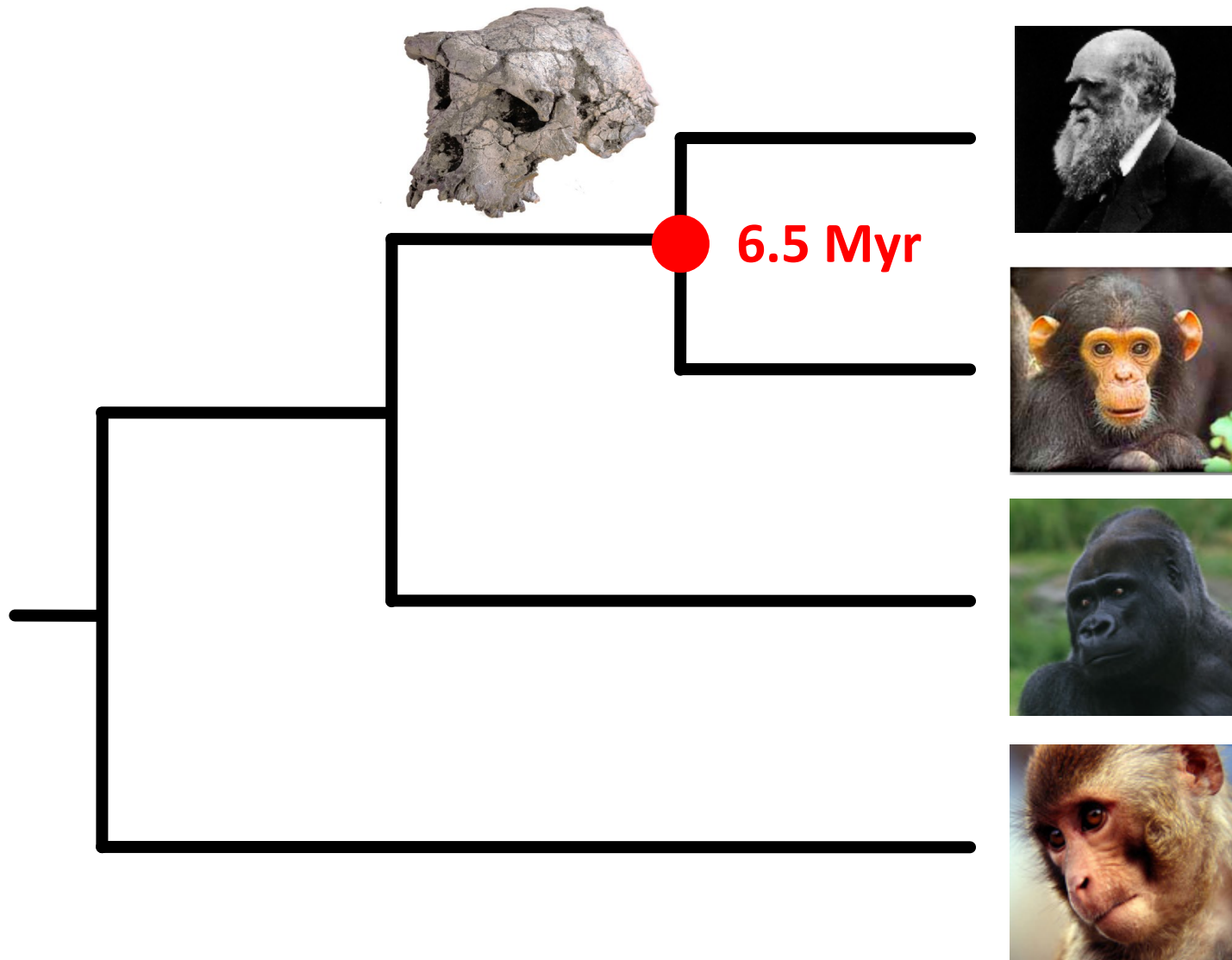Lecture 2.4

# Calibrating the Molecular Clock

# Calibrating the molecular clock

- Information about **substitution rate**

  - Use to fix rate or to specific prior distribution of rate


- Information about **node times**

  - Fossil record

  - Biogeography

  - Sampling times

  - Documented pedigree

# Calibration: Fossil record



**6.5 Myr**

# Calibration: Fossil record

1. **Use fossil data to inform priors on node times**

   - Minimum age of a node based on oldest fossil assignable to any of its descendent lineages

   - Prior distribution of node age specified by user

2. **Use fossil directly in the analysis**

   - Model diversification process use fossil occurrence data

   - Include fossil taxa in the data matrix (total-evidence dating)

# Choosing fossil calibrations

1. Museum numbers of specimen that demonstrate all the relevant characters and provenance data

2. Apomorphy-based diagnosis or phylogenetic analysis of the specimen

3. Explicit statements on the reconciliation of morphological and molecular data sets

4. Locality and stratigraphic level from which the calibrating fossil was collected

5. Reference to a published radioisotopic age and/or numeric timescale and details of numeric age selection
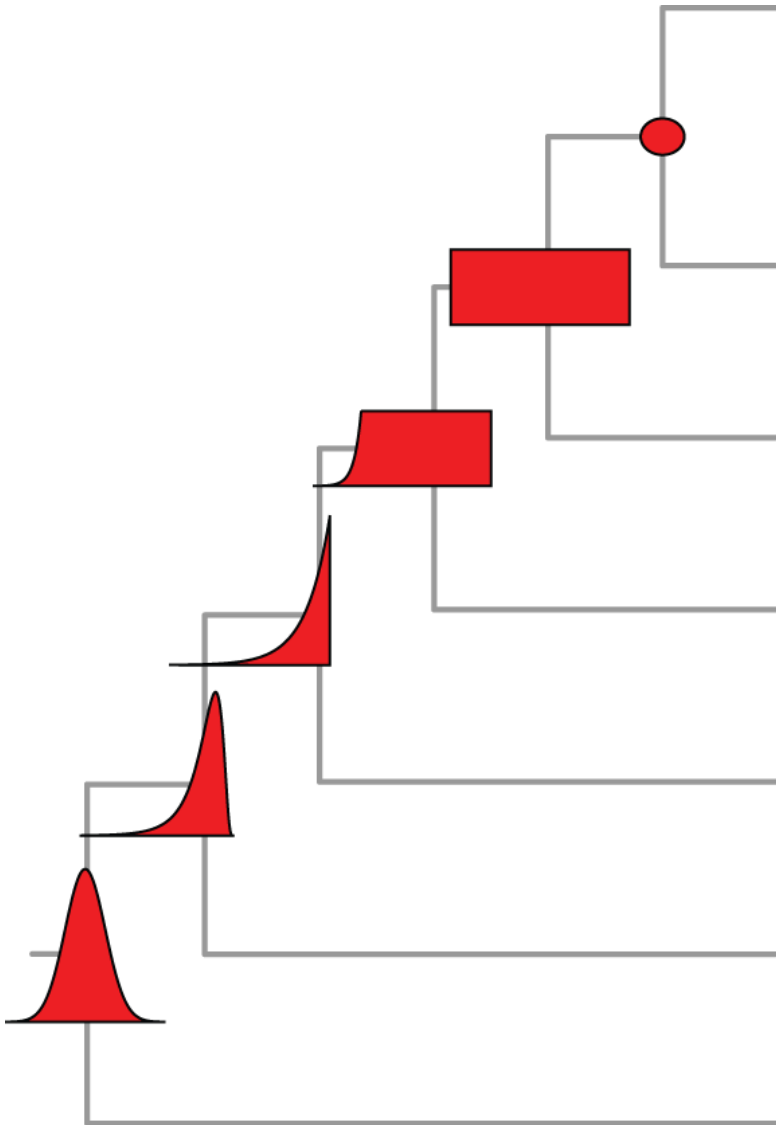
# Calibration Priors

# Calibrations
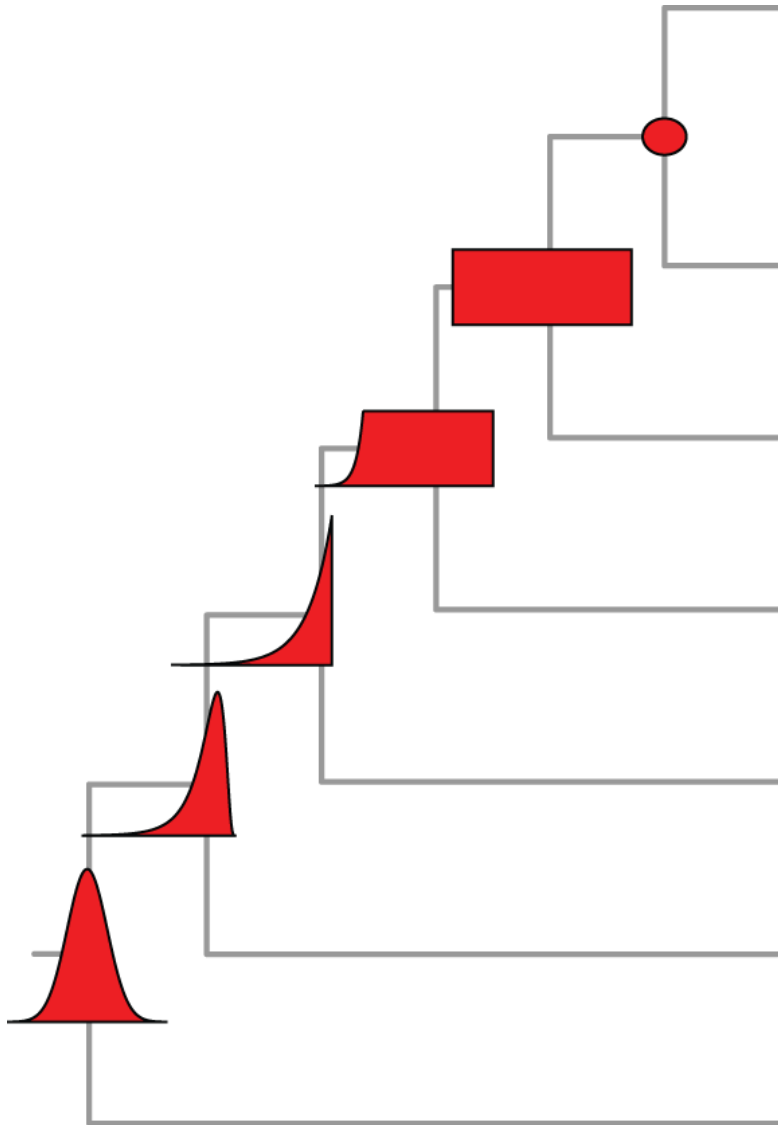


**Point calibration**

- Ignores uncertainty due to preservational biases, isotopic dating errors, *etc*.
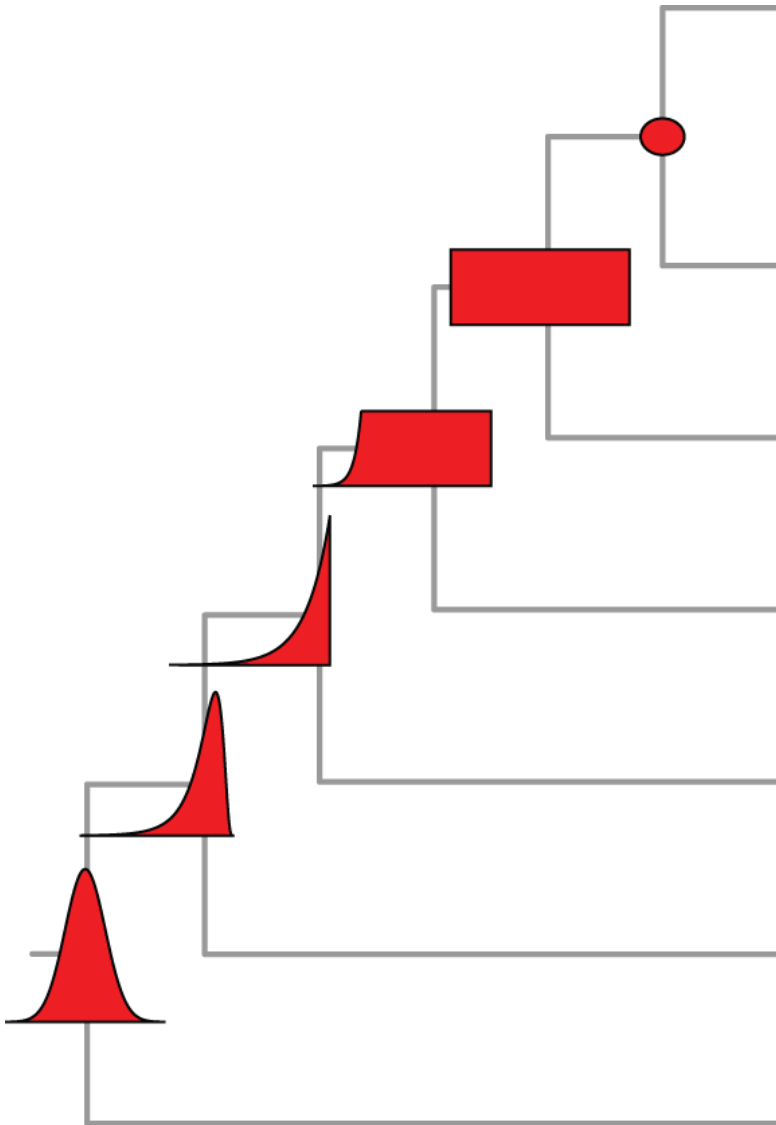
# Calibrations



**Uniform prior**

- Combination of hard minimum and maximum bounds

- Does not effectively use information at hand

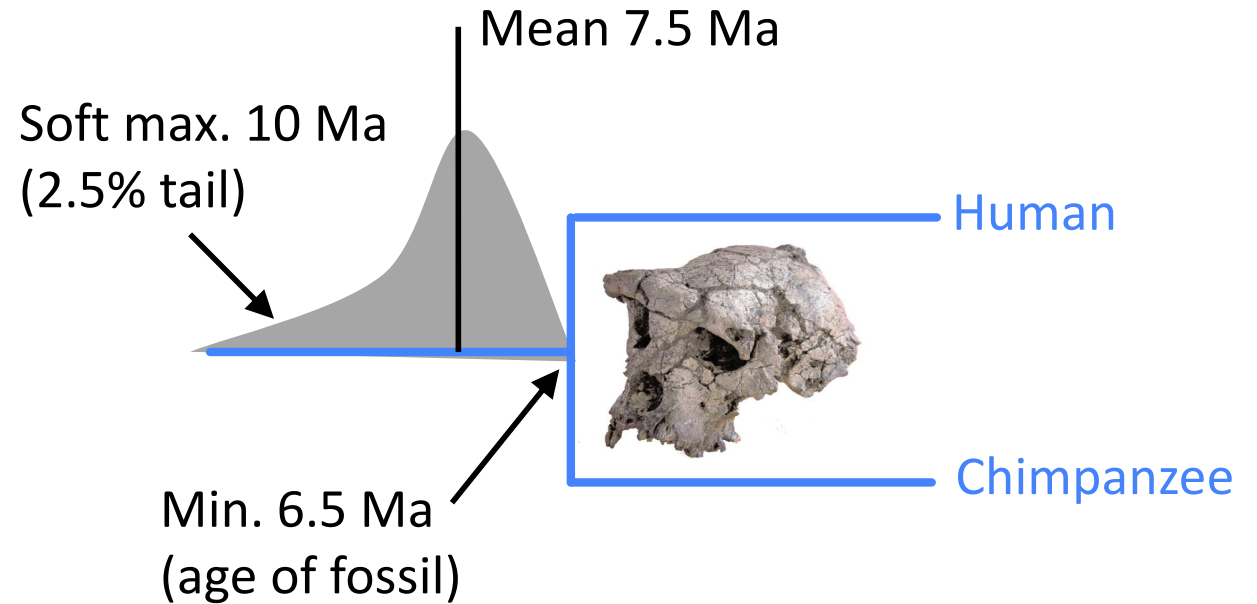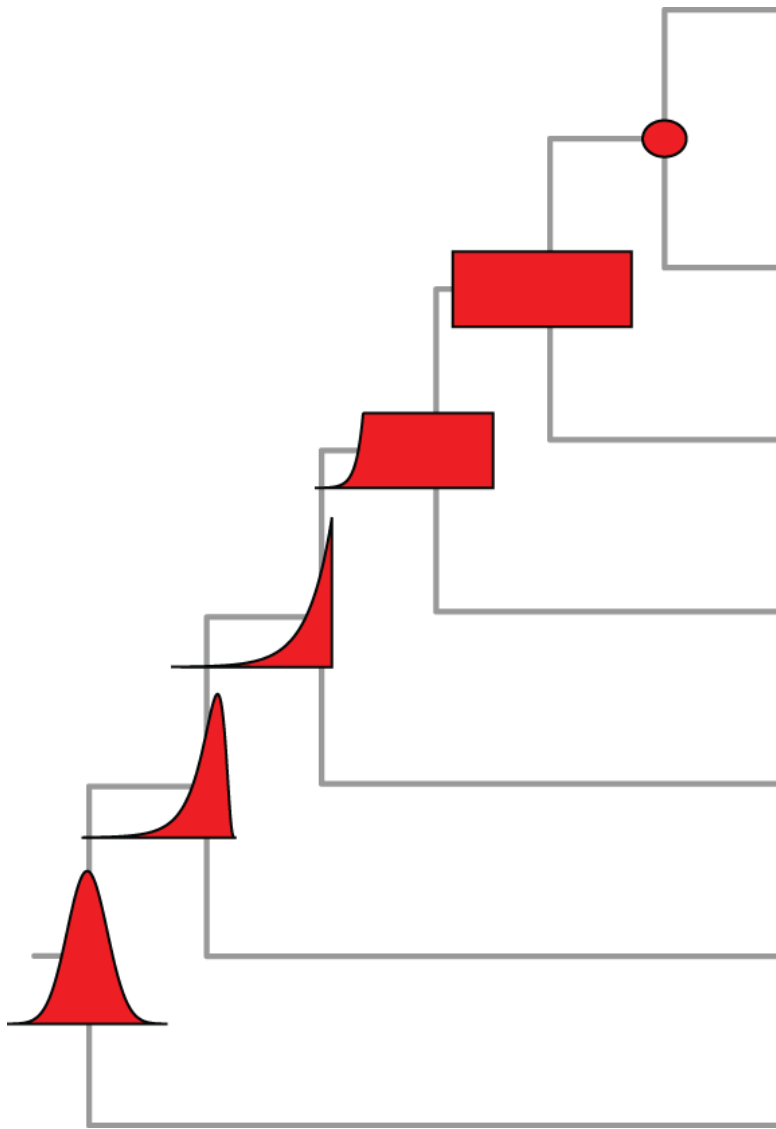- Difficult to choose useful maximum bounds
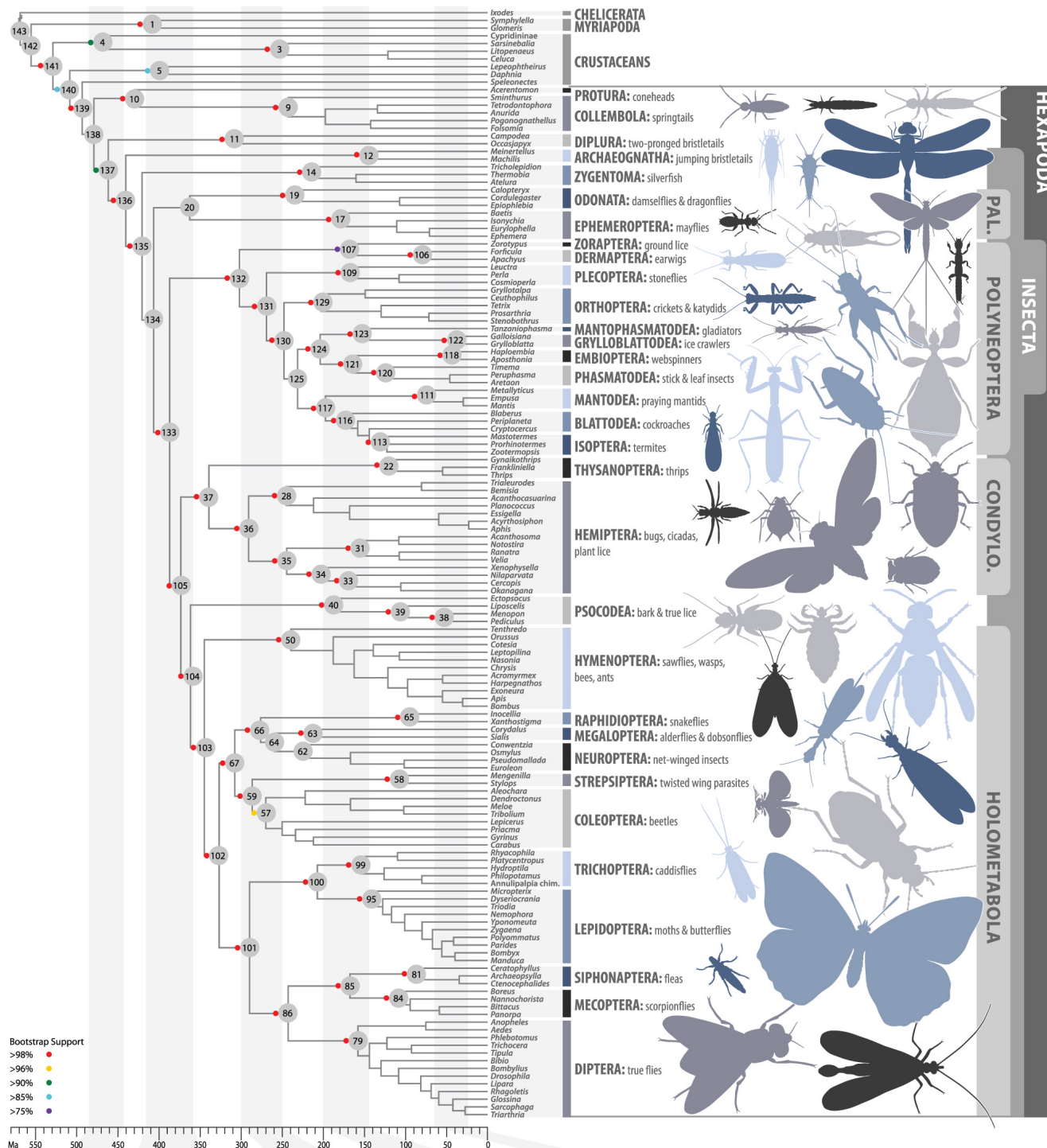
# Calibrations

**Exponential prior**

- Need 2 values: minimum and mean

- Strong assumption about relationship of fossil taxon to internal node

# Calibrations



Mean 7.5 Ma

Soft max. 10 Ma
(2.5% tail)

Human

Chimpanzee

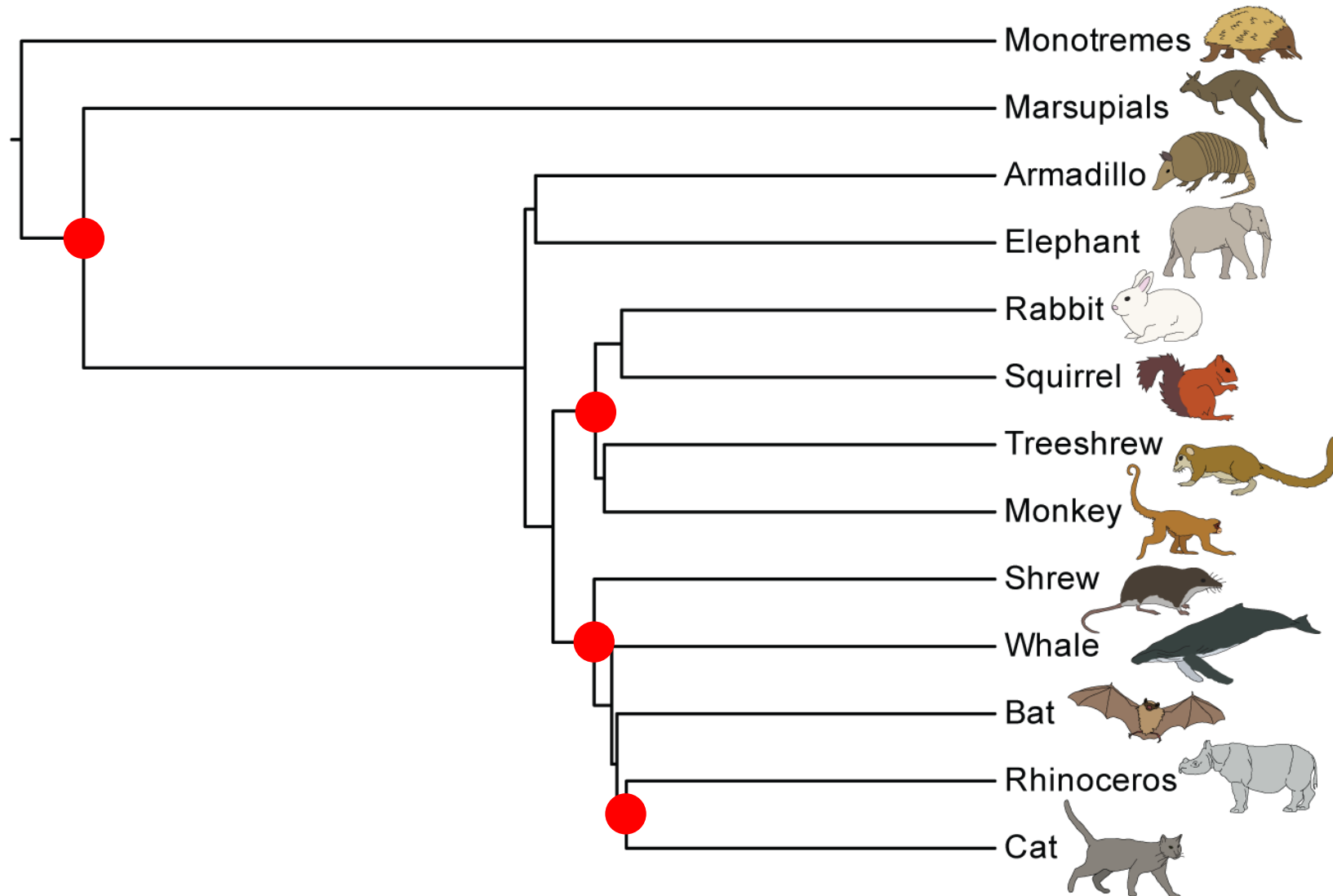Min. 6.5 Ma
(age of fossil)

**Lognormal prior**

- Need 3 values: minimum, mean, and stdev

- Perhaps the most appropriate for fossils

- **Misof *et al*. (2014)**

- Lognormal priors for ages of 20 nodes

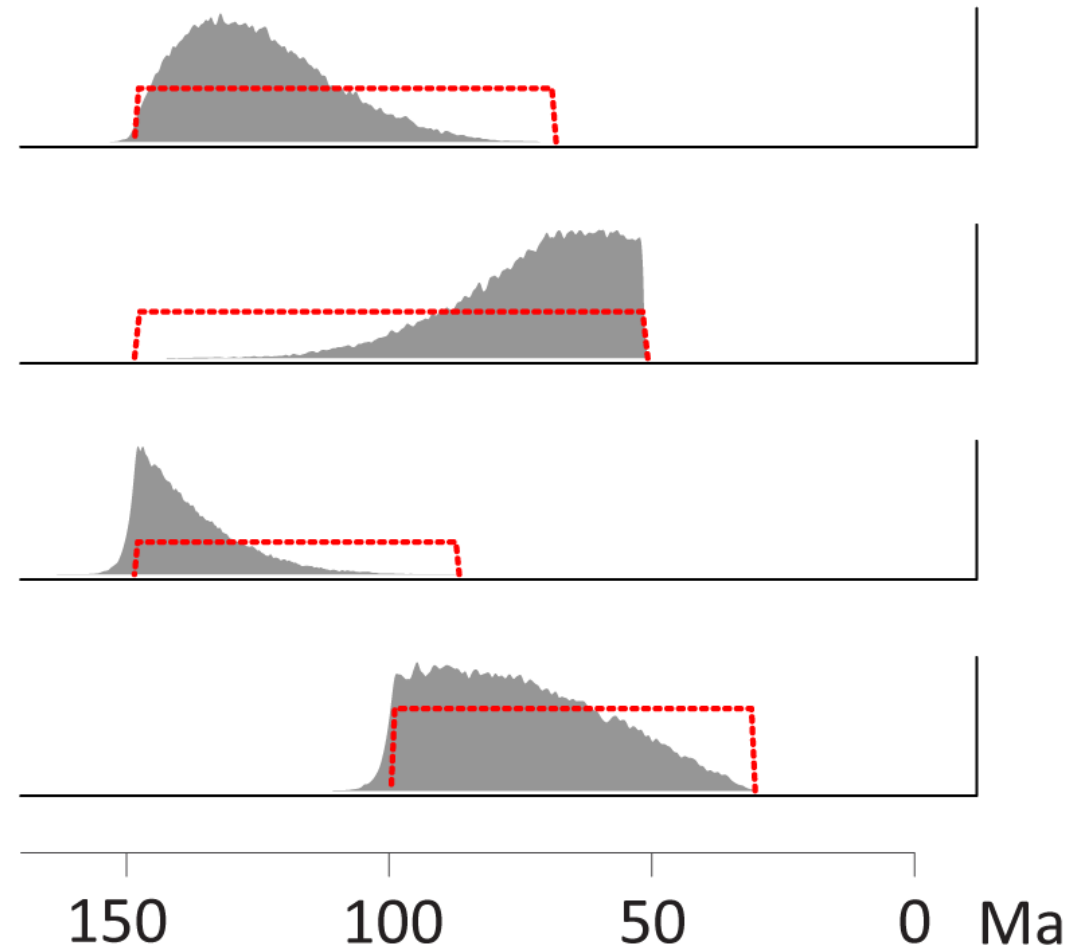- Arbitrary values:
  Mean = 2
  St. dev. = 0.5

# Multiple calibrations
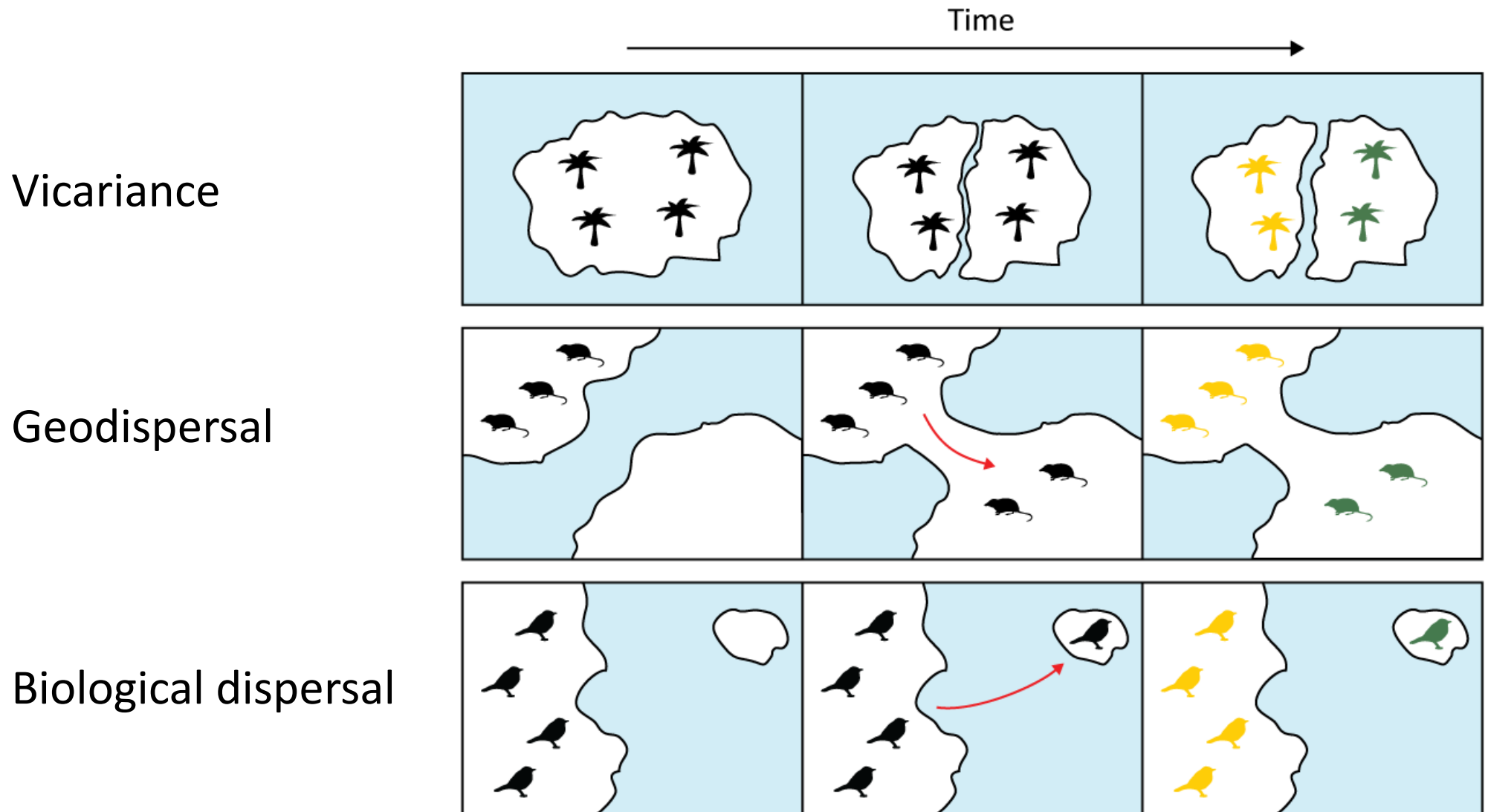
- Use multiple calibrations if possible
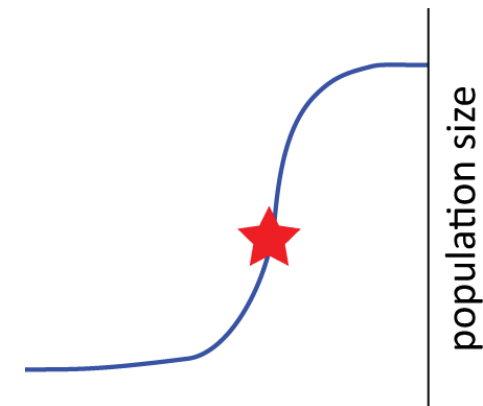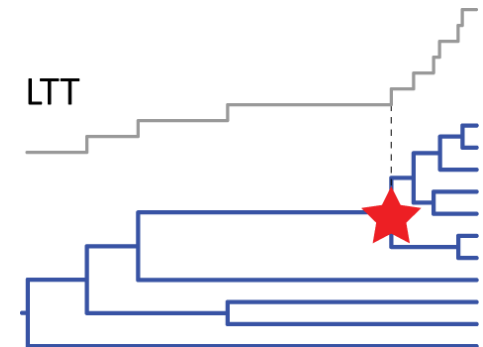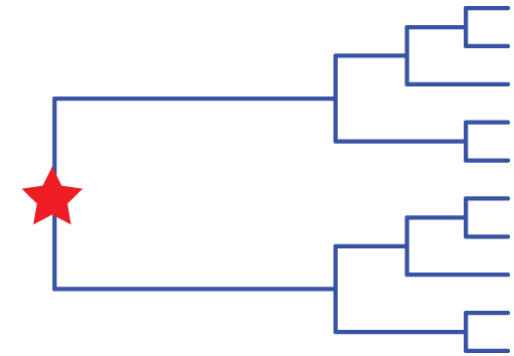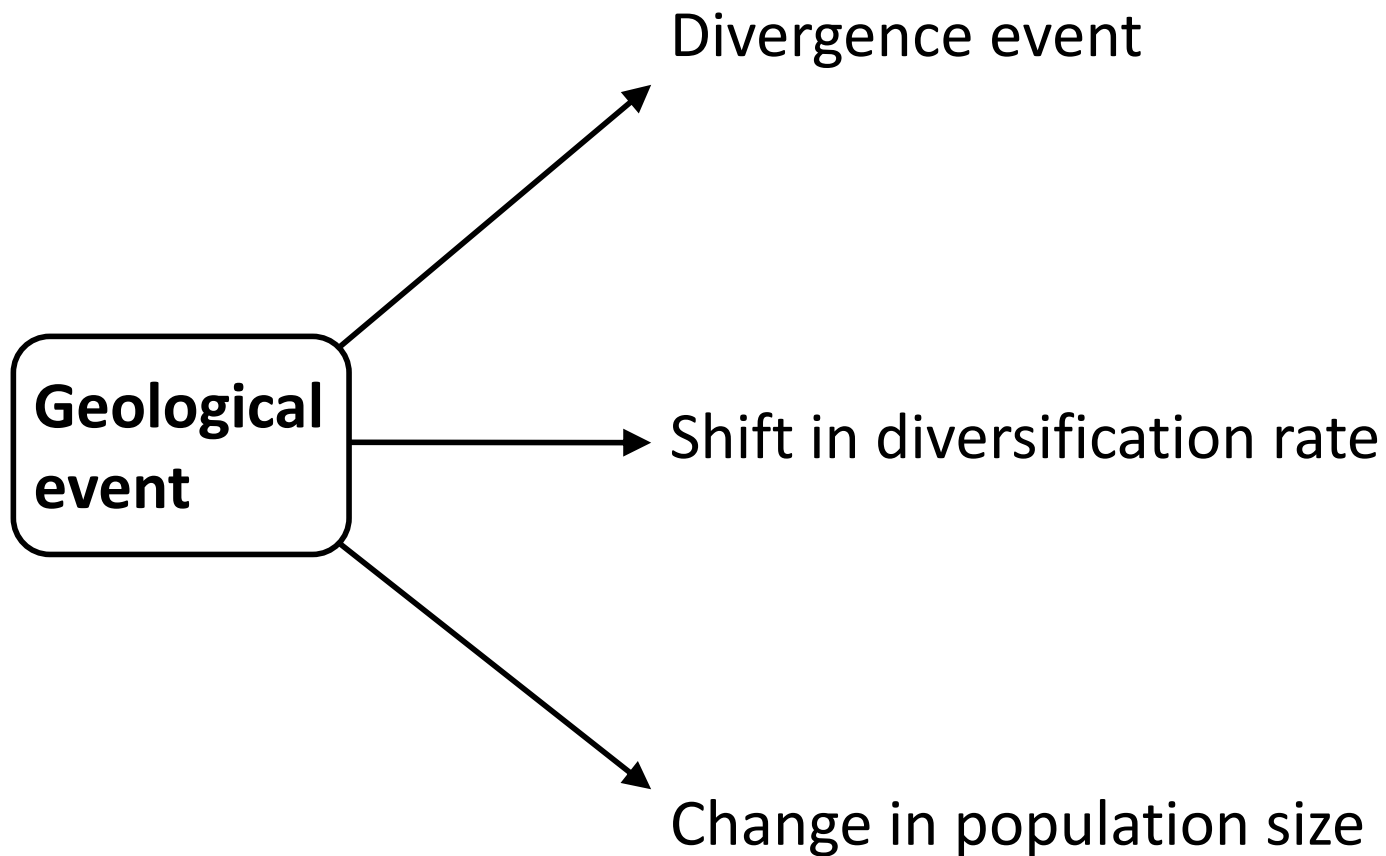
# Multiple calibrations

- Priors on node ages are the joint product of the tree prior and the user-specified calibration priors

- These priors can interact

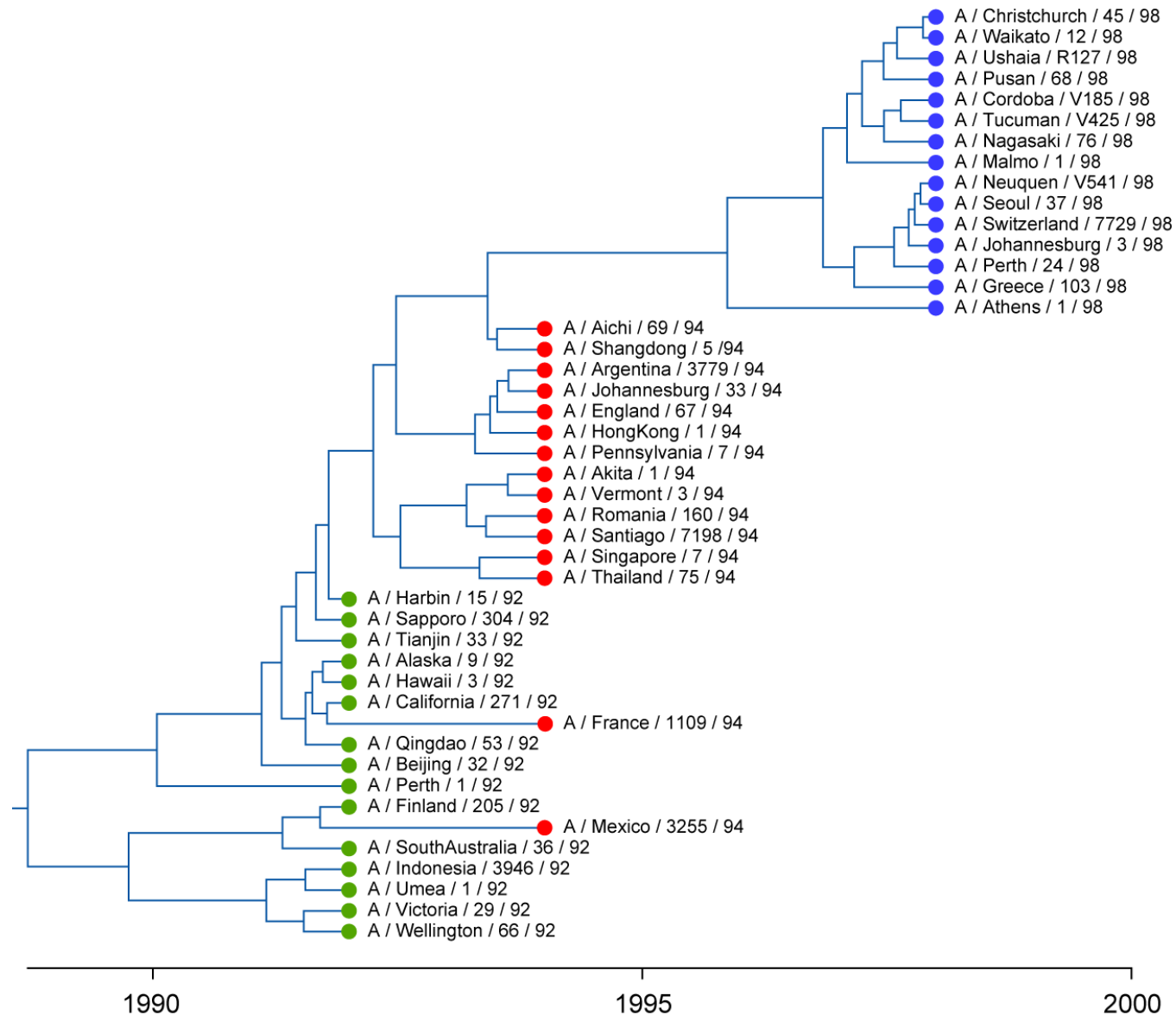- Marginal priors can differ from user-specified priors



150    100    50    0  Ma

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# Calibration: Biogeography



Vicariance

Geodispersal

Biological dispersal

Time

# Calibration: Biogeography

Geological event

Divergence event

Shift in diversification rate

LTT

Change in population size

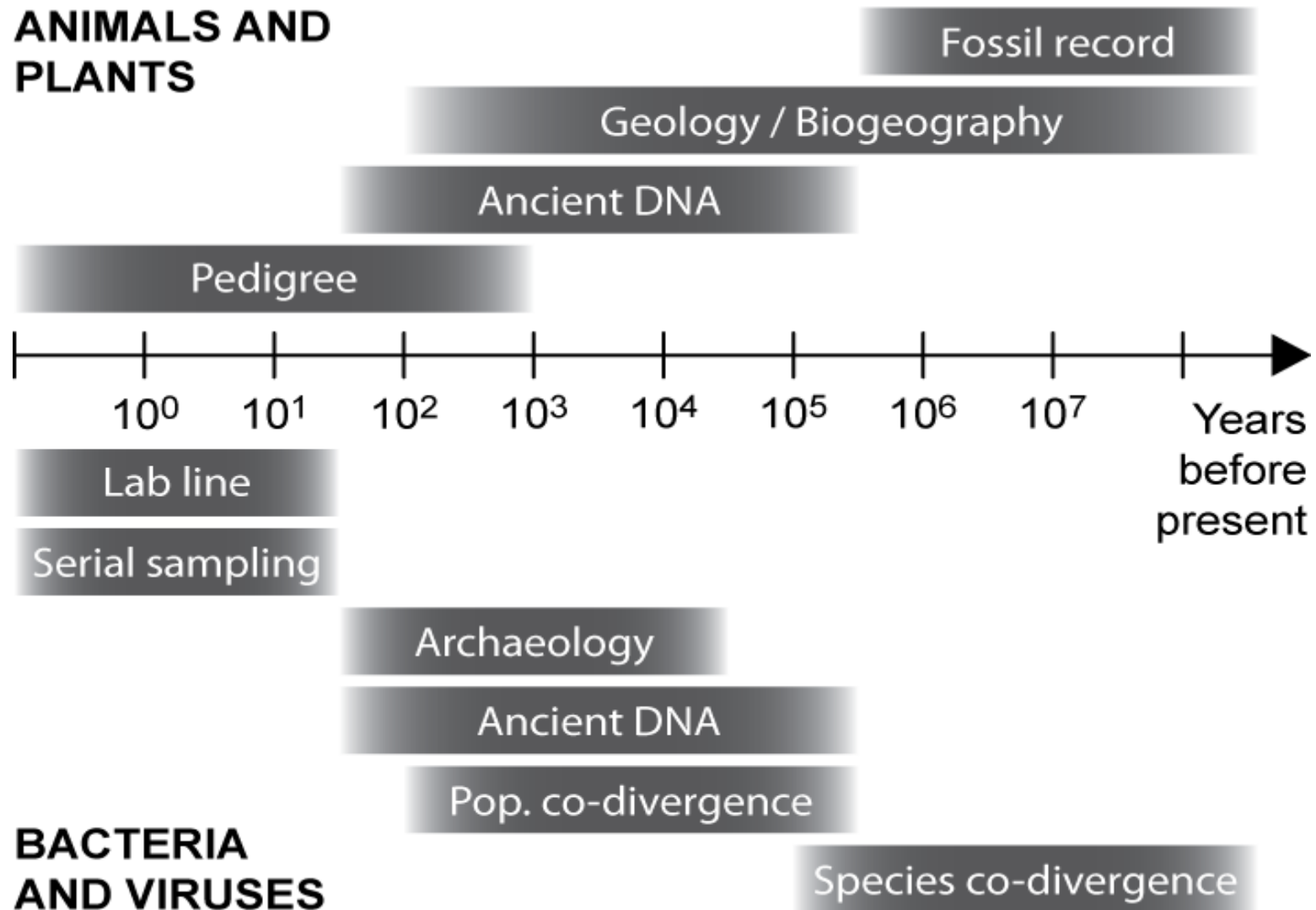population size

# Calibration: Sampling times

# Calibration: Sampling times



50 ky
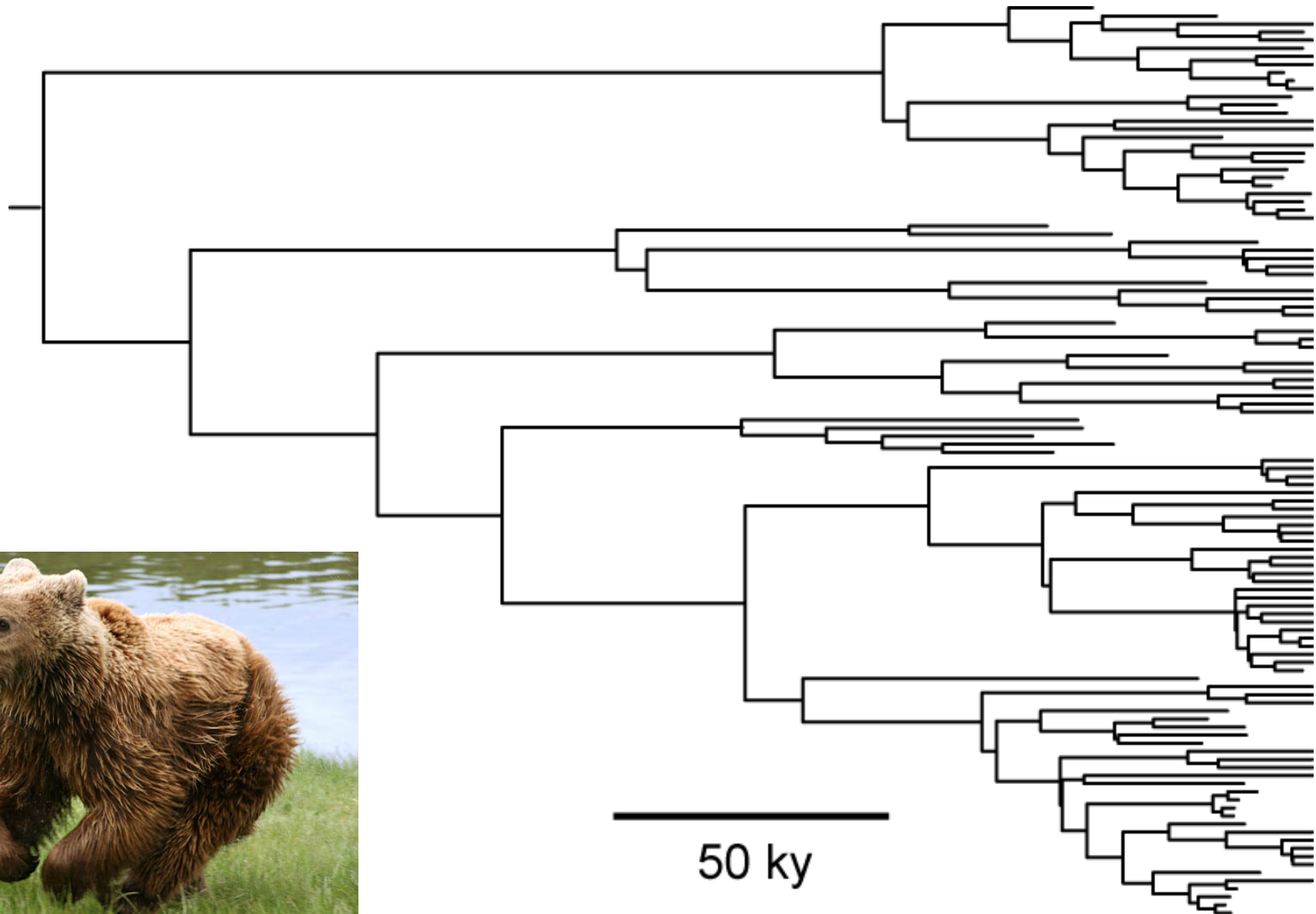
# Calibrations

# Time-dependent rate estimates

# Time-dependent rate estimates



Duchene, Holmes, & Ho (2014) *Proc Roy Soc B* 20
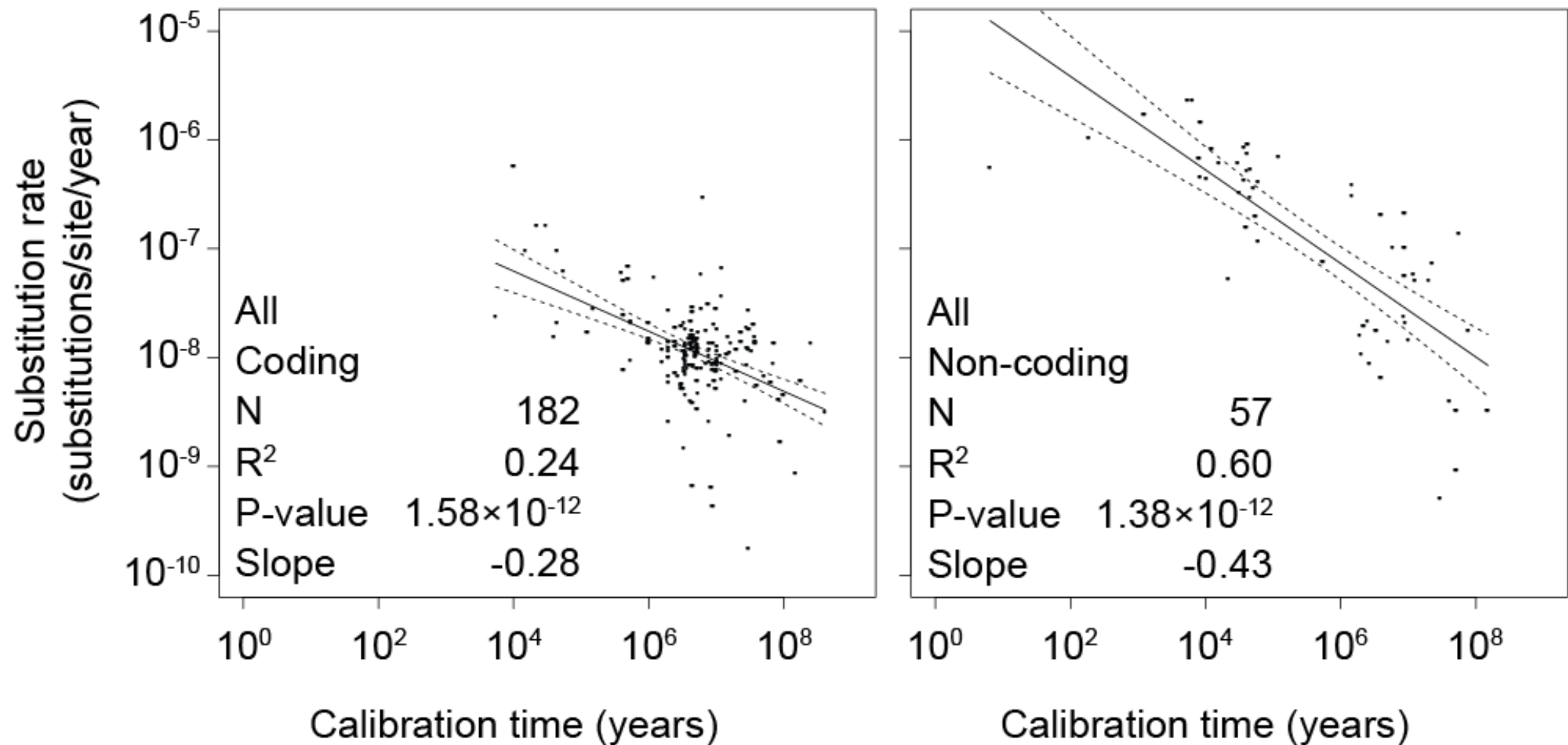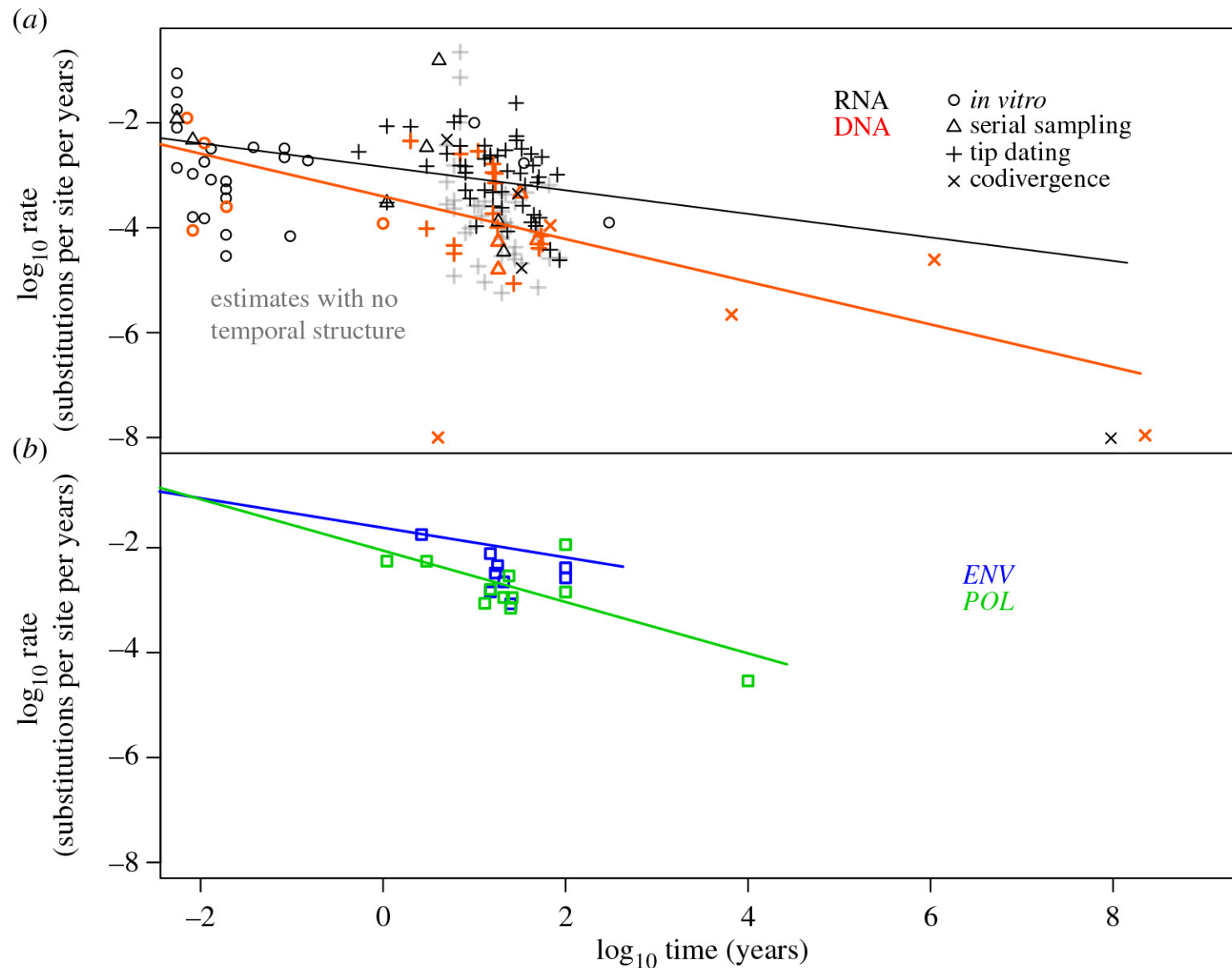
# Choosing calibrations

- Use multiple calibrations if possible

- The age estimates for poorly supported clades should be interpreted carefully

- Careful selection of clock models can improve the estimates
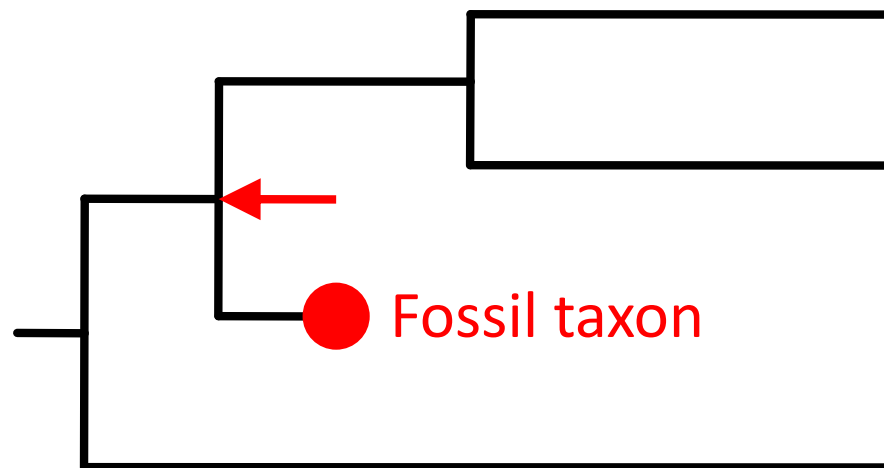
# Total-Evidence Dating

# Total-evidence dating

- Combined morphological and molecular data set

- Fossil taxa included

  - Phylogenetic placement estimated using morphological data

  - Age acts as a calibration by constraining the age of parent node
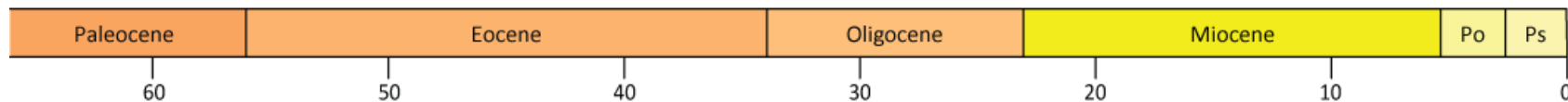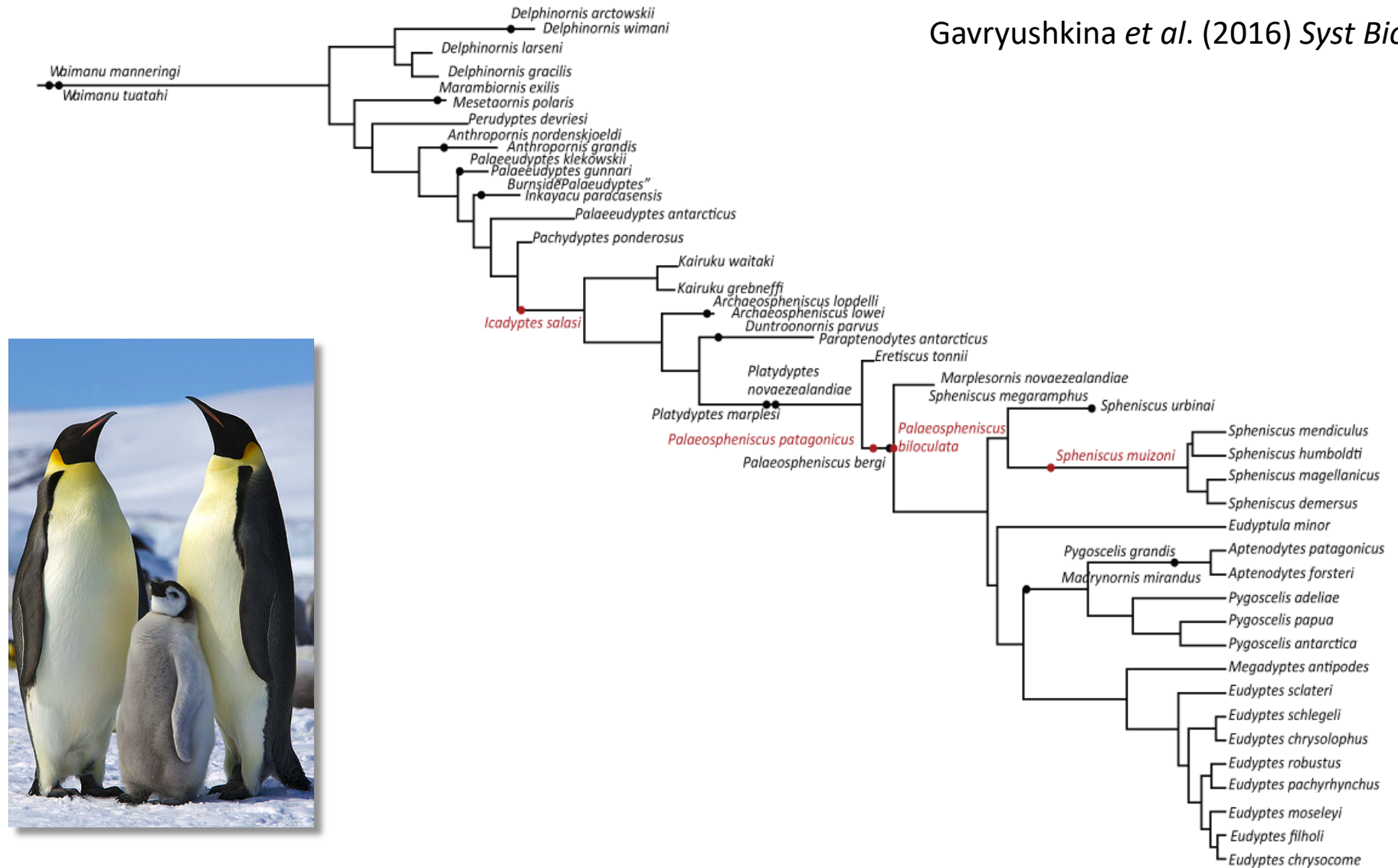
- Birth-death tree prior

# Total-evidence dating

- Avoids the need to construct priors for ages of internal nodes

- Can include fossil taxa with uncertain phylogenetic position

- Can provide sufficient calibration without the need to include maximum age constraints

Fossil taxon

# Total-evidence dating



Gavryushkina *et al.* (2016) *Syst Biol*

# Useful references

- **Calibration uncertainty in molecular dating analyses: there is no substitution for the prior evaluation of time priors**
Warnock *et al.* (2014) *Proceedings of the Royal Society B*, 282: 20141013.

- **Time-dependent rates of molecular evolution**
Ho *et al.* (2011) *Molecular Ecology*, 20: 3087–3101.

- **Accounting for uncertainty in phylogenetic estimation of evolutonary divergence times**
Ho & Phillips (2009) *Systematic Biology*, 58: 367–380.

- **Best practices for justifying fossil calibrations**
Parham *et al.* (2012) *Systematic Biology*, 61: 346–359.

- **Biogeographic calibrations for the molecular clock**
Ho *et al.* (2015) *Biology Letters*, 11: 20150194.