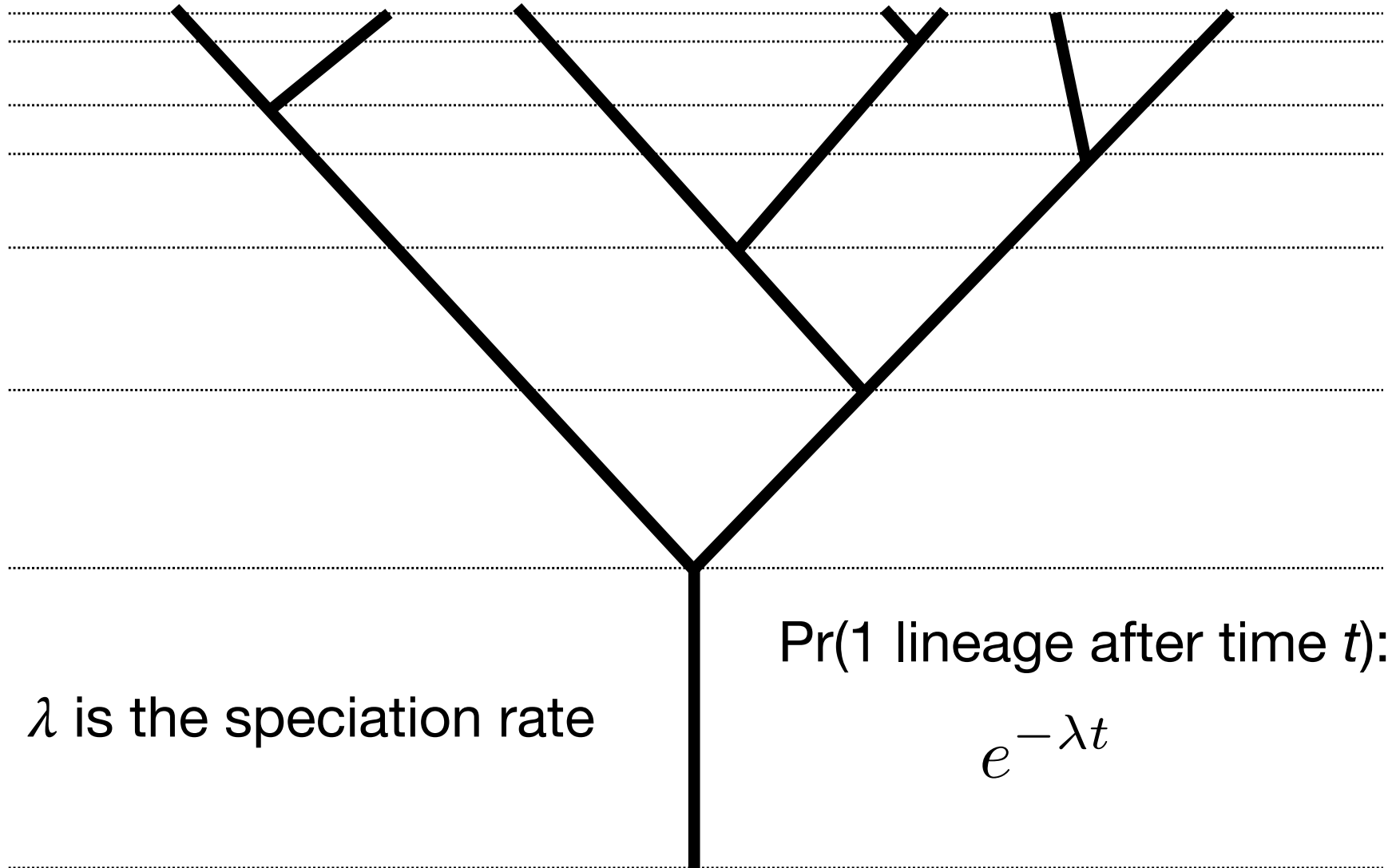
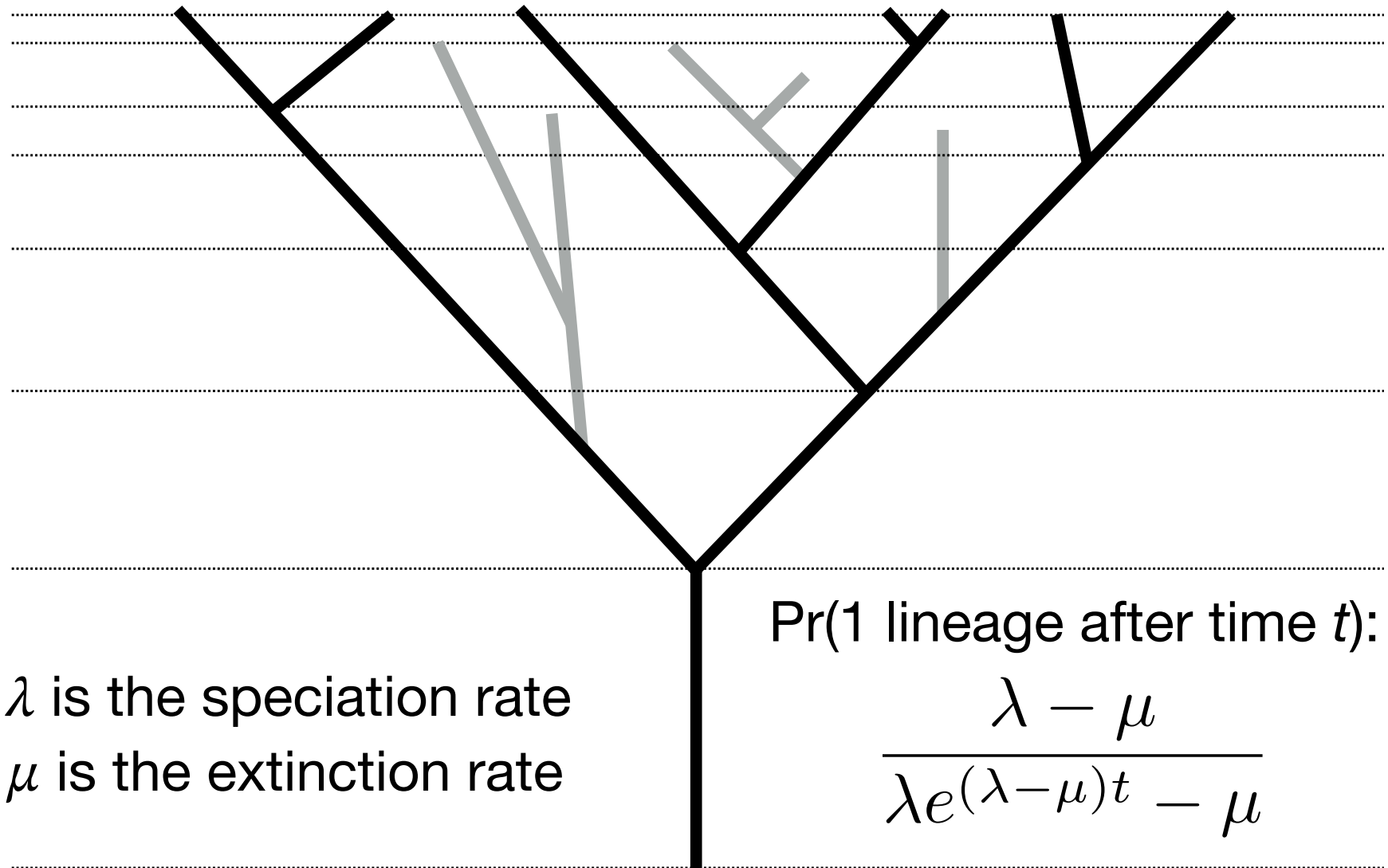


Yule model: pure birth process

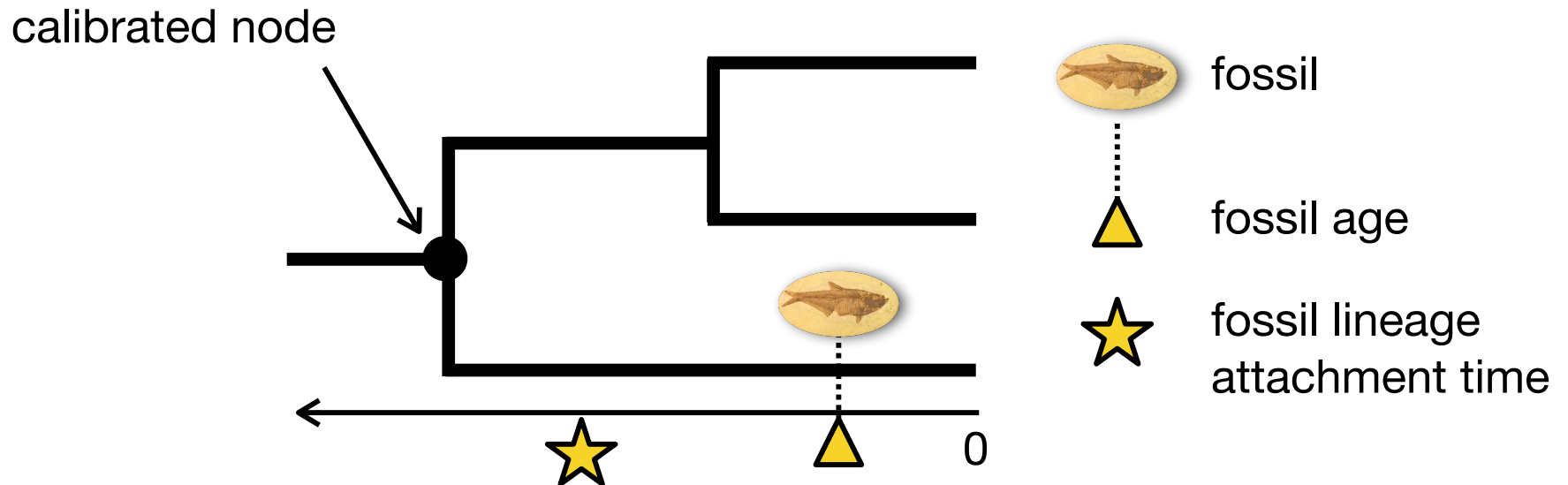


More general birth-death process



Fossilized Birth-Death Process

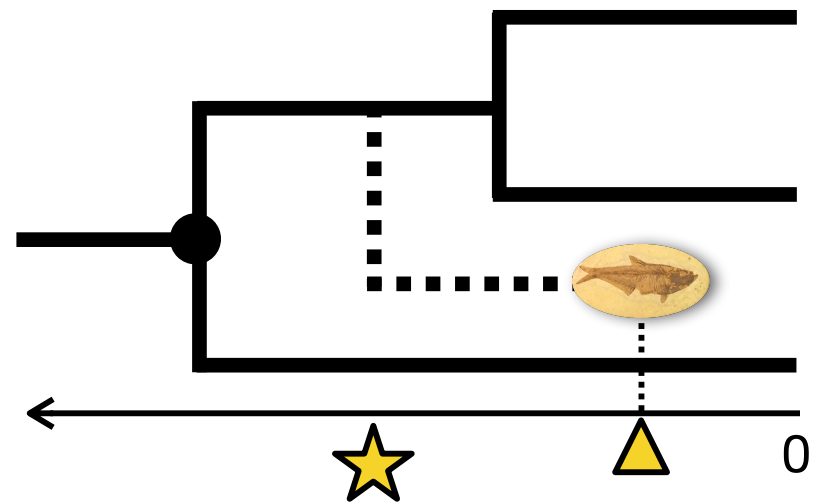
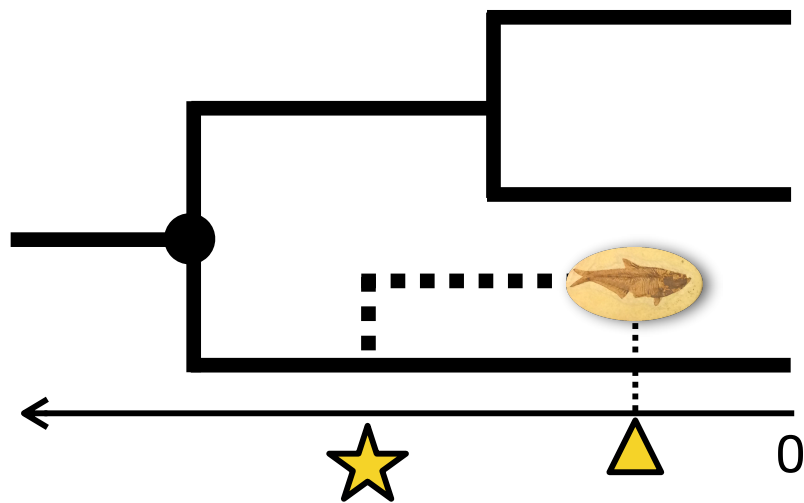
Assumes only that fossil is a descendant of the *calibrated node*



Assume for a moment that you know the age of the fossil and the time at which the fossil's lineage attached to the tree...

Fossilized Birth-Death Process

Given the tree, the calibrated node, the fossil age, and the attachment time, there are only **2 places** the fossil could attach to the tree



fossil



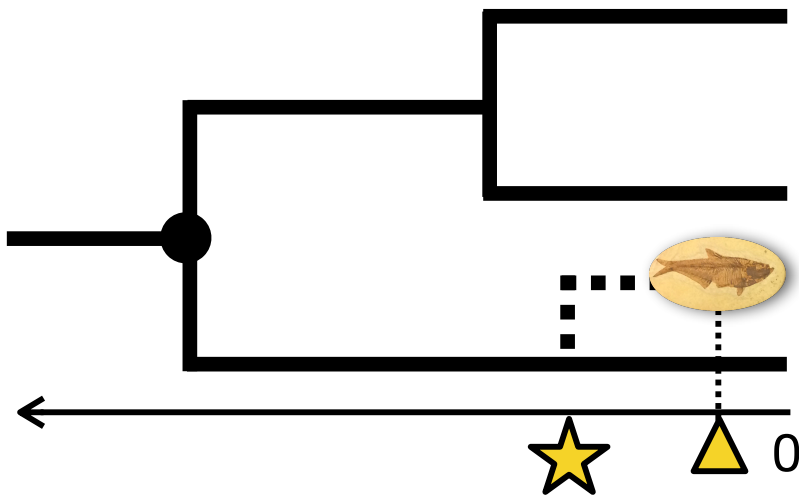
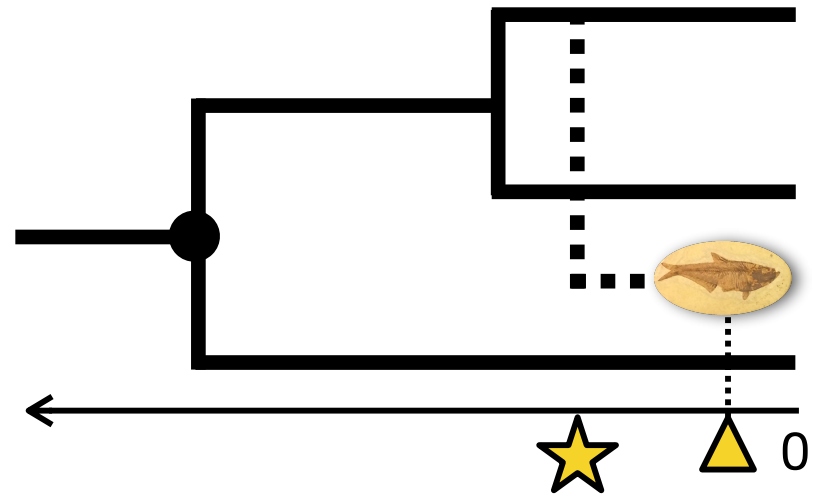
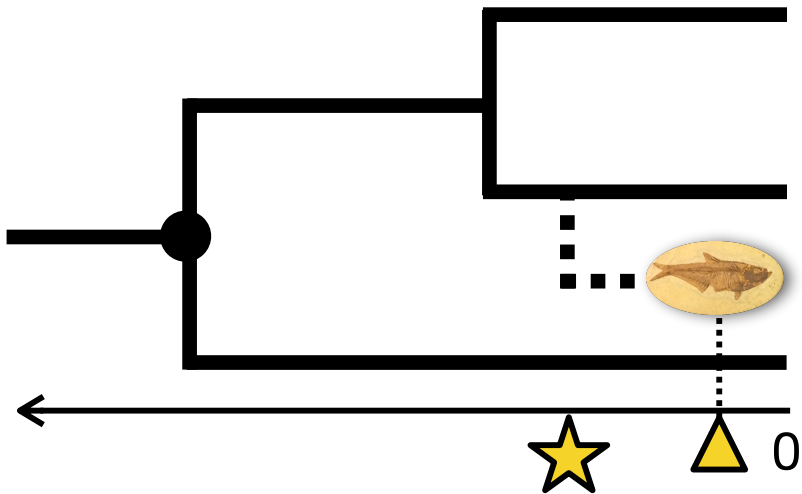
fossil age



fossil lineage attachment time

Fossilized Birth-Death Process

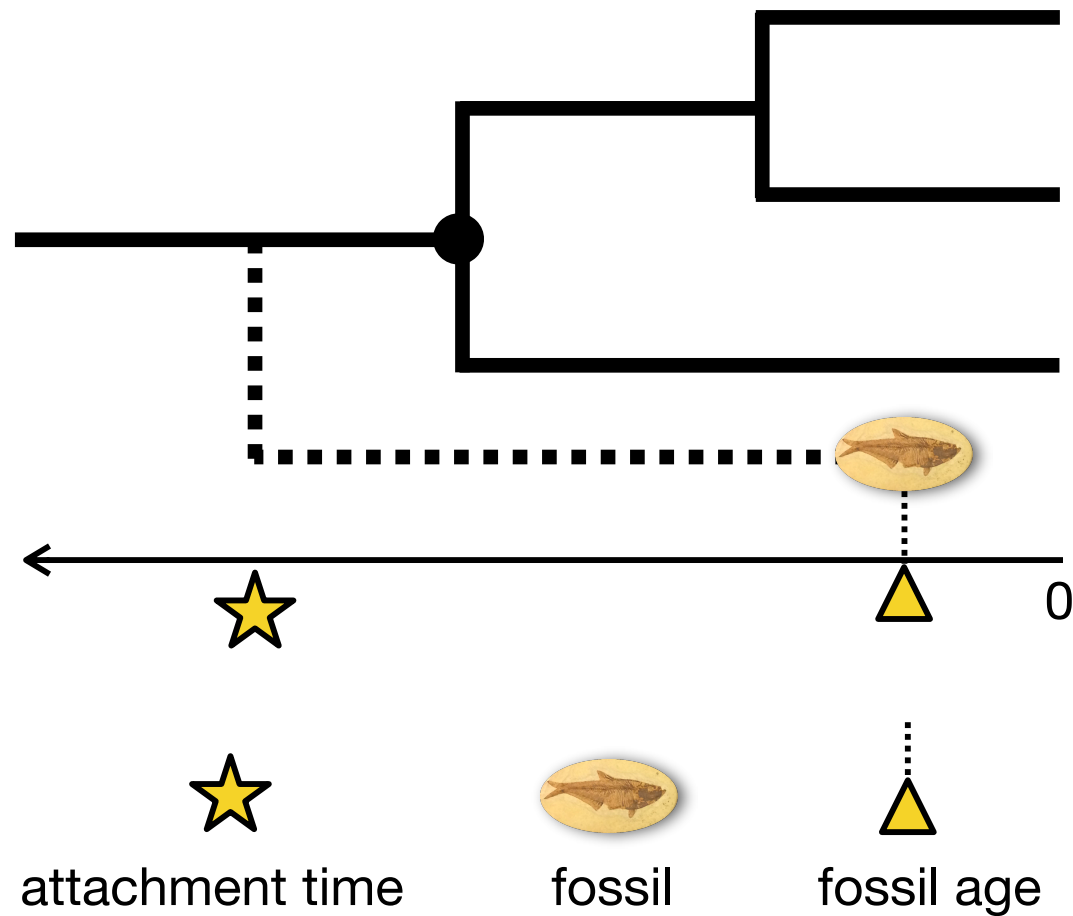
In this case, there are 3 possible attachment points



The birth-death prior model provides the probability density of each of these alternatives

Fossilized Birth-Death Process

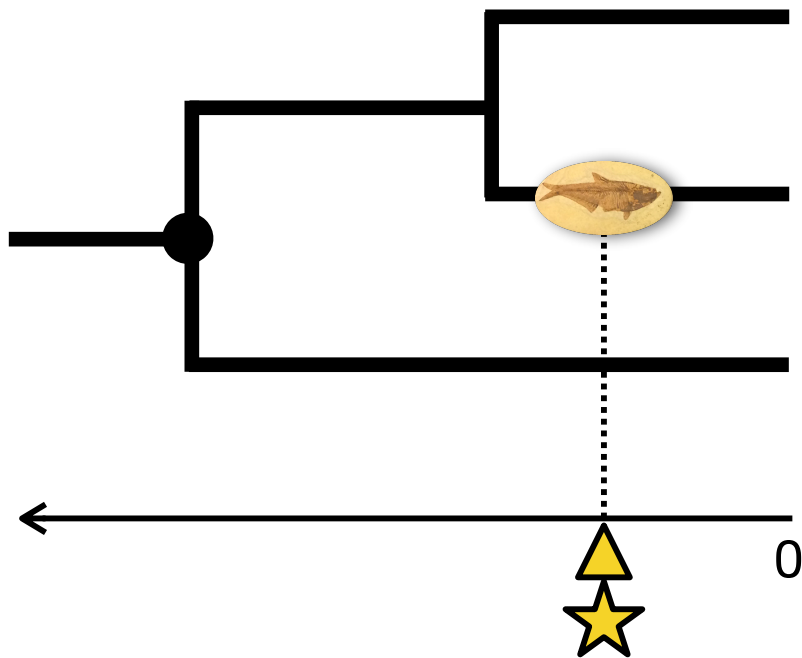
It is possible for the fossil to attach along the **stem** of the calibrated node



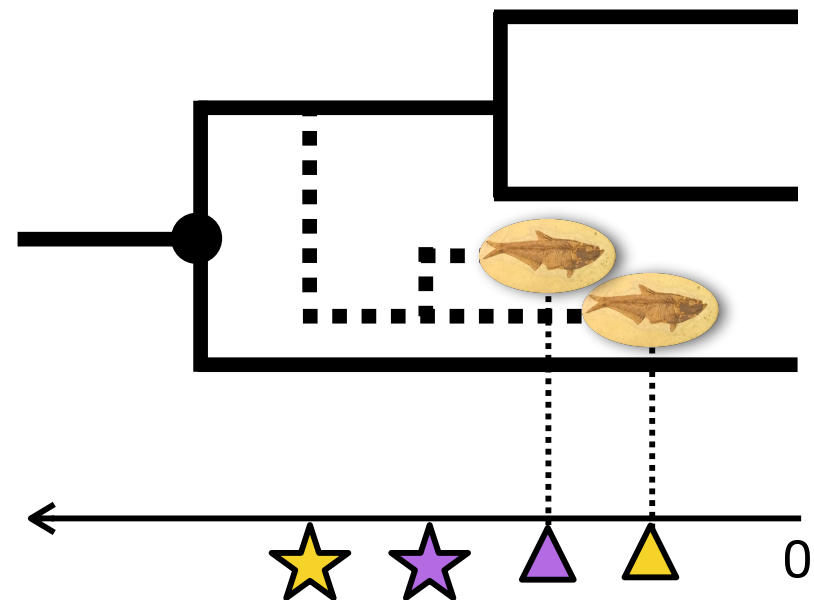
Fossilized Birth-Death Process

Direct ancestry and *ghost lineages* are also possible.

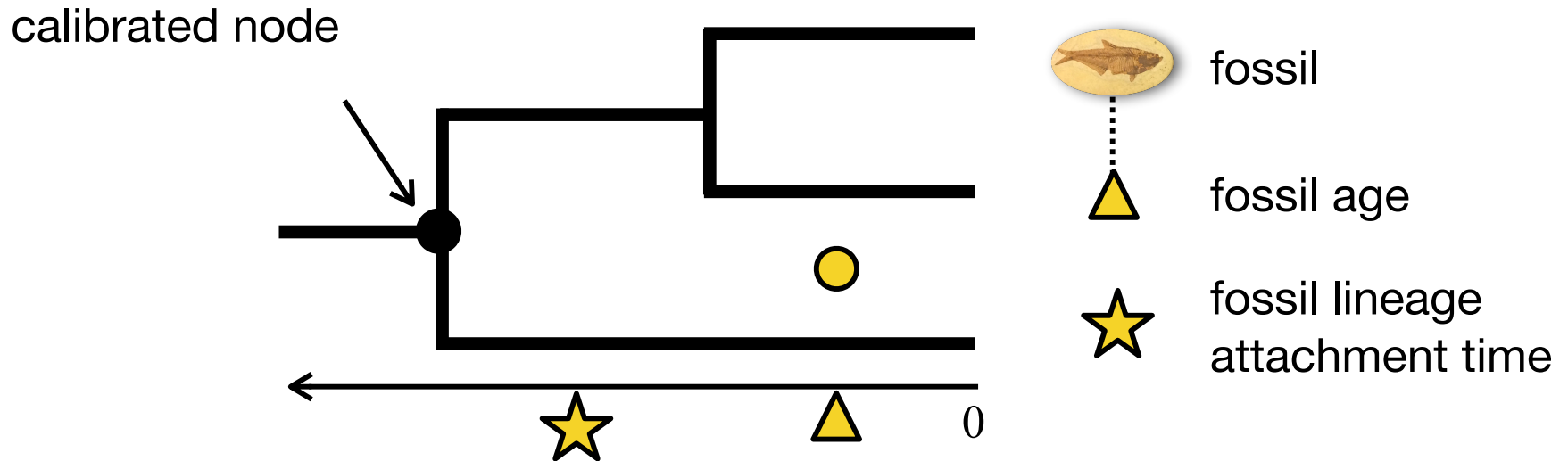
Direct ancestry means fossil is a direct ancestor of a sampled taxon (not at the end of an unsampled lineage)




Ghost lineages are fossil lineages that attach to other fossil lineages



Fossilized Birth-Death Process



MCMC is used to propose many different values of  and attachment points (conditional on attachment time) for each available fossil. This is in addition to proposed changes to edge-specific rates and divergence times.

The marginal posterior distribution of divergence times thus accounts, in principle, for all possible fossil placements consistent with the assumption that fossils descend from their calibrated nodes.

Bears

