4.2 Mountain heights

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Next estimate the force. It is proportional to the mass:

$$F \propto m.$$

In other words, F/m is independent of mass, and that independence is why the proportionality $F \propto m$ is useful. The mass is proportional to l^3:

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wouldn't the easiest method here be to use a spring model...? that seems to be what the image is implying.

I found printing the pdf and reading it before reading the version with the comment helped me get through the reading better because it gave me a clean look at the section. I think recommending that people make sure to read it without reading the comments while going along will help people figure out the readings better (and helped me note specific things that I thought were questionable).

I feel like these are great examples. Can we do something that is more course 6 related just to get a different frame of reference?

I really enjoyed this section. The examples were clear and to the point. Proportionality is making more sense to me than the previous topics.

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Read Section 4.2 and Section 4.3.1 (the first part of the section on animals jumping) for the Tuesday memo.

The page breaks are not great, but I don't worry too much about that because they'll all change anyway after the revision.

go away you stupid box.

It feels like considering all mountains to be cubical is such a big approximation... Mountains are all sloped...

This sentence is intriguing! I really like this as the beginning of a new section- it makes me eager to read more!!

how high is too high? haha

Agreed, great sentence...cut and dry and right down to the point, letting the reader know exactly what will be covered.

i'm just curious whether anyone has anyone ever wondered about this?

I have not, and not only do I find this first sentence intriguing, but I have no idea where we'll begin with this calculation. Usually with this class I could at least guess an approach we could take even if I didn't know how to do it.

I guess this will be useful for our homework problem

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I would have guessed they're more triangular.

me too, but if you assume them all to be that way it probably doesn't matter.

Wait I'm so confused - I've never seen a mountain that even vaguely resembles a cube shape.

While I've only read the next few lines, I don't think the shape of the mountain really matters. It is just an easy approximation to prove the point that mountains can't exceed a certain height.

The way that I envisioned this was a series of smaller & smaller cubes...however, rereading this made me realize that it was just my brain trying to make it make since.

My guess is any solid 3D structure would work, a cube is probably to simplify math

I think for this estimation, we're just looking at mountains as a blob of mass, to try to prove that mountains cant exceed a certain height

Well, pyramidal / tetrahedral would be the best guess, but really, a pyramid's volume is 1/3 of that of the cube (and since pyramids are an underestimate - mountains are more parabolic); the error factor is within 10ˆ0.5.

i think that's why this says "assume that all mountains are cubical," not "model all mountains as cubical.

This is definitely an interesting assumption.. Can we have some reasoning?

Although it may be misleading, it will give us a relationship. Which is always nice to have before trying to model something to actual dimensions.

The important thing to take away is that mass heightˆ3, or any linear dimensionˆ3. It assumes that all mountains have the same shape (and density), regardless of what that shape is.

This reminds me of the "assume the cow is a sphere" joke

Wouldn't a cone make more sense? or does this complicate too much?

Couldn't it be equally as easy to estimate a mountain as a right triangle?

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In addition to solving problems like these while making assumptions like all planes are about the same and all mountains are cubical and same material, etc. it would be nice if you discussed briefly the effects of differences between the planes or mountains.

this whole paragraph is awkward....and redundant with the third paragraph

Uh, not it's not (to either of your points).

?

probably means to insert a section number here that he does not yet know.

Yeah I'm pretty sure that's what's happened.

Could be an error with some formatting or an image / equation that got lost in file format?

something to do with not oversimplifying?

is this a typo or a question posed to the read?

How can we assume that the reason that mountains aren't taller is the fact that there is too much pressure at the bottom. Could there not be some other limiting factor that we are not addressing before making this assumption?

I agree, even if I can't think of what another limiting factor could be.

Redundant, but kind of nice

Maybe rephrase the end of the sentence as "so we need to estimate the force and the area"

Probably should have read this before I tackled the pset.

Definitely. I was struggling until I gave up to do the reading.

i don't think f = mg is a hard concept to understand here.

True, but skipping this step of explanation can make the next bit more convoluted, especially for people who do not see equations on a day to day basis.

Yeah – even if it's a simple equation, I don't think having it there detracts from anything.

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I don't really understand how F being proportional to mass makes F/m independent of the mass. Isn't mass a part of F/m?

So when we say that some ratio is "independent" of a quantity, are we saying that it stays constant as something changes? I don't know why I'm not understanding this intuitively.

Yes, x independent of y if changing y does not change x.

or the constant, gravity.

so the force inhibiting mountain height is independent of gravity? In this week's PSET there's a question that insinuates the height of mountains on different planets is related to gravity?

Is it possible that gravity figures into the force, such that that F/m is independent, but F is not?

yeah, when he says that F/m is independent of mass, he means it's a constant–the constant of gravity. so, F does depend on gravity, and m doesnt; look at weight: F=mg, mg/m = g. a constant. that's all he's saying here.

I know this language of "being independent" was used in the previous reading, but it's still really confusing. I feel like I shouldn't have to think this hard to figure out what the original definition of this term means.

When you say that F/m is independent of mass, it makes me think that as m changes, F/m won't change, which is clearly not true. I think another phrase might be more useful and create less confusion.

wait as m changes, F/m DOESN'T change. F=mg so as m changes F changes proportionally and thus F/m does not change. so your assertion that this statement is not true is not a proper assertion

Yeah, "When you say that F/m is independent of mass, it makes me think that as m changes, F/m won't change, which is clearly not true. I think another phrase might be more useful and create less confusion."

It is clearly true, which is why it is independent.

how is F/m independent of mass- if m is mass??

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I dont understand how F/M is independent of mass when mass is included in it. what exactly does this mean?

It means that the ratio between force and mass does not depend on mass. For example, no matter what my mass, my force of gravity divided by my mass is always the same.

A bit of a subject jump here. It almost seemed like the l^3 relation was related to the mass relation, which made me read it twice. Looking at the proportionality below it made everything clear though.

I fell like this while part is confusingly worded & ^3. therefore F proportional to l^3

I agree with this sentiment. I read this without seeing any comments first (printed it out), and after getting through the first page had a "What?" moment. I makes sense going back to it, but just having F prop m, and m prop vol, and f prop l^3 just felt like running down an actual mountain,.

why are you using the symbol here?

Yeah I'm confused about that as well - mass is proportional to volume, but volume is definitely equal to L^3.

maybe since we're acknowledging that we made a big assumption when we said mountains are cubical?

I had been reading as "is approximated by" and the proportionality symbol as just that (throwing out constants, arbitrary or not).

Is this related to the proportionality with density?

I think I get why when you make the equations a fraction, they become independent, but if you could expand a little bit on the explanation, it'd be more helpfull.

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I don't understand why this is independent of l, a little more explanation could be used.

same reason that F/m is independent of m, it takes into account m...the proportionality is unchanged

if you think about it, m=density*volume, so m/volume=density. here we're assuming that density of mountains is the same, or "constant" so the ratio of mass/volume is unchanging for different mountains.

l^3 = volume.

This was a little confusing to understand at first and I made some mistakes on the homework in this area but now that I understand it it is incredibly useful

the constant, density

This was a little confusing

I think another sentence to explain/clarify the use of constants would be helpful.

I'm still a little confused about this, you don't really explain why the equation becomes independent of l

Every time i see the word independent I think they are actually dependent on each other.... confused.

Yeah, I think I'm also confused... why is it m/l^3 is independent of l and not, say, m? Is it because m is a function of l? And that m/l is a constant...?

relating it back to density (see above comment) made it clearer for me... because i know that objects of varying sizes can have the same density

I'm confused with this wording.

Yes, we do seem to be spending a lot of words to argue a fairly straightforward point.

yeah i think the wording of this sentence is weird, and kind of hard to follow.

i see you're using parallel structure to mimic what you argued above but i don't think it's necessary again. i feel like the second time it's a "duh" point

Maybe writing out the full equation and then showing which variable s are eliminated because they are constant would make this more clear.

All he's saying is F m l^3, so F l^3.

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It would be interesting to see if any of the mountains on earth are anywhere close to this limit.

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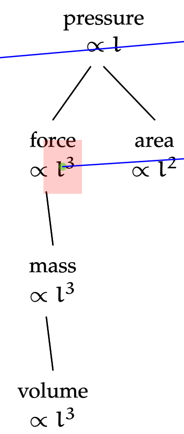

With a large-enough mountain, the pressure is larger than the maximum pressure that the rock can withstand. Then the rock flows like a liquid, and the mountain cannot grow taller.

This estimate shows only that there is a maximum height but it does not compute the maximum height. To do that next step requires estimating the strength of rock. Later in this book when we estimate the strength of materials, I revisit this example.

This estimate might look dubious also because of the assumption that mountains are cubical. Who has seen a cubical mountain? Try a reasonable alternative, that mountains are pyramidal with a square base of side l and a height l, having a 45° slope. Then the volume is $l^3/3$ instead of l^3 *but the factor of one-third does not affect the proportionality between force and length*. Because of the factor of one-third, the maximum height will be higher for a pyramidal mountain than for a cubical mountain. However, there is again a maximum size (and height) of a mountain. In general, the argument for a maximum height requires only that all mountains are similar – are scaled versions of each other – and does not depend on the shape of the mountain.

4.3 Jumping high

We next use proportional reasoning to understand how high animals jump, as a function of their size. Do kangaroos jump higher than fleas? We study a jump from standing (or from rest, for animals that do not stand); a running jump depends on different physics. This problem looks underspecified. The height depends on how much muscle an animal has, how efficient the muscles are, what the animal's shape is, and much else. The first subsection introduces a simple model of jumping, and the second refines the model to consider physical effects neglected in the crude approximations.

beautiful...I actually get it!

Yeah this was a really awesome example!

I'd change this to m

I think this works as l^3 since the pressure=force/area assertion earlier clearly combines with this to show that force/area=l^3/l^2=l

I didn't even realize he used L^3. But he didn't make an accidental mistake. He is doing the same thing he did earlier when he said mass is proportional to volume (L^3). In fact, force is as well, since the force component of an object's pressure on the ground is its mass times the little g (gravitational constant). We don't worry about "g" so the m in F=ma reduces to L^3.

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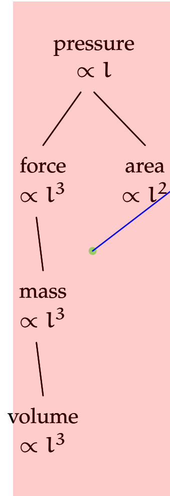

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this doesn't make any sense to me. it's not our traditional tree...

A small introduction to this structure would be helpful.

Agreed it's new, but it's similar to what we did before. Instead of having numbers, we just keep the variables to see how things scale wrt proportion. For example, before when we were estimating mass a common tree structure was to first estimate volume and density and multiply the two. In that scenario we used numbers. In this example it's enough for us to know that they scale in proportion. In other words, mass is proportional to density and volume. (increase volume –> increase mass and increase density –> increase mass)

It's pretty similar to what we had done previously. In a tree, you stop at a branch if you know how to estimate that variable. In this case we break pressure into area and force. We can easily find area but we can't estimate the force of a mountain so we need another branch. We know that F prop to mass but we can't estimate the mass of a mountain either so we extend it to volume which is something that we know how to find

yeah, I agree–this is pretty similar to what we've seen. in the first case, there's two values we need to estimate pressure: area and force. We can estimate area right off the bat, so we use more branches for force. then we say force depends on m*g, but g is constant. so look at m. but we cant confidently guess m, so we look at m: it's density*volume. but density of all mountains is the same, so we then have volume, which using our cube approximation, we can find

I would definitely rather have the tree than not have it at all. It is always hepful to have a diagram that summarizes your steps to solving the problem. Not to mention that it is very easy to follow. (much easier than reading the entire paragraph)

i would argue for keeping the tree. though it may not be helpful for everyone, i personally (and i know that i am not alone) really like graphical approaches. those who don't like could always opt to not use it.

I think its easy enough to see how this tree is like the divide and conquer we did.

The force and area results show that the pressure is proportional to l:

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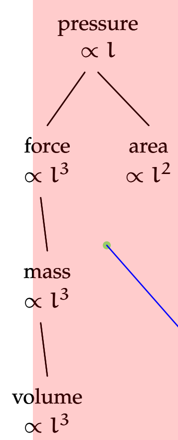

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The reply above give a nice explanation of the tree. I only understood the first section after seeing the diagram. You should fuse the two and use the text to explain the tree instead of using them seperately.

Keep the tree. But if there was some way to put it on the previous page where you go through all the steps, that would be more helpful

I actually like this proportionality tree A LOT. Lining up the proportionalities makes this very clear.

The proportionalities are made clear but I had to read the text to understand the purpose and function of the nodes. Why not add a leaf for density and g?

i'm having a hard time understanding how to read these trees

It doesn't say anything explicitly about a maximum though, just that the pressure consistently increases with height. But perhaps the pressure can go almost infinitely high or the proportionality constant is infinitely small?

It makes sense to me that the rock would become liquid but isn't it dependent on the fact that you are assuming the mountain is a cube?

The idea here was to explain why there _is_ a maximum height, not to show what it is.

but that would be fun/interesting!

I am sure that finding it is as easy as finding the pressure (at a constant temperature) where the rock turns into liquid and finding [L] in terms of pressure to find its max height.

I don't think he's saying that the rock turns to liquid but that pressure from the height of the mountain will cause it to compress and make the base widen, like a liquid would. I could be way off here though.

I like this paragraph. It makes sense reading it.

This explanation that the rock will flow like liquid should be earlier in the section. Otherwise the reader is imagining how a mountain's height can be limited.

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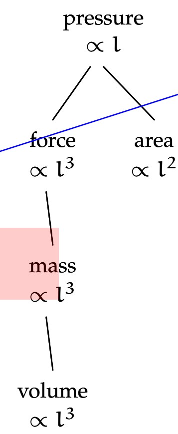

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This is only partially true. What about erosion from rain, snow and glaciers? Mountains on mars are much larger than mountains on earth because they lack these.

Well, you can also think about it in terms of why a mountain of height very tall h couldn't even form in the first place, right...?

But to illustrate the example at hand none of this information is really relevant. It would be an entirely different problem to try and approximate how much height a mountain loses each year due to errosion.

I still think it's good to keep in mind that on earth other effects dominant the restriction on height of mountains so that you have a sanity check for your estimation. The maximum height of a mountain based on the strength of rocks should be much larger than the observable height of mountains on earth.

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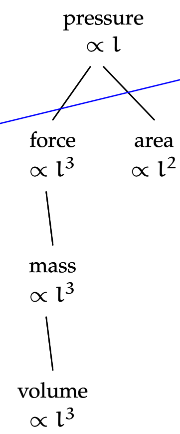

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So the inside of the mountain turns to lava? Does the mountain shrink down into the earth at that point?

shrink? no. i think you mean sink. and sink into what? more rock. that doesnt make any sense either.

maybe the rock "overflows" the mountain and just starts rolling down, or something. perhaps like a liquid overflowing its container and spilling out the sides.

a little earth 101: reference image (http://www.nasa.gov/images/content/103949main_earth

The outer part of the earth is the "crust" ... the hard earthy parts that we know and love, yet take up less than 1% of the earth's volume.

Below the crust is the mantle ... esentilly magma, or liquid rock.

Then there's the outter core (liquid metals) & the inner core (solid metals)...both mostly iron.

...

The idea is that there is only so high that the crust can get before the mountain's weight applies enough pressure to melt the bottom of it into the mantle.

I'm sorry, I can't let this slide - the mantle is not a liquid!!!!!!! The asthenosphere (right under the crust) is hot and acts like a fluid – in fact, the mantle solid-state convects (think about it), but it is certainly not a liquid. In some place, yes, the mantle may have some melt, but not more than a few percent. And...it has been suggested that mountains (or dense bottom parts of continents) loose their roots...the dense bottoms drip down...making more melt! anyways, the point is...the mantle is not a liquid.

He said the rock flows LIKE a liquid... he didn't say it turned into liquid.

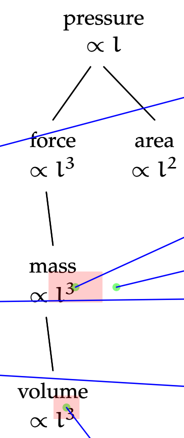
I'm guessing that's you steph

So I guess this makes sense since there's conservation of mass, because the earth could be thought of a big mountain (different shape) but with the middle turning to lava because of the pressure....

Are you implying that if the earth gets too big, there will be too much pressure and the core will melt?

The force and area results show that the pressure is proportional to l:

$$p \sim \frac{F}{A} \propto \frac{l^3}{l^2} = l.$$



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I'm sure this is heavily dependent on the material that the mountain is made of. Volcanic rock like granite is a lot more robust than dirt hills or mountains made of sedimentary rock

and this to volume

This actually made things alot clearer. I guess visual effects can do that to you.

this logic is a little fuzzy to me

this clears up my earlier comment about how do we know that pressure is the limiting factor. Pressure is something we know that will limit the height and lets us know that the mountain does have a max height.

Is it really necessary to even use math to show there exists a maximum height? Can't an argument just be made without all this?

> Not necessarily. If we didn't know the math, we might think that the pressure on the base of the mountain was constant with increasing size, which would not predict an upper limit on height. I admit that the fact we've proven is not very difficult to grasp intuitively, but as an instructional example this is very useful, especially since we can use our intuition to confirm the result of the math.

and this to = l^3

but now modeling the mountain as a cube, not a cone or pyramid, could put us off by a factor of few right from the start, no?

Oops, next paragraph addresses this.

I like this section, and my comment is just that I feel a little jipped that I don't get the answer now! But it's understandable...

> I was just about to write the same thing.
>
> > I agree as well, but it's a good thing that reading the book makes us want to read more of the book.

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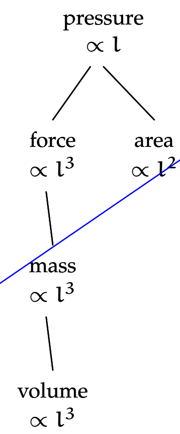

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this is something that meche's would just look up in a book, or run an experiment on. experiments are how the strengths are actually found.

As a course 2 student, I agree, but I think the idea is to use the knowledge you know about things like this in order to approximate and not get an exact answer.

it's one of those examples though that you never really bother to examine until someone points it out. i think it would be rather cool to derive the answer using estimation!

I think most Mech-E's probably learned this in thermo. Remember dimensional analysis?

yea i'm a mechE too but do i really EVER feel like figuring out the strength of a rock or ever expect to understand anything from the # i pick up? i'd rather approximate

Furthermore, its good to have a general intuition about these things so that you know that the numbers you look up are good or are in the correct units. Sometimes you are in the field or it may be too inconvenient or even impossible to look up particular values.

Assuming that objects take on square or cube-like shapes seems to be popular in this course. I guess it has to deal with the fact that those are relatively easy to approximate.

answer to the question someone had earlier.

It's interesting that the proportionalities make it boil down to just one factor of length. However, we've linked the base length and height. If those aren't related, you have mountains with the base not proportional to height (Dolomites, some Chinese mountain ranges), which might experience different limits.

This paragraph might more useful towards the beginning, especially considering how many people commented on the seemingly questionable estimation of a cube.

It would have been nice at the beginning to see something acknowledging that a cubical mountain seems like an odd assumption but promising to address that at the end (once we've gone through the proportionality stuff)

The force and area results show that the pressure is proportional to l:

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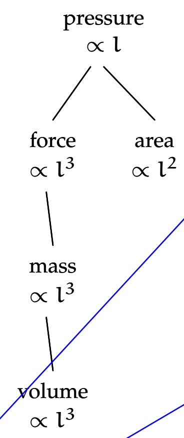

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This isn't totally clear to me.

I think it's saying that if there is any sort of multiplier, because it is a ratio that we are looking for, the multiplier will just cancel out.

I don't think its so much a matter of the multipler cancelling out as it is how the multiplier doesn't affect the proportionality. The exact result may vary b/c of the multiplier but the general relationship is the same regardless.

ar-huh here's why, I was confused at the beginning and now i got it

So when making a proportional argument, do we always throw out constant factors? If we have a large constant, can we assume that our variables are sufficiently large to make the constant irrelevant for the sake of proportionality?

Yeah, I don't quite get this either. Why doesn't the one-third matter?

I think it has more to do with the right order of magnitude and factors like 2 or 3 don't matter too much. Of course, if you throw out too many factors eventually they add up to something more significant.

Why can't this argument be use to say there there is basically no limit to mountain height, since as the ratio of the length of the base to the height decreases the maximum height increases. So a mountain with an arbitrarily large base could be arbitrarily tall.

I really like how this paragraph questions the initial assumption of using a cube to approximate the volume of the mountain, and that it shows that even if we had used a more realistic shape, we would have reached the same conclusion.

I don't think this was too complicated to just include earlier.

But not including it demonstrated that we got the right answer without using that detail. Next time it may indeed save us a lot of effort to assume the object in question is cubical.

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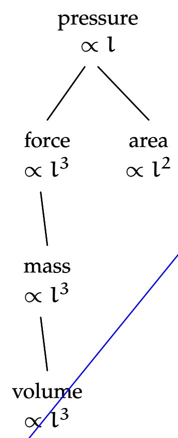

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Does anyone actually know the answer, and are current mountains not nearly tall enough to come close to the maximum hieght?

I tried to find it on the internet or wikipedia. I'd be interested to know...

each rock type has different properties, so it's one of those things where _every_ region has a different 'maximum size.' based on the specific minerals that are in (and under) them, where in different plates that they are, and everything else. I think that every mountain is at it's maximum height.

Naw...the maximum height can only be considered when the mountain is actively being made (aka the Himalayas). Older mountains are not at their max height...erosion works way too fast! The Appalachian Mountains were once as tall as the Himalayan mountains...but are they now? Mountains only last for on the order of 10 - 100s of millions of years.

I don't know if this is true, but I once heard that the Himalayas stay at around the same height since the erosion works about as fast as the fact it's growing, which makes it sound like the maximum height is limited by erosion... is this untrue?

The Himalayas is still growing, but at a very slow rate due to erosion.

Interesting, thanks for the comments guys.

Interesting, thanks for the comments guys.

Is there a reason why you explain the cubical approximation later in the page? I guess it kind of has a nice build up effect, but people would question in the beginning why you say cubical.

So what is the maximum height of a mountain?

This make sense since scaled computations should be good comparison.

Why do you need to assume all mountains are made of the same material? Couldn't you still calculate the maximum height for every mountain based on the different rock strengths?

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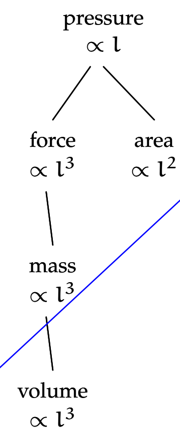

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I don't really feel like the mountain and the jumping tie in together very well. Maybe there should be some better sort of transition here.

And the mountain doesn't transition from the flight section earlier.

But I don't think that is the point. They are just different examples showing proportional reasoning.

Sometimes transitions can be helpful though as they remind you of things you learned in the previous section that are pertinent to the next example. Sometimes we are presented with so many facts and methods in the previous section that it is a little unclear what our starting context is for the next example.

Maybe the kangaroos are planning to jump over the mountain.

proportionally?

Yeah I would like this to be clarified- I assume like the bird and 747 example it would be proportionally

I thought it was just the exact height, thought considering we are leaning proportional reasoning, it can get confusing.

I thought the 747/bird example wasn't proportional. We concluded that they could fly the same distance but the amount of fuel they need is proportional. This seems different because the kangaroo and flea aren't going to jump the same height even if they have the same muscle/mass ratio (I think.... maybe that's totally wrong).

Yeah, clarification is needed about whether or not this means proportionally...

I mean, I think this is an unnecessary comment given the examples involved. Obviously, a Meter+ size animal will jump higher than a mm size insect.

penguins can jump 6 feet.

Is this really true? I would be amazed if this were a fact considering they have tiny legs and are pretty awkward on land

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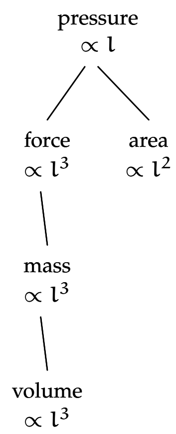

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the way this sentence is introduced sounds way random

yeah what does this mean? it sounds like a comment we might make

a colon or semicolon instead of a period after 'underspecified' would probably help the sentence feel more connected to the next phrase, which explains what it meant.

This section is good because it prepares us well for what we'll have coming. In a lot of the past readings I've been confused about why we were making the calculations that we made.

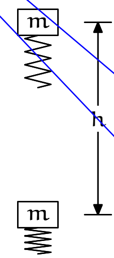
The height of the jump (it makes the sentence clearer)

4.3.1 Simple model

We want to determine only how jump height varies with body mass. Even this problem looks difficult; the height still depends on muscle efficiency, and so on. Let's see how far we get by just plowing along, and using symbols for the unknown quantities. Maybe all the unknowns cancel.

We want an equation for the height h in the form $h \sim m^{\beta}$, where m is the animal's mass and β is the so-called scaling exponent.

Jumping requires energy, which must be provided by muscles. This first, simplest model equates the required energy to the energy supplied by the animal's muscles.



The required energy is the easier estimation: An animal of mass m jumping to a height h requires an energy $E_{\text{jump}} \propto mh$. Because all animals feel the same gravity, this relation does not contain the gravitational acceleration g. You could include it in the equation, but it would just carry through the equations like unused baggage on a trip.

The available energy is the harder estimation. To find it, divide and conquer. It is the product of the muscle mass and of the energy per mass (the energy density) stored in muscle.

To approximate the muscle mass, assume that a fixed fraction of an animals mass is muscle, i.e. that this fraction is the same for all animals. If α is the fraction, then

$$m_{\text{muscle}} \sim \alpha m$$

or, as a proportionality,

$$m_{\text{muscle}} \propto m,$$

where the last step uses the assumption that all animals have the same α.

For the energy per mass, assume again that all muscle tissues are the same: that they store the same energy per mass. If this energy per mass is $\mathcal{E}$, then the available energy is

$$E_{\text{avail}} \sim \mathcal{E} m_{\text{muscle}}$$

or, as a proportionality,

Actually quite clever, since this way, we can disregard actual systems of mechanical movement between species.

I am not convinced that we can just use body mass. There was an article in the BBC about an ant that could lift 100 times its mass.

http://news.bbc.co.uk/2/hi/uk_news/8526086.stm

What is this "so on" referring to?

the factors mentioned earlier, such as: how much muscle the animal has, what the animal's shape is, etc.

These are factors that were mentioned before. Other factors I can think of include how athletic a person is, how much a person has practiced, etc.

I don't think I'm reassured by the same blind hope that you are. Then again, perhaps it's not so blind for you.

this seems like a very tricky statement. unknowns, by definition, can't cancel. They'll just change the values by unknown scalars.

The point is that they are unknown quantities but if we can approximate the level of them we might be able to have them equal one another.

I see what you're saying... However, i think he is referring to the possibility of having the same variable somewhere in the numerator and also somewhere in the denominator. For example, you could have height in the numerator and volume in the denominator. But volume uses height, so the height cancels.

This statement just seems out of the place the way that it's worded.

It kind of makes the paragraph sound like you have the problem all worked out - know the variables are going to cancel - but are just playing along for the reader. It sounds awkward.

I read this statement to mean that the factors contributing to the max height would cancel..for ex., higher body mass would offset more muscle. Not necessarily would the units cancel, just their relation to whether it enabled the animal to jump higher or not.

I sometimes get frustrated when things just cancel. But it is interesting to just try without much information than give up, because I think ordinarily I would just give up.

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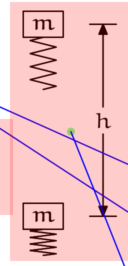

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If I was just doing a problem I haven't seen before, this method makes me feel very uneasy. But maybe by being very consistent with what does unknowns are, it could work out. I feel like a lot of problems would arise by not being consistent with when the unknown variables should appear and when they should not.

How do you know you want the exponential relationship. I think there was a "jump" in logic.

Can you motivate the need for /beta now?

Well we don't know if h will be proportional to m, m^2, m^3.. etc

Yep, beta is an exponent, not a constant in front of m.

This is just what we did in class today with n^k for the schooling method.

You should specify whether this is the animals height, or the height of the jump. could be confusing

i'm confused.

I am too but maybe I can be a little more specific. How do you know that you are looking for a result in this form? There may be a simple step I am missing.

I just read the comment above and am no longer confused this makes perfect sense

agreed, but i still have no idea how to proceed from here. i realize that below will explain, but i would not have been able to do this alone

I don't know that the point is to be able to do this alone on your first try seeing it but to show you an example so that next time you can do it alone

Could we model these as springs? It wasn't mentioned, but this drawing gives me the impression of using 1/2kx^2

Doesn't this assume all animals have the same center of mass? An animal with little mass in their legs could make a small jump and pull up their legs and clear a height larger than the change in the position of their center of mass.

I really like the order that we approach things in this section. It's very logical and intuitive, and even reproducible.

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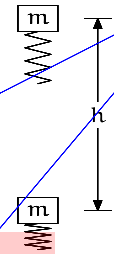
We want an equation for the height h in the form $h \sim m^{\beta}$, where m is the animal's mass and β is the so-called scaling exponent.



Jumping requires energy, which must be provided by muscles. This first, simplest model equates the required energy to the energy supplied by the animal's muscles.

The required energy is the easier estimation: An animal of mass m jumping to a height h requires an energy $E_{jump} \propto mh$. Because all animals feel the same gravity, this relation does not contain the gravitational acceleration g. You could include it in the equation, but it would just carry through the equations like unused baggage on a trip.

The available energy is the harder estimation. To find it, divide and conquer. It is the product of the muscle mass and of the energy per mass (the energy density) stored in muscle.

To approximate the muscle mass, assume that a fixed fraction of an animals mass is muscle, i.e. that this fraction is the same for all animals. If α is the fraction, then

$$m_{muscle} \sim \alpha m$$

or, as a proportionality,

$$m_{muscle} \propto m,$$

where the last step uses the assumption that all animals have the same α.

For the energy per mass, assume again that all muscle tissues are the same: that they store the same energy per mass. If this energy per mass is $\mathcal{E}$, then the available energy is

$$E_{avail} \sim \mathcal{E} m_{muscle}$$

or, as a proportionality,

I think this explanation should have come much early in the proportionality concept.

Good analogy that brings home a very good idea when doing proportionality problems: since everything is relative to each other, anything in common can be replaced with a 1.

but wont you need it when it comes to actual calculations?

This was hilarious!

I also liked the comparison.

The humor lightens up the material and makes it more fun to read :) good job!

Agreed. I enjoyed this as well.

The humor is good.

Definitely a great analogy. I find my self doing both, carrying unnecessary baggage on trips, and unnecessary quantities in equations all the time, never thought of them as the same mistake.

is there a reason why we're going through it here?

I agree, it seems like a strange time to bring up how much energy is necessary.

Because it was mentioned as proportional to mh, thus if we can solve for m (we can assume the mass of the animal) and we can solve for E, we can get h

I am confused about what available energy is. If we already know how to calculate the amount of energy it takes to jump, why do we need available energy?

I liked this. I should really learn to think in terms of energy densities more when making approximations.

so out of curiosity, what is the power density in human muscle compared to say gas, or lithium-ion batteries?

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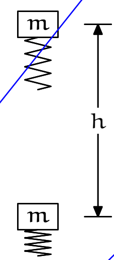

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is this a valid assumption here? is it a necessary one?

I think it's pretty legit, and it's definitely needed, since right above, we estimated energy per mass in muscle, so to estimate energy we need to estimate the muscle mass in an animal, and we're assuming that for most animals, this fraction is probably pretty similar

I wouldn't have made this assumption in my first pass through. Its tough to accept, knowing that it is not true, but only roughly true. Knowing that, aren't we limited to making the assumption that all animals jump "roughly" the same height?

isnt this already detracting from the original question? of which animals jump hihger? if they all have the same muscle fraction, and then i assume we'll say they all have the same muscle efficiency, we'll just get that they all jump the same

No, even if they have the same muscle fraction and efficiency, their masses are different.

But we're trying to differentiate between animals. This groups them all together. How can we possibly tell which animals jump higher, if they're all the same?

We're saying that their muscle fractions may be the same, but their masses are still different. If our final answer depends on mass, then a flea and a kangaroo will not have the same jump height.

i don't like the use of alpha as the fraction because this is used for proportionality

Yeah it is a little confusing at first...

You might want to use a greek letter other than alpha here. Alpha looks a lot like the "proportional to" symbol and might confuse people.

that is exactly what i was thinking

definitely. there's so many greek letters available to be used too...

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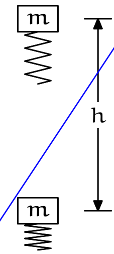

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Does it matter that all animals have the same alpha for this to work? I thought the proportionality only meant that they all varied linearly (similarly) with overall mass, but not necessarily with a particular constant associated with all of them (because then you could just state that m_muscle = alpha*muscle, right?)

He does state earlier that m_muscle= alpha * m but I think for approximation's sake it makes sense to assume that alpha is the same for all animals because then it will just cancel out in our ratios.

I fell like you have to do this but it is interesting to think about whether this is true when comparing fleas and kangaroos since they have such different skeletal structure.

I'm not sure that makes sense, some animals work a lot harder than others, or have more effecient systems! oh well

i agree, but how else are we going to move on...

Exactly, it's better to go forward incorrectly than stay stuck correctly.

This is quite an assumption, there are many other things that come together to make up the mass of an animal (i.e. bones, organs).

right here he's only talking about muscle–assume all muscle tissue is the same. we know it's not, that's why it's an assumption

I guess with both this point and the point about alpha above I would let this slide if I wasn't thinking of, say, a flea versus a kangaroo because it's difficult for me to believe that their body functions similarly at all in terms of muscle, muscle mass, etc.

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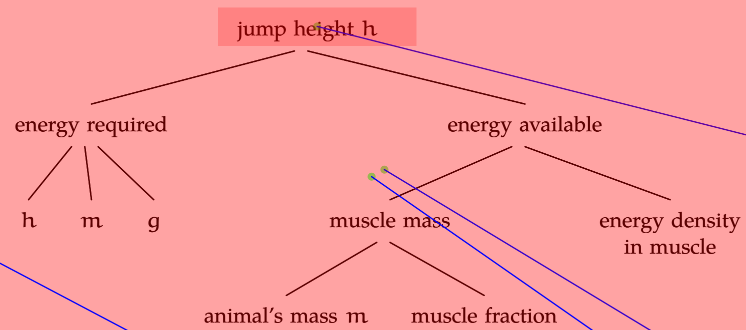
where this last step uses the assumption that all muscle has the same energy density $\mathcal{E}$.

Here is a tree that summarizes this model:



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Now compare the available and required energies to find how the jump height as a function of mass. The available energy is

$$E_{avail} \propto m$$

and the required energy is

$$E_{required} \propto mh.$$

Equate these energies, which is an application of conservation of energy. Then $mh \propto m$ or

$$h \propto m^0.$$

In other words, all animals jump to the same height.

I feel like we've been making so many assumptions, such as the fraction of muscle is fixed, the efficiency is the same across all animals, but is there a way to account for these factors at the end? or they are not significant in our calculations. I think these factors can contribute to a lot of variations, unless they all got canceled out at the end

I think it's valid since we're only looking for a ballpark number in the end. It's highly unlikely that one animal will be an order of magnitude more efficient than another animal. The muscle efficiency assumption is also reasonable, as muscle is all essentially the same tissue type, and it functions as a spring.

I feel like the surface they're jumping from is important too for energy loss reasons. I guess you can wrap it all up in the energy argument, but it might be something to mention, if merely as an aside.

Hmm, interesting point. Surely assuming it to be an elastic reaction isn't too far of a stretch?

wow, yeah that would probably make a difference...didn't think of that

Since we're doing a comparison, we can assume they are jumping on the same surface. So, really, it doesn't matter. It's not like one is jumping off concrete and another rubber. It's either both concrete or both rubber.

hmmm any body else feel like they're going through case in point lol

I like how this tree combines proportions with divide and conquer. It makes so much sense!

I really like how the trees have carried throughout the notes to help tie everything together. I'm a visual learner to some degree, and they greatly help with clarification.

This diagram really cleared things up for me

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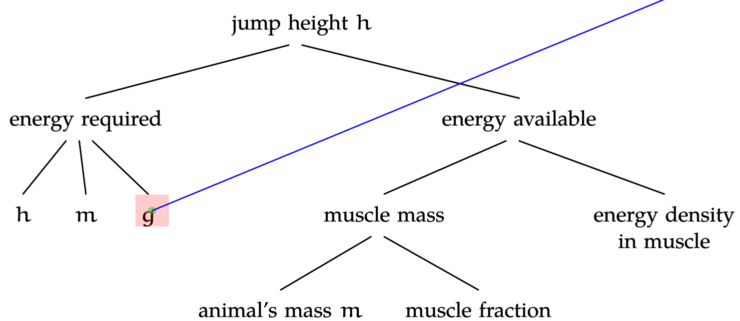

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why are we including this here?

I thought 'g' was supposed to be ignored...

I think he's putting 'g' there in order to show that he is not forgetting that it exists in this problem. Even though it was mentioned before that all animals experience the same g so we can ignore it, it's still good practice to have it here in the tree diagram in order to make it cognizant to readers that it the energy required for a jump depends on g.

yeah, but why didn't he include it in the earlier problem when we said that F is proportional to m–here E is proporitonal to h*m...same kind of thing right?

i think it's because the equation for E is mgh, and all three variables feed into the equation for E. even if they cancel later, it still has to feed in now.

there should just be something in parenthesis or some other way of indicating that we won't be using it to avoid confusion and stay consistent with the explanation above

I think it's self-explanatory why everything is listed. The tree is a way to organize the bits of information you need for the problem in general. Not using things in the tree because they are the same (gravity, energy density of muscle, etc) comes later when you are putting everything together.

The muscle fraction and the energy density in muscle are also included, even though they eventually divide out.

These things are kept because they're needed to calculate an animal's jump height (which is what the tree claims to calculate). When calculating the _ratios_ of jump heights, these constants cancel.

The tree really should be put alongside or above the explanation. Obviously the explanation is needed, but a lot of times the assumptions are obvious, and tedious to read through

I find this tree really helpful...its easy to forget steps as you move down

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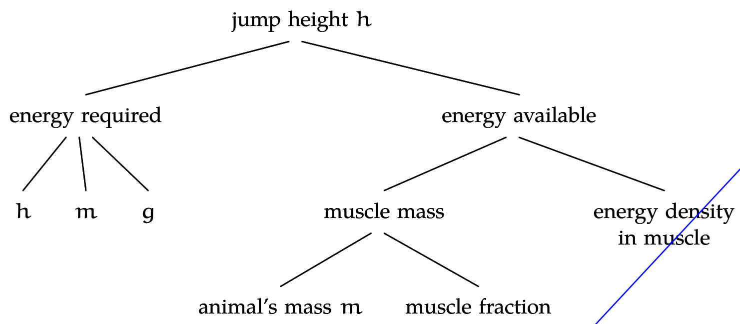

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that seems intuitive, no?

this method does seem intuitive. i think that it is because it is stuff that we have learned before

for me, the method is not at all intuitive. you could argue the final result is intuitive, but personally I would not have come up with these steps for approximating on my own.

Still, we are only looking at the muscular power of an animal. Isn't it possible that animals that are larger have to have an exponentially higher amount of muscle to exert the same amount of power on their legs?

This is true but we are focusing on animals in general and if we can use various specific animals to get an estimate we can make an approximation for all animals.

Which would make sense without using equations and just common sense

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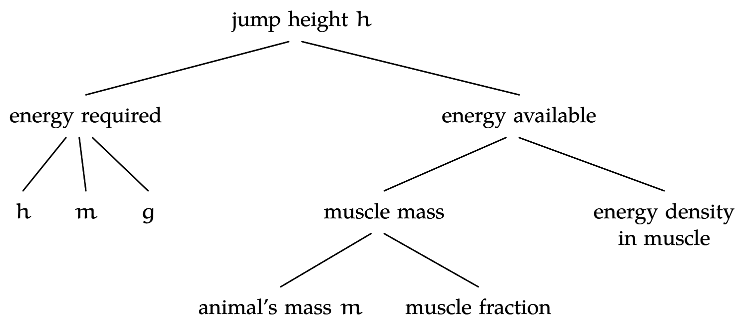

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How come some humans can jump higher than others, assuming both are athletes?

I think the idea that all humans can jump the same high is a very broad generalization. One athlete may have a different muscle fraction and thus muscle mass, and/or a different energy density in his or her muscles, which changes the energy available. Hence, they are able to use that higher available energy to overcome the larger energy required for a higher jump.

I agree...but we made a fair amount of assumptions here, so I feel like we aren't really learning anything new.... only that we can "roughly" jump the same height.

I think the point is more about how high different species jump relative to each other.

and from this class's perspective, all humans do jump the same height. whether you can jump 1 meter or half of a meter, it's all the same within a factor of about 10^0.3.

This is generalized 'to hell'; of course all people don't jump the same, but it's a really nice approximation, and a very good example here. I think adding some more animals would be nice, but there's really no way of going into more detail without going into way more detail about muscle structure and densities and it's going to get messy. This was definitely one of the clearest examples so far, for me.

This explanation makes a lot of sense. Maybe it shouldn't be all animals jump to the same height but all animals with the same muscles jump to the same height.

This is cool.

is this really true? is there a way to validate our approximation

this is because we modeled all animals the same

which we know is false- what is the use of "proving" this?

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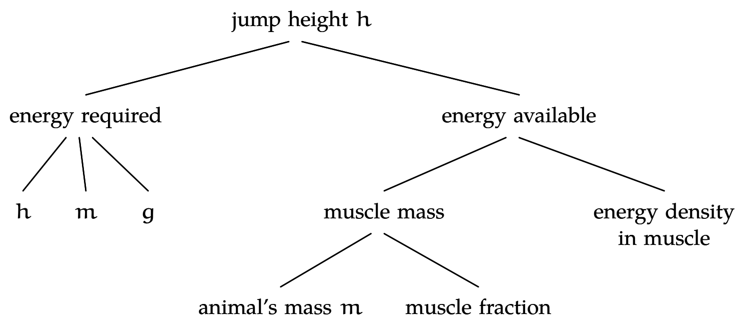

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I wouldn't have guessed this.

Me neither, but I think some of our more questionable assumptions (for example, all animals are equal percentage muscle, which I find suspicious) probably brought this result about.

I agree, I believe this result is mostly a function of our assumptions.

I think this is just a function of the assumptions. Most importantly that energy and mass scale with each other. I might be interesting to estimate the amount of mass that an animals legs make up and incorporate that....

It's not supposed to be an exact approximation, but it does imply that a flea would not be able to jump 10 times higher than a human given the respective muscle masses. The approximation is rough but pretty accurate given our generalized assumptions.

this seems strange to me too. it also seems false.

This seems sketchy to me too but I think the idea is that, with the exception of a few very extrordinary animals, all animals jump about the same height.

Maybe all animals of equivalent mass can jump the same height, but all animals cannot jump the same height. That simply doesn't make sense

I feel as though this is an example in which there is too much error approximation, and the true answer (which is within a small number of magnitudes) has been lost.

I agree, this feels similar to the plane range problem in the previous reading. A lot of assumptions were made, and then it was just declared that all planes travel the same distance. Similarly, here, a lot of assumptions were made, and then it was just declared that all animals jump the same height. However, I think it would be better to remind the reader that this is the result for comparing 2 animals with similar mass, muscle percentage, etc. You're basically comparing 2 identical animals, so it's no wonder they can jump the same height.

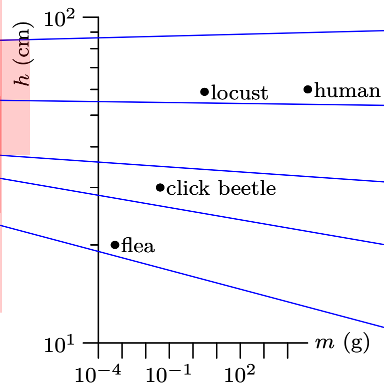
this is amazing

I feel like this conclusion is analogous to the plane/bird one. We learned that birds can fly about the same distance as planes, and now that all animals can jump to the same height.

I'm a little surprised by this conclusion.

The result, that all animals jump to the same height, seems surprising. Our intuition tells us that people should be able to jump higher than locusts. The graph shows jump heights for animals of various sizes and shapes [source: *Scaling: Why Animal Size is So Important* [26, p. 178]. Here is the data:

Animal	*Mass* (g)	*Height* (cm)
Flea	$5 \cdot 10^{-4}$	20
Click beetle	$4 \cdot 10^{-2}$	30
Locust	3	59
Human	$7 \cdot 10^{4}$	60



The height varies almost not at all when compared to variation in mass, so our result is roughly correct! The mass varies more than eight orders of magnitude (a factor of 10^8), yet the jump height varies only by a factor of 3. The predicted scaling of constant h ($h \propto 1$) is surprisingly accurate.

This is a pretty impressive result and a really cool example!

this is confusing- I think you mean total height, while most people would think this means proportionally

Really? I would guess that locusts can jump higher..

I like this follow-up with some numbers to check our calculations. This problem in particular does a good job of it.

I don't know about this. Locusts are pretty "jumpy" Maybe we'd expect to jump higher than, say ants, or things you don't normally see jumping anyways.

Is this graph intending on showing a general trend among all animals? For example, do elephants jump really high?

This makes sense with the assumptions we made but I feel as though it takes the mean of all animals when in reality different animals have been able to survive due to their ability to exercise the strengths they have, such as the fact that ants can hold much more weight then themselves whereas humans don't have the same ability.

This conclusion isn't trying to say that ants can jump as high as locusts. That's too specific of a comparison. Ants weren't designed to jump, so you're comparing apples to oranges.

What the conclusion is saying is that out of all the creatures that do take advantage of jumping, they jump to about the same height, regardless of how much they weigh.

It is a very broad estimate on a theoretical limit of how high living things can jump, given physiology of living things and the chemical power of muscle matter.

Actually, that's a really good point that makes all this a lot more believable to me. I think it'd be good to have something like that in the book, too?

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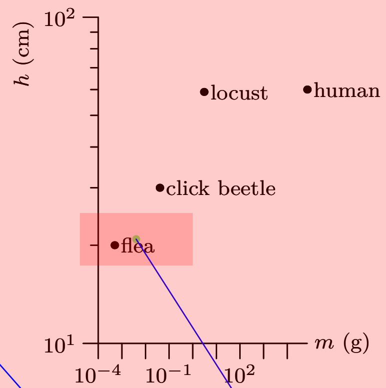

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I think it might be good to add the kangaroo on this graph seeing that you specifically mentioned it before. For those who are interested, after a quick google search, a kangaroo can jump 10 ft or 300 cm.

Is that how high a kangaroo can jump from a standing position? The data in the table is for a "standing high jump". In a running high jump, you get to store energy in your motion and then convert that into height. In the standing high jump, all the energy has to be stored in your muscles (or shell, if you have one).

I understand the argument being made, but i have to disagree. Lets put it this way. Muscle fiber, regardless of the size of animal it is in, has the same strenght (as the cells that make it are always the same. The strength of muscle depends on cross-sectional area (call it l^2) but the weight depends on the volume (l^3). This implies that smaller animals (even ones with the same muscle-weight percentage) will be stronger per body weight than larger ones. this is why ants carry so many times their weight, and why elephants cant jump. THis should also imply that smaller animals should be able to jump higher in proportion to thier size than humans. IS this reasoning incorrect?

So why can ants carry so much more than a human??

Wait, how does that relate to jumping?

Hahaha it doesn't, I was just wondering if similar principles apply?

It probably does.

given how they plagued my childhood pets, i'm a bit underwhelmed by how they stack up.

This last section was really helpful in understanding the previous part. I'm really glad that this section is included.

I'm not sure about the accuracy of this. I think fleas have about a 6 foot max range - so about 180 cm.

That's horizontally, though. This is vertically. I'm not sure how that affects your number.

I like that you make assumptions generally in the beginning and then work through the calculations, then finally provide data.

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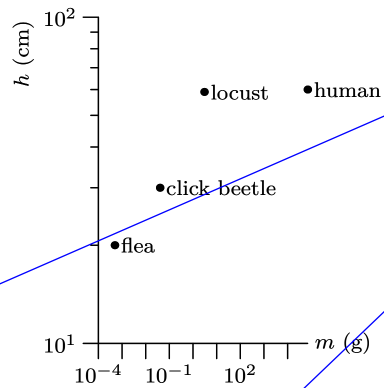

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I think penguins should be here, I read somewhere that they are unique in jumping and it would be nice to analyze them

wait–are you saying that jump height is proportional to mass, or that the variation in the data is significant? i'm confused.

At first I thought it was saying that height is proportional to mass but then it goes on to say that jump height variations are much smaller than the variations in mass, so I'm not really sure.

Right, it just means that the height doesn't change nearly as much with huge changes in mass (i.e. a large animal still jumps about the same height as a small one). I like this observation, it acknowledges the rough approximation but still reveals an interesting fact.

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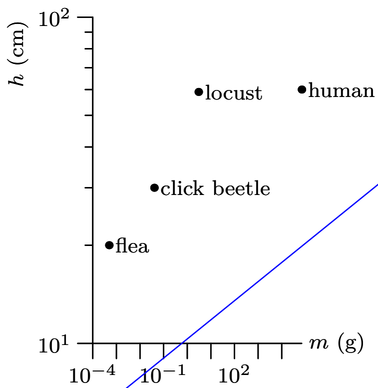

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What about animals that can't jump? I don't think, for example, turtles or elephants or some things even can jump...

Or starfish.

It looks like everything listed there is also an insect - if we throw in things like lions and kangaroos, wouldn't that throw things off?

Not sure, but I agree it would be nice to have data from something else besides people and insects...

I think that's one of the problems with the simple model.

I thought we were going to make some corrections to this simple estimation that would refine it to handle other mammals?

I don't think turtles or elephants jump at all, so maybe we're restricting our analysis to animals that jump regularly or have the ability to jump regularly?

well i mean, if we say turtles can't jump at all–well no fish can jump so obviously we're not talking about fish. but yeah, if we got into the case oflarger animals like elephants or giraffes or something, we might have to make a new category–maybe different categories of jumping height would make the result a little more realistic

fish do jump...

read the above thread for an answer to this thread

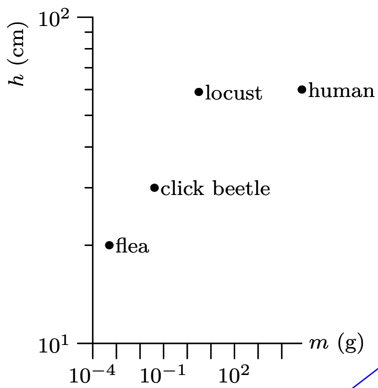
This may have something to do with the simple spring model of jumping we assumed at the beginning of the section. It's probably only reasonable to apply it to animals that can more or less jump up and down.

Is it that elephants and turtles physically can't jump, or they just...don't?

The muscle fraction issue comes into play with things like elephants, I think. Bone strength is proportional to cross sectional area (L^2), while mass goes as L^3, so heavier animals need comparatively larger bones to support their own weights. I suspect that you would find that the muscle fraction of an elephant is lower than that of a kangaroo.

ok, it answers my question here =)

The result, that all animals jump to the same height, seems surprising. Our intuition tells us that people should be able to jump higher than locusts. The graph shows jump heights for animals of various sizes and shapes [source: *Scaling: Why Animal Size is So Important* [26, p. 178]. Here is the data:



Animal	*Mass* (g)	*Height* (cm)
Flea	$5 \cdot 10^{-4}$	20
Click beetle	$4 \cdot 10^{-2}$	30
Locust	3	59
Human	$7 \cdot 10^4$	60

The height varies almost not at all when compared to variation in mass, so our result is roughly correct! The mass varies more than eight orders of magnitude (a factor of 10^8), yet the jump height varies only by a factor of 3. The predicted scaling of constant h ($h \propto 1$) is surprisingly accurate.

While this does make sense, I feel like this contradicts the previous statement saying all animals jump the same height. I understand that they all jump with similar heights, I just don't like how the example went out of its way to "prove" that all animals jump the same height.

So i guess this is where the whole issue of how we can compare such differently shaped and sized animals together. I was wondering how we take into account the clear advantages larger animals have. But spread out over a graph, our guess was right.

this seems really cool, but I am having trouble using this method in my own calculations- how to I know how to take it- should I start with a tree or start by just figuring out proportions

Sometimes, the first time I read these kinds of parentheticals, I think they are products...

Is this the first time we've seen this notation? I think it's confusing since 1 is unitless, though I realize h is proportional to mˆ0 and things to the zeroth power are 1.

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I thought this was a great summary.

So basically, per unit mass, all animals can jump to the same height?

I think it'd be cool to bring back the gravitational constant g, just to prove how height varies with it. It'd be cool to prove exactly how high people on the moon can jump using proportionality between the earth and moons gravity. Just an idea...

I think the problem most people have with this is that yes - the order of magnitude for the jumps is all the same relative to mass, but when we consider jumping, a factor of 2 seems like a LOT to witness physically, but not all that much in this calculation. So while yes, we all jump the same magnitude of height, there are some differences...is this correct?

Hold on though, the jumps changed by a factor of 3, while the masses changed by a factor of 10ˆ8. To me that makes me believe our calculations.

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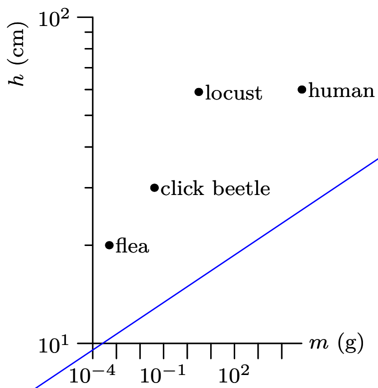

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it'd also be cool to see what the limits to our jumping capability based on the average weight and range in weight a human has