this range, a permanent change in the object's size or shape occurs.
- Any load that continues beyond the plastic range ultimately causes a failure of the object, F.



Stress-strain curve.

Creep

- Creep occurs when a low-level stress, usually starting in the elastic range of the tissue, is applied over a long enough period to cause deformation of the tissue in its plastic range.

- Creep causes a realignment of tissue's collagen, proteoglycans, and water so a permanent change occurs
- Increasing the temperature of the tissue increases the rate of creep.
- For this reason, applying heat to an area before stretching may make the stretch more effective.
- This concept also explains why longer stretches produce better results.

- It also demonstrates why poor posture over time causes changes in muscles, joints, and connective tissue;
- Sitting with your head forward for a prolonged time as you read this book will cause the ligaments and muscles of your posterior neck and upper back to lengthen, making it ultimately more difficult to resume a proper posture.
- Permanent changes in tissue length result over time with repetition of any position.

Structural Fatigue

- All tissues and objects are subject to structural fatigue.
- Structural fatigue is the point at which a tissue or object can no longer withstand a stress, and breaks.
- This can occur in a sudden movement, as when a ligament is suddenly torn, or it can occur over time with an accumulation of stress.
- The point at which tissue failure results from long term stress is sometimes referred to as the endurance limit or fatigue failure.
- Breakdown of bone from cumulative trauma is called a stress fracture.
- Injuries caused by repeated stress, such as carpal tunnel syndrome, are called repetitive stress syndromes or overuse syndromes