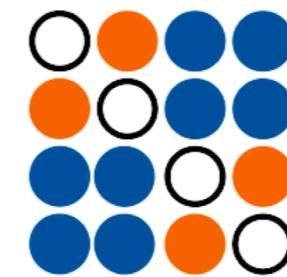
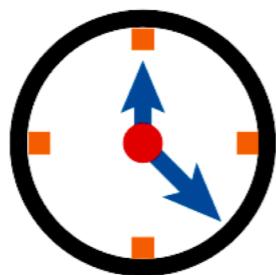


Setting priors

Sarah Nadeau
Taming the BEAST Online 2021



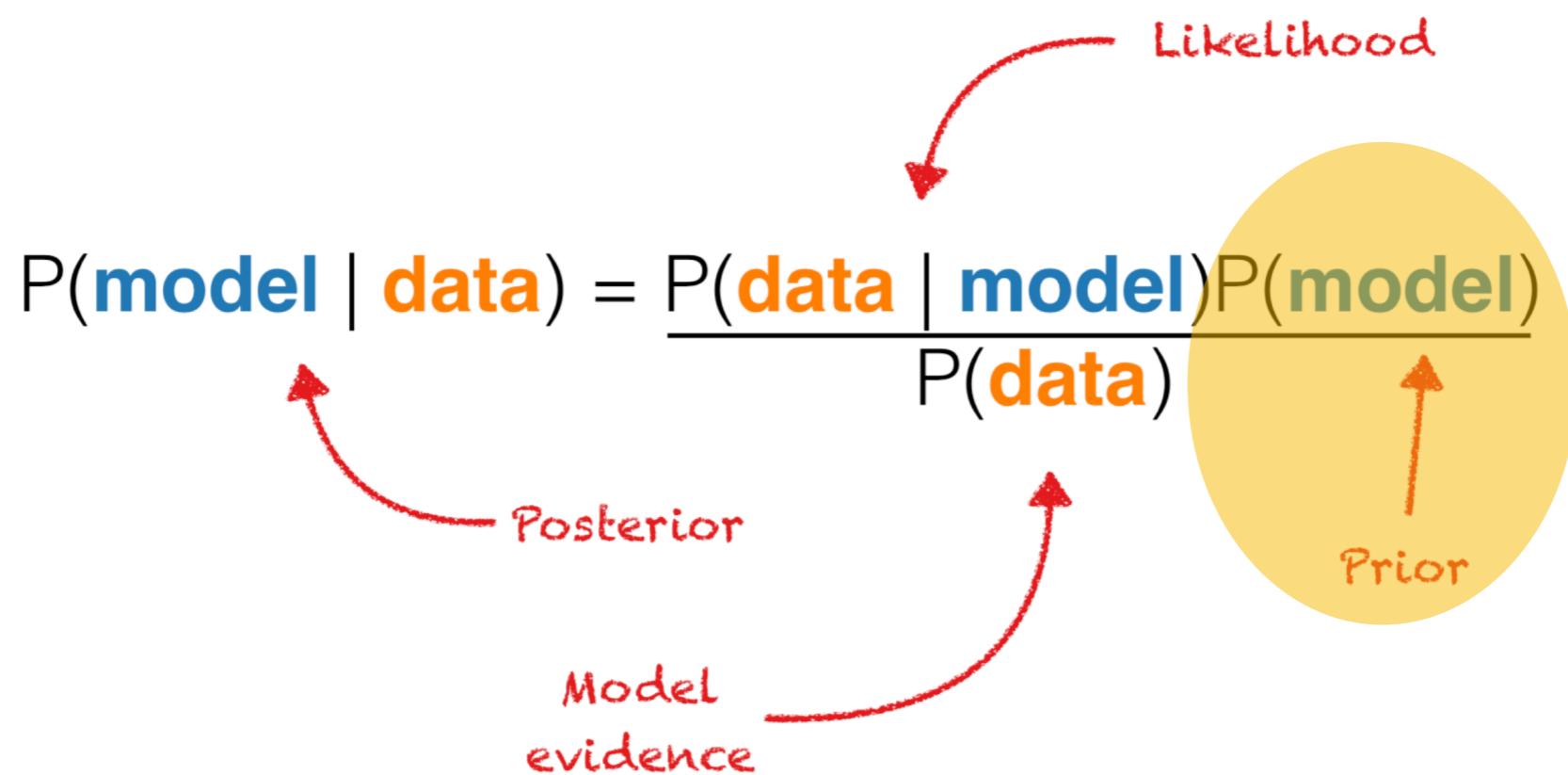
Slides inspired by Louis du Plessis, Veronika Bošková, Chi Zhang, & the Computational Biology course script

What do we mean by prior?

- Bayesian statistics: probability expresses a degree of belief

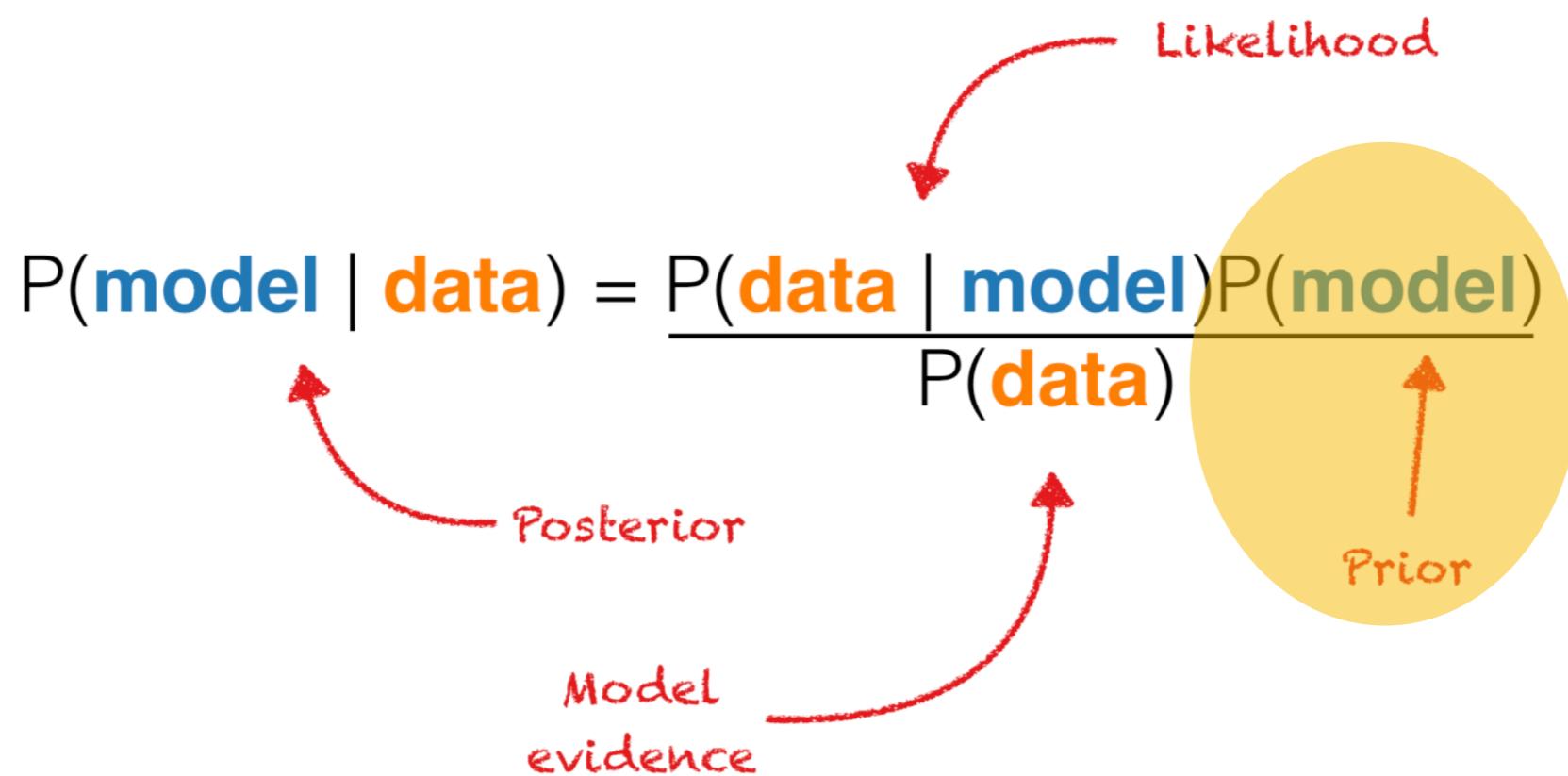
What do we mean by prior?

- Bayesian statistics: probability expresses a degree of belief
 - Degree of belief can be influenced by **prior** knowledge



What do we mean by prior?

- Bayesian statistics: probability expresses a degree of belief
 - Degree of belief can be influenced by **prior** knowledge
 - Prior = $P(\text{model})$ = original probability of model parameters/components



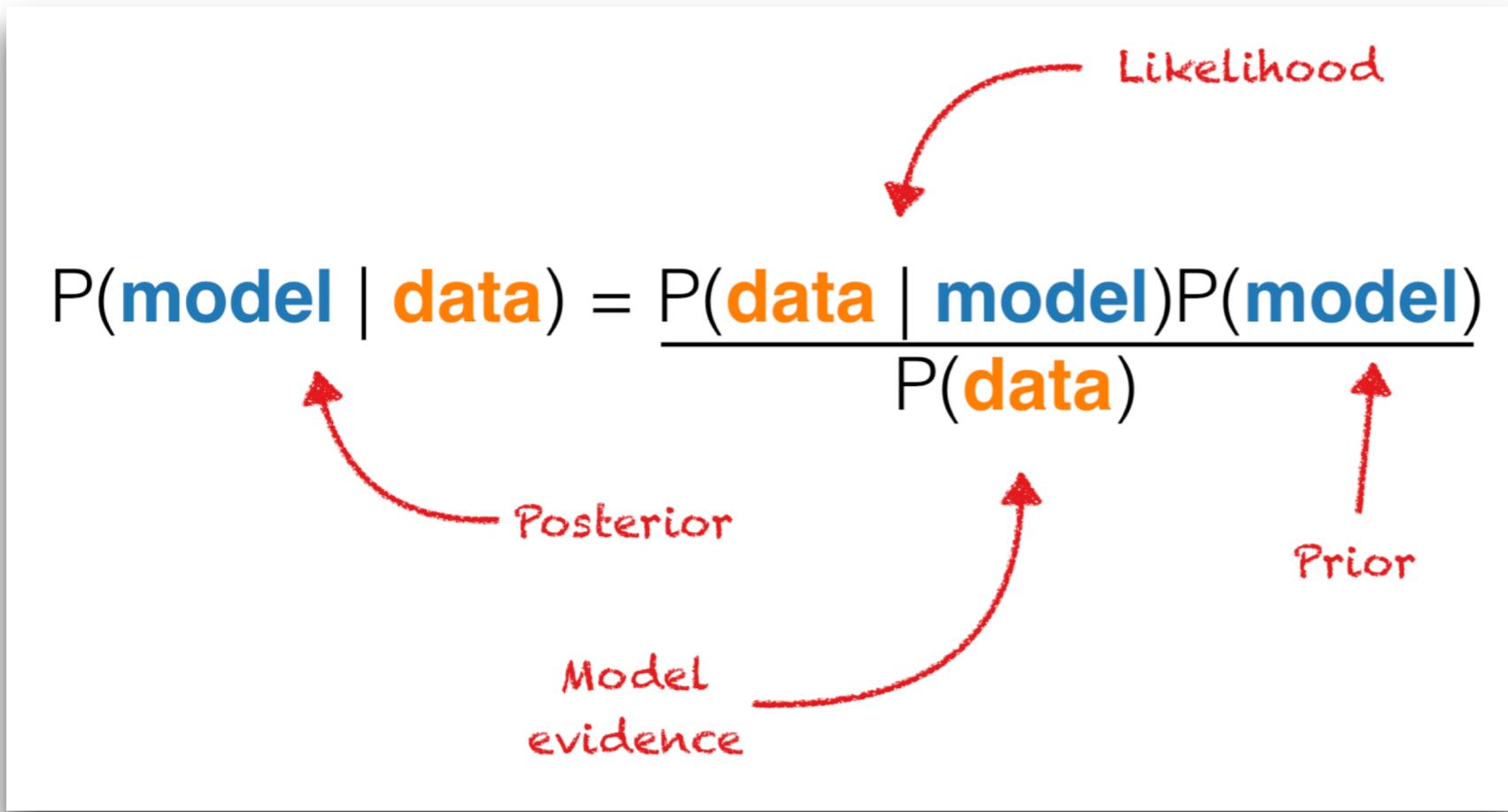
Why do we need the prior?

- Statistically necessary to transform a likelihood into a posterior probability

Why do we *like* the prior?

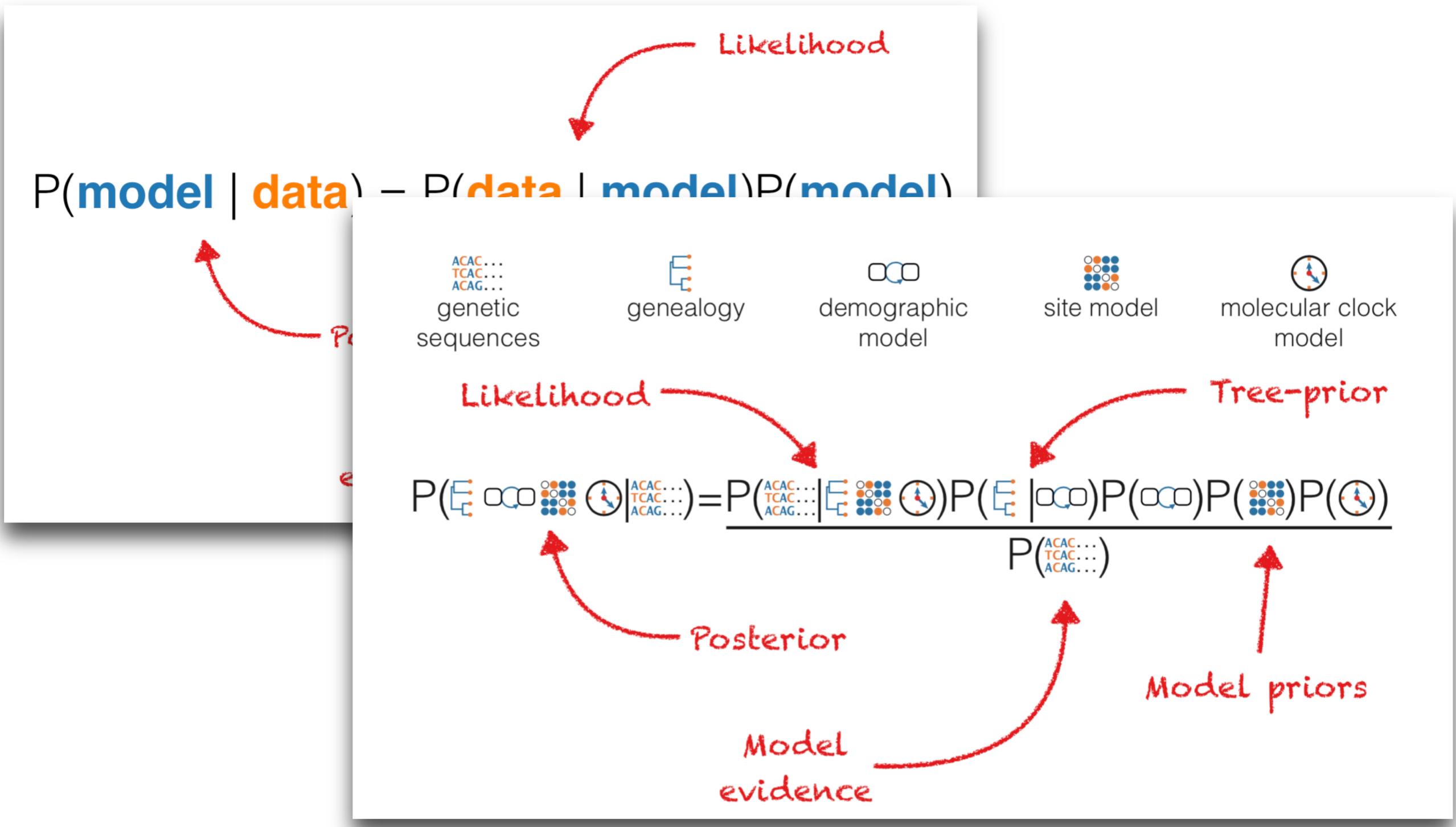
- Statistically necessary to transform a likelihood into a posterior probability
- Allows us to incorporate our prior knowledge!

So what *is* a prior in BEAST?



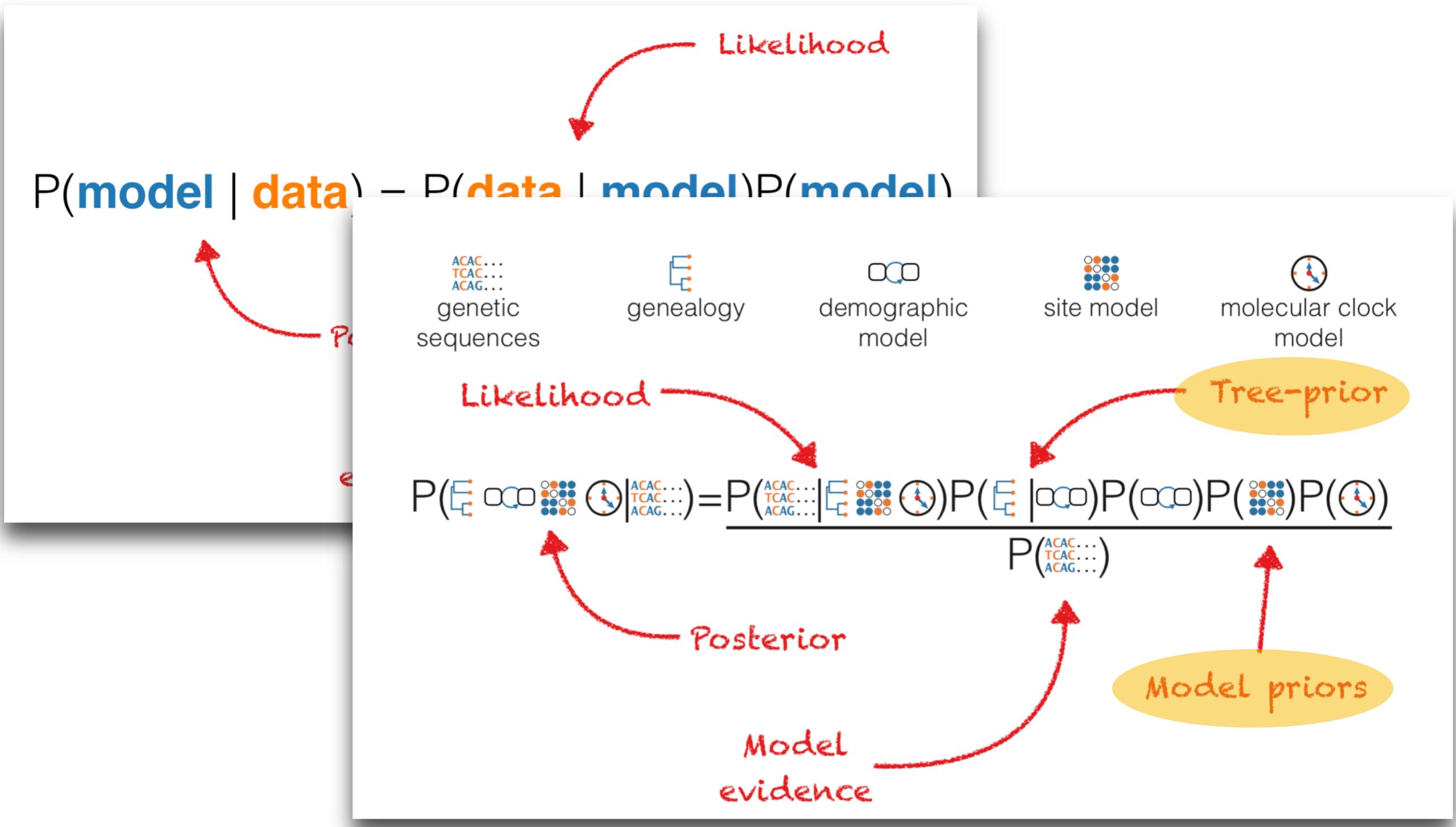
Bayes theorem (general)

So what *is* a prior in BEAST?



Bayes theorem (BEAST)

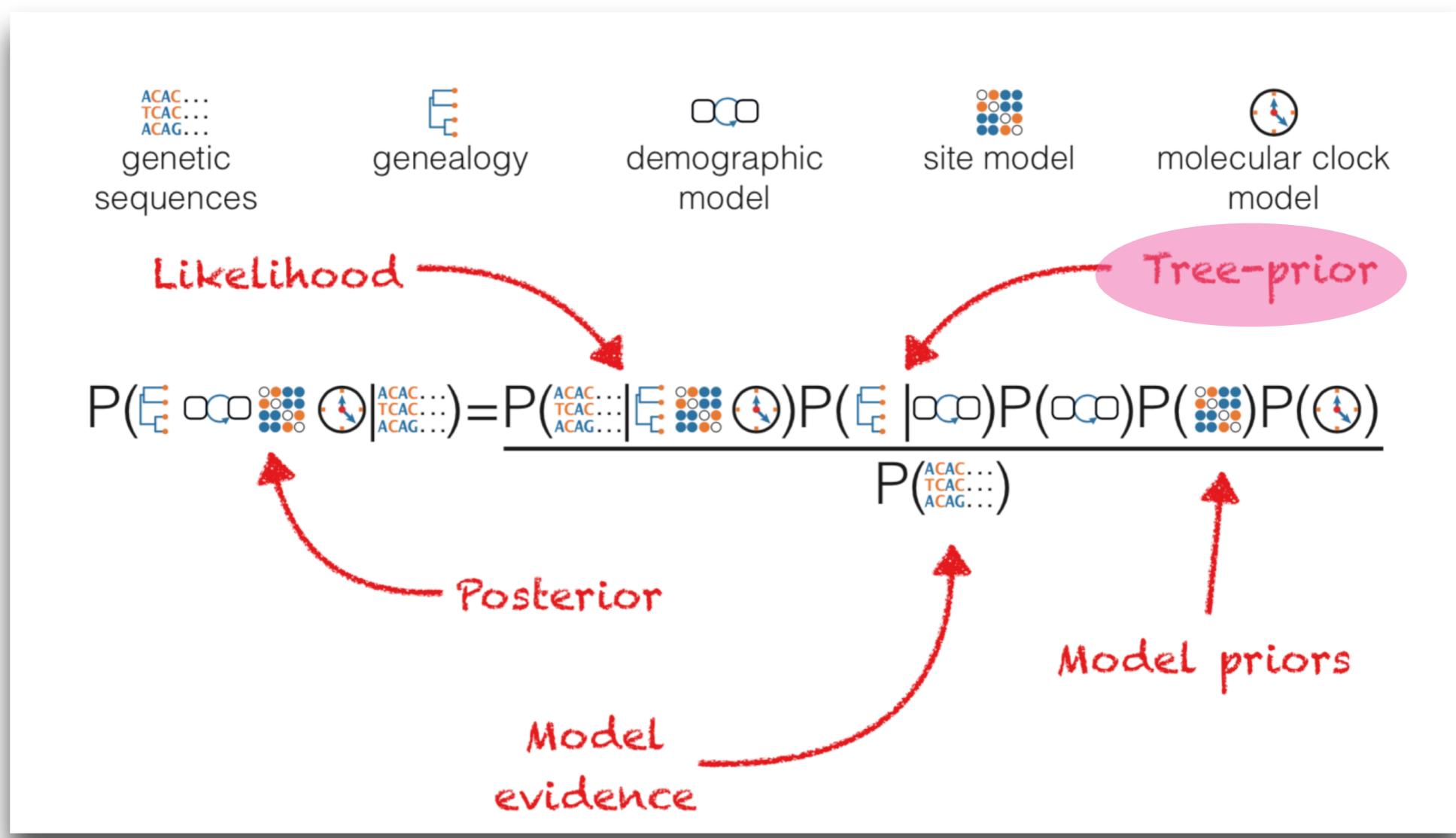
So what *is* a prior in BEAST?



Bayes theorem (BEAST)

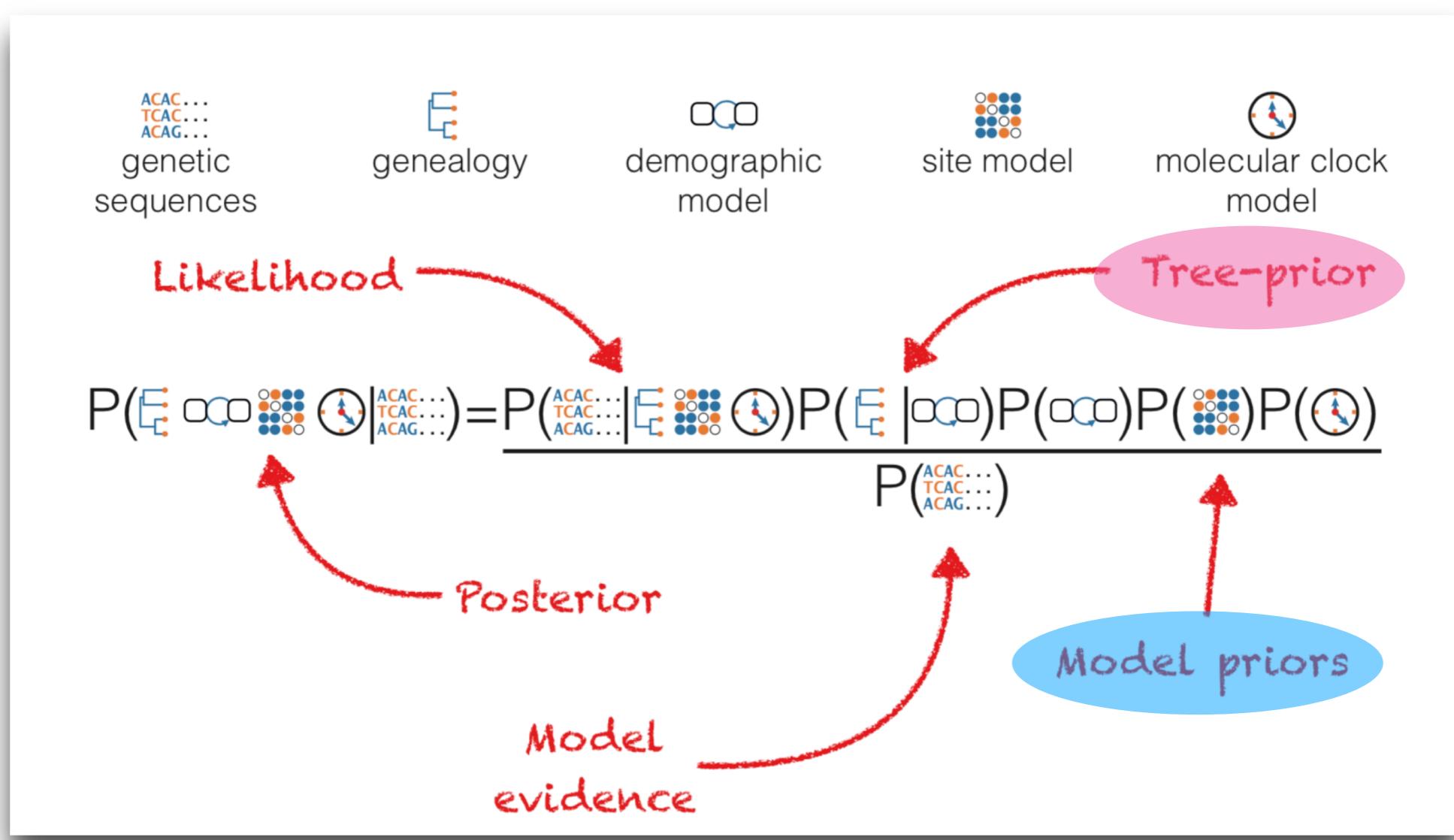
So what *is* a prior in BEAST?

- A choice of model components



So what *is* a prior in BEAST?

- A choice of **model components**
- A choice of **distribution for a model parameter**



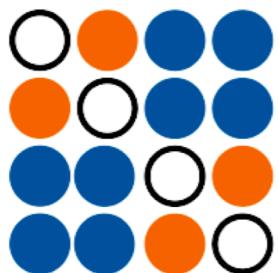
All parameters have priors

*whether you specify them or not



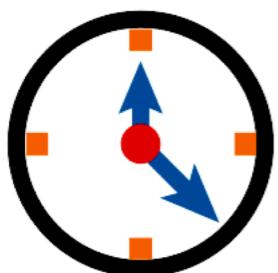
Demographic model (e.g. Birth-death-sampling model)

- β = birth rate
- δ = death rate
- S = sampling rate



Site model (e.g. K80 model)

- α rate of transitions
- β rate of transversions



Molecular clock model (e.g. strict clock model)

- μ = evolutionary rate

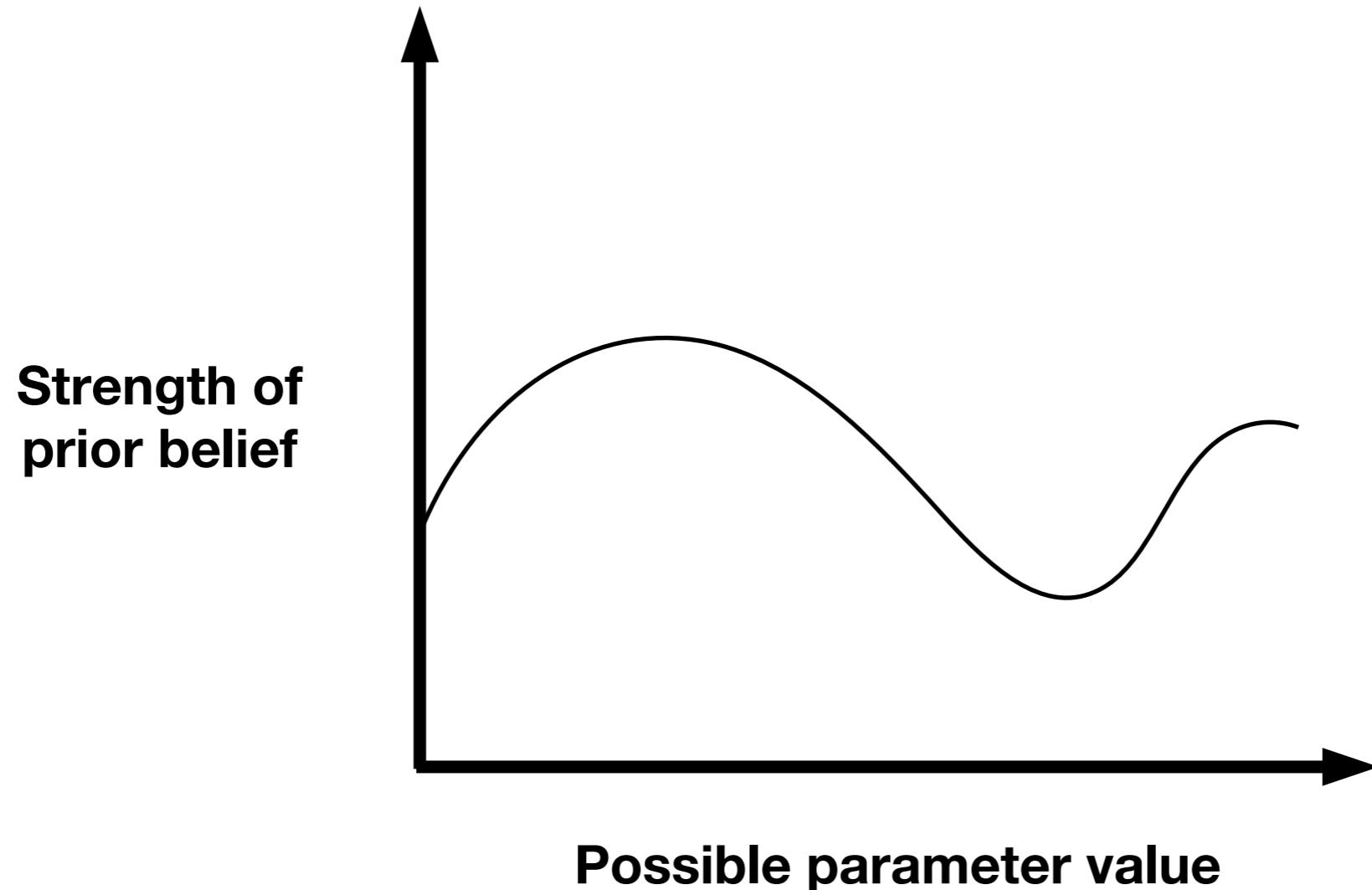
How do we set priors?

- Prior = $P(\text{model})$ = original probability of model parameters/components
- In practice, a choice of distribution for a model parameter

How do we set priors?

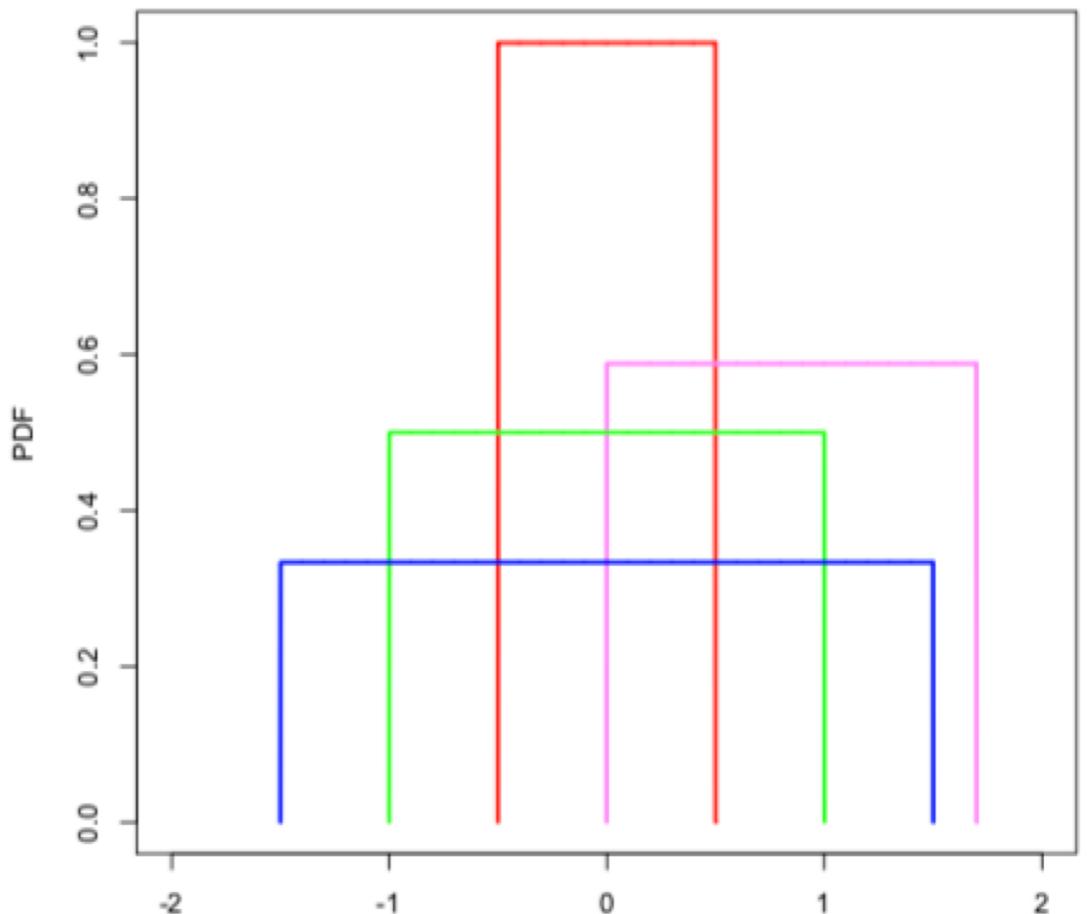
- Prior = $P(\text{model})$ = original probability of model parameters/components
- In practice, a choice of distribution for a model parameter
 - Uniform, $1/x$, normal, lognormal, ...
 - Parameter bounds are part of the prior

Some common prior distributions...



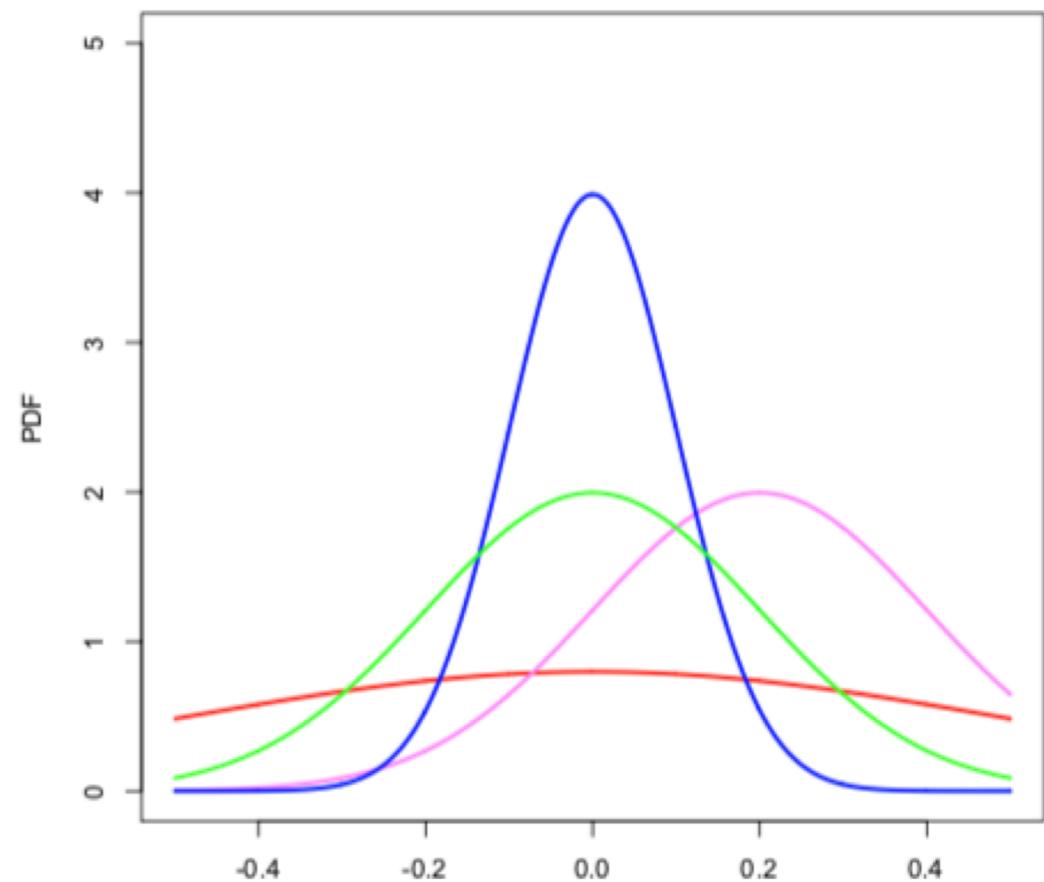
Uniform distribution

- Parameters: lower and upper bound
- Range of values: $(-\infty, \infty)$
- Example: Sampling proportion between 0 and 1



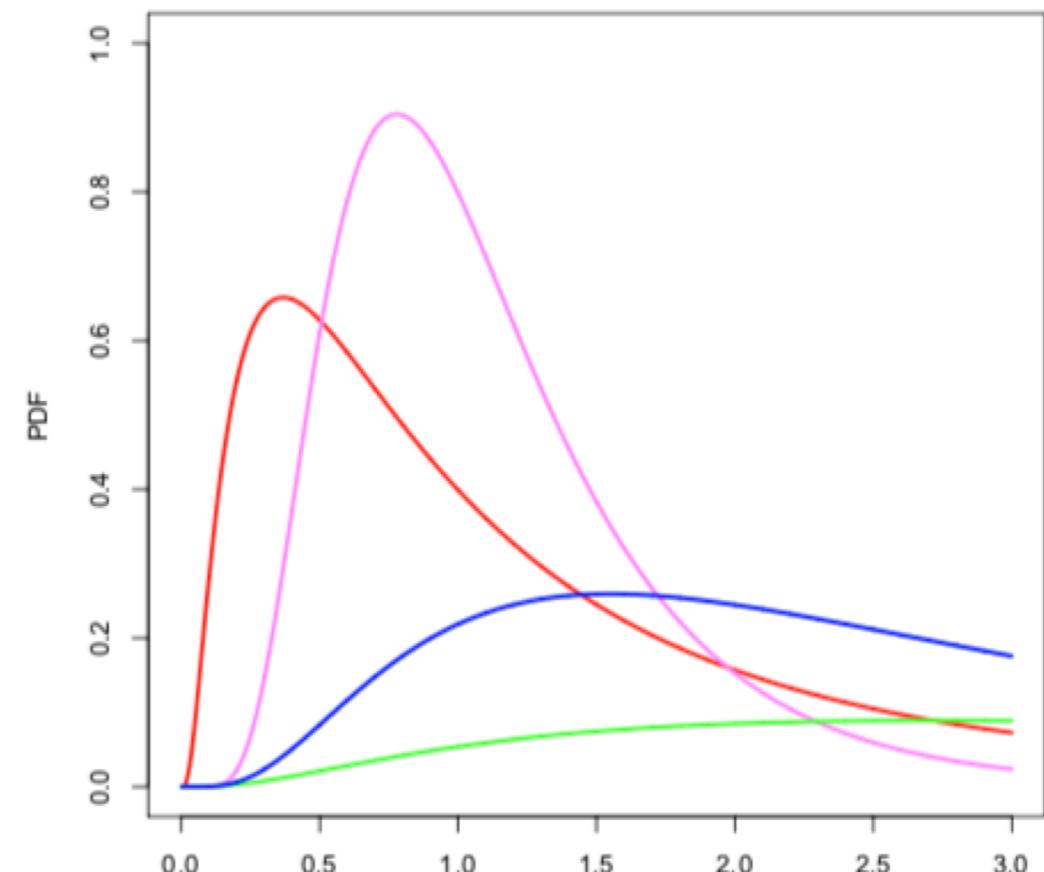
Normal distribution

- Parameters: mean and standard deviation
- Range of values: $(-\infty, \infty)$
- Example: time of origin centered around 3 MYA



Lognormal distribution

- Parameters: mean and standard deviation
- Range of values: $[0, \infty)$
- Example: birth rate centered around 1



$1/x$ = Log-uniform distribution

- Parameters: lower and upper bound
- Range of values: $[0, \infty)$
- Example: sampling rate default in BEAUti for BDMMPrime package

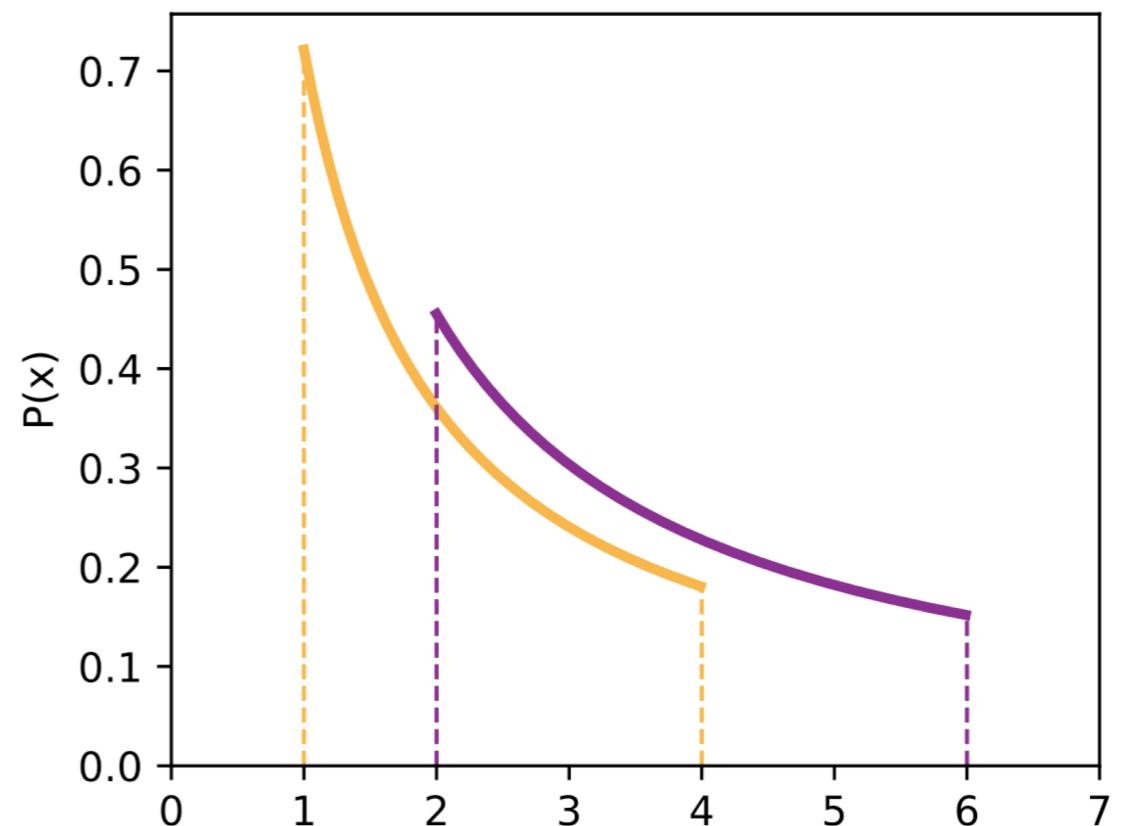


Image from:
[wikipedia.org/wiki/Reciprocal_distribution](https://en.wikipedia.org/wiki/Reciprocal_distribution)

Careful! Avoid improper priors

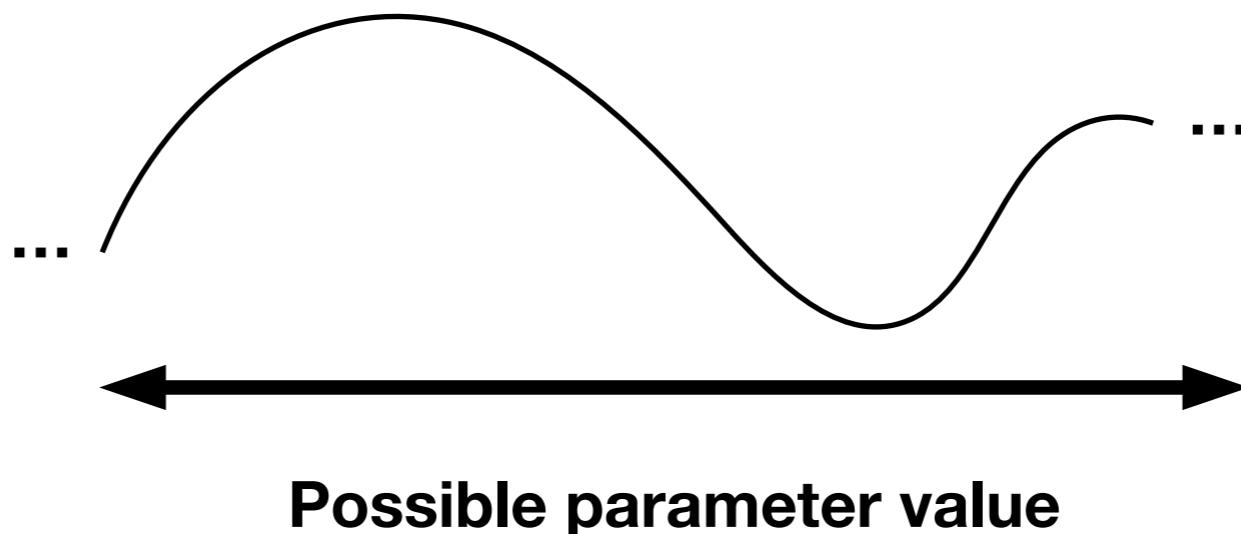
- Improper priors = priors that integrate to ∞

Careful! Avoid improper priors

- Improper priors = priors that integrate to ∞
- Common examples: Uniform and $1/x$ distributions without bounds

Careful! Avoid improper priors

- Improper priors = priors that integrate to ∞
- Common examples: Uniform and $1/x$ distributions without bounds
- Can cause mixing problems because your MCMC has to explore... so much



How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies

Careful! Do your reviewers also like study X?

Consider a sensitivity analysis using an alternate estimate

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies
 - Common sense

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies
 - Common sense

Careful! No priors are universal; BEAUti defaults may be inappropriate.

E.g. default clock rate prior goes up to infinity!

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies
 - Common sense
 - If you don't know, use a diffuse prior

How to pick a prior

- Use your prior knowledge to pick what you think are the best models and most reasonable distributions
 - Independent parameter estimates from other studies
 - Common sense
 - If you don't know, use a diffuse prior

Careful! No prior is truly non-informative.

E.g. a Uniform(0, 1) prior for sampling proportion puts 9/10 of all weight on the belief that at least 1 in every 10 individuals is sampled

Summary advice

- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate

Summary advice

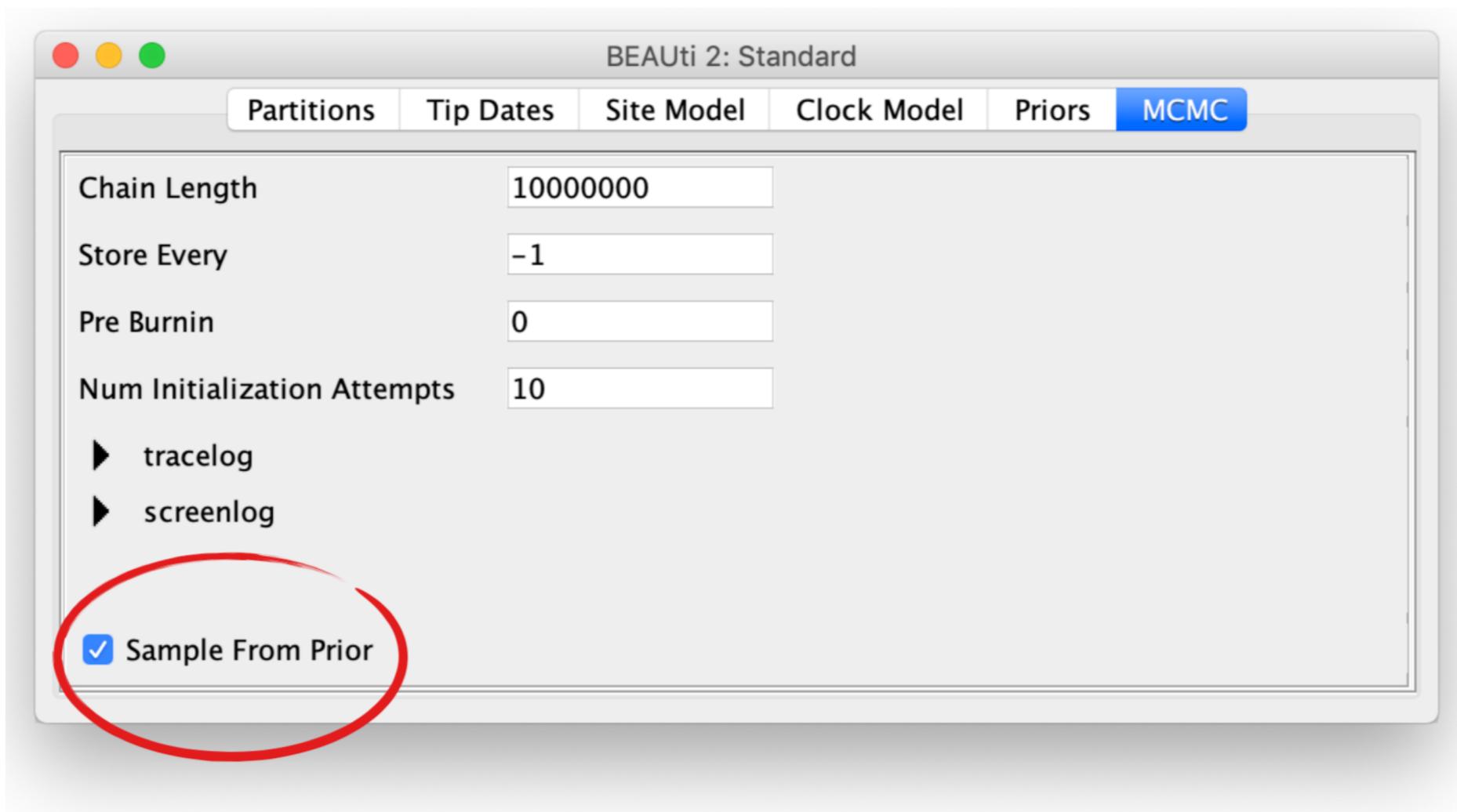
- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate
- Avoid improper priors (i.e. priors that integrate to ∞)

Summary advice

- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate
- Avoid improper priors (i.e. priors that integrate to ∞)
- Induced priors (i.e. different parameters interact) may change your ‘real’ prior

Summary advice

- Induced priors (i.e. different parameters interact) may change your ‘real’ prior
 - Sample from the prior without data to see the ‘real’ prior



Summary advice

- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate
- Avoid improper priors (i.e. priors that integrate to ∞)
- Induced priors (i.e. different parameters interact) may change your ‘real’ prior
 - Sample from the prior without data to see the ‘real’ prior
- Check the impact of the prior on your results

Summary advice

- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate
- Avoid improper priors (i.e. priors that integrate to ∞)
- Induced priors (i.e. different parameters interact) may change your ‘real’ prior
 - Sample from the prior without data to see the ‘real’ prior
- Check the impact of the prior on your results
 - Does changing the priors change your posteriors? Or does the data dominate?

Summary advice

- Think about your priors – all parameters in BEAST have priors, and the defaults may not be appropriate
- Avoid improper priors (i.e. priors that integrate to ∞)
- Induced priors (i.e. different parameters interact) may change your ‘real’ prior
 - Sample from the prior without data to see the ‘real’ prior
- Check the impact of the prior on your results
- Report your priors – without them, your analysis is not repeatable!