BIOL 652 Advanced Ecology

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Wk 1

Epistemology: How do we gain knowledge?

Gaining knowledge in science

- reality
- data: a biased subset of reality
- opinion: what we believe about reality

$\rightarrow$**Science** : an attitude linking belief and data, whereby we do not, at least in principle, maintain beliefs that are not supported by data

Scientific Theory

- We may refer to beliefs supported by data, or which at least do not always contradict data, as theories
- We will like theories to have a few other properties such as:
  - logical consistency
  - coherence with other scientific theories

What are models?

- **Model**: a representation of reality
- A structure that:
  - embodies some of our beliefs about reality (e.g., predators negatively impact prey populations $\frac{dN}{dt} = f(N) - g(N, P)$)
  - mimics some aspect of data (e.g., linear regression $y_i = \beta_0 + \beta_1 x_i + \epsilon$)
  - combines these two components by making a statement about the expected pattern of data in light of theory (e.g., predator consumption rate can be described as a type II functional response: $\frac{g(N,P)}{P} = \frac{aN}{N+N_0}$)

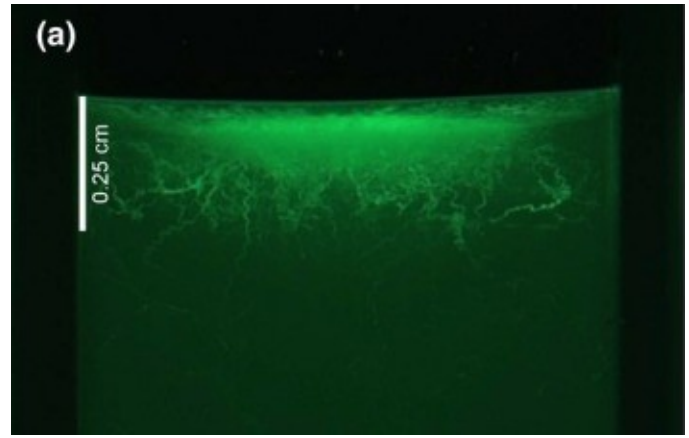
Types of models (activity-based classification)

conceptual (e.g., a statement)

"predators can positively impact prey"

physical (e.g., lab experiment)

Bell & Cuddington (2018)



mathematical (e.g., ODE)

$\frac{dN}{dt} = f(N, E) + g(N, P, E)$

data-driven (e.g., regression)

$E(y_i) = \beta_0 + f(x_i) + \epsilon$

computational (e.g., IBM)

Cuddington & Yodzis (1990)

Main characteristic of models

-models are always false in some aspects of their representation theory or data

Theory $\neq$ Model $\neq$ Reality

Other characteristics of models

- trade off precision, generality and realism (Levins 1966)
- a model is more specific than a theory, but less detailed than reality
- why? a one-to-one scale map of a city may include all details but is useless as a guide to finding your hotel

  "We actually made a map of the country, on the scale of a mile to the mile!" "Have you used it much?" I enquired. "It has never been spread out, yet," said Mein Herr, "the farmers objected: they said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well.

  Lewis Carroll - The Complete Illustrated Works. Gramercy Books, New York (1982)

Why model: to gain knowledge!

1. Explanation
2. Prediction

The role of mechanism in modelling

What is mechanism?

- "a natural or established process by which something takes place or is brought about" OED
- answers the "how" question
- explains the patterns in data by identifying the cause

What is a mechanistic model?

- something is a "mechanistic model", because it includes *a priori* knowledge of ecological processes (rather than patterns)
- e.g., mechanistic niche model based on first principles of biophysics and physiology vs correlational niche model based on environmental associations derived from analyses of geographic occurrences of species (see Peterson et al. 2015)

Phenomenological models describe pattern

- a phenomenological model does not explain why
- simply describes the relationship between input and output
- sometimes, the authors of these models make the assumption that the relationship extends past the measured values
- but of course, that is always a problem (e.g., extrapolation of linear regression beyond input data range)

All models can include phenomenological or mechanistic components or both

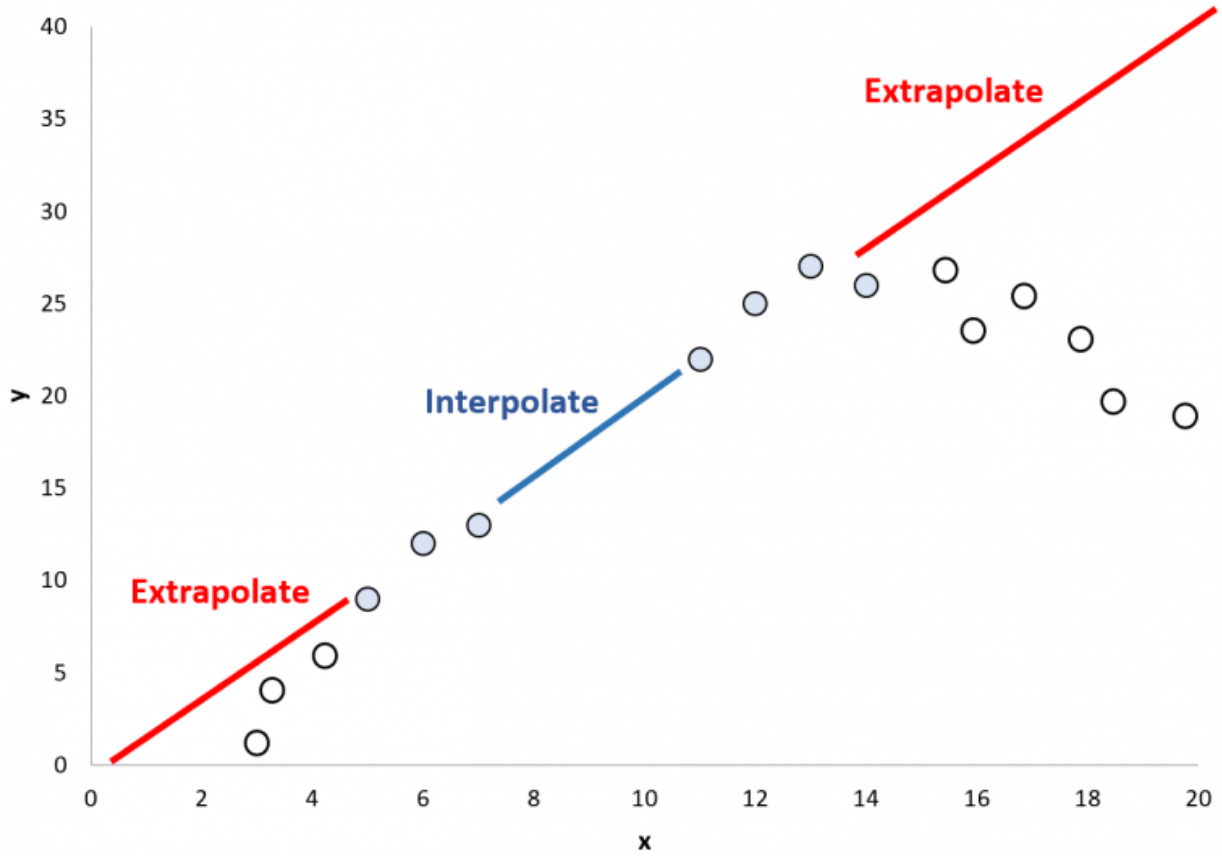
- and in general it is a spectrum rather than a dichotomy

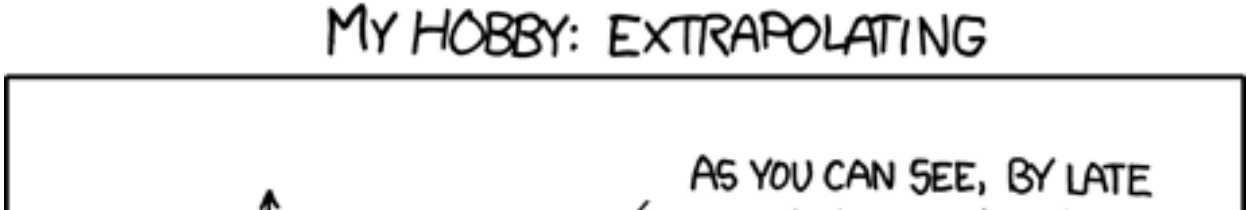
- particularly true for models at large scale, we will often code small-scale mechanisms as phenomenological components
  - (i.e., when modelling forest stand dynamics, we may not include a mechanistic description of photosynthesis and evapotranspiration) ### Data-driven models, used by themselves, are generally phenomenological
- Data-driven: I'm including here standard statistical models (both frequentist and Bayesian), as well as machine learning models
- these models are good at finding patterns
- in the machine learning literature sometimes referred to as the 'inductive capability' of algorithms (from past data, one can

Phenomenological models and prediction

Phenomenological models and prediction

- under novel conditions, phenomenological models will not be suitable for prediction (or at least, there is no guarantee they will be) $\rightarrow$ extrapolation problem





why do we model?

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