## Walking Speed of an Animal

There is a very generic idea in biology called allometry, which states that many properties of animals scale as mass to some power, more or less "universally" for all animals. For example, in 1997 a beautiful paper showed why the lifetime of an organism should scale as

$$
t_{\text {life }} \sim M^{1 / 4}
$$

where $M$ is the mass of an organism.
In this problem, we will estimate the walking speed of an animal using a very simple toy model, and try to understand how walking speed scales with mass $M$.
(a) How should the length, height and width of an animal scale with mass $M$ ? In addition to guessing the exponent, what do you think the coefficient should be?
(b) Now, suppose we model the leg of an organism as a simple pendulum. If the amplitude of pendulum oscillations is $a$, and the frequency of pendulum oscillations is $\omega$, then the walking speed is given by $v=a \omega$. Show that we expect $v \sim M^{1 / 6}$, and estimate the coefficient of proportionality.
(c) Now, determine if your proportionality constant is reasonable, by estimating your walking speed. How close do you get (think in terms of multiplicative factors, not additive factors!)?

