Role of Theory in Biology

Alternative approaches to biological investigation

Natural history - descriptive biology

Experimental manipulation - field or lab - isolate effects of some factors on some aspect of organism/population/community behavior - observe response to interactions of several factors

Theory development - abstract general properties of system by ignoring certain components and emphasizing others (selective ignorance). Can do this (i) ad hoc - don't think it's important so will ignore it, (ii) data suggests a factor or set of factors can be ignored, (iii) based upon scale so processes on a fast or slow time scale (or equivalently spatial) are ignored dependent upon scale you are interested in

Expressing theory

Verbally
Graphically
Mathematically
Through Simulation

Science is thought to be a process of pure reductionism, taking the meaning out of mystery, explaining everything away, concentrating all our attention on measuring things and counting them up. It is not like this at all. The scientific method is guesswork, the making up of stories. The difference between this and other imaginative works of the human mind is that science is then obliged to find out whether the guesses are correct, the stories true. Curiousity drives the enterprise, and the open acknowledgement of ignorance.

Lewis Thomas - Sierra Club Bulletin, March/April 1982, P. 52

What can theory do?

1. Suggest observations and experiments
2. Provide a framework to assemble bodies of facts - provide a means to standardize data collection
3. "Allows us to imagine and explore a wider range of worlds than ours, giving new perceptions and questions about how our world came to be as it is" F. Jacob - The Possible and the Actual, 1982
4. Clarifies hypotheses and chains of argument
5. Identifies key components in systems
6. Allows simultaneous consideration of spatial and temporal change
7. Extrapolate to broad spatial or long temporal scales for which data can not easily be obtained
8. Prompts tentative and testable hypotheses
9. Serves as a crude guide to decision making in circumstances where action cannot wait for detailed studies
10. Provides an antidote to the helpless feeling that the world is too complex to understand in any generality - provides a means to get at general patterns and trends

What is a Model?

Just as story tellers can take their audience on trips to faraway places and provide a glimpse at life in different cultures, scientists tell their stories about the way the world works by making models. Such models never provide a complete view of how the world works, but do give us glimpses that help us to piece together interactions between different parts of the world and the processes that connect them. These models take many forms, some being mostly verbal, others mostly qualitative and graphical, some phrased in various mathematical forms and still others set up as collections of rules within a computer program.

A Model is a Map -a simplification of reality

Models provide maps of varying levels of complexity to help us understand the topography of science. There are coarse road maps that provide merely the outline of major arteries for traffic, telling us nothing about buildings or other features of the landscape, but providing an overview of the linkages between key components of a system. More elaborate models show us the buildings and the infra-structure that links these buildings - the sewer and power lines. Even more complex models would indicate the humans in each building, their occupations, and the flow of money or capital goods between them.

Purposes for Model Construction:

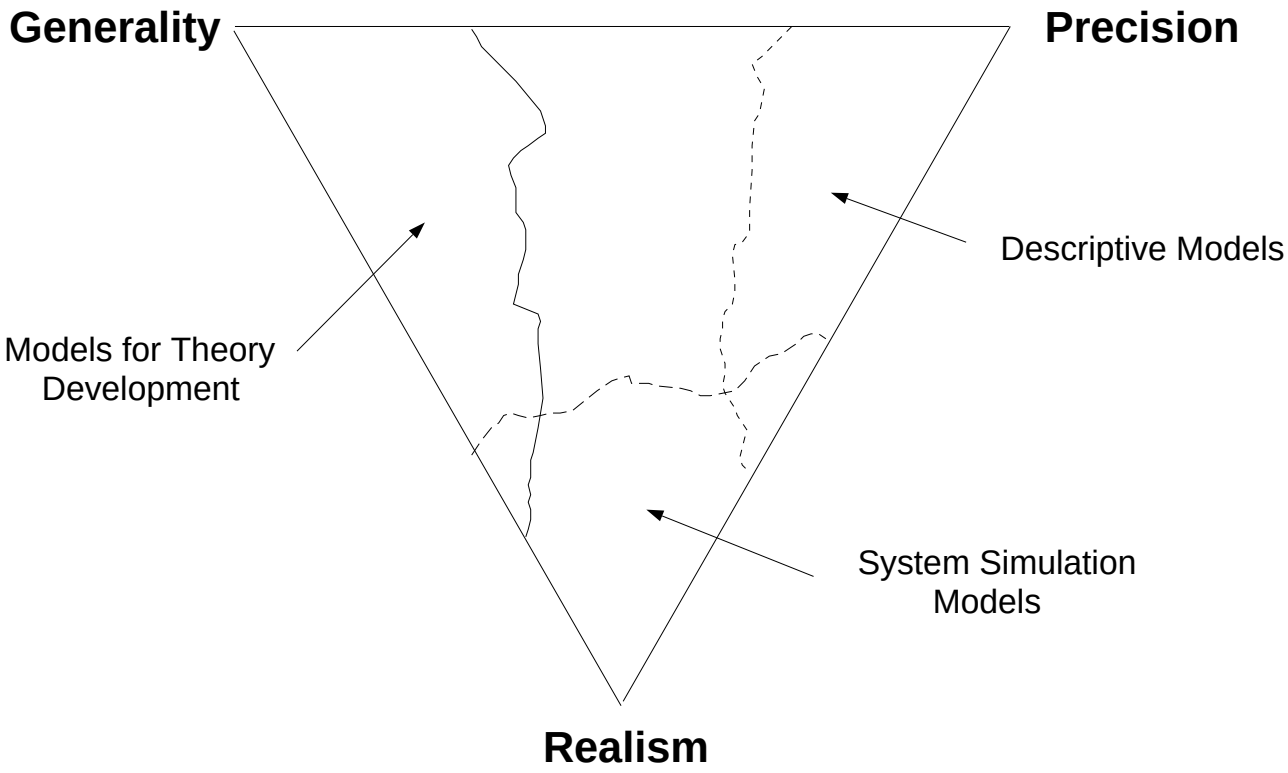
1. Descriptive - use as a summary for data sets
2. Analysis - wish to determine effects of varying inputs
3. Simulation - guide for experiments, as a teaching aid
4. Prediction/forecasting - contrast alternative management options

Objectives define the appropriate scale (spatial, temporal), level of resolution (including the hierarchical levels within biology to utilize), and sometimes the type of modeling approach.

Models cannot be proven, only falsified or rejected at the level of interest.

Approaches - numerous possible taxonomies are possible. One is:

1. Descriptive (a) Empirical or statistical
   (b) Comparative
2. Mechanistic (a) Compartmental
   (b) Optimization - adaptationist
3. Systems - hierarchy theory
4. Individual-based
5. Expert systems


Generality
Precision
Descriptive Models
Models for Theory Development
System Simulation Models
Realism

It is a common fallacy to confuse scientists' models of reality with reality itself. A model is a map. A map is not the territory it describes.

Richard Casement