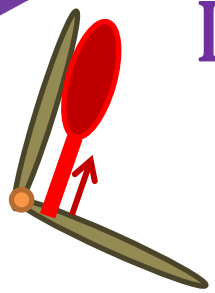
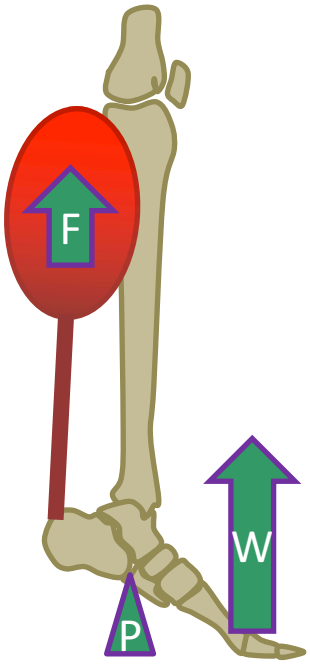
Lever Systems In The Body

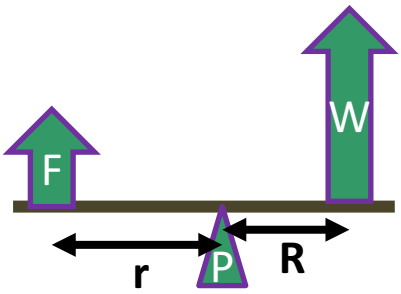


Theory:

In order to understand how the body moves, as well as understanding how injuries occur (and how to treat them), we are interested in the forces experienced by muscles. These muscle forces are also really important in our building of mechanical models, such is the focus of this resource.

Investigation of muscle forces is also a really neat way to give a biological and real-world application of lever systems. A really simple lever system is the ankle, as shown below:





P = Pivot, in this case, the ankle joint.
F = Force, in this case the force in the calf muscle and Achilles tendon.
W = Body weight, this should be in Newtons (mass in kg x 10). This is the force resisting your muscle.
r = The perpendicular distance from the pivot to the Achilles (in metres).
R = The perpendicular distance from the pivot to the ball of foot (where the weight is acting) (in metres).

If you try standing on your tiptoes, especially on one leg, you will feel your calf muscles really starting to ache. By taking simple measurements of the distances above and the bodyweight, you can calculate the force in the Achilles tendon when you stand on tiptoes:

Achilles force (N) = $\frac{weight\ x\ R}{r}$

- Gruesome fact: when an Achilles tendon snaps, everyone around can hear it!
- The force is reasonably low in your tiptoes exercise, likely around your bodyweight.
- In walking, your Achilles can experience up to 4 times your bodyweight in force and up to 8 times your weight in running!

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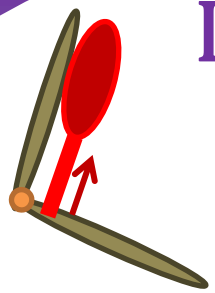
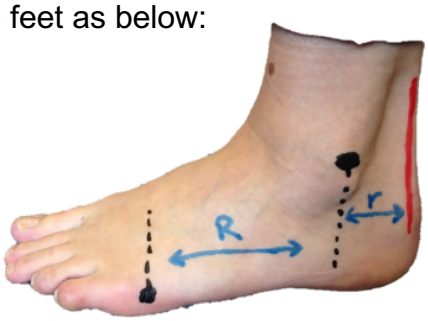


Suggested Lesson Plan:

Start by recapping basic levers and then ask children to suggest how and where they might find levers in their bodies.

Introduce the ankle (you may wish to include some basic anatomy here regarding muscles and bones, or equally you could make this the main focus). Set children the first task: working in pairs get children to time how long they can stand on tip-toes – this will be much quicker on only one foot! Ask the children where their legs ached.

Introduce the ankle lever system and get children to draw the system onto each other's feet as below:



(We used non-toxic board markers but face paints or other water-soluble paints also work – check with you school's safety guidelines).

Get children to weigh themselves on some scales; measure the straight line between the pivot line and the line at the front of the foot (R), and the distance between the tendon line and the pivot line (r) with weight in Newtons and distance in m. Note, foot must be flat.

They can then use the equation Calf muscle force (N) = $\frac{weight\ x\ R}{r}$ to calculate the force in their Achilles! Note, this is for both legs divide by 2 to get per leg.

Potential Learning Outcomes/ Skills Addressed:

- Mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect.
- Taking measurements.
- Reporting and presenting findings.
- Skeletal and muscular systems (KS3)

Engaging Different Levels & Abilities:

This session can be scaled for both KS2 and KS3. Ensure lower ability learners can make basic measurements. Ask higher ability learners to suggest what would happen with different bodyweights. This could be furthered by looking at other joint systems.