What is a model?

People are often unsure about what models are, leading to confusion and mistrust. ***Emily Griffiths*** *dispels some myths and describes the various types of model.*

Let's be totally honest here, the world is very complex and hard to understand, no matter how brainy you are. To make things easier to grasp, reality is generally broken down into bitesize chunks. These chunks are abstracted from the real world and simplified into things called models. This is the standard way science works. Models come in various forms so people - even professional modelers - are often unsure about what exactly models are. Here I present four types of model. This makes the meaning of 'model' discussed here unashamedly broad. It's hard to escape the term 'model', since it is used in many contexts, but the typology offered should help make sense of things modelers do and why it's necessary.

Perhaps the simplest type of model to start with is the **conceptual model**. They are so simple and commonplace that I have already used them while writing this article. In turn, readers like yourself use conceptual models to understand what you read. Conceptual models basically convey meaning and can be pieced together to make sense of a bigger, trickier thing. Accordingly, every single word refers to a thing or an idea and words are joined into clauses to deliver a message[1]. Electronic diagrams are also conceptual models, summarising how current flows around the various bits of circuitry represented by standard symbols.

Beyond conceptual models there are ***in vivo* models**, from the Latin for 'live'. These are actual live organisms either in the field or in the laboratory sufficiently similar to real phenomena to be able to give clear results. Examples include the use of live mice to reflect aspects of the human immune system or to test the effects of nutrients or drugs. Despite their utility, *in vivo* models do have their drawbacks. Concern over their use, for instance regarding animal rights, means great care is now taken to ensure research is ethical. Modelling generally simplifies the research process, but researchers using *in vivo* models take on a large burden of administration, monetary cost, care for organisms and, in some cases, risking their own safety at the hands of activists. Thankfully other types of model are available, so these difficulties can often be overcome.

A third type of model is an ***in vitro* model**. *In vitro* is also from Latin, meaning 'in the glass', a phrase made popular by In-Vitro Fertilisation (IVF), where eggs are fertilised outside the body. *In vitro* models offer conditions outside of those of direct interest, but they are sufficiently similar that comparable processes will occur. An example of this kind of model would be a bionic eye that performs the same basic functions as a real eye, but is built from different materials. Another example would be any chemical reaction involving an isolated enzyme in a way that is far simpler than studying the entire biochemistry of a cell. Both *in vivo* and *in vitro* models are limited by the materials that are readily available for research and resources and labour to use them appropriately. Often it is not possible to conduct experiments in as many different systems as one would like and, even if these models are used, they can leave intricate questions unanswered.

This brings us to the fourth and final kind of model. It is perhaps the hardest to comprehend, bur has great power and versatility. ***In silico* models** refer to simulations using mathematical models in computers, thus relying on silicon chips. *In silico* models analyse and solve mathematical equations to give results under certain circumstances. These equations summarise relationships between things scientists study. To use these models, it is first necessary to describe the phenomena in question using numbers. Then quantitative relationships can be included in the equation and where these relationships are complex, a computer is necessary to solve them. These often involve some kind of mechanism that changes over time, like mimicking the changing price of a Mars bar from the 1970s to the present day. For this economic model many things need to be specified like inflation, supply and demand of sugar and coca etc. The results from this model may not be bang on the actual price of a Mars bar, but the model is useful in revealing what we do know (where the model works and the price is right) and what we don't (where the model fails and the price is wrong). In the same way, all models can fall down on some points, but these revelations are very useful in helping to advance scientific knowledge.

With the breadth of models in mind, it is now possible to dispel an everyday myth about models. A common disparaging remark concerning the work of modelers is, "Oh, but that's just a model."[1] *Just* a model. Certainly all models are simplifications and can seem ugly, clunky and inadequate. But models do usefully break the world up into manageable pieces. All models described above are ***in simulacra***, that is they bear some likeness to the real world and are constructed to reflect certain parts that are essential for the job in hand. Some people are tempted to give up on models when they inevitably fail at points. But do we stop using the word 'Britain' when people get confused with how it relates to 'England', 'The United Kingdom' or 'The British Isles'? Surely not. If there is a problem with a model it should prompt refinement of the model so that it bears a greater likeness to the phenomena we wish to represent. Just as conceptual models used in political debates around Britishness are changing, so too do *in silico* mathematical models develop to more clearly reflect intricate atmospheric physics, biogeochemical cycling etc. It would be impossible to communicate this article to you without using conceptual models. Models are vital to our understanding of the world and I hope I have convinced you of their versatility and utility.

*Email me with questions/comments/criticisms `ecgriffi-at-ncsu.edu`.

References

[1] E. Goldsmith. Words and models (systems approach to linguistics). *Kybernetes*, 1(4):243–249, 1993.

[1]This rough quote comes from a question asked of a climate modeler by John Humphries on BBC Radio 4's Today Programme in October 2009