Module Descriptions

Genomewide Markers in Plant Breeding (Dr. Rex Bernardo)

Principles, concepts, and practices regarding the use of molecular markers to improve quantitative traits in plants. The course will include both theory and hands-on computer sessions in an active-learning format. (Prerequisites: a course in plant breeding and a course in statistics)

- Session 1: Review of plant breeding; overview of marker-assisted selection strategies; review of population and quantitative genetics; computer exercises on quantitative trait locus mapping
- Session 2: Linkage mapping in biparental populations; association mapping; computer exercises in linkage and association mapping
- Session 3: Marker-assisted selection for major QTL; F_2 enrichment; introduction to genomewide selection
- Session 4: Theory and framework for genomewide prediction; factors affecting prediction accuracy; computer exercises in genomewide prediction
- Session 5: Best practices and challenges in integrating markers in a breeding program

CRISPRing in Plants (Dr. Thomas Jacobs)

The objective of this course is to provide students with the fundamental theory and experience to perform genome editing (CRISPR) experiments in their own projects. Using a combination of lecture and hands-on computer work, students will learn the fundamentals of performing a CRISPR experiment; the variety of techniques and editing outcomes, best practices and quality control steps throughout the whole pipeline, and how to analyze genotyping results.

- Session 1: Theory; Introduction on current (CRISPR) technologies for genome editing in plants.
- Session 2: Theory and computer lab; how to design CRISPR targets
- Session 3: Theory and computer lab; in-silico cloning of CRISPR reagents, best practices, quality control steps
- Session 4: Theory and computer lab; analyzing genome editing outcomes, Sanger sequencing and NGS
- Session 5: Design your own genome editing experiment

Machine Learning Applied to Plant Science (Dr. Tolutola Oyetunde)

This short course provides an introduction to core concepts in machine learning and data science. It will separate hype from fact, demystify machine learning, and critically examine prospects and limitations of data science as applied to plant science. Lectures, demonstrations, and hands-on exercises are designed to encourage the participants to think of ways of applying machine learning to solve practical problems in their current and future research. (Prerequisite: basic knowledge of programming in R)

- Session 1: Lecture - Introduction to machine learning; Lab - review of R programming and basic data analyses in R, laptop setup
- Session 2: Lecture - Fundamentals of machine learning; Code-along demo - a typical workflow for an end-to-end machine learning project; Lab - data cleaning and preprocessing

- Session 3: Lecture - Strengths and weaknesses of different machine learning models, evaluating machine algorithms, feature engineering; Lab - supervised machine learning
- Session 4: Lecture - Machine learning for quantitative genetics in plant breeding; Code-along demo - Machine learning for genomic selection; Lab - unsupervised machine learning
- Session 5: Lecture - Introduction to deep learning and reinforcement learning, computer vision in agriculture, machine learning for precision farming; Lab - short end-to-end machine learning project

Genetic Analysis in Understudied Plants (Dr. Laura Shannon)

Genetic analysis is an incredibly powerful tool in crop breeding and research, allowing us to predict breeding values, simplify selection processes, identify causative loci and pathways for traits of interest, and describe and assess diversity. However, many important plants lack prerequisites, like reference genomes or genetic maps, for commonly used analyses. New technologies have made it relatively cheap and easy to generate genetic data on these organisms, but effectively analyzing this data is more complicated. We'll use case studies from my research and yours to talk about some of the challenges of working on non-model systems. This course will be heavily discussion based with lectures, problem sets, and hands on data analysis activities.

- Session 1: Starting from scratch, what questions can you ask without a reference genome or genetic map?
- Session 2: Effective genotyping
- Session 3: Sequencing complex genomes
- Session 4: Ploidy determination
- Session 5: Application to research challenges, how are we going to use this?

The Many Dimensions of Plant Phenotyping (Dr. Hilde Nelissen)

Plant phenotyping is a very broad field. Everyone involved in plant breeding or plant research will at one point, knowingly or unknowingly, deal with plant phenotyping. Plant phenotyping occurs at many scales, from the field down to the cell, at different temporal resolutions, from one-off measurements to time-series of constant measurements, at varying levels of details. Continuous advancements in technology keep extending the borders of what is possible, allowing us to take measurements in ever-higher detail or at an ever-higher throughput. In this course you will get an overview of plant phenotyping at the different scales, followed by a deep-dive at each level, to show you what is possible.

- Session 1: From the field to the cell: an overview of plant phenotyping at all scales
- Session 2: Field phenotyping
- Session 3: Whole plant phenotyping
- Session 4: Organ level phenotyping
- Session 5: Plant cell phenotyping

Data Bootcamp for Genomic Prediction in Plant Breeding (Dr. Aaron Lorenz)

This course will cover common data structures, analysis techniques, and tools used for genomic selection in plant breeding. This course will include lectures and hands-on activities. (Prerequisite: basic knowledge of programming in R)

- Sessions 1-2: Formatting and quality control of genotype/phenotype data for genomic prediction, model implementation and exploration of various types of models, techniques in cross validation for assessing prediction accuracy
- Sessions 3-4: Training population optimization, multi-trait prediction, genomic prediction for genotype x environment interaction, predictions of all possible crosses
- Session 5: Other special topics in genomic prediction, tour of available tools for implementing genomic prediction