

Week 6: Mechanistic Models in Ecology and Evolution

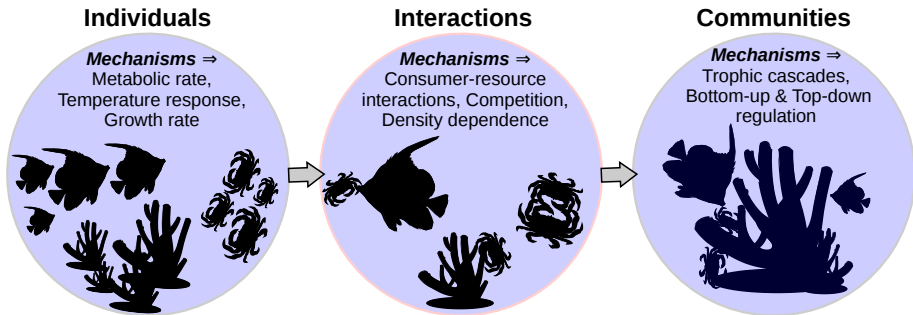
CMEE Masters 2015-16

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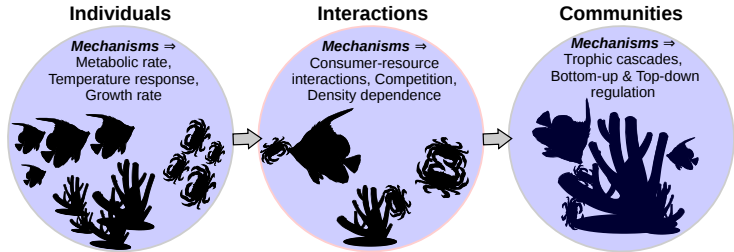
November 10, 2015

WHAT ARE MECHANISMS?



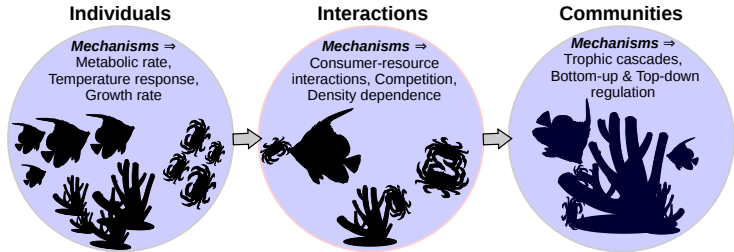
- Mechanistic models aim to explain the PROCESSES underlying observed patterns
- Empirical or phenomenological models show relationships between observed data (e.g. population size as a function of temperature or rainfall), but provide no insights into why they are related

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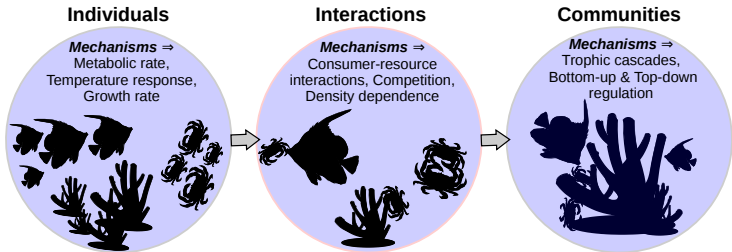
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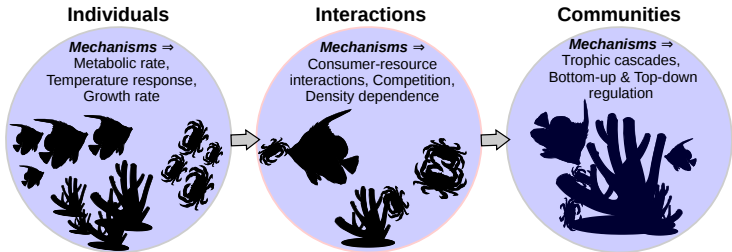
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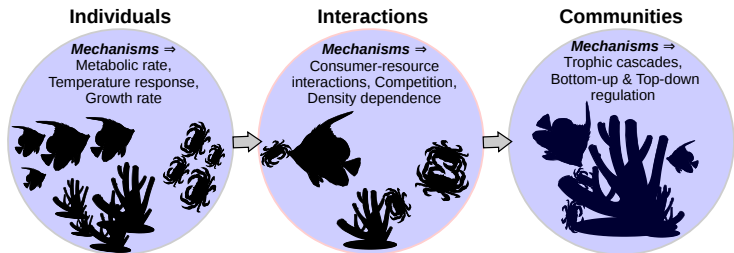
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- For example, Larch Budmoth (http://www.sandyliebholt.com/pubs/science_DC1/) — papers in your Readings directory
 - Why the cycles?, Why the travelling waves? What mechanisms operate? (budmoth/parasitoid interaction? (budmoth/food quality interaction?)
- Another example, measles outbreaks (Papers in your Readings directory)

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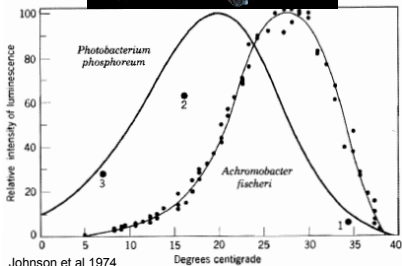
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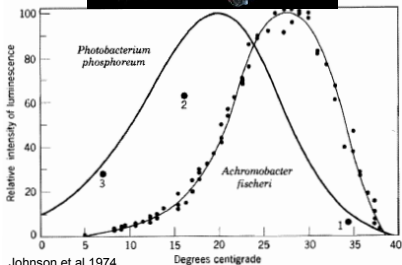
- What is the mechanism?
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- If the Ricker model and another model with contest competition were compared with data — that would be mechanistic modelling because one is trying to get at the underlying mechanism, scramble or contest competition
- But is this REALLY mechanistic? What are r and k really?
- Many (including yours truly!) now argue that we have not progressed far enough because the first level has been ignored!

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k = Boltzmann constant (eV K^{-1})

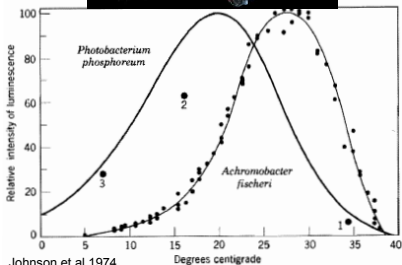
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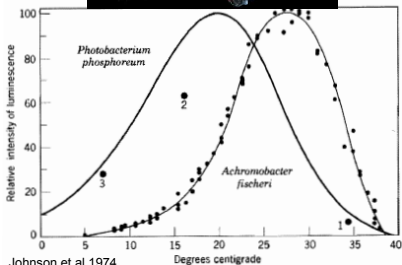
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- *What about alternative models?*

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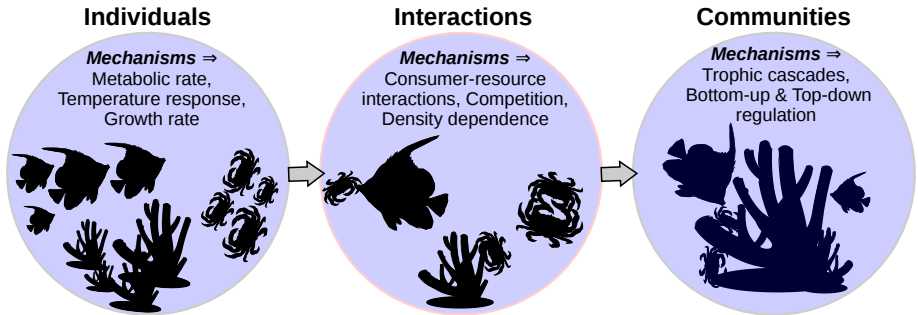
But first: A preview of the long practical

MECHANISTIC MODELLING: WHAT'S THE BIG IDEA?

- Use biological knowledge to construct models
- See if the models “agree well” with data
- Whichever model “agrees best” is most likely to have the right mechanisms
- That's the one that's best for predictions (e.g. population cycles), estimating rates (e.g. growth rates), etc.
- Don't use models you already know have the wrong mechanisms!

MECHANISTIC MODELLING: HOW TO BUILD THEM?

- It's an art, take practice (look at Levins' paper on the strategy of model building in biology)
- Build models one mechanism at a time — in biology, it means start at the right level of organization!



MECHANISTIC MODELLING: HOW TO BUILD THEM?

- For example, the Boltzmann-Arrhenius model is a good first try describe and uncover mechanisms underlying individual level rates
- The next step would be to include high-temperature effects (e.g., the Schoolfield model)
- The next step would be to include species interactions with temperature dependence of individuals (or go in an evolutionary direction!)

FITTING MODELS TO DATA

Two common ways to do it:

- One-step forecasting (appropriate for discrete models)
- Ensemble fitting (appropriate for full time series or responses) – this is what you will be doing in NLLS

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There include maximum likelihood, bayesian methods, and Non-linear least squares (NLLS) optimization or fitting. You will use NLLS.

Basically, this is how it works:

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- 6 Repeat 4–5
- 7 Stop simulations when the adjustments make virtually no difference to the rss

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Once the algorithm has converged (hopefully – but you may be surprised how well it usually works),

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- `residuals = Observations - Predictions`
- `rss = sum(residuals ** 2)`
- Then, AIC is $n * \log((2 * \pi) / n) + n + 2 + n * \log(rss) + 2 * k$
(*what is n and k?*)
- And BIC is $n + n * \log(2 * \pi) + n * \log(rss / n) + (\log(n)) * (k + 1)$
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Also note that:

- $R^2 = 1 - (\text{rss}/\text{tss})$, where tss is total sum of squares:
 $\text{tss} = \text{sum}((\text{Observations} - \text{mean}(\text{Predictions})) ** 2)$
(a useful measure of goodness of fit – you should report it)

READINGS

- Levins, R. 1966 The strategy of model building in population biology. *Am. Sci.* 54, 421–431.
- Johnson, J. B. & Omland, K. S. 2004 Model selection in ecology and evolution. *Trends Ecol. Evol.* 19, 101–108.
- Papers in the `Temperature_response_papers`, but especially Schoolfield, R. M., Sharpe, P. J. & Magnuson, C. E. 1981 Non-linear regression of biological temperature-dependent rate models based on absolute reaction-rate theory. *J. Theor. Biol.* 88, 719–31.