Other models of continuous trait evolution on trees

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Brownian motion model

$$dX(t) = \sigma^2 dB(t)$$

- 2 parameters:
  - σ^2 the rate parameter
  - X(0) the starting value

Ornstein-Uhlenbeck model of evolution

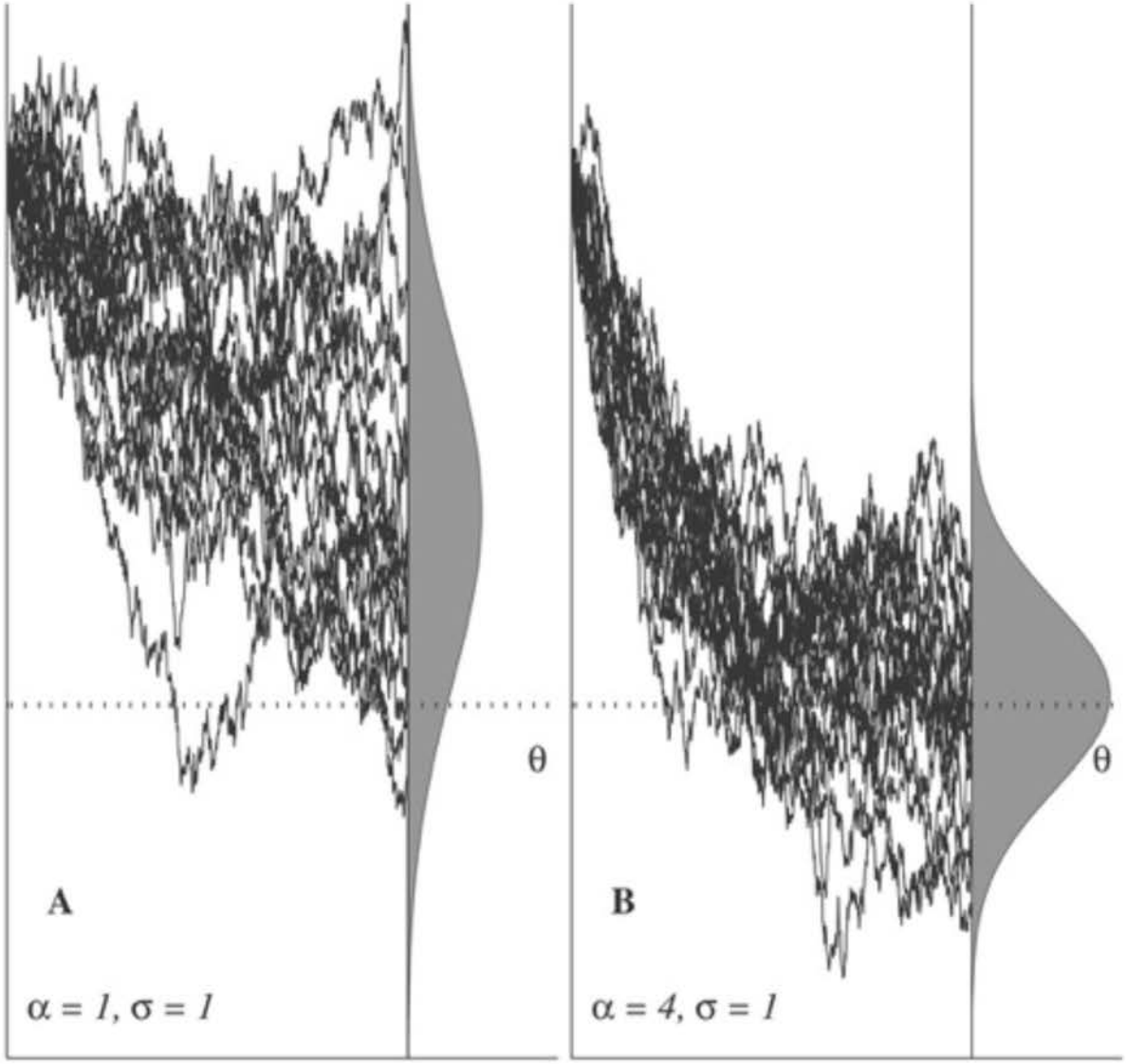
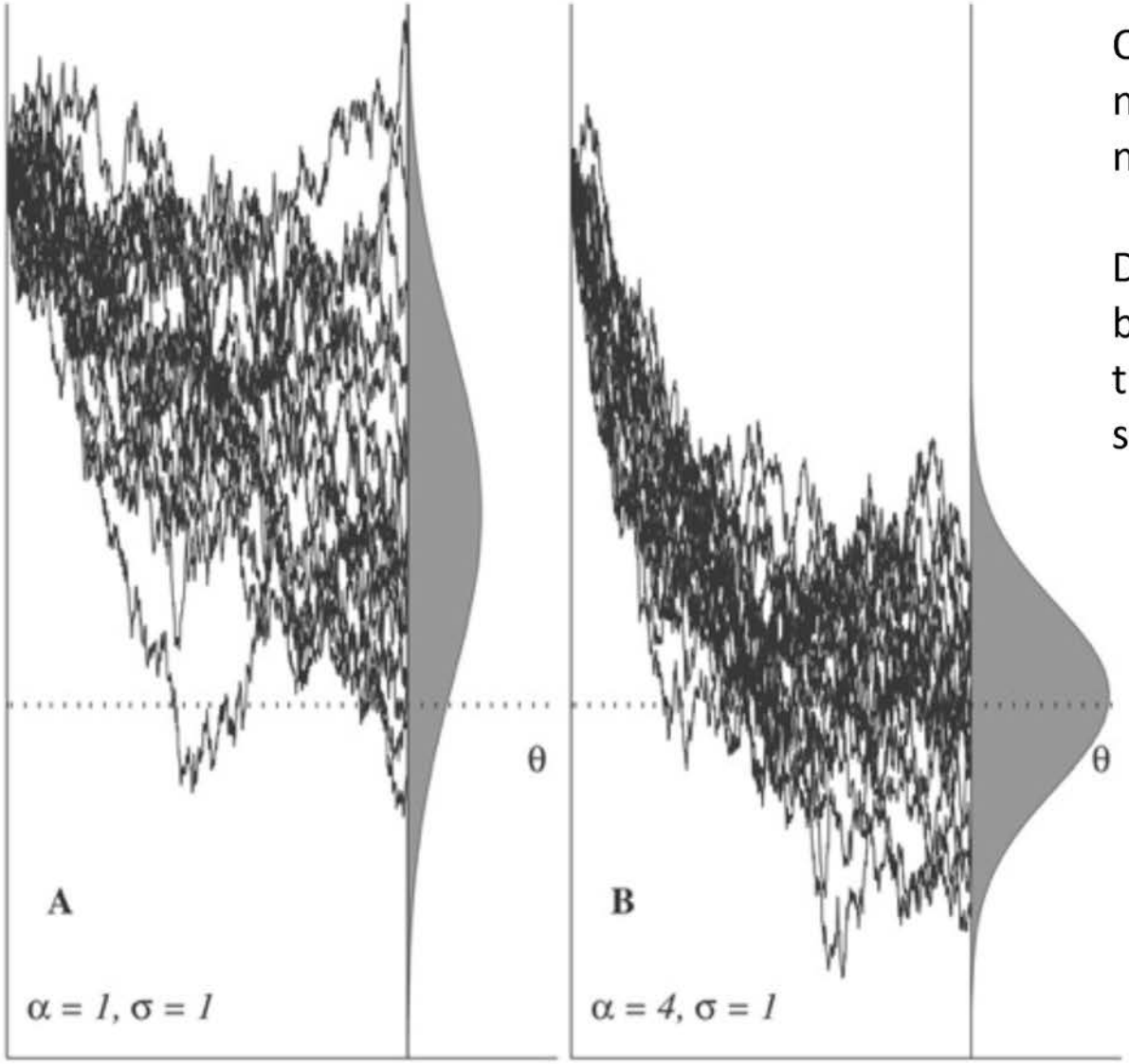


Figure from Butler et al. 2004

Ornstein-Uhlenbeck model of evolution



OU model is the simplest mathematical expression of a model incorporating selection

Differs from the Brownian model by incorporating an optimum trait value and a parameter simulating selection.

Figure from Butler et al. 2004

Ornstein-Uhlenbeck model of evolution

$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

Brownian motion

Ornstein-Uhlenbeck model of evolution

$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

Change towards optimum

Brownian motion

Ornstein-Uhlenbeck model of evolution

$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

Optimum

Ornstein-Uhlenbeck model of evolution

$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

Strength of selection
is proportional to
distance of trait to
optimum value

Ornstein-Uhlenbeck model of evolution

$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

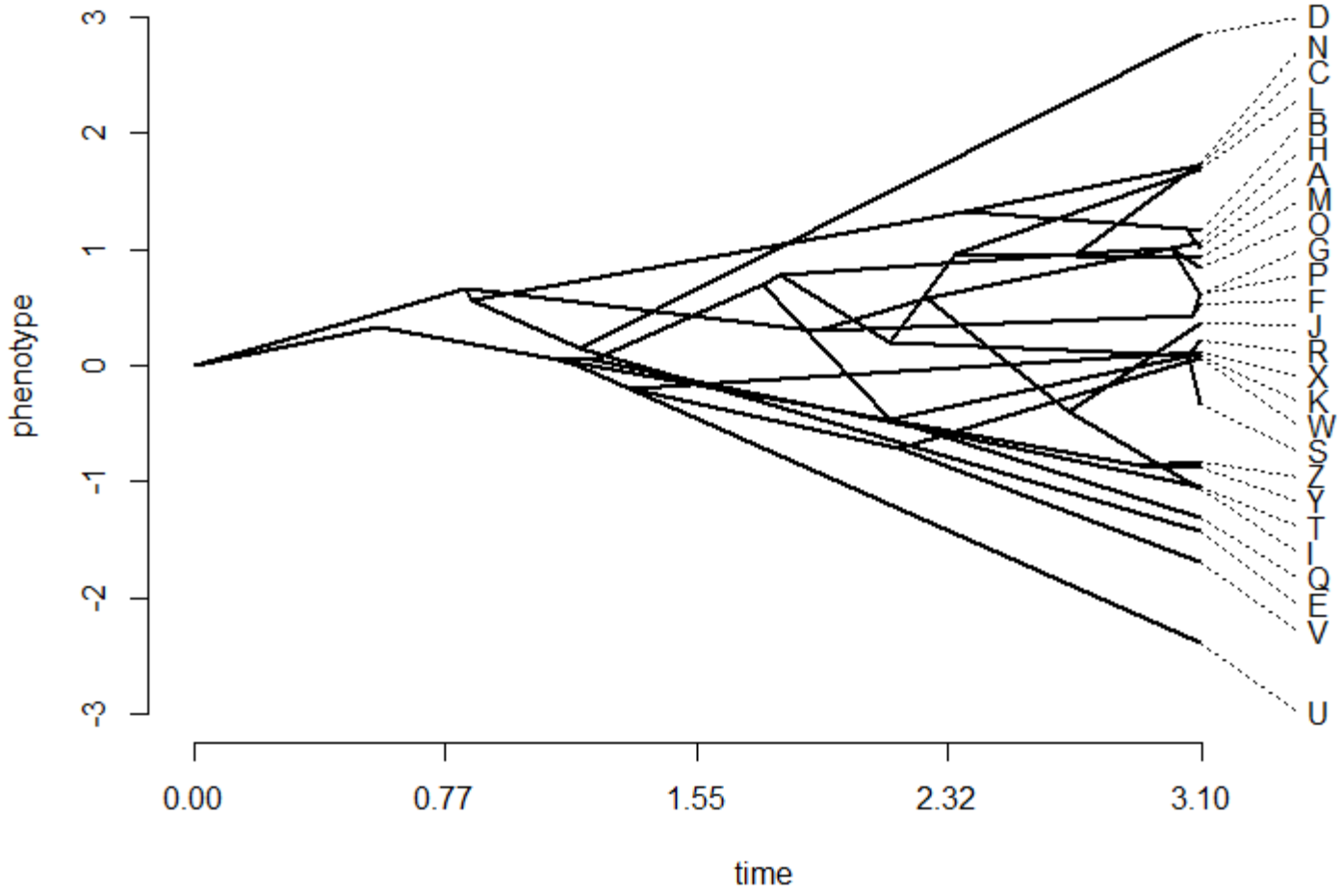
"Pull"
towards
optimum

Ornstein-Uhlenbeck model of evolution

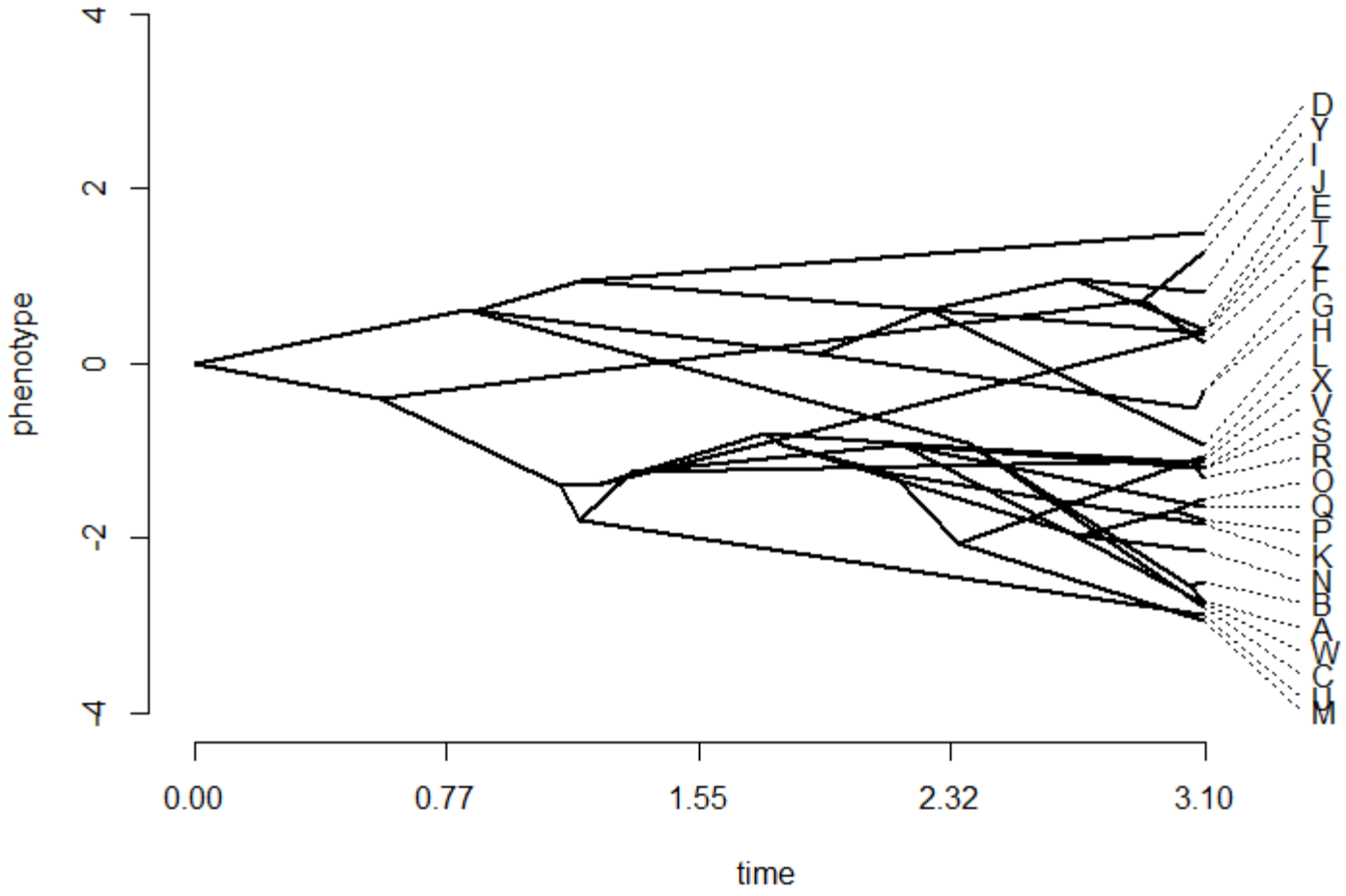
$$dX(t) = \alpha[\theta - X(t)]dt + \sigma^2 dB(t)$$

When alpha = 0 the OU model becomes a Brownian motion model

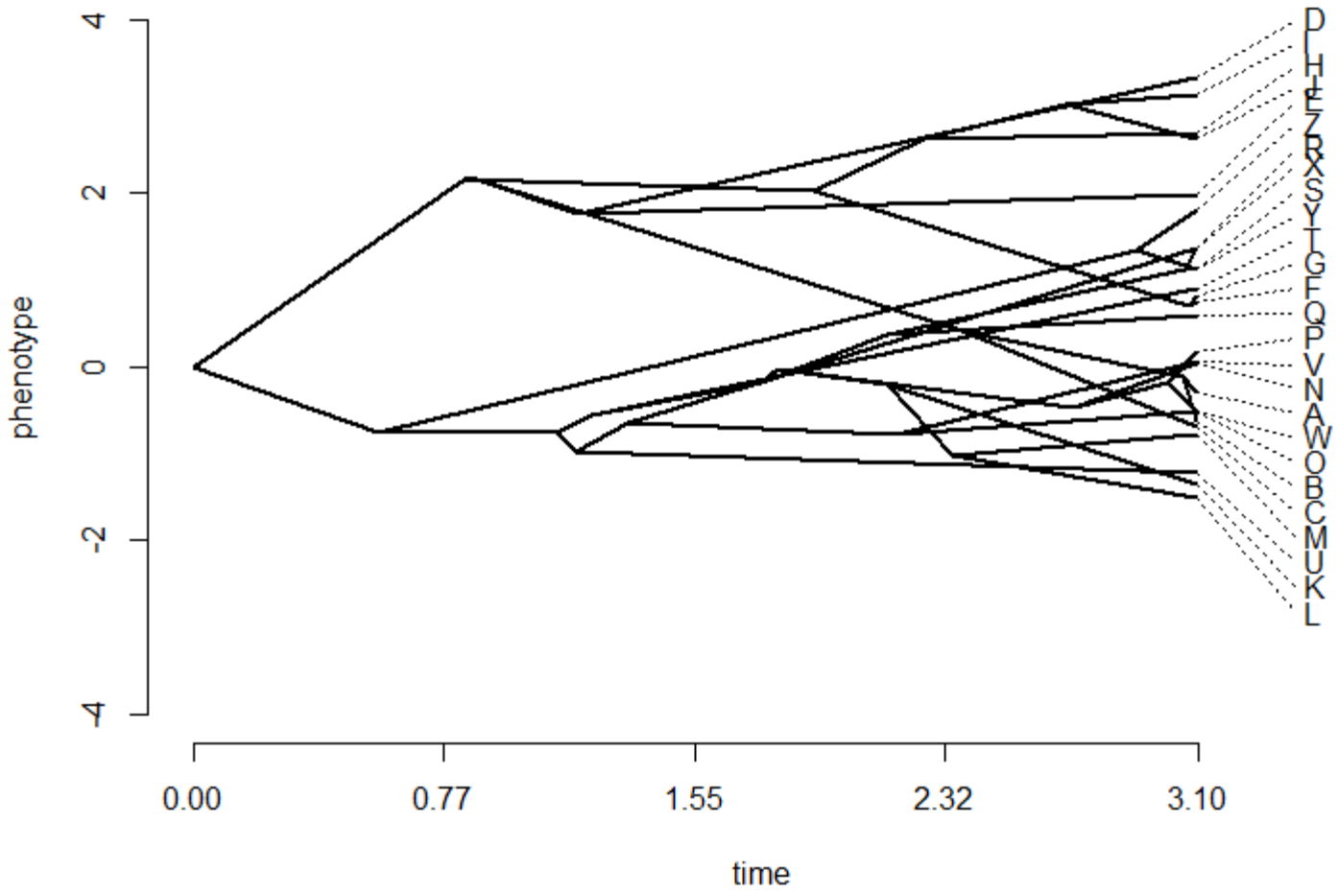
Brownian motion



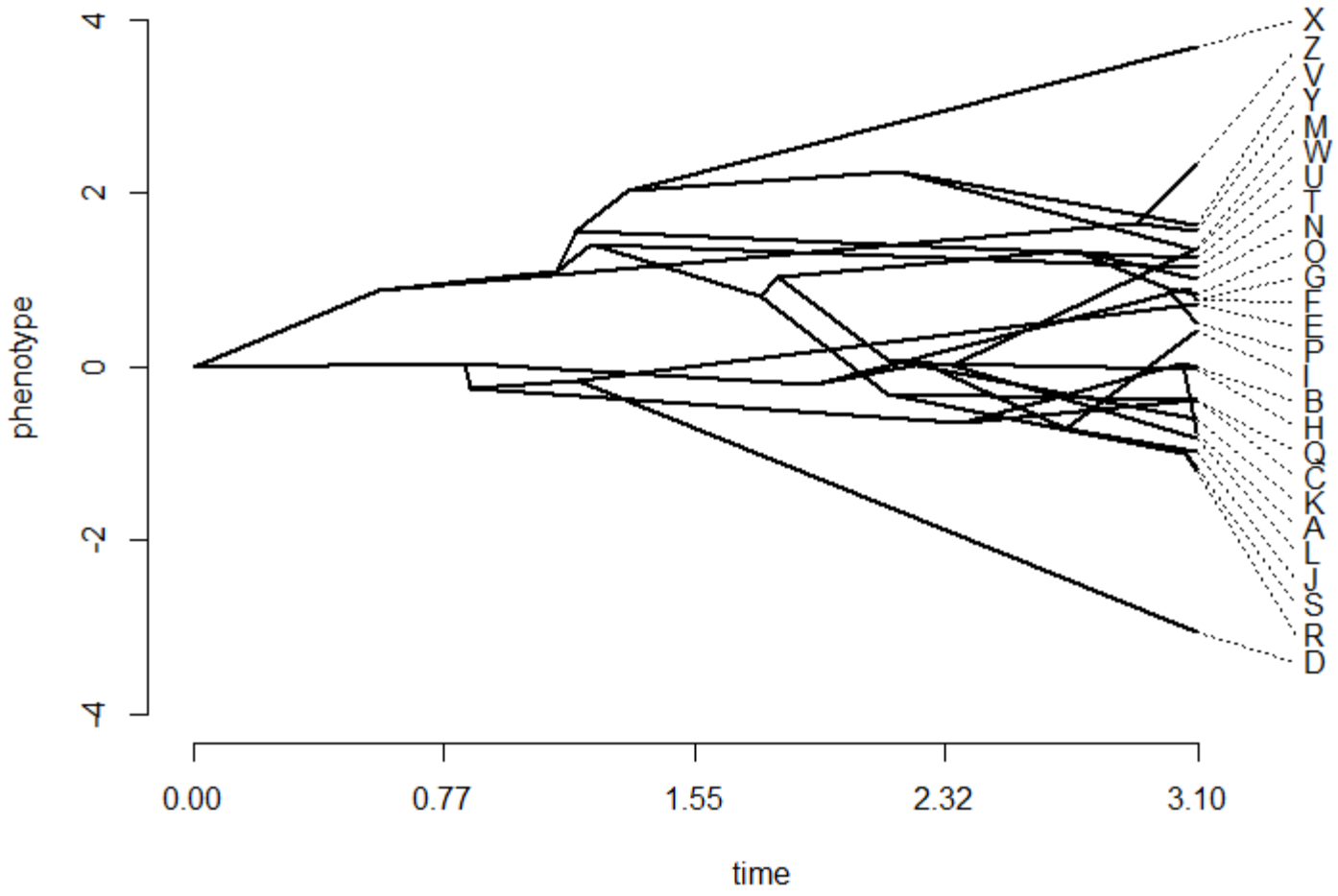
Brownian motion



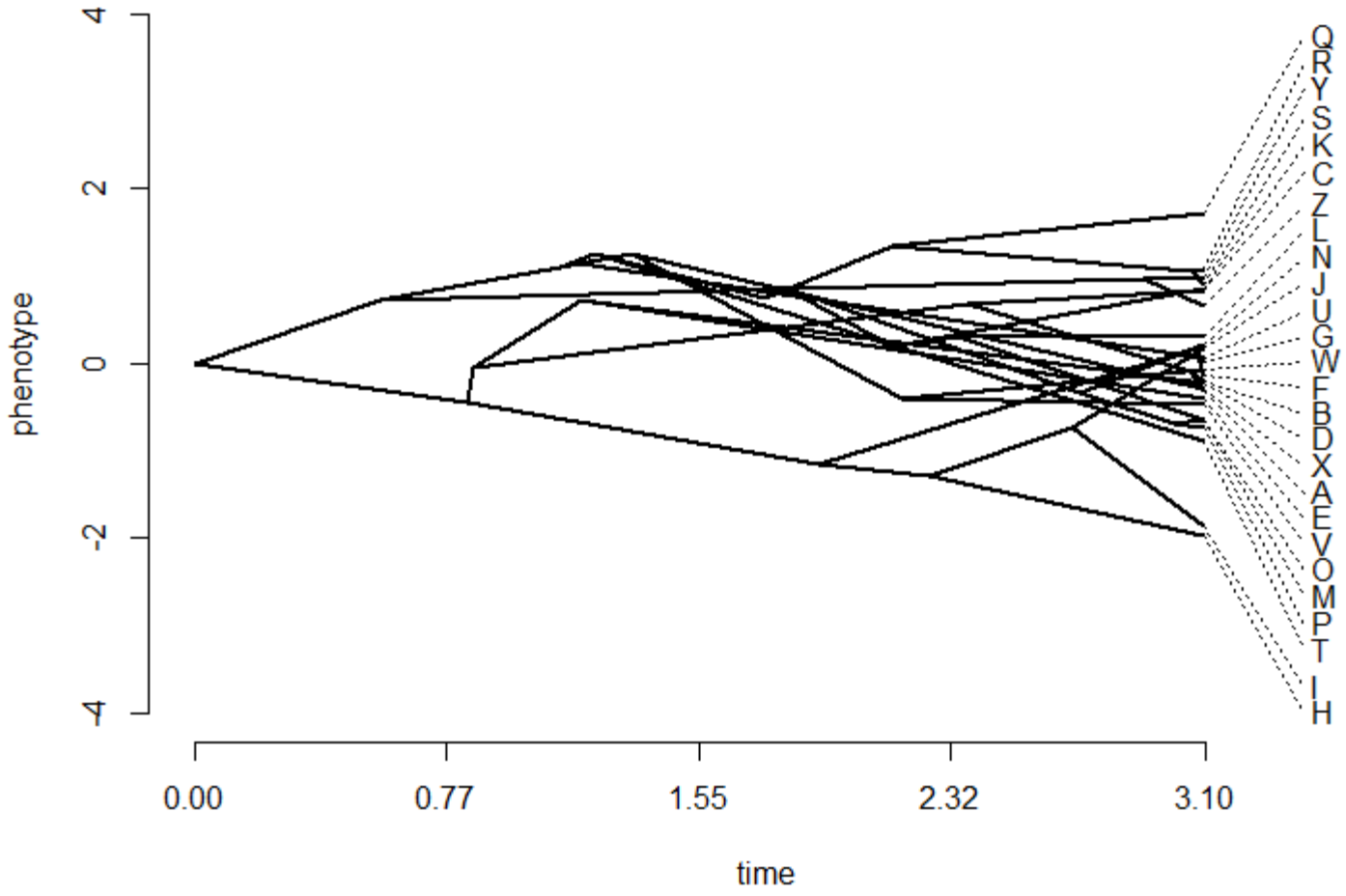
Brownian motion



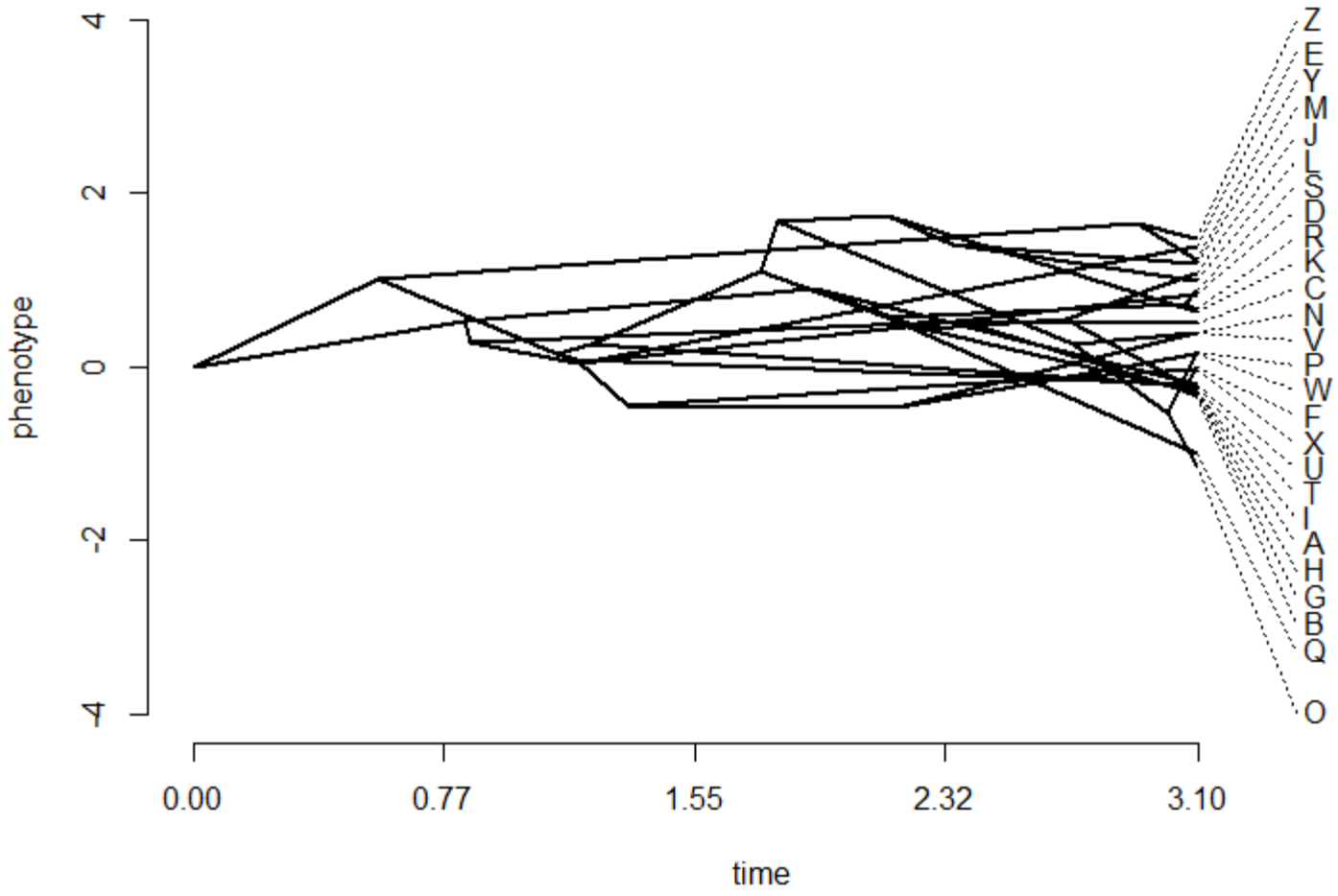
Ornstein-Uhlenbeck, α = 0.2



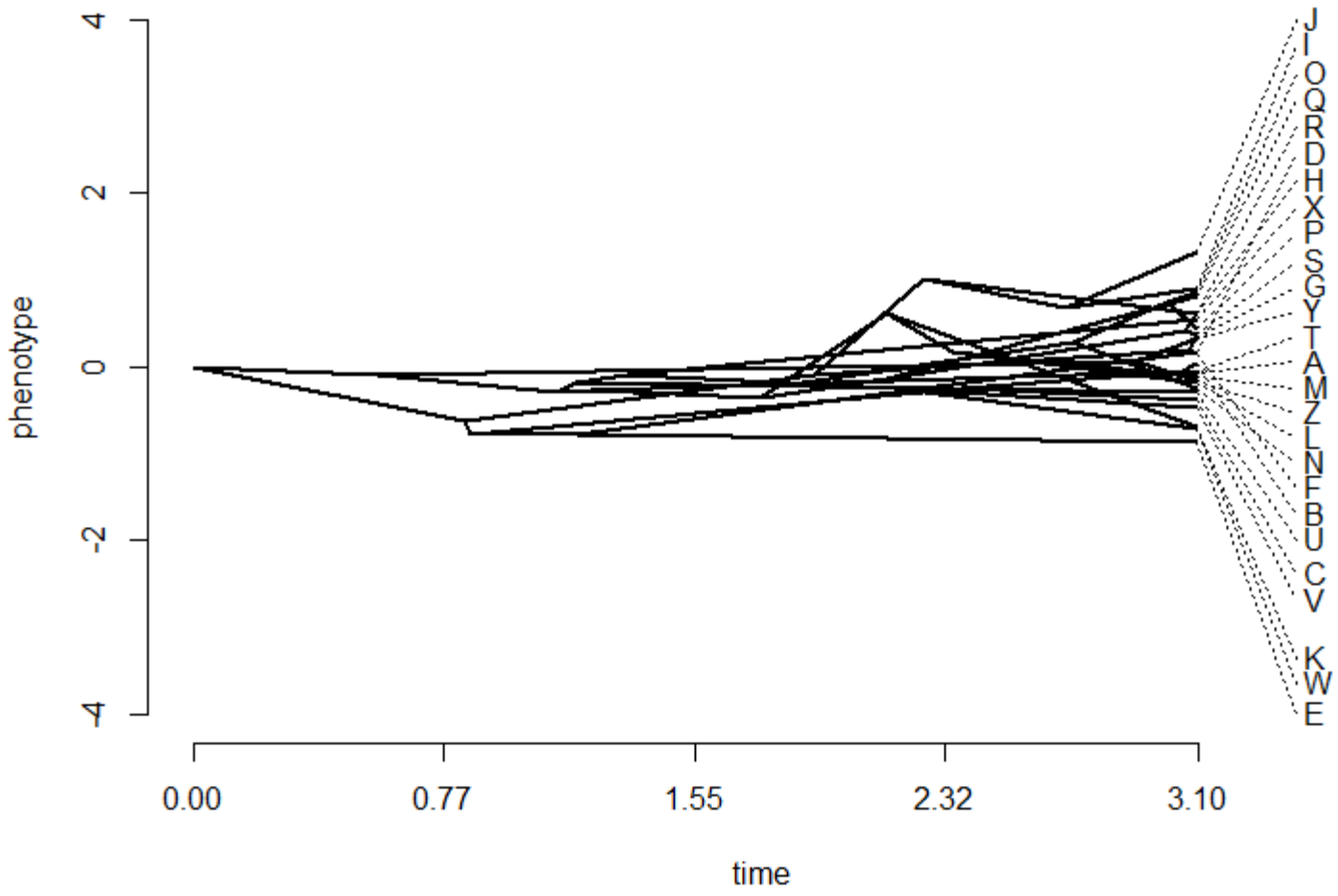
Ornstein-Uhlenbeck, α = 0.5



Ornstein-Uhlenbeck, α = 1.0



Ornstein-Uhlenbeck, α = 2.0

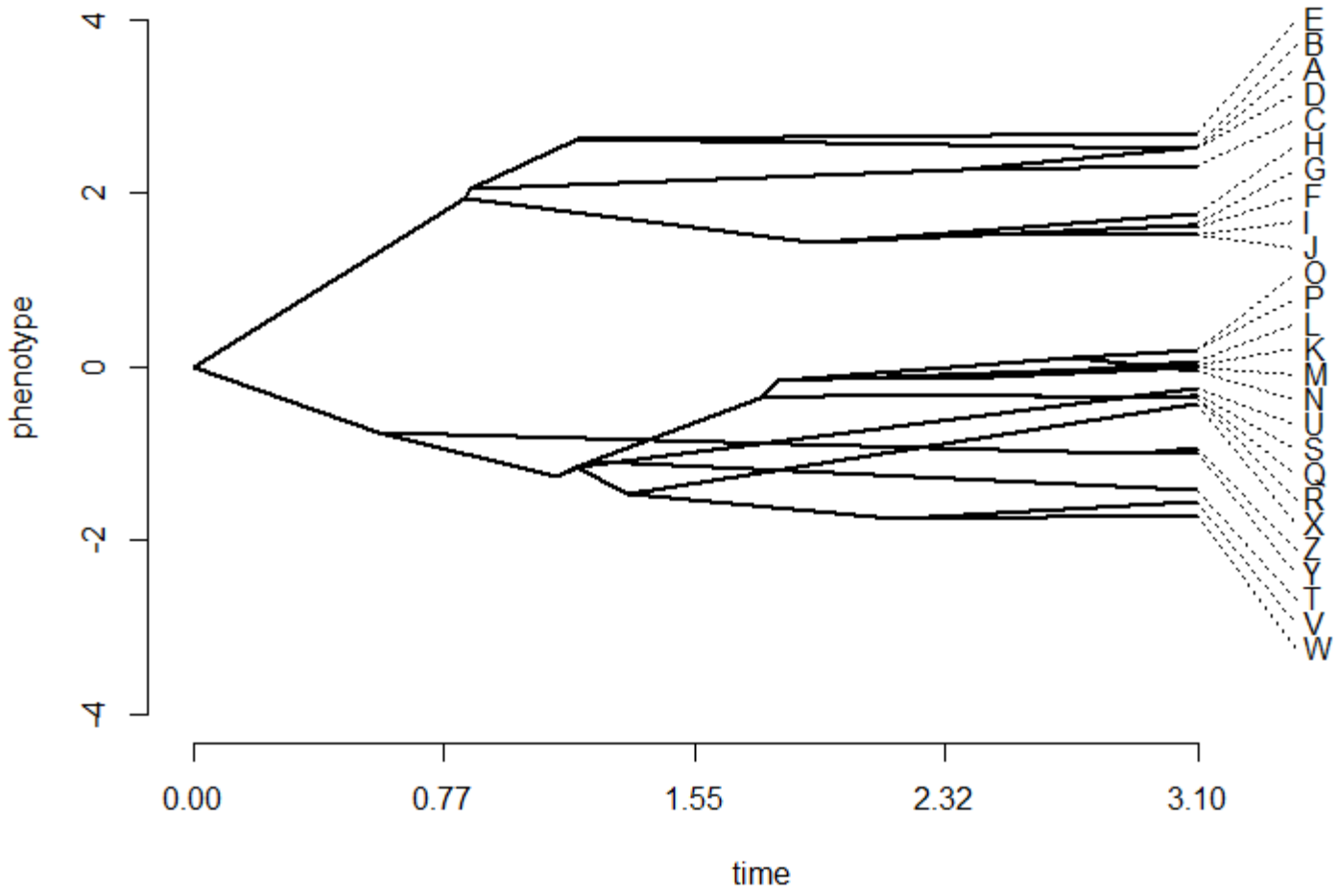


- Under Brownian motion model traits of species sharing a more distant common ancestor will be more different than traits of species sharing a less distant common ancestor
- Under an OU model trait similarity between species also decreases with distance to the nearest common ancestor
  - Rate of change of the trait depends on:
    - 1 distance between the trait value and the optimum
    - 2 strength of selection pulling the trait towards the optimum
  - Depending on the strength of selection rate of phenotypic evolution (rate of change in trait values) can be faster than under Brownian motion

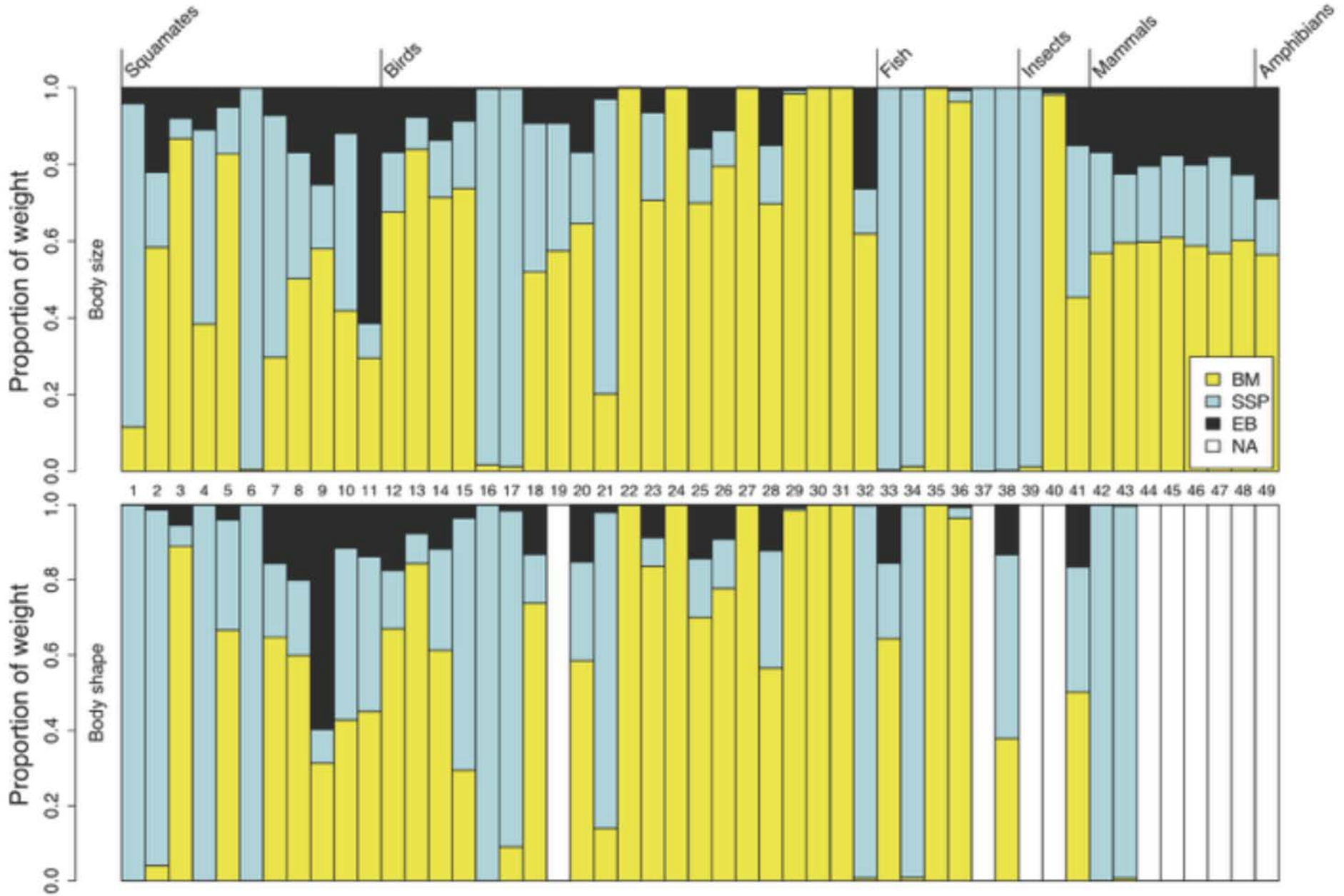
The early burst model

- Rate of evolution slows through time
- Highest rate is at the root of the tree
- Three parameters: starting value (θ), starting rate (σ^2_0) & rate of change (r)
- Adaptive radiation

Early-burst model

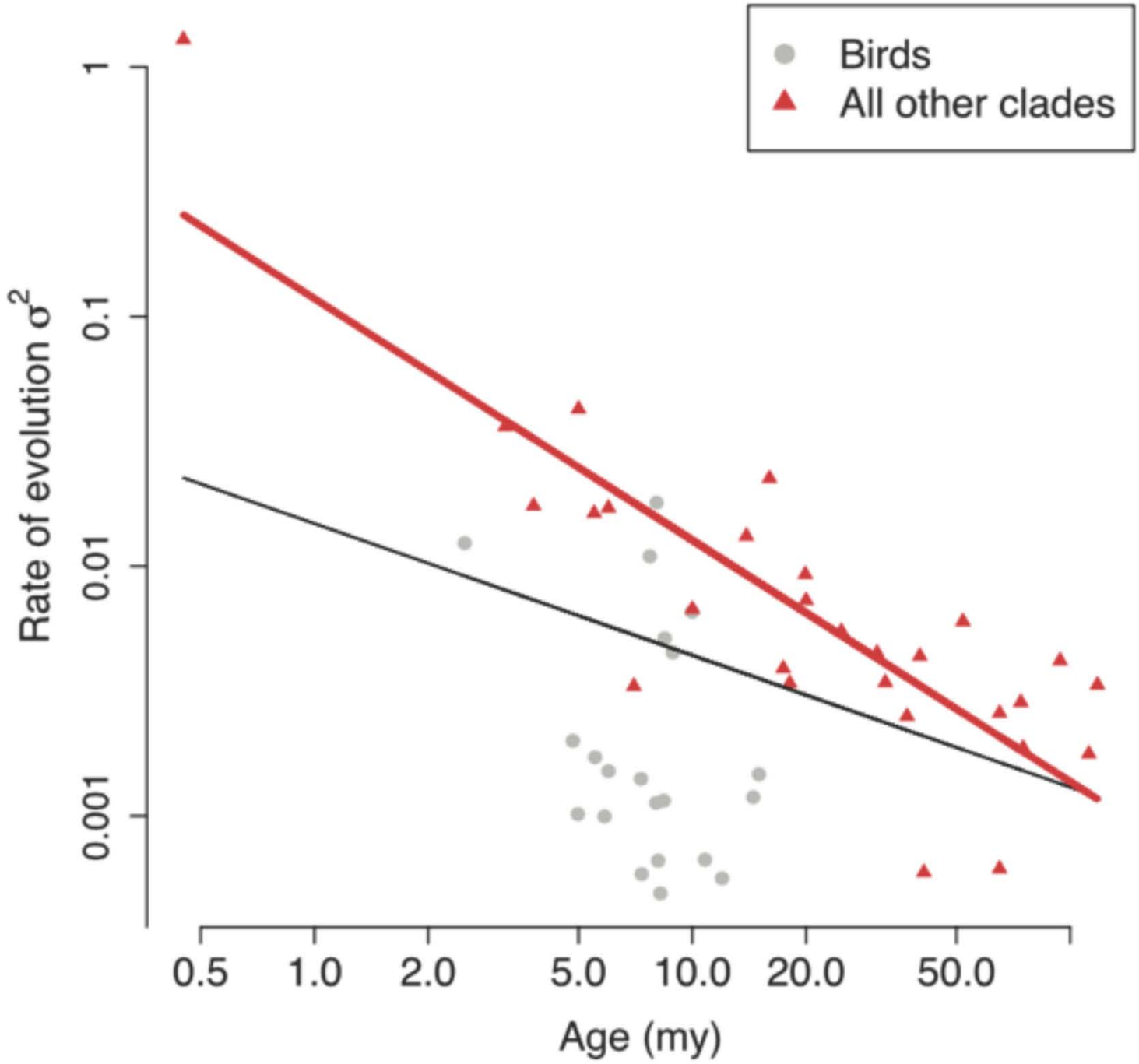


Early burst models are difficult to detect

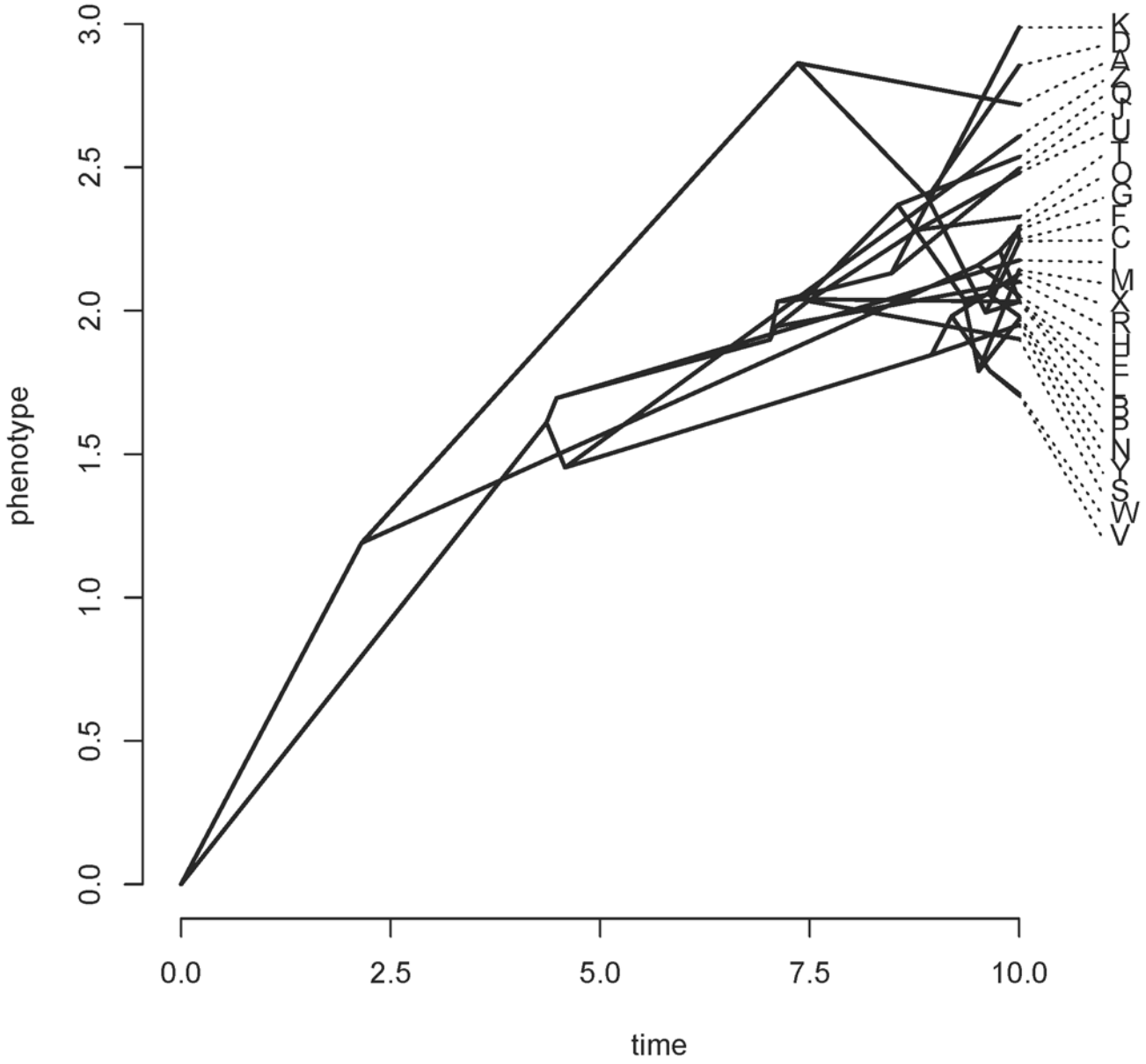


49 clades of animals; body size & shape data

Harmon et al 2010


Birds
All other clades
Rate of evolution σ^2
1
0.1
0.01
0.001
0.5
1.0
2.0
5.0
10.0
20.0
50.0
Age (my)

Brownian motion with a trend



Trait evolution models

- More complex models of trait evolution allow us to capture real complexity of how biological organisms may change through time.
- In a further lecture, we will discuss models in which the process can itself change among branches or clades of a phylogeny.