International Doctoral Program in Integrative Neuroscience

ADVANCED COURSES
2026/2027

# Introduction to Scientific Programming

**Oct 9, 2026 – Jan 22, 2027 (all Fridays afternoon)**

**Coordinator:** Renato Duarte (renato.duarte@cnc.uc.pt)

**Location:** CNC-UC - Polo I

## Aim:

This advanced course is designed for first-year PhD students in Integrative Neuroscience to equip them with the programming, computational, and software development skills necessary to produce reproducible, efficient, and modern scientific analyses. It bridges the gap between research programming and professional software development, guiding students from fundamental coding principles to advanced applications such as data analysis, visualization, simulation, and machine learning.

## Considerations:

- **13 days total**
- **1-hour lecture** plus **2-3 hours hands-on** per day
- Days 10-13 can be customized based on student interests
- Students need to bring their laptop
- Course materials and student contributions will be made via a shared GitHub repository

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## Part I: Fundamentals (Days 1-3)

**Day 1: Introduction & Modern Development Ecosystem**

- What is scientific programming? Research programming vs. software development
- The development cycle & reproducible research principles
- Programming languages for science (Python, R, Julia comparison)
- AI-assisted coding: GitHub Copilot, ChatGPT, and "vibe coding" - how to use AI effectively while understanding fundamentals
- Setting up the development environment (VS Code, extensions, basic terminal)

**Day 2: Programming Fundamentals**

- Variables, data structures, and basic I/O
- Operators, expressions, and control structures
- Functions and modular programming
- Basic object-oriented programming for scientists

**Day 3: Development Tools & Workflow**

- Code editors and IDEs (VS Code deep dive)
- Virtual environments (conda, poetry, uv)
- Git fundamentals and GitHub workflow
- Jupyter notebooks vs. scripts - when to use what
- Advanced(ish) Git & Collaboration
- Version control best practices
- Branching, merging, collaboration workflows
- Documentation with Markdown and docstrings

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## Part II: Scientific Computing Core (Days 4-7)

### Day 4: Numerical Computing Foundations

- NumPy fundamentals and array operations
- Basic plotting with matplotlib
- Introduction to SciPy

### Day 5: Data Manipulation & Analysis

- Pandas for data handling
- Data cleaning and preprocessing
- Advanced SciPy (statistics, signal processing)

### Day 6: Visualization & Communication

- Advanced matplotlib (publication-quality figures)
- Seaborn for statistical visualization
- Plotly for interactive plots
- Best practices for scientific figures

### Day 7: Intermediate Programming Concepts

- Error handling and debugging strategies
- Type hints and code documentation
- Code organization and packaging

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## Part III: Advanced Applications (Days 8-12)

### Day 8: Statistical Analysis & Machine Learning I

- Statistical foundations for data science
- Machine learning foundations: supervised and unsupervised learning
- Scikit-learn fundamentals

### Day 9: Statistical Analysis & Machine Learning II

- Machine learning foundations: neural networks
- Introduction to deep learning concepts
- FFNs, RNNs, Transformers and other ANN architectures and uses
- PyTorch, TensorFlow basics; JAX and automatic differentiation

### Day 9: Simulation & Modeling

- Differential equations and Numerical integration methods
- Mathematical modeling in neuroscience: from biology to behavior
- Performance optimization and profiling

### Day 10: Specialized Tools & Domain Applications

- Neural data analysis tools (Neo, Elephant, MNE, CAIman, ...)
- Behavioral analysis (DeepLabCut, KeyPoint-MoSeq)
- Omics data handling and exploratory analysis
- Students present their use cases

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**Day 11: Professional Development & Advanced Topics**

- Testing and continuous integration
- Code review and collaboration
- Packaging and distribution
- Career paths in computational neuroscience / NeuroAI / Data science and Data management

**Day 12/13: Student projects**

- Students develop custom solutions to their specific problems and present their findings to peers

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