

# Biomechanics & Terrestrial Locomotion

## Approaches for studying motion:

### **Kinematics**

A description of how an animal moves in space (1D, 2D, or 3D)

Uses video analysis, often high-speed

### **Biomechanics**

Measurements of the forces exerted by an animal in order to produce motion

Uses force plate to measure ground reaction forces

### **Morphology**

Anatomical analysis of arrangement of bones, muscles, tendons, ligaments and supporting structures Analysis of muscle activity patterns during behavior

Uses dissection (anatomy), Electromyography (analysis of electrical firing patterns of muscle).

Most comprehensive approach integrates Kinematics, Biomechanics, and Functional Morphology approaches.

## (Classical) Mechanics: Newton's Laws of Motion:

First Law of Motion : **The law of inertia**: a body retains its state of rest or motion unless acted on by an external force.

Second Law of Motion:  **$F = Ma$** . (Force = Mass \* acceleration). A force gives a body acceleration in the direction of the force.

Third Law of Motion: **For every action there is an equal and opposite reaction**. If one body exerts force on another body, the second body exerts an equal but opposite force on the first.

center of mass = **the point about which a solid body is evenly balanced**. In analyzing forces acting on a body, we can simplify the analysis by thinking of the force acting on the center of mass

Vector analysis of forces help in studying dynamics

**Scalar quantities**: magnitude (eg., mass, length) . **Vectors quantities**: magnitude AND direction (e.g., force, velocity) .

Vectors are drawn as arrows:

direction of arrow = **direction of force**

length = proportional to **magnitude**.

Vectors at any angle can be broken down to their component vectors at right angles (eg., horizontal [thrust, lateral] and vertical [gravitational] components).

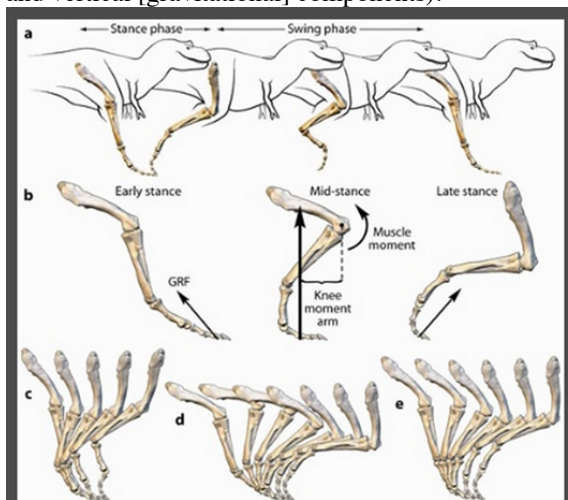


Figure 2. The stance and swing phases of a stride, and possible limb motions during stance.

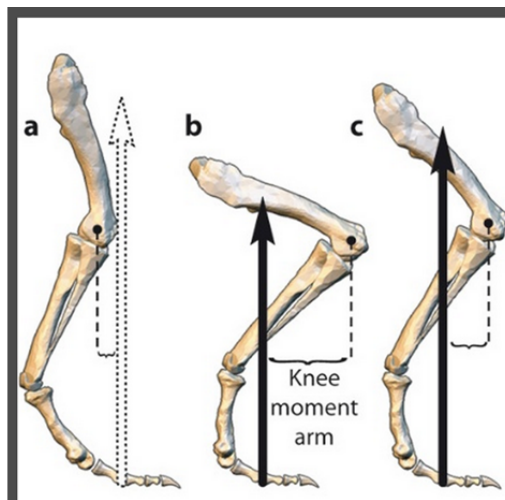


Figure 3. Three limb poses for Tyrannosaurus and how one might eliminate some as possibilities.

<https://www.rvc.ac.uk/Media/Default/Structure%20and%20Motion/Documents/Beyond-the-bones.pdf>

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### Gait Parameters:

We decompose the walk or run into portions of a limb cycle.

Stride length = The distance the body moves between successive footfalls of same foot (eg., foot down to foot down).

Stride frequency = strides per second.

Step length = The distance the body moves while foot is in contact with ground (eg., foot down to foot up).

Step duration = the length of time the foot is on ground .

Duty factor = step duration / stride duration. Walk > 50% duty factor, Run < 50% duty factor

Stance phase = portion of limb cycle that foot is on ground .

Swing phase = portion of limb cycle when foot is in air

Limb cycle or one stride = stance + swing phase.

### Lever Mechanics:

Limbs that rotate about a joint (fulcrum) and actuated by muscles (load generation) can be thought of as a Lever System.

Levers (think see-saw) can be used to amplify input force, or can be designed to move limbs faster.

Torque Equation:

Forces must be balanced around the joint (fulcrum) which we can calculate using the

Torque equation:  $T = l * F$ , torque ( $T$ ) = lever arm length ( $l$ ) \* force ( $F$ )

When there is no movement, torque about a joint must be balanced:

$$T_{in} = T_{out}$$

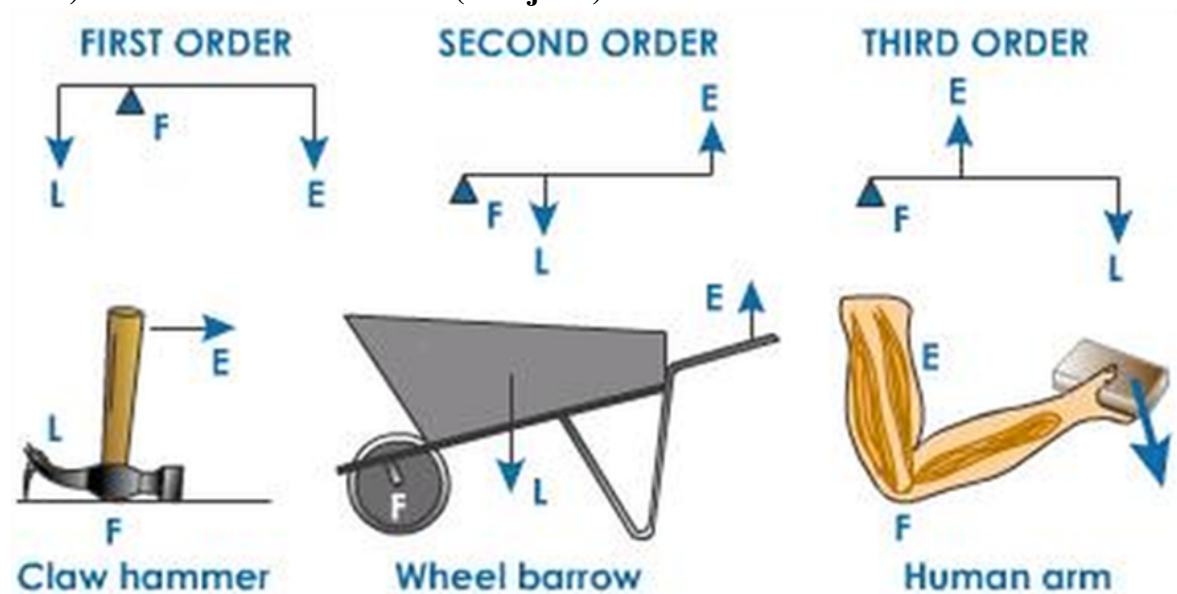
$$l_{in} * F_{in} = l_{out} * F_{out}$$

We can rearrange the torque equation to calculate Force Advantage or Distance Advantage

Force Advantage:  $F_{out}/F_{in} = l_{in}/l_{out}$

Distance Advantage:  $l_{out}/l_{in} = F_{in}/F_{out}$

**Three typical Classes of Levers - defined by where the force in (E effort) and force out (L load) are relative to the fulcrum (F or joint).**



<https://physics.stackexchange.com/questions/345601/does-the-fulcrum-of-a-2nd-or-3rd-class-lever-have-to-be-at-the-end-if-so-why/345908>