First class lever in the body examples

Simple machines are mechanical devices that are used to make work easier. Combinations of two or more simple machines working together are called compound machines. These machines create systems for different kinds of movement to occur when force is applied to a load. Both simple and compound machines make work easier by changing the size or direction of the force. There are six standard types of simple machines. They are the: Lever Wheel and axle Pulley Inclined plane Wedge Screw Let us consider the first of these simple machines: the lever. Misconception Alert When you hear the word "machine" do you automatically think of something with a motor, like a forklift or a washing machine? Machines do not have to have motors. In fact, a machine is any device that transmits or modifies force. What is a Lever? A lever is a simple machine made of a rigid beam and a fulcrum. The effort (input force) and load (output force) are applied to either end of the beam. The fulcrum is the point on which the beam pivots. When an effort is applied to one end of the lever, a load is applied at the other end of the lever. This will move a mass upward. Levers rely on torque for their operation. Torque is the amount of force required to cause an object to rotate around its axis (or pivot point). What is mechanical advantage? A lever provides mechanical advantage. Mechanical advantage refers to how much a simple machine multiplies an applied force. The location of the effort, load, and fulcrum will determine the type of lever and the amount of mechanical advantage the machine has. The farther the effort is away from the fulcrum, the easier it is to move the load. Mechanical advantage can be calculated using this formula: Mechanical advantage is equal to the ratio of the effort to the load as well as to the distance from the effort to the fulcrum to the distance from the load to the fulcrum (©2020 Let's Talk Science). If the distance from the effort to the fulcrum is greater than the distance from the load to the fulcrum, then the lever has a mechanical advantage. In other words, the ratio of these two distances is greater than one. This means that a long distance from the effort to the fulcrum and a short distance from the load to the fulcrum will allow a small effort to move a large load! Basic parts of a lever showing the locations of the beam, fulcrum, effort and load (© 2019 Let's Talk Science). First Class Levers There are three types, or classes of levers. In a first class lever, the fulcrum is located between the load and the effort. In a first class lever, the fulcrum is located between the load and the effort. When the fulcrum is closer to the load, then less effort is needed to move the load (©2020 Let's Talk Science). If the fulcrum is closer to the load, then less effort is needed to move the load a shorter distance. If the fulcrum is closer to the effort, then more effort is needed to move the load a greater distance. A teeter-totter, a car jack, and a crowbar are all examples of first class levers. First class levers are very useful for lifting large loads with little effort. First class levers include scissors (left), teeter-totters (centre) and crowbars (right) (Sources: Thamizhpparithi Maari [CC BY-SA 3.0] via Wikimedia Commons, Tiia Monto [CC BY-SA 3.0] via Wikimedia Commons and Pearson Scott Foresman [Public domain] via Wikimedia Commons). Second Class Levers In a second class lever, the load is located between the effort and the fulcrum. In a second class lever, the load is located between the effort and the fulcrum. When the fulcrum is closer to the load, then less effort is needed to move the load (©2020 Let's Talk Science). If the load is closer to the fulcrum than the effort, then less effort will be required to move the load. If the load is closer to the effort than the fulcrum, then more effort will be required to move the load. A wheelbarrow, a bottle opener, and an oar are examples of second class levers. Second class levers are used in wheelbarrows (left), when going on tiptoes (centre) and when doing push-ups (Sources: MarkusHagenlocher [CC BY-SA 3.0] via Wikimedia Commons, BruceBlaus [CC BY-SA 4.0] via Wikimedia Commons and U.S. Navy [Public domain] via Wikimedia Commons). Third Class Levers In a third class lever, the effort is located between the load and the fulcrum. In a third class lever, the effort is located between the load and the fulcrum. If the fulcrum is closer to the load, then less effort is needed to move the load (©2020 Let's Talk Science). If the fulcrum is closer to the load, then less effort is needed to move the load. If the fulcrum is closer to the effort, then the load will move a greater distance. A pair of tweezers, swinging a baseball bat or using your arm to lift something are examples of third class levers. These levers are useful for making precise movements. Third class levers are used when swinging a tennis racquet (left), in staple-removers (centre) and when you lift objects using the muscles in your biceps (right) (Sources: Australian Paralympic Committee [CC BY-SA 3.0] via Wikimedia Commons, Frank C. Müller [CC BY-SA 4.0] via Wikimedia Commons and John Seb Barber [CC BY 2.0] via Wikimedia Commons). Levers are very useful simple machines used for transferring force. You may not realize it, but you use levers every day! In nature, most motion uses the principle of levers, with 1st class levers being one of the most common forms. How Do First Class Levers Work? Levers work on the principal of a rigid bar that pivots around a stationary fulcrum think, for example, of a see-saw. In the human body, the fulcrum is the joint axis, the bones function as the levers, while our skeletal muscles provide the energy to create the motion. By changing the position of the fulcrum, you can gain extra power with less effort. Resistance takes a variety of forms, and can include the weight of a body part, the tension of an antagonistic muscle, or the weight of an object one is trying to move. Different types of lever. Physicists class levers as first, second, and third class, depending upon the relationship between the fulcrum, the effort, and the resistance. Example of a 1st Class Lever In the human body the best example of a 1st class lever is displayed when we nod our head the top of the spinal column acts as the fulcrum to allow the head to move. Moving patients is a routine part of Jolene's work as a MED floor RN, but in reality there is nothing routine about the biomechanics of lifting and transferring patients. In fact, "disabling back injury and back pain affect 38% of nursing staff" and healthcare makes up the majority of positions in the top ten ranking for risk of back injury, primarily due to moving patients. Spinal load measurements indicated that all of the routine and familiar patient handling tasks tested placed the nurse in a high risk category, even when working with a patient that "[had a mass of] only 49.5 kg and was alert, oriented, and cooperative—not an average patient." People are inherently awkward shapes to move, especially when the patient's bed and other medical equipment cause the nurse to adopt awkward biomechanic positions. The forces required to move people are large to begin with, and the biomechanics of the body can amplify those forces by the effects of leverage, or lack thereof. To analyze forces in the body, including the effects of leverage, we must study the properties of levers. The ability of the body to both apply and withstand forces is known as strength. One component of strength is the ability apply enough force to move, lift or hold an object with weight, also known as a load. A is a rigid object used to make it easier to move a large load a short distance or a small load a large distance. There are three , and all three classes are present in the body.   For example, the forearm is a because the biceps pulls on the forearm between the joint (fulcrum) and the ball (load). The elbow joint flexed to form a 60° angle between the upper arm and forearm while the hand holds a 50 lb ball . Image Credit: Openstax University Physics Using the standard terminology of levers, the forearm is the , the biceps is the , the elbow joint is the , and the ball is the . When the resistance is caused by the weight of an object we call it the . The   are identified by the relative location of the resistance, fulcrum and effort. have the fulcrum in the middle, between the load and resistance. have resistance in the middle. have the effort in the middle. First (top), second(middle), and third(bottom) class levers and real-world examples of each. Image Credit: Pearson Scott Foresman The foot acting as a lever arm with calf muscle supplying an upward effort, the weight of the body acting as downward load, and the ball of the foot acting as the fulcrum. Image adapted from OpenStax Anatomy and Physiology For all levers the and () are actually just that are creating because they are trying to rotate the lever. In order to move or hold a load the created by the effort must be large enough to balance the caused by the load. Remembering that torque depends on the distance that the force is applied from the , the effort needed to balance the resistance must depend on the distances of the effort and resistance from the pivot. These distances are known as the and (load arm). Increasing the reduces the size of the effort needed to balance the load torque. In fact, the ratio of the effort to the load is equal to the ratio of the effort arm to the load arm: (1)   Let's calculate the biceps tension need in our initial body lever example of a holding a 50 lb ball in the hand. We are now ready to determine the bicep tension in our forearm problem. The effort arm was 1.5 in and the load arm was 13.0 in, so the load arm is 8.667 times longer than the effort arm.   That means that the effort needs to be 8.667 times larger than the load, so for the 50 lb load the bicep tension would need to be 433 lbs! That may seem large, but we will find out that such forces are common in the tissues of the body! *Adjusting Significant Figures Finally, we should make sure our answer has the correct . The weight of the ball in the example is not written in , so it's not really clear if the zeros are placeholders or if they are significant. Let's assume the values were not measured, but were chosen hypothetically, in which case they are exact numbers like in a definition and don't affect the significant figures. The forearm length measurement includes zeros behind the decimal that would be unnecessary for a definition, so they suggest a level of in a measurement. We used those values in multiplication and division so we should round the answer to only two significant figures, because 1.5 in only has two (13.0 in has three). In that case we round our bicep tension to 430 lbs, which we can also write in scientific notation: . *Neglecting the Forearm Weight Note: We ignored the weight of the forearm in our analysis. If we wanted to include the effect of the of the forearm in our example problem we could look up a typical forearm weight and also look up where the of the forearm is located and include that and . Instead let's take this opportunity to practice making justified . We know that forearms typically weigh only a few pounds, but the ball weight is 50 lbs, so the forearm weight is about an (10x) smaller than the ball weight. Also, the of the forearm is located closer to the than the weight, so it would cause significantly less . Therefore, it was reasonable to assume the forearm weight was for our purposes. The ratio of to is known as the (MA). For example if you used a (like a wheelbarrow) to move 200 lbs of dirt by lifting with only 50 lbs of effort, the mechanical advantage would be four. The is equal to the ratio of the to . (2)   We normally think of as helping us to use less to hold or move large , so our results for the forearm example might seem odd because we had to use a larger effort than the load. The bicep attaches close to the elbow so the is much shorter than the and the is less than one. That means the force provided by the bicep has to be much larger than the weight of the ball. That seems like a mechanical disadvantage, so how is that helpful? If we look at how far the weight moved compared to how far the bicep contracted when lifting the weight from a horizontal position we see that the purpose of the forearm lever is to increase rather than decrease required. Diagram showing the difference in distance covered by the contracting bicep and the weight in the hand when moving the forearm from horizontal.Image Adapted from Openstax University Physics Looking at the similar triangles in a stick diagram of the forearm we can see that the ratio of the distances moved by the and must be the same as the ratio of to . That means increasing the effort arm in order to decrease the size of the effort required will also decrease the of the load by the same factor. It's interesting to note that while moving the attachment point of the bicep 20% closer to the hand would make you 20% stronger, you would then be able to move your hand over a 20% smaller range. Diagram of the forearm as a lever, showing the similar triangles formed by parts of the forearm as it moves from 90 degrees to 60 degrees from horizontal. The hypotenuse (long side) of the smaller blue triangle is the effort arm and the hypotenuse of the larger dashed red triangle is the load arm. The vertical sides of the triangles are the distances moved by the effort (blue) and the load (dashed red). For the is always farther from the fulcrum than the , so they will always increase , but that means they will always increase the amount of effort required by the same factor. Even when the effort is larger than the load as for third class levers, we can still calculate a , but it will come out to be less than one. always have the load closer to the fulcrum than the effort, so they will always allow a smaller effort to move a larger load, giving a greater than one. can either provide or increase , depending on if the effort arm or load arm is longer, so they can have mechanical advantages of greater, or less, than one. A lever cannot provide mechanical advantage and increase range of motion at the same time, so each type of lever has advantages and disadvantages: Comparison of Advantages and Disadvantages of Lever Classes Lever Class Advantage Disadvantage 3rd Range of Motion The load moves farther than the effort. (Short bicep contraction moves the hand far) Effort Required Requires larger effort to hold smaller load. (Bicep tension greater than weight in hand) 2nd Effort Required Smaller effort will move larger load. (One calf muscle can lift entire body weight) Range of Motion The load moves a shorter distance than the effort. (Calf muscle contracts farther than the distance that the heel comes off the floor) 1st (effort closer to pivot) Range of Motion The load moves farther than the effort. (Head moves farther up/down than neck muscles contract) Effort Required Requires larger effort to hold smaller load. 1st (load closer to pivot) Effort Required Smaller effort will move larger load. Range of Motion The load moves shorter distance than the effort. Check out the following lever simulation explore how force and distance from fulcrum each affect the equilibrium of the lever. This simulation includes the effects of friction, so you can see how in the joint () works to stop motion and contributes to maintaining by resisting a start of motion. a rigid structure rotating on a pivot and acting on a load, used multiply the effect of an applied effort (force) or enhance the range of motion There are three types or classes of levers, according to where the load and effort are located with respect to the fulcrum a lever with the effort between the load and the fulcrum. the force that is provided by an object in response to being pulled tight by forces acting from opposite ends, typically in reference to a rope, cable or wire referring to a lever system, the force applied in order to hold or lift the load the point on which a lever rests or is supported and on which it pivots the force of gravity on on object, typically in reference to the force of gravity caused by Earth or another celestial body the force working against the rotation of a lever that would be caused by the effort a weight or other force being moved or held by a structure such as a lever levers with the fulcrum placed between the effort and load levers with the resistance (load) in-between the effort and the fulcrum any interaction that causes objects with mass to change speed and/or direction of motion, except when balanced by other forces. We experience forces as pushes and pulls. the result of a force applied to an object in such a way that the object would change its rotational speed, except when the torque is balanced by other torques the central point, pin, or shaft on which a mechanism turns or oscillates in a lever, the distance from the line of action of the effort to the fulcrum or pivot shortest distance from the line of action of the resistance to the fulcrum each of the digits of a number that are used to express it to the required degree of accuracy, starting from the first nonzero digit a way of writing very large or very small numbers. A number is written in scientific notation when a number between 1 and 10 is multiplied by a power of 10. refers to the closeness of two or more measurements to each other a point at which the force of gravity on body or system (weight) may be considered to act. In uniform gravity it is the same as the center of mass. ignoring some compilation of the in order to simplify the analysis or proceed even though information is lacking designating which power of 10 (e.g. 1,10,100,100) small enough as to not push the results of an analysis outside the desired level of accuracy ratio of the output and input forces of a machine distance or angle traversed by a body part a force that resists the sliding motion between two surfaces a force that resists the tenancy of surfaces to slide across one another due to a force(s) being applied to one or both of the surfaces the state being in equilibrium (no unbalanced forces or torques) and also having no motion