Week 6: Mechanistic Models in Ecology and Evolution

MSc/MRes CMEE 2014-15

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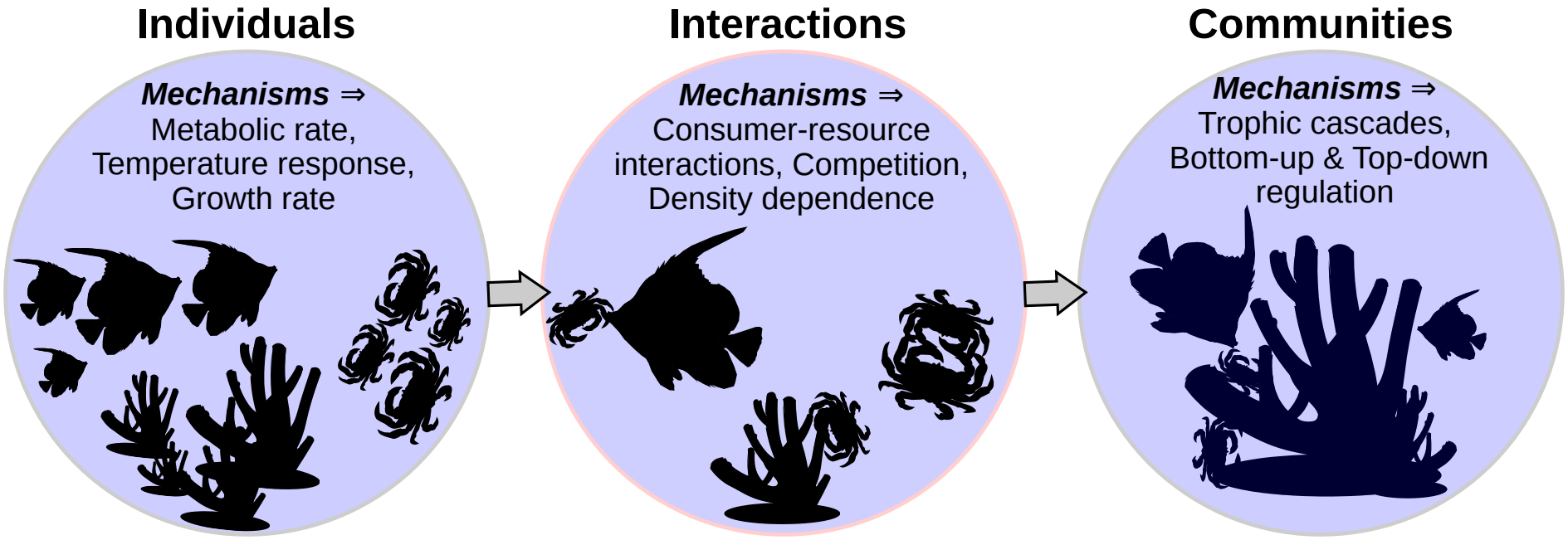
What are Mechanisms?



- 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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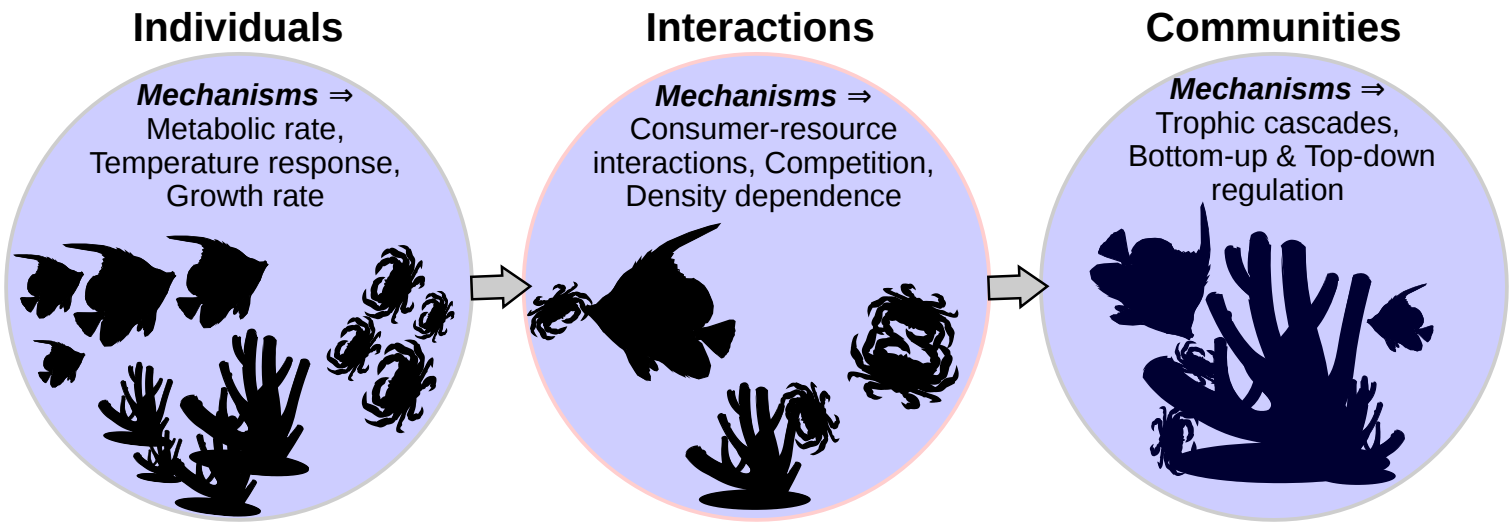

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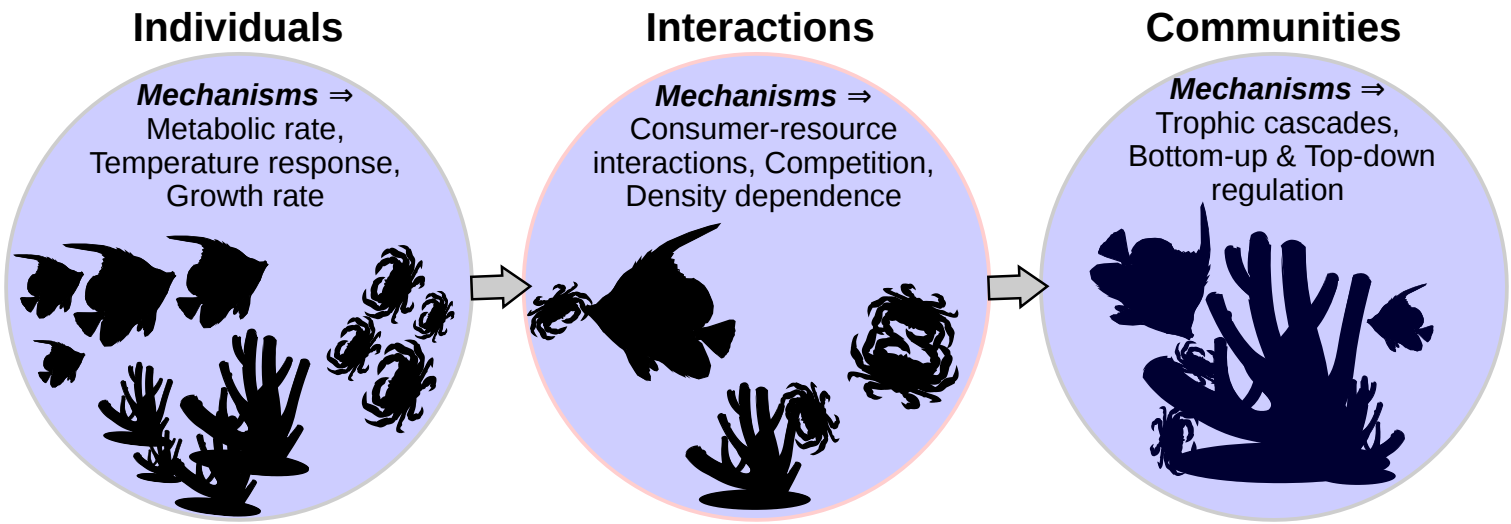

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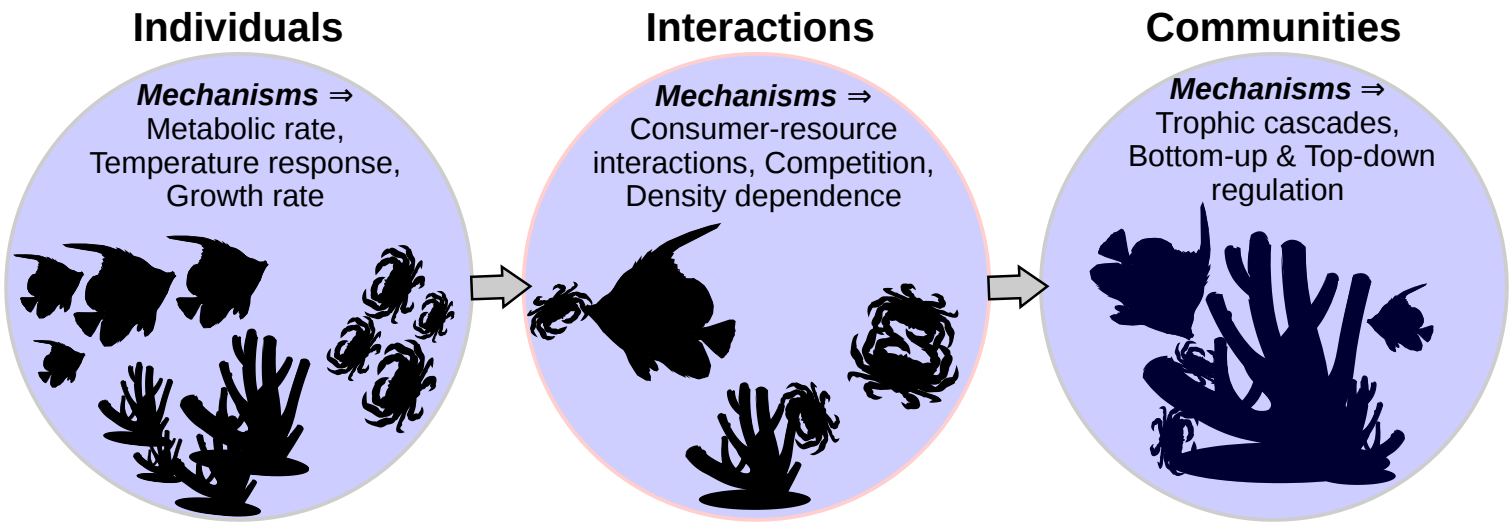

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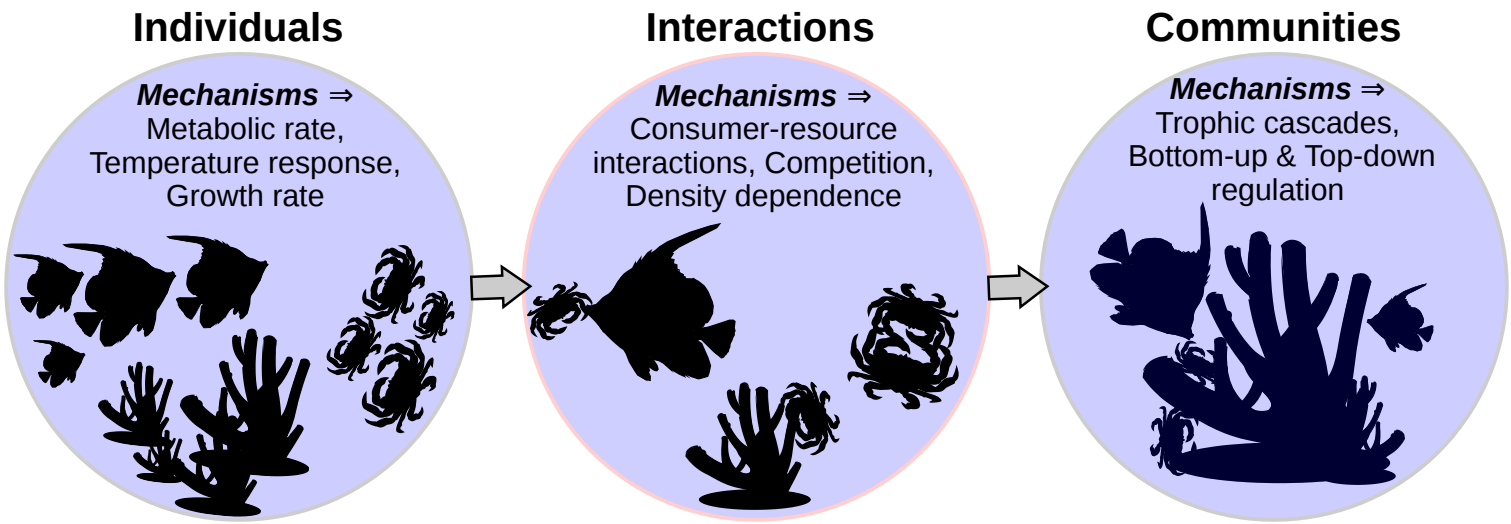

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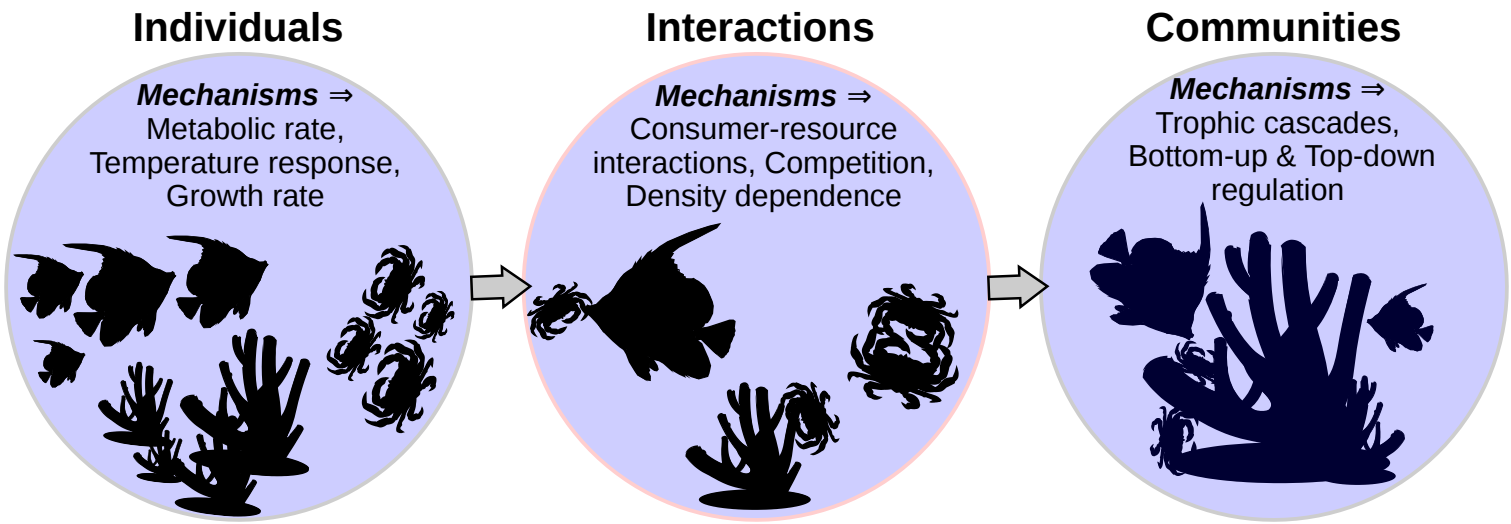

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- For example, Larch Budmoth (http://www.sandyliebhold.com/pubs/science_DC1/) — papers in your `Readings` directory
  - Why the cycles?, Why the travelling waves? What mechanisms operate? (budmoth/parasitoid interaction? (budmoth/food quality interaction?)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

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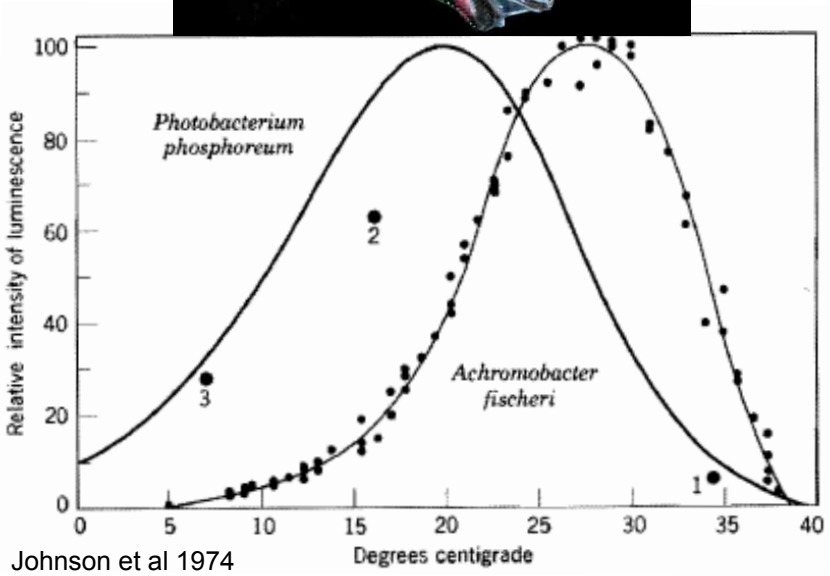
- But is this REALLY mechanistic? What are r and k really?
- Many (including yours truly!) now argue that we have not progressed far enough because the first level has been ignored!

A fundamental mechanism: Temperature drives metabolism

A FUNDAMENTAL MECHANISM: TEMPERATURE DRIVES METABOLISM



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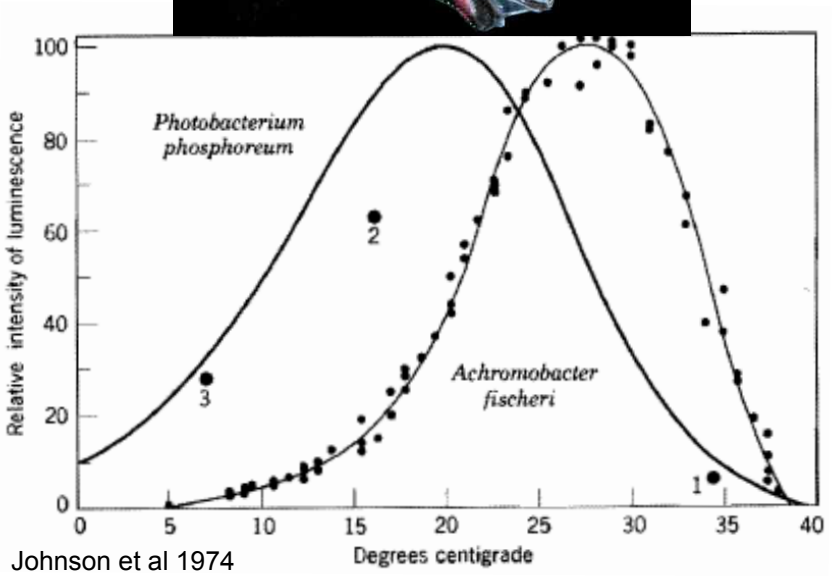

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$$B = B_0 \boxed{e^{-\frac{E}{kT}}} f(T, T_{pk}, E_D)$$

T = temperature (K)
k = Boltzmann constant (eV K^{-1})
E = Activation energy (eV)
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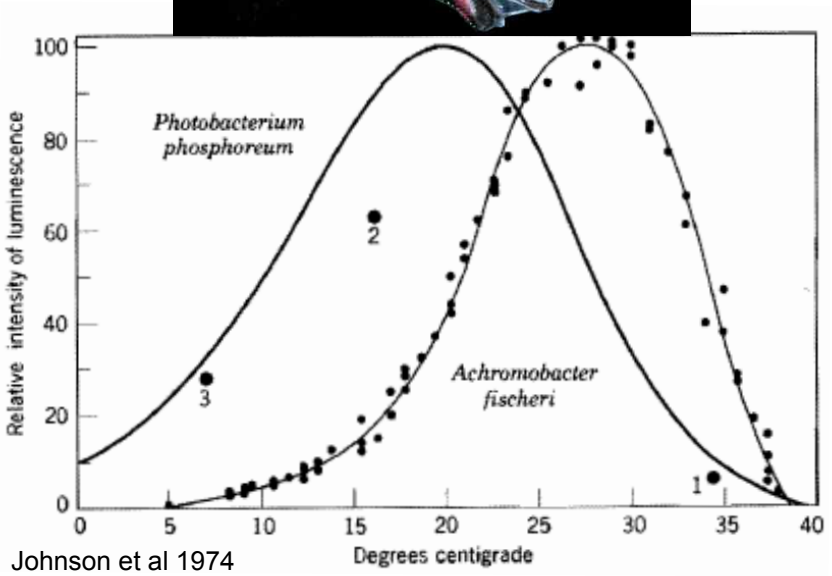

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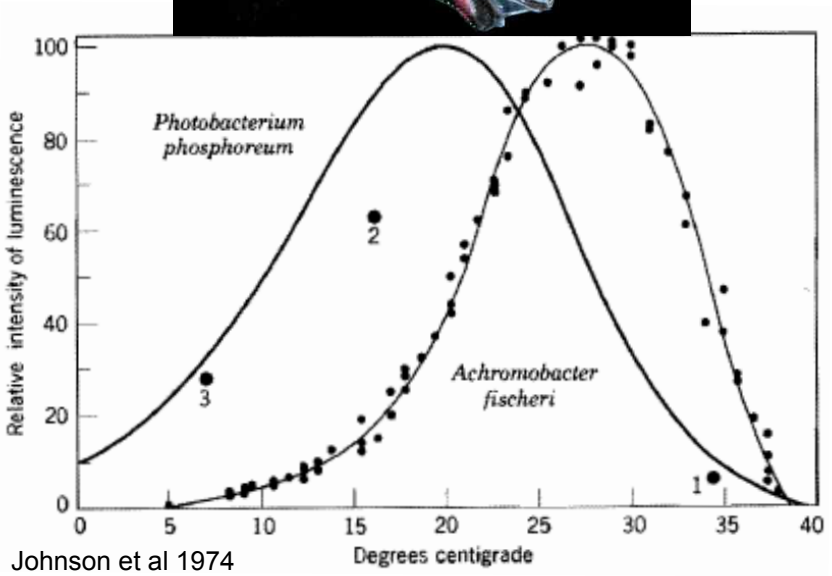

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- *What about alternative models?*

MECHANISTIC MODELLING

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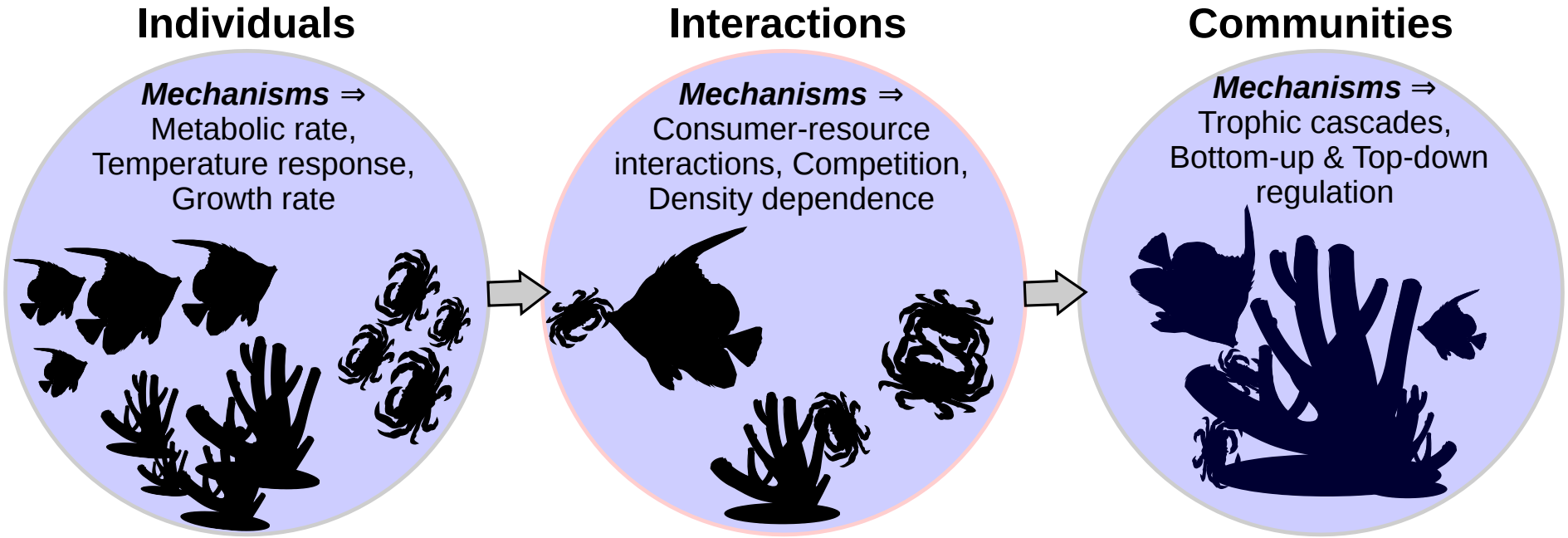
But first: A preview of the long practical

MECHANISTIC MODELLING: WHATS 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
- Thats the one thats best for predictions (e.g.g population cycles), estimating rates (e.g. growth rates), etc.
- Dont use models you already know have the wrong mechanisms!

MECHANISTIC MODELLING: HOW TO BUILD THEM?

- Its an art, take practice (recall 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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`python` seems to have a better Levenberg-Marqualdt implementation than `R`

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- residuals = Observations - Predictions
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- 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 - (rss/tss), where tss is total sum of squares:
  tss = sum((Observations - mean(Predictions)) ** 2)
  (a useful measure of goodness of fit – you should report it)