

MODELING THE DYNAMICS OF CULTURAL DIVERSIFICATION

DySoC / NIMBioS Webinars on Cultural Evolution

November 3, 2020

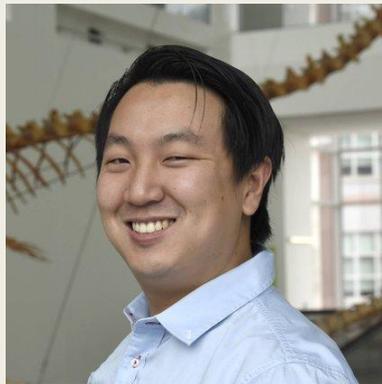




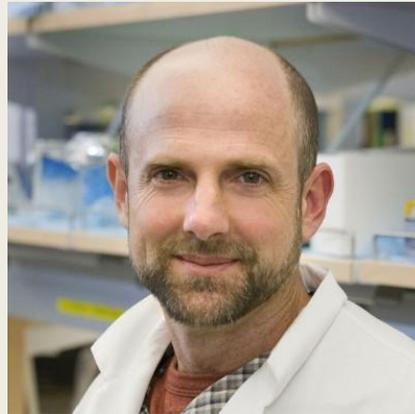
Bernard
Koch



Erik
Gjesfjeld



Jonathan
Chang



Mike
Alfaro



Daniele
Silvestro



Jacob
Foster

Goals of CES modules

- Provide an introduction to dynamic modeling frameworks
- Investigate common problems within cultural evolution
- Encourage the application of emerging computational frameworks for the study of cultural evolution
- Combination of both introductory (undergraduate) and advanced (graduate) modules

Goals of our module

- Encourage a macroevolutionary approach to the study of cultural change
- Expand the methodological toolbox of cultural macroevolution
- Demonstrate the value of a quantitative and probabilistic approach to modeling cultural diversification

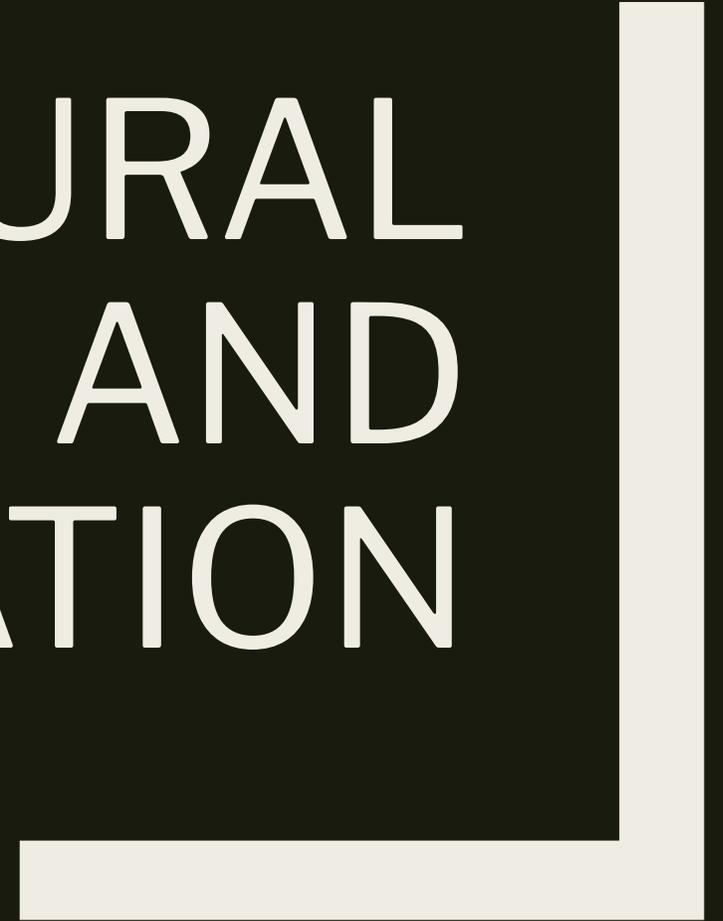
Outline of our module

1. Cultural Diversity and Diversification
2. Introduction to birth-death processes and LiteRate
3. Interpreting LiteRate Results
4. Modeling Evolutionary Mechanisms with Diversification Rates
5. Cultural Phylogenies (Supplemental)

Module Housekeeping

- Tutorials are presented using the Google CoLaboratory platform
 - colab.research.google.com
 - www.dysoc.org/cesmodules/diversification_module/
- What is CoLab?
 - Write and execute python (and some R) in your browser
 - Interactive coding experience
- Requirements: Google account

CULTURAL DIVERSITY AND DIVERSIFICATION



What is culture?

- Culture is information capable of affecting individuals' behavior that they acquire from other members of their species through teaching, imitation, and other forms of social transmission (Richerson and Boyd 2004: pg. 5)
- Population of related “representations” and material “objects” that circulate between people
- Representations (personal culture)
 - beliefs, skills, values, practices, etc...
- Objects (public culture)
 - Social media data, art, folktales, artifacts, lyrics, etc...

What is cultural diversity?

- The variety of cultural representations and material objects that circulate between individuals
- Cultural diversity inevitably develops through the course of cultural transmission
- Cultural evolutionary research has produced substantial empirical and experimental evidence for these transmission processes

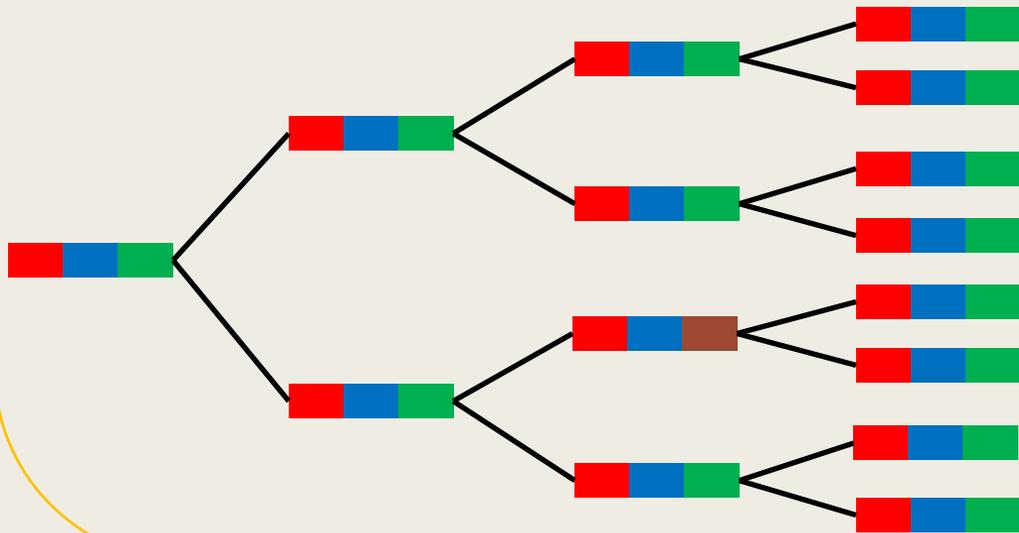
The macroevolution of cultural diversity

- The distribution of cultural forms / traits can also be studied across cultures at long time scales
- A macroevolutionary approach
 - Estimating rates of evolutionary change
 - Identifying transitions in the historical record of culture
 - Exploring the historical, demographic, social, and environmental factors that influenced changes
 - Associating patterns with underlying processes (competition, adaptive radiation, red queen, etc.)
 - Reconstructing evolutionary relationships (phylogeny)

Are cultural phylogenies possible? (Boyd et al. 1997)

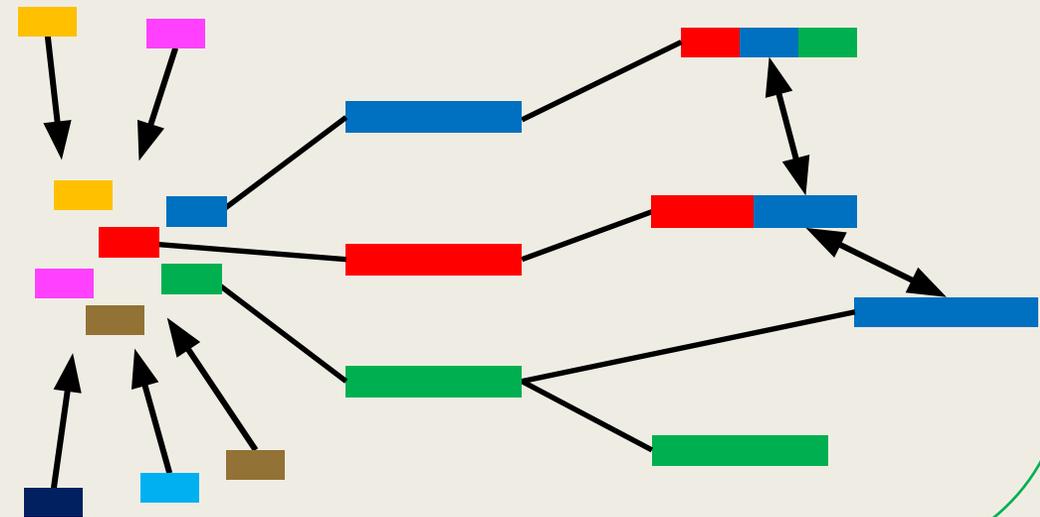
Cores

- Coherent “large” bundles of shared traditions
- Stable, vertical
- Reconstruct deep histories

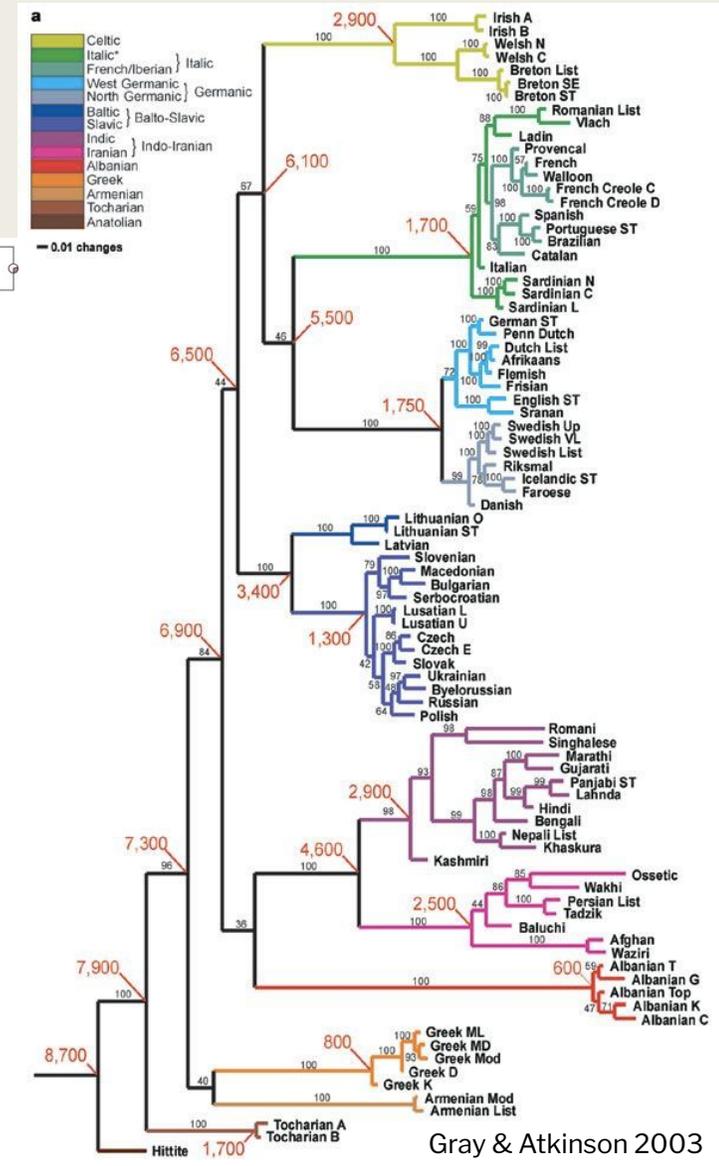
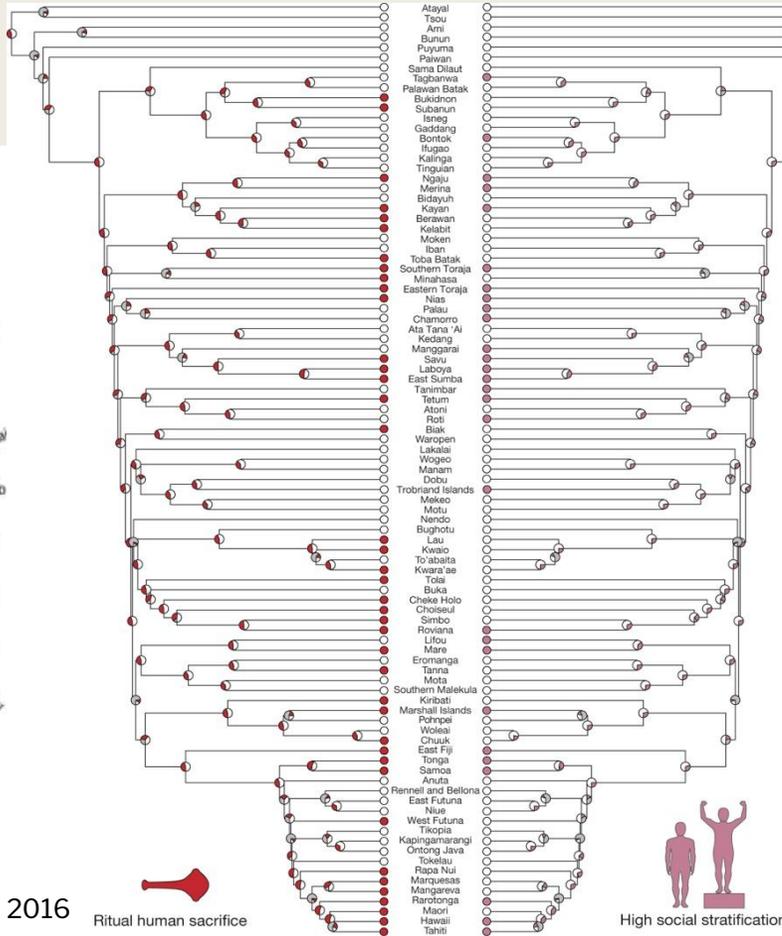
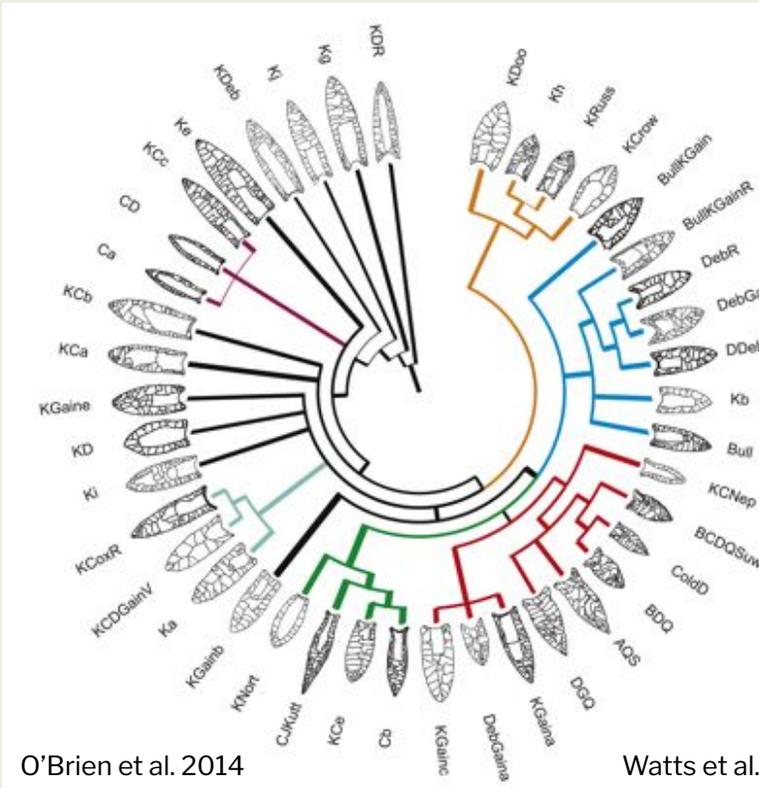


Packages

- Smaller bundles of traditions
- Variable, horizontal
- Sometimes can reconstruct deep histories



Are cultural phylogenies possible?



- “Traditional phylogenetic analyses have rather limited application for unveiling material culture phylogenies” (Temkin and Eldredge 2007)

Patterns of diversity

- Concerns about a phylogenetic approach
 - Determining *a priori* which traits are similar due to descent
 - Assumption of a branching pattern
 - Need for detailed, trait-level data (ATU index, song lyrics database, etc.)
 - Difficulties in estimating rates of extinction
- Can we examine patterns of cultural diversity without using a phylogenetic approach?

Patterns of diversity

- Inspiration from paleobiology and the similar challenges associated when using the fossil record
- Tempo and mode in evolution
 - Evolutionary rates, temporal patterns of diversity

Taxonomic Diversity during the Phanerozoic

The increase in the number of marine species since the Paleozoic may be more apparent than real.

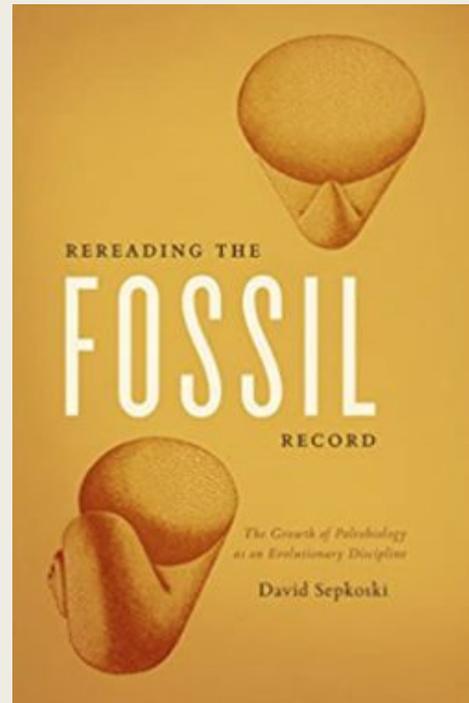
David M. Raup

Tempo and Mode in Evolution

George Gaylord Simpson

A Columbia Classic in Evolution

With a new introduction by George Gaylord Simpson



Mass Extinctions in the Marine Fossil Record

Abstract. A new compilation of fossil data on invertebrate and vertebrate families indicates that four mass extinctions in the marine realm are statistically distinct from background extinction levels. These four occurred late in the Ordovician, Permian, Triassic, and Cretaceous periods. A fifth extinction event in the Devonian stands out from the background but is not statistically significant in these data. Background extinction rates appear to have declined since Cambrian time, which is consistent with the prediction that optimization of fitness should increase through evolutionary time.

Diversity dynamics: molecular phylogenies need the fossil record

Tiago B. Quental, Charles R. Marshall

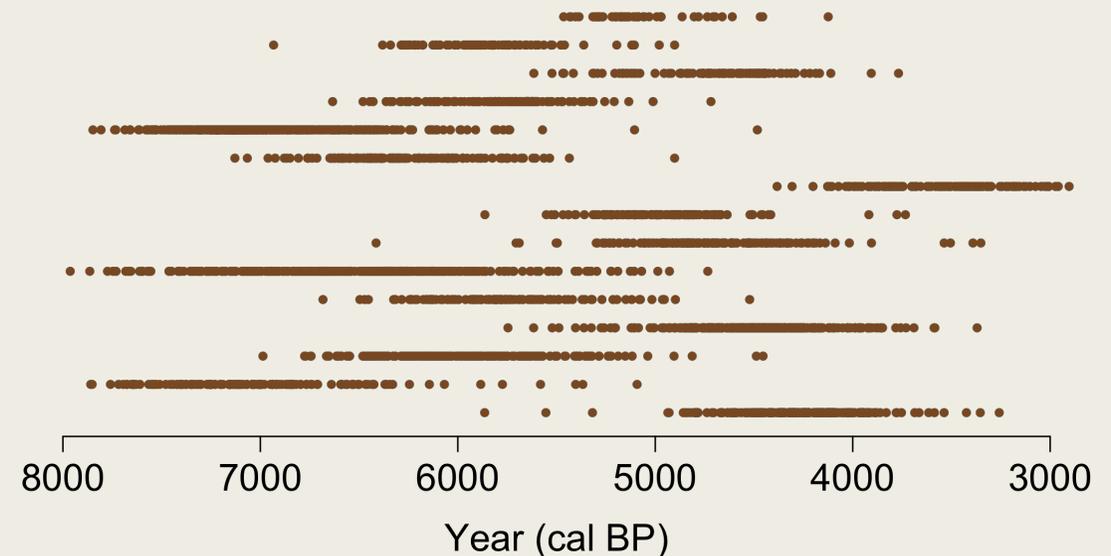
Bayesian Estimation of Speciation and Extinction from Incomplete Fossil Occurrence Data

Daniele Silvestro^{1,2,3}, Jan Schnitzler^{4,5}, Lee Hsiang Liow⁶, Alexandre Antonelli^{3,7}, and Nicolas Salamin^{1,2}

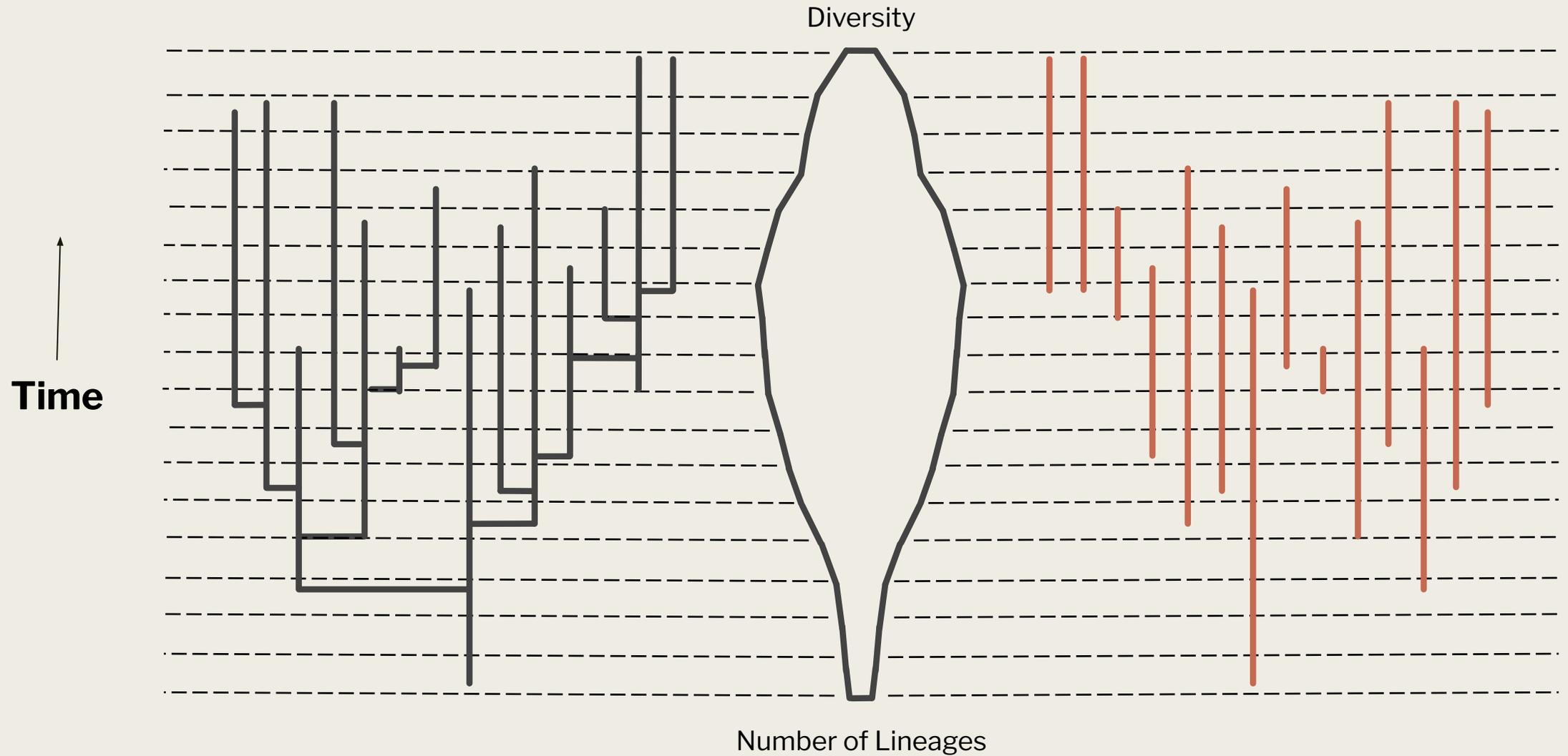
Patterns of diversity

- The unit of analysis is the *lineage*
- What is a material culture lineage?
 - A lineage in material culture can be broadly defined as a suite of features that persist in generation after generation of artifacts and display relatively minor changes through time (Gjesfjeld et al. 2020).

- Linearbandkeramik Pottery Styles (Gjesfjeld et al. 2020).



Patterns of diversity



Quantifying Diversity

- Diversity can be broadly described as the distribution of “things” into categories
- The two main properties of diversity are:
 - Richness: presence or absence of a thing in a category
 - Evenness: distribution of things between categories
- Often measured through diversity indices
 - Counts, Shannon-Weaver index, Simpson index, etc.

Quantifying Diversity

- However, diversity indices are static, summary statistics
 - Challenging to compare when data have variable temporal durations, sample sizes, and/or sampling intensities
 - Do not account that the emergence and loss of cultural diversity is an evolutionary process
 - Only provide limited insight into rates of evolutionary change

Modeling Diversification

- Transition from quantifying cultural diversity to modeling cultural diversification
- How do we go about doing this?
 - Longitudinal cultural richness data (Erik)
 - Continuous birth-death model (Bernie)
 - Probabilistic modeling framework (Bernie)

Diversification of American Automobiles

- What are the rates of origination and extinction within American automobiles?
- Does the diversity of American automobiles change gradually over time or in rapid or punctuated changes?



Modeling Automobile Diversification

- What type of data do we need?
 - Longitudinal richness data (i.e. occurrence data)
 - Presence of a cultural lineage during temporal intervals (minimum of two)

Car Model Name	First Year of Production	Last Year of Production
Chevrolet Corvette	1953	2020
Ford Mustang	1964	2020
Dodge Viper	1992	2017

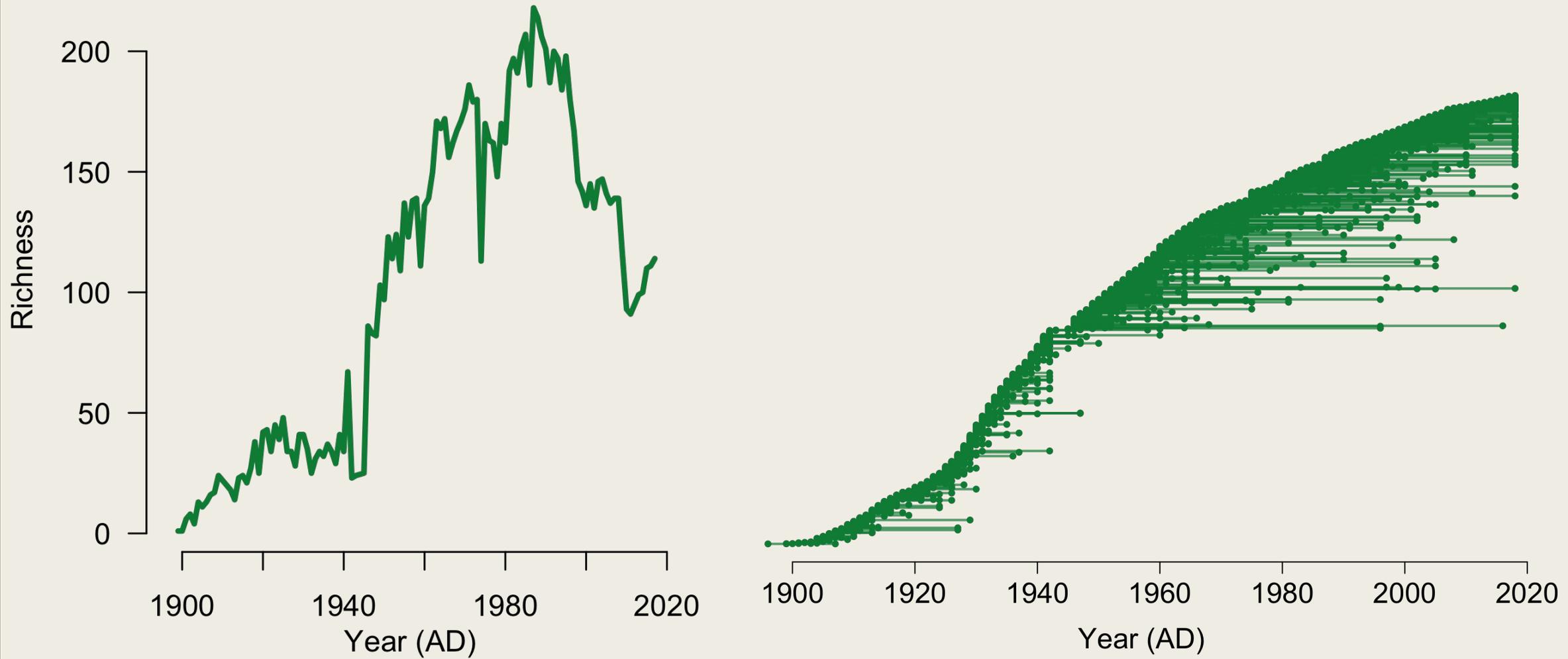


Why cars?

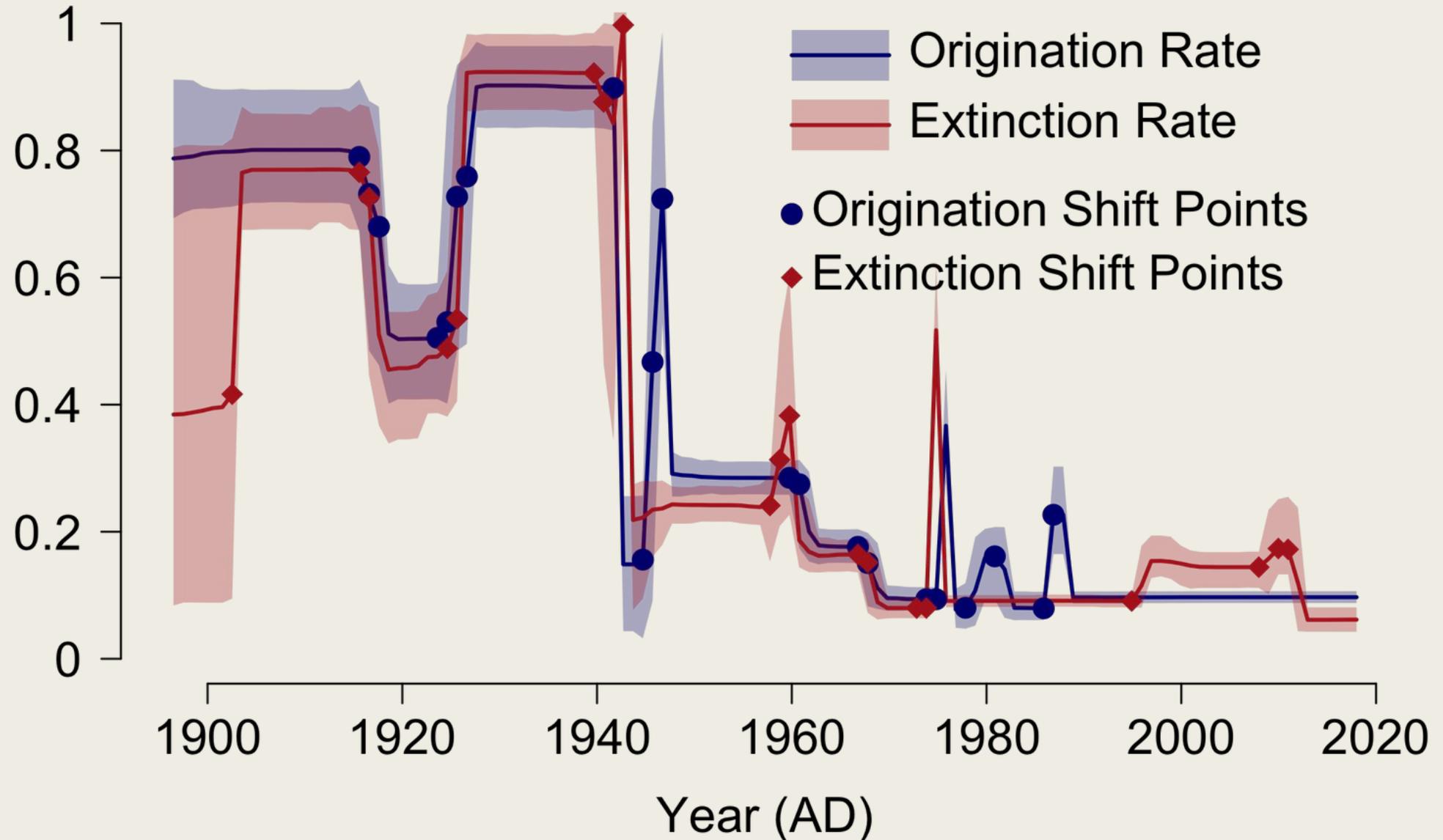
- Perhaps the most significant innovation of the 20th century
- Diverse technological system with nearly complete historical data
 - 3500 car models
- Established classification scheme
 - Make, model, trim
- Variation in model lifespans



Modeling Automobile Diversification



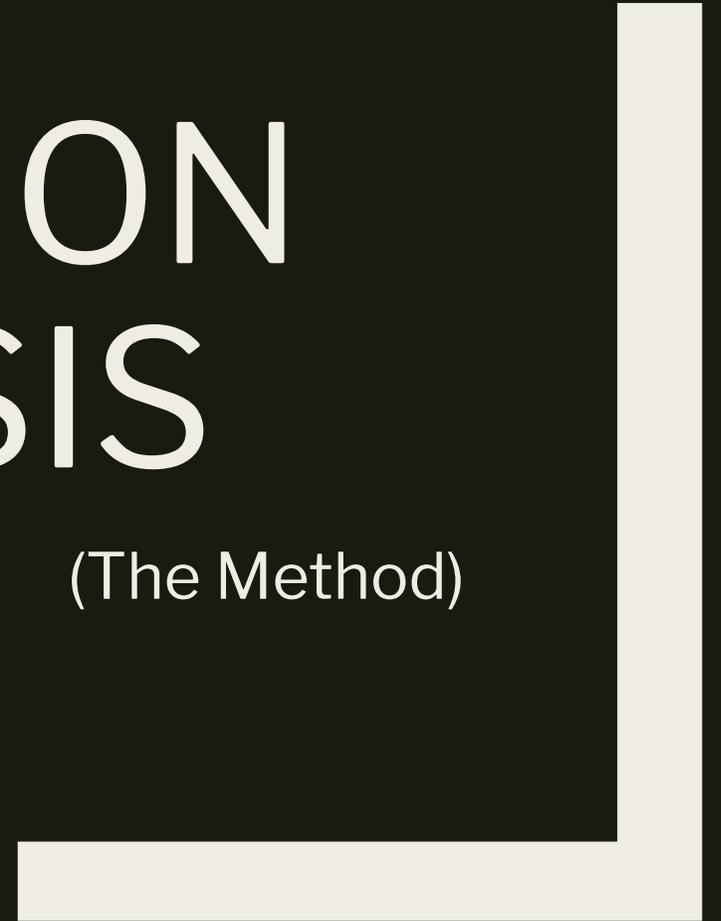
Modeling Automobile Diversification



Figures from Gjesfjeld et al. 2020 - A Quantitative Workflow for Modeling Diversification in Material Culture (Plos One)

DIVERSIFICATION RATE ANALYSIS

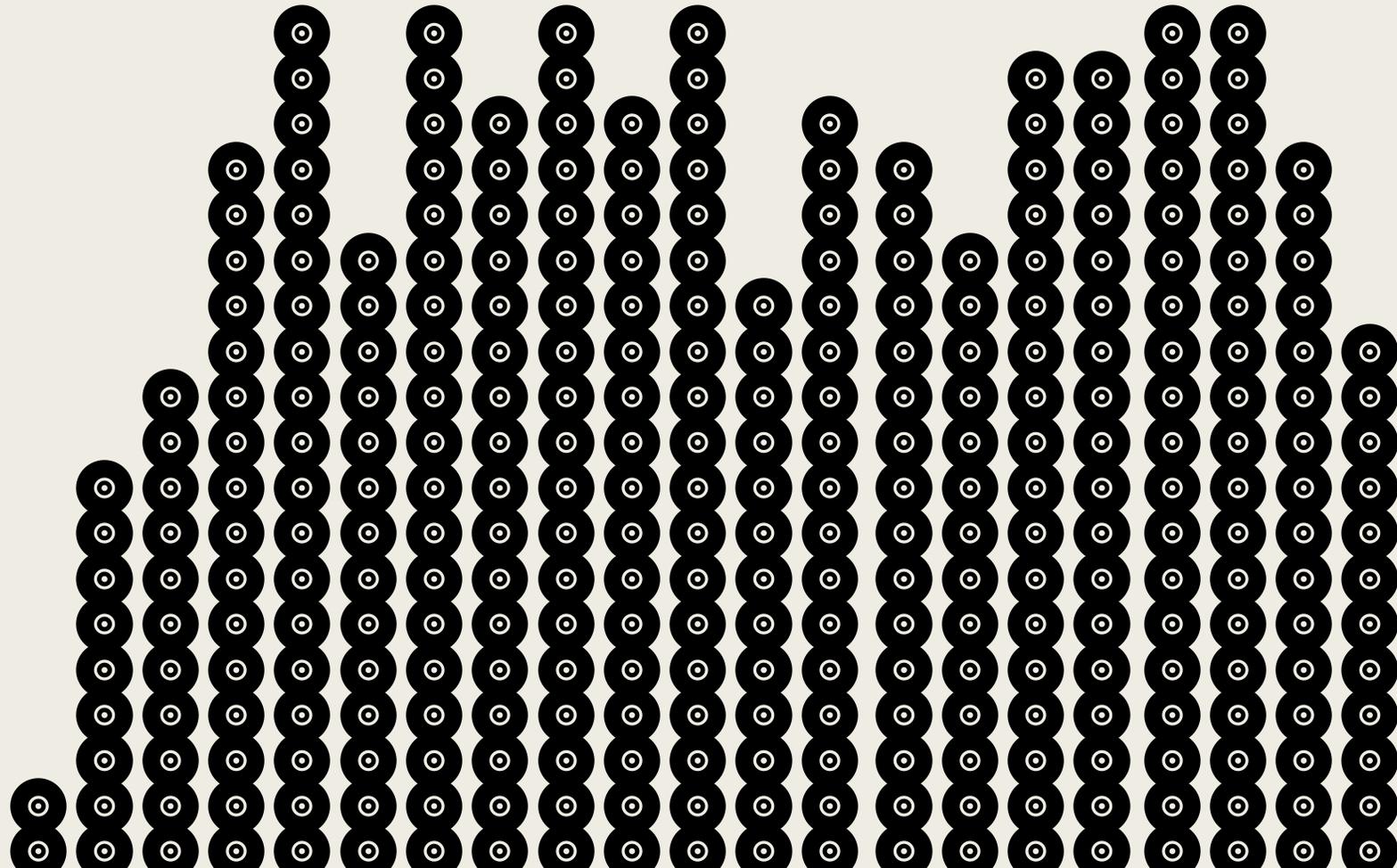
(The Method)



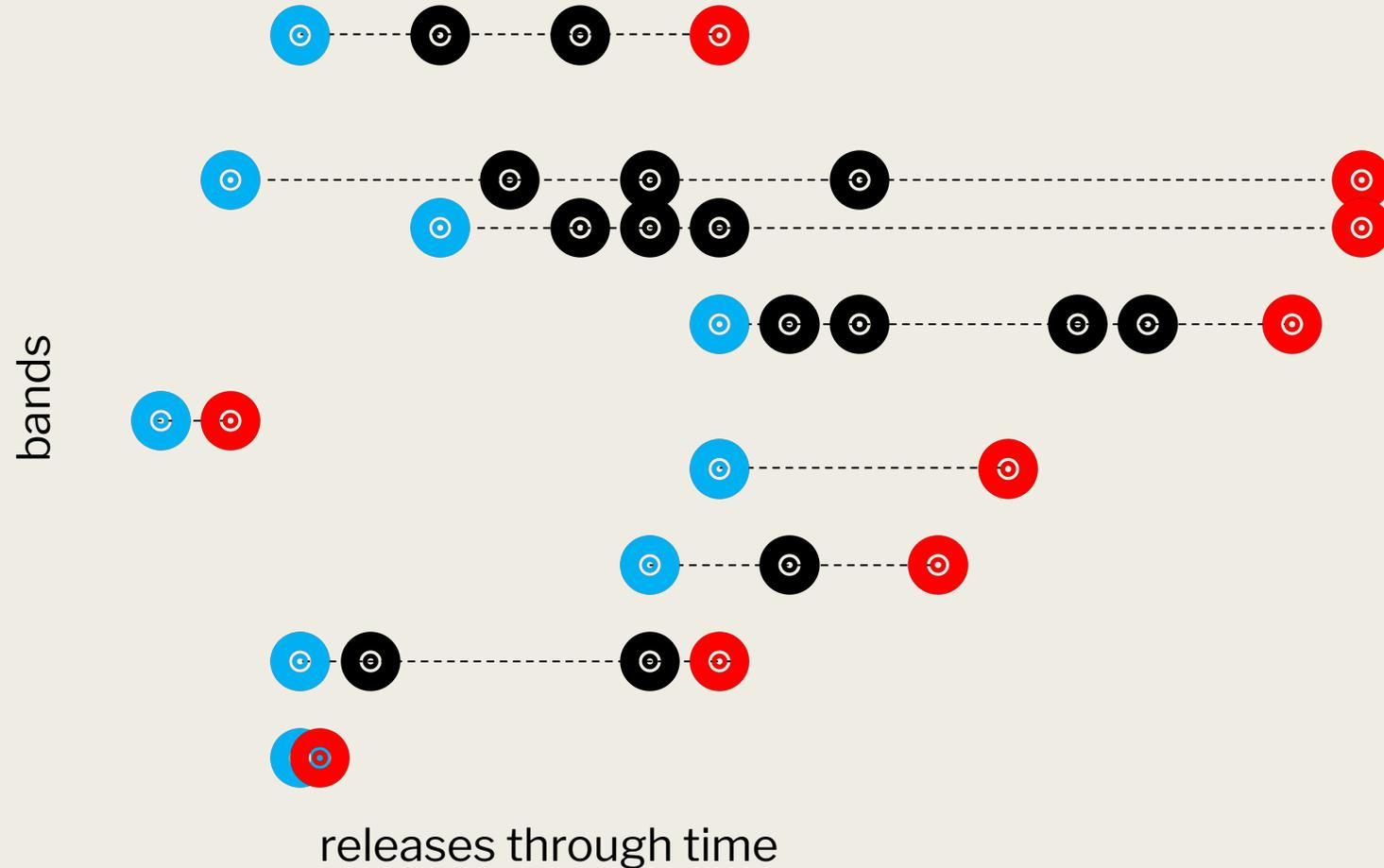
Theory of What We're Doing (My View)

- Culture is both personal and public
- Transmission and variation of culture comes from learning from and reproduction of objects
- Creates cultural “lineages” that persist over time
- Associated lineages make up “cultural form”
- Form circulates amongst any actors who share ideas
- Macro-evolutionary mechanisms shape population of ideas over large and long frames of analysis

Measuring Cultural Objects Can Tell Us About Change in Culture



Measuring Cultural Objects Can Tell Us About Change in Culture

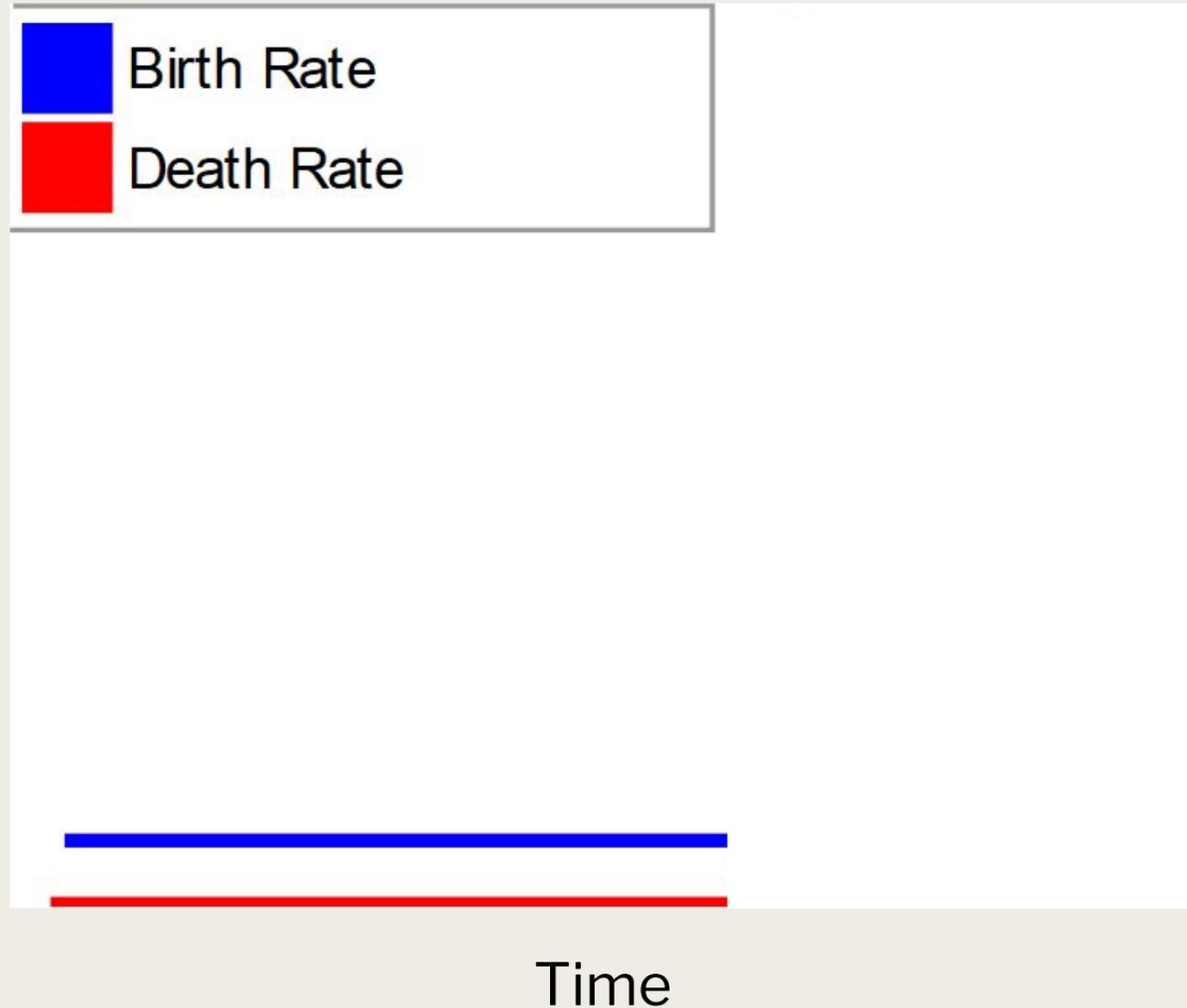


Estimating Birth and Death Rates within Public Cultures

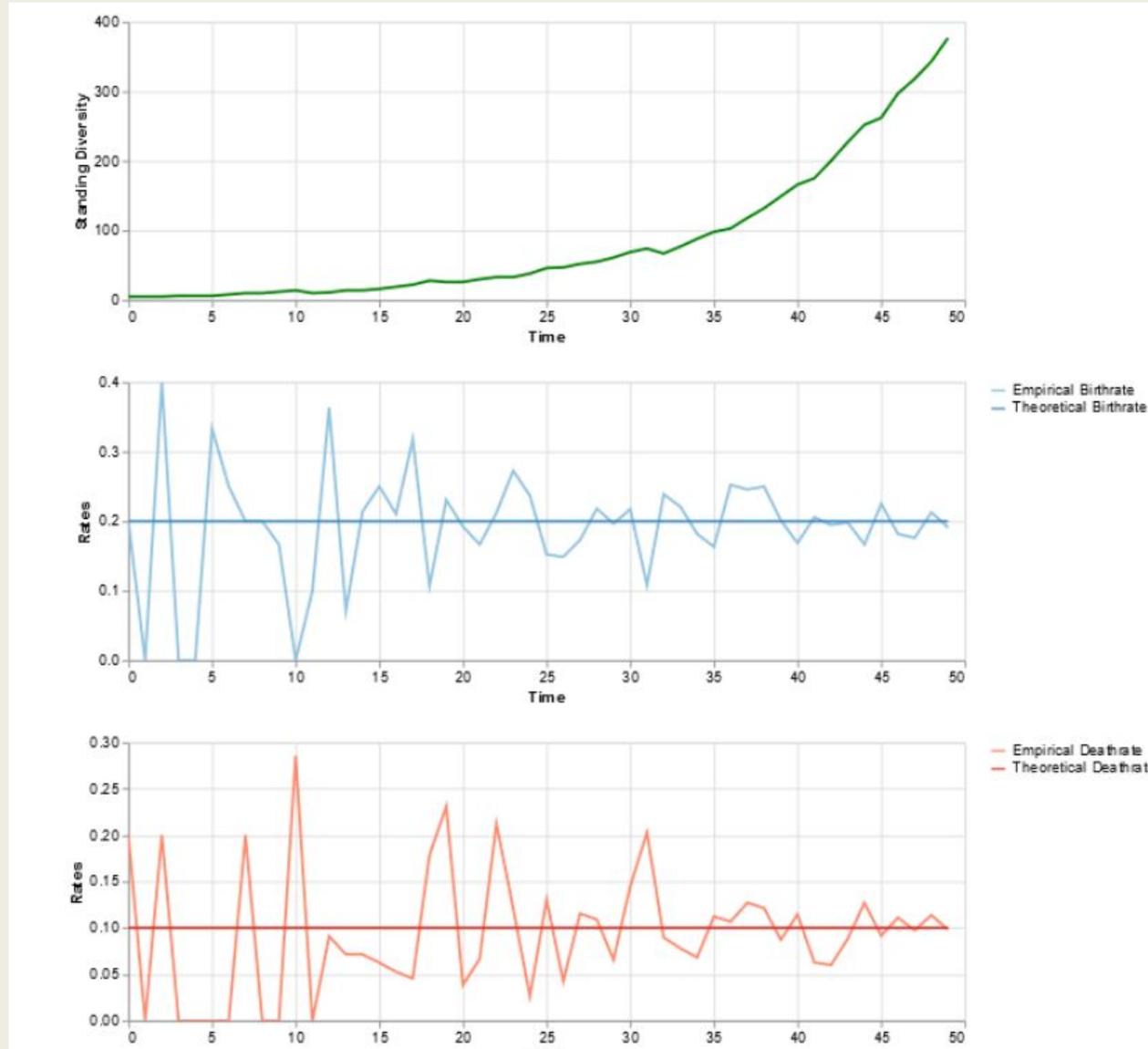
$$\lambda = \frac{\textit{births}}{\textit{diversity}}$$

$$\mu = \frac{\textit{deaths}}{\textit{diversity}}$$

Understanding Birth-Death Processes



Why We Need A Statistical Model



Estimating Birth and Death Rates within Public Cultures

$$\lambda = \frac{\textit{births}}{\textit{time lived}}$$

$$\mu = \frac{\textit{deaths}}{\textit{time lived}}$$

$$P(\mathbf{s}, \mathbf{e} | \lambda, \mu) \propto \lambda^B \mu^D e^{-(\lambda + \mu)S}$$

Estimating Birth and Death Rates within Public Cultures

$$\lambda = \frac{\textit{births}}{\textit{time lived}}$$

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$$P(\mathbf{s}, \mathbf{e} | \lambda, \mu) \propto \lambda^B \mu^D e^{-(\lambda + \mu)S}$$

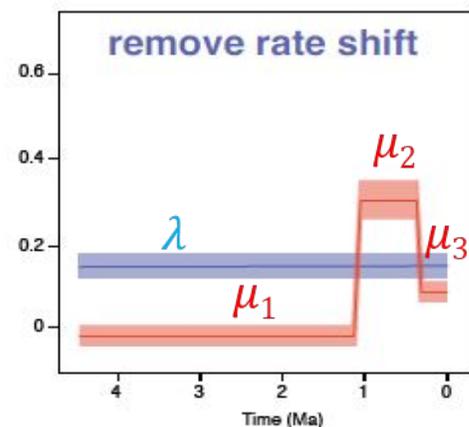
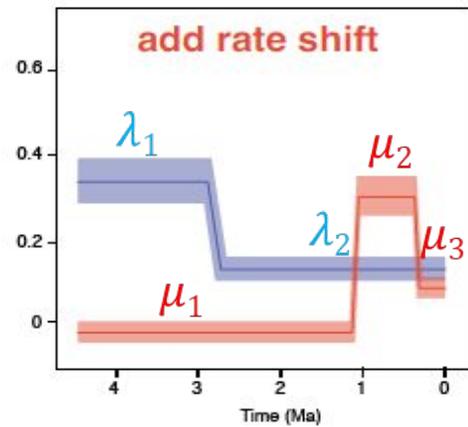
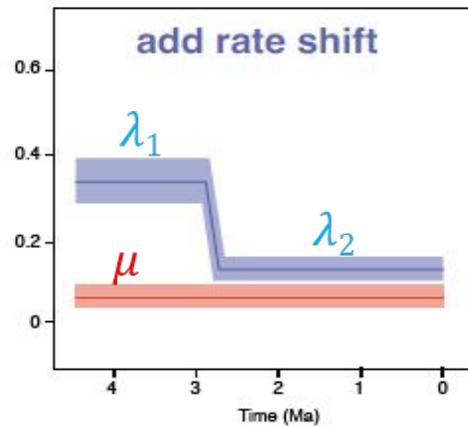
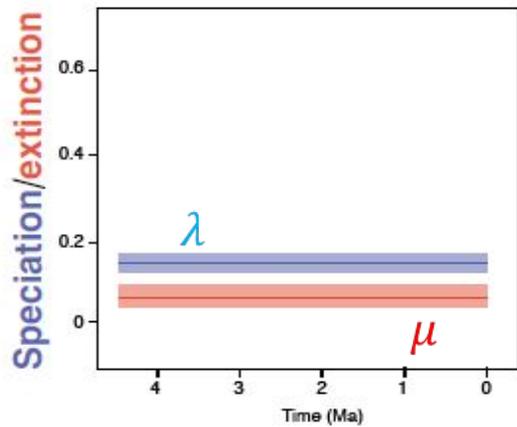
of births/deaths

times of births/deaths

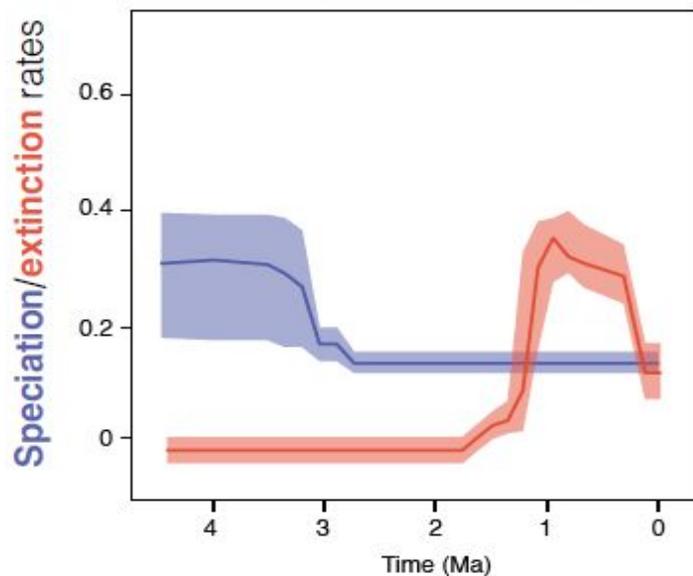
birth/death rates

Total time lived by all lineages

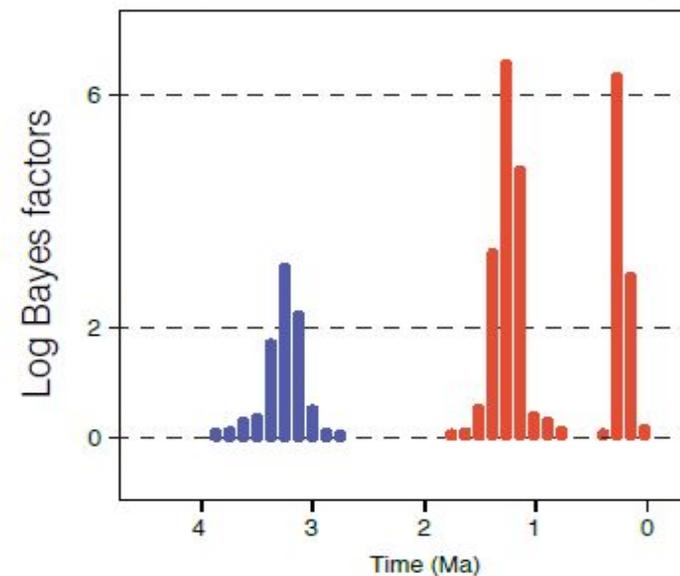
Estimating rate heterogeneity through time – RJMCMC



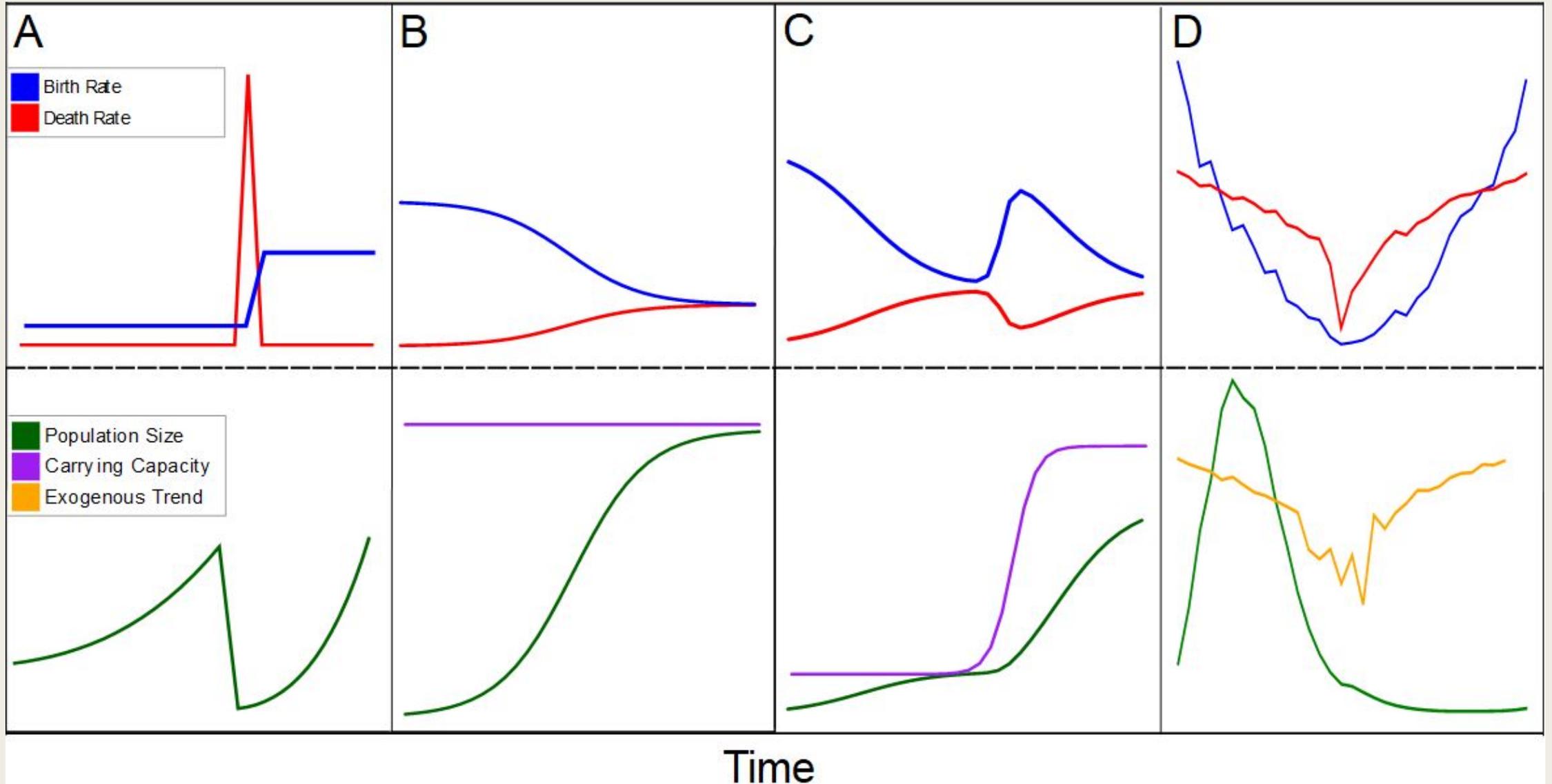
Marginal rates



Times of rate shifts

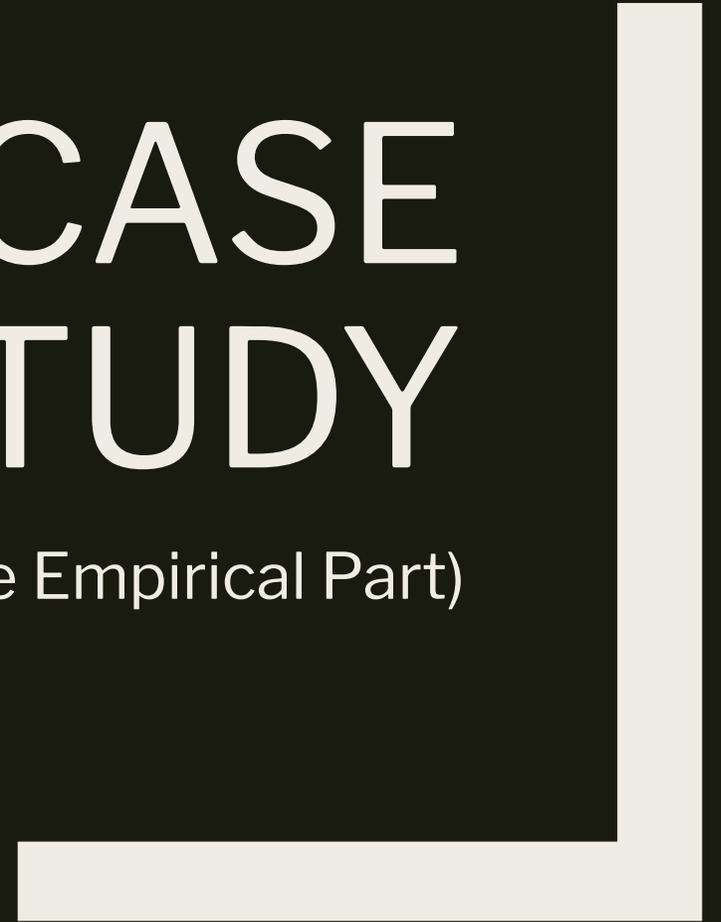


Mechanisms Revealed by Rate Analysis



METAL AS A CASE STUDY

(The Empirical Part)



The Data

- All Metal Bands from 1968-2000
- Rich history with highs, lows, and, good qualitative coverage
- 30,217 bands, 101,838 releases

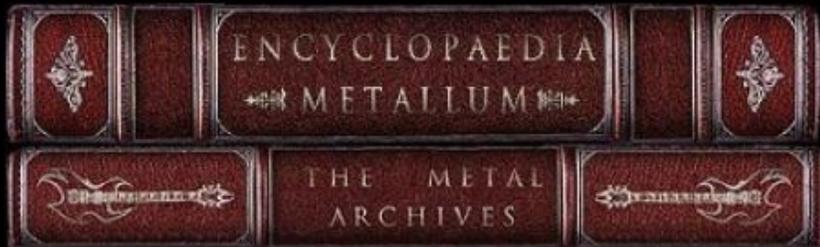
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AMORPHIS

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Country of origin: [Finland](#)
 Location: [Helsinki](#)
 Status: [Active](#)
 Formed in: [1990](#)
 Years active: [1990-present](#)

Genre: [Progressive/Death/Doom Metal \(early\)](#),
[Melodic Heavy Metal/Rock \(later\)](#)
 Lyrical themes: [War \(early\)](#), [Death](#), [Finnish legends](#), [Kalevala](#)
 Current label: [Nuclear Blast](#)

First band added to the Metal Archives!

Amorphis is derived from the Greek 'amorphous' which means without determinate form, shapeless.

With Violent Solution's break-up, Jan Rechberger and Esa Holopainen formed Amorphis in 1990 with Jan on drums, Esa on lead guitars, Tomi Koivusaari as vocalist, and Olli-Pekka Laine as bassist. Soon after signing with Relapse Records (which would remain their ...

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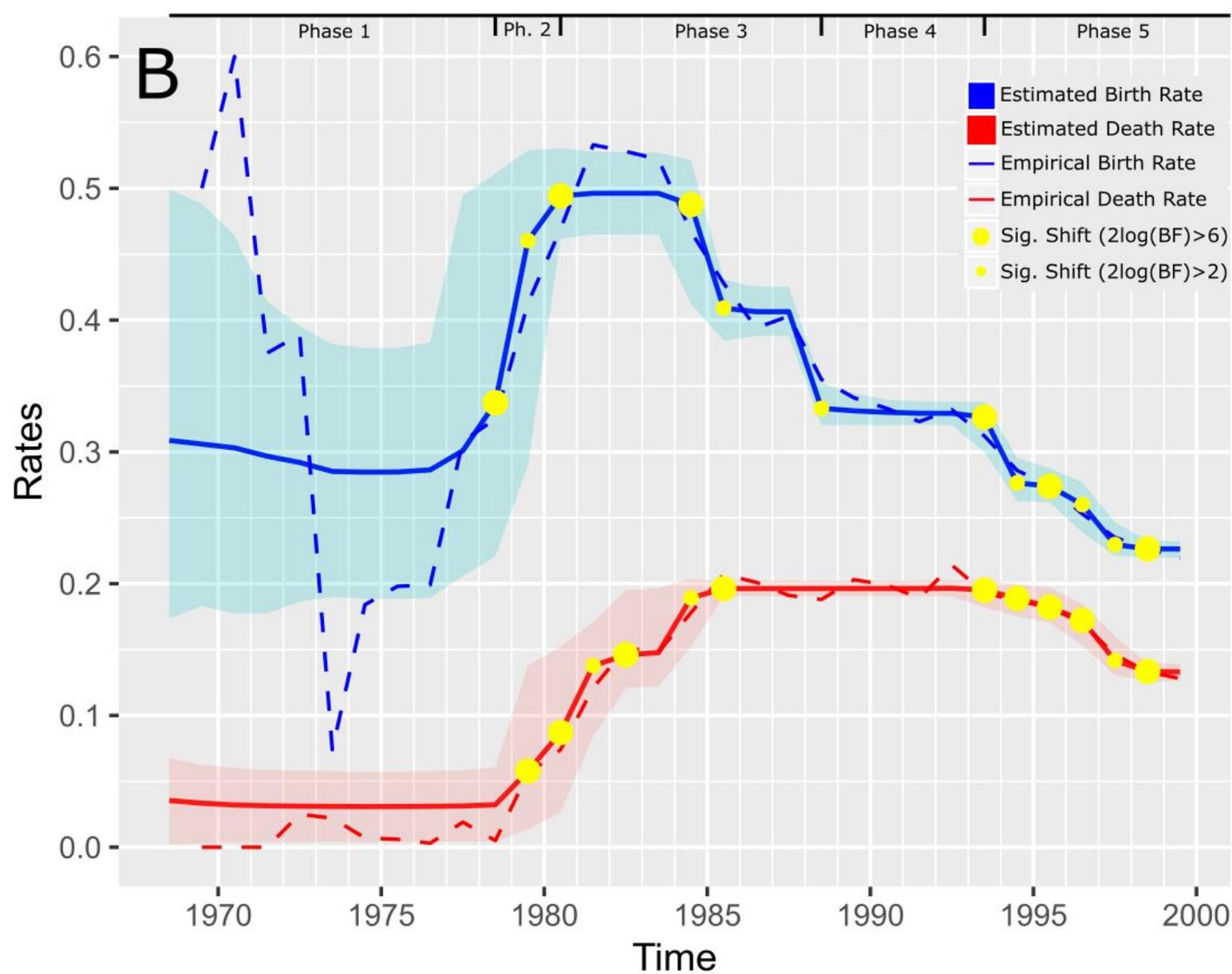
Name	Type	Year	Reviews
<i>Dismant of Soul</i>	Demo	1991	1 (78%)
Amorphis	Single	1991	1 (85%)
The Karelian Isthmus	Full-length	1992	8 (85%)
Privilege of Evil	EP	1993	6 (89%)
Tales from the Thousand Lakes	Full-length	1994	17 (82%)
Black Winter Day	Single	1994	3 (70%)
Black Winter Day / Fear	Split	1995	



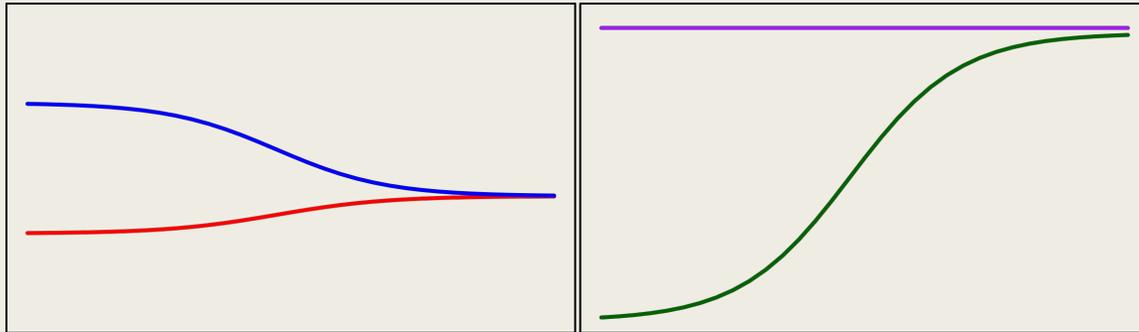
Analyses

- Unsupervised Exploration of Rates
- Testing the Competition Hypothesis
- Competition + Carrying Capacity Expansion
- Popular Music
- Evidence for Carrying Capacity

5 Phases of Metal History



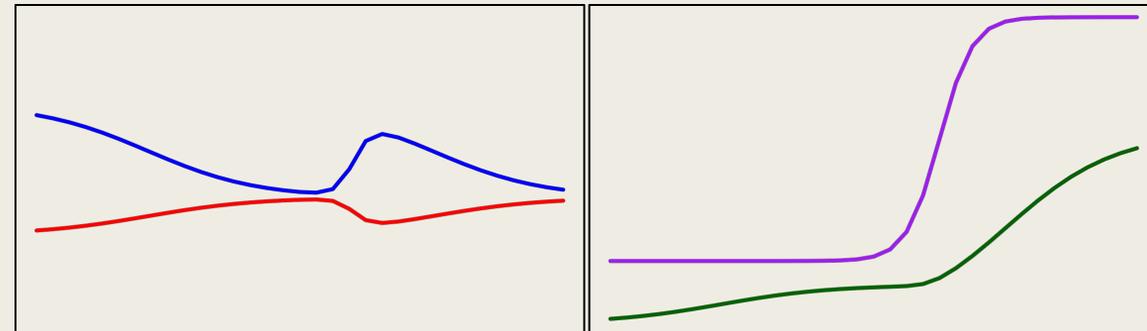
Mechanisms Revealed by Rate Analysis



Competition for a fixed Niche

$$\lambda(t) = \lambda_{max} - (\lambda_{max} - \kappa) * \frac{D(t)}{K}$$

$$\mu = \mu_{min} + (\kappa - \mu_{min}) * \frac{D(t)}{K}$$

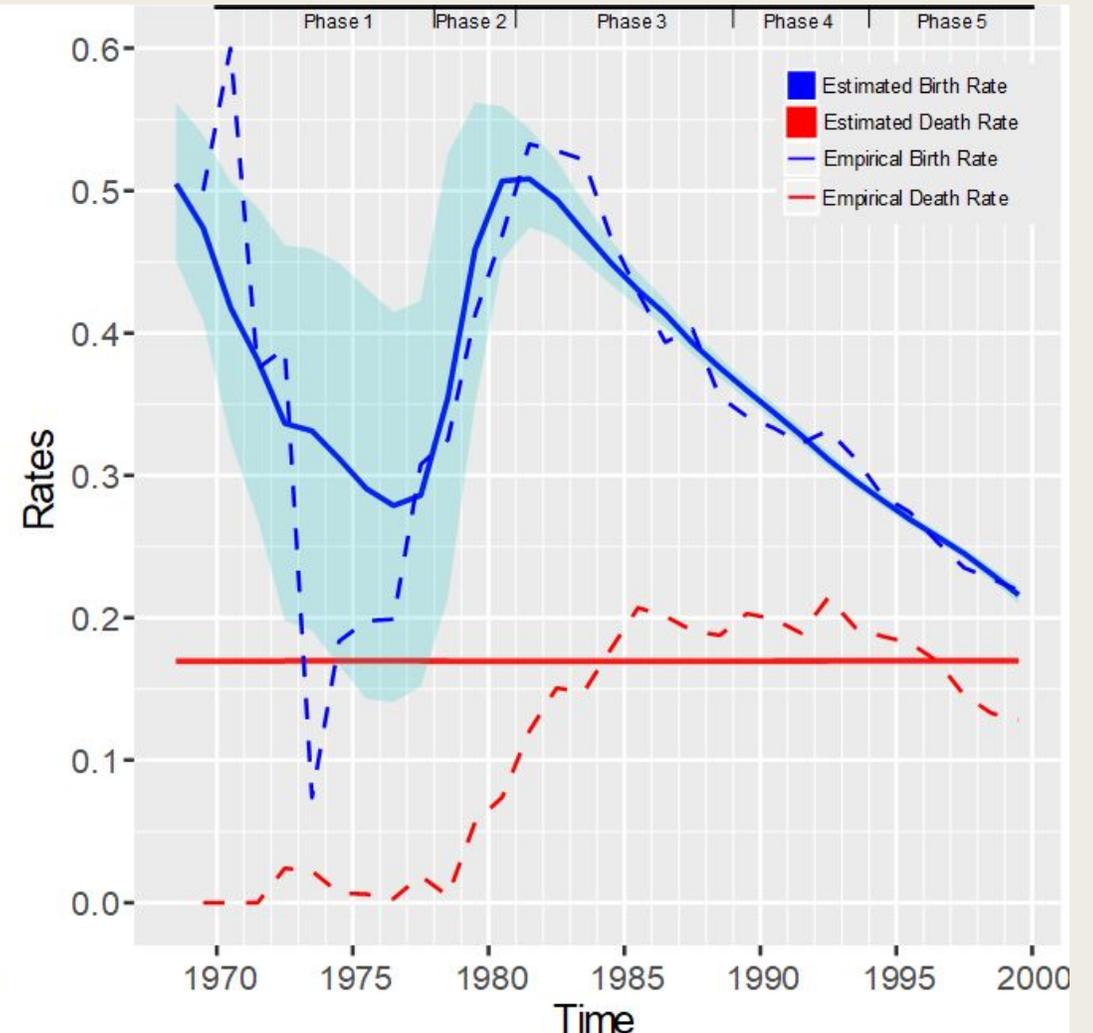
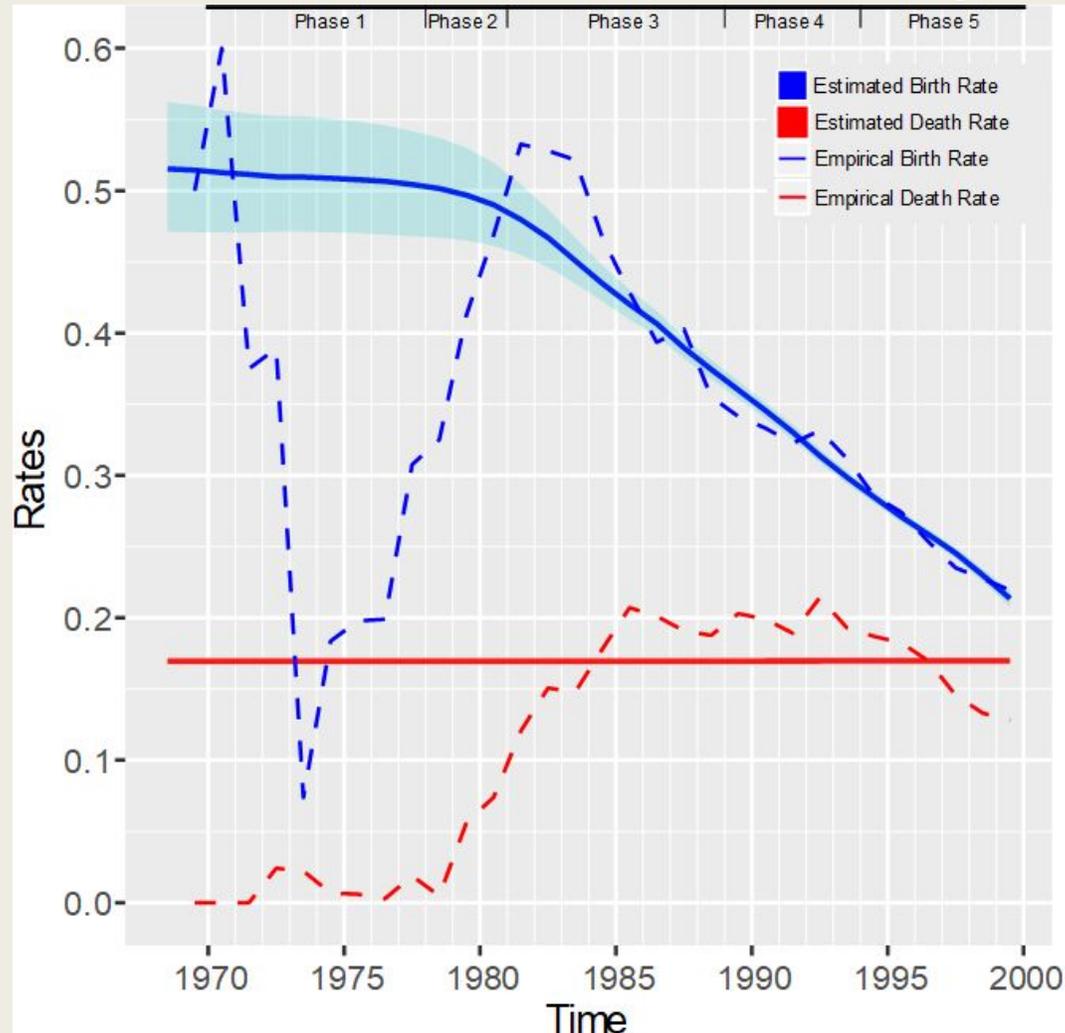


Competition + Niche Construction

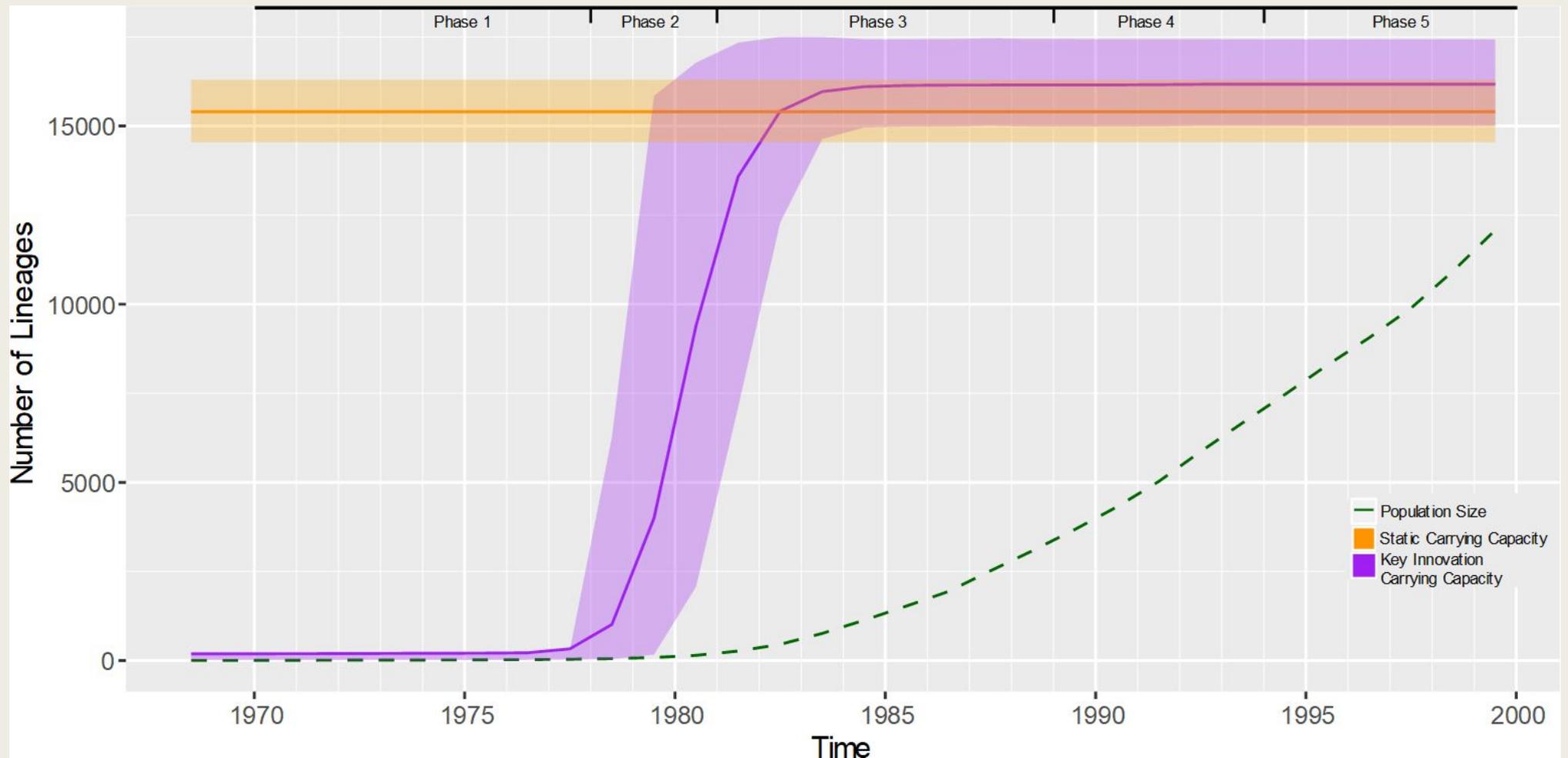
- Hypothetical Birth Rate
- Hypothetical Death Rate
- Hypothetical Net Diversity
- Hypothetical Carrying Capacity

$K = \textit{logistic}$

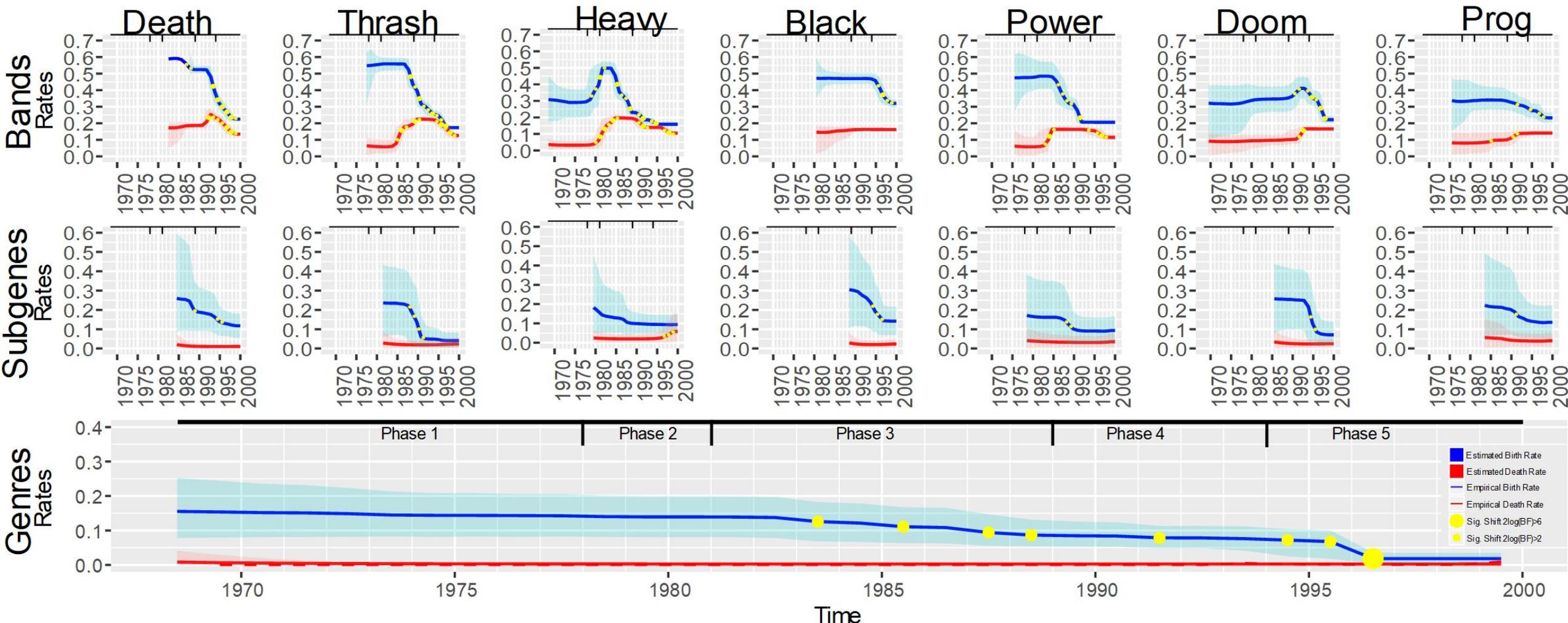
Competition + Capacity Expansion Best Explanation



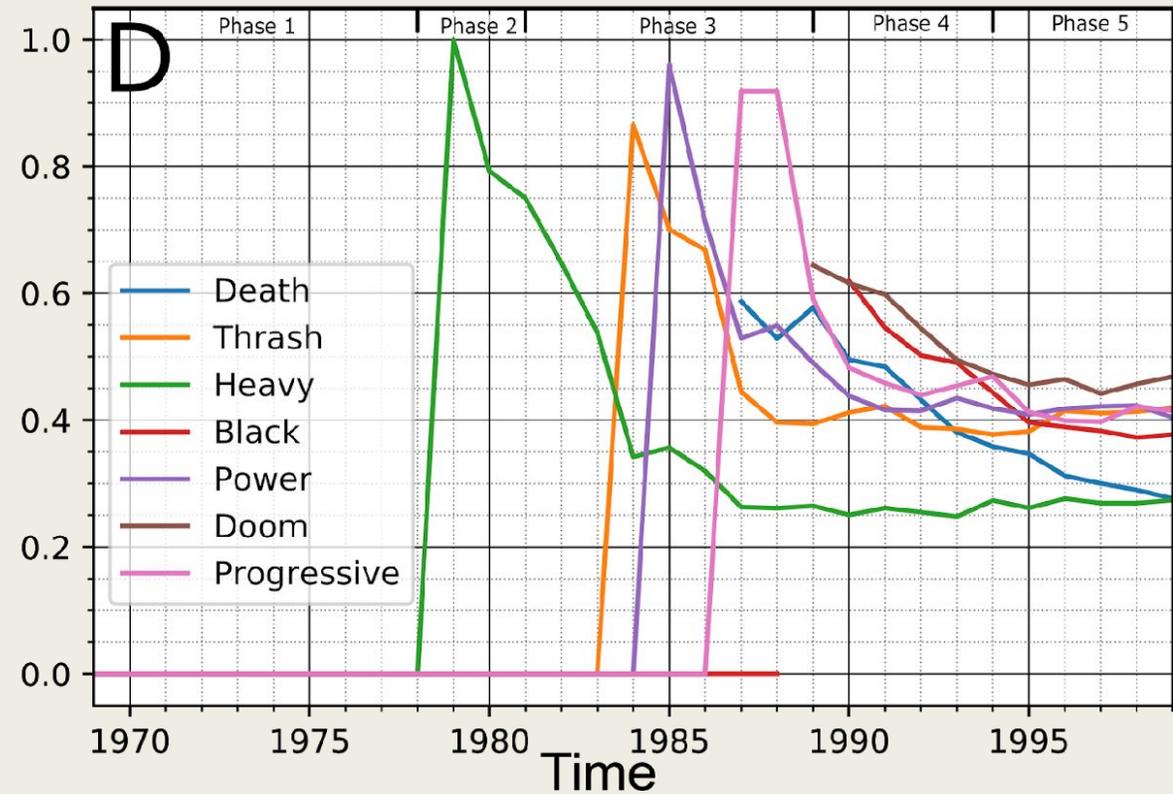
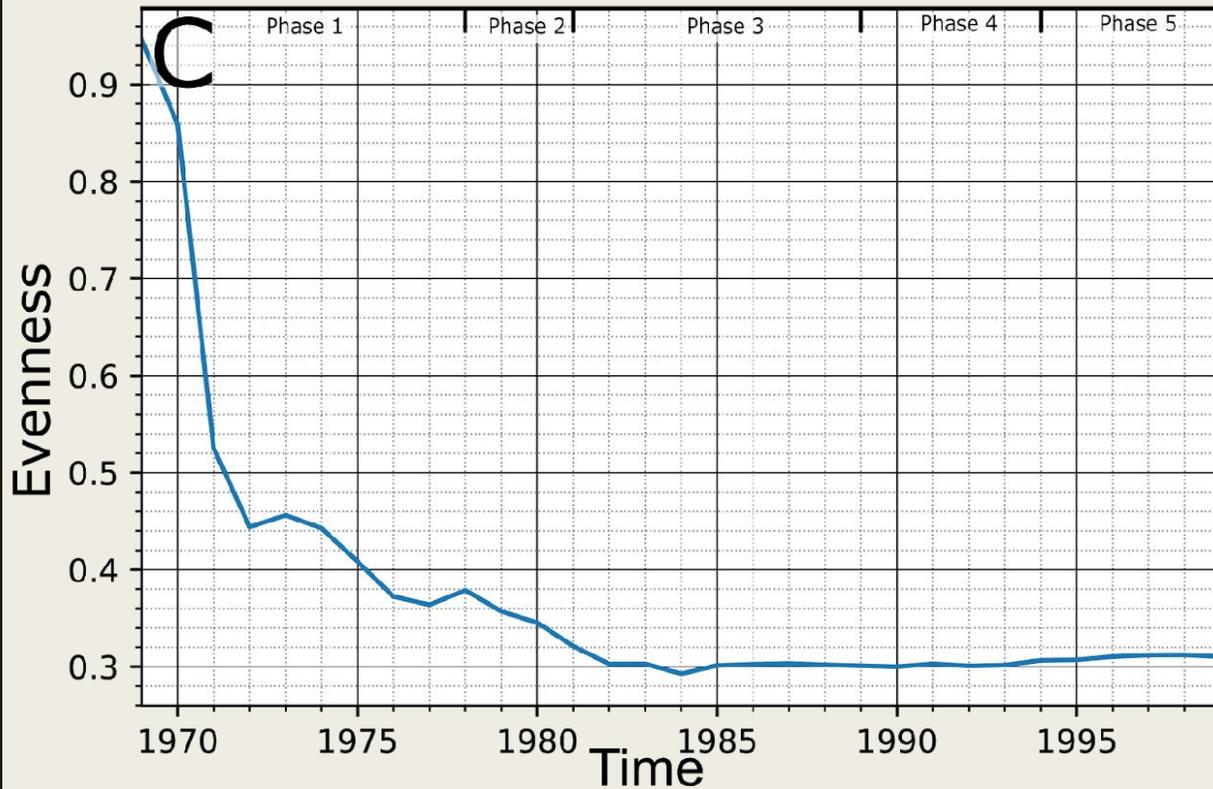
Competition + Capacity Expansion Best Explanation



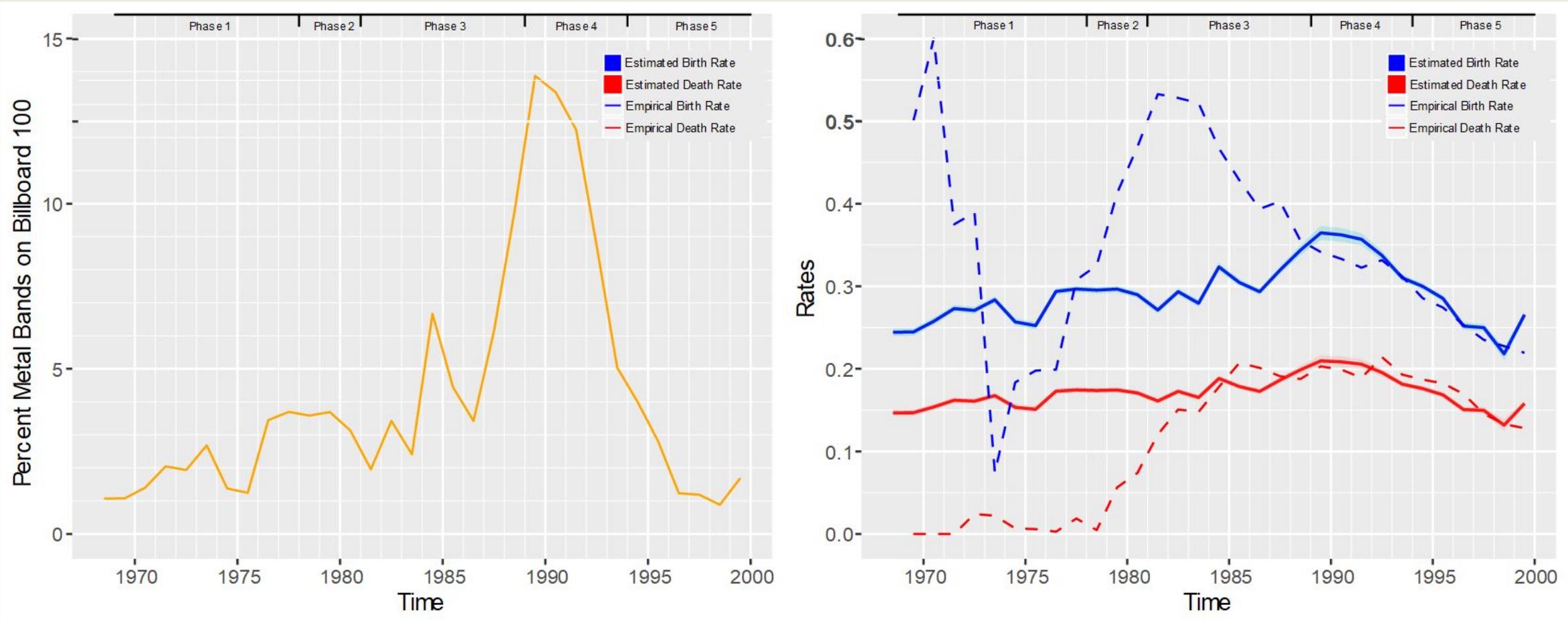
Competition Signatures for Genres and Subgenres



Bands Exploit Constant Proportion of Genre Space Over Time



Pop Music Does Not Explain Rates



Conclusions & Future Work

- Metal's growth is best explained by dueling processes of competition and cultural carrying capacity expansion over time
- Cultural evolution is a unifying theory to generate generic top-down hypotheses about cultural change
- Diversification rate analysis is a natural empirical framework for this theory
- More work is needed to think about cultural death

Where Can I Find the Final Tutorials

<http://www.dysoc.org/cesmodules/>

Draft Paper on SocArxiv:

osf.io/preprints/socarxiv/659bt



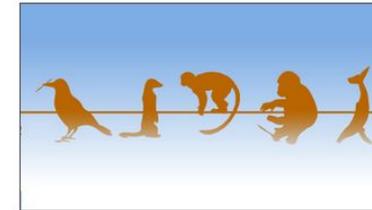
Online Learning: Cultural Evolution

These online modules present many basic and applied issues in cultural evolution and introduce students to methods of dynamical systems theory as applied to the evolution of human systems. Without the aid of mathematical models, human intuitions about dynamic systems of any complexity can be quite faulty. The materials have been developed with self-guided study in mind. Through a variety of online learning methods, students will be able to independently work through the material to gain both a theoretical understanding of the method and practical experience doing it. The modules could serve as a basis for intensive short courses, seminars, or as components of a regular quarter or semester course. It is our hope that the concepts and techniques covered in these modules will facilitate interdisciplinary conversations and collaborations.



Models of Social Dynamics: An Introductory Module

This module takes an interdisciplinary approach to modeling social behavior, drawing on insights from across the social sciences and evolutionary ecology. It focuses on constructing and analyzing simulations using the NetLogo programming language.



Animal Cultures: Core Discoveries and New Horizons

This module offers an overview of core discoveries and new developments in the study of animal cultures. The significance of animal culture for evolutionary biology and ecology, understanding human cultural evolution, and conservation are highlighted.



The Neverending Story: Cultural Evolution and Narratives

This module explores the universal and uniquely human behavior of narrative and how cultural evolution theory has provided vital insights into the transmission and evolution of narratives and why some become culturally successful.



Foundations of Cultural Evolution

An introductory guide to the body of formal theory in the study of the cultural evolution in humans and other animals, this module guides participants through the basic machinery of dynamic models and key results from a variety of cultural evolution topics.



Coming soon!

Modeling the Dynamics of Cultural Diversification

This module trains researchers in a model-based Bayesian framework that allows them to estimate rates of cultural change, distinguish stochastic fluctuations from actual rate changes, and identify when major events, trends, or evolutionary mechanisms shaped the history of a cultural population.



Coming soon!

Dynamic Models of Human Systems

This primarily non-mathematical introduction to dynamic models of human ecosystems describes Lotka-Volterra models of early hunter-gatherers, farming communities, agrarian civilizations, and runaway technical civilizations. Related models of socio-political dynamics, economic growth, and epidemiology are also presented.

THANKS

SUPPORTED BY

