	Credits	Coordinator	Name	Learning Objectives	Targeted Skills	Content
	120		**Master in Biology and Health**			
	120		**Program in Biomarkers and Artificial Intelligence**			
	60		**M2 Biomarkers and Artificial Intelligence Program**			
	30		**3rd Semester of the M2 Biomarkers and Artificial Intelligence Program**			
Support for Transformation in a Professional Context	3	P. SUCHON	Descriptive Statistics Adapted to Biomarkers	Understand the fundamental principles of descriptive statistics applied to biomarkers. Be able to prepare and clean biomedical datasets for analysis. Apply descriptive techniques adapted to the specific characteristics of biomarkers (distributions, variability, bias). Be able to interpret statistical findings correctly in a biomedical context.	Be proficient in basic statistical tools such as mean, median, variance, and standard deviation. Identify potential biases in biomedical data. Employ statistical software tools to analyze biomarker data. Communicate statistical results clearly and accurately.	Introduction to Biomarkers and Data-Specific Features. Classical and Adapted Descriptive Statistics (Measures of Central Tendency and Dispersion). Data Visualization Techniques (Histograms, Boxplots, Scatter Plots). Prevention of Common Biases and Errors. Use of Software Tools for Descriptive Analysis.
	3	DUBOIS + GILSON	Ethics for Modern Artificial Intelligence in Healthcare II	Understand the specific ethical issues related to the use of AI in healthcare. Analyze the societal, legal, and moral implications of AI technologies. Apply rigorous ethical reflection in the development and evaluation of AI tools in biomedicine. Raise awareness of issues related to bias, transparency, accountability, and consent.	Identify the main ethical dilemmas and technical solutions related to AI in healthcare. Assess ethical risks and propose mitigation strategies. Communicate ethical issues with diverse stakeholders (scientists, patients, regulators). Integrate ethical principles into the design of biomedical AI projects.	Ethical and Regulatory Frameworks in Health and AI. Critical and Practical Analysis of Algorithmic Biases and Their Consequences. Privacy, Data Protection, and Informed Consent Procedures. Accountability and Transparency in AI Systems. Real-World Case Studies and Ethical Debates.
	3	C. DUBOIS	Bibliographic Project	Develop a systematic and rigorous approach to scientific literature review. Be able to synthesize and critically evaluate scientific literature in a specialized field. Build a structured and coherent scientific argument. Be proficient in academic writing and citation guidelines.	Effectively search for relevant sources in scientific databases. Analyze and synthesize complex scientific articles. Write a clear, structured, and well-argued scientific document. Use bibliographic and reference management tools (e.g., Zotero, Mendeley). Professionally present the bibliographic project orally.	Advanced Document Search Techniques. Standards for Evaluating and Choosing Sources. Methods of Synthesis and Critical Analysis. Scientific Writing and Editorial Standards. Bibliographic Management Tools. Oral Presentation and Defense of the Bibliographic Project.
Advanced and Specialized Uses of Digital Tools	6	A.S. CHRETIEN	Machine Learning: Application to the Analysis of Single-Cell Datasets	Understand the fundamentals of machine learning applied to biomedical data. Apply machine learning methods to data derived from single cells. Analyze results to derive meaningful biological insights. Use appropriate programming tools and libraries (Python, scikit-learn, etc.).	Preprocess and normalize single-cell data. Implement supervised and unsupervised algorithms adapted to these data. Evaluate the performance of machine learning models. Identify and visualize important features from datasets. Evaluate and improve models based on biological goals.	Introduction to Single-Cell Data. Preprocessing and Normalization Techniques. Supervised Learning Algorithms (Classification, Regression). Unsupervised Learning Algorithms (Clustering, Dimensionality Reduction). Cross-validation and Model Evaluation. Biological Applications and Interpretation of Results.
	3	R. BOUTALBI	Advanced Programming	Enhance programming skills for applications in biomedical and biological data analysis. Have a strong command of advanced programming techniques for handling, analyzing, and visualizing complex datasets. Create reliable applications and scripts for scientific settings.	Use programming languages effectively (Python, R, and possibly others). Implement complex data structures and algorithms adapted to biomarkers. Develop automated and reproducible analysis pipelines. Apply best software development practices (testing, documentation, modularity). Integrate specialized libraries for biomedical data processing.	Advanced Concepts in Object-Oriented and Functional Programming Advanced Data Manipulation with pandas, numpy (Python), or data.table (R) Programming Reusable Functions and Modules Exception Handling and Debugging Advanced Visualization Techniques (matplotlib, seaborn, ggplot2) Automation of Analysis Workflows Introduction to Unit Testing and Continuous Integration Code Documentation and Best Collaborative Practices
Development and Application of Expert-Level Knowledge	3	C. BEROUD	Introduction to Unit Testing and Continuous Integration	Understand the fundamental principles of bioinformatics applied to the analysis of genetic mutations. Gain the skills needed to handle genomic and transcriptomic data effectively. Be proficient in tools and techniques for mutation analysis in biomedical settings.	Handle and analyze sequencing data (NGS, WES, WGS). Use bioinformatics pipelines for mutation detection and interpretation. Integrate genetic and clinical databases for biomarker context. Analyze and interpret mutation analysis results in a biomedical context.	Introduction to Genomic Bioinformatics Genomic Data Formats (FASTQ, BAM, VCF) Sequence Analysis Workflows: Alignment, Variant Detection, and Annotation Mutation Databases and Genetic Biomarkers Statistical Analysis of Mutations Commonly Used Software and Tools (GATK, Samtools, Annovar, etc.) Integrate genetic and clinical databases for biomarker context. Ethics and Confidentiality in the Handling of Genetic Data
	3	K. CHAUMOITRE	Image Analysis – Biomarker Diagnosis	Understand the fundamentals of imaging techniques and reconstruction methods. Understand image analysis techniques to identify and quantify biomarkers. Be proficient in AI-driven image analysis tools and algorithms applied to research and clinical settings.	Processing and preprocessing of biomedical images (medical imaging) Applying methods for extracting and segmenting visual features of biomarkers. Using image analysis tools for computer-assisted diagnosis. Integrating artificial intelligence techniques into image analysis. Assessing the quality and reproducibility of image analyses.	Introduction to the Principles of Biomedical Imaging Types of Images and Imaging Modalities (Ultrasound, CT, MRI, Nuclear Medicine) Image Preprocessing: Filtering, Segmentation, Correction Feature Extraction: Shapes, Textures, Intensities Classical Methods and Machine Learning Applied to Imaging, Radiomics Software Tools: ImageJ, Python (OpenCV, scikit-image), AI-based Computer-Aided Diagnosis Software Clinical Applications: Diagnosis, Therapeutic Monitoring, Research Practical Cases and Workshops on Biomedical Image Analysis
	6	C. BEROUD	Open Science and Reproducible Science	To understand the fundamental principles of open science in the context of biomedical research. Mastering the concepts and tools required to ensure the reproducibility of scientific work. Integrating best practices for the management, sharing, and dissemination of data and source codes. Promoting a culture of transparency, collaboration, and rigor in research.	Applying the FAIR principles (Findable, Accessible, Interoperable, Reusable) to research data. Using open sharing platforms and tools (GitHub, Zenodo, etc.). Implementing reproducible analysis protocols (notebooks, workflows). Writing publications and reports with methodological transparency. Collaborating effectively in open and multidisciplinary research projects.	Introduction to Open Science: Issues and Contexts Standards and Norms for Data Management (FAIR Principles) Platforms for Data and Code Deposition and Archiving Methodologies for Reproducibility: Scripts, Notebooks (Jupyter, RMarkdown) Version Control and Collaborative Project Management Tools (Git, GitHub) Case Studies and Best Practices in Biomedical Research Ethical and Legal Issues in Open Science Practical Workshop: Implementing a Reproducible Workflow on a Biomedical Project
30			**Semester 4 – M2 Biomarkers and Artificial Intelligence**			
Support for Organizational or Process Transformation in a Professional Context	30	C. DUBOIS	Internship and Thesis	Applying the skills acquired throughout the master's program in a professional or research context. Developing autonomy in conducting a complex scientific or technical project. Producing rigorous, well-structured research work that meets academic standards. Preparing for oral and written scientific communication in a professional environment.	Designing, planning, and carrying out a research project or a technological development project. Analyzing and interpreting data in a biomedical and/or artificial intelligence context. Writing a high-quality scientific thesis, including a literature review, methodology, results, and discussion. To present one's work orally before a panel, with clarity and well-structured arguments. Integrating effectively into a research team or a company.	Professional or research internship (4 to 6 months), under the supervision of an academic advisor and a professional mentor. Writing a scientific thesis in accordance with academic standards. Oral defense before a panel composed of faculty members and/or professionals. Educational supervision and guidance throughout the internship.