Somatic evolution in modular species

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1. Unitary vs. modular organisms

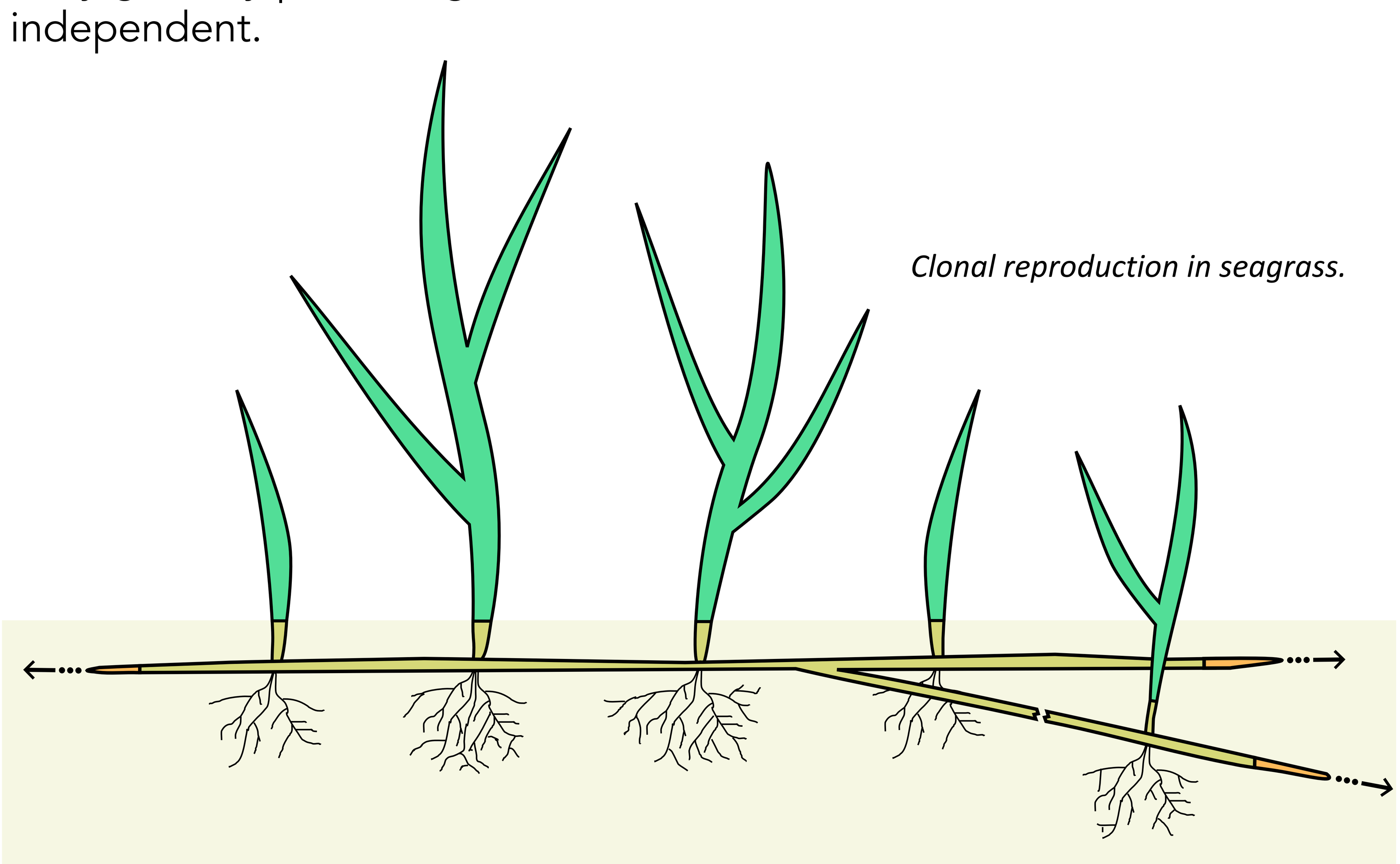
Cells accumulate mutations when they divide, leading to somatic genetic variation within individual organisms. Selection acts on this variation resulting in somatic evolution.

In unitary organisms, which rely on non-redundant organs, somatic evolution can lead to cancer.

Modular organisms, like plants or corals, are not susceptible to cancer. Somatic evolution may play a more positive role, e.g., in adaption [1].

2. Growth and reproduction

Modular organisms comprise basic units or *modules* that are repeated. They grow by producing more modules, which can become independent.



Clonal reproduction in seagrass.

Modular organisms can grow to be large clones, comprised of individuals descended from a single zygote.

3. Multilevel selection

Somatic genetic variation occurs on two levels:

- *Intra-module variation*: mutations initially arise in a single cell but can spread as cells divide and differentiate.
- *Inter-module variation*: some mutations become fixed in modules, due to cell turnover and module branching. Fixed mutations differ between modules.

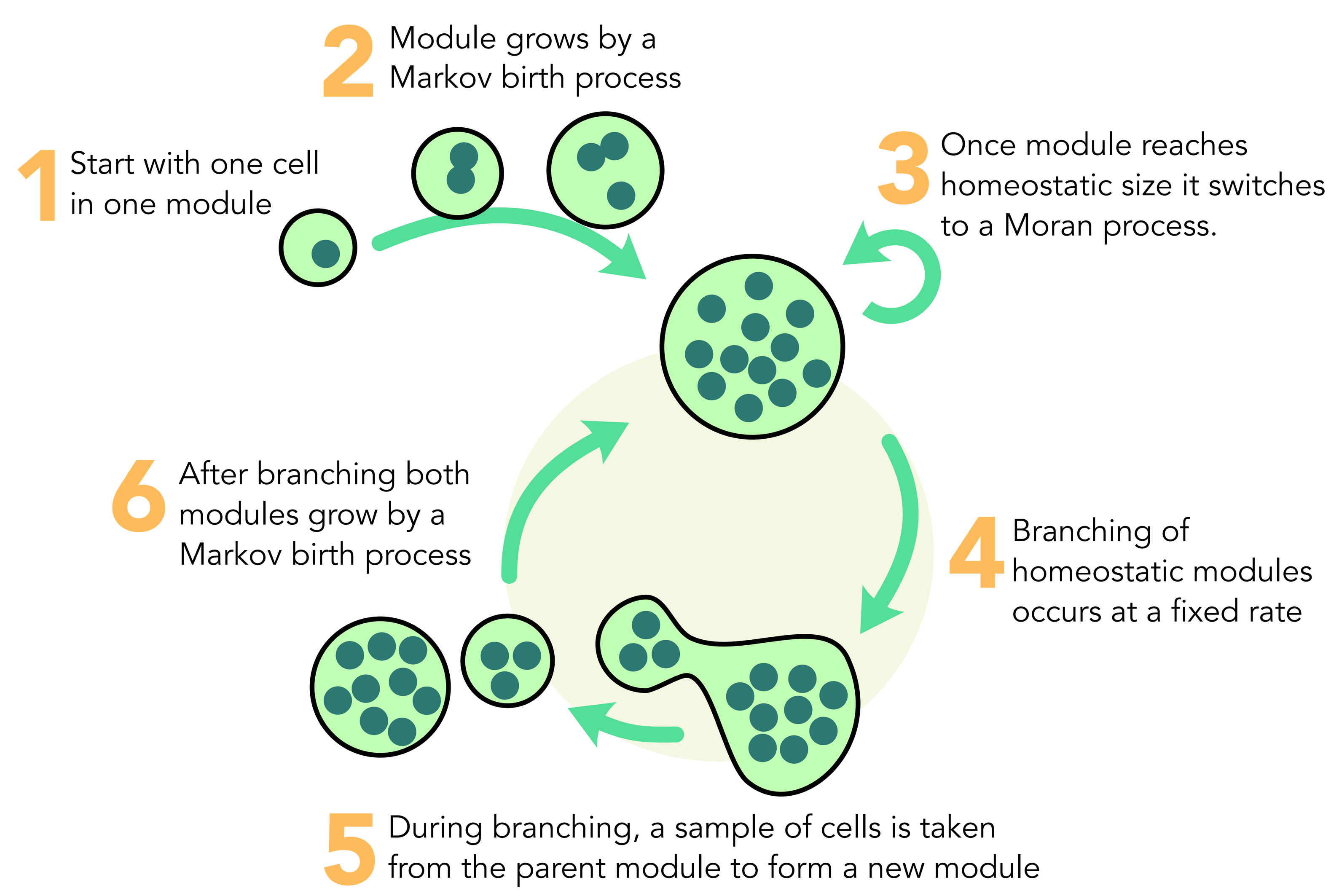
Thus, selection can act both within modules and between modules.

One way to characterise inter-module somatic genetic variation is to compute pairwise fixed differences between modules.

Pairwise fixed differences = the number of fixed mutations that are in one module, but not in the other.

This has been done experimentally for seagrasses [2].

3. Multilevel evolutionary model



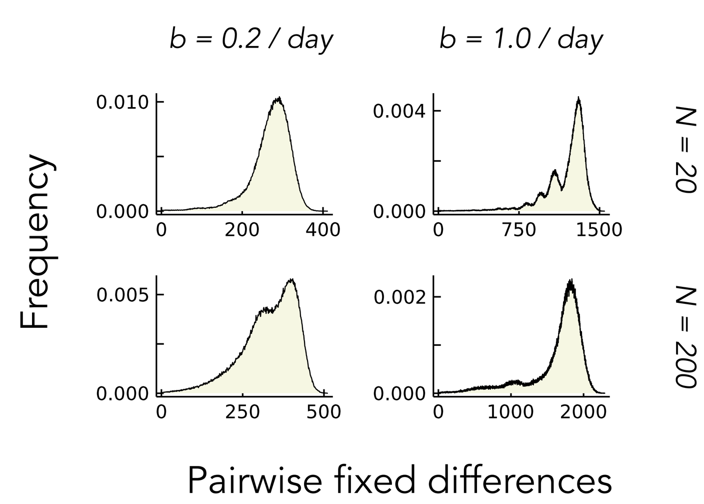
Cells acquire new mutations at division, which are passed on to descendants. The number of mutations follows a Poisson distribution.

Julia package: https://github.com/jessierenton/SomaticEvolution.jl

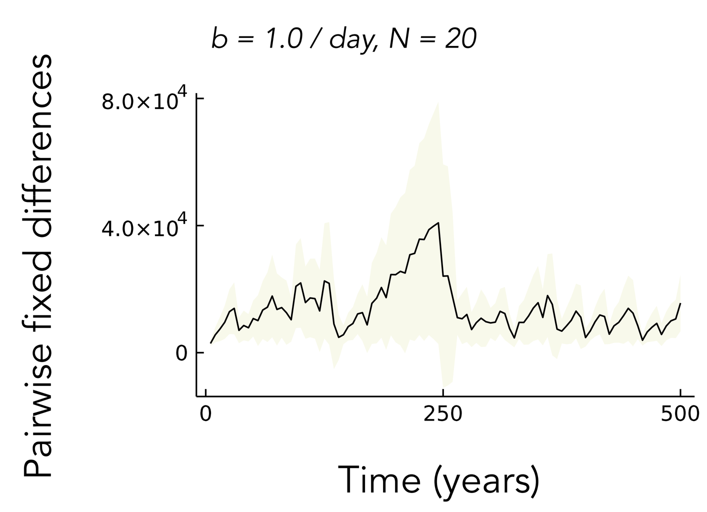
4. Pairwise fixed differences

We can calculate pairwise fixed differences from the model by simulation.

Distribution for all pairs in a population of one thousand modules after exponential growth.



Change in mean over time for a homeostatic population of one hundred modules.



Cell division rate = b; homeostatic module size = N
Mutation rate = *0.52 per cell per division;* Branching rate = *3 per year;* Initial module size = *1*

5. Future aims

- Incorporate real data from seagrasses and corals
- Investigate the effect of selection by introducing non-neutral mutations in the model
- Consider the role of population bottlenecks, e.g., due to external environmental factors or seasonal population decline

References:
[1] Reusch, Thorsten BH et al. (2021) *Trends in Ecology and Evolution* 36(12).
[2] Yu, Lei et al. (2020) *Nature Ecology and Evolution* 4(7).

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