

## **Unit 1: Arrays (p. 2)**

- Basic datatypes (lists, strings, dictionaries, etc.)
- Why and where we use arrays (images, scientific data, vectorization)
- Array shapes (vectors, matrices, tensors) and axes
- Creating arrays (zeros, ones, random, ranges)
- Slicing, indexing, rearranging, and Boolean masking
- Array operations (arithmetic, aggregate functions, broadcasting)

## **Unit 2: Numerical Issues and Tensors (p. 9)**

- Floating-point representation (sign, exponent, mantissa)
- Special values: infinities, NaNs; causes and behavior
- Round-off, precision, overflow, underflow, and stability issues
- Memory layout of arrays (strides, transpose, reshaping)
- Tensors: operations and vectorized computation strategies

## **Unit 3: Scientific Visualisation (p. 16)**

- Fundamentals of data plotting (grammar of graphics, guides, geoms)
- 1D and 2D plots, histograms, scatterplots, contour plots
- Choosing appropriate scales (linear, log, polar) and facets
- Statistical transforms: binning, smoothing, regression
- Plotting best practices for clarity, labels, and communicating uncertainty

## **Unit 4: Vector Spaces and Matrices (p. 23)**

- Vectors in  $R^n$ , norms, and inner products
- Matrix basics: multiplication, transposition, linear operators
- Matrices as transformations, adjacency matrices for graphs
- Covariance matrices and their role in data analysis

### **Unit 5: Computational Linear Algebra (p. 30)**

- Matrix decompositions (eigendecomposition, SVD)
- Eigenvalues, eigenvectors, and stability analysis
- Determinant, trace, and special matrix properties (positive/negative definiteness)
- Inversion, pseudo-inverse, condition numbers, and numerical issues
- Low-rank approximations and dimensionality reduction

### **Unit 6: Introduction to Optimization (p. 37)**

- Formulating optimization problems (parameters, objective functions)
- Types of optimization (continuous, discrete, constrained)
- Convexity vs. non-convexity, local/global minima
- Simple algorithms (grid search, random search) and basic iterative methods

### **Unit 7: Numerical Nonlinear Optimization (p. 46)**

- Gradient-based methods (gradient descent, Newton's method)
- Convergence criteria and step-size strategies
- Handling constraints (Lagrange multipliers, penalty methods)
- Example applications to real-world nonlinear problems

### **Unit 8: Probability and Random Variables (p. 53)**

- Foundations of probability (axioms, conditional probability)
- Random variables, distributions (discrete and continuous)
- Expectation, variance, common distributions (Normal, Poisson, etc.)
- Transformations and basic limit theorems

### **Unit 9: Sampling and Inference (p. 57)**

- Sampling methods (Monte Carlo, importance sampling)
- Parameter estimation (maximum likelihood, Bayesian inference)
- Hypothesis testing and confidence intervals
- Practical considerations in computational inference

### **Unit 10: Time Series and Signals (p. 62)**

- Basic concepts (stationarity, autocorrelation, power spectra)
- Discrete Fourier transform, filtering, convolution
- Signal processing techniques and applications
- Introduction to forecasting and seasonality in time series