

# The changing functional composition of the North American species pool

modeling species origination-extinction as a function of  
functional group and environmental context

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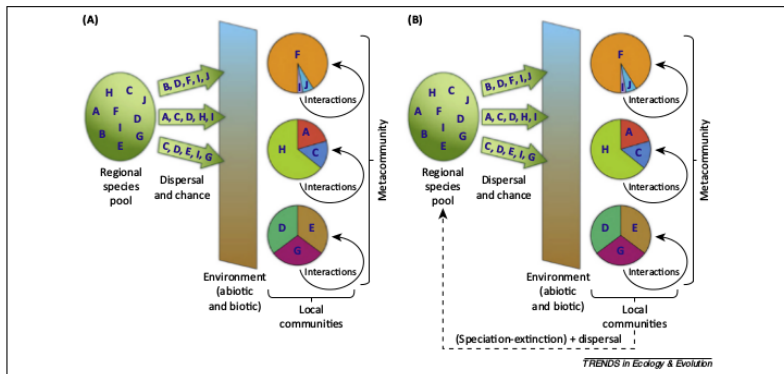
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## Question

When are certain ecologies, ecotypes, or functional groups enriched or depleted in a species pool?

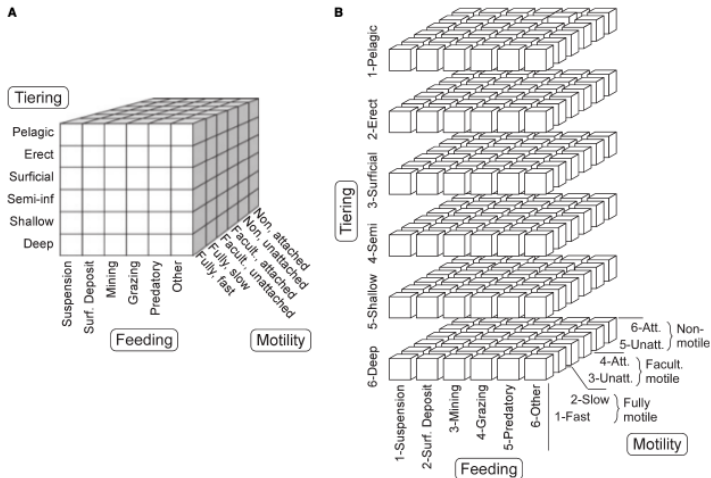
# Species pool concept



**Figure 1.** Two models of community assembly. (A) Local communities comprise a subset of species from the regional species pool that have passed through environmental filters. There is no feedback from the metacommunity (collection of local communities) to the regional species pool. Adapted from [5]. (B) Local communities are assembled as in (A), but speciation adds new species to the pool, extinction removes others, and dispersal allows the persistence of species that might otherwise go extinct.

(Mittelbach and Schemske, 2015, *TREE*)

# Functional groups

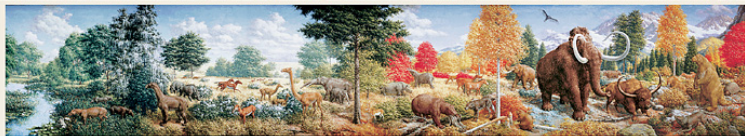


**TEXT-FIG. 1.** Ecospace as defined by the three axes of tiering, motility level and feeding strategy. A, the ecospace cube with categories on each axis labelled. B, the ecospace cube 'exploded', showing 216 'bins' or modes of life specified by the combination of the categories on each ecospace axis.



# Age of Mammals

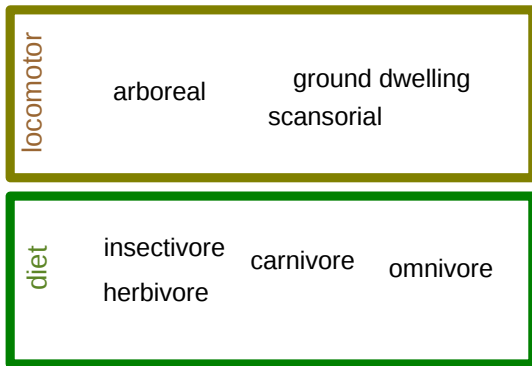
## THE AGE OF MAMMALS



# Differences in extinction risk

relative expected species duration

short  $\longleftrightarrow$  long



(Smits 2015 *PNAS*)

# Covariates of interest

## individual-level

(species  $i$  at time unit  $t$ )

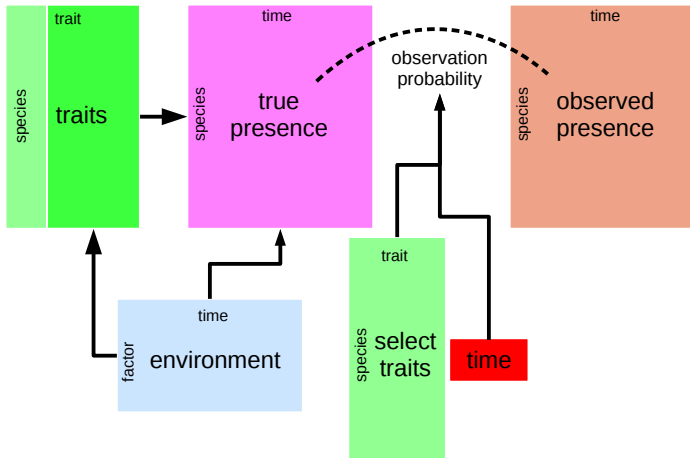
- ▶ effect of locomotor type
  - ▶ arboreal, digitigrade, plantigrade, unguligrade, fossorial, scansorial
- ▶ effect of dietary type
  - ▶ carnivore, herbivore, insectivore, omnivore
- ▶ effect body size  
(rescaled log body mass)

## group-level (2 My time unit $t$ )

- ▶ temperature record based on Mg/Ca estimates
  - ▶ mean and range  
(rescaled log degrees)
- ▶ plant community phase following Graham 2011



# Paleo-fourth corner model



# Model and sampling statement definition

$$y_{i,t} \sim \text{Bernoulli}(p_{i,t} z_{i,t})$$

$$p_{i,t} = \text{logit}^{-1}(\alpha_0 + \alpha_1 m_i + r_t)$$

$$r_t \sim \mathcal{N}(0, \sigma)$$

$$\alpha_0 \sim \mathcal{N}(0, 1)$$

$$\alpha_1 \sim \mathcal{N}(1, 1)$$

$$\sigma \sim \mathcal{N}^+(1)$$

$$z_{i,1} \sim \text{Bernoulli}(\phi_{i,1})$$

$$z_{i,t} \sim \text{Bernoulli}\left(z_{i,t-1}\pi_{i,t} + \sum_{x=1}^t (1 - z_{i,x})\phi_{i,t}\right)$$

$$\phi_{i,t} = \text{logit}^{-1}(a_{t,j[i]}^{\phi} + b_1^{\phi} m_i + b_2^{\phi} m_i^2)$$

$$\pi_{i,t} = \text{logit}^{-1}(a_{t,j[i]}^{\pi} + b_1^{\pi} m_i + b_2^{\pi} m_i^2)$$

$$a^{\phi} \sim \text{MVN}(U\gamma^{\phi}, \Sigma^{\phi})$$

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$$\Sigma^{\phi} = \text{diag}(\tau^{\phi})\Omega^{\phi}\text{diag}(\tau^{\phi})$$

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$$\rho \sim \text{U}(0, 1)$$

$$b_1^{\phi} \sim \mathcal{N}(0, 1)$$

$$b_1^{\pi} \sim \mathcal{N}(0, 1)$$

$$b_2^{\phi} \sim \mathcal{N}(-1, 1)$$

$$b_2^{\pi} \sim \mathcal{N}(-1, 1)$$

$$\gamma^{\phi} \sim \mathcal{N}(0, 1)$$

$$\gamma^{\pi} \sim \mathcal{N}(0, 1)$$

$$\tau^{\phi} \sim \mathcal{N}^+(1)$$

$$\tau^{\pi} \sim \mathcal{N}^+(1)$$

$$\Omega^{\phi} \sim \text{LKJ}(2)$$

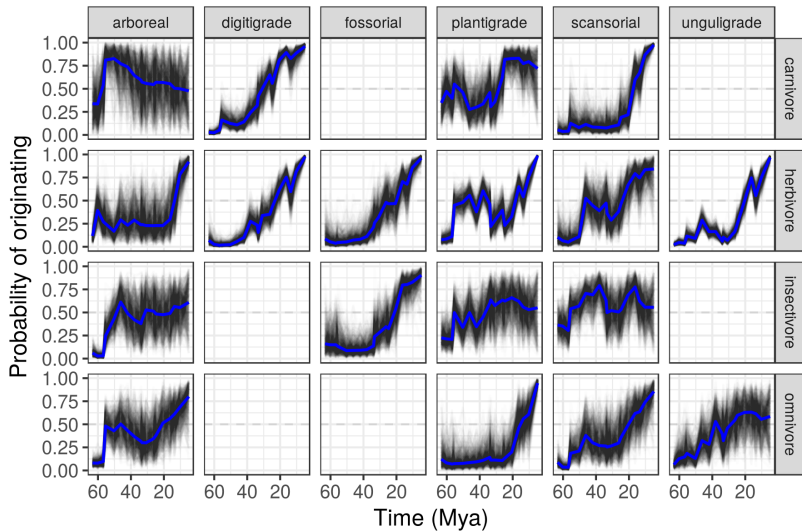
$$\Omega^{\pi} \sim \text{LKJ}(2).$$

# Bayesian inference and statistics

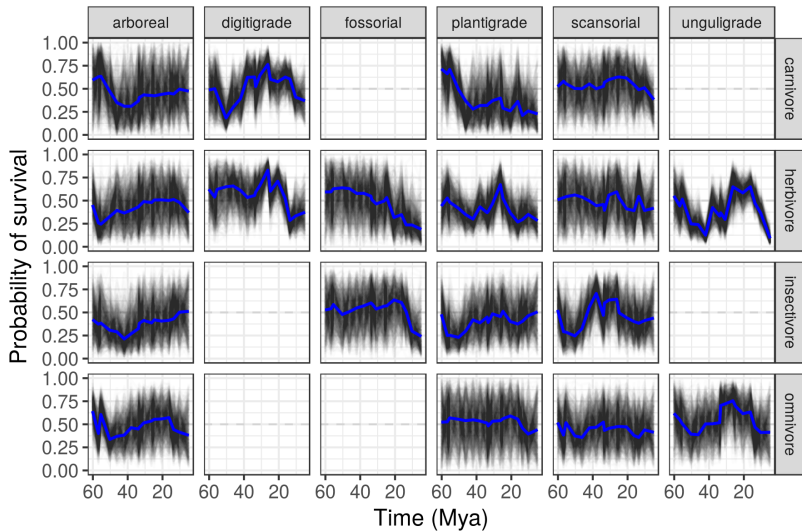
- ▶ flexible, expressive, intuitive
- ▶ regularize, partial pooling, external information
- ▶ Stan probabilistic programming language
  - ▶ **Hamiltonian Monte Carlo**
  - ▶ Automatic Differentiation Variational Inference



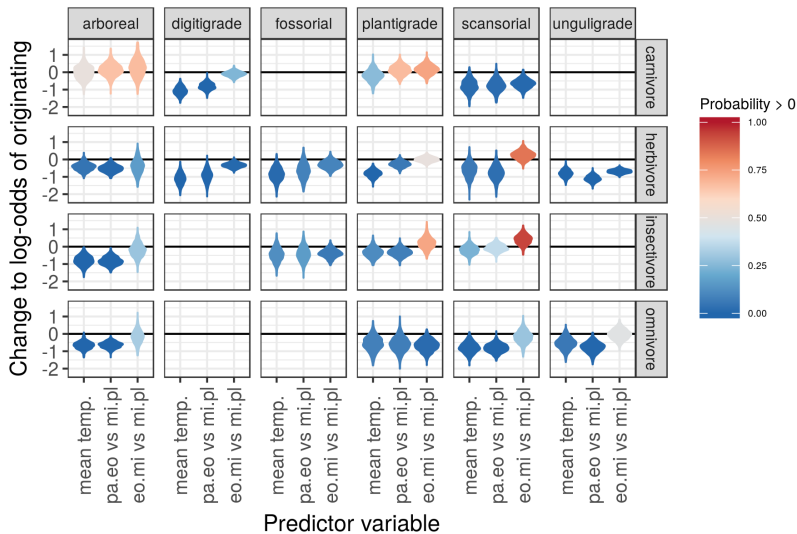
# Probability of ecotype origination



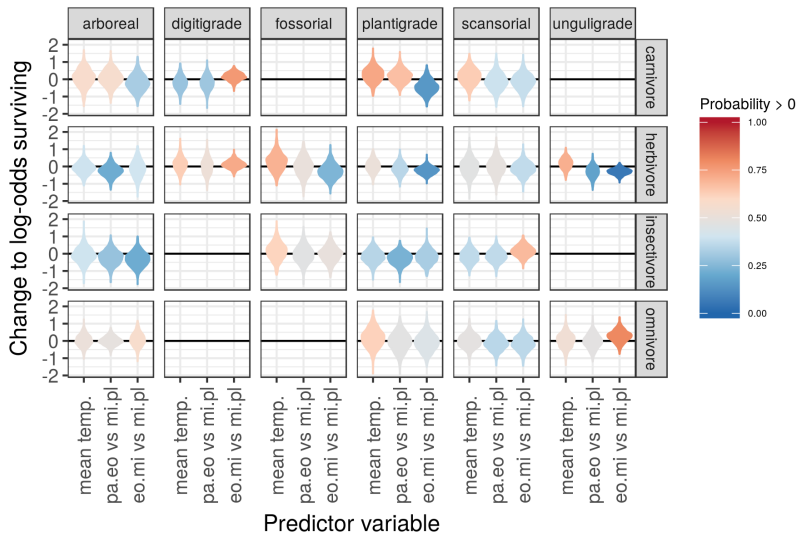
# Probability of ecotype survival



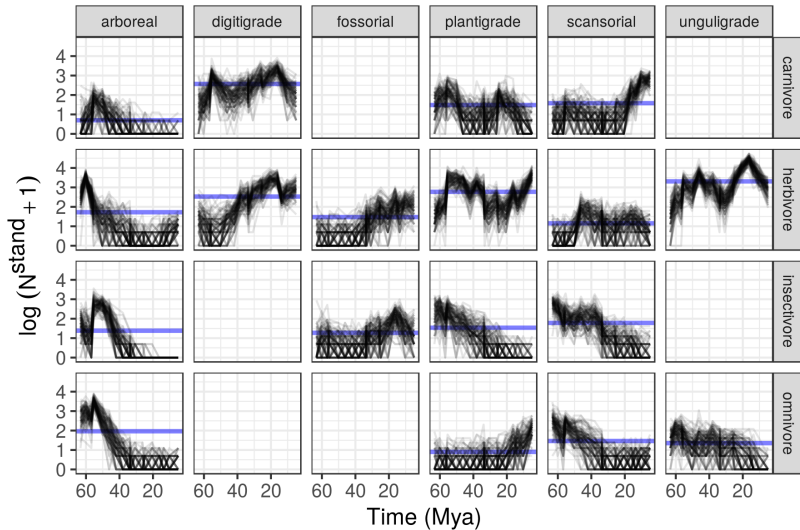
# Group-level effects (plant phase, climate) on origination



# Group-level effects (plant phase, climate) on survival

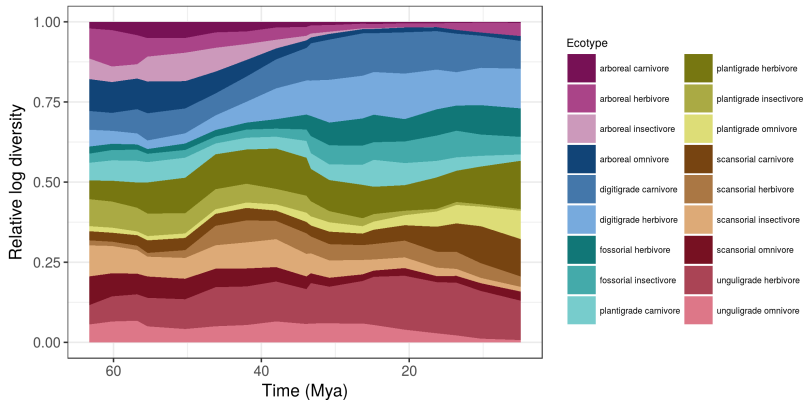


# Ecotype-specific diversity





# Relative ecotype diversity



## Summary of results

- ▶ changes to ecotype composition driven by origination, not extinction
  - ▶ specific ecotypes source of most variation in overall origination
- ▶ arboreal taxa decrease through Paleogene, all but absent by Neogene
- ▶ digitigrade and unguligrade herbivores only groups with sustained increase
- ▶ environmental covariates virtually always affect origination, not survival

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