Implementing a Complex Biological Model in TreePPL

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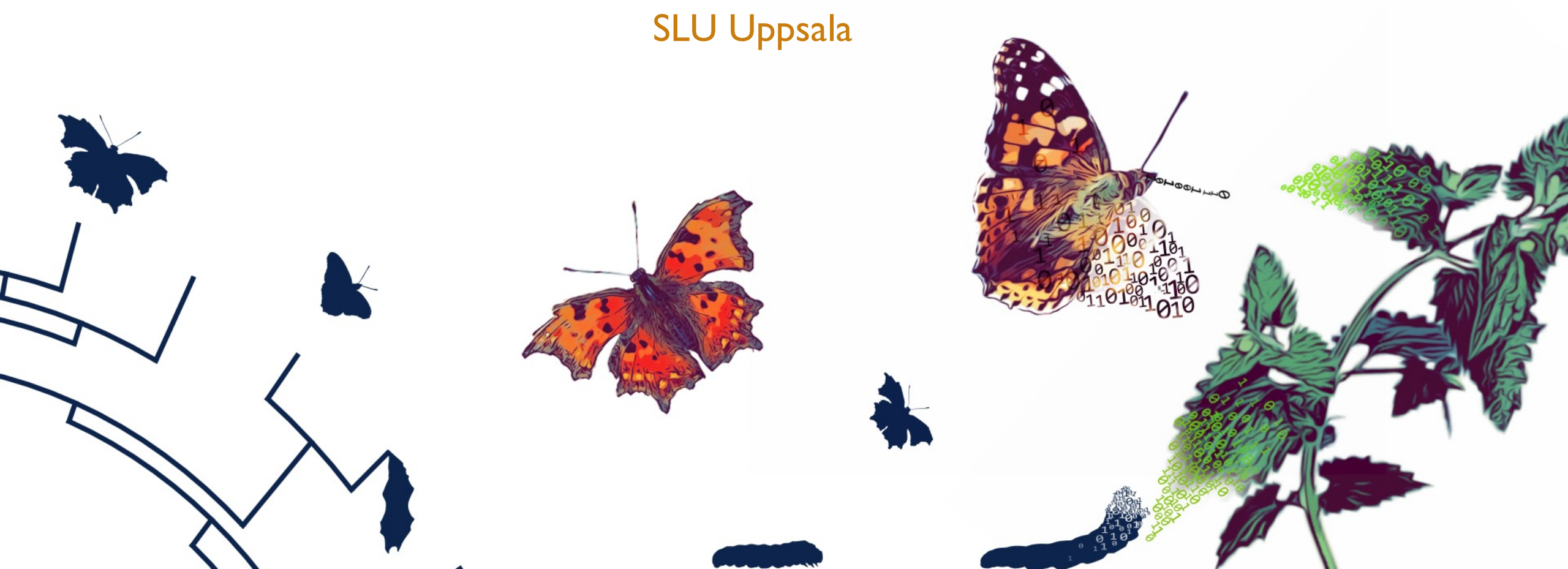


Parasitic interactions

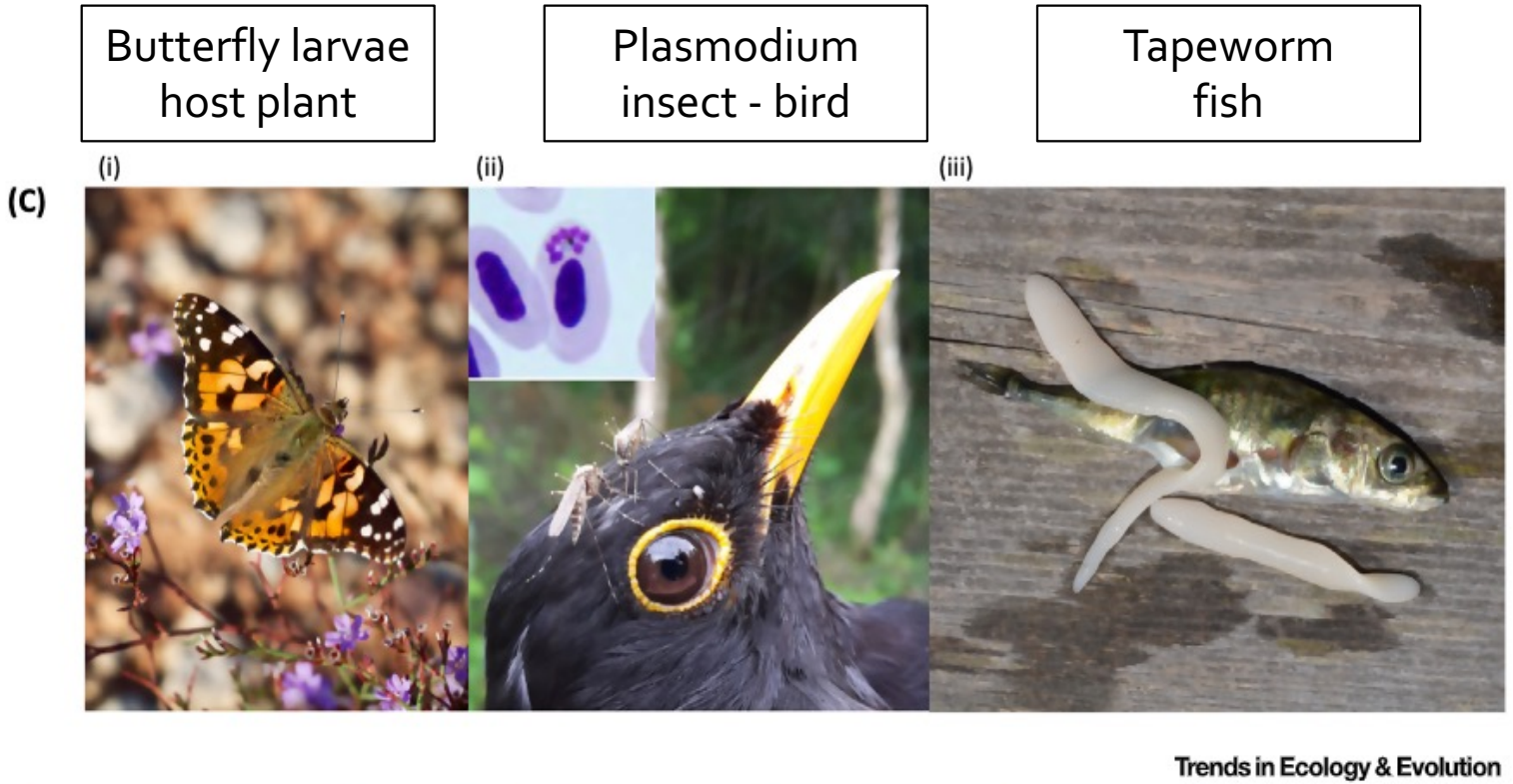
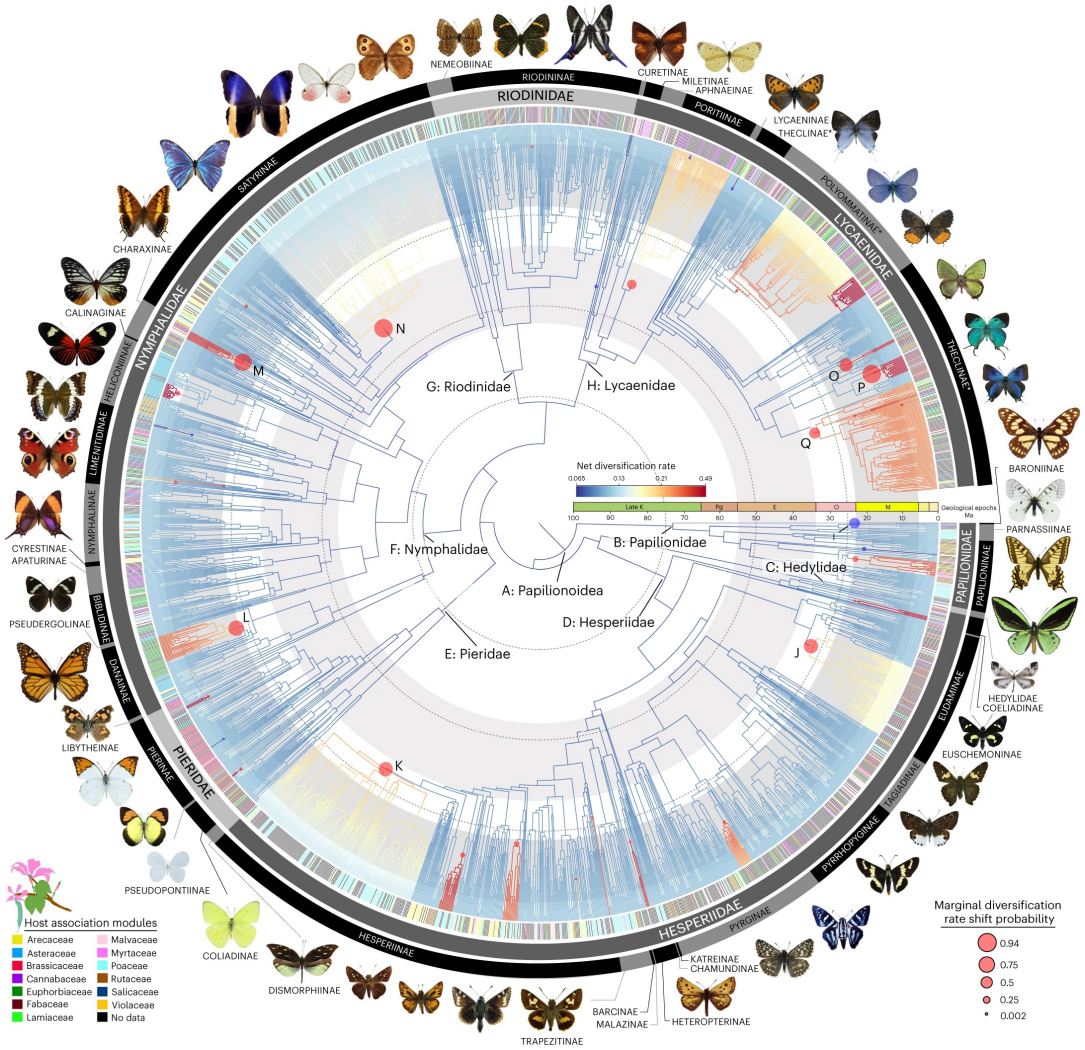


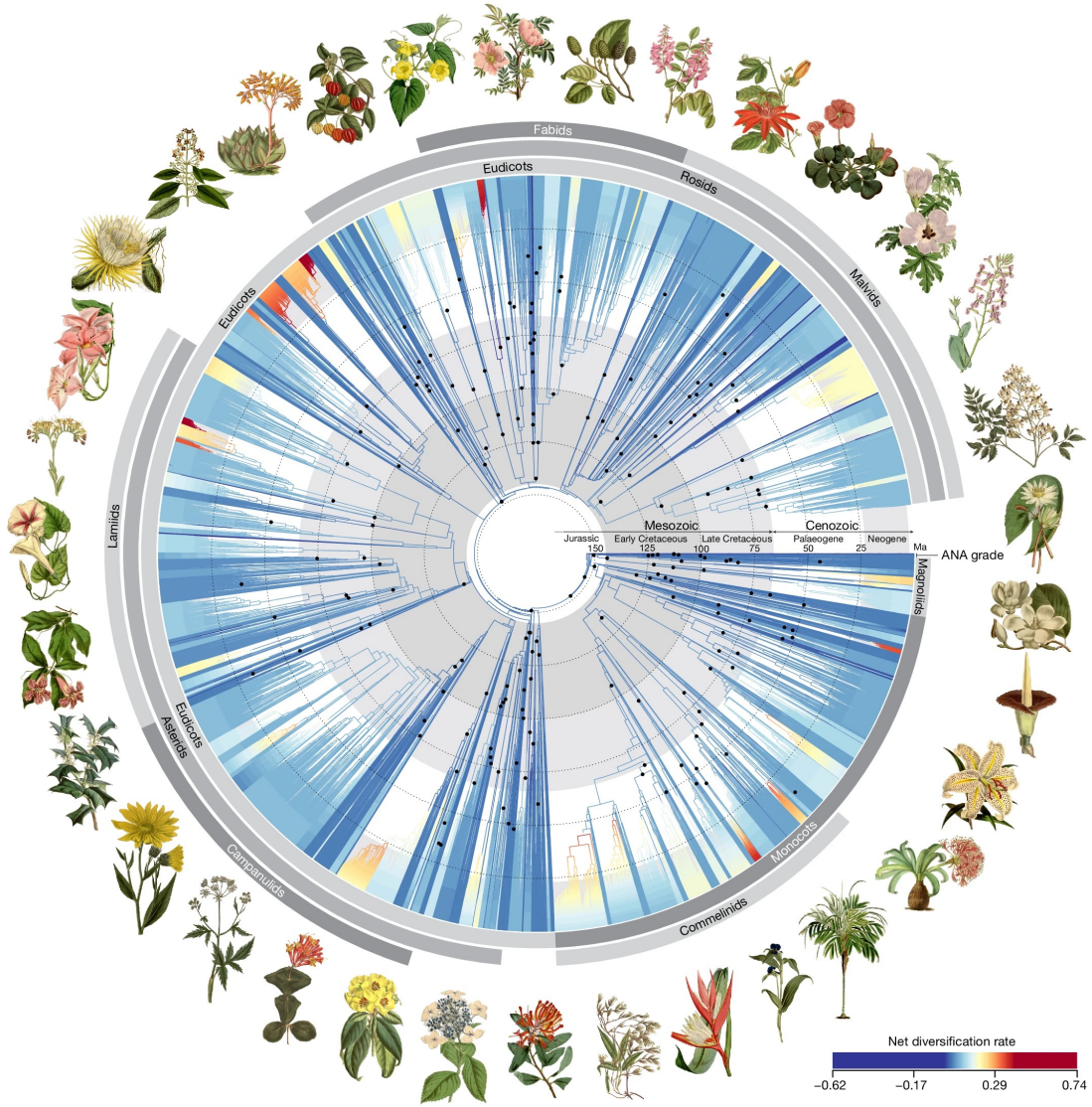
Figure 1. Examples of Strong Similarities between Ecological and Evolutionary Patterns Observed in Parasite–Host and Insect–Plant Systems.

Yeah, caterpillars are parasites!

Nylin et al. (2018) Embracing colonizations: a new paradigm for species association dynamics. TREE

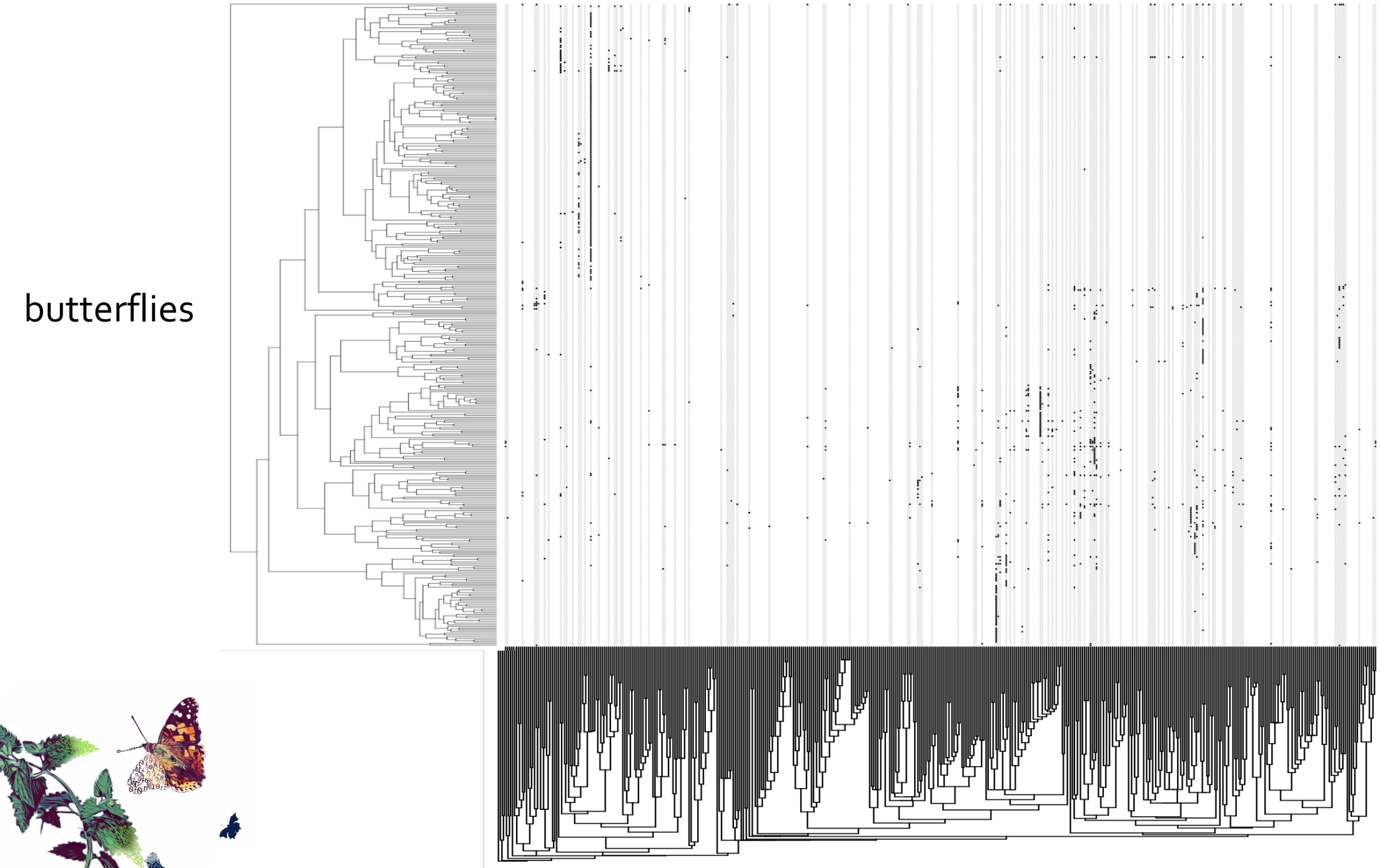


butterflies



flowering plants

butterflies



flowering plants

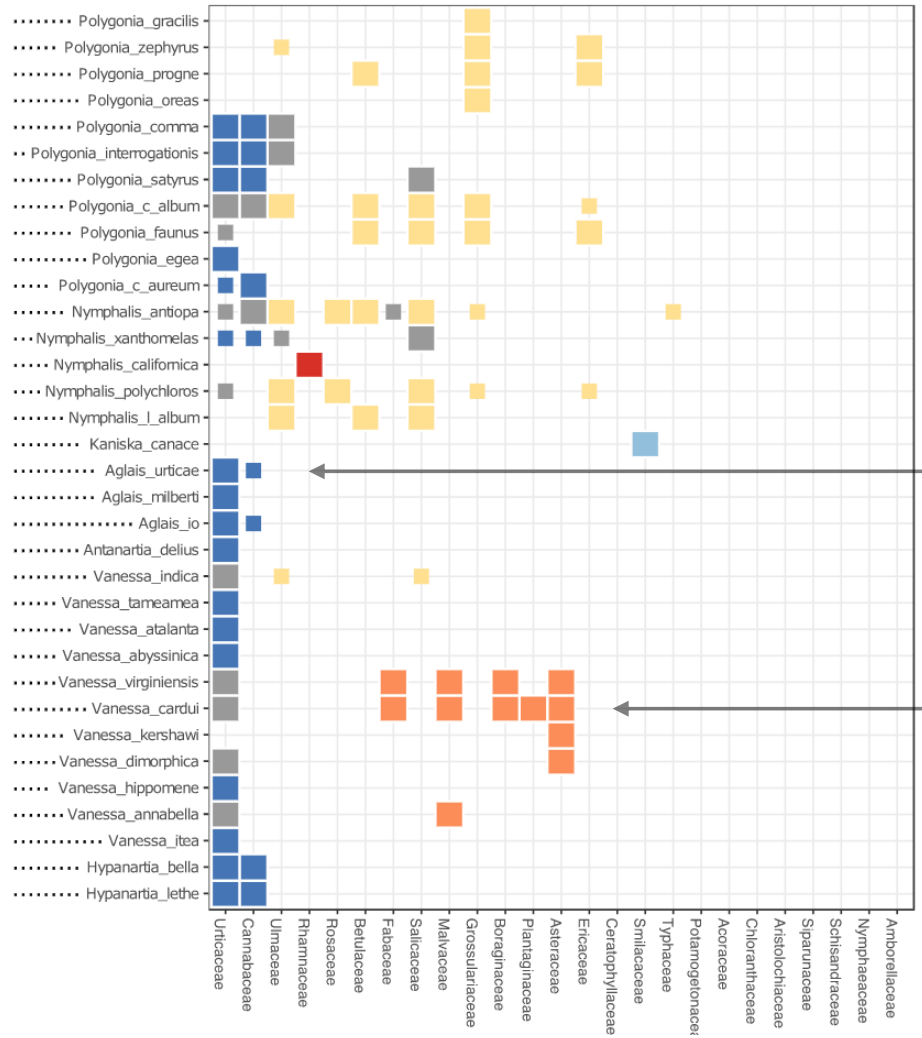
Variation in host repertoire

Aglais urticae (nässelfjäril)

Urtica	Urticaceae	Rosales
Humulus	Cannabaceae	Rosales
Cannabis	Cannabaceae	Rosales

Vanessa cardui (tistelfjäril)

Urtica, Boehmeria, Girardinia, Laportea, Obetia, Soleirolia, Parietaria	Urticaceae	Rosales
Alcea, Althaea, Malva, Sida, Sphaeralcea, Gossypium	Malvaceae	Malvales
Carduus, Cirsium, Arctotheca, Arctotis, Artemisia, Berkheya, Dicoma, Dimorphoteca, Filago, Gazania, Gnaphalium, Helicrysum, Hirpicum, Madia, Pentzia, Venidium, Sonchus etc	Asteraceae	Asterales
Anchusa, Borago, Cyanoglossum, Echium, Symphytum, Amsinckia, Nonea etc	Boraginaceae	Boraginales
Eriodictyon, Phacelia	Hydrophyllaceae	Boraginales
Argyrolobium, Glycine, Lotononis, Lupinus, Phaseoulus, Medicago, Pisum, Trifolium	Fabaceae	Fabales
Plantago	Plantaginaceae	Lamiales
Priva, Lantana	Verbenaceae	Lamiales
Mentha, Salvia, Stachys	Lamiaceae	Lamiales
Potentilla, Fragaria, Prunus	Rosaceae	Rosales
Anthriscus, Heracleum, Eryngium	Apiaceae	Apiales
Nicotiana, Petunia, Solanum	Solanaceae	Solanales

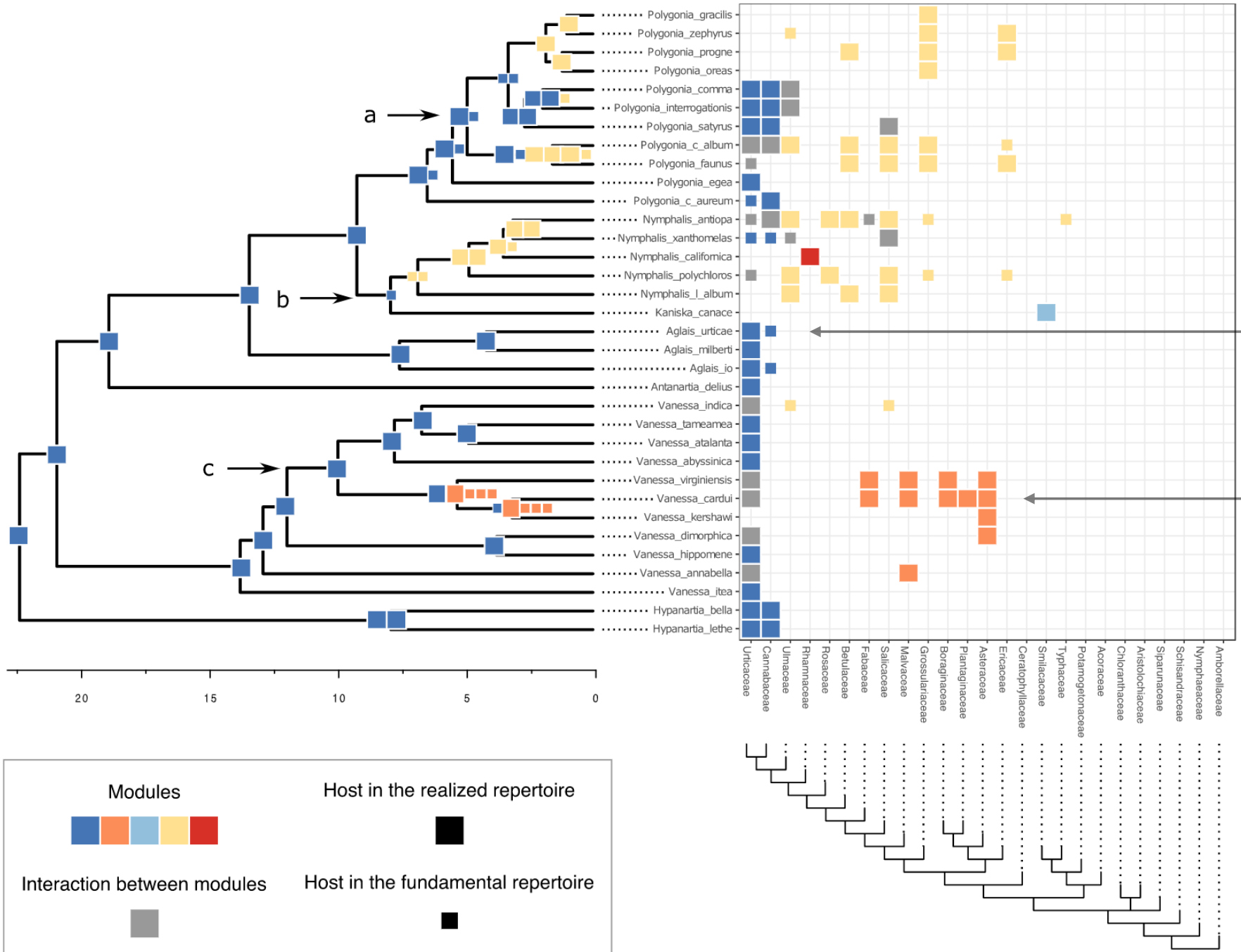


Modules

Host in the realized repertoire

Interaction between modules

Host in the fundamental repertoire


Polygonia_gracilis
Polygonia_zephyrus
Polygonia_progne
Polygonia_oreas
Polygonia_comma
Polygonia_interrogationis
Polygonia_satyrus
Polygonia_c_album
Polygonia_faunus
Polygonia_egea
Polygonia_c_aureum
Nymphalis_antiopa
Nymphalis_xanthomelas
Nymphalis_californica
Nymphalis_polychloros
Nymphalis_l_album
Kaniska_canace
Aglais_urticae
Aglais_milberti
Aglais_io
Antanartia_delius
Vanessa_indica
Vanessa_tameamea
Vanessa_atalanta
Vanessa_abyssinica
Vanessa_virginiensis
Vanessa_cardui
Vanessa_kershawi
Vanessa_dimorphica
Vanessa_hippomene
Vanessa_annabella
Vanessa_itea
Hypanartia_bella
Hypanartia_lethe
a
b
c
20
15
10
5
0
Urticaceae
Cannabaceae
Ulmaceae
Rhamnaceae
Rosaceae
Betulaceae
Fabaceae
Salicaceae
Malvaceae
Grossulariaceae
Boraginaceae
Plantaginaceae
Asteraceae
Ericaceae
Ceratophyllaceae
Smilacaceae
Typhaceae
Potamogetonaceae
Acoraceae
Chloranthaceae
Aristolochiaceae
Sipanunaceae
Schisandraceae
Nymphaeaceae
Amborellaceae

Modules
Host in the realized repertoire
Interaction between modules
Host in the fundamental repertoire

{} input.json > ...


```
{
    "symbiont_tree": {
        "__constructor__": "Node",
        "__data__": {
            "label": 4,
            "age": 1.0,
            "left": {
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                "__data__": {
                    "label": 5,
                    "age": 0.793457,
                    "left": {
                        "__constructor__": "Leaf",
                        "__data__": {
                            "label": 2,
                            "age": 0.0
                        }
                    },
                    "right": {
                        "__constructor__": "Leaf",
                        "__data__": {
                            "label": 1,
                            "age": 0.0
                        }
                    }
                }
            },
            "right": {
                "__constructor__": "Leaf",
                "__data__": {
                    "label": 3,
                    "age": 0.0
                }
            }
        }
    },
    "ntips": 3,
    "nhosts": 3,
    "interactions": [2,0,2,
                     2,0,1,
                     2,2,0],
    "host_distances": [      0.0, 0.6798581, 1.832457,
                       0.6798581,       0.0, 1.832457,
                       1.832457, 1.832457,        0.0],
    "dMean": 1.448257,
    "tune": 0.9
}
```
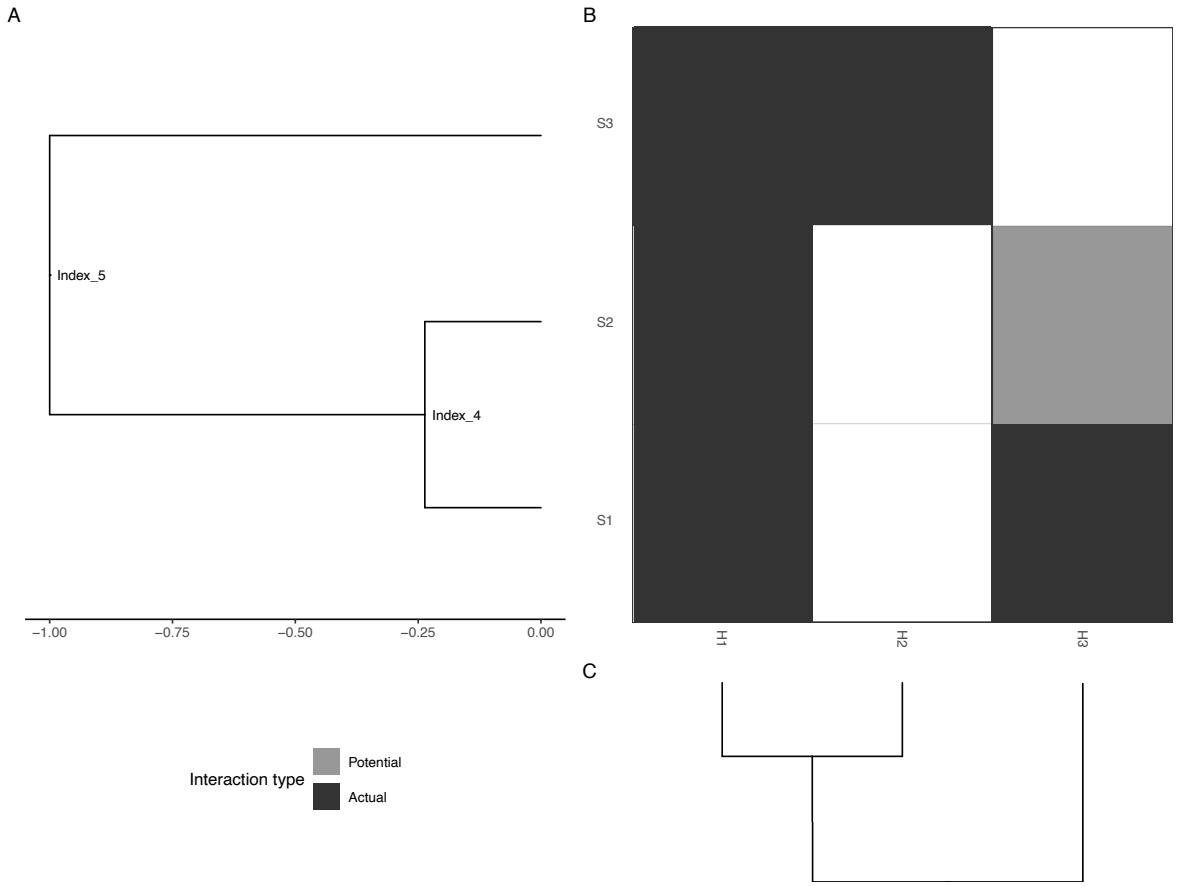




Modeling the evolution of interactions

HOST REPERTOIRE

HOW MANY HOSTS (RANGE) + WHICH HOSTS

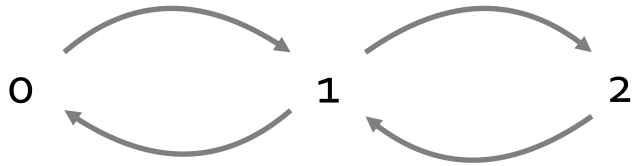
$(h_1\ h_2\ h_3\ h_4\ \cdots\ h_n)$

$h_i = \{0,1,2\}$

0 non-host

1 potential host (e.g. larvae is able to feed)

2 actual host (used in nature)



Modeling the evolution of interactions

HOST REPERTOIRE

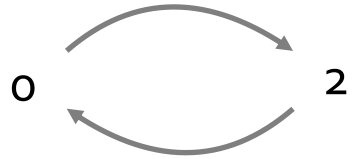
HOW MANY HOSTS (RANGE) + WHICH HOSTS

$(h_1 \; h_2 \; h_3 \; h_4 \; \cdots \; h_n)$

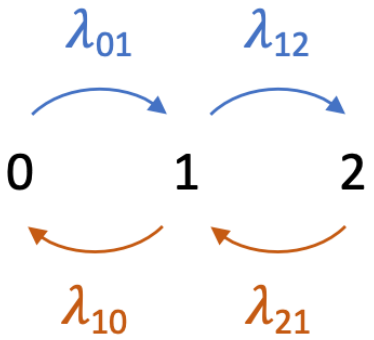
$h_i = \{0, 2\}$

0 non-host

2 actual host (used in nature)



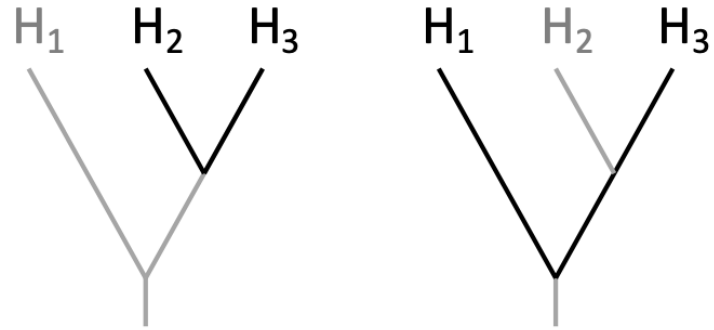
A



B

	[0,0,2]	[1,0,2]	[0,1,2]	[0,2,2]	…
[0,0,2]	-	λ_{01}*	λ_{01}*	0	
[1,0,2]	λ_{10}	-	0	0	
[0,1,2]	λ_{10}	0	-	λ_{12}*	
[0,2,2]	0	0	λ_{21}	-	
…					

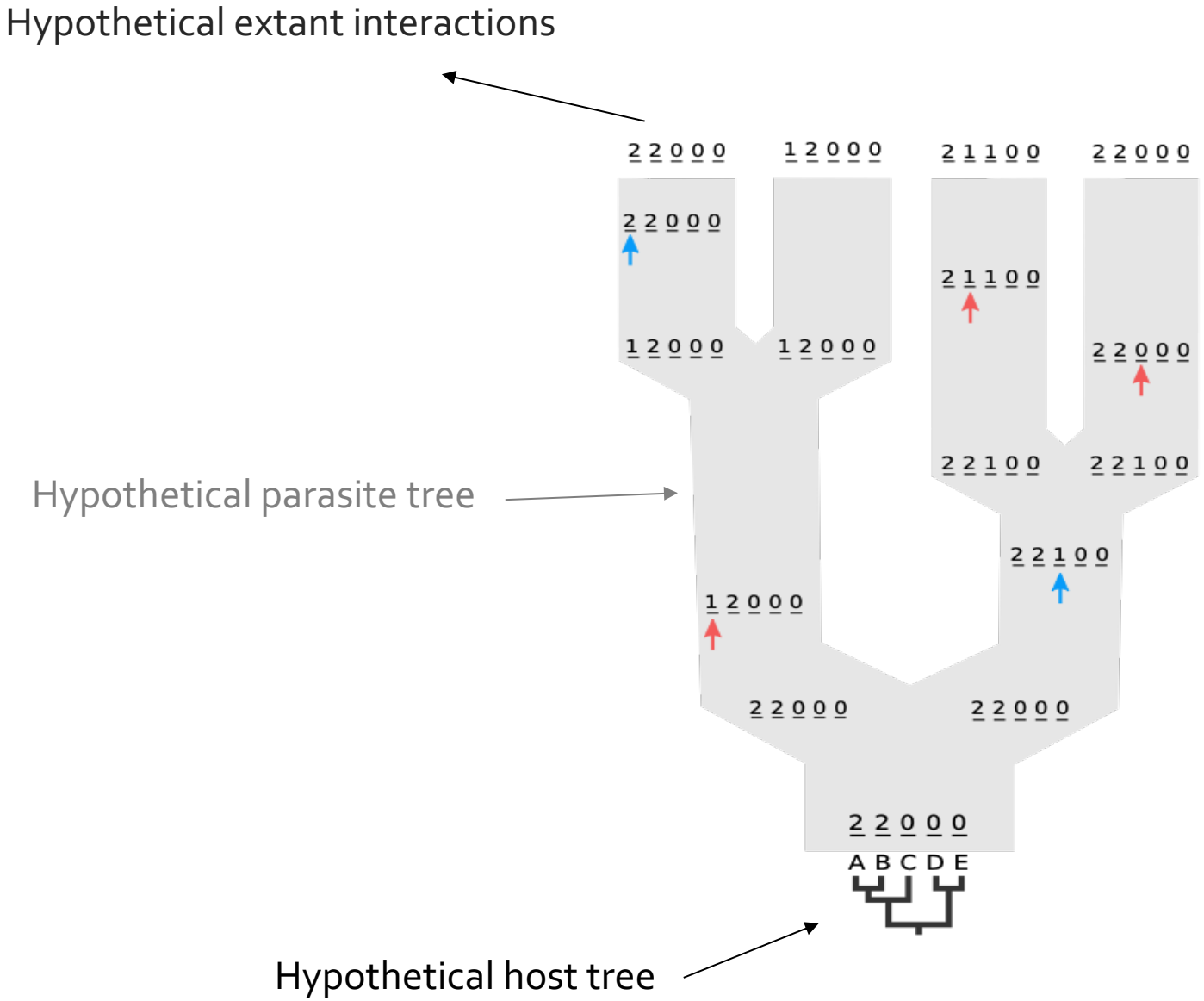
C



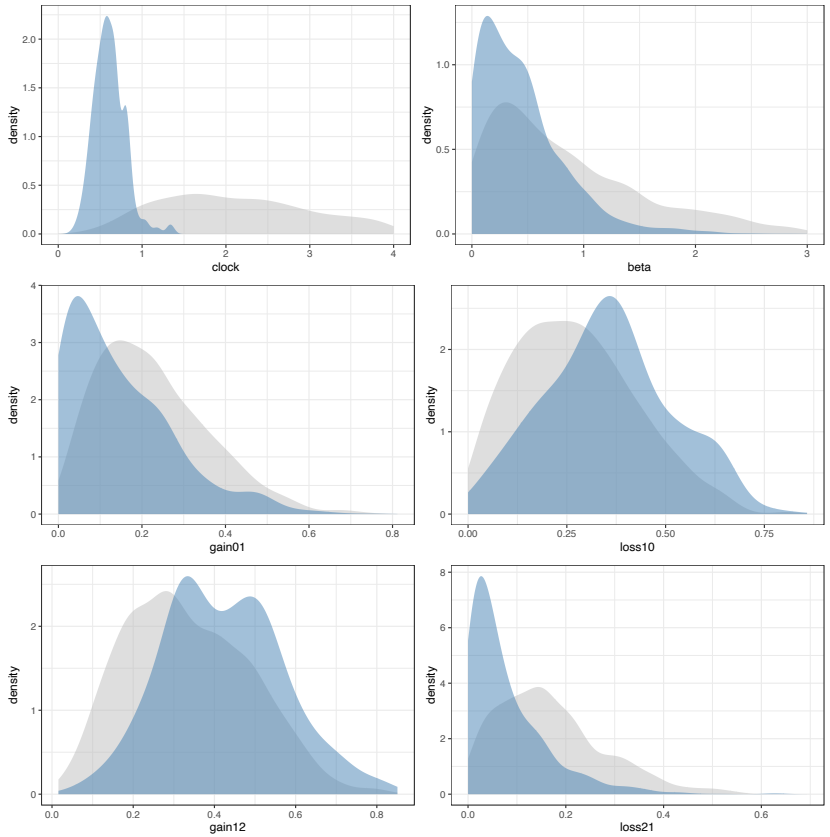
P (H_2 0→1 | H_3 = 2) > P (H_1 0→1 | H_3 = 2)

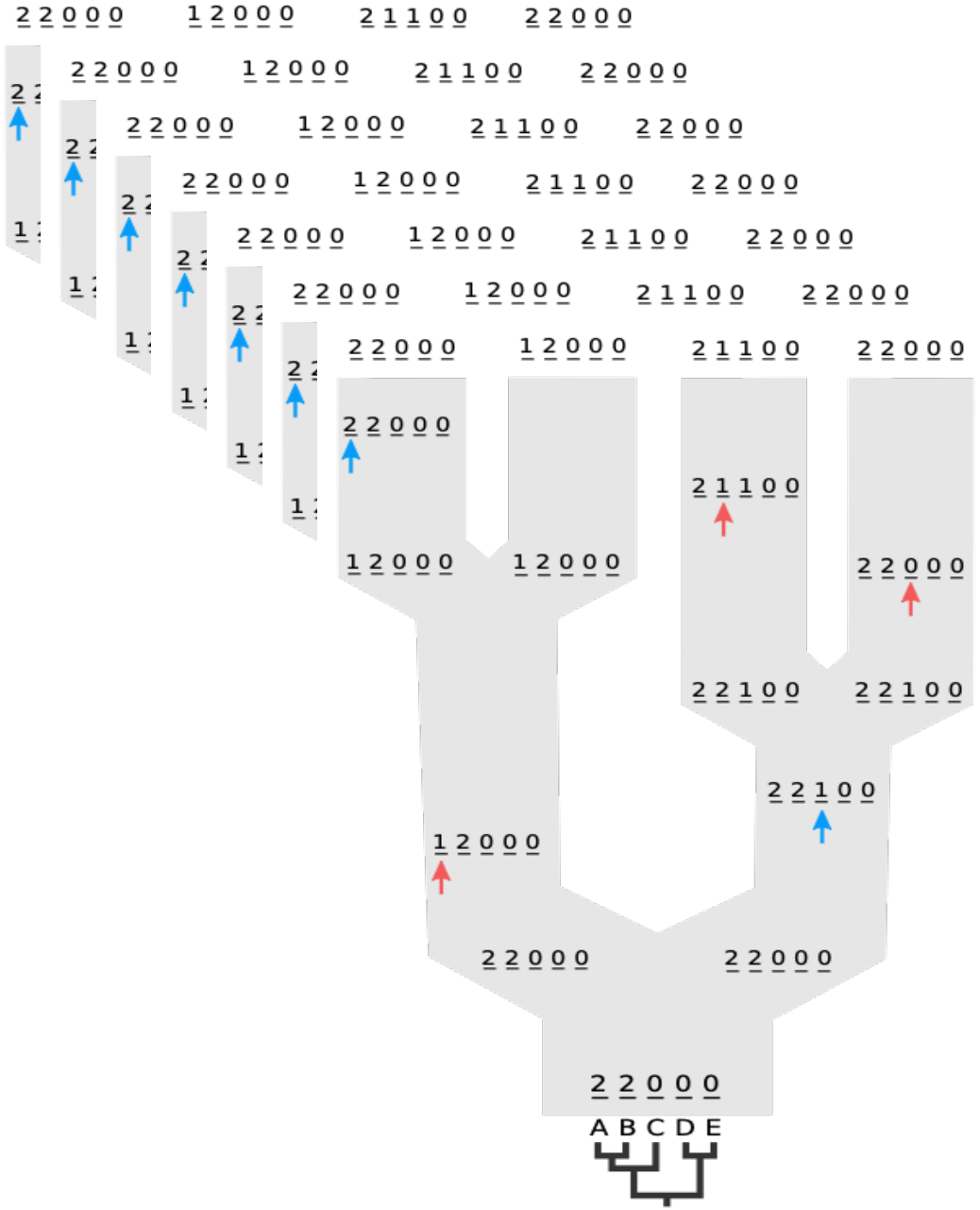
Number of allowed states = $3^{\text{Nhosts}} - 2^{\text{Nhosts}}$

Inference of historical interactions

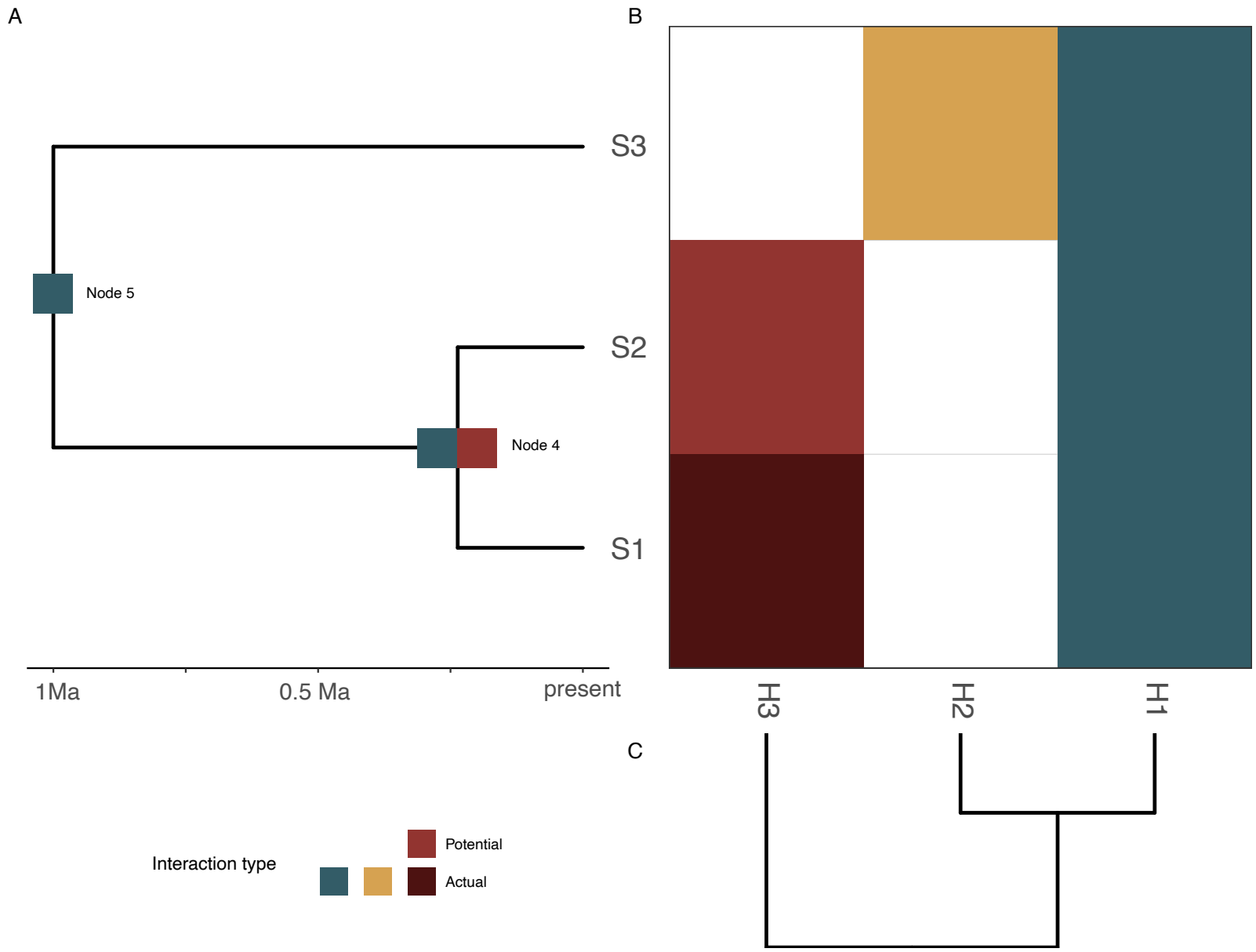


Output: Posterior distributions

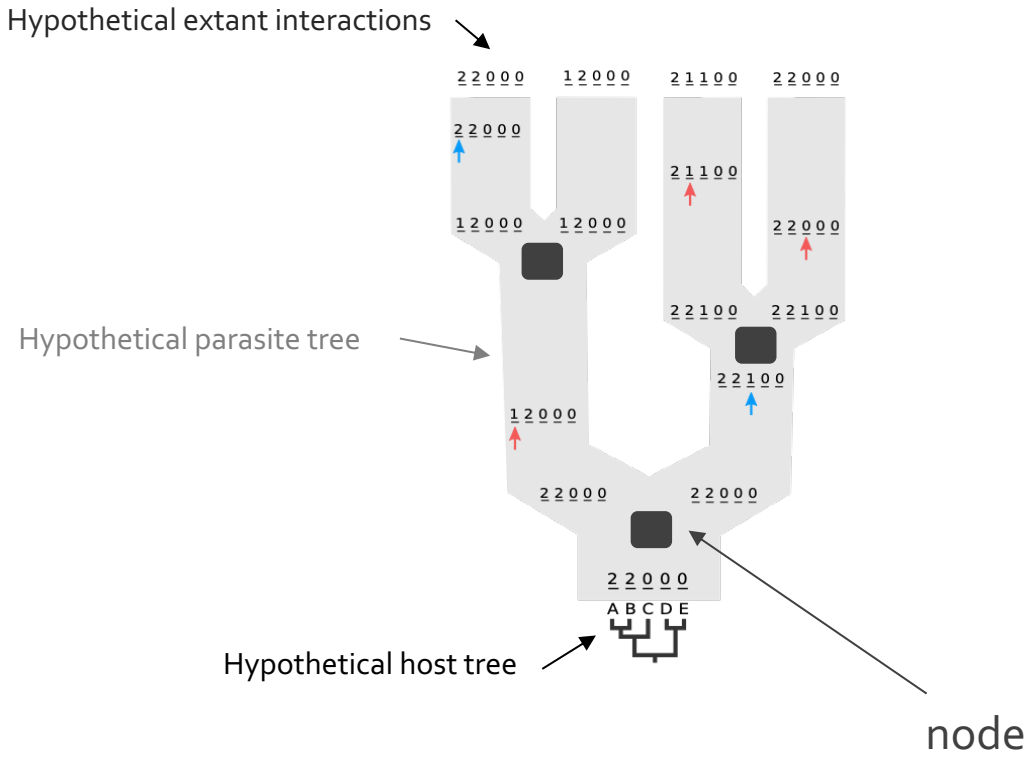


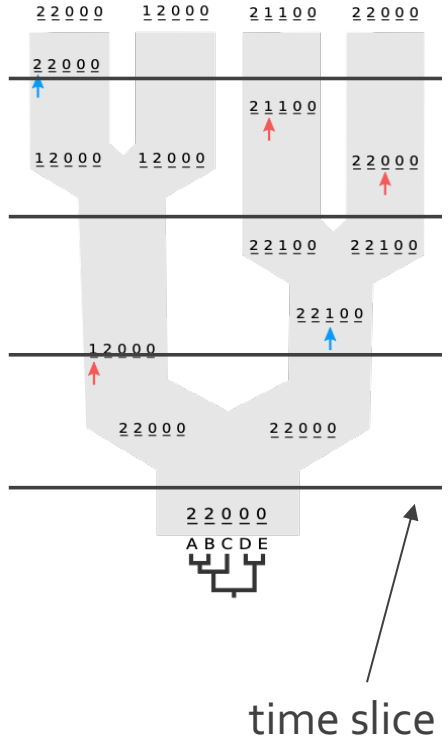


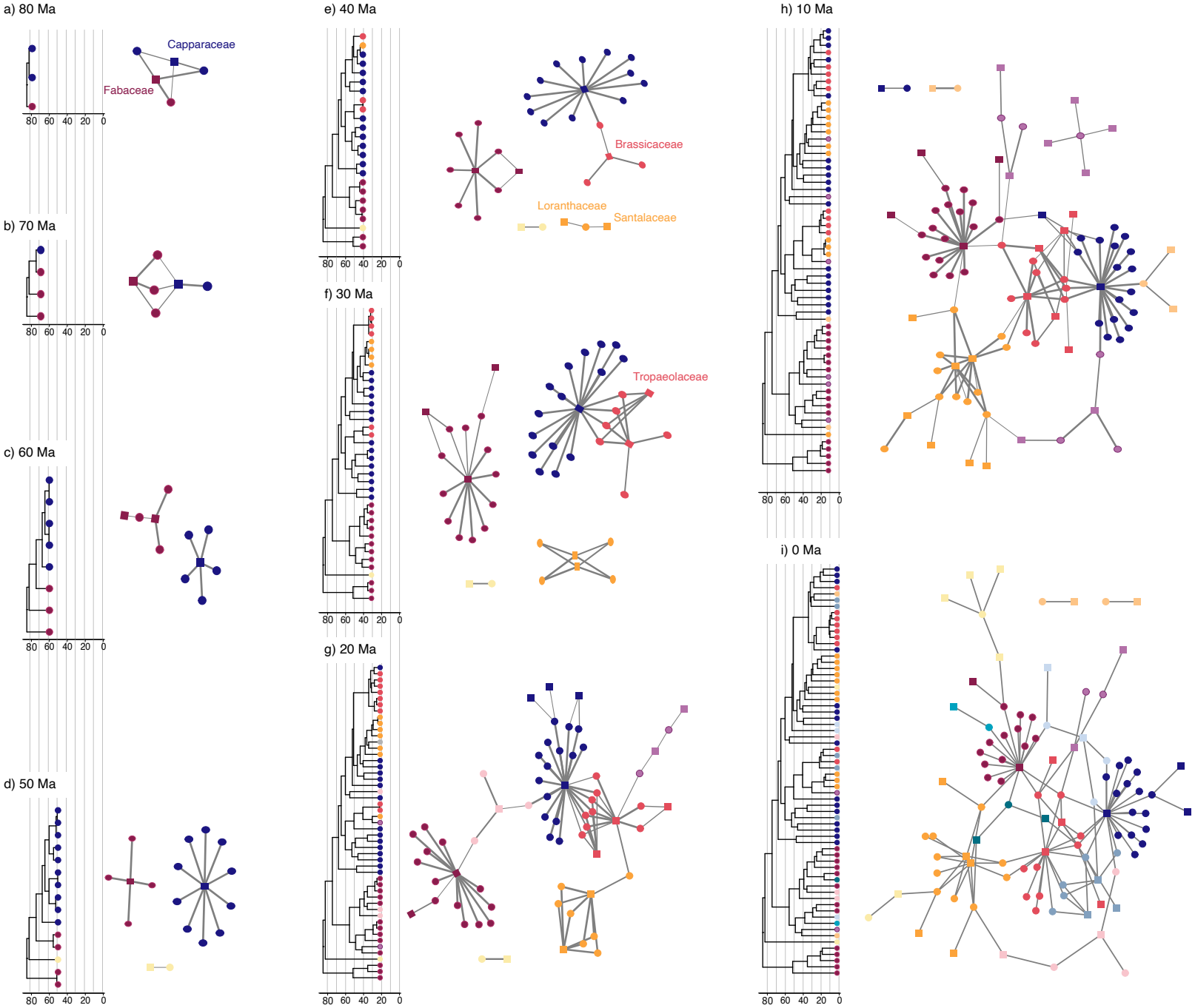
Most likely evolutionary history



Inference of historical interactions






a) 80 Ma
Capparaceae
Fabaceae
80 60 40 20 0
b) 70 Ma
80 60 40 20 0
c) 60 Ma
80 60 40 20 0
d) 50 Ma
80 60 40 20 0
e) 40 Ma
Brassicaceae
Loranthaceae
Santalaceae
80 60 40 20 0
f) 30 Ma
Tropaeolaceae
80 60 40 20 0
g) 20 Ma
80 60 40 20 0
h) 10 Ma
80 60 40 20 0
i) 0 Ma
80 60 40 20 0

Thank you!

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