

# Phylogenetics, Molecular Epidemiology and Phylodynamics

*Montevideo, Facultad de Ingeniería (UdelaR)–  
December 6-10, 2021*

## Instructors

- Paul Bastide (PB)
- Miraine Davila Felipe (MDF)
- Olivier Gascuel (OG)
- Martin Graña (MG)
- Enrique Lessa (EL)
- Hugo Naya (HN)
- Hector Romero (HR)
- Anna Zhukova (AZ)

## Friday 12/3: Preliminary round on biology, evolution and phylogenetics

**Morning:** Molecular evolution, Multiple Sequence Alignments, tree interpretation (and limitations), sequence databases. Tree interpretation: gene vs species trees, ILS and horizontal transfer; evolution of gene families: duplications, deletions, gene conversion and other processes of concerted evolution

**Afternoon:** functional to students' needs (concepts and/or methods).

# Program

## **Monday 12/6: Phylogenetic tree inference in a likelihood framework**

9:00-9:45 **Molecular evolution, speciation, selection, pathogen evolution**

9:45-10:30 Continuous time Markov models, model selection (LRT, AIC, BIC)

Coffee break

11:00-11:45 Models for DNA and proteins, likelihood calculation

11:45-12:30 The 10h gene of HIV

Lunch

14:00-15:30 Hands-on, ML tree inference using Seaview/IQ-TREE

## **Tuesday 12/7: Ancestral character reconstruction, dating, phylogeography**

9:00-9:45 **The spread of pathogens**

9:45-10:30 Unrooted, rooted and dated trees, molecular clock models

Coffee break

11:00-11:45 Methods and algorithms for ancestral character reconstructions (ACR)

11:45-12:30 HIV-1 CRF19 epidemics in Cuba

Lunch

14:00-15:30 Hands-on, dating using LSD2/Beast, ACR with PastML

## **Wednesday 12/8: The comparative approach**

9:00-9:45 **Heritability of traits**

9:45-10:30 Stochastic processes on trees: Brownian motion and beyond

Coffee break

11:00-11:45 Phylogenetic regression (mixed models, ANOVA)

11:45-12:30 **Heritability of viral load in HIV**

Lunch

Afternoon for social activities with the students

## **Thursday 12/9: Modeling and reconstructing the evolution of continuous traits**

**9:00-9:45 Ecological Niche Modeling**

9:45-10:30 Heterogeneous and multidimensional models

Coffee break

11:00-11:45 Bayesian analysis of continuous traits (MCMC, HMC, Beast)

11:45-12:30 **Continuous phylogeography**

Lunch

14:00-15:30 Hands-on using Beast: Yellow fever virus (Beast workshop tutorial)

## **Friday 12/10: Molecular epidemiology, phylodynamics**

**9:00-9:45 Mathematical epidemiology, virus evolution, variant tracking**

9:45-10:30 Compartment and tree models

Coffee break

11:00-11:45 Variant tracking: methods and algorithms

11:45-12:30 **Phylodynamics: methods and algorithms, ABC, Beast**

Lunch

14:00-15:30 **Student seminars (e.g. SARS-Cov-2 in Uruguay, deep phylogenies with faint signal)**

Farewell party

## **Keywords**

### **Math keywords:**

12/6 Generator matrix with continuous-time, discrete-state Markov models ; Probability matrix ; Matrix exponentiation ; Likelihood Ratio Test ; Penalized likelihood approaches (Akaike, Bayesian Information Criterion).

**12/7** Ultrametric trees and condition ; Unrooted trees, additive distance matrices, four-point condition ; Strict molecular clock models ; Uncorrelated relaxed clock models ; Correlated clock models ; Smoothing methods to date trees ; Decision and information theory.

**12/8** Stochastic processes; Brownian motion; Ornstein-Uhlenbeck; Linear mixed model; ANOVA; Likelihood ratio test

**12/9** Markov Chain Monte Carlo; Hamiltonian Monte Carlo; Bayesian statistics; Hierarchical models; Shifted processes; Regularisation; Model selection; Multivariate processes; phylogenetic PCA

**12/10** Approximate Bayesian computation (ABC); Differential equations; Likelihood calculation; MCMC

### **Algorithmic and computer science keywords:**

**12/6** Pruning algorithm

**12/7** Recursion, pre-order and post-order tree-traversals; Visualization

**12/8** Tree traversals; Tree transformation

**12/9** Phylogenetic Kalman filter

**12/10** Tree traversals; Machine learning

### **Biology and epidemiology keywords:**

**12/6** Genetic code; Genes and proteins; Phylogenetics ; Population genetics ; Selection, adaptation ; Molecular evolution ; Virus evolution ; Bacterial evolution ; Human evolution.

**12/7** HIV; Recombination; Molecular clock

**12/8** Heritability; Stabilizing selection; HIV

**12/9** Ecological niche; Correlated evolution; Continuous phylogeography

**12/10** Virus transmission; Sars-CoV-2 variants