Lecture 2.4

Calibrating the Molecular Clock

Calibrating the molecular clock

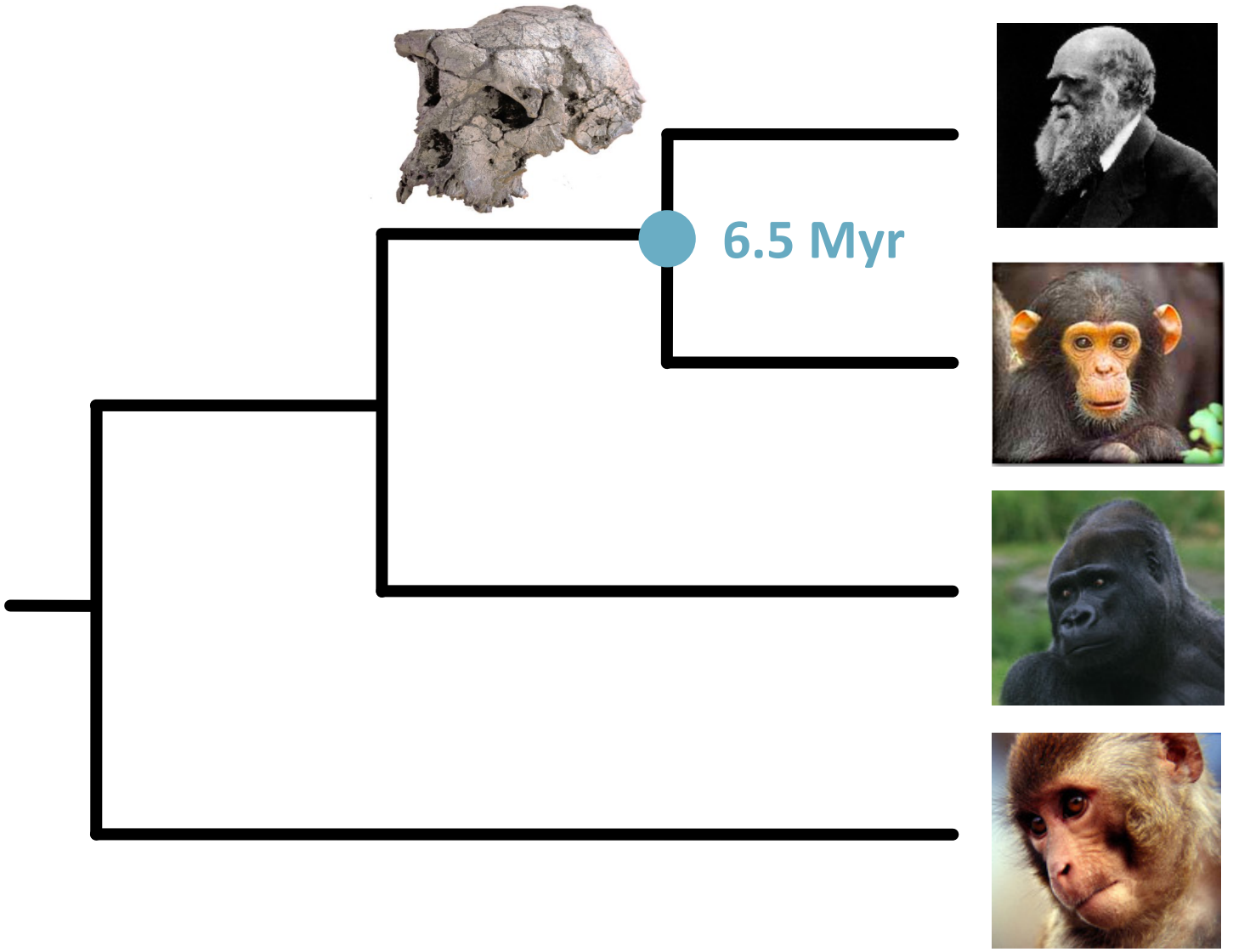
- Rates and times are **non-identifiable**
- Likelihood only depends on their product
  - Branch lengths in substitutions per site
- To separate rate and time, we need (prior) information about one or the other

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



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)

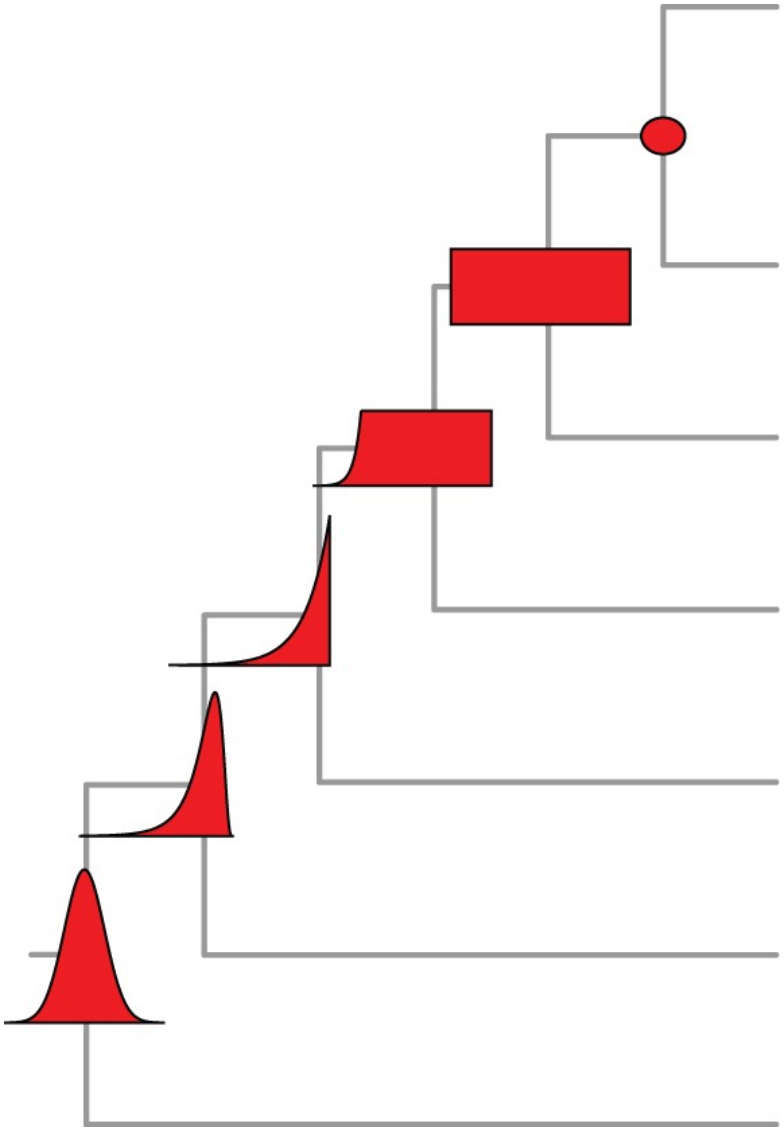
Choosing fossil calibrations

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

Parham *et al*. (2012) *Syst Biol*

Calibration Priors

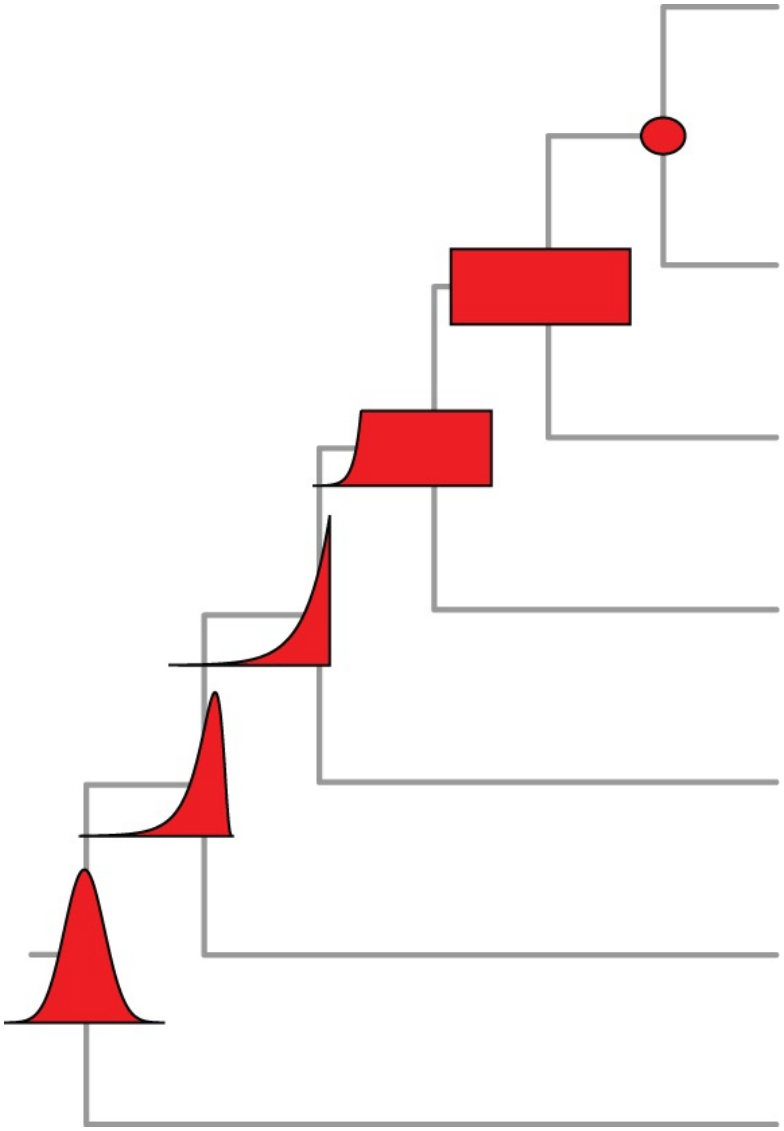
Calibrations



Point calibration

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

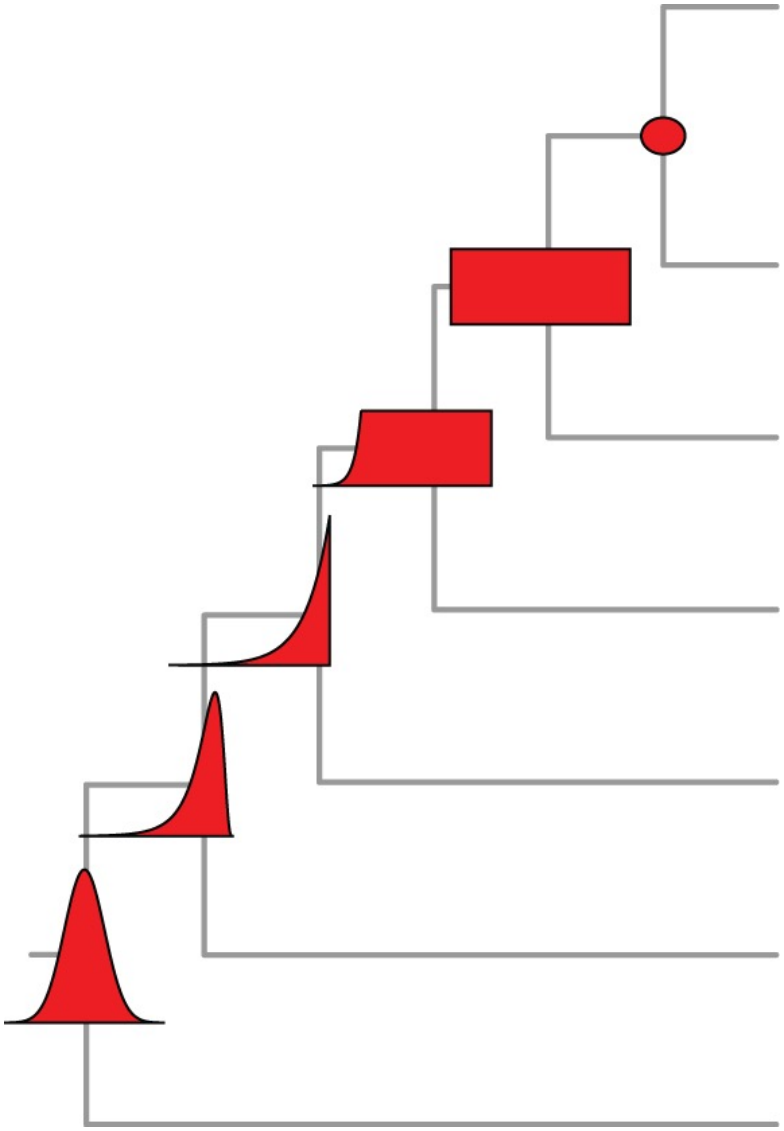
Calibrations



Uniform prior

- Combination of hard minimum and maximum bounds
- Does not effectively use information at hand
- Difficult to choose useful maximum bounds

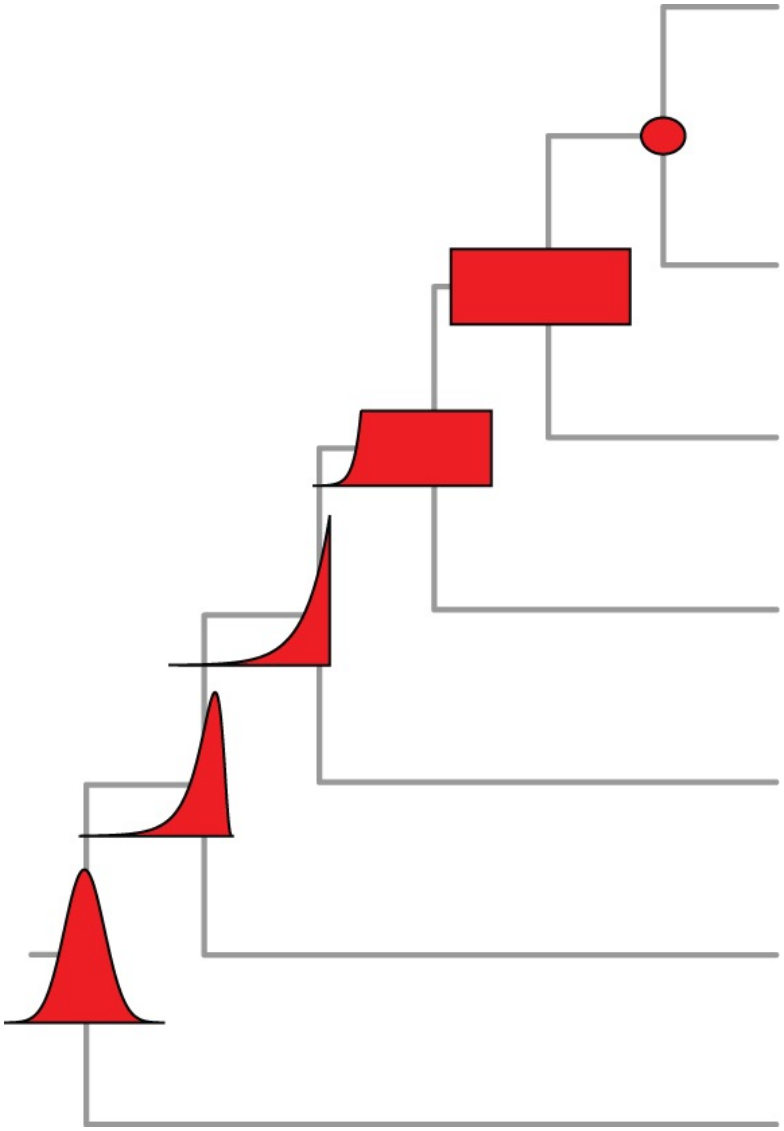
Calibrations

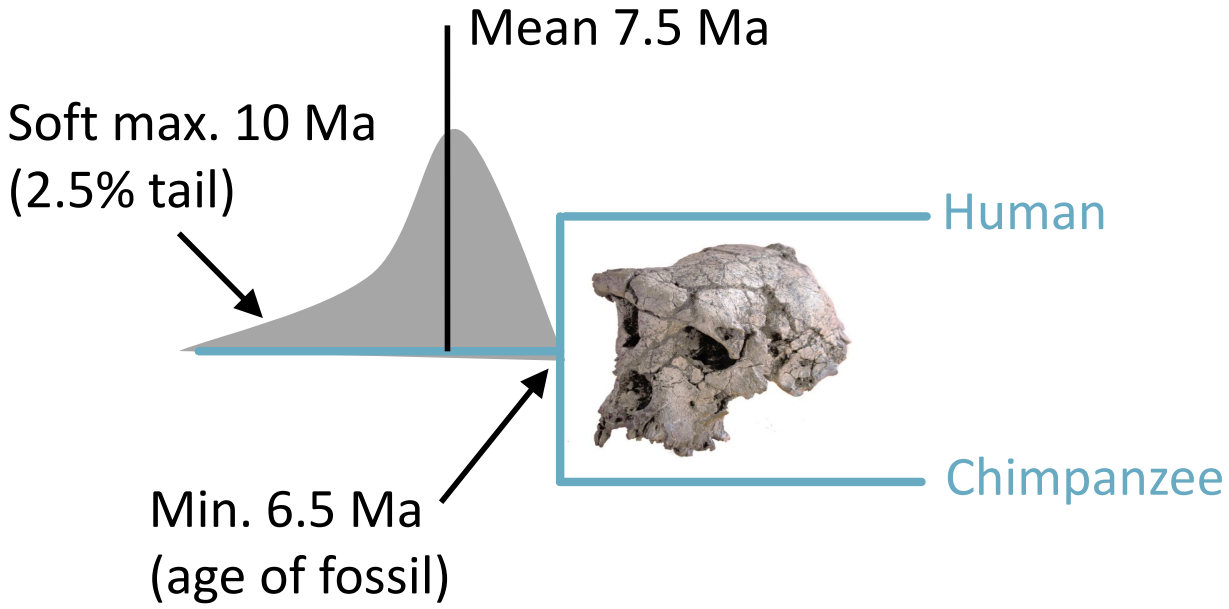


Exponential prior

- Need 2 values: minimum and mean
- Strong assumption about relationship of fossil taxon to internal node

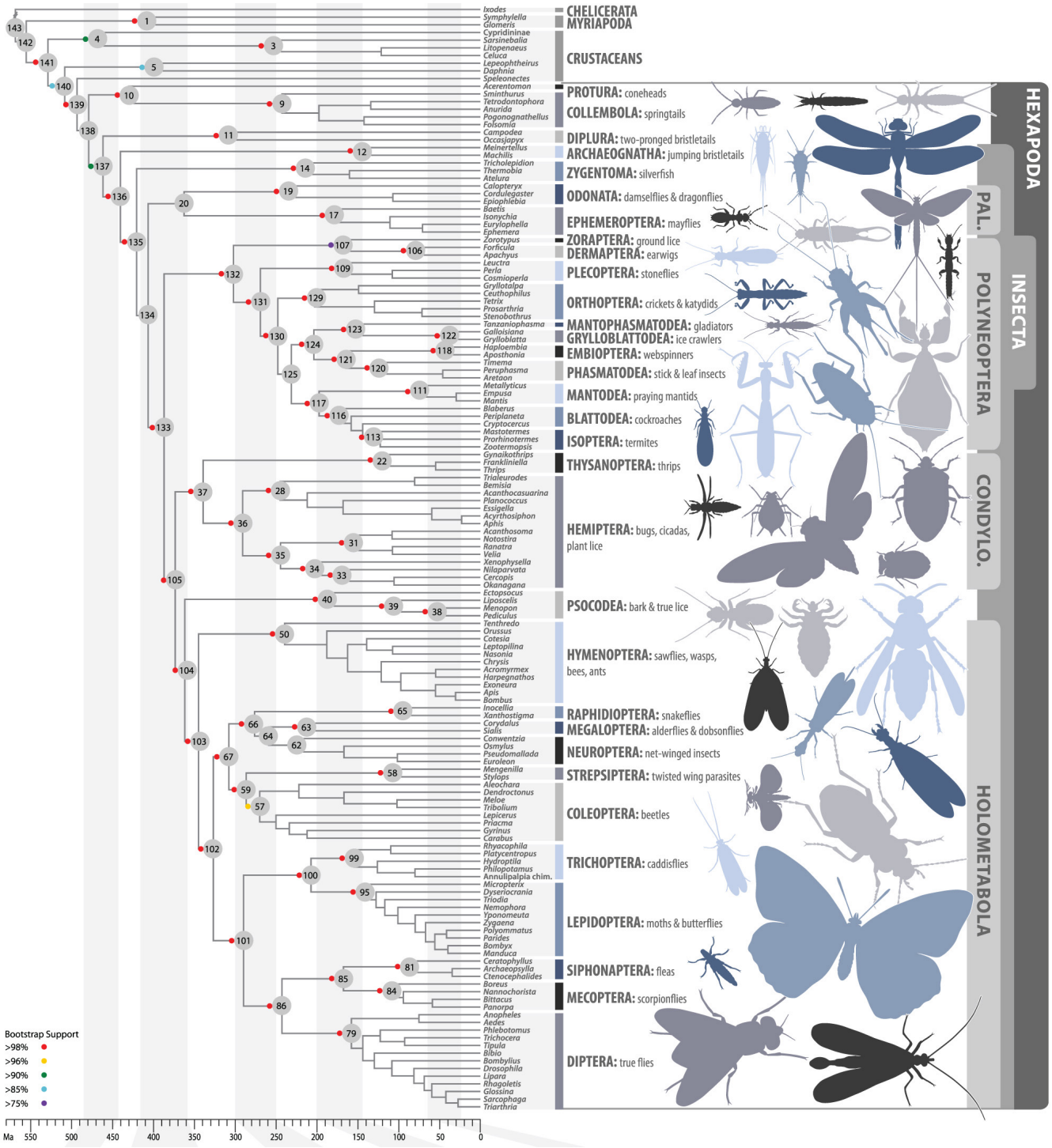
Calibrations





Lognormal prior

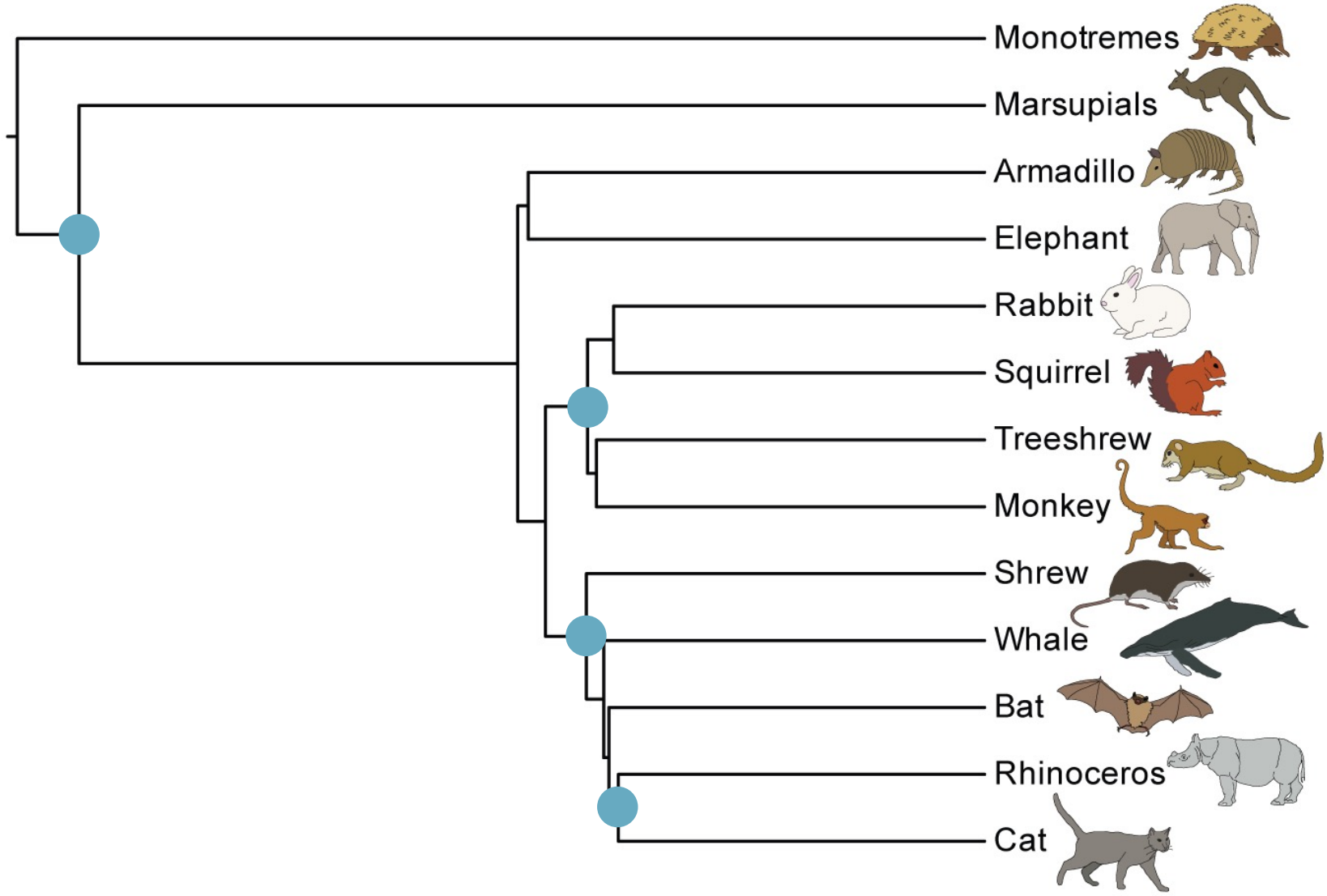
- Need 3 values: minimum, mean, and stdev
- Perhaps the most appropriate for fossils



- **Misof *et al*. (2014)**
- Lognormal priors for ages of 20 nodes
- Arbitrary values:
  Mean = 2
  St. dev. = 0.5

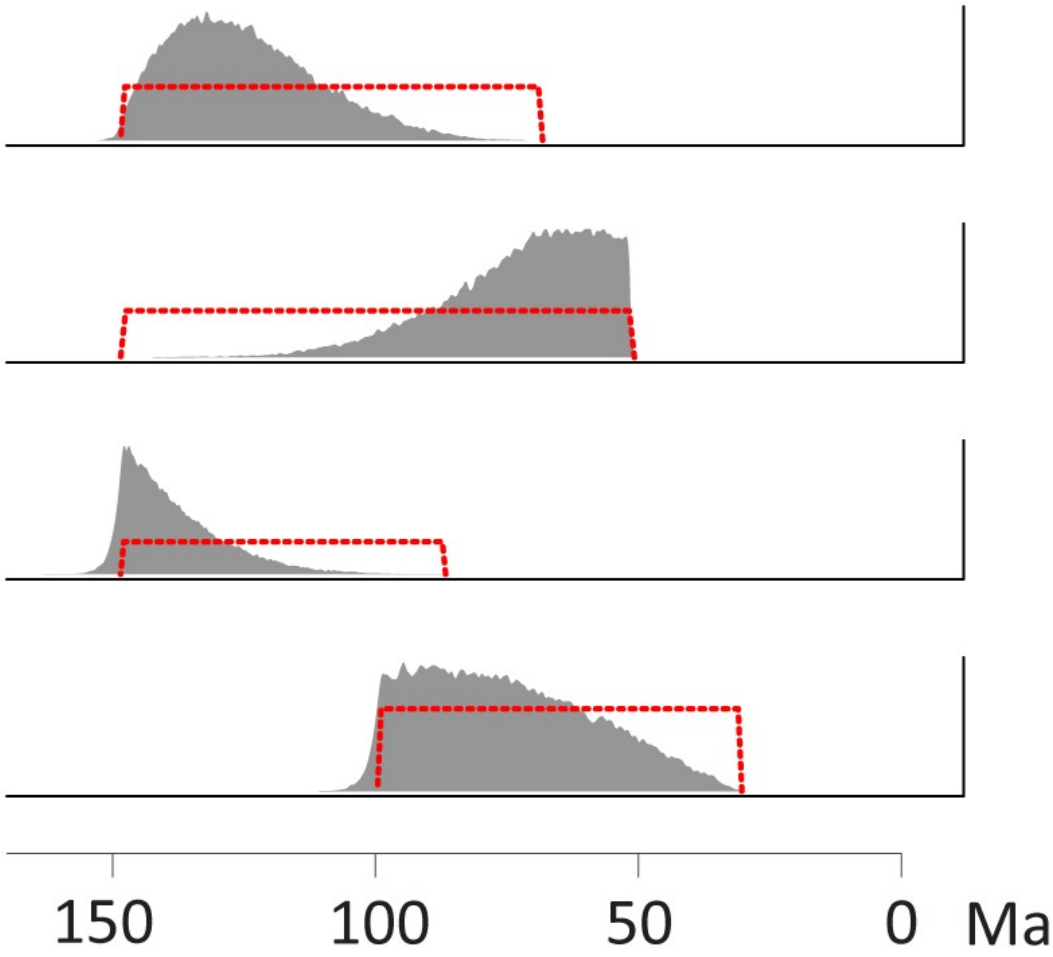
Multiple calibrations

- 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



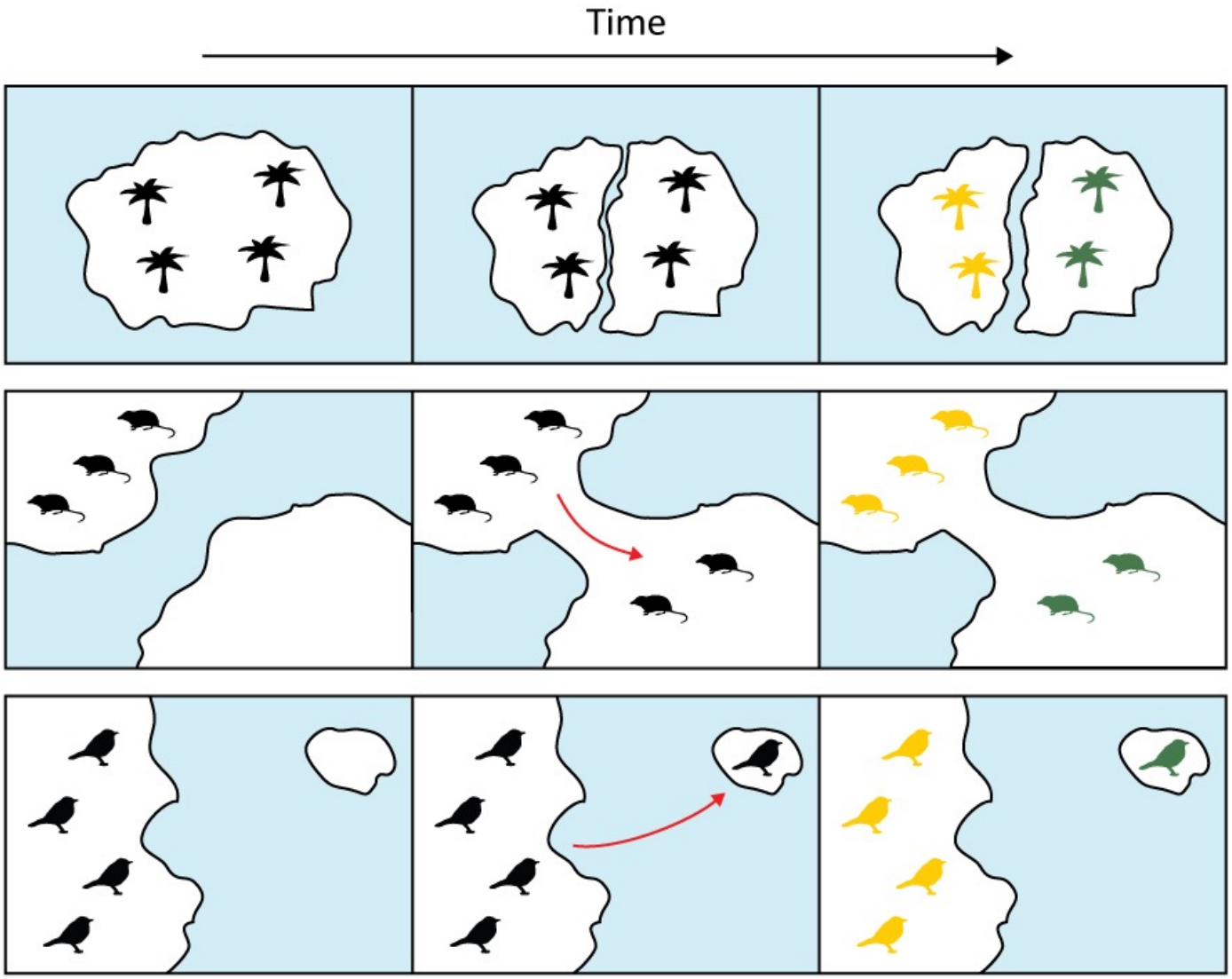
Warnock *et al*. (2014) *Proc Roy Soc B*

Calibration: Biogeography

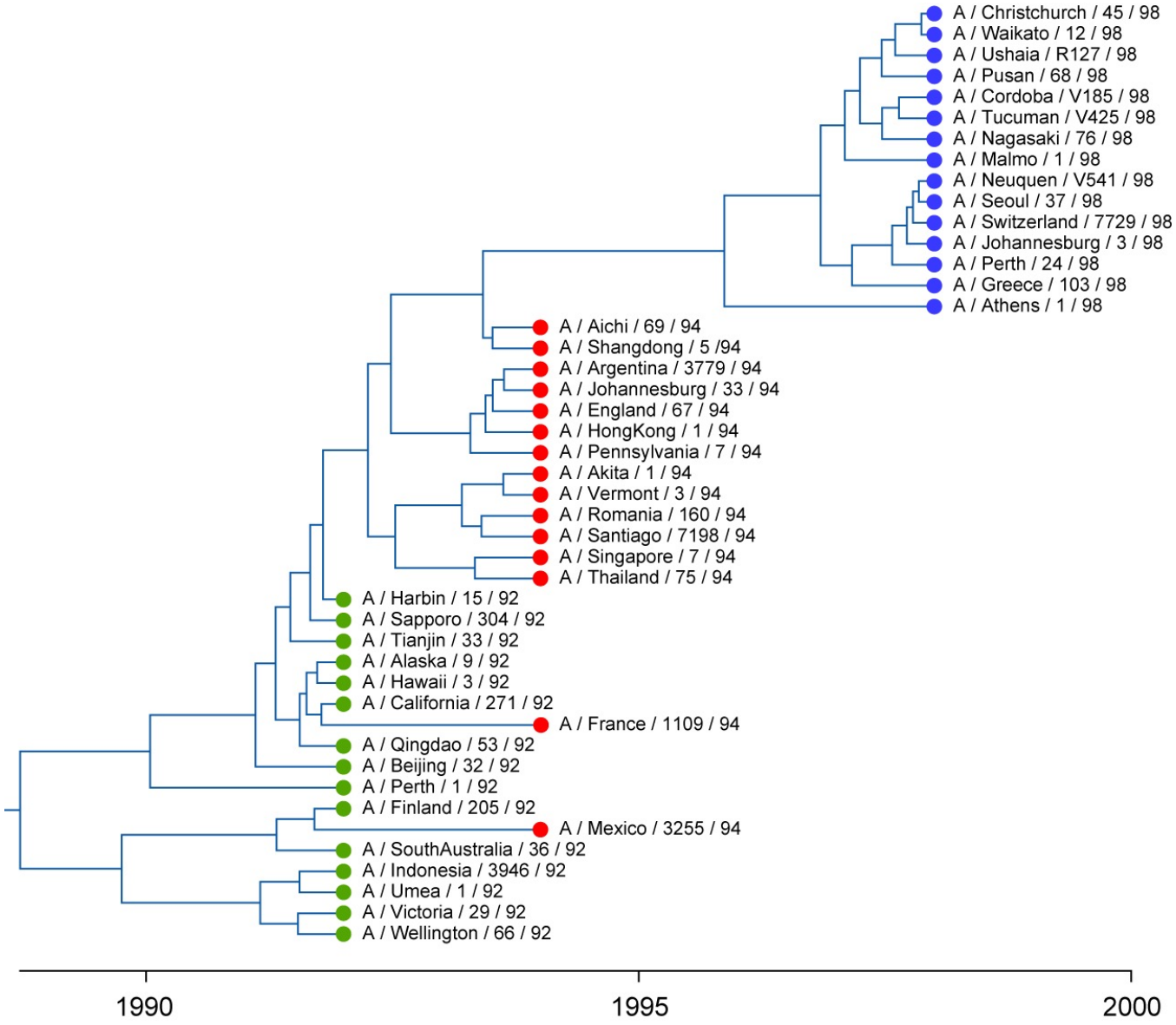
Vicariance

Geodispersal

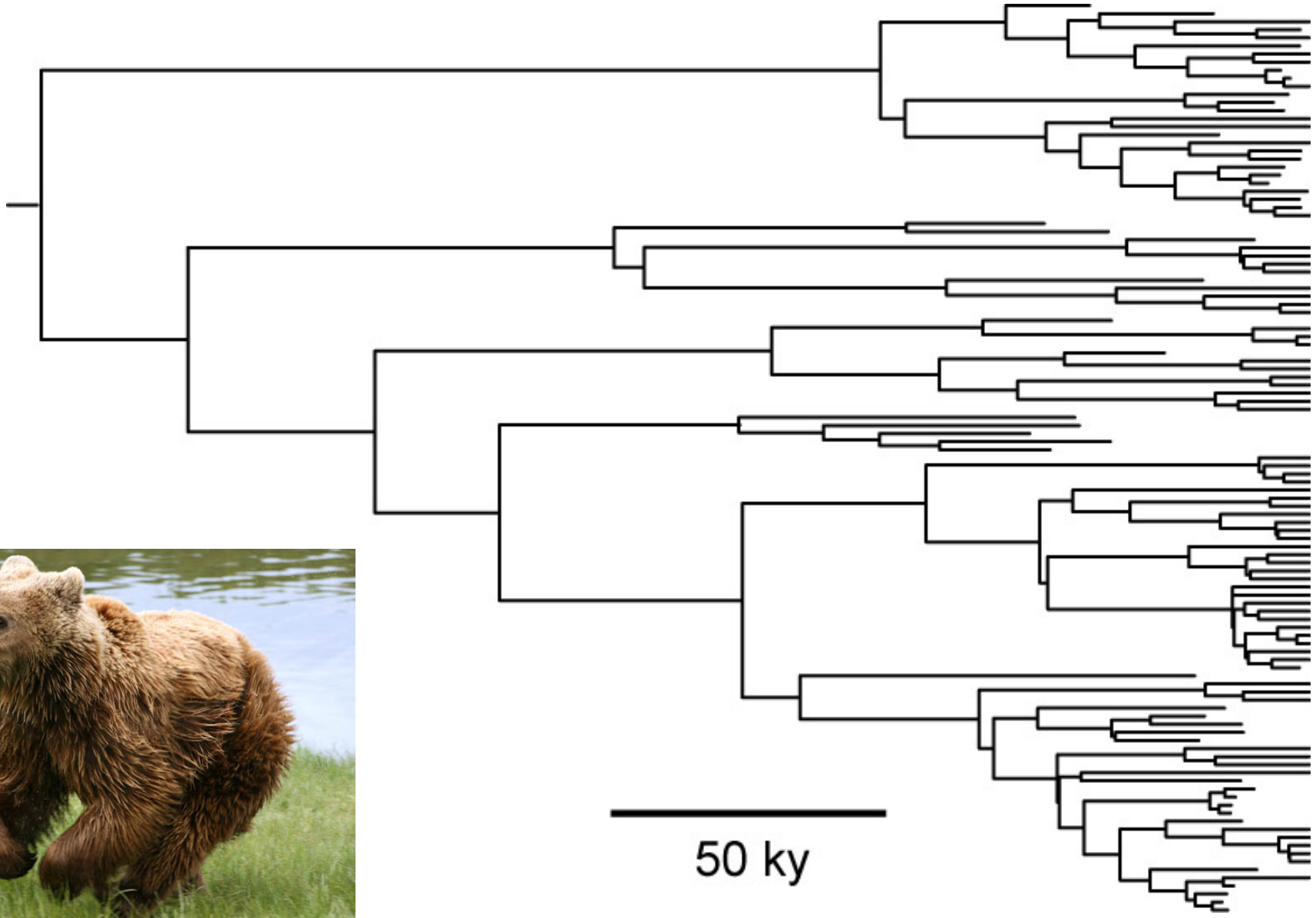
Biological dispersal



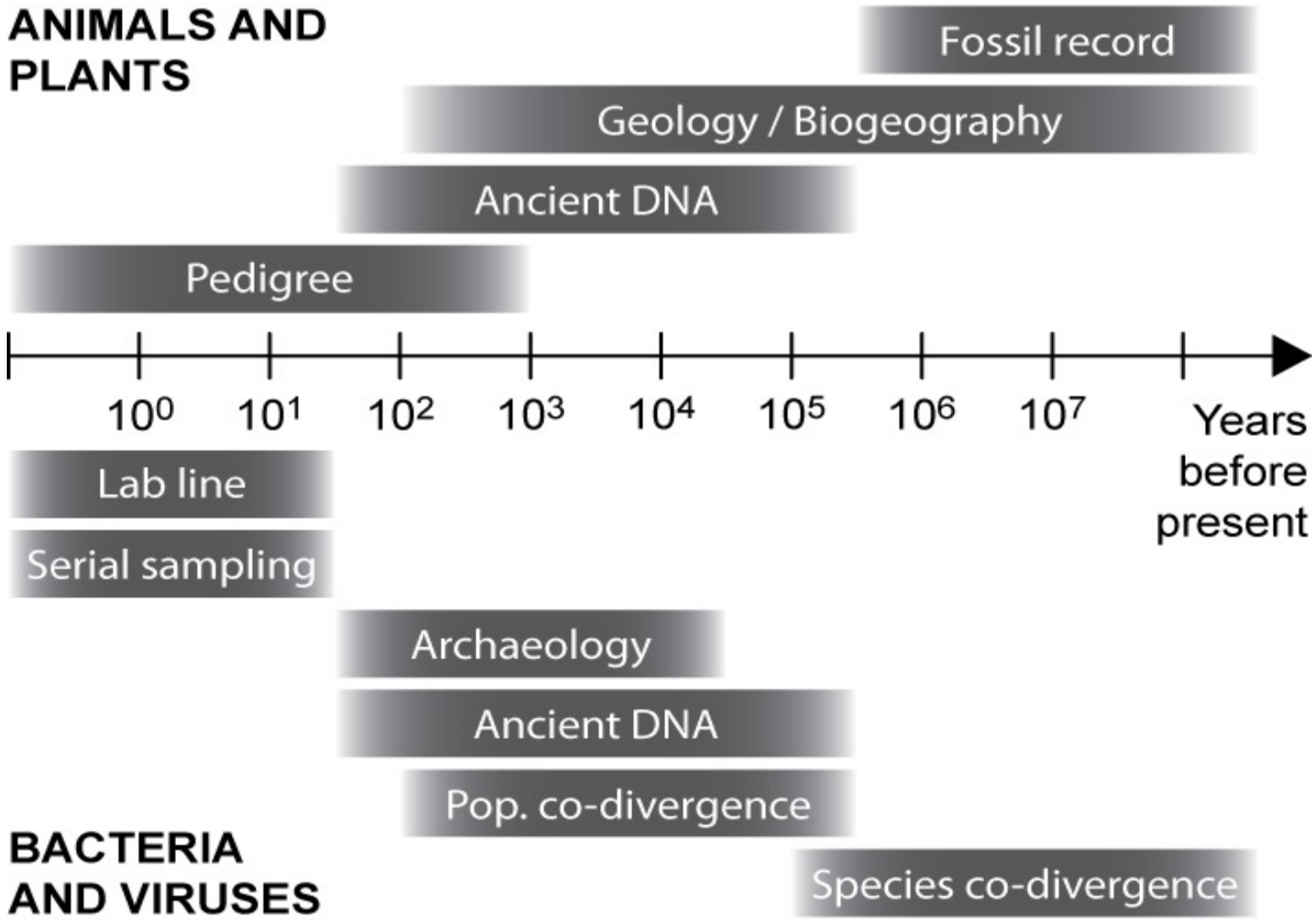
Calibration: Sampling times



Calibration: Sampling times



Calibrations



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

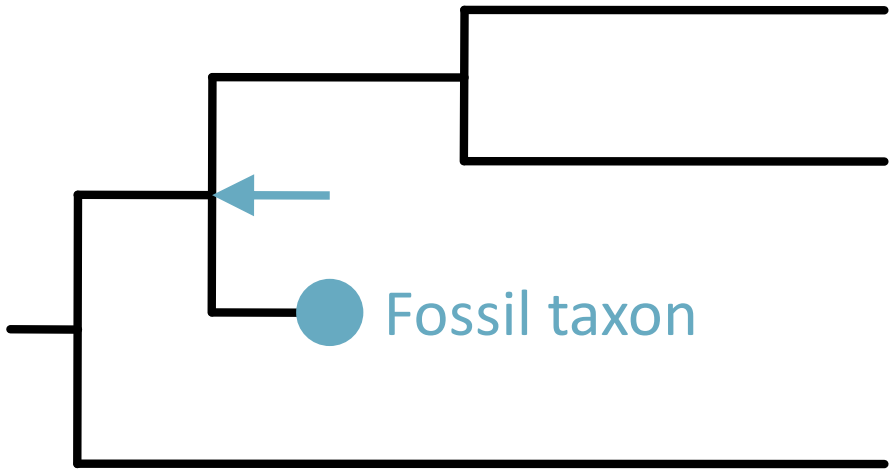
Total-Evidence Dating

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



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.
- **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.