Assignment 7

Michelle

4/28/2020

#First get packages we need

```
install.packages("yearn")
install.packages("OUwie")
install.packages("nloptr")
install.packages("lattice")
install.packages("phytools")
```

```
library(ape)
library(geiger)
```

```
## Registered S3 method overwritten by 'geiger':
##   method            from
##   unique.multiPhylo ape
```

```
library(OUwie)
```

```
## Loading required package: nloptr
```

```
## Loading required package: lattice
```

```
## Registered S3 method overwritten by 'phytools':
##   method      from
##   logLik.gfit geiger
```

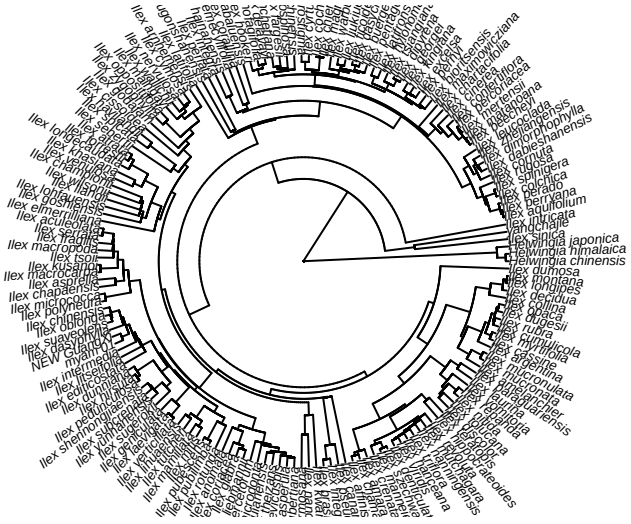
```
library(nloptr)
library(lattice)
library (corHMM)
```

```
## Loading required package: GenSA
```

```
library(phangorn)
library(openxlsx)
library(rotl)
library(phytools)
```

```
## Loading required package: maps
```

```
hollies <- get_study_tree("ot_1984", "tree1")
hollies.study.metadat<-get_study_meta("ot_1984")
hollies.tree.ids<-get_tree_ids(hollies.study.metadat)
plot(hollies, type="fan", cex = 0.4)
```

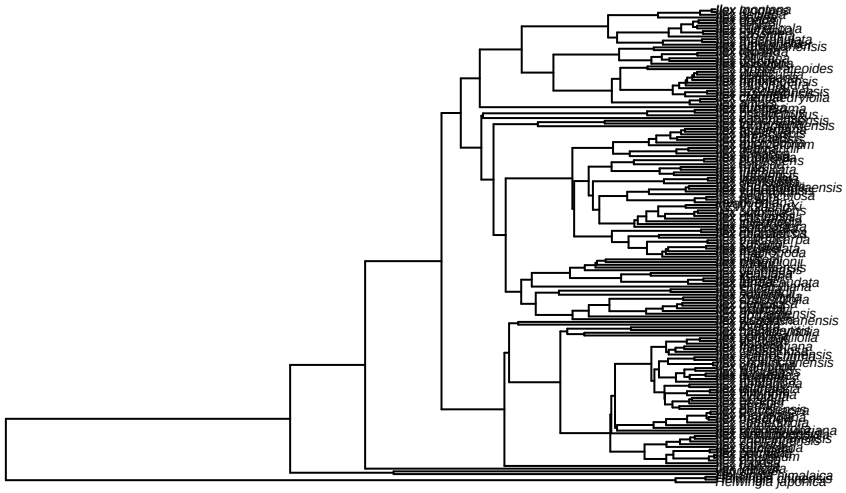


#Now get the tree and data. For these exercises, knowing uncertainty in your measurements can also be important. #(remember for homework to change eval=FALSE to eval=TRUE).

```
hollies <- get_study_tree("ot_1984", "tree1")
print (hollies)
```

```
##
## Phylogenetic tree with 175 tips and 174 internal nodes.
##
## Tip labels:
##  Helwingia_chinensis, Helwingia_himalaica, Helwingia_japonica, Ilex_sinica, yangchajie, Ilex_intrica
##
## Rooted; includes branch lengths.
```

```
hollies.study.metadat<-get_study_meta("ot_1984")
hollies.tree.ids<-get_tree_ids(hollies.study.metadat)
plot(hollies, cex = 0.4)
```




```
setwd("~/phylometh_exercises-/data\ set\ 6\ and\ 7")

hollies.data <- read.xlsx (xlsxFile = "hollies.xlsx", startRow = 2)
head(hollies.data )
```

```
##                                species colour fruit.diameter.(mm)  margin
## 1                  Ilex aculeolata Nakai  black                 7.0 serrate
## 2                   Ilex affinis Gardner  black                 4.0 serrate
## 3                       Ilex amara Loes.    red                 5.5 serrate
## 4 Ilex amelanchier M.A. Curtis ex Chapm.    red                 7.5  entire
## 5              Ilex anomala Hook. & Arn.  black                 9.0  entire
## 6                     Ilex aquifolium L.    red                 8.0   spiny
##   maximum.height.(m)
## 1                  4
## 2                  6
## 3                  4
## 4                  2
## 5                  9
## 6                 25
```

```
#Take the first 2 names and anytime there is an "_" it will split and put it together.
GetGenusSpeciesOneTaxon <- function(x) {
  x <- gsub("_", " ", x)
  x <- strsplit(x, "\\s+")[[1]]
  return(paste0(x[1:2], collapse="_"))
```

```
}
GetGenusSpeciesManyTaxa <- function(x) {
  return(unname(sapply(x, GetGenusSpeciesOneTaxon)))
}
# To get ride of the space and replace it with an "_"
hollies.data$species <- GetGenusSpeciesManyTaxa(gsub(" ", "_", hollies.data$species))

head(hollies.data )
```

```
##            species colour fruit.diameter.(mm)  margin maximum.height.(m)
## 1  Ilex_aculeolata  black                 7.0 serrate                  4
## 2     Ilex_affinis  black                 4.0 serrate                  6
## 3       Ilex_amara    red                 5.5 serrate                  4
## 4 Ilex_amelanchier    red                 7.5  entire                  2
## 5     Ilex_anomala  black                 9.0  entire                  9
## 6  Ilex_aquifolium    red                 8.0   spiny                 25
```

```
#To read csv files
#discrete.data <- read.csv(file= "hollies.xlsx", stringsAsFactors=FALSE)
```

```
#To get the fruit.diameter.(mm) data
#hollies.traits <- hollies.data[,c("species", "fruit.diameter", "colour")]
#print(head(hollies.traits))
print(colnames(hollies.data))
```

```
## [1] "species"             "colour"              "fruit.diameter.(mm)"
## [4] "margin"              "maximum.height.(m)"
```

```
hollies.fruit.diameter <- hollies.data$fruit.diameter
names(hollies.fruit.diameter) <- hollies.data$species
print(head(hollies.fruit.diameter))
```

```
##  Ilex_aculeolata     Ilex_affinis       Ilex_amara Ilex_amelanchier
##              7.0              4.0              5.5              7.5
##     Ilex_anomala  Ilex_aquifolium
##              9.0              8.0
```

```
print(hollies.fruit.diameter)
```

```
##       Ilex_aculeolata          Ilex_affinis            Ilex_amara
##                  7.00                  4.00                  5.50
##      Ilex_amelanchier          Ilex_anomala       Ilex_aquifolium
##                  7.50                  9.00                  8.00
##        Ilex_argentina      Ilex_arnhemensis         Ilex_asperula
##                  6.50                  4.50                  4.00
##         Ilex_asprella           Ilex_atrata         Ilex_beecheyi
##                  6.00                  6.50                 10.00
##     Ilex_bioritsensis     Ilex_brasiliensis      Ilex_brevicuspis
##                  7.00                  5.50                  3.75
##         Ilex_buergeri      Ilex_canariensis          Ilex_cassine
```

```
##                 5.25                10.00                 5.50
##  Ilex_centrochinensis   Ilex_chamaedryfolia       Ilex_championii
##                 6.50                 3.50                 3.50
##      Ilex_chapaensis    Ilex_chartacifolia        Ilex_chieniana
##                17.50                 6.00                10.00
##       Ilex_chinensis     Ilex_ciliospinosa          Ilex_cinerea
##                 7.00                 5.50                 7.00
##       Ilex_cissoidea  Ilex_cochinchinensis         Ilex_colchica
##                 3.00                 6.00                10.00
##         Ilex_collina    Ilex_confertiflora        Ilex_corallina
##                 7.50                 5.00                 3.50
##        Ilex_coriacea         Ilex_cornuta          Ilex_crenata
##                 8.00                 9.00                 7.00
##      Ilex_cumulicola          Ilex_cymosa          Ilex_cyrtura
##                 9.00                 3.00                 6.00
##   Ilex_dabieshanensis        Ilex_dasyclada       Ilex_dasyphylla
##                 4.50                 3.50                 6.00
##         Ilex_decidua         Ilex_delavayi      Ilex_denticulata
##                 6.50                 5.00                 6.50
##   Ilex_dimorphophylla         Ilex_dipyrena         Ilex_discolor
##                 6.00                 8.00                 5.00
##         Ilex_dugesii           Ilex_dumosa         Ilex_dunniana
##                 8.00                 6.00                 5.00
##     Ilex_editicostata    Ilex_elmerrilliana          Ilex_excelsa
##                 8.00                 5.00                 4.25
##         Ilex_fargesii         Ilex_ficoidea        Ilex_formosana
##                 6.00                 6.00                 5.00
##        Ilex_forrestii         Ilex_fragilis     Ilex_franchetiana
##                 4.00                 5.00                 6.50
##       Ilex_geniculata          Ilex_georgei          Ilex_glabra
##                 4.00                 3.50                 6.35
##         Ilex_godajam       Ilex_goshiensis       Ilex_guianensis
##                 4.00                 4.00                 3.50
##      Ilex_hainanensis         Ilex_hanceana       Ilex_havilandii
##                 3.00                 5.00                 3.00
##  Ilex_hippocrateoides          Ilex_hirsuta          Ilex_hookeri
##                 3.50                 6.00                 6.00
##         Ilex_hylonoma      Ilex_integerrima          Ilex_integra
##                11.00                 7.50                 7.50
##       Ilex_intermedia        Ilex_intricata         Ilex_khasiana
##                 5.00                 5.00                11.00
##    Ilex_kinabaluensis         Ilex_kingiana          Ilex_kusanoi
##                 9.00                 9.00                 6.00
##   Ilex_kwangtungensis        Ilex_laevigata        Ilex_latifolia
##                 8.00                 7.50                 7.00
##        Ilex_latifrons          Ilex_laurina       Ilex_leucoclada
##                 7.00                 6.00                10.00
##          Ilex_liangii       Ilex_liebmannii       Ilex_lihuaensis
##                 5.00                 4.00                 3.00
##      Ilex_litseifolia      Ilex_liukiuensis      Ilex_lohfauensis
##                 6.00                 6.00                 3.50
##     Ilex_longecaudata         Ilex_longipes       Ilex_macrocarpa
##                 3.50                12.00                12.00
##        Ilex_macropoda      Ilex_macrostigma         Ilex_maingayi
```

```
##                 5.00                 5.00                 3.00
##       Ilex_mamillata     Ilex_manneiensis       Ilex_matanoana
##                 5.00                 7.00                 5.00
##   Ilex_maximowicziana    Ilex_melanotricha    Ilex_memecylifolia
##                 7.50                 5.50                11.00
##       Ilex_mertensii      Ilex_micrococca      Ilex_microdonta
##                 3.00                 4.00                 7.00
##           Ilex_mitis         Ilex_montana     Ilex_mucronulata
##                 7.25                 8.47                 7.25
##      Ilex_mutchagara      Ilex_myrtifolia    Ilex_nanchuanensis
##                 7.50                 7.00                 4.50
##     Ilex_nanningensis       Ilex_nervulosa          Ilex_nitida
##                10.00                 3.00                 6.50
##   Ilex_nothofagifolia         Ilex_oblonga          Ilex_opaca
##                 3.25                 3.00                 9.00
##    Ilex_oppositifolia   Ilex_paraguariensis     Ilex_pedunculosa
##                 6.00                 4.00                 7.50
##       Ilex_pentagona          Ilex_perado     Ilex_percoriacea
##                 8.00                10.00                 8.00
##         Ilex_perlata          Ilex_pernyi        Ilex_perryana
##                 8.00                 7.50                 7.00
##       Ilex_polyneura     Ilex_pseudobuxus       Ilex_pubescens
##                 4.00                 4.00                 4.00
##       Ilex_pubilimba     Ilex_quercetorum         Ilex_repanda
##                 7.50                 4.00                 3.00
##        Ilex_revoluta         Ilex_rotunda          Ilex_rubra
##                 5.50                 5.00                10.00
##          Ilex_rugosa        Ilex_sebertii         Ilex_serrata
##                 6.00                 7.00                 5.00
## Ilex_shennongjiaensis          Ilex_sinica             Ilex_sp.
##                10.00                 4.50                26.00
##         Ilex_spicata       Ilex_spinigera      Ilex_suaveolens
##                 8.00                10.00                 6.00
##      Ilex_subcrenata     Ilex_subficoidea    Ilex_szechwanensis
##                 2.00                 7.50                 7.50
##     Ilex_taubertiana       Ilex_teratopis        Ilex_theizans
##                 3.25                 7.00                 7.00
##        Ilex_tolucana        Ilex_triflora      Ilex_tsiangiana
##                 7.00                 6.50                 3.50
##            Ilex_tsoi        Ilex_tutcheri        Ilex_venulosa
##                 7.00                 5.00                 4.00
##     Ilex_verticillata         Ilex_viridis       Ilex_vomitoria
##                 7.00                10.00                 6.35
##       Ilex_warburgii       Ilex_wallichii        Ilex_wilsonii
##                10.00                 5.50                 4.00
##   Ilex_wugonshanensis     Ilex_yunnanensis    Ilex_zhejiangensis
##                 6.50                 5.50                 7.50
##      Ilex_zygophylla
##                 4.00
```

```
hollies.colour <- hollies.data$colour
names(hollies.colour) <- hollies.data$species
print(head(hollies.colour))
```

```
##  Ilex_aculeolata     Ilex_affinis       Ilex_amara Ilex_amelanchier
##          "black"          "black"            "red"            "red"
##     Ilex_anomala  Ilex_aquifolium
##          "black"            "red"
```

```
print(hollies.colour)
```

```
##       Ilex_aculeolata          Ilex_affinis            Ilex_amara
##                 "black"               "black"                 "red"
##      Ilex_amelanchier          Ilex_anomala       Ilex_aquifolium
##                 "red"               "black"                 "red"
##        Ilex_argentina      Ilex_arnhemensis         Ilex_asperula
##                  "na"               "brown"                  "na"
##         Ilex_asprella           Ilex_atrata         Ilex_beecheyi
##                 "black"                 "red"                  "na"
##     Ilex_bioritsensis     Ilex_brasiliensis      Ilex_brevicuspis
##                 "red"               "black"                "black"
##         Ilex_buergeri      Ilex_canariensis          Ilex_cassine
##                 "red"                 "red"                  "red"
##  Ilex_centrochinensis   Ilex_chamaedryfolia       Ilex_championii
##                 "red"               "black"                  "red"
##       Ilex_chapaensis    Ilex_chartacifolia        Ilex_chieniana
##                 "black"                 "red"                  "red"
##        Ilex_chinensis     Ilex_ciliospinosa          Ilex_cinerea
##                 "red"                 "red"                  "red"
##        Ilex_cissoidea  Ilex_cochinchinensis         Ilex_colchica
##                  "na"                 "red"                  "red"
##          Ilex_collina    Ilex_confertiflora        Ilex_corallina
##                 "red"                  "na"                  "red"
##         Ilex_coriacea          Ilex_cornuta          Ilex_crenata
##                 "black"                 "red"                "black"
##       Ilex_cumulicola           Ilex_cymosa          Ilex_cyrtura
##                 "red"                 "red"                  "red"
##    Ilex_dabieshanensis        Ilex_dasyclada       Ilex_dasyphylla
##                 "red"                 "red"                  "red"
##          Ilex_decidua         Ilex_delavayi      Ilex_denticulata
##                 "black"                 "red"                "black"
##    Ilex_dimorphophylla         Ilex_dipyrena         Ilex_discolor
##                 "red"                 "red"                  "na"
##          Ilex_dugesii           Ilex_dumosa         Ilex_dunniana
##                 "red"                "black"                  "red"
##      Ilex_editicostata    Ilex_elmerrilliana          Ilex_excelsa
##                 "red"                 "red"                  "red"
##         Ilex_fargesii         Ilex_ficoidea        Ilex_formosana
##                 "red"                 "red"                  "red"
##        Ilex_forrestii         Ilex_fragilis     Ilex_franchetiana
##                 "red"                 "red"                  "red"
##       Ilex_geniculata          Ilex_georgei           Ilex_glabra
##                  "na"                 "red"                "black"
##          Ilex_godajam       Ilex_goshiensis       Ilex_guianensis
##                 "red"                 "red"                "black"
##      Ilex_hainanensis         Ilex_hanceana       Ilex_havilandii
##                  "na"                 "red"                  "na"
##  Ilex_hippocrateoides          Ilex_hirsuta          Ilex_hookeri
```

```
##                 "na"                 "na"                 "na"
##         Ilex_hylonoma      Ilex_integerrima          Ilex_integra
##                 "red"                 "na"                 "red"
##       Ilex_intermedia        Ilex_intricata         Ilex_khasiana
##                 "red"                 "red"                  "na"
##    Ilex_kinabaluensis         Ilex_kingiana          Ilex_kusanoi
##                 "red"                 "red"                  "na"
##   Ilex_kwangtungensis        Ilex_laevigata        Ilex_latifolia
##                 "red"                 "red"                 "red"
##        Ilex_latifrons          Ilex_laurina       Ilex_leucoclada
##                  "na"                 "red"                 "red"
##          Ilex_liangii       Ilex_liebmannii       Ilex_lihuaensis
##                 "red"                  "na"                 "red"
##      Ilex_litseifolia      Ilex_liukiuensis      Ilex_lohfauensis
##                 "red"                  "na"                 "red"
##     Ilex_longecaudata         Ilex_longipes       Ilex_macrocarpa
##                 "red"                 "red"                "black"
##        Ilex_macropoda      Ilex_macrostigma         Ilex_maingayi
##                 "red"                  "na"                  "na"
##        Ilex_mamillata      Ilex_manneiensis        Ilex_matanoana
##                 "red"               "black"                 "red"
##   Ilex_maximowicziana     Ilex_melanotricha     Ilex_memecylifolia
##                  "na"                 "red"                 "red"
##        Ilex_mertensii       Ilex_micrococca       Ilex_microdonta
##                 "red"               "black"                 "red"
##            Ilex_mitis         Ilex_montana      Ilex_mucronulata
##                 "red"                 "red"                 "red"
##       Ilex_mutchagara       Ilex_myrtifolia     Ilex_nanchuanensis
##               "black"                 "red"                 "red"
##     Ilex_nanningensis        Ilex_nervulosa           Ilex_nitida
##                 "red"                  "na"                 "red"
##   Ilex_nothofagifolia          Ilex_oblonga           Ilex_opaca
##                 "red"                 "red"                 "red"
##    Ilex_oppositifolia   Ilex_paraguariensis      Ilex_pedunculosa
##               "black"                 "red"                 "red"
##        Ilex_pentagona           Ilex_perado      Ilex_percoriacea
##                  "na"                 "red"                 "red"
##          Ilex_perlata          Ilex_pernyi         Ilex_perryana
##                  "na"                 "red"                 "red"
##        Ilex_polyneura      Ilex_pseudobuxus        Ilex_pubescens
##                 "red"               "black"                 "red"
##        Ilex_pubilimba      Ilex_quercetorum          Ilex_repanda
##                 "red"                  "na"                  "na"
##         Ilex_revoluta         Ilex_rotunda            Ilex_rubra
##                  "na"                 "red"                  "na"
##           Ilex_rugosa         Ilex_sebertii         Ilex_serrata
##                 "red"                 "red"                 "red"
## Ilex_shennongjiaensis          Ilex_sinica             Ilex_sp.
##                 "red"                 "red"               "brown"
##          Ilex_spicata        Ilex_spinigera       Ilex_suaveolens
##                  "na"                 "red"                 "red"
##       Ilex_subcrenata      Ilex_subficoidea     Ilex_szechwanensis
##                 "red"                 "red"                "black"
##      Ilex_taubertiana        Ilex_teratopis         Ilex_theizans
```

```
##               "brown"               "black"                 "red"
##         Ilex_tolucana         Ilex_triflora       Ilex_tsiangiana
##                 "red"               "black"                 "red"
##             Ilex_tsoi         Ilex_tutcheri         Ilex_venulosa
##               "black"                 "red"                 "red"
##     Ilex_verticillata          Ilex_viridis        Ilex_vomitoria
##                 "red"               "black"                 "red"
##        Ilex_warburgii        Ilex_wallichii         Ilex_wilsonii
##                 "red"                  "na"                 "red"
##   Ilex_wugonshanensis      Ilex_yunnanensis    Ilex_zhejiangensis
##                 "red"                 "red"                 "red"
##       Ilex_zygophylla
##                 "red"
```

```
hollies.colour <- hollies.colour[!grepl("na", hollies.colour)]
print(hollies.colour)
```

```
##       Ilex_aculeolata          Ilex_affinis            Ilex_amara
##               "black"               "black"                 "red"
##      Ilex_amelanchier          Ilex_anomala       Ilex_aquifolium
##                 "red"               "black"                 "red"
##      Ilex_arnhemensis         Ilex_asprella           Ilex_atrata
##               "brown"               "black"                 "red"
##     Ilex_bioritsensis     Ilex_brasiliensis      Ilex_brevicuspis
##                 "red"               "black"                "black"
##         Ilex_buergeri      Ilex_canariensis          Ilex_cassine
##                 "red"                 "red"                 "red"
##  Ilex_centrochinensis   Ilex_chamaedryfolia       Ilex_championii
##                 "red"               "black"                 "red"
##       Ilex_chapaensis    Ilex_chartacifolia        Ilex_chieniana
##               "black"                 "red"                 "red"
##        Ilex_chinensis     Ilex_ciliospinosa          Ilex_cinerea
##                 "red"                 "red"                 "red"
##  Ilex_cochinchinensis         Ilex_colchica          Ilex_collina
##                 "red"                 "red"                 "red"
##        Ilex_corallina         Ilex_coriacea          Ilex_cornuta
##                 "red"               "black"                 "red"
##          Ilex_crenata       Ilex_cumulicola           Ilex_cymosa
##               "black"                 "red"                 "red"
##          Ilex_cyrtura   Ilex_dabieshanensis        Ilex_dasyclada
##                 "red"                 "red"                 "red"
##       Ilex_dasyphylla          Ilex_decidua         Ilex_delavayi
##                 "red"               "black"                 "red"
##      Ilex_denticulata   Ilex_dimorphophylla         Ilex_dipyrena
##               "black"                 "red"                 "red"
##          Ilex_dugesii           Ilex_dumosa         Ilex_dunniana
##                 "red"               "black"                 "red"
##     Ilex_editicostata    Ilex_elmerrilliana          Ilex_excelsa
##                 "red"                 "red"                 "red"
##         Ilex_fargesii         Ilex_ficoidea        Ilex_formosana
##                 "red"                 "red"                 "red"
##        Ilex_forrestii         Ilex_fragilis     Ilex_franchetiana
##                 "red"                 "red"                 "red"
##          Ilex_georgei           Ilex_glabra          Ilex_godajam
```

```
##                "red"              "black"                "red"
##       Ilex_goshiensis       Ilex_guianensis        Ilex_hanceana
##                "red"              "black"                "red"
##         Ilex_hylonoma          Ilex_integra       Ilex_intermedia
##                "red"                "red"                "red"
##        Ilex_intricata    Ilex_kinabaluensis        Ilex_kingiana
##                "red"                "red"                "red"
##   Ilex_kwangtungensis        Ilex_laevigata        Ilex_latifolia
##                "red"                "red"                "red"
##         Ilex_laurina       Ilex_leucoclada         Ilex_liangii
##                "red"                "red"                "red"
##       Ilex_lihuaensis      Ilex_litseifolia      Ilex_lohfauensis
##                "red"                "red"                "red"
##     Ilex_longecaudata         Ilex_longipes       Ilex_macrocarpa
##                "red"                "red"               "black"
##        Ilex_macropoda        Ilex_mamillata      Ilex_manneiensis
##                "red"                "red"               "black"
##        Ilex_matanoana     Ilex_melanotricha    Ilex_memecylifolia
##                "red"                "red"                "red"
##        Ilex_mertensii       Ilex_micrococca       Ilex_microdonta
##                "red"              "black"                "red"
##           Ilex_mitis          Ilex_montana      Ilex_mucronulata
##                "red"                "red"                "red"
##       Ilex_mutchagara       Ilex_myrtifolia    Ilex_nanchuanensis
##               "black"                "red"                "red"
##     Ilex_nanningensis           Ilex_nitida   Ilex_nothofagifolia
##                "red"                "red"                "red"
##          Ilex_oblonga            Ilex_opaca    Ilex_oppositifolia
##                "red"                "red"               "black"
##   Ilex_paraguariensis      Ilex_pedunculosa           Ilex_perado
##                "red"                "red"                "red"
##      Ilex_percoriacea           Ilex_pernyi         Ilex_perryana
##                "red"                "red"                "red"
##        Ilex_polyneura      Ilex_pseudobuxus        Ilex_pubescens
##                "red"              "black"                "red"
##        Ilex_pubilimba         Ilex_rotunda           Ilex_rugosa
##                "red"                "red"                "red"
##         Ilex_sebertii         Ilex_serrata Ilex_shennongjiaensis
##                "red"                "red"                "red"
##           Ilex_sinica             Ilex_sp.        Ilex_spinigera
##                "red"              "brown"                "red"
##       Ilex_suaveolens       Ilex_subcrenata      Ilex_subficoidea
##                "red"                "red"                "red"
##    Ilex_szechwanensis      Ilex_taubertiana        Ilex_teratopis
##               "black"              "brown"               "black"
##         Ilex_theizans         Ilex_tolucana         Ilex_triflora
##                "red"                "red"               "black"
##       Ilex_tsiangiana            Ilex_tsoi         Ilex_tutcheri
##                "red"              "black"                "red"
##         Ilex_venulosa     Ilex_verticillata          Ilex_viridis
##                "red"                "red"               "black"
##        Ilex_vomitoria        Ilex_warburgii         Ilex_wilsonii
##                "red"                "red"                "red"
##   Ilex_wugonshanensis      Ilex_yunnanensis    Ilex_zhejiangensis
```

```
##                 "red"                 "red"                 "red"
##       Ilex_zygophylla
##                 "red"
```

```
#Omit NA from data set
hollies.fruit.diameter <- hollies.fruit.diameter[!grepl("na", hollies.fruit.diameter)]
print(hollies.fruit.diameter)
```

```
##       Ilex_aculeolata          Ilex_affinis            Ilex_amara
##                  7.00                  4.00                  5.50
##      Ilex_amelanchier          Ilex_anomala       Ilex_aquifolium
##                  7.50                  9.00                  8.00
##        Ilex_argentina      Ilex_arnhemensis         Ilex_asperula
##                  6.50                  4.50                  4.00
##         Ilex_asprella           Ilex_atrata         Ilex_beecheyi
##                  6.00                  6.50                 10.00
##     Ilex_bioritsensis     Ilex_brasiliensis      Ilex_brevicuspis
##                  7.00                  5.50                  3.75
##         Ilex_buergeri      Ilex_canariensis          Ilex_cassine
##                  5.25                 10.00                  5.50
##  Ilex_centrochinensis   Ilex_chamaedryfolia       Ilex_championii
##                  6.50                  3.50                  3.50
##       Ilex_chapaensis    Ilex_chartacifolia        Ilex_chieniana
##                 17.50                  6.00                 10.00
##        Ilex_chinensis     Ilex_ciliospinosa          Ilex_cinerea
##                  7.00                  5.50                  7.00
##        Ilex_cissoidea  Ilex_cochinchinensis         Ilex_colchica
##                  3.00                  6.00                 10.00
##          Ilex_collina    Ilex_confertiflora        Ilex_corallina
##                  7.50                  5.00                  3.50
##         Ilex_coriacea          Ilex_cornuta          Ilex_crenata
##                  8.00                  9.00                  7.00
##       Ilex_cumulicola           Ilex_cymosa          Ilex_cyrtura
##                  9.00                  3.00                  6.00
##   Ilex_dabieshanensis        Ilex_dasyclada       Ilex_dasyphylla
##                  4.50                  3.50                  6.00
##          Ilex_decidua         Ilex_delavayi      Ilex_denticulata
##                  6.50                  5.00                  6.50
##   Ilex_dimorphophylla         Ilex_dipyrena         Ilex_discolor
##                  6.00                  8.00                  5.00
##          Ilex_dugesii           Ilex_dumosa         Ilex_dunniana
##                  8.00                  6.00                  5.00
##     Ilex_editicostata    Ilex_elmerrilliana          Ilex_excelsa
##                  8.00                  5.00                  4.25
##         Ilex_fargesii         Ilex_ficoidea        Ilex_formosana
##                  6.00                  6.00                  5.00
##        Ilex_forrestii         Ilex_fragilis     Ilex_franchetiana
##                  4.00                  5.00                  6.50
##       Ilex_geniculata          Ilex_georgei          Ilex_glabra
##                  4.00                  3.50                  6.35
##          Ilex_godajam       Ilex_goshiensis       Ilex_guianensis
##                  4.00                  4.00                  3.50
##      Ilex_hainanensis         Ilex_hanceana       Ilex_havilandii
##                  3.00                  5.00                  3.00
```

```
##  Ilex_hippocrateoides          Ilex_hirsuta          Ilex_hookeri
##                  3.50                  6.00                  6.00
##         Ilex_hylonoma      Ilex_integerrima          Ilex_integra
##                 11.00                  7.50                  7.50
##       Ilex_intermedia        Ilex_intricata        Ilex_khasiana
##                  5.00                  5.00                 11.00
##    Ilex_kinabaluensis         Ilex_kingiana         Ilex_kusanoi
##                  9.00                  9.00                  6.00
##   Ilex_kwangtungensis        Ilex_laevigata       Ilex_latifolia
##                  8.00                  7.50                  7.00
##        Ilex_latifrons          Ilex_laurina       Ilex_leucoclada
##                  7.00                  6.00                 10.00
##          Ilex_liangii       Ilex_liebmannii       Ilex_lihuaensis
##                  5.00                  4.00                  3.00
##      Ilex_litseifolia      Ilex_liukiuensis      Ilex_lohfauensis
##                  6.00                  6.00                  3.50
##     Ilex_longecaudata         Ilex_longipes       Ilex_macrocarpa
##                  3.50                 12.00                 12.00
##        Ilex_macropoda      Ilex_macrostigma         Ilex_maingayi
##                  5.00                  5.00                  3.00
##        Ilex_mamillata      Ilex_manneiensis        Ilex_matanoana
##                  5.00                  7.00                  5.00
##   Ilex_maximowicziana     Ilex_melanotricha     Ilex_memecylifolia
##                  7.50                  5.50                 11.00
##        Ilex_mertensii       Ilex_micrococca       Ilex_microdonta
##                  3.00                  4.00                  7.00
##            Ilex_mitis          Ilex_montana      Ilex_mucronulata
##                  7.25                  8.47                  7.25
##       Ilex_mutchagara       Ilex_myrtifolia    Ilex_nanchuanensis
##                  7.50                  7.00                  4.50
##     Ilex_nanningensis        Ilex_nervulosa           Ilex_nitida
##                 10.00                  3.00                  6.50
##   Ilex_nothofagifolia          Ilex_oblonga           Ilex_opaca
##                  3.25                  3.00                  9.00
##    Ilex_oppositifolia   Ilex_paraguariensis      Ilex_pedunculosa
##                  6.00                  4.00                  7.50
##        Ilex_pentagona           Ilex_perado      Ilex_percoriacea
##                  8.00                 10.00                  8.00
##          Ilex_perlata          Ilex_pernyi         Ilex_perryana
##                  8.00                  7.50                  7.00
##        Ilex_polyneura      Ilex_pseudobuxus        Ilex_pubescens
##                  4.00                  4.00                  4.00
##        Ilex_pubilimba      Ilex_quercetorum          Ilex_repanda
##                  7.50                  4.00                  3.00
##         Ilex_revoluta          Ilex_rotunda            Ilex_rubra
##                  5.50                  5.00                 10.00
##           Ilex_rugosa         Ilex_sebertii         Ilex_serrata
##                  6.00                  7.00                  5.00
## Ilex_shennongjiaensis           Ilex_sinica             Ilex_sp.
##                 10.00                  4.50                 26.00
##          Ilex_spicata        Ilex_spinigera       Ilex_suaveolens
##                  8.00                 10.00                  6.00
##       Ilex_subcrenata      Ilex_subficoidea     Ilex_szechwanensis
##                  2.00                  7.50                  7.50
```

```
##      Ilex_taubertiana        Ilex_teratopis         Ilex_theizans
##                  3.25                  7.00                  7.00
##         Ilex_tolucana         Ilex_triflora       Ilex_tsiangiana
##                  7.00                  6.50                  3.50
##             Ilex_tsoi         Ilex_tutcheri         Ilex_venulosa
##                  7.00                  5.00                  4.00
##     Ilex_verticillata          Ilex_viridis        Ilex_vomitoria
##                  7.00                 10.00                  6.35
##        Ilex_warburgii        Ilex_wallichii         Ilex_wilsonii
##                 10.00                  5.50                  4.00
##   Ilex_wugonshanensis      Ilex_yunnanensis    Ilex_zhejiangensis
##                  6.50                  5.50                  7.50
##       Ilex_zygophylla
##                  4.00
```

#A function to clean data, make sure taxon names match between tree and data, etc. #fruit diameter

```
CleanData_cont <- function(phy, data) {
  data <- log(data) #because we can't have negative fruit size.
 #result=treedata(phy, data,sort = TRUE, warnings = FALSE)
  #return(result) You can used the two above functions (results or return) or the function below
  return(treedata(phy, data,sort = TRUE, warnings = FALSE))
}
h_cleanedF<-CleanData_cont(hollies, hollies.fruit.diameter)
print(h_cleanedF)
```

```
## $phy
##
## Phylogenetic tree with 165 tips and 164 internal nodes.
##
## Tip labels:
##  Ilex_sinica, Ilex_intricata, Ilex_aquifolium, Ilex_perryana, Ilex_perado, Ilex_colchica, ...
##
## Rooted; includes branch lengths.
##
## $data
##                           [,1]
## Ilex_sinica          1.5040774
## Ilex_intricata       1.6094379
## Ilex_aquifolium      2.0794415
## Ilex_perryana        1.9459101
## Ilex_perado          2.3025851
## Ilex_colchica        2.3025851
## Ilex_spinigera       2.3025851
## Ilex_rugosa          1.7917595
## Ilex_cornuta         2.1972246
## Ilex_dabieshanensis  1.5040774
## Ilex_dimorphophylla  1.7917595
## Ilex_zhejiangensis   2.0149030
## Ilex_leucoclada      2.3025851
## Ilex_beecheyi        2.3025851
## Ilex_matanoana       1.6094379
## Ilex_mertensii       1.0986123
```

```
## Ilex_percoriacea      2.0794415
## Ilex_confertiflora    1.6094379
## Ilex_cinerea          1.9459101
## Ilex_chartacifolia    1.7917595
## Ilex_maximowicziana   2.0149030
## Ilex_bioritsensis     1.9459101
## Ilex_pernyi           2.0149030
## Ilex_excelsa          1.4469190
## Ilex_kingiana         2.1972246
## Ilex_georgei          1.2527630
## Ilex_dipyrena         2.0794415
## Ilex_tsiangiana       1.2527630
## Ilex_hylonoma         2.3978953
## Ilex_latifrons        1.9459101
## Ilex_pentagona        2.0794415
## Ilex_buergeri         1.6582281
## Ilex_dasyclada        1.2527630
## Ilex_ficoidea         1.7917595
## Ilex_liukiuensis      1.7917595
## Ilex_warburgii        2.3025851
## Ilex_chieniana        2.3025851
## Ilex_cochinchinensis  1.7917595
## Ilex_cyrtura          1.7917595
## Ilex_macrostigma      1.6094379
## Ilex_centrochinensis  1.8718022
## Ilex_ciliospinosa     1.7047481
## Ilex_fargesii         1.7917595
## Ilex_franchetiana     1.8718022
## Ilex_delavayi         1.6094379
## Ilex_nothofagifolia   1.1786550
## Ilex_hookeri          1.7917595
## Ilex_kinabaluensis    2.1972246
## Ilex_corallina        1.2527630
## Ilex_memecylifolia    2.3978953
## Ilex_hainanensis      1.0986123
## Ilex_integra          2.0149030
## Ilex_perlata          2.0794415
## Ilex_wugonshanensis   1.8718022
## Ilex_latifolia        1.9459101
## Ilex_arnhemensis      1.5040774
## Ilex_cymosa           1.0986123
## Ilex_nervulosa        1.0986123
## Ilex_wallichii        1.7047481
## Ilex_maingayi         1.0986123
## Ilex_oppositifolia    1.7917595
## Ilex_zygophylla       1.3862944
## Ilex_godajam          1.3862944
## Ilex_cissoidea        1.0986123
## Ilex_havilandii       1.0986123
## Ilex_spicata          2.0794415
## Ilex_sebertii         1.9459101
## Ilex_atrata           1.8718022
## Ilex_forrestii        1.3862944
## Ilex_longecaudata     1.2527630
```

```
## Ilex_khasiana         2.3978953
## Ilex_venulosa         1.3862944
## Ilex_championii       1.2527630
## Ilex_wilsonii         1.3862944
## Ilex_liangii          1.6094379
## Ilex_lohfauensis      1.2527630
## Ilex_goshiensis       1.3862944
## Ilex_elmerrilliana    1.6094379
## Ilex_aculeolata       1.9459101
## Ilex_serrata          1.6094379
## Ilex_fragilis         1.6094379
## Ilex_macropoda        1.6094379
## Ilex_kusanoi          1.7917595
## Ilex_macrocarpa       2.4849066
## Ilex_asprella         1.7917595
## Ilex_chapaensis       2.8622009
## Ilex_micrococca       1.3862944
## Ilex_polyneura        1.3862944
## Ilex_chinensis        1.9459101
## Ilex_oblonga          1.0986123
## Ilex_suaveolens       1.7917595
## Ilex_dasyphylla       1.7917595
## Ilex_intermedia       1.6094379
## Ilex_litseifolia      1.7917595
## Ilex_editicostata     2.0794415
## Ilex_dunniana         1.6094379
## Ilex_hirsuta          1.7917595
## Ilex_pedunculosa      2.0149030
## Ilex_shennongjiaensis 2.3025851
## Ilex_subcrenata       0.6931472
## Ilex_yunnanensis      1.7047481
## Ilex_geniculata       1.3862944
## Ilex_laevigata        2.0149030
## Ilex_verticillata     1.9459101
## Ilex_lihuaensis       1.0986123
## Ilex_tutcheri         1.6094379
## Ilex_mamillata        1.6094379
## Ilex_mitis            1.9810015
## Ilex_pubescens        1.3862944
## Ilex_pubilimba        2.0149030
## Ilex_rotunda          1.6094379
## Ilex_anomala          2.1972246
## Ilex_coriacea         2.0794415
## Ilex_glabra           1.8484548
## Ilex_liebmannii       1.3862944
## Ilex_quercetorum      1.3862944
## Ilex_microdonta       1.9459101
## Ilex_guianensis       1.2527630
## Ilex_theizans         1.9459101
## Ilex_brevicuspis      1.3217558
## Ilex_asperula         1.3862944
## Ilex_taubertiana      1.1786550
## Ilex_formosana        1.6094379
## Ilex_nanchuanensis    1.5040774
```

```
## Ilex_kwangtungensis   2.0794415
## Ilex_brasiliensis     1.7047481
## Ilex_integerrima      2.0149030
## Ilex_pseudobuxus      1.3862944
## Ilex_canariensis      2.3025851
## Ilex_affinis          1.3862944
## Ilex_chamaedryfolia   1.2527630
## Ilex_amara            1.7047481
## Ilex_crenata          1.9459101
## Ilex_manneiensis      1.9459101
## Ilex_szechwanensis    2.0149030
## Ilex_denticulata      1.8718022
## Ilex_viridis          2.3025851
## Ilex_hanceana         1.6094379
## Ilex_triflora         1.8718022
## Ilex_nanningensis     2.3025851
## Ilex_mutchagara       2.0149030
## Ilex_revoluta         1.7047481
## Ilex_hippocrateoides  1.2527630
## Ilex_teratopis        1.9459101
## Ilex_discolor         1.6094379
## Ilex_tolucana         1.9459101
## Ilex_nitida           1.8718022
## Ilex_repanda          1.0986123
## Ilex_vomitoria        1.8484548
## Ilex_laurina          1.7917595
## Ilex_paraguariensis   1.3862944
## Ilex_amelanchier      2.0149030
## Ilex_mucronulata      1.9810015
## Ilex_argentina        1.8718022
## Ilex_cassine          1.7047481
## Ilex_myrtifolia       1.9459101
## Ilex_cumulicola       2.1972246
## Ilex_rubra            2.3025851
## Ilex_dugesii          2.0794415
## Ilex_opaca            2.1972246
## Ilex_collina          2.0149030
## Ilex_decidua          1.8718022
## Ilex_longipes         2.4849066
## Ilex_montana          2.1365305
## Ilex_dumosa           1.7917595
```

#fruit color

```
CleanData_discrete <- function(phy, data) {
 #result=treedata(phy, data,sort = TRUE, warnings = FALSE)
  #return(result) or the function below
  return(treedata(phy, data,sort = TRUE, warnings = FALSE))
}
# three objects: original tree, colour, diameter
# first cleaning: tree_diameter_cleaned, diameter_tree_cleaned, original colour
# second cleaning: tree_diameter_and_colour_cleaned, diameter_tree_cleaned, colour_diameter_and_tree_cl
# third cleaning: tree_diameter_and_colour_cleaned, diameter_tree_and_colour_cleaned, colour_diameter_a
```

```
#Tree: A, B, C, D, E, no F
# Diameter: A, C, D, E, F, no B
# Colour: B, C, D, E, F, no A


# Tree + Colour + Diameter, all with C, D, E only


# Tree diameter cleaning:
# Tree A, C, D, E  CLEAN
# Diameter A, C, D, E CLEAN
# Colour, B, C, D, E, F

# Colour cleaning
# Tree C, D E CLEAN
# Diameter A, C, D, E
# Colour C, D. E CLEAN

# clean both
# TREE C, D, E CLean
# Diameer C D E
# Colour C D E CLEAN
h_cleanedC<-CleanData_discrete(h_cleanedF$phy, hollies.colour)
print(str(h_cleanedC))
```

```
## List of 2
##  $ phy :List of 4
##   ..$ edge       : int [1:268, 1:2] 136 136 137 137 138 139 139 140 141 142 ...
##   ..$ tip.label  : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana" ...
##   ..$ Nnode      : int 134
##   ..$ edge.length: num [1:268] 50.75 8.94 41.8 9.11 7.5 ...
##   ..- attr(*, "class")= chr "phylo"
##   ..- attr(*, "order")= chr "cladewise"
##  $ data: chr [1:135, 1] "red" "red" "red" "red" ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana" ...
##   .. ..$ : NULL
## NULL
```

#Third cleaned

```
h_cleanedBoth <- treedata(h_cleanedC$phy, h_cleanedF$data )
```

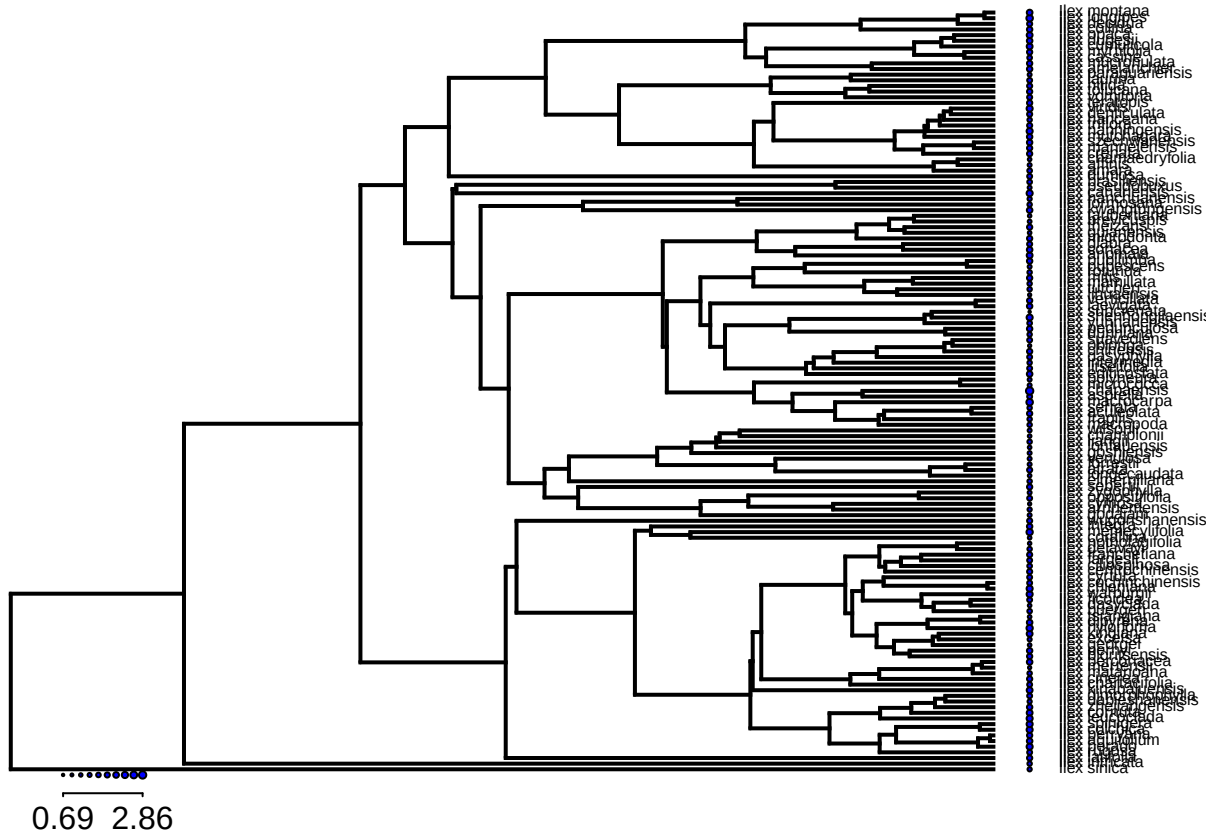
```
## Warning in treedata(h_cleanedC$phy, h_cleanedF$data): The following tips were not found in 'phy' and
##  Ilex_argentina
##  Ilex_asperula
##  Ilex_beecheyi
##  Ilex_cissoidea
##  Ilex_confertiflora
##  Ilex_discolor
##  Ilex_geniculata
##  Ilex_hainanensis
```

```
##  Ilex_havilandii
##  Ilex_hippocrateoides
##  Ilex_hirsuta
##  Ilex_hookeri
##  Ilex_integerrima
##  Ilex_khasiana
##  Ilex_kusanoi
##  Ilex_latifrons
##  Ilex_liebmannii
##  Ilex_liukiuensis
##  Ilex_macrostigma
##  Ilex_maingayi
##  Ilex_maximowicziana
##  Ilex_nervulosa
##  Ilex_pentagona
##  Ilex_perlata
##  Ilex_quercetorum
##  Ilex_repanda
##  Ilex_revoluta
##  Ilex_rubra
##  Ilex_spicata
##  Ilex_wallichii
```

```
clean.tree <- h_cleanedBoth$phy
clean.colour <- h_cleanedC$data
clean.diameter <- h_cleanedBoth$data
```

#A function to plot data. Look at phytools::contMap(). This is all part of checking: do your data all seem #sensible? #LOOK AT IT.

```
VisualizeData_Discrete <- function(phy=phy, data=data) {
  dotTree(phy,data,length=10,fsize=0.5,lwd=2)
}
VisualizeData_Discrete(phy=clean.tree, data=clean.diameter)
```




```
print(paste("This tree has a polytomy? ", is.binary(h_cleanedF$phy)))
```

```
## [1] "This tree has a polytomy?  TRUE"
```

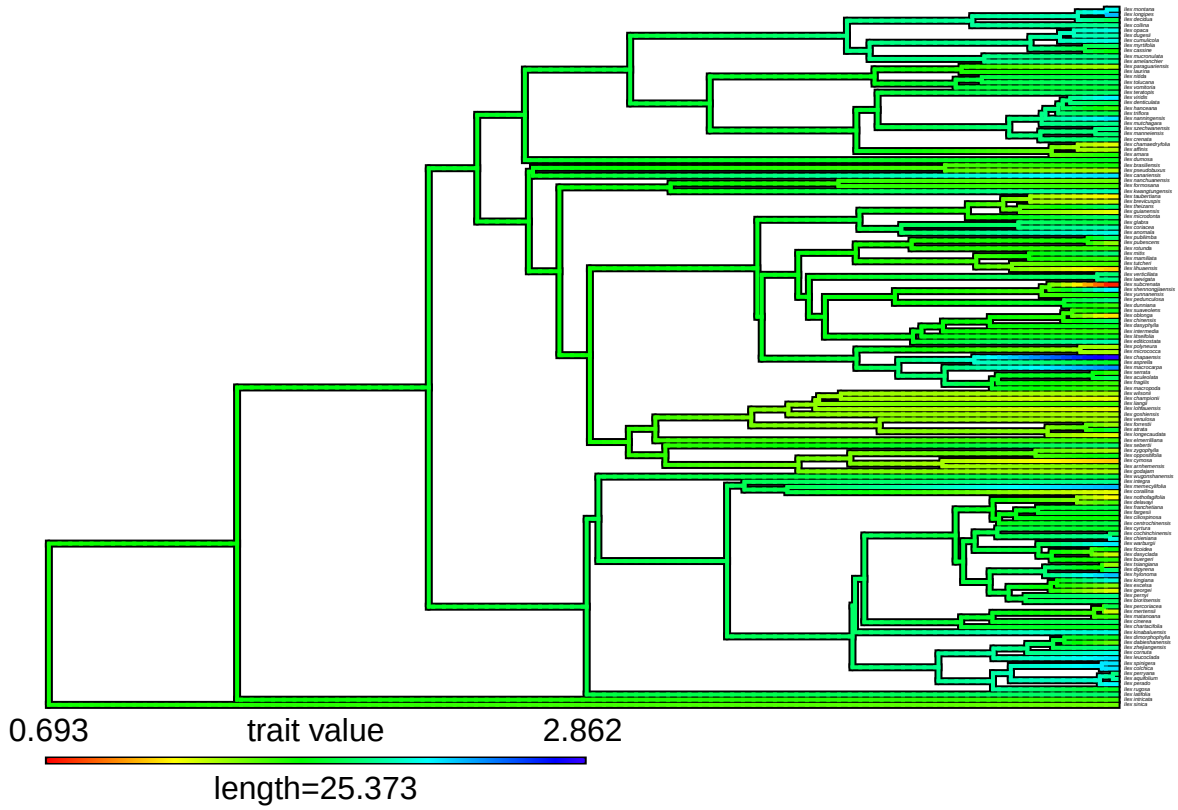
```
print(h_cleanedF$data[,1])
```

```
##           Ilex_sinica       Ilex_intricata      Ilex_aquifolium
##             1.5040774            1.6094379            2.0794415
##         Ilex_perryana         Ilex_perado        Ilex_colchica
##             1.9459101            2.3025851            2.3025851
##        Ilex_spinigera         Ilex_rugosa         Ilex_cornuta
##             2.3025851            1.7917595            2.1972246
##   Ilex_dabieshanensis  Ilex_dimorphophylla   Ilex_zhejiangensis
##             1.5040774            1.7917595            2.0149030
##       Ilex_leucoclada        Ilex_beecheyi       Ilex_matanoana
##             2.3025851            2.3025851            1.6094379
##        Ilex_mertensii     Ilex_percoriacea    Ilex_confertiflora
##             1.0986123            2.0794415            1.6094379
##          Ilex_cinerea   Ilex_chartacifolia  Ilex_maximowicziana
##             1.9459101            1.7917595            2.0149030
##     Ilex_bioritsensis          Ilex_pernyi         Ilex_excelsa
##             1.9459101            2.0149030            1.4469190
##         Ilex_kingiana         Ilex_georgei        Ilex_dipyrena
##             2.1972246            1.2527630            2.0794415
```

```
##       Ilex_tsiangiana         Ilex_hylonoma        Ilex_latifrons
##             1.2527630             2.3978953             1.9459101
##        Ilex_pentagona         Ilex_buergeri        Ilex_dasyclada
##             2.0794415             1.6582281             1.2527630
##         Ilex_ficoidea      Ilex_liukiuensis        Ilex_warburgii
##             1.7917595             1.7917595             2.3025851
##        Ilex_chieniana  Ilex_cochinchinensis          Ilex_cyrtura
##             2.3025851             1.7917595             1.7917595
##      Ilex_macrostigma  Ilex_centrochinensis     Ilex_ciliospinosa
##             1.6094379             1.8718022             1.7047481
##         Ilex_fargesii     Ilex_franchetiana         Ilex_delavayi
##             1.7917595             1.8718022             1.6094379
##   Ilex_nothofagifolia          Ilex_hookeri    Ilex_kinabaluensis
##             1.1786550             1.7917595             2.1972246
##        Ilex_corallina    Ilex_memecylifolia      Ilex_hainanensis
##             1.2527630             2.3978953             1.0986123
##          Ilex_integra          Ilex_perlata   Ilex_wugonshanensis
##             2.0149030             2.0794415             1.8718022
##        Ilex_latifolia      Ilex_arnhemensis           Ilex_cymosa
##             1.9459101             1.5040774             1.0986123
##        Ilex_nervulosa        Ilex_wallichii         Ilex_maingayi
##             1.0986123             1.7047481             1.0986123
##     Ilex_oppositifolia       Ilex_zygophylla          Ilex_godajam
##             1.7917595             1.3862944             1.3862944
##        Ilex_cissoidea       Ilex_havilandii          Ilex_spicata
##             1.0986123             1.0986123             2.0794415
##         Ilex_sebertii           Ilex_atrata        Ilex_forrestii
##             1.9459101             1.8718022             1.3862944
##      Ilex_longecaudata         Ilex_khasiana         Ilex_venulosa
##             1.2527630             2.3978953             1.3862944
##       Ilex_championii         Ilex_wilsonii          Ilex_liangii
##             1.2527630             1.3862944             1.6094379
##      Ilex_lohfauensis       Ilex_goshiensis    Ilex_elmerrilliana
##             1.2527630             1.3862944             1.6094379
##       Ilex_aculeolata          Ilex_serrata         Ilex_fragilis
##             1.9459101             1.6094379             1.6094379
##        Ilex_macropoda          Ilex_kusanoi       Ilex_macrocarpa
##             1.6094379             1.7917595             2.4849066
##         Ilex_asprella       Ilex_chapaensis       Ilex_micrococca
##             1.7917595             2.8622009             1.3862944
##        Ilex_polyneura        Ilex_chinensis          Ilex_oblonga
##             1.3862944             1.9459101             1.0986123
##       Ilex_suaveolens       Ilex_dasyphylla       Ilex_intermedia
##             1.7917595             1.7917595             1.6094379
##      Ilex_litseifolia     Ilex_editicostata         Ilex_dunniana
##             1.7917595             2.0794415             1.6094379
##          Ilex_hirsuta      Ilex_pedunculosa Ilex_shennongjiaensis
##             1.7917595             2.0149030             2.3025851
##       Ilex_subcrenata      Ilex_yunnanensis       Ilex_geniculata
##             0.6931472             1.7047481             1.3862944
##        Ilex_laevigata     Ilex_verticillata       Ilex_lihuaensis
##             2.0149030             1.9459101             1.0986123
##         Ilex_tutcheri        Ilex_mamillata            Ilex_mitis
##             1.6094379             1.6094379             1.9810015
```

```
##        Ilex_pubescens        Ilex_pubilimba          Ilex_rotunda
##             1.3862944             2.0149030            1.6094379
##         Ilex_anomala        Ilex_coriacea          Ilex_glabra
##             2.1972246             2.0794415            1.8484548
##       Ilex_liebmannii     Ilex_quercetorum       Ilex_microdonta
##             1.3862944             1.3862944            1.9459101
##       Ilex_guianensis        Ilex_theizans      Ilex_brevicuspis
##             1.2527630             1.9459101            1.3217558
##         Ilex_asperula     Ilex_taubertiana        Ilex_formosana
##             1.3862944             1.1786550            1.6094379
##    Ilex_nanchuanensis   Ilex_kwangtungensis     Ilex_brasiliensis
##             1.5040774             2.0794415            1.7047481
##      Ilex_integerrima     Ilex_pseudobuxus      Ilex_canariensis
##             2.0149030             1.3862944            2.3025851
##          Ilex_affinis   Ilex_chamaedryfolia           Ilex_amara
##             1.3862944             1.2527630            1.7047481
##          Ilex_crenata     Ilex_manneiensis    Ilex_szechwanensis
##             1.9459101             1.9459101            2.0149030
##      Ilex_denticulata          Ilex_viridis         Ilex_hanceana
##             1.8718022             2.3025851            1.6094379
##         Ilex_triflora     Ilex_nanningensis       Ilex_mutchagara
##             1.8718022             2.3025851            2.0149030
##         Ilex_revoluta  Ilex_hippocrateoides        Ilex_teratopis
##             1.7047481             1.2527630            1.9459101
##         Ilex_discolor         Ilex_tolucana          Ilex_nitida
##             1.6094379             1.9459101            1.8718022
##          Ilex_repanda        Ilex_vomitoria          Ilex_laurina
##             1.0986123             1.8484548            1.7917595
##   Ilex_paraguariensis      Ilex_amelanchier      Ilex_mucronulata
##             1.3862944             2.0149030            1.9810015
##        Ilex_argentina          Ilex_cassine       Ilex_myrtifolia
##             1.8718022             1.7047481            1.9459101
##       Ilex_cumulicola            Ilex_rubra          Ilex_dugesii
##             2.1972246             2.3025851            2.0794415
##            Ilex_opaca          Ilex_collina          Ilex_decidua
##             2.1972246             2.0149030            1.8718022
##         Ilex_longipes          Ilex_montana           Ilex_dumosa
##             2.4849066             2.1365305            1.7917595
```

```
VisualizeData_Conti <- function(phy, data) {
 pretty_pic <- phytools::contMap(tree = phy, x = data, fsize = c(.2,1), lwd = 2)
 #polytomy <- is.binary(phy = phy)
 pretty_pic
}
VisualizeData_Conti(phy=clean.tree,data=clean.diameter[,1])
```




```
## Object of class "contMap" containing:
##
## (1) A phylogenetic tree with 135 tips and 134 internal nodes.
##
## (2) A mapped continuous trait on the range (0.693147, 2.862201).
```

#First, start basic. What is the rate of evolution of your trait on the tree?

```
BM1 <- geiger::fitContinuous(phy=clean.tree, dat=clean.diameter, model="BM")
print(str(BM1))
```

```
## List of 4
##  $ lik:function (pars, ...)
##   ..- attr(*, "argn")= chr "sigsq"
##   ..- attr(*, "cache")=List of 26
##   .. ..$ tip.label  : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana" .
##   .. ..$ node.label : NULL
##   .. ..$ len        : num [1:269] 50.745 41.8 0.175 0.175 0.794 ...
##   .. ..$ children   : int [1:269, 1:2] NA NA NA NA NA NA NA NA NA NA ...
##   .. ..$ order      : num [1:134] 218 217 216 171 207 215 165 222 255 163 ...
##   .. ..$ root       : num 136
##   .. ..$ n.tip      : int 135
##   .. ..$ n.node     : int 134
##   .. ..$ tips       : int [1:135] 1 2 3 4 5 6 7 8 9 10 ...
##   .. ..$ edge       : int [1:268, 1:2] 269 269 268 268 267 267 266 266 265 265 ...
```

```
##   .. ..$ edge.length: num [1:268] 0.462 0.462 1.841 1.379 6.858 ...
##   .. ..$ nodes      : int [1:268] 133 134 132 269 131 268 129 130 128 266 ...
##   .. ..$ binary     : logi TRUE
##   .. ..$ desc       :List of 4
##   .. .. ..$ tips :List of 269
##   .. .. .. ..$ : int 1
##   .. .. .. ..$ : int 2
##   .. .. .. ..$ : int 3
##   .. .. .. ..$ : int 4
##   .. .. .. ..$ : int 5
##   .. .. .. ..$ : int 6
##   .. .. .. ..$ : int 7
##   .. .. .. ..$ : int 8
##   .. .. .. ..$ : int 9
##   .. .. .. ..$ : int 10
##   .. .. .. ..$ : int 11
##   .. .. .. ..$ : int 12
##   .. .. .. ..$ : int 13
##   .. .. .. ..$ : int 14
##   .. .. .. ..$ : int 15
##   .. .. .. ..$ : int 16
##   .. .. .. ..$ : int 17
##   .. .. .. ..$ : int 18
##   .. .. .. ..$ : int 19
##   .. .. .. ..$ : int 20
##   .. .. .. ..$ : int 21
##   .. .. .. ..$ : int 22
##   .. .. .. ..$ : int 23
##   .. .. .. ..$ : int 24
##   .. .. .. ..$ : int 25
##   .. .. .. ..$ : int 26
##   .. .. .. ..$ : int 27
##   .. .. .. ..$ : int 28
##   .. .. .. ..$ : int 29
##   .. .. .. ..$ : int 30
##   .. .. .. ..$ : int 31
##   .. .. .. ..$ : int 32
##   .. .. .. ..$ : int 33
##   .. .. .. ..$ : int 34
##   .. .. .. ..$ : int 35
##   .. .. .. ..$ : int 36
##   .. .. .. ..$ : int 37
##   .. .. .. ..$ : int 38
##   .. .. .. ..$ : int 39
##   .. .. .. ..$ : int 40
##   .. .. .. ..$ : int 41
##   .. .. .. ..$ : int 42
##   .. .. .. ..$ : int 43
##   .. .. .. ..$ : int 44
##   .. .. .. ..$ : int 45
##   .. .. .. ..$ : int 46
##   .. .. .. ..$ : int 47
##   .. .. .. ..$ : int 48
##   .. .. .. ..$ : int 49
```

```
##   .. .. .. ..$ : int 50
##   .. .. .. ..$ : int 51
##   .. .. .. ..$ : int 52
##   .. .. .. ..$ : int 53
##   .. .. .. ..$ : int 54
##   .. .. .. ..$ : int 55
##   .. .. .. ..$ : int 56
##   .. .. .. ..$ : int 57
##   .. .. .. ..$ : int 58
##   .. .. .. ..$ : int 59
##   .. .. .. ..$ : int 60
##   .. .. .. ..$ : int 61
##   .. .. .. ..$ : int 62
##   .. .. .. ..$ : int 63
##   .. .. .. ..$ : int 64
##   .. .. .. ..$ : int 65
##   .. .. .. ..$ : int 66
##   .. .. .. ..$ : int 67
##   .. .. .. ..$ : int 68
##   .. .. .. ..$ : int 69
##   .. .. .. ..$ : int 70
##   .. .. .. ..$ : int 71
##   .. .. .. ..$ : int 72
##   .. .. .. ..$ : int 73
##   .. .. .. ..$ : int 74
##   .. .. .. ..$ : int 75
##   .. .. .. ..$ : int 76
##   .. .. .. ..$ : int 77
##   .. .. .. ..$ : int 78
##   .. .. .. ..$ : int 79
##   .. .. .. ..$ : int 80
##   .. .. .. ..$ : int 81
##   .. .. .. ..$ : int 82
##   .. .. .. ..$ : int 83
##   .. .. .. ..$ : int 84
##   .. .. .. ..$ : int 85
##   .. .. .. ..$ : int 86
##   .. .. .. ..$ : int 87
##   .. .. .. ..$ : int 88
##   .. .. .. ..$ : int 89
##   .. .. .. ..$ : int 90
##   .. .. .. ..$ : int 91
##   .. .. .. ..$ : int 92
##   .. .. .. ..$ : int 93
##   .. .. .. ..$ : int 94
##   .. .. .. ..$ : int 95
##   .. .. .. ..$ : int 96
##   .. .. .. ..$ : int 97
##   .. .. .. ..$ : int 98
##   .. .. .. ..$ : int 99
##   .. .. .. .. [list output truncated]
##   .. .. ..$ fdesc:List of 269
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
```

```
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
```

```
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. .. [list output truncated]
##   .. .. ..$ adesc:List of 269
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
```

```
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
```

```
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. .. [list output truncated]
##   .. .. ..$ anc  :List of 269
##   .. .. .. ..$ : int 136
##   .. .. .. ..$ : int [1:2] 137 136
##   .. .. .. ..$ : int [1:12] 147 146 145 144 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 147 146 145 144 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:11] 146 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:11] 148 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:11] 148 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:9] 144 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:10] 150 149 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:12] 152 151 150 149 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 152 151 150 149 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:11] 151 150 149 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:9] 149 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:12] 157 156 155 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:13] 158 157 156 155 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:13] 158 157 156 155 154 153 142 141 140 139 ...
```

```
##   .. .. .. ..$ : int [1:11] 156 155 154 153 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:10] 155 154 153 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:14] 163 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 163 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:15] 165 164 162 161 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:15] 165 164 162 161 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:14] 164 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 167 166 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 167 166 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:13] 166 161 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 170 169 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:15] 171 170 169 168 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:15] 171 170 169 168 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:13] 169 168 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 173 172 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 173 172 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:13] 172 168 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:12] 175 174 159 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:13] 176 175 174 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 177 176 175 174 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 177 176 175 174 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:12] 178 174 159 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 178 174 159 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:8] 153 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:8] 180 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:8] 180 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:7] 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:5] 140 139 138 137 136
##   .. .. .. ..$ : int [1:4] 139 138 137 136
##   .. .. .. ..$ : int [1:12] 189 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 189 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 190 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 190 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:10] 187 186 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:9] 186 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:13] 195 194 193 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 195 194 193 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 194 193 192 191 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 193 192 191 185 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:14] 199 198 197 196 192 191 185 184 183 182 ...
##   .. .. .. ..$ : int [1:14] 199 198 197 196 192 191 185 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 198 197 196 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 197 196 192 191 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 196 192 191 185 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:9] 191 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:15] 207 206 205 204 203 202 201 200 184 183 ...
##   .. .. .. ..$ : int [1:15] 207 206 205 204 203 202 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 206 205 204 203 202 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 205 204 203 202 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 204 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 208 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 208 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 209 202 201 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:11] 209 202 201 200 184 183 182 181 138 137 ...
```

```
##   .. .. .. ..$ : int [1:17] 217 216 215 214 213 212 211 210 201 200 ...
##   .. .. .. ..$ : int [1:18] 218 217 216 215 214 213 212 211 210 201 ...
##   .. .. .. ..$ : int [1:18] 218 217 216 215 214 213 212 211 210 201 ...
##   .. .. .. ..$ : int [1:16] 216 215 214 213 212 211 210 201 200 184 ...
##   .. .. .. ..$ : int [1:15] 215 214 213 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 214 213 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 213 212 211 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:14] 220 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:14] 220 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:15] 222 221 219 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:15] 222 221 219 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 221 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:12] 223 211 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 223 211 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:13] 226 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 226 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 227 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 227 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 229 228 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 229 228 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 228 224 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:10] 231 230 200 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:11] 232 231 230 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:11] 232 231 230 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:10] 233 230 200 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:12] 235 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 235 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 236 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 236 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. .. [list output truncated]
##   .. ..$ SE         : Named num [1:135] 0 0 0 0 0 0 0 0 0 0 ...
##   .. .. ..- attr(*, "names")= chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_peri
##   .. ..$ dat        : Named num [1:135] 1.5 1.61 2.08 1.95 2.3 ...
##   .. .. ..- attr(*, "names")= chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_peri
##   .. ..$ phy        :List of 4
##   .. .. ..$ edge       : int [1:268, 1:2] 269 269 268 268 267 267 266 266 265 265 ...
##   .. .. ..$ tip.label  : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana
##   .. .. ..$ Nnode      : int 134
##   .. .. ..$ edge.length: num [1:268] 0.462 0.462 1.841 1.379 6.858 ...
##   .. .. ..- attr(*, "class")= chr "phylo"
##   .. .. ..- attr(*, "order")= chr "postorder"
##   .. ..$ y          : num [1:2, 1:269] 1.5 0 1.61 0 2.08 ...
##   .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. .. ..$ : chr [1:2] "m" "s"
##   .. .. .. ..$ : NULL
##   .. .. ..- attr(*, "given")= num [1:269] 1 1 1 1 1 1 1 1 1 1 ...
##   .. .. ..- attr(*, "adjse")= num [1:135] 0 0 0 0 0 0 0 0 0 0 ...
##   .. ..$ ordering   : chr "postorder"
##   .. ..$ N          : int 135
##   .. ..$ n          : int 134
##   .. ..$ nn         : int [1:133] 137 138 139 140 141 142 143 144 145 146 ...
##   .. ..$ intorder   : int [1:133] 218 217 216 171 207 215 165 222 255 163 ...
##   .. ..$ tiporder   : int [1:135] 1 2 3 4 5 6 7 8 9 10 ...
##   .. ..$ z          : int 269
```

```
##   .. ..$ attb       : chr "sigsq"
##   ..- attr(*, "class")= chr [1:2] "bm" "function"
##   ..- attr(*, "model")= chr "BM"
##  $ bnd:'data.frame': 1 obs. of  2 variables:
##   ..$ mn: num 7.12e-218
##   ..$ mx: num 2.69e+43
##  $ res: num [1:100, 1:3] 0.033 0.033 0.033 0.033 0.033 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:100] "Brent" "Brent" "Brent" "Brent" ...
##   .. ..$ : chr [1:3] "sigsq" "lnL" "convergence"
##  $ opt:List of 7
##   ..$ sigsq : num 0.033
##   ..$ z0    : num 1.7
##   ..$ lnL   : num -109
##   ..$ method: chr "Brent"
##   ..$ k     : num 2
##   ..$ aic   : num 222
##   ..$ aicc  : num 222
##  - attr(*, "class")= chr [1:2] "gfit" "list"
## NULL
```

```
print(paste("The rate of evolution is", BM1$opt$sigsq, "in units of", "(log mm)^2 / millions of years"))
```

```
## [1] "The rate of evolution is 0.0330447896057778 in units of (log mm)^2 / millions of years"
```

#Important: What are the rates of evolution? In what units?

```
OU1 <- fitContinuous(phy=clean.tree, dat=clean.diameter, model="OU")
```

```
## Warning in fitContinuous(phy = clean.tree, dat = clean.diameter, model = "OU"):
## Non-ultrametric tree with OU model, using VCV method.
```

```
## Warning in cache$dat - mu: Recycling array of length 1 in vector-array arithmetic is deprecated.
##   Use c() or as.vector() instead.
```

```
## Warning in cache$dat - mu: Recycling array of length 1 in vector-array arithmetic is deprecated.
##   Use c() or as.vector() instead.
```

```
par(mfcol=c(1,2))
plot(h_cleanedF$phy, show.tip.label=FALSE)
axisPhylo()
print(OU1)
```

```
## GEIGER-fitted comparative model of continuous data
##  fitted 'OU' model parameters:
##  alpha = 1.259539
##  sigsq = 0.332299
##  z0 = 1.780054
##
##  model summary:
##  log-likelihood = -54.306144
```

```
##  AIC = 114.612288
##  AICc = 114.795494
##  free parameters = 3
##
## Convergence diagnostics:
##  optimization iterations = 100
##  failed iterations = 45
##  frequency of best fit = NA
##
##  object summary:
##  'lik' -- likelihood function
##  'bnd' -- bounds for likelihood search
##  'res' -- optimization iteration summary
##  'opt' -- maximum likelihood parameter estimates
```

```
print("now doing str")
```

```
## [1] "now doing str"
```

```
print(str(OU1))
```

```
## List of 4
##  $ lik:function (pars, root = "max", ...)
##   ..- attr(*, "argn")= chr [1:2] "alpha" "sigsq"
##   ..- attr(*, "cache")=List of 26
##   .. ..$ tip.label  : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana" .
##   .. ..$ node.label : NULL
##   .. ..$ len        : num [1:269] 50.745 41.8 0.175 0.175 0.794 ...
##   .. ..$ children   : int [1:269, 1:2] NA NA NA NA NA NA NA NA NA NA ...
##   .. ..$ order      : num [1:134] 218 217 216 171 207 215 165 222 255 163 ...
##   .. ..$ root       : num 136
##   .. ..$ n.tip      : int 135
##   .. ..$ n.node     : int 134
##   .. ..$ tips       : int [1:135] 1 2 3 4 5 6 7 8 9 10 ...
##   .. ..$ edge       : int [1:268, 1:2] 269 269 268 268 267 267 266 266 265 265 ...
##   .. ..$ edge.length: num [1:268] 0.462 0.462 1.841 1.379 6.858 ...
##   .. ..$ nodes      : int [1:268] 133 134 132 269 131 268 129 130 128 266 ...
##   .. ..$ binary     : logi TRUE
##   .. ..$ desc       :List of 4
##   .. .. ..$ tips :List of 269
##   .. .. .. ..$ : int 1
##   .. .. .. ..$ : int 2
##   .. .. .. ..$ : int 3
##   .. .. .. ..$ : int 4
##   .. .. .. ..$ : int 5
##   .. .. .. ..$ : int 6
##   .. .. .. ..$ : int 7
##   .. .. .. ..$ : int 8
##   .. .. .. ..$ : int 9
##   .. .. .. ..$ : int 10
##   .. .. .. ..$ : int 11
##   .. .. .. ..$ : int 12
##   .. .. .. ..$ : int 13
```

```
##   .. .. .. ..$ : int 14
##   .. .. .. ..$ : int 15
##   .. .. .. ..$ : int 16
##   .. .. .. ..$ : int 17
##   .. .. .. ..$ : int 18
##   .. .. .. ..$ : int 19
##   .. .. .. ..$ : int 20
##   .. .. .. ..$ : int 21
##   .. .. .. ..$ : int 22
##   .. .. .. ..$ : int 23
##   .. .. .. ..$ : int 24
##   .. .. .. ..$ : int 25
##   .. .. .. ..$ : int 26
##   .. .. .. ..$ : int 27
##   .. .. .. ..$ : int 28
##   .. .. .. ..$ : int 29
##   .. .. .. ..$ : int 30
##   .. .. .. ..$ : int 31
##   .. .. .. ..$ : int 32
##   .. .. .. ..$ : int 33
##   .. .. .. ..$ : int 34
##   .. .. .. ..$ : int 35
##   .. .. .. ..$ : int 36
##   .. .. .. ..$ : int 37
##   .. .. .. ..$ : int 38
##   .. .. .. ..$ : int 39
##   .. .. .. ..$ : int 40
##   .. .. .. ..$ : int 41
##   .. .. .. ..$ : int 42
##   .. .. .. ..$ : int 43
##   .. .. .. ..$ : int 44
##   .. .. .. ..$ : int 45
##   .. .. .. ..$ : int 46
##   .. .. .. ..$ : int 47
##   .. .. .. ..$ : int 48
##   .. .. .. ..$ : int 49
##   .. .. .. ..$ : int 50
##   .. .. .. ..$ : int 51
##   .. .. .. ..$ : int 52
##   .. .. .. ..$ : int 53
##   .. .. .. ..$ : int 54
##   .. .. .. ..$ : int 55
##   .. .. .. ..$ : int 56
##   .. .. .. ..$ : int 57
##   .. .. .. ..$ : int 58
##   .. .. .. ..$ : int 59
##   .. .. .. ..$ : int 60
##   .. .. .. ..$ : int 61
##   .. .. .. ..$ : int 62
##   .. .. .. ..$ : int 63
##   .. .. .. ..$ : int 64
##   .. .. .. ..$ : int 65
##   .. .. .. ..$ : int 66
##   .. .. .. ..$ : int 67
```

```
##   .. .. .. ..$ : int 68
##   .. .. .. ..$ : int 69
##   .. .. .. ..$ : int 70
##   .. .. .. ..$ : int 71
##   .. .. .. ..$ : int 72
##   .. .. .. ..$ : int 73
##   .. .. .. ..$ : int 74
##   .. .. .. ..$ : int 75
##   .. .. .. ..$ : int 76
##   .. .. .. ..$ : int 77
##   .. .. .. ..$ : int 78
##   .. .. .. ..$ : int 79
##   .. .. .. ..$ : int 80
##   .. .. .. ..$ : int 81
##   .. .. .. ..$ : int 82
##   .. .. .. ..$ : int 83
##   .. .. .. ..$ : int 84
##   .. .. .. ..$ : int 85
##   .. .. .. ..$ : int 86
##   .. .. .. ..$ : int 87
##   .. .. .. ..$ : int 88
##   .. .. .. ..$ : int 89
##   .. .. .. ..$ : int 90
##   .. .. .. ..$ : int 91
##   .. .. .. ..$ : int 92
##   .. .. .. ..$ : int 93
##   .. .. .. ..$ : int 94
##   .. .. .. ..$ : int 95
##   .. .. .. ..$ : int 96
##   .. .. .. ..$ : int 97
##   .. .. .. ..$ : int 98
##   .. .. .. ..$ : int 99
##   .. .. .. .. [list output truncated]
##   .. .. ..$ fdesc:List of 269
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
```

```
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
```

```
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. .. [list output truncated]
##   .. .. ..$ adesc:List of 269
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
```

```
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
##    .. .. .. ..$ : int(0)
```

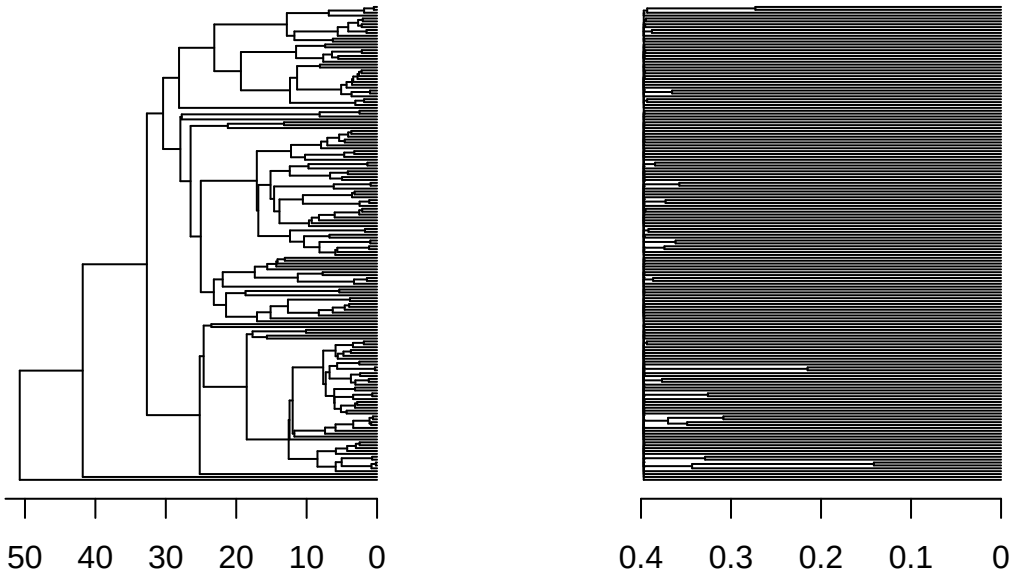
```
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. ..$ : int(0)
##   .. .. .. .. [list output truncated]
##   .. .. ..$ anc  :List of 269
##   .. .. .. ..$ : int 136
##   .. .. .. ..$ : int [1:2] 137 136
##   .. .. .. ..$ : int [1:12] 147 146 145 144 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 147 146 145 144 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:11] 146 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:11] 148 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:11] 148 145 144 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:9] 144 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:10] 150 149 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:12] 152 151 150 149 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 152 151 150 149 143 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:11] 151 150 149 143 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:9] 149 143 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:12] 157 156 155 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:13] 158 157 156 155 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:13] 158 157 156 155 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:11] 156 155 154 153 142 141 140 139 138 137 ...
##   .. .. .. ..$ : int [1:10] 155 154 153 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:14] 163 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 163 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:15] 165 164 162 161 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:15] 165 164 162 161 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:14] 164 162 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 167 166 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 167 166 161 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:13] 166 161 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 170 169 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:15] 171 170 169 168 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:15] 171 170 169 168 160 159 154 153 142 141 ...
##   .. .. .. ..$ : int [1:13] 169 168 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 173 172 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 173 172 168 160 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:13] 172 168 160 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:12] 175 174 159 154 153 142 141 140 139 138 ...
```

```
##   .. .. .. ..$ : int [1:13] 176 175 174 159 154 153 142 141 140 139 ...
##   .. .. .. ..$ : int [1:14] 177 176 175 174 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:14] 177 176 175 174 159 154 153 142 141 140 ...
##   .. .. .. ..$ : int [1:12] 178 174 159 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:12] 178 174 159 154 153 142 141 140 139 138 ...
##   .. .. .. ..$ : int [1:8] 153 142 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:8] 180 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:8] 180 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:7] 179 141 140 139 138 137 136
##   .. .. .. ..$ : int [1:5] 140 139 138 137 136
##   .. .. .. ..$ : int [1:4] 139 138 137 136
##   .. .. .. ..$ : int [1:12] 189 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 189 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 190 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 190 188 187 186 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:10] 187 186 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:9] 186 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:13] 195 194 193 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 195 194 193 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 194 193 192 191 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 193 192 191 185 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:14] 199 198 197 196 192 191 185 184 183 182 ...
##   .. .. .. ..$ : int [1:14] 199 198 197 196 192 191 185 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 198 197 196 192 191 185 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 197 196 192 191 185 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 196 192 191 185 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:9] 191 185 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:15] 207 206 205 204 203 202 201 200 184 183 ...
##   .. .. .. ..$ : int [1:15] 207 206 205 204 203 202 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 206 205 204 203 202 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 205 204 203 202 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 204 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 208 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 208 203 202 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:11] 209 202 201 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:11] 209 202 201 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:17] 217 216 215 214 213 212 211 210 201 200 ...
##   .. .. .. ..$ : int [1:18] 218 217 216 215 214 213 212 211 210 201 ...
##   .. .. .. ..$ : int [1:18] 218 217 216 215 214 213 212 211 210 201 ...
##   .. .. .. ..$ : int [1:16] 216 215 214 213 212 211 210 201 200 184 ...
##   .. .. .. ..$ : int [1:15] 215 214 213 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 214 213 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:13] 213 212 211 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:14] 220 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:14] 220 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:15] 222 221 219 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:15] 222 221 219 212 211 210 201 200 184 183 ...
##   .. .. .. ..$ : int [1:14] 221 219 212 211 210 201 200 184 183 182 ...
##   .. .. .. ..$ : int [1:12] 223 211 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 223 211 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:13] 226 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 226 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 227 225 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 227 225 224 210 201 200 184 183 182 181 ...
```

```
##   .. .. .. ..$ : int [1:13] 229 228 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:13] 229 228 224 210 201 200 184 183 182 181 ...
##   .. .. .. ..$ : int [1:12] 228 224 210 201 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:10] 231 230 200 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:11] 232 231 230 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:11] 232 231 230 200 184 183 182 181 138 137 ...
##   .. .. .. ..$ : int [1:10] 233 230 200 184 183 182 181 138 137 136
##   .. .. .. ..$ : int [1:12] 235 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 235 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 236 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. ..$ : int [1:12] 236 234 233 230 200 184 183 182 181 138 ...
##   .. .. .. .. [list output truncated]
##   .. ..$ SE         : Named num [1:135] 0 0 0 0 0 0 0 0 0 0 ...
##   .. .. ..- attr(*, "names")= chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_peri
##   .. ..$ dat        : Named num [1:135] 1.5 1.61 2.08 1.95 2.3 ...
##   .. .. ..- attr(*, "names")= chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_peri
##   .. ..$ phy        :List of 4
##   .. .. ..$ edge       : int [1:268, 1:2] 269 269 268 268 267 267 266 266 265 265 ...
##   .. .. ..$ tip.label  : chr [1:135] "Ilex_sinica" "Ilex_intricata" "Ilex_aquifolium" "Ilex_perryana
##   .. .. ..$ Nnode      : int 134
##   .. .. ..$ edge.length: num [1:268] 0.462 0.462 1.841 1.379 6.858 ...
##   .. .. ..- attr(*, "class")= chr "phylo"
##   .. .. ..- attr(*, "order")= chr "postorder"
##   .. ..$ y          : num [1:2, 1:269] 1.5 0 1.61 0 2.08 ...
##   .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. .. ..$ : chr [1:2] "m" "s"
##   .. .. .. ..$ : NULL
##   .. .. ..- attr(*, "given")= num [1:269] 1 1 1 1 1 1 1 1 1 1 ...
##   .. .. ..- attr(*, "adjse")= num [1:135] 0 0 0 0 0 0 0 0 0 0 ...
##   .. ..$ ordering   : chr "postorder"
##   .. ..$ N          : int 135
##   .. ..$ n          : int 134
##   .. ..$ nn         : int [1:133] 137 138 139 140 141 142 143 144 145 146 ...
##   .. ..$ intorder   : int [1:133] 218 217 216 171 207 215 165 222 255 163 ...
##   .. ..$ tiporder   : int [1:135] 1 2 3 4 5 6 7 8 9 10 ...
##   .. ..$ z          : int 269
##   .. ..$ attb       : chr [1:2] "alpha" "sigsq"
##   ..- attr(*, "class")= chr [1:2] "bm" "function"
##   ..- attr(*, "model")= chr "OU"
##  $ bnd:'data.frame': 2 obs. of  2 variables:
##   ..$ mn: num [1:2] 7.12e-218 7.12e-218
##   ..$ mx: num [1:2] 2.72 2.69e+43
##  $ res: num [1:100, 1:4] 1.26 1.26 NA NA NA ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:100] "L-BFGS-B" "L-BFGS-B" "FAIL" "FAIL" ...
##   .. ..$ : chr [1:4] "alpha" "sigsq" "lnL" "convergence"
##  $ opt:List of 8
##   ..$ alpha : num 1.26
##   ..$ sigsq : num 0.332
##   ..$ z0    : num 1.78
##   ..$ lnL   : num -54.3
##   ..$ method: chr "L-BFGS-B"
##   ..$ k     : num 3
##   ..$ aic   : num 115
```

```
##   ..$ aicc  : num 115
##  - attr(*, "class")= chr [1:2] "gfit" "list"
## NULL
```

```
ou.tree <- rescale(h_cleanedF$phy, model="OU", OU1$opt$alpha)
plot(ou.tree, show.tip.label=FALSE)
axisPhylo() #see how long the tree is
```



#Compare trees

```
AIC.BM1 <- BM1$opt$aic
AIC.OU1 <- OU1$opt$aic
delta.AIC.BM1 <-AIC.BM1-min(AIC.BM1,AIC.OU1)
delta.AIC.OU1 <- AIC.OU1-min(AIC.OU1,AIC.BM1)
print(delta.AIC.BM1)
```

```
## [1] 107.4016
```

```
print(delta.AIC.OU1)
```

```
## [1] 0
```

#First, we need to assign regimes. The way we do this is with ancestral state estimation of a discrete trait. We #can do this using ace() in ape, or similar functions in corHMM or diversitree. Use only one discrete char

```
one.discrete.char <- clean.colour
reconstruction.info <- ace(one.discrete.char, clean.tree, type="discrete", method="ML", CI=TRUE)
best.states <- colnames(reconstruction.info$lik.anc)[apply(reconstruction.info$lik.anc, 1, which.max)]
```

#Now add these labels to your tree

```
labeled.tree <- best.states
print(clean.diameter)
clean.diameter.df<-data.frame(species=rownames(clean.diameter), diameter=clean.diameter[,1])
nodeBased.OUMV <- OUwie(clean.tree, clean.diameter.df, model="OUMV", simmap.tree=FALSE, diagn=FALSE)
print(nodeBased.OUMV)
```

#What do the numbers mean?

#Now run all OUwie models:

```
models <- c("BM1","BMS","OU1","OUM","OUMV","OUMA","OUMVA")
results <- lapply(models, RunSingleOUwieModel, phy=h_cleanedF$phy, data=h_cleanedF$data)

AICc.values<-sapply(results, "[[", "AICc")
names(AICc.values)<-models
AICc.values<-AICc.values-min(AICc.values)


print(AICc.values) #The best model is the one with smallest AICc score

best<-results[[which.min(AICc.values)]] #store for later

print(best) #prints info on best model
```

```
alpha.values<-seq(from= _____ , to= _____ , length.out=50)
```

#Keep it simple (and slow) and do a for loop:

```
likelihood.values <- rep(NA, length(alpha.values))
for (iteration in sequence(length(alpha.values))) {
    likelihood.values[iteration] <- OUwie.fixed(tree, trait, model="OUMV", alpha=rep(alpha.values[itera
}

plot(x= _____ , y= _____, xlab="_____", ylab="_____", type="l",
points(x=best$solution[1,1], y=best$loglik, pch=16, col="red")
text(x=best$solution[1,1], y=best$loglik, "unconstrained best", pos=4, col="red")
```

#A rule of thumb for confidence for likelihood is all points two log likelihood units worse than the best value. Draw a dotted line on the plot to show this

```
abline(h=_____, lty="dotted") #Two log-likelihood
```

#Now, let's try looking at both theta parameters at once, keeping the other parameters at their #MLEs

```
require("akima")
nreps<-400
theta1.points<-c(best$theta[1,1], rnorm(nreps-1, best$theta[1,1], 5*best$theta[1,2])) #center on optima
theta2.points<-c(best$theta[2,1], rnorm(nreps-1, best$theta[2,1], 5*best$theta[2,2])) #center on optima
likelihood.values<-rep(NA,nreps)

for (iteration in sequence(nreps)) {
    likelihood.values[iteration] <- OUwie.fixed(tree, trait, model="OUMV", alpha=best$solution[1,], sig
}
```

#Think of how long that took to do 400 iterations. Now remember how long the search took (longer).

```
likelihood.differences<-(-(likelihood.values-max(likelihood.values)))
```

#We are interpolating here: contour wants a nice grid. But by centering our simulations on the MLE values, we made sure to sample most thoroughly there

```
interpolated.points<-interp(x=theta1.points, y=theta2.points, z= likelihood.differences, linear=FALSE,

contour(interpolated.points, xlim=range(c(theta1.points, theta2.points)),ylim=range(c(theta1.points, th

points(x=best$theta[1,1], y=best$theta[2,1], col="red", pch=16)

points(x=trait$X[which(trait$Reg==1)],y=rep(min(c(theta1.points, theta2.points)), length(which(trait$Re
points(y=trait$X[which(trait$Reg==2)],x=rep(min(c(theta1.points, theta2.points)), length(which(trait$Re
```

```
library(phytools)
trait.ordered<-data.frame(trait[,2], trait[,2],row.names=trait[,1])
trait.ordered<- trait.ordered[tree$tip.label,]
z<-trait.ordered[,1]
names(z)<-rownames(trait.ordered)
tree.mapped<-make.simmap(tree,z,model="ER",nsim=1)
leg<-c("black","red")
names(leg)<-c(1,2)
plotSimmap(tree.mapped,leg,pts=FALSE,ftype="off", lwd=1)

simmapBased<-OUwie(tree.mapped,trait,model="OUMV", simmap.tree=TRUE, diagn=FALSE)
print(simmapBased)
print(best)
```