1.9 Scientific Predictions

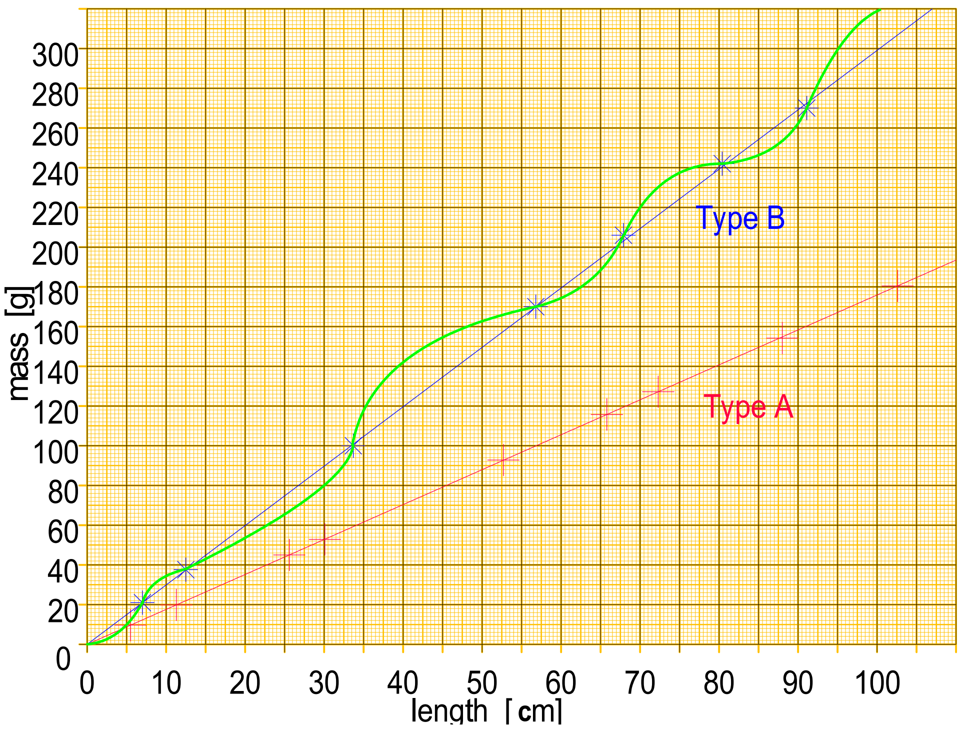
In the previous section we discussed a law, although not a fundamental one, valid for pieces of transformer wires. We found that the mass values of the pieces of a given type are proportional to their length. But what justifies this statement? The straight lines of figure 1.8.1 actually do not pass though the data points. We could have drawn other curves that pass exactly though the measured data points. And there is an infinity of possible curves that pass exactly though the data points. What justifies picking out just a straight line when there are infinitely many other curves that fit the data much better?

We used the excuse that the small deviations from the straight line are due to experimental errors. Experimental error exists, that is true, but still we need an argument to prefer the linear interpretation of the data. The linear interpretation of data convinced our minds, but we would like to know how the mind works. The missing ingredient is simplicity. Of course we could choose a different curve that fits the data points exactly. But this curve would in some sense be more complicated than the straight line. Right now we do not have the means to formulate a precise criterion to decide what degree of simplification justifies what kind of deviations. If we have error estimates of the experimental data we may demand that the deviations of data points should be compatible with these estimates. But in general, this compatibility will not determine a data interpreting curve uniquely. At the moment we do not have a systematic criterion for choosing the most adequate fit and in general there may even not exist a unique systematic way of defining a best fit or best data interpretation. Nevertheless, scientific statements such as "the mass and length of wires are proportional" or "quantity y is proportional to the square of quantity x " work and are useful. Let us see how they work.

The usefulness of statements of the type "the mass and length of wires are proportional" resides in the possibility to predict values and to employ such predictions in quantitative planning. Imagine you are involved in the final experimental steps of the exercise that was given at the end of section 1.6. You have already constructed the balance and now you are fabricating the 9 metallic objects with rational mass ratios. The mass values are of the order of a few grams and you will have to fabricate them with precision better that a milligram in order to guarantee that your students get satisfactory results. One could use pieces of transformer wire for some of the objects. It takes about 8 hours work to fabricate such an object with the desired precision if one does not use quantitative planning. With quantitative methods one may construct such an object in a few minutes. First one cuts a piece of wire and measures length and mass of that piece in order to determine the linear density. With that value one calculates the necessary length to obtain a desired mass value. Then one cuts a piece that is a little bit longer than this calculated value. This is a precaution in order to take care of possible experimental errors. Then one measures the mass of that piece and calculates how much has to be cut away to get to the precise mass value. Then one shortens the piece by an amount little less than the calculated value. Then measure again, calculate a necessary shortening, cut little less and so on. This method furnishes an adequate object in a few minutes.

During the described procedure one uses several predictions of values. They correspond to points on the straight line of a length-mass graph that are not present in the data set that was used to establish the line. So we have a set of data collected in the past, we give a simple interpretation of these data and then we extrapolate the simple law to possible future observations. Nothing justifies such a prediction. But the positive fact is that we use predictions of that kind. That fact depends crucially on simplicity. Without the simplicity criterion one has an infinite number of possible curves that might fit the experimental data and no prediction would be possible.

Now imagine that someone preferred a different data interpretation of the wire type B of table 1.8.1. Figure 1.9.1 shows this interpretation with a green curve.



Now imagine we cut a piece of wire of type B with (40.00 ±0.03) cm length. Putting that piece on a balance we measure a mass value $(119.70 \pm 0.02)\,\mathrm{g}$, which is compatible with the linear prediction but which is definitely not compatible with the alternative green curve. This new observation does not justify the predictions based on the linear curve but it eliminates the alternative data interpretation.

The observations never prove a law. One should not be disappointed because the empirical laws cannot be proven. Instead of looking for absolute truth one should view experimental scientific laws as part of an evolution. The green curve of our example just dyed like an animal species that was not adequate for the tasks in its environment. So our scientific strategy is to work with the simple most data interpretation as long as the incoming data permit this. The day when new, perhaps more precise data force us to use additional complexity we shall do so.

History of science has many examples of evolutions that started with simple laws and later had to admit more complexity. For example Edward Hubble[1] discovered the empirical law that galaxies retrieve from our galaxy with speeds proportional to their distance to us. More and more and ever more precise data confirmed this law during many decades, until the time when new techniques were developed to measure distances and speeds of extremely distant objects. These new data show a slight deviation from the linear law, which occupies the cosmologist a lot.

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[1] *November 20, 1889 – †September 28, 1953