How to turn an evolutionary biologist upside down

Sylvain Billiard [1]

[1] University of Lille - Lab Évo-Éco-Paléo - UMR CNRS 8198 - France

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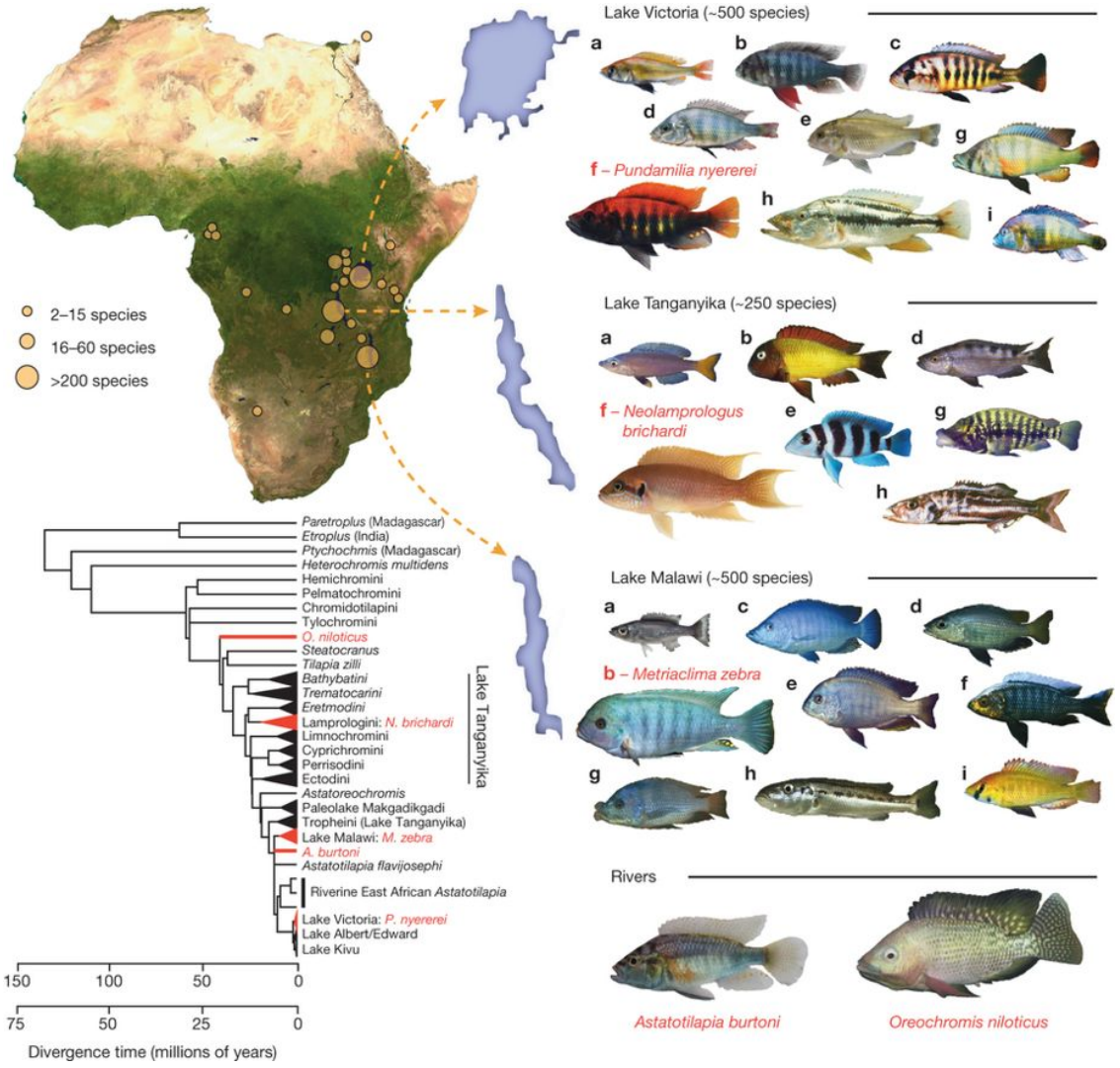
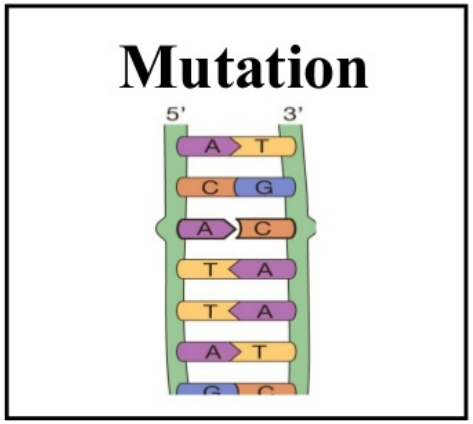
The biological world: A big mess

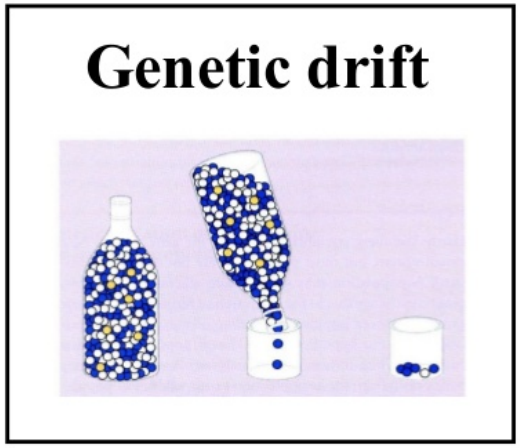
Job: Patterns and Processes

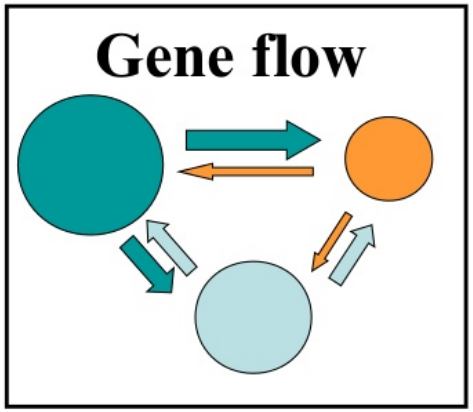


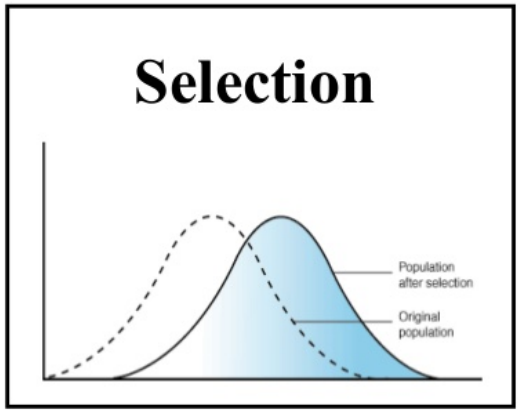
The central paradigm

Four Major Evolutionary Forces - Review









Two separate worlds: Pop. dynamics vs. Pop. genetics

Population dynamics and ecology is not important

The central paradigm

Biological world

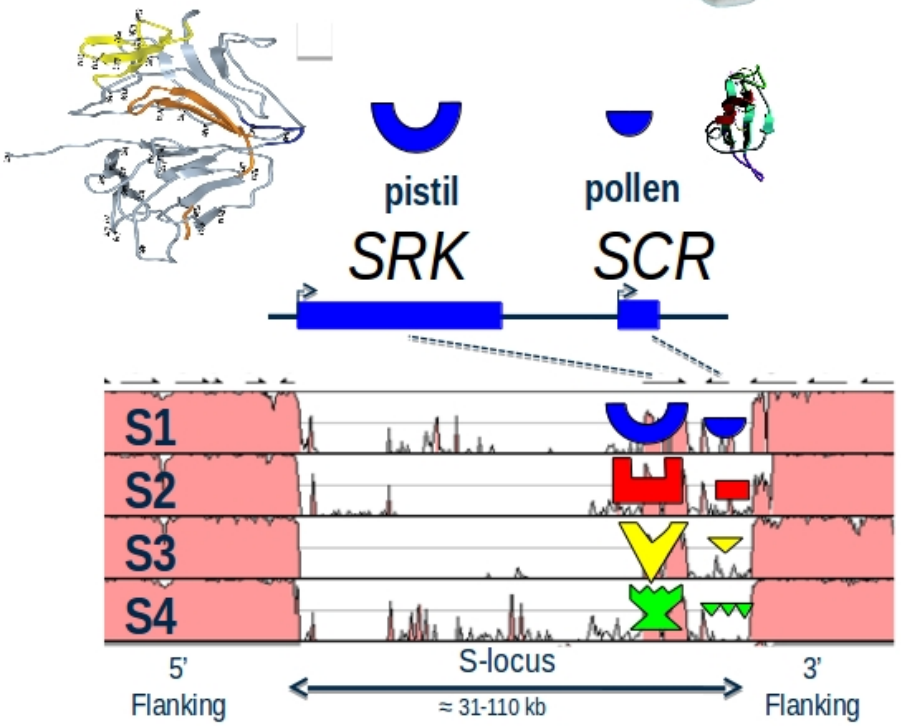
- Deterministic Processes (mutation, selection, migration)
- \+ Stochastic Processes (genetic drift)
- \+ Noise (environmental change)

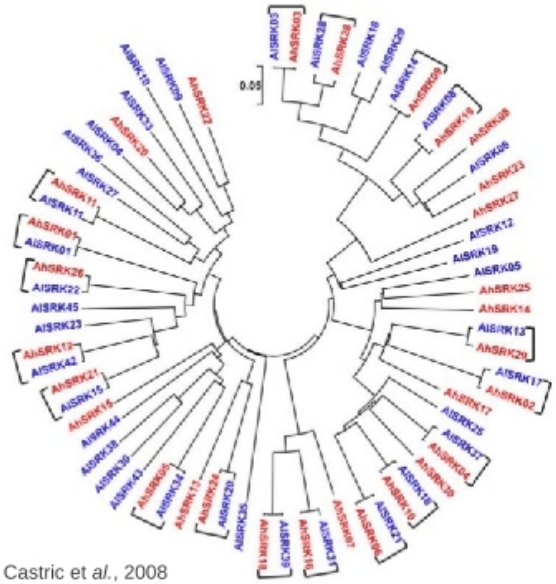
The central paradigm

Sample among > 1500 articles

- “the relative contribution of stochastic and deterministic processes to genomewide responses” (Linnen 2018, Molecular Ecology)
- “the relative importance of deterministic and stochastic assembly processes” (Spasojevic et al. 2018, Ecology)
- “allowing inference of the relative importance of deterministic versus stochastic processes”(Martins et al. Oecologia 2018)
- “deterministic (selection) and stochastic (genetic drift) mechanisms are expected to affect trait evolution” (Zastavniouk et al. 2017, Ecology and Evolution)
- “notably regarding the relative contributions of deterministic versus stochastic evolutionary forces” (Chevin 2016, Evolution)

My work: the evolution of self-incompatibility in plants





Castric et *al.*, 2008

Arabidopsis lyrata
Arabidopsis halleri

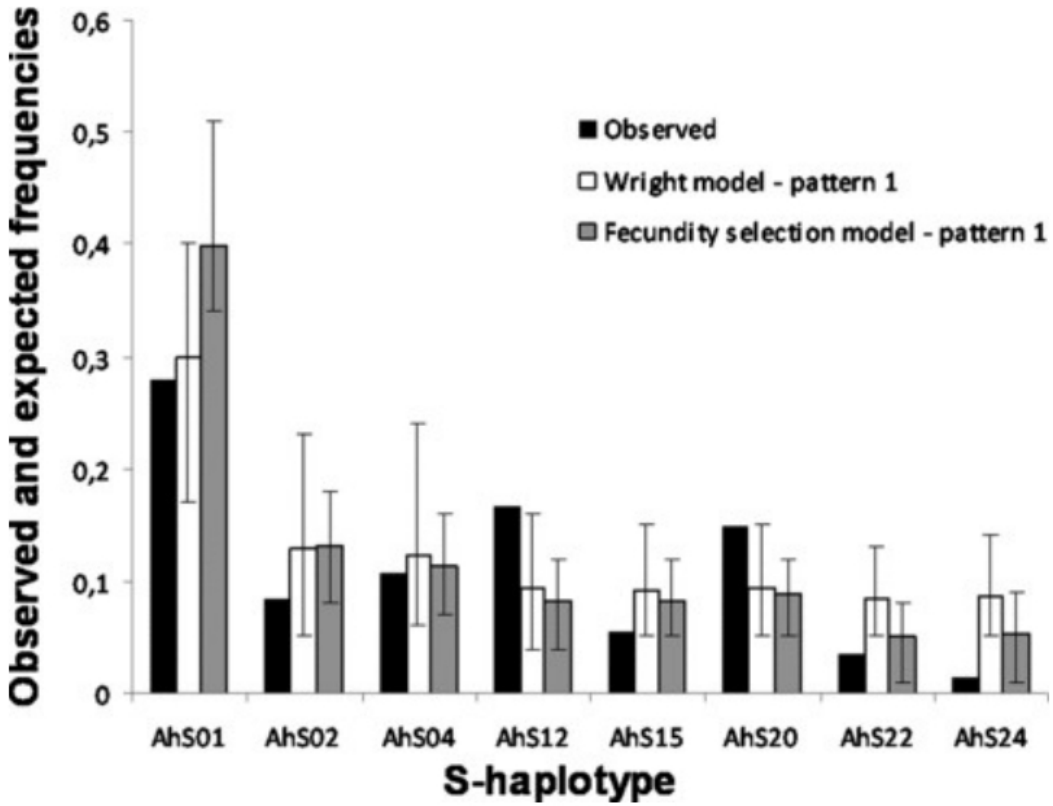
Goubet et al. (2012), Castric et al. (2013)

Deterministic genetic frequency change due to selection

$$f_{t+1}^{G} = \sum_{g,g'} \pi(g,g') f_t^g f_t^{g'} \tag{1}$$

Generating genetic drift

$$F_{t+1} \sim \text{Multinomial}\left(N, f_{t+1}^{g}, \ldots\right) \tag{2}$$



Llaurens et al. 2008

... and then came Chi

with words like...

- Poisson point measure
- Dirac mass
- Martingale
- Stochastic Differential Equations and their approximations
- Renormalization and scaling

... and my plants population became

$$N_t^G = N_0^G + \int_0^t \left(r^G(Z_s) - d\, N_s^G \right) ds + M_t^G \tag{3}$$

What did I learn?

1^{st} lesson: both population genetics and dynamics is possible

The particular case of the Primerose: an extinction problem for an nonhomogeneous random walk in the quarter plane

Kilian Raschel

$$j$$

$$\frac{r}{2(r+d)}$$

$$\frac{r}{2(r+d)}$$

$$\frac{d\,i}{(r+d)(i+j)}$$

$$\frac{d\,j}{(r+d)(i+j)}$$

$$i$$

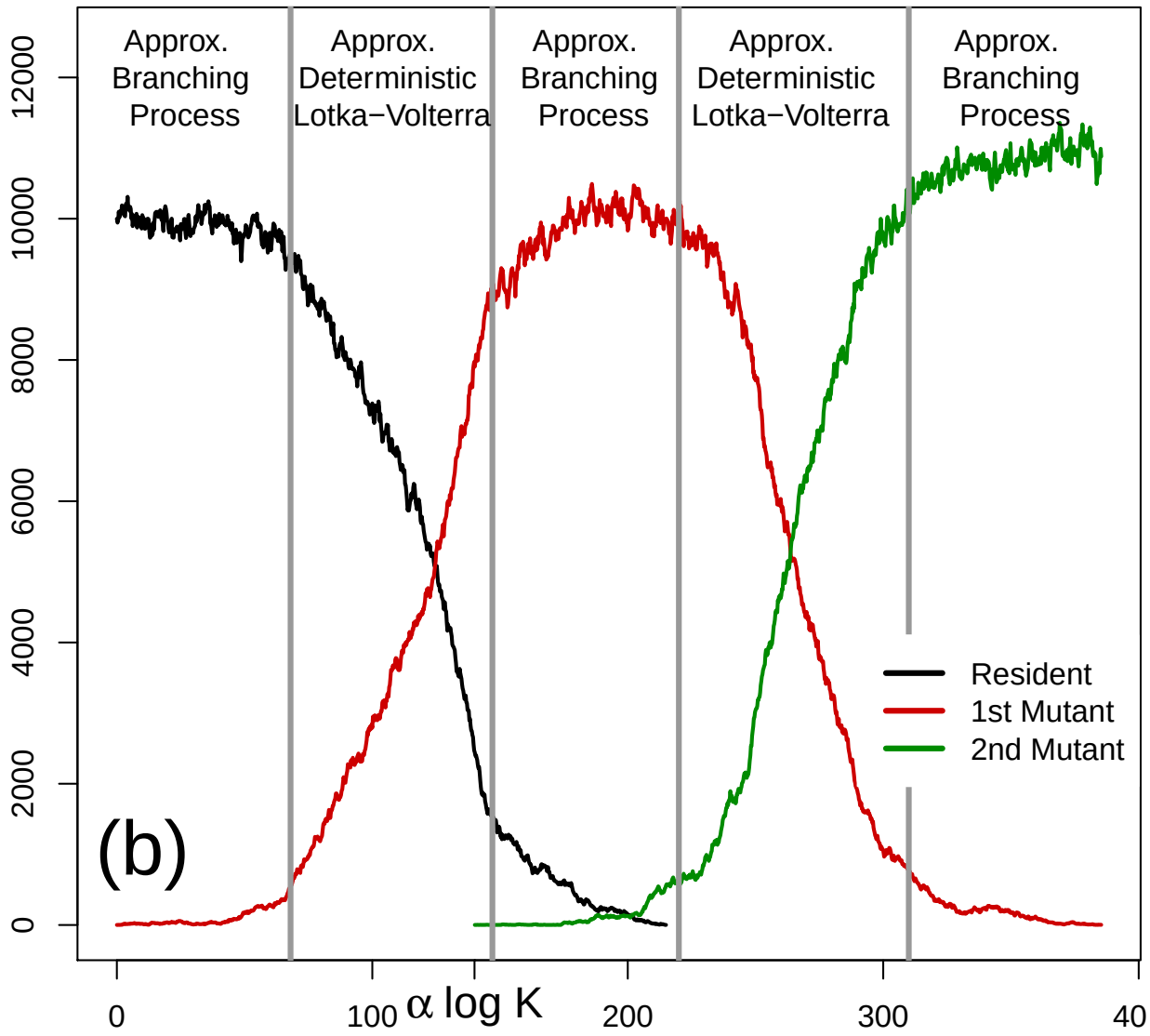
What did I learn?

1^{st} lesson: both population genetics and dynamics is possible

2^{nd} lesson: Biology can bring new questions to Mathematics

... and then came Sylvie, her students and colleagues

Ex. Dynamics of multiple competing clones (with Charline Smadi)



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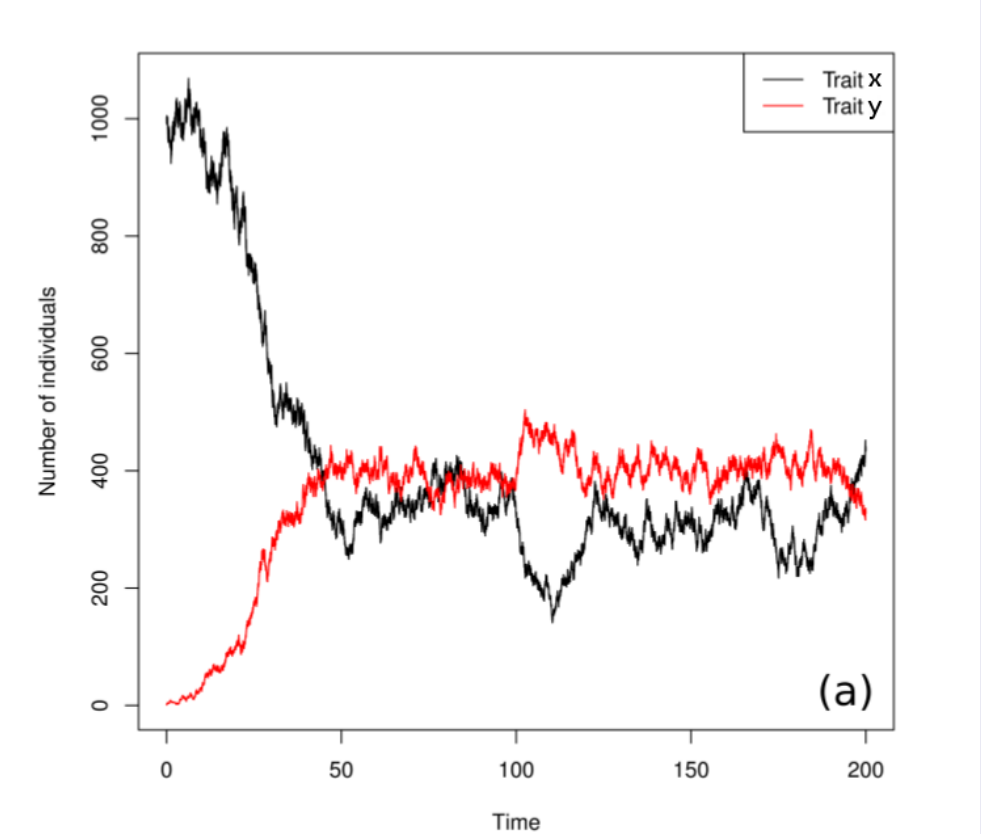
Ex. Evolution with horizontal transfer (with Sylvie, Pierre, Chi, Régis)



Different approximations of the stochastic processes

- ODE
- Diffusion

What did I learn?

1^{st} lesson: both population genetics and dynamics is possible

2^{nd} lesson: Biology can bring new questions to Mathematics

3^{rd} lesson: Different approximations of the stochastic processes, depending on scaling and parameters

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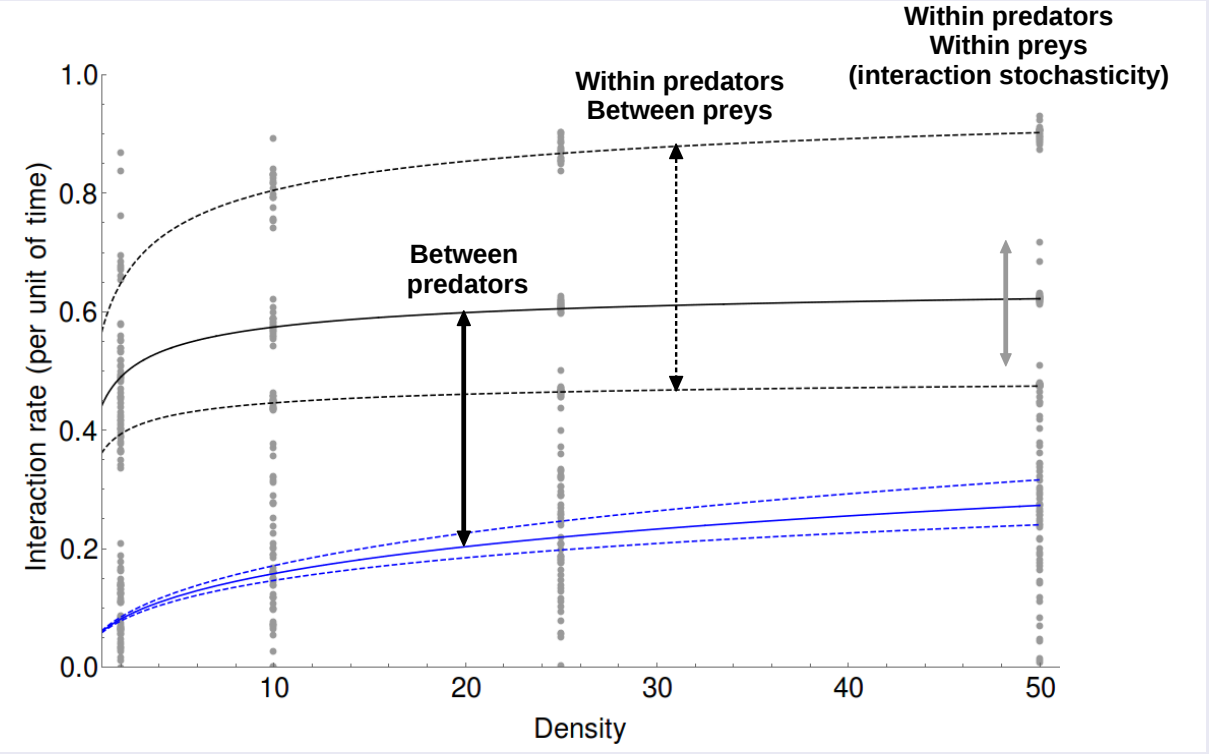
Ex. Derivation of key parameters in ecology: Functional Responses (with Vincent and Jean-René)



What did I learn?

1^{st} lesson: both population genetics and dynamics is possible

2^{nd} lesson: Biology can bring new questions to Mathematics

3^{rd} lesson: Different approximations of the stochastic processes, depending on scaling and parameters

4^{th} lesson: Fluctuations come from the process, there is information in it!

What did it change?

Biological world

Fundamentally stochastic

→ Different approximations

→ Importance of scalings and hypotheses about parameters

→ Evolution as a statistical property

No good reasons for opposing/separating

- Statistical models and mechanistic models
- Deterministic models and stochastic models
- Population genetics and Population dynamics

What did it change?

a bit confused now!

(thank you Sylvie.....really...)

Why confused?

I am not sure to understand the relevancy of...

- “stochastic vs. deterministic” forces, pressures, processes...
- “Genetic drift vs. selection”: neutralism-selectionism controversy

Consider the level of the individual

- Migration - ✓
- Mutation - ✓
- Selection - ✓
- Genetic drift - ?

At different levels

- Teaching: Evolution is not deterministic $\rightarrow$ avoid finalism
- New perspectives: noise, variance, variability, not a nuisance!
- Our understanding $\rightarrow$ different models $\rightarrow$ different scalings

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Upside down now... might be worse in the future!

A suggestion: consider the evolution of

- Inheritance systems: Mendelian $1/2$, dominance, recombination rates, mutation rates, multilevel selection, etc.
- Indirect selection: Hitch-hiking, background selection, epistasis, Hill-Robertson effect, altruism, etc.
- Life history: ageing, senescence, life cycles, haploidy-polyploidy, clonality, etc.

For instance: Why a lower boundary to mutation rate?

" the lower barrier to mutation rate evolution may ultimately be defined not by molecular limitations but by the power of random genetic drift" (Lynch 2011).

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I learned so much...

... what did I teach in return?

Sylvain, tell me…

boys and girls, how does it work?

Sylvain, explain me once more…

What is sex?