PAst Links in the Evolution of Ocean's Global ENvironment and Ecology (PALEOGENiE)

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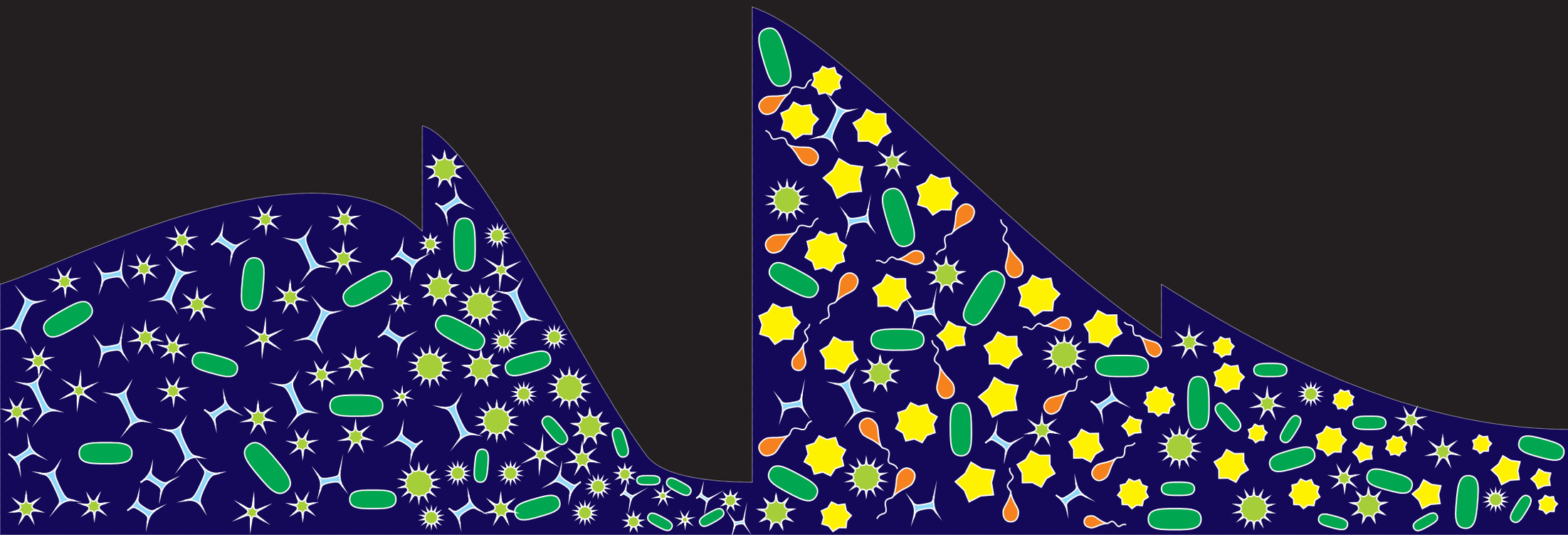

PALEOGENiE – motivation

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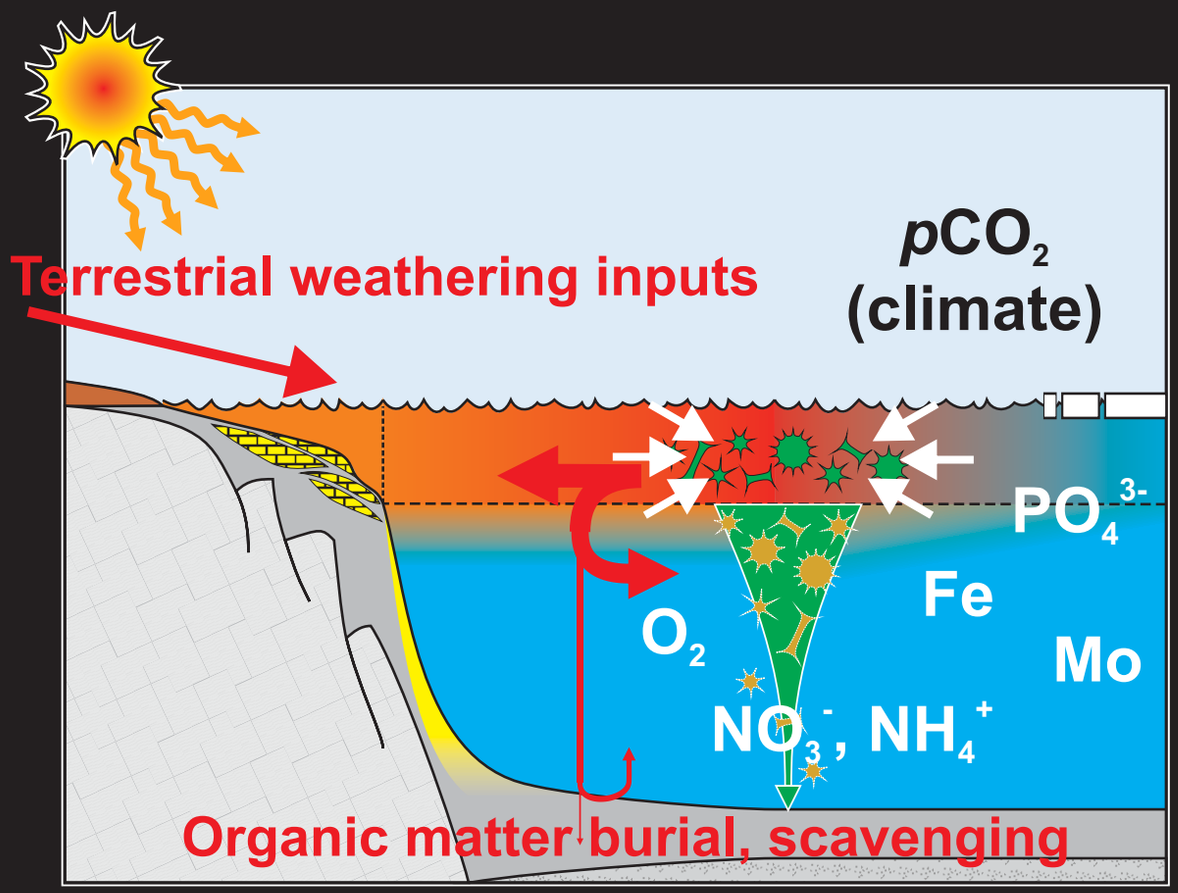

The nature marine ecosystems and strength of biological productivity and remineralization affects:

- Oceanic macros nutrient inventories, esp. P and the form of fixed N.
- Ocean oxygenation and hence micro nutrient inventories, esp. Fe – scavanged in an oxic ocean, and Mo – scavenged in a sulphidic ocean.
- Atmospheric pCO_2 and climate.

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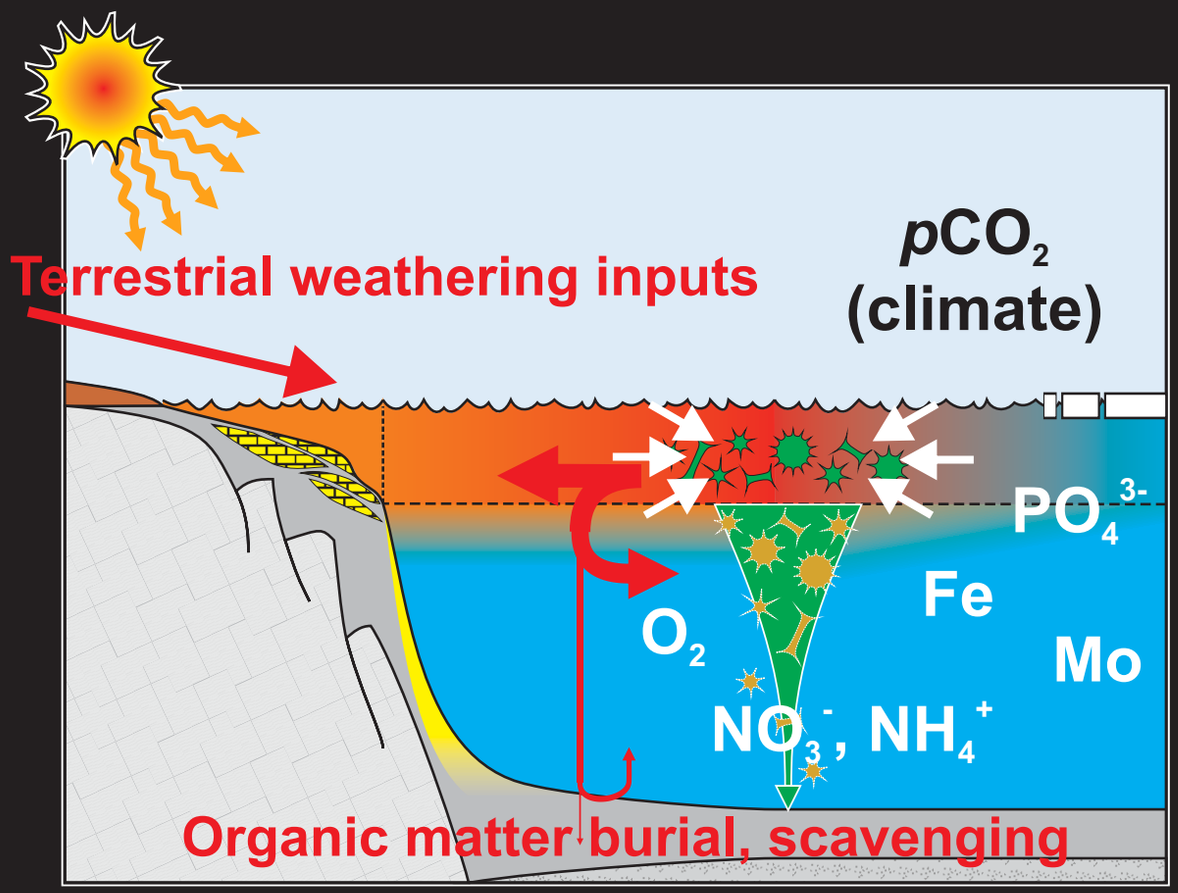

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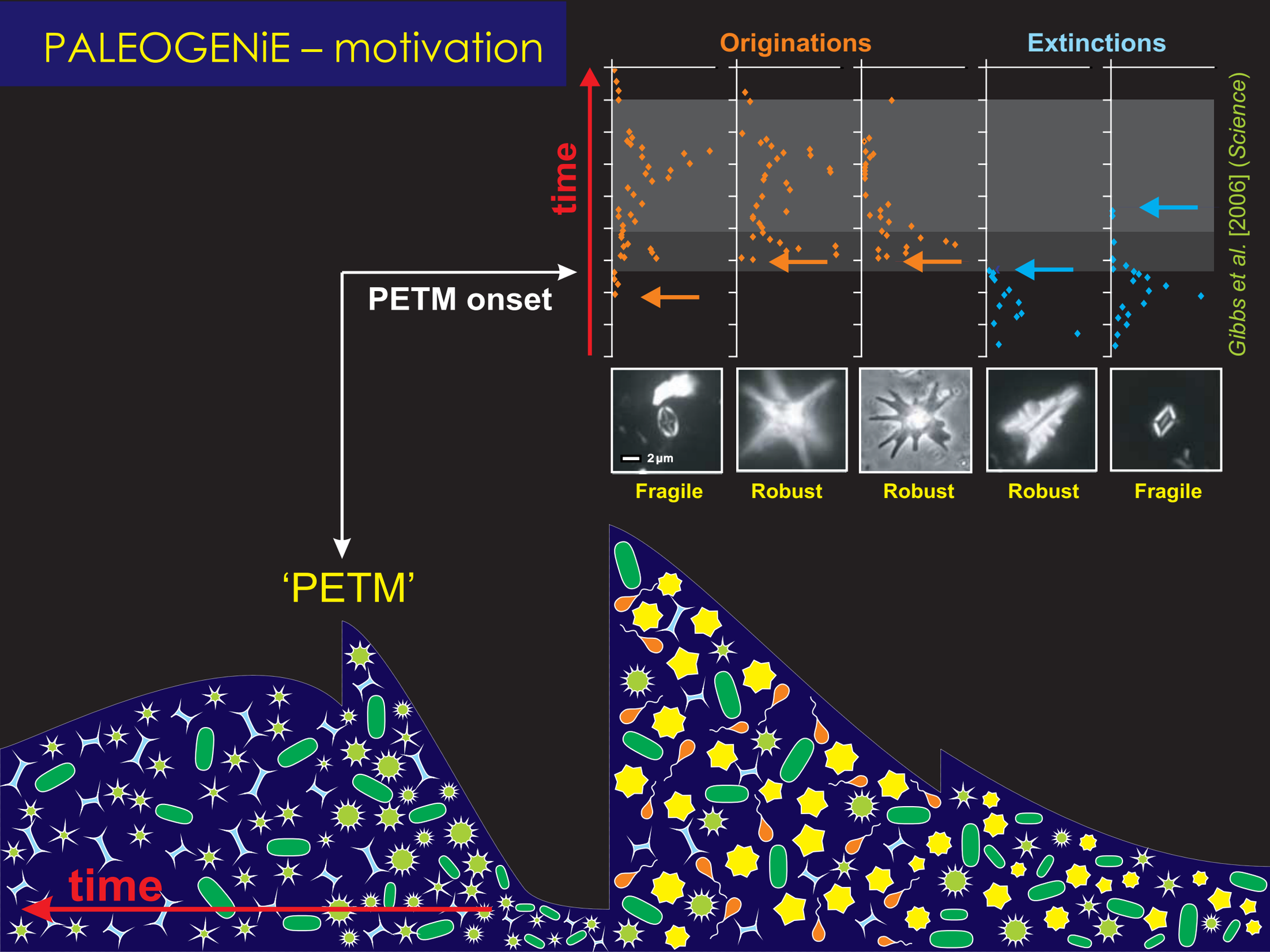
- Atmospheric pCO_2 and climate.

In turn, changes in the physical and biogeochemial (nutrient) environment will affect ecosystem composition and drive selection.

The approximate coincidence between plankton evolutionary time-scales and the residence time of many of the key ocean and atmospheric tracers raises the possibility of interesting dynamical behaviours of the full system.

`/end speculation`

PALEOGENiE – motivation



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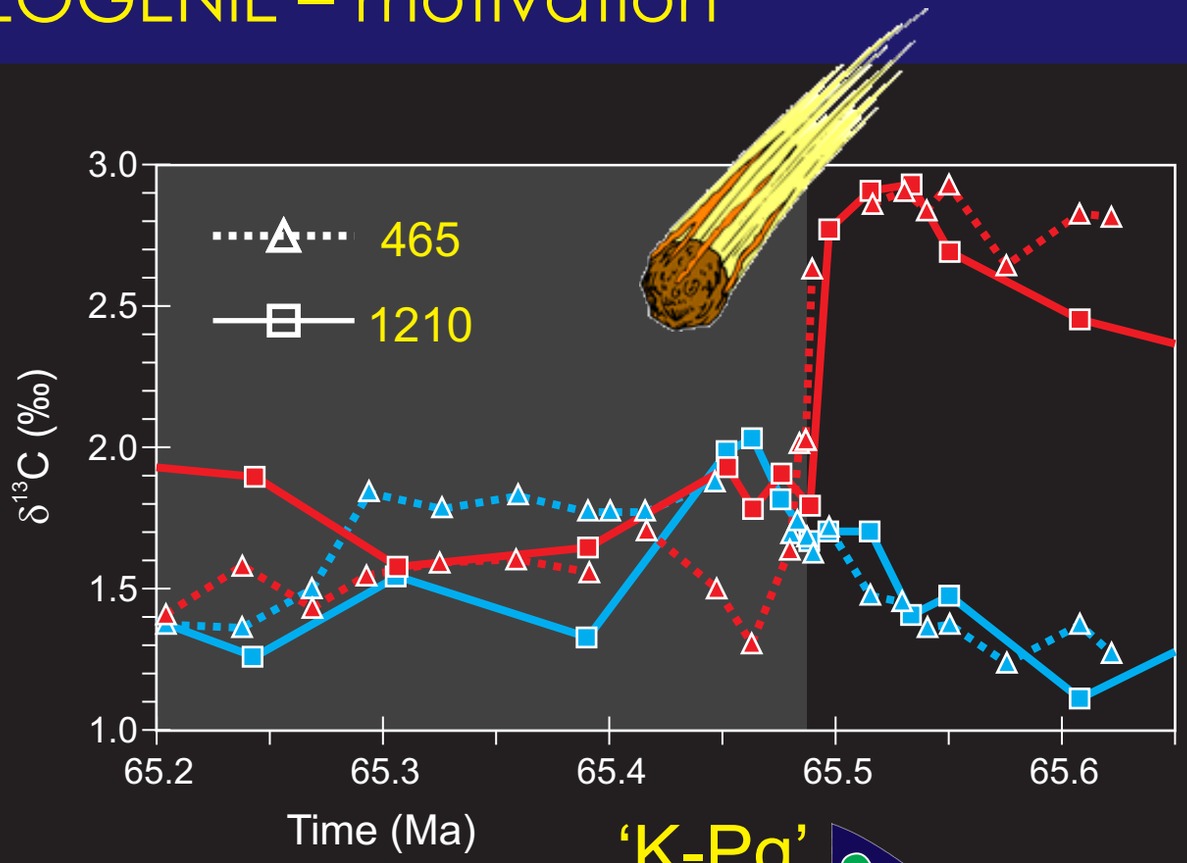

‘K-Pg’

recovery ‘gap’

time

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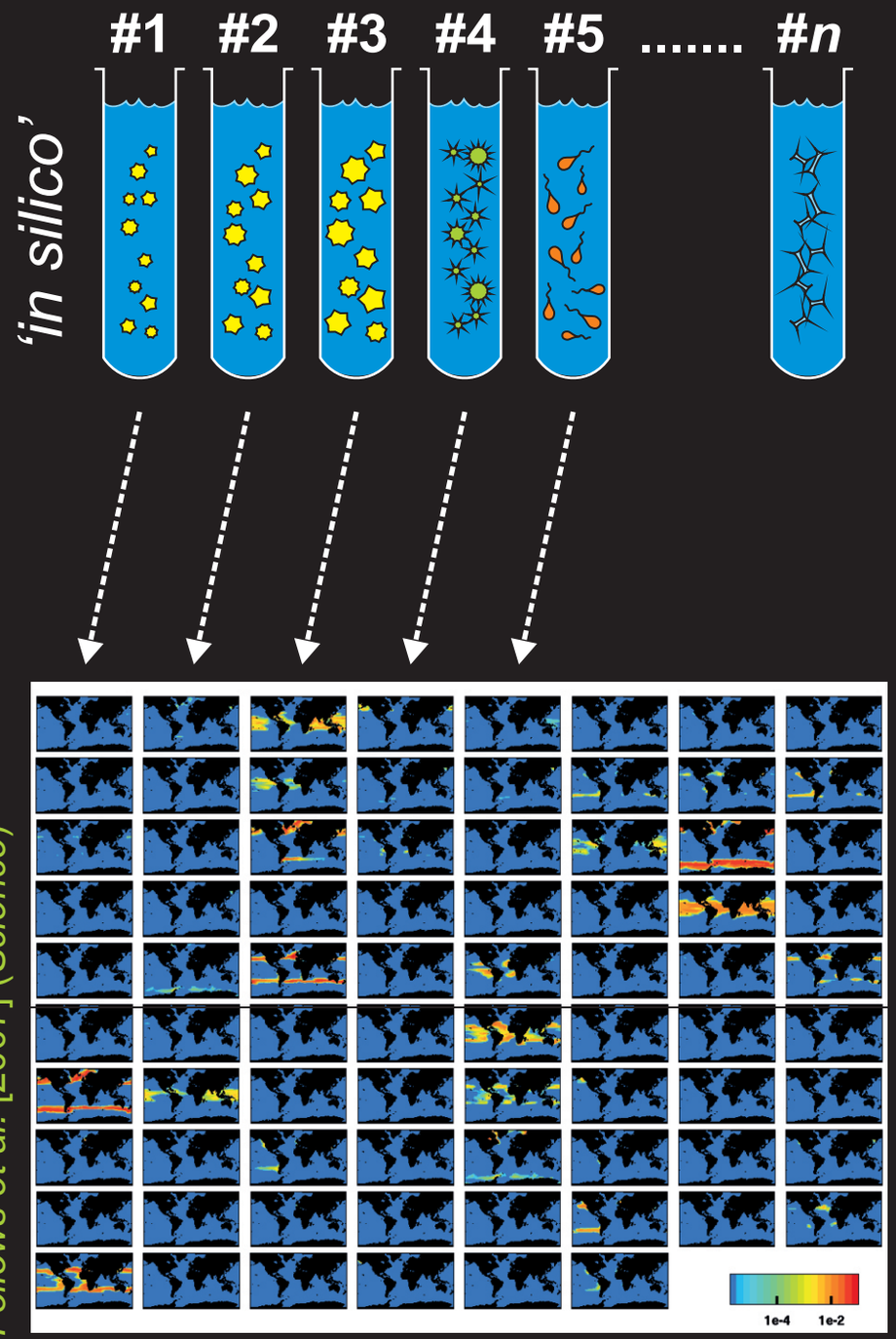

Follows et al. [2007] (Science)

Marine ecosystems *in silico*:

- The MIT ‘Darwin’ model typically considered ca. *n* = 76 randomly-generated trait vectors (’plankton’).
- Plankton trait vectors set according to physiological ‘rules’, e.g. larger cells have a higher nutrient limitation threshold, the ability to fixed N_2 comes at the expense of reduced growth rate, etc.
- Plankton compete and the ecosystem is an **emergent** rather than prescribed property.

But ...

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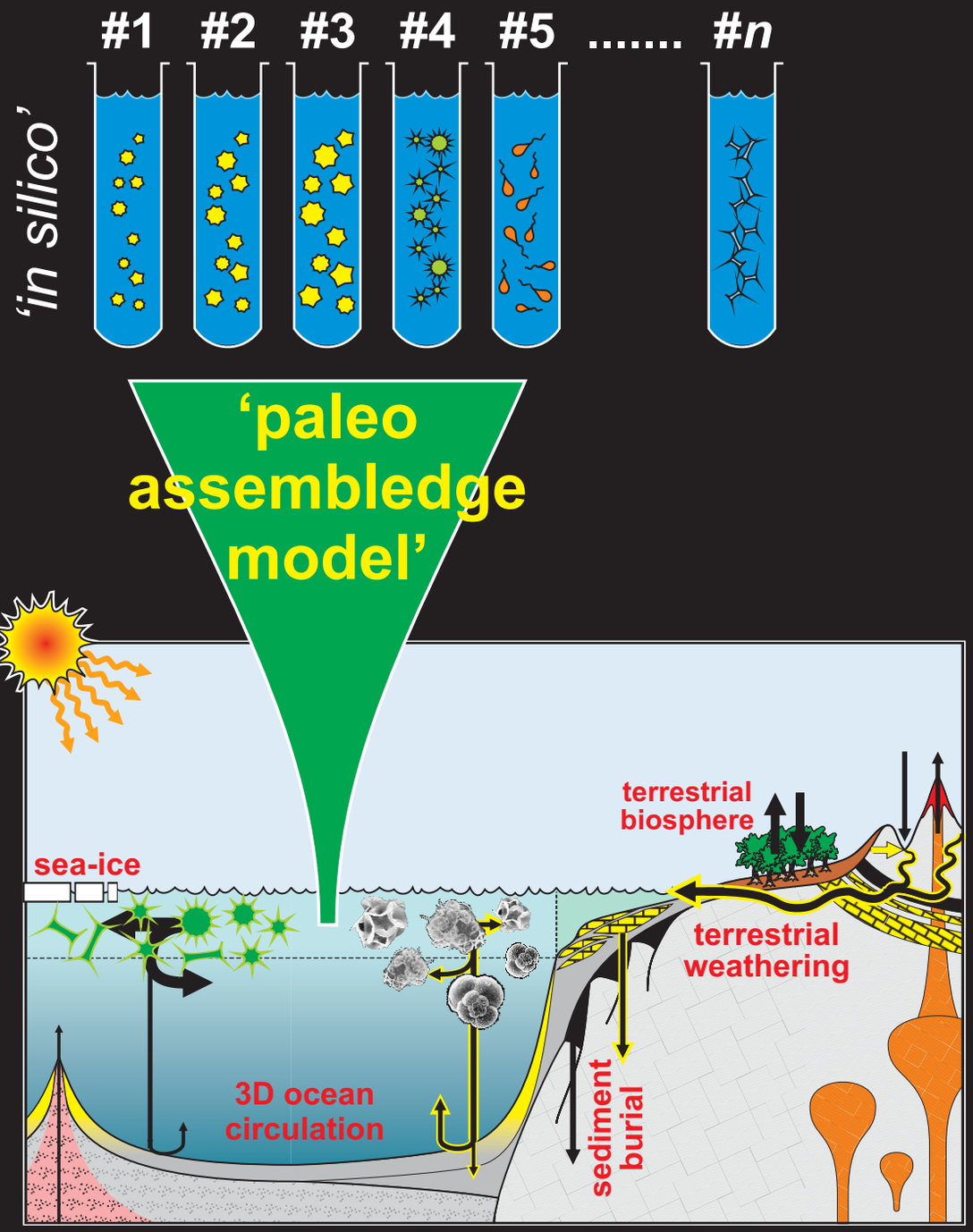

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But ...

... the geochemical environment and climate co-evolves as global nutrient cycles are modified.

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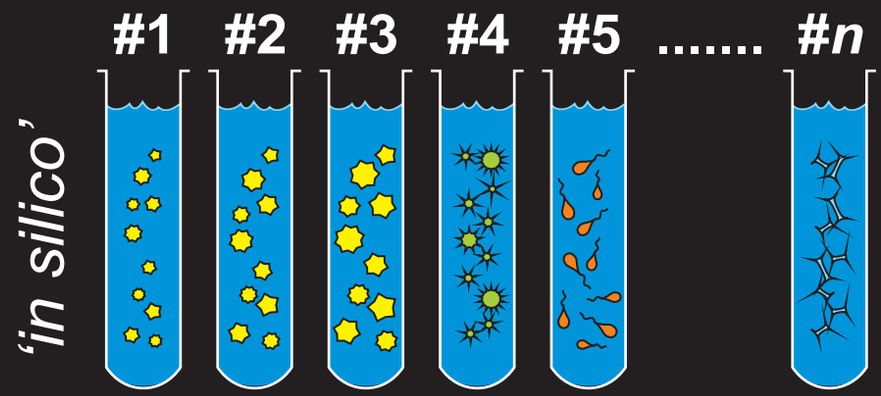
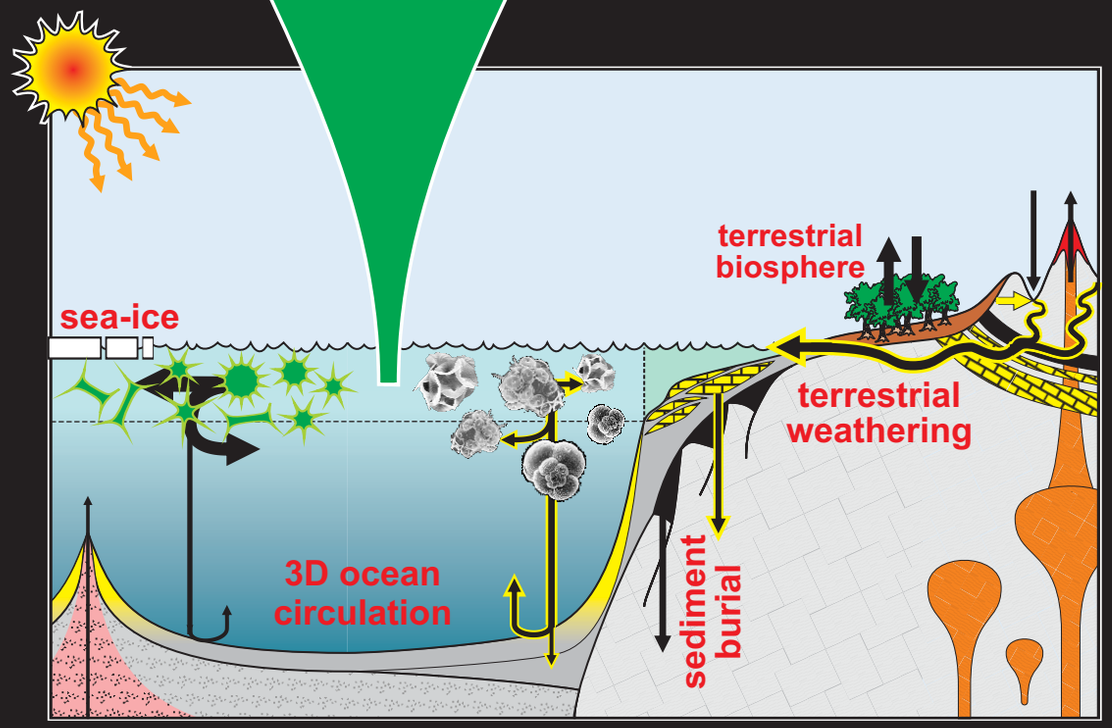


‘paleo assembledge model’



- *n* = 1,000-10,000 randomly-generated trait vectors (’plankton’).
- Plankton trait vectors set according to physiological ‘rules’, e.g. larger cells have a higher nutrient limitation threshold, the ability to fixed N_2 comes at the expense of reduced growth rate, etc.
- Plankton compete and the ecosystem is an **emergent** rather than prescribed property.
  But ...
  ... the geochemical environment and climate co-evolves as global nutrient cycles are modified.
- At very high resolved diversity, we can explore questions of **adaptation** and rates of **evolutionary change** by spawning new plankton with perturbed characteristics.

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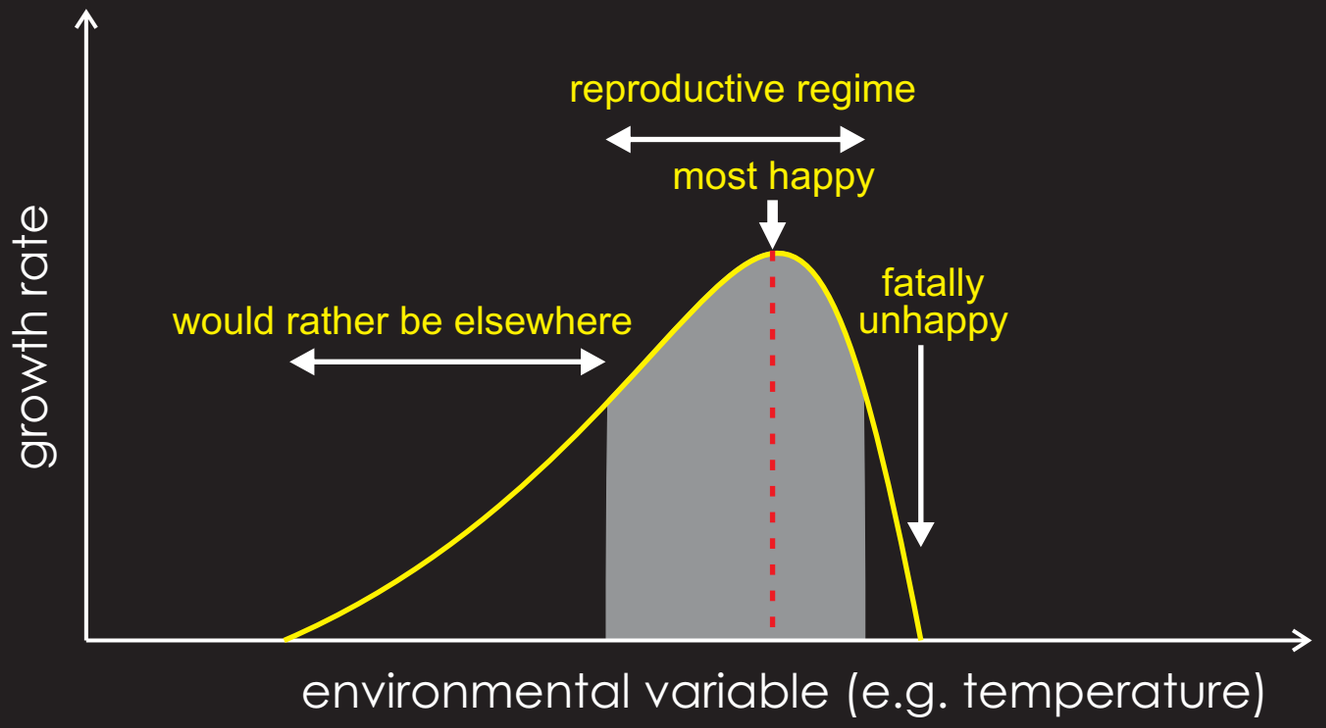
‘re-drawn’, with sincere apologies, from Schmidt et al. [2006]



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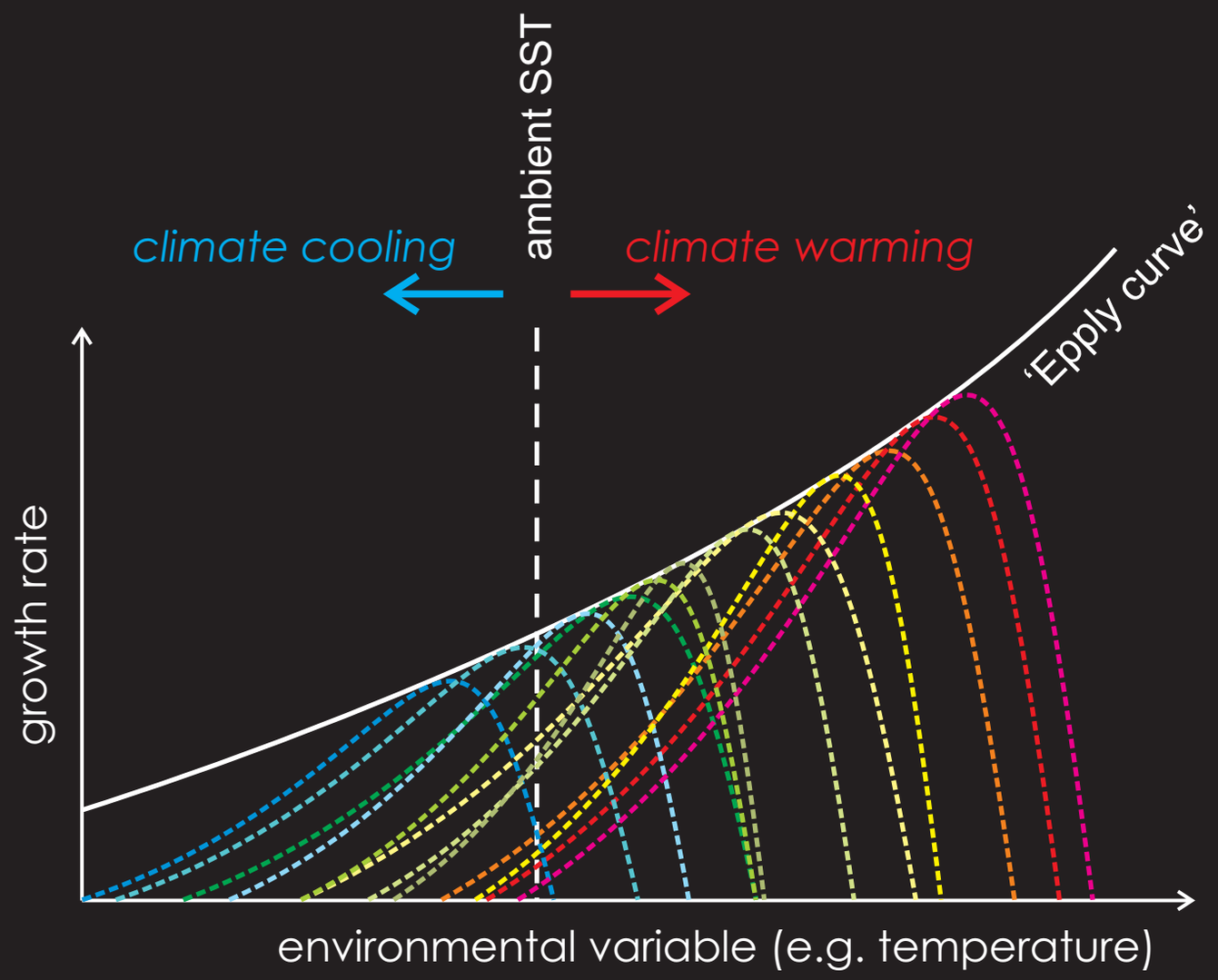

In traditional 'functional type' ecosystem models, diversity is not resolved, but instead its effects highly parameterized (e.g. the 'Epply curve').

The response to a change in climate is then instantaneous and fully reversible.

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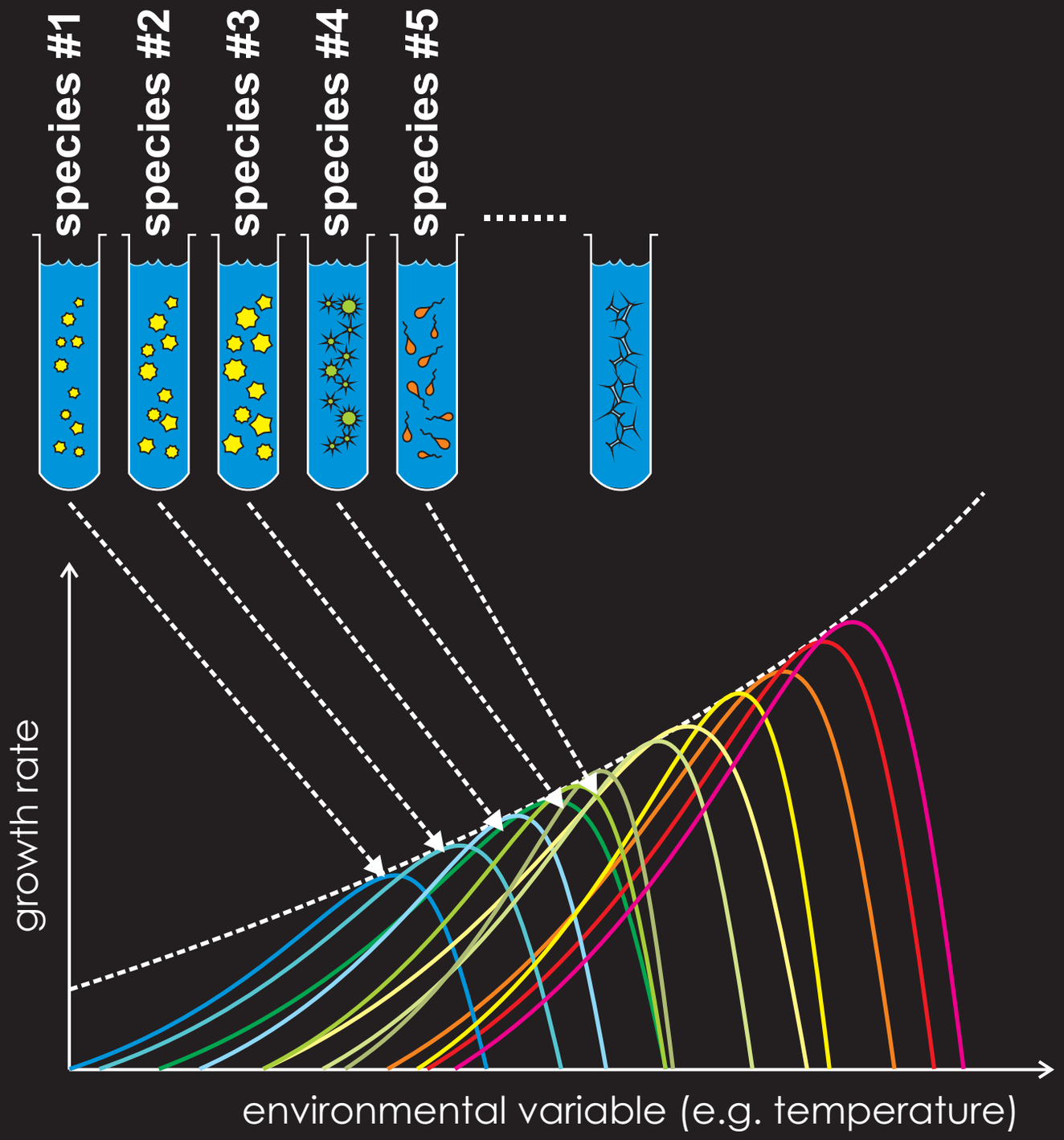

Instead, in a highly diverse model, the environmental response of individual ‘species’ can be resolved ...

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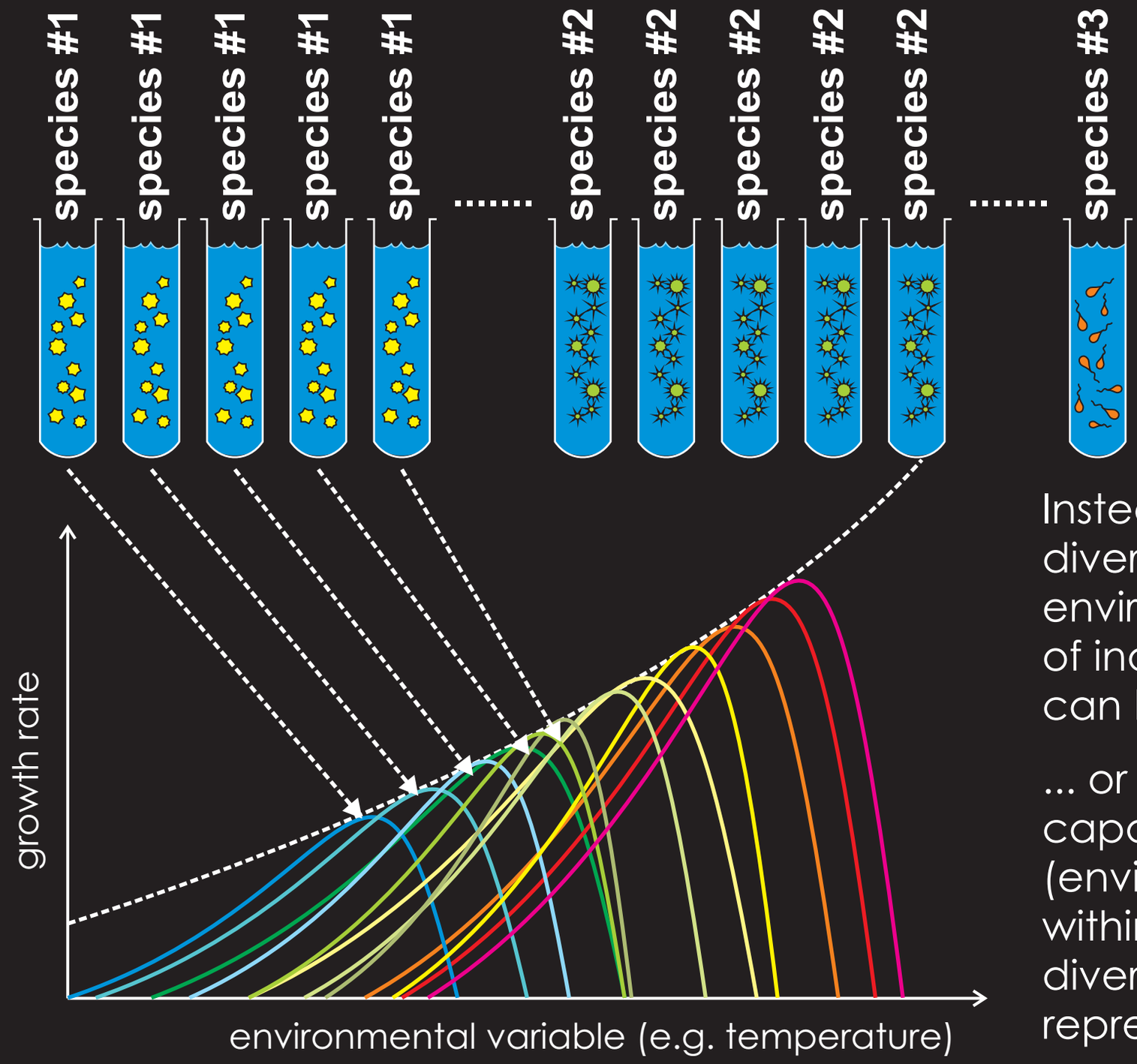

Instead, in a highly diverse model, the environmental response of individual ‘species’ can be resolved ...

... or instead, the capability for adaptation (environmental selection within existing genetic diversity) can be represented(?)

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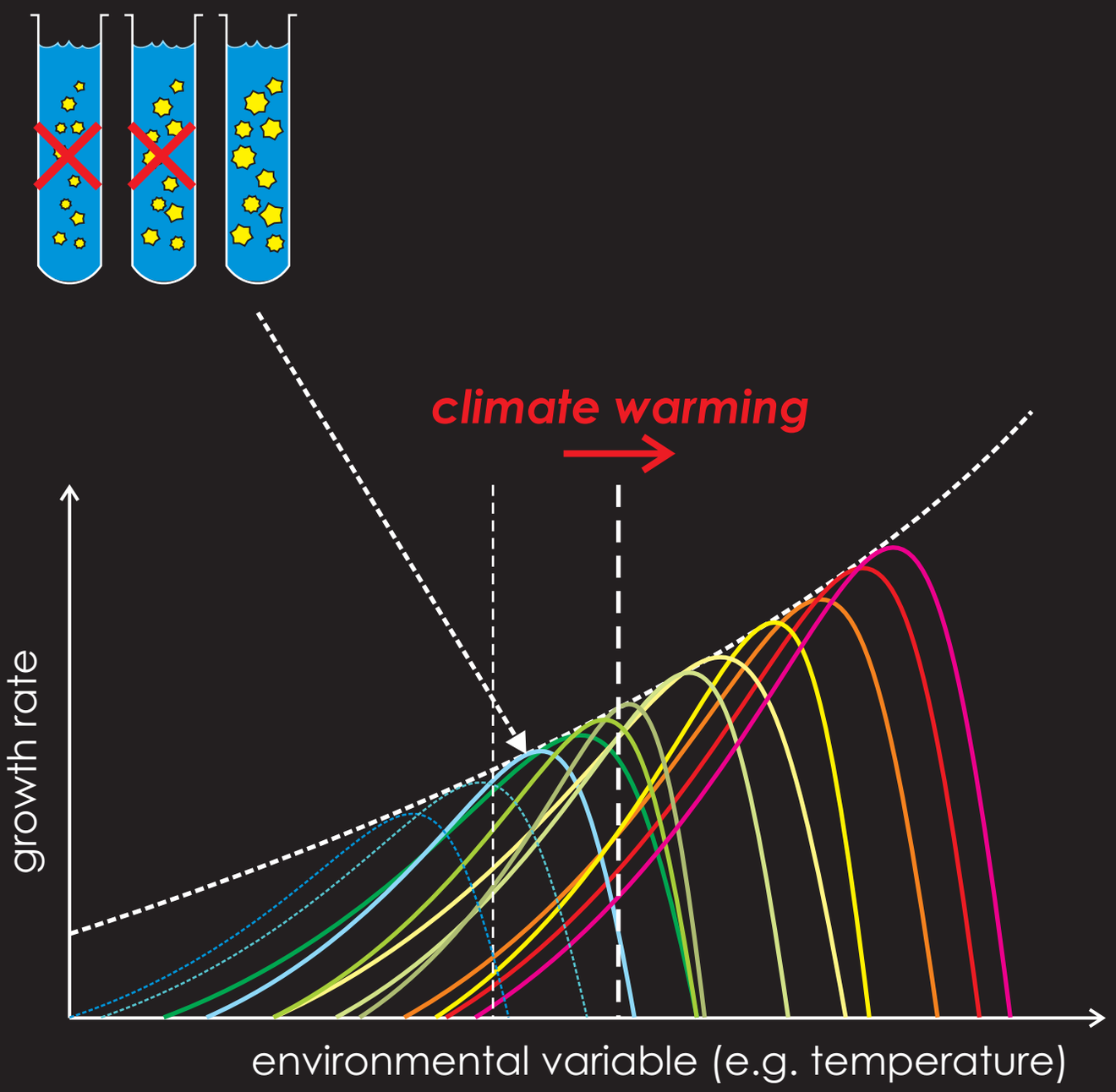

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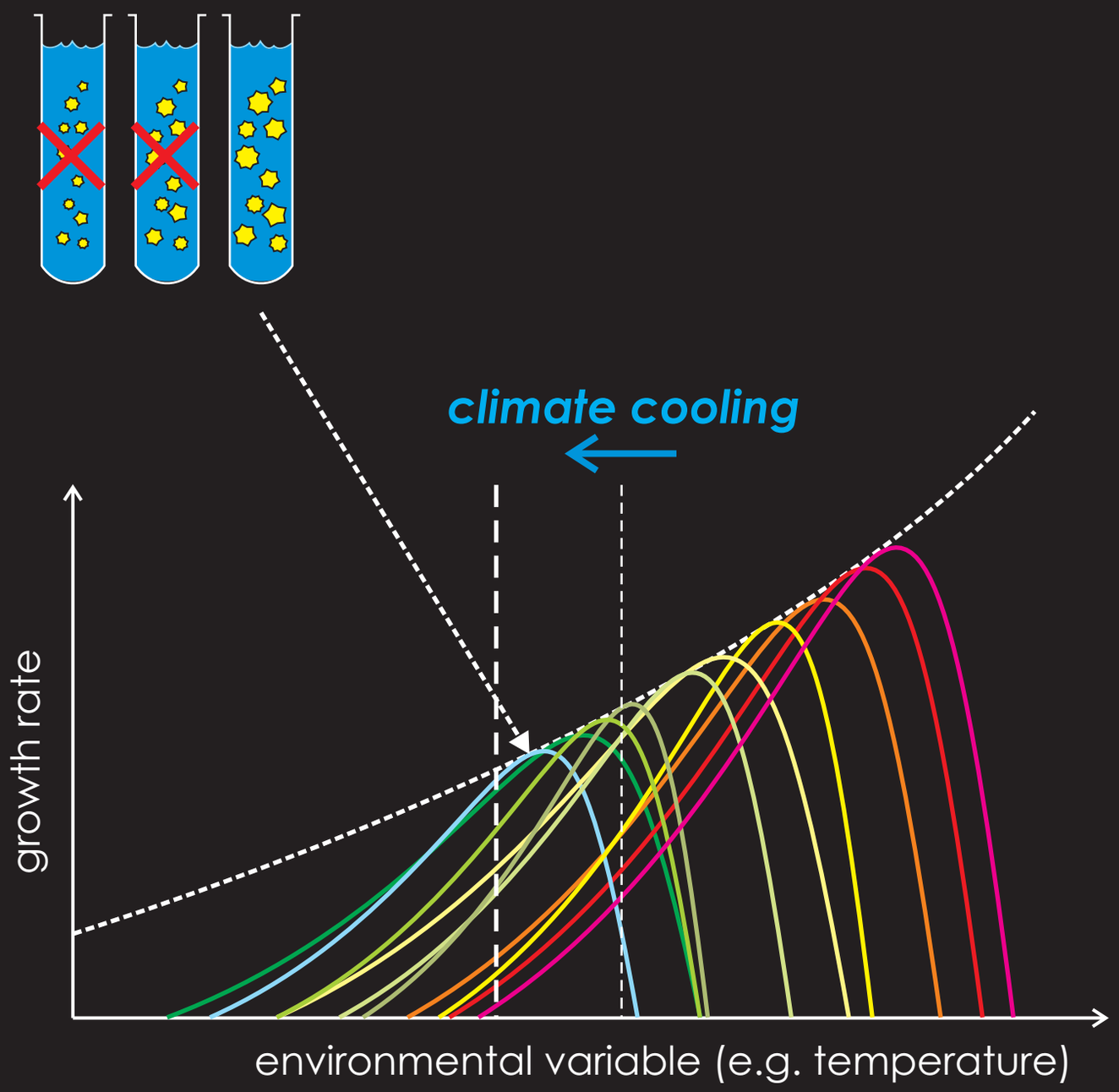

If climate cools, the low SST optimized species/varients no longer exist. Ecosystem dynamics are presumably different.

Niches are unfilled, so ...

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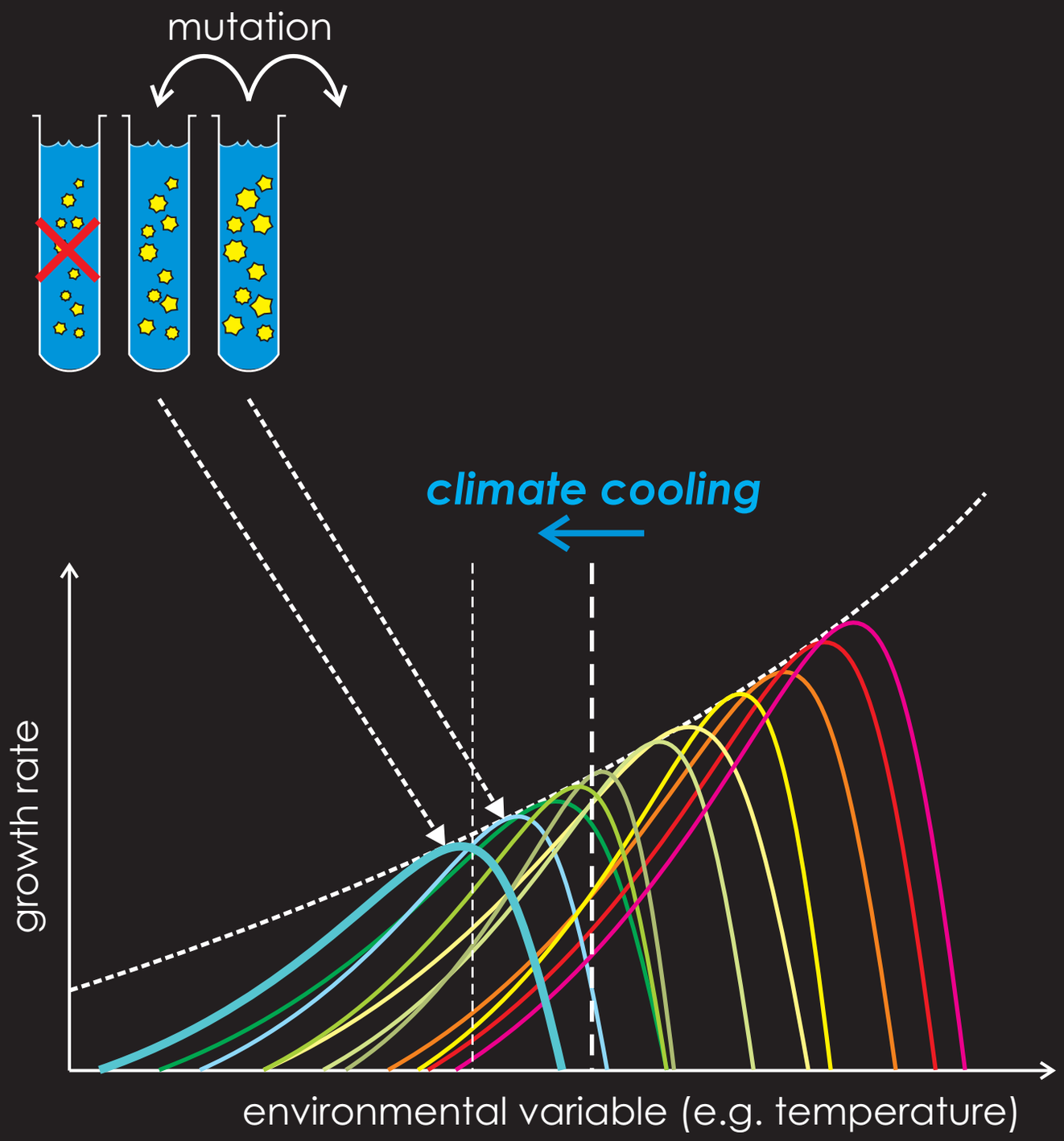

Allow non-viable plankton to be replaced with ‘mutations’ of surviving species, using the trait based trade-offs.

Q. How ‘frequently’ to mutate, and as a function of what?

Q. What ‘step size’ to take for mutation?

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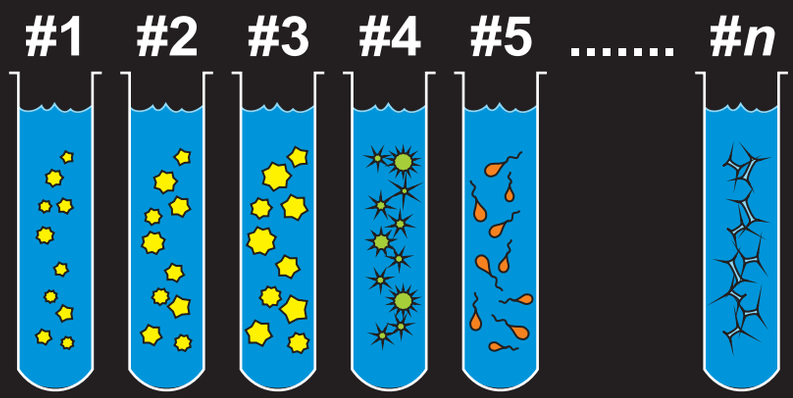

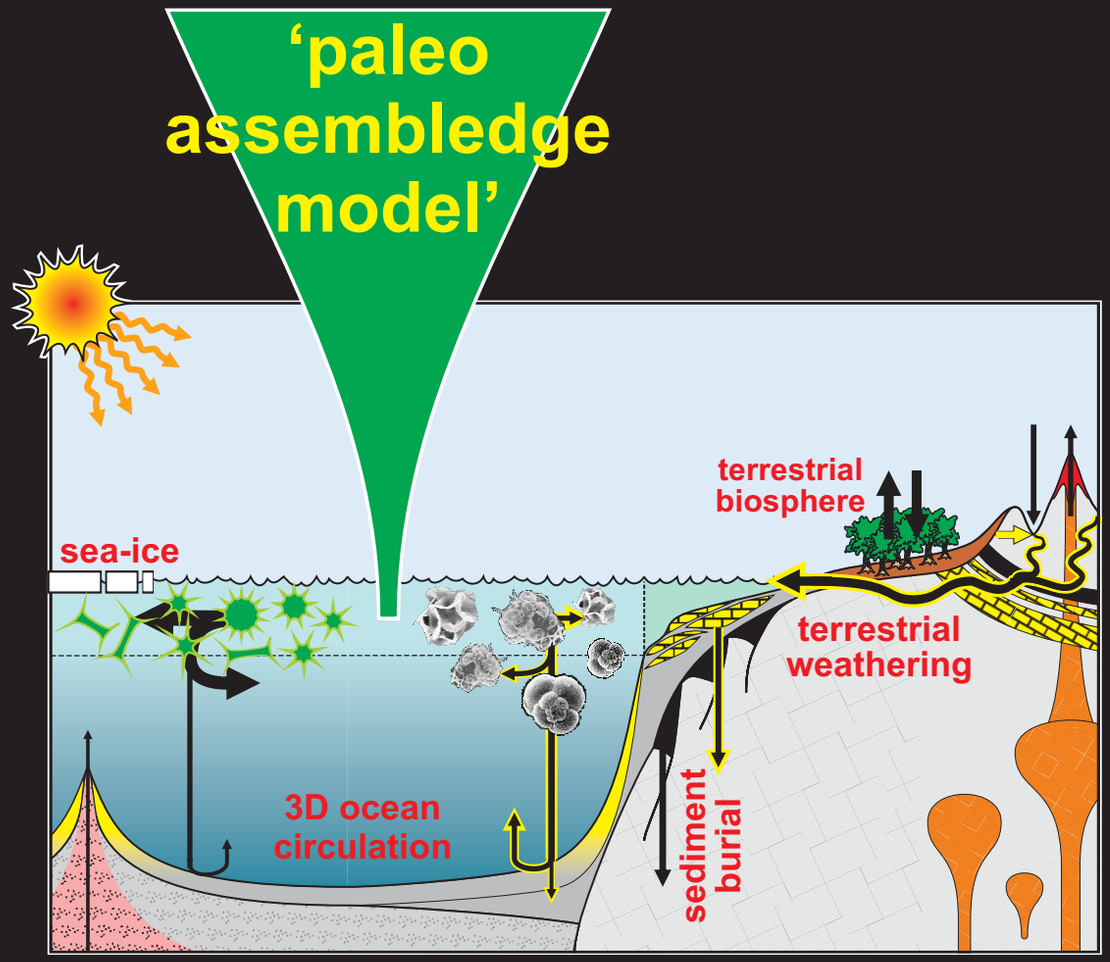

‘PALEOGENiE’:

- A radical paleo model-data concept for theoretically exploring questions of marine plankton adaptation and evolution.
- Specific questions:
Cause(s) of the delayed recovery (100s of kyr) from end Cretaceous extinction
Determining which factor(s) best explain ecological responses to PETM carbon release.
- A tool for gaining understanding about future ecosystem stability (+ proof concepts for future models).

‘PALEOGENiE’ – computational strategies

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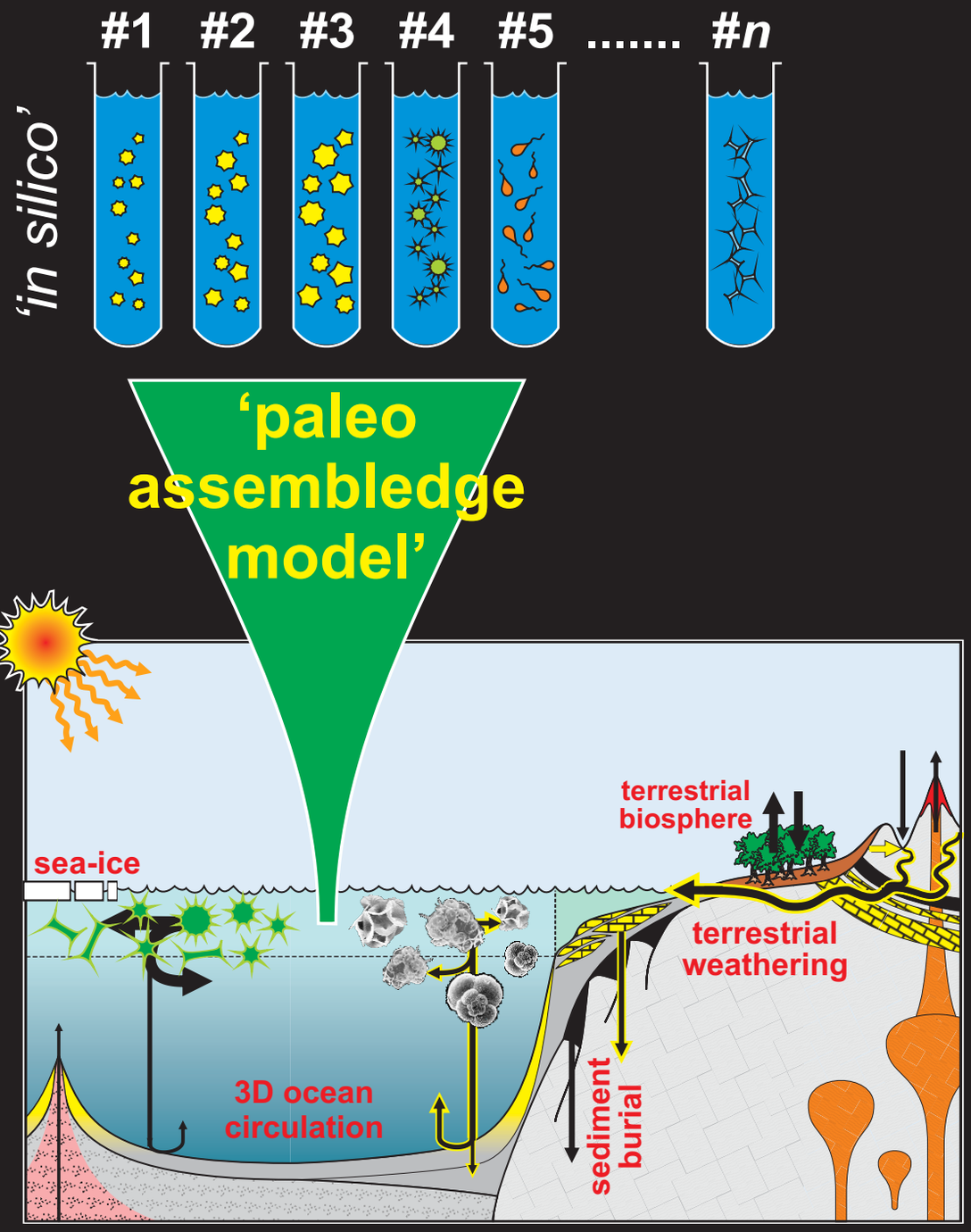

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...

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There is clearly a very significant computational expense involved, even if using low resolution/efficient Earth system models such as ‘GENIE’.

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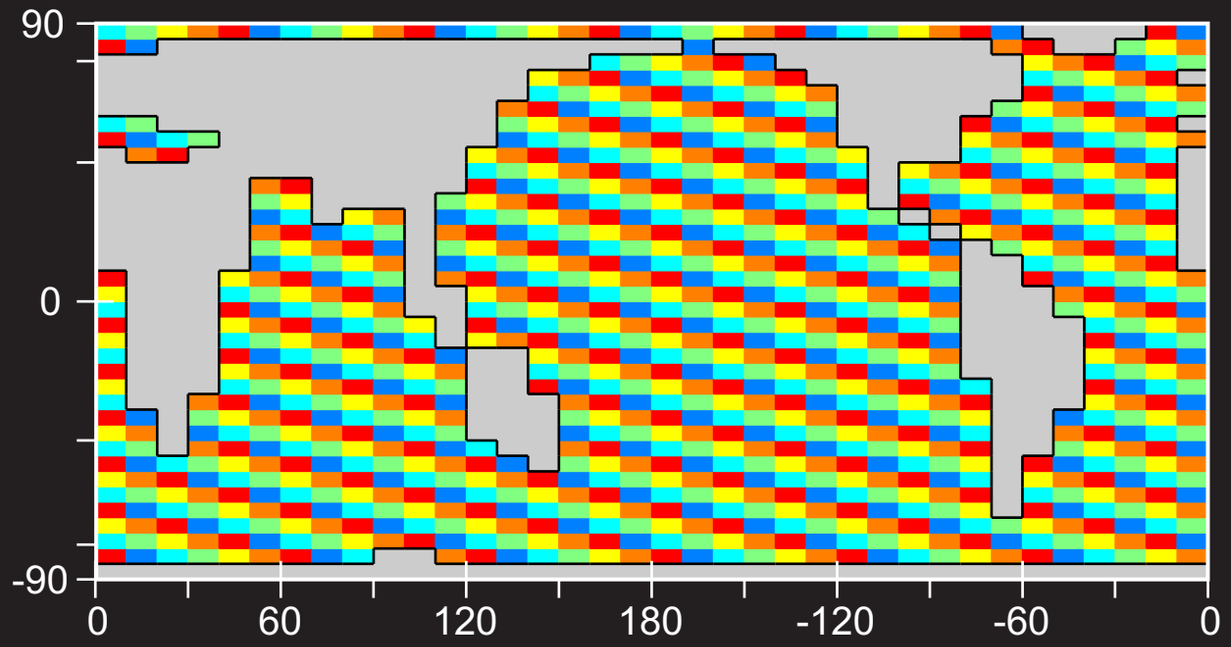
‘Color’ tracer pattern to unambiguously diagnose surface ocean transport



=> Diagnose full 3D circulation, and employ (sparse) parallelized matrix multiplication.

=> Calculate plankton transport separately from nutrients (and other dissolved tracers)?

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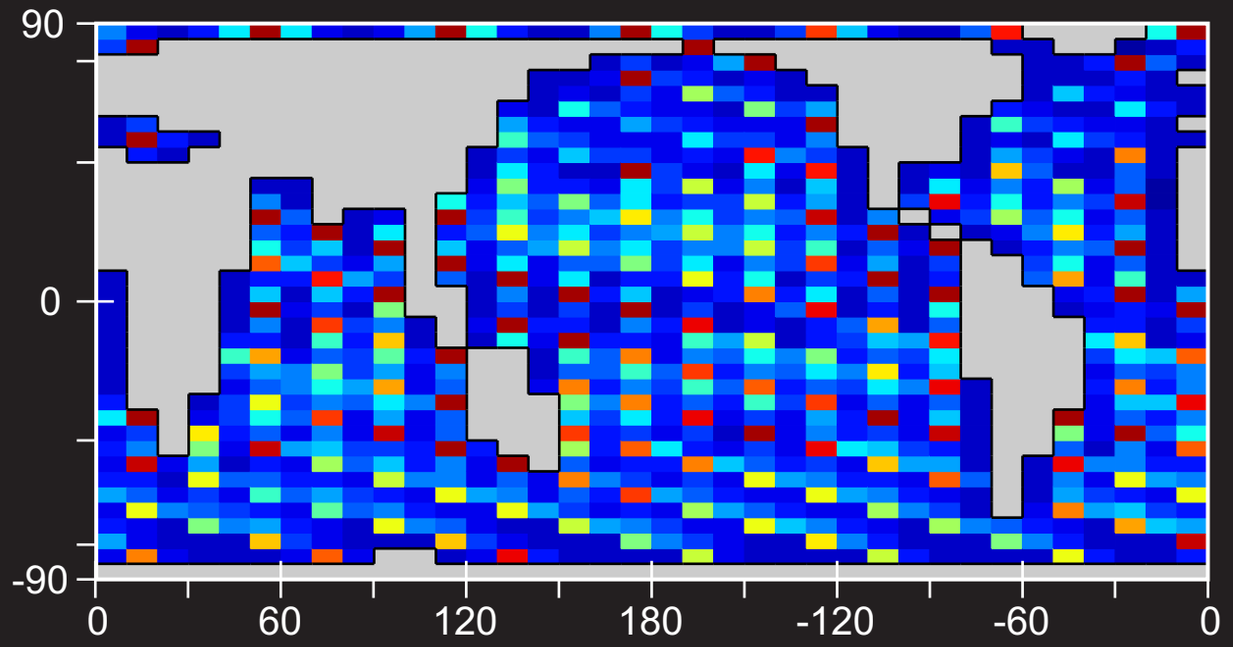
Dispersal of a single ‘color’ after 1 year



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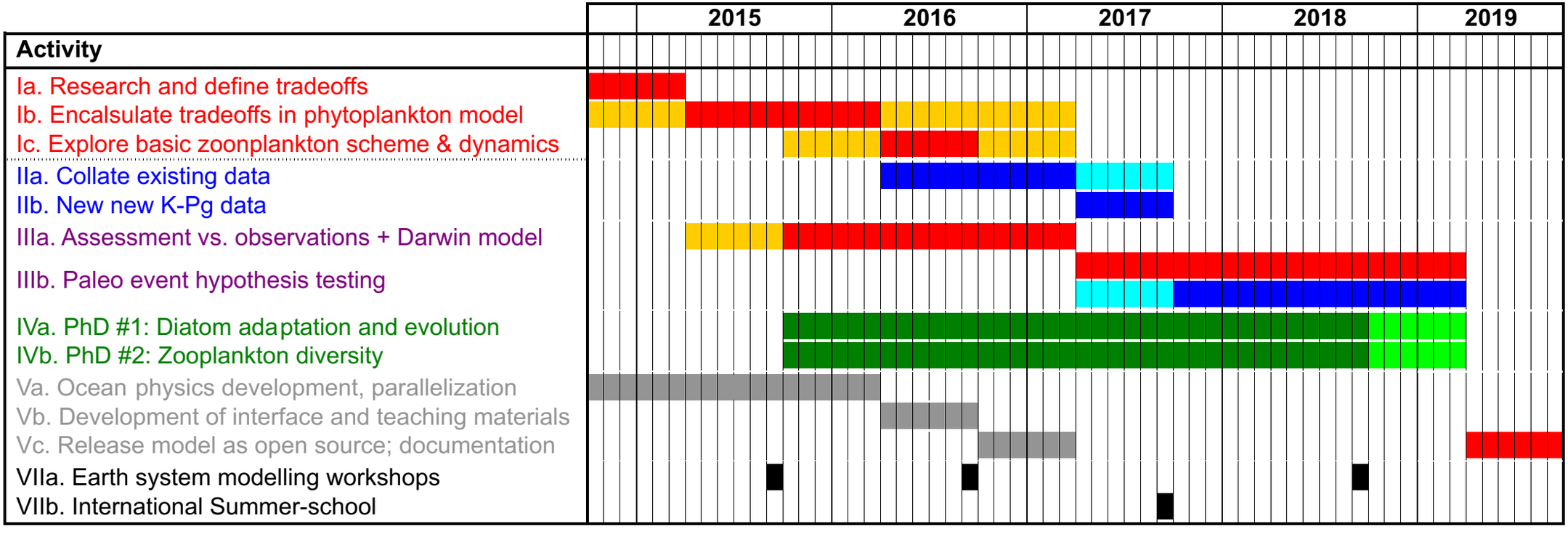
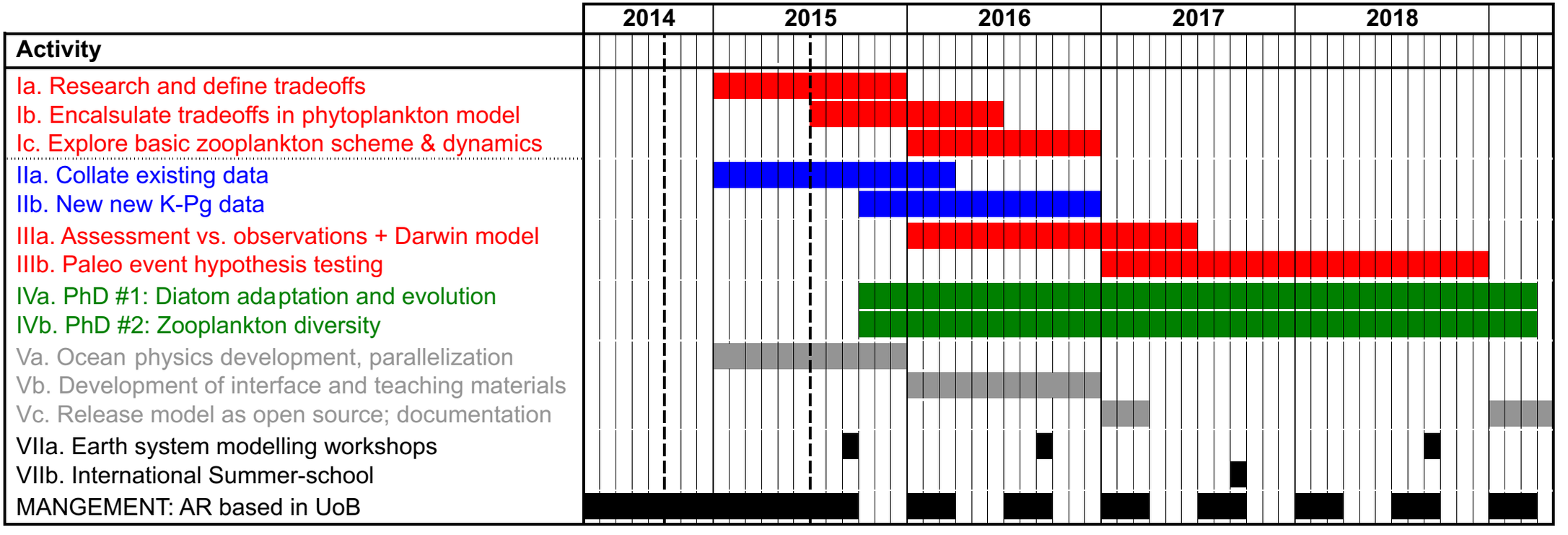

2015
2016
2017
2018
2019
Activity
Ia. Research and define tradeoffs
Ib. Encalsulate tradeoffs in phytoplankton model
Ic. Explore basic zoonplankton scheme & dynamics
IIa. Collate existing data
IIb. New new K-Pg data
IIIa. Assessment vs. observations + Darwin model
IIIb. Paleo event hypothesis testing
IVa. PhD #1: Diatom adaptation and evolution
IVb. PhD #2: Zooplankton diversity
Va. Ocean physics development, parallelization
Vb. Development of interface and teaching materials
Vc. Release model as open source; documentation
VIIa. Earth system modelling workshops
VIIb. International Summer-school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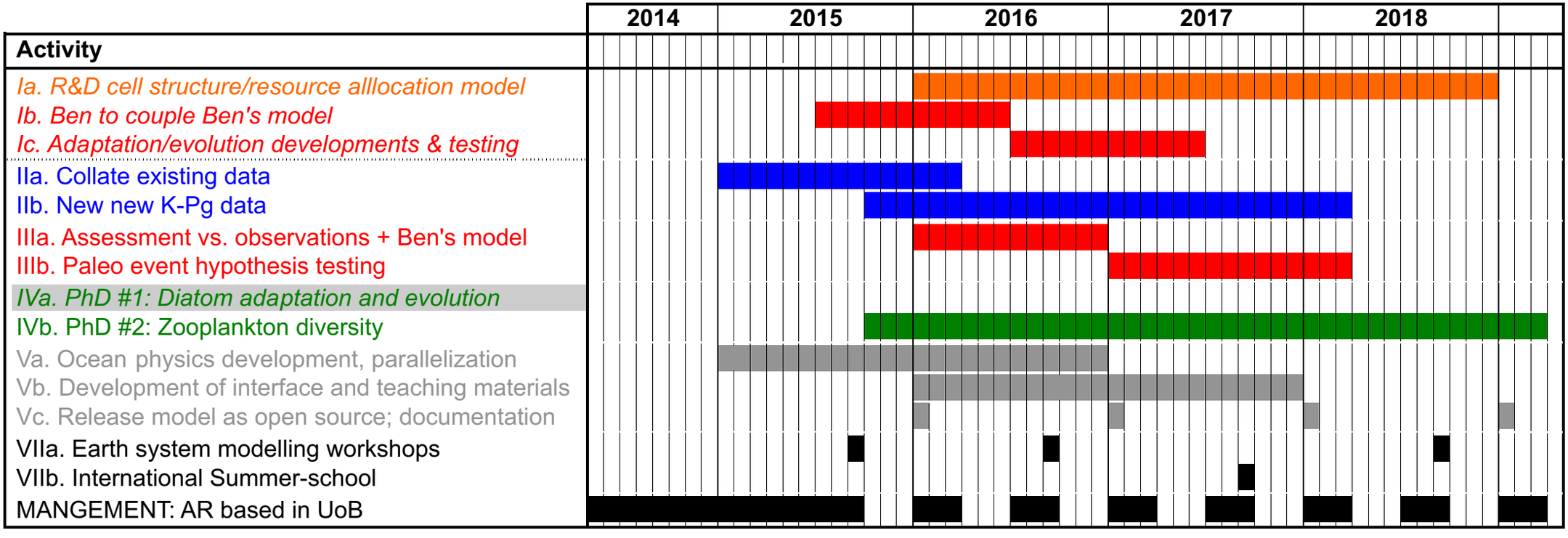
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Ib. Ben to couple Ben's model
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