Cellular Biophysics
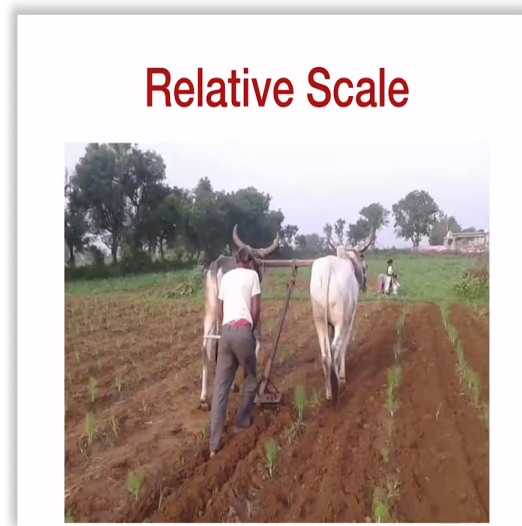**Professor. Doctor Chaitanya Athale**
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Order of Magnitude Estimates and Approximations

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Hi. We are all familiar with cows and bulls, especially in India.

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And they form agronomically and culturally important group of animals. But what if I asked you, and many of you may be going to school, college, university, coming back wandering around

your neighborhood, we have encountered some stray cows or bulls. But if I asked you, how much do they weigh, what is the weight of a cow, or what is the weight of a bull. Unless you are a farmer buying and selling these animals, you may not necessarily know.

And the purpose of asking this question is not to know your general knowledge but to provide you a method or toolbox by which using order of magnitude estimates, dimensional analysis and simplification, you can quantify a biological system, cows are biological animals of animal kingdom, Kingdom Animalia. And you will use the same approach with us. So, far, as you saw, we did this with atomic bomb explosion, cows are innocent comparatively.

So, how do we go about it? We need a religious tool, we need size obviously, we want weight, remember, mass. The farmer who is using this bull, I think this is somewhere in Maharashtra, is standing next to the bull. So, the bull height and the farmers height are comparable. If we imagine that the farmer is a five-and-a-half-foot person, maybe even 6 feet, we are looking at a dimension in terms of metrics of around 1.6 meters, that is 1 meter 67 centimeters.

If we want to simplify our calculations, we can say this is rounding of either arithmetically correct way would be 2 meters. So, we say the bull is 2 meters tall. But it has horns, it has length, it has legs, so maybe there is 2 meters is an overestimate because a lot of the height of the bull is made up of legs like space which has no stomach, so unless it is very fat cow or a bull. So, we can say maybe 1 meter is a better approximation.

Now, in order to calculate mass of an object, we need a shape. This is a very complicated shape. And you can, maybe if you are artistic, you can draw it, you can fit a cylinder with small cylinders that represent the legs. And then there is the hollow intestines in which the food goes, there is the urinary tract from which the urine comes out, there is the mouth which has a gap. So, there are many hollow spaces the eye spaces and so on. But we are going to try and make a simplification.
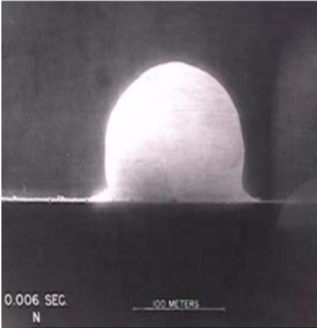
The simplification is that we make a spherical assumption. Remember I said this earlier also circle is a simple geometrical object, it has one axis of symmetry, it has multiple axis of symmetry which are characterized by one variable I am sorry, I mean radius, and that is all you need to know. And from high school geometry you know the volume of the sphere is 4 by 3 pi r cube.

So, you can find the volume of your cow because you can assume that the radius as we said is 0.5 meters, because the diameter is 1 meter. In the same spirit that we discussed estimating the yield of an atomic bomb, we will now turn to an agronomically and culturally important animal,

the cow. The first thing we need to know is the relative scale. So, we can say between 1 and 2 meters is a reasonable height to assume.

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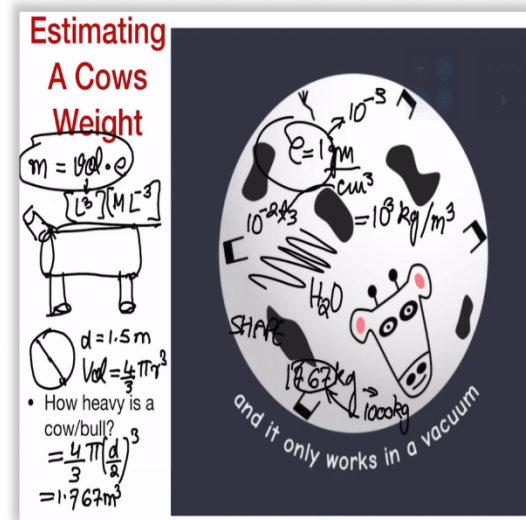
But, if we want to answer the question how heavy is a cow or a bull we need to make further simplifications because the complex shape of a cow may suggest that something more like a cylinder with cylindrical legs to be combine two legs in front and two legs back into one, and then a cylindrical head, how much depends on the structure.

So, instead we consider a spherical cow, not just as a joke, but also because it helps us make certain simplified assumptions. For example, we can ask and answer ourselves the question that the mass must be equal to the volume into the density because this is in length cube and this is in mass per length cube. So, dimensionally it should be correct. So, what is the volume of a cow?

If we assume a sphere and we assume about one and a half meters as its diameter, d is equal to 1.5 meters then the volume of a sphere is 4 by 3 pi r cube, which is 4 by 3 pi d by 2 cube. If I use my calculator, then taking my volume as, taking my diameter 1.5 meters I get 4 into pi into 1.5 divided by 2 whole to the power 3, which is 1.767 meter cube. In order to get the mass, I now need to multiply this with the density.

The density we will take, assuming that it is mostly made up of water is rho is equal to 1 gram per cm cube, which is 10 to the power 3 kg per meter cube, this is because this is 10^{-2} into 3 that is minus 6, this is 10 to the power minus 3. Therefore, 10 to the power 3 kg per meter cube. So,
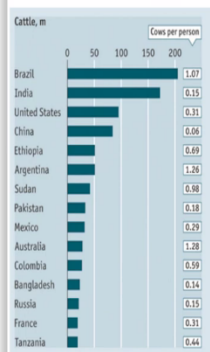
1.767, we get 1.767 into 1000 is 1767 kg. This is a bit on the higher side. So, if you look however the adult bull has a mass from agronomical databases of around 1000 kg.

So, we are slightly above with 700 kilograms extra, maybe twice as much even, but it is not such a big problem. So, we just this simple arithmetic and some guesswork and simplification of shape, assumption of density of water and dimensionally correct multiplication we can get an answer to work. Otherwise, not very easy question to solve.

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A field of ~~physics~~ cows ©2001 Drew Ness

Riddle: What is the cow/ buffalo density in India?

| Cattle, m	Cows per person
Brazil	1.07
India	0.15
United States	0.31
China	0.06
Ethiopia	0.69
Argentina	1.26
Sudan	0.98
Pakistan	0.18
Mexico	0.29
Australia	1.28
Colombia	0.59
Bangladesh	0.14
Russia	0.15
France	0.31
Tanzania	0.44

- Magazine numbers
- Size estimates
- India area: 3.287×10^6 km^2

You can of course, imagine a whole field of such football cows or spherical cows and you can imagine that if you want to know what is the cow density of India, then make the size estimates and the approximate area of India and number of cow population you can actually estimate the cow density and try to find out what is it comparable to the human density.

There are countries where cattle density is higher than human density. As it appears, this is probably not the case in the case of India. But, I need you to do this calculation yourself, the case of India incidentally cows per person is 0.15 meaning for 10 peope there is 1.5 cows, so not 1 is to 1 yet, you can fold fewer cows.

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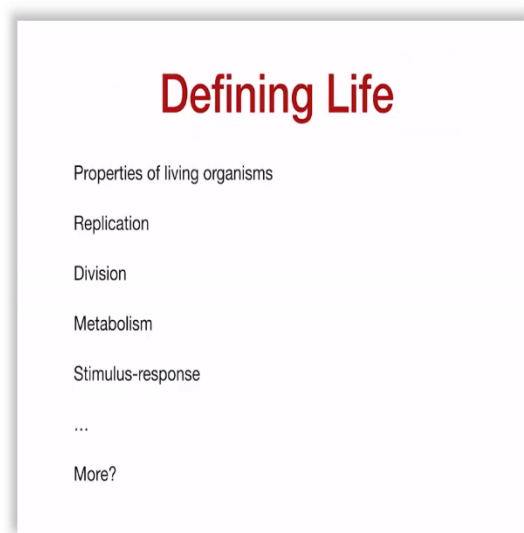
We have done a lot of approximations in the last few lectures and we are now going to talk a little bit about some fundamental properties of living materials.