CHAPTER 4: MODELS ARE THE BUILDING BLOCKS OF SCIENCE

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MODELS

You know what a model airplane is. But models are ubiquitous. Advertisers manipulate you with models, and models determine your success in business or school. Because the scientific method is a way to think about models, if you are to understand the scientific method, you must be able to recognize models when you see them and appreciate their limitations.

Models as Building Blocks and Substitutes

The model is the most basic element of the scientific method. Everything done in science is done with models. A model is any simplification, substitute or stand-in for what you are actually studying or trying to predict. Models are used because they are convenient substitutes, the way that a recipe is a convenient aid in cooking. This section of the book is dedicated to explaining what models are and how they are used.

Models are very common. The ingredients list on a bottle of ketchup is a model of its contents, and margarine is a model of butter. A box score from a baseball game is a model of the actual event. A trial over an automobile accident is a model of the actual accident. A history exam is a model designed to test your knowledge of history.

A model is a substitute, but it is also similar to what it represents. Thus the ingredients list is a fairly accurate guide to the contents of the ketchup bottle. Margarine looks and spreads like butter, and can substitute for it in many recipes. The box score contains most of the critical information about the baseball game---such as the winner, the final score, and the pitchers. Similarly, trials and history exams contain the essence of the events they model. In fact, models are more than just common, they are ubiquitous. Nearly everything we encounter is a model. To drive home this point, we list in Table 4.1 several objects or ideas that are models.

MODEL	WHAT THE MODEL REPRESENTS
CAKE RECIPE	Process of making a cake
WEDDING PICTURES	The wedding
CHAPTER TITLE	Chapter contents
NEWS ARTICLE ABOUT CHICAGO CUBS' LATEST LOSS	The game itself
HOME VIDEO OF POLICE ARRESTING A MOTORIST	Police conduct in general
ROAD MAP OF MADISON, WISCONSIN	Paths of transit in Madison
HOUSEHOLD BUDGET	Household expenses and income
POLITICAL CANDIDATE'S CAMPAIGN PROMISES	Candidate's performance if elected
A STATISTICAL AVERAGE	Something close to what can be expected

Section 2

Models Inside Science

Scientific models are fundamentally the same as models outside of science, which will be introduced below. Many people think mistakenly that scientific models are always complicated, impenetrable mathematical equations. But in truth, many scientific models are just as understandable as are models found outside of science.

The USDA food pyramid, which recommends the proportions of different kinds of foods in a healthy diet, is a model of the thousands of scientific studies that have been undertaken on the relation among cancer, heart disease and diet. The figure summarizes these studies in a picture that recommends healthy diets. Thus, this figure is a substitute for the many scientific studies on diet, and it is also a substitute for an actual diet.

As a second example, when scientists use rats to determine whether a food additive causes cancer, the rats become a model of humans. Rats are convenient because they are relatively easy to raise in the lab (at least compared to humans), and one can perform experiments on them relatively quickly (in a matter of months rather than years). Moreover, most people find it more ethical to experiment on rats rather than humans.

Hypotheses and Theories as Models/Big Models and Small Models

We've all heard about hypotheses and theories, especially in physics and chemistry. Theories usually comprise some idea that scientists have about how nature works, but that they aren't totally sure. Hypotheses and theories are merely particular kinds of models that we will refer to below as abstract models.

Even the most rudimentary science course contains some of the grand, all-encompassing, models that scientists have discovered. The periodic table of the elements is a model chemists use for predicting properties of the elements. Physicists use Newton's law to predict how objects will interact, such as planets and spaceships. In geology, the continental drift model predicts the past positions of continents. But these three models are atypical because they are immensely successful. Most models used are nowhere near so powerful or widely useful. But scientists use these less-successful ones anyway. Models are used at every turn in a scientific study. Samples are models. Ideas are models. Methods are models. Every attempt at a scientific study involves countless models, many of them small and of interest only to a small group of other scientists. The primary activity of the hundreds of thousands of U.S. scientists is to produce new models, resulting in tens of thousands of scientific papers published per year.

Models Outside Science

Trying to enumerate all the models found in business, industry, and society is simply impossible. Models pervade all white collar jobs. Table 4.2 shows models from fields as diverse as advertising, architecture, finance and manufacturing. In this table we have chosen to give a single model from each of a number of fields. However, we could have just as easily picked one job, say retail sales, and listed 150 models associated with it.

MODELS IN BUSINESS AND GOVERNMENT (TABLE 4.2)

FIELD	COMMON TYPE OF MODEL
Advertising	Response to an advertisement tested in a single city is a model of the national response to the ad.
Architecture	The plans for a new building are a model of the actual building.
Business	Past dealings with a client are a model of the trustworthiness and promptness you can expect from her/him in the next deal.
Education	A student's performance on a history exam is a model of everything learned about history since the last exam.
Finance	The rating *Morningstar* gives a bond fund is a model of the fund's future performance.
Federal Government	The federal budget is based on an economic model that predicts next year's revenues and expenditures.
Franchising	A company uses its existing stores to model the likely success of stores it is considering building.
Law	A criminal trial provides a model of the actual crime.
Manufacturing	Profit projections are based on a model of material and labor costs as well as sales price.
Medicine	Your doctor's diagnosis of the cause of your back pain is a model of its actual cause.
Prisons	A model, based on age, crime, and family status, is used to predict which prisoners are good candidates for parole.
Retail Sales	The December sales in 1995-2003 model the December sales expected in the coming year.

The ability to recognize, construct, and improve models gives you an advantage in many walks of life. A salesperson who recognizes that a sales pitch is a model can take steps to improve it. Other models are obvious but are so complicated that years of effort go into learning how to build them, as with the house, computer, and automobile models that are the trade of architects and engineers. Sometimes, the critical skill is not finding or building a model, but knowing how to improve an existing model, as with a budget or airline design.

Models are important outside of science because success in any professional endeavor involves accurately predicting or manipulating the future, and we need models to do this. Correctly predicting the stock market would net a person fame and fortune. The path to success in sales is only slightly less direct. If a salesperson can accurately predict how a particular client will respond to a particular pitch, the pitch can be modified to have maximum effectiveness, thereby increasing the probability of a sale or abandoning a non-buyer before wasting much time. Similarly, budgets predict the financial consequences of taking various actions, allowing the company to cut losses and increase profits.

The arts---whether an action movie like Lethal Weapon III, an abstract painting by Picasso, a historical novel by Michener, or Whitman's poetry---consist of models designed to evoke emotions and present unusual events or viewpoints. Because a scene from a Hollywood movie appears to be a plausible representation of the real world, it can make you frightened (a stunt man hanging out the window), or sad (a dead heroine), or anxious (an oncoming train). The protagonist of a historical novel substitutes for someone that actu-

Models exhibit a one-to-many and many-to-one relationship

There is no such thing as just one model of something, nor is anything we use as a model necessarily useful as just one kind of model. A wedding will have many different models to remind us of the day: pictures, memories, wedding presents, and newspaper accounts -- all models of one event. At the same time, one of those wedding presents (e.g., a toaster) will be a model of the wedding but is also a model of other toasters, of the company that made the toaster (and its other products), and it may eventually become a model of electronic appliances when one of the kids (or parents) takes it apart to fix it or see how it works.

It is neither profound nor particularly useful to learn that everything is a model. If this was all we could say about models, there would be no call to focus heavily on them. The models we have discussed thus far were chosen to show that you are already familiar with models. In the remainder of this chapter, we describe models that are more subtle, and we explain how an understanding of models may be important to people outside of science.

Classes of Models

Different kinds of models are used for different purposes. Table 4.3 lists three major types that will be used in this class: abstract, physical, and sampling models. Not all models fit neatly into these categories. Moreover, we won't bother to classify many of the models in this course. However, these three classes do accommodate many of models that we will focus on and discuss, so it is convenient to group them in this fashion.

CLASSES OF MODELS (TABLE 4.3)		
CLASS	**FAMILIAR TYPES**	**EXAMPLES AND COMMENTS**
Abstract	predictions, theories, hypotheses, many mathematical and computer models	Newton's laws in physics, plans, recipes, statements such as "taking anabolic steroids increases one's strength," or "smoking causes lung cancer."
Physical	organisms and their properties, replicas, structures, demonstrations	a globe is a physical model of the earth, each of us is a model for other humans, and the physical structures used in chemistry class are models of molecules
Sampling	random choice, personal preference	the sampling model refers to the way that subjects are chosen for a study and divided up among the different groups; sampling models are the subject of our section on Data.

Section 7

Summary

You should end this chapter with an understanding that models are a crucial element of the scientific method. A model is in some way a substitute for what is being studied. They are widely used, and there are many types of them. At this point in the book, you should be able to begin using the information being taught. For example, when reading news articles on topics relevant to scientific study, you should be able to identify models used in those studies and should be able to identify those belonging to the classes in Table 4.3.

External Links

Human Bohr Model

Bill Nye with a model of an Atom

Bohr Model Explained

Quantum Mechanics

Origami DNA Model

DNA Replication Model

DNA lecture (28 minutes)

The Secret of Life -- Discovery of DNA Structure: http://www.youtube.com/watch?v=sf0YXnAFBs8

Bacteria lecture: http://youtu.be/TD0GrbpJJ14

Natural Selection model: http://youtu.be/GcjgWov7mTM

The Universe Modeled: http://youtu.be/mwyTGcHP7kc