



UNIVERSITÉ
**PARIS
SCIENCES
& LETTRES**

ST4Health

Science & Technology for Health Master's Program

Year 2026-2027



ST4Health

At a Glance



Welcome to ST4Health

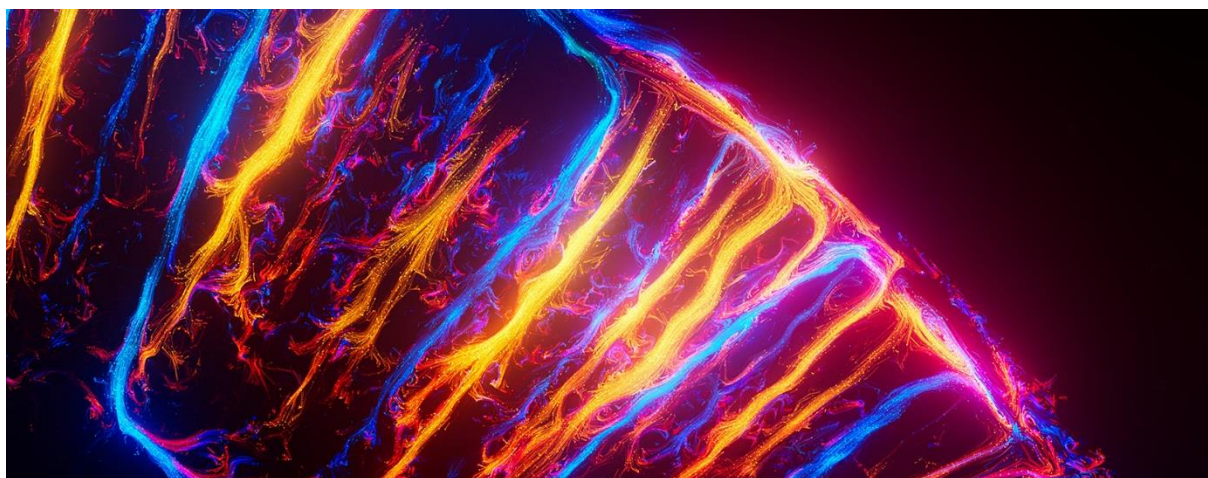


Photo credit: Alexandre Dizeux/ Physics for Medicine Paris

Shaping the future of healthcare through science, engineering and innovation

Welcome to the Master's program Science & Technology for Health (ST4Health) at Université PSL.

Healthcare is undergoing profound transformations driven by advances in biomedical engineering, artificial intelligence, digital technologies, data science, biotechnology and neuroscience. Addressing today's healthcare challenges requires professionals capable of working across disciplines and collaborating with scientists, engineers, clinicians, entrepreneurs and policymakers.

ST4Health was designed to train this new generation of innovators.

Bringing together expertise from across PSL University and its partners, the program combines rigorous scientific training, project-based learning, research experience and exposure to real-world healthcare challenges. Students from diverse backgrounds in engineering, life sciences, medicine, physics, mathematics, computer science and related disciplines learn to work together to design tomorrow's health solutions.

Over two years, you will acquire both a broad understanding of biomedical engineering and advanced expertise in one of three specialization tracks:

- **Artificial Intelligence & Digital Health (AIH)**
- **Biomaterials & Engineering for Health (BEH)**
- **Digital Mental Health (DMH)**

Whether your ambition is to pursue research, develop innovative medical technologies, contribute to digital health transformation, launch a startup or continue towards a PhD, ST4Health provides the scientific foundations, interdisciplinary mindset and professional skills needed to become a key actor in healthcare innovation.

Located within the dynamic ecosystem of Université PSL, Paris Santé Campus and Institut Curie, ST4Health offers a unique environment where education, research, clinical practice and innovation converge to shape the future of health.

We are delighted to welcome you to this exciting journey.

The ST4Health Team

Your Journey at ST4Health

Master 1

Semester 1

Core courses (3 ECTS)

- Scientific communication & Soft skills
- Language (English/French)
- Weekly conferences

Elective specialization courses (21 ECTS)

Life sciences, Data science, Engineering, Neurosciences,...

Project (6 ECTS)

State-of-the-Art study

Semester 2

Elective specialization courses (21 ECTS + Language 1 ECTS)

Life sciences, Data science, Engineering, Neurosciences...

Project (8 ECTS)

Biomedical engineering group project

Master 2

Semester 3

Core courses (all M2 tracks – 12 ECTS)

- ST4Health Challenge
- Research methodology
- Medical sciences for engineers
- Society & Innovation for health
- Upgrade in biology
- Upgrade in programming
- Weekly conferences
- Language (English/French)

Track courses (minimum 18 ECTS in one of the tracks)

AI & Digital Health
7 track courses

Biomat. & Eng. for Health
8 track courses

Digital Mental Health
8 track courses

Semester 4

Core courses (all M2 tracks – 6 ECTS)

- Healthcare organization & development of health products
- Entrepreneurship in health and medtech

Master thesis (24 ECTS – 5-6 month research internship)

AI & Digital Health

Biomat. & Eng. for Health

Digital Mental Health



Three specialization tracks

Track – AI & Digital Health (AIH)

Study & design of data science, AI and image analysis approaches to accelerate progress in personalized medicine and support the emergence of new healthcare technologies.

Track – Biomaterials & Engineering for Health (BEH)

Study & design of materials, devices and technologies interfaced with biological systems to create and develop innovative therapeutic and diagnostic solutions.

Track – Digital Mental Health (DMH)

Study & design of innovative solutions using digital sciences and technologies for the diagnosis and treatment of mental health pathologies.

What skills will you develop?

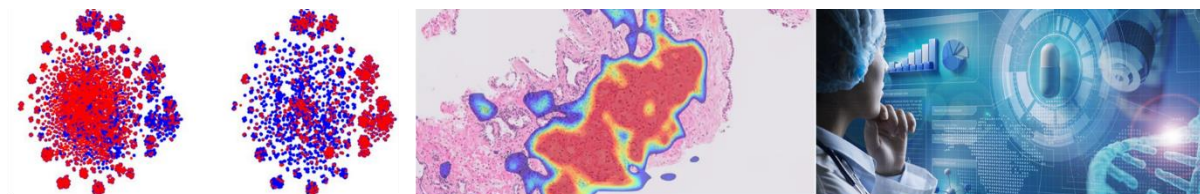
- Biomedical Engineering
- Artificial Intelligence & Data Science
- Life Sciences & Medicine
- Research Methodology
- Innovation & Entrepreneurship
- Project Management
- Scientific Communication
- Interdisciplinary Teamwork

Where can ST4Health take you?

- Research Engineer
- Biomedical Engineer
- Health Data Scientist
- AI Engineer for Healthcare
- Medical Device Specialist
- Neurotechnology Specialist
- Innovation Consultant
- Entrepreneur
- PhD Candidate

Artificial Intelligence & Digital Health (AIH Track)

A forward-looking program at the interface of artificial intelligence, data science, and healthcare innovation. The AIH track trains students to design responsible AI-based solutions for prevention, diagnosis, treatment, and healthcare organization, while placing clinical relevance, ethical awareness, and patient benefit at the heart of digital health transformation.



From Gichevaux et al. JGIM 2024 – CC-BY 4.0

Turning health data into medical innovation

The AIH track trains students to use artificial intelligence, data science and computational methods to address major challenges in biomedical research and healthcare. Students learn how to analyse complex health data, design robust AI workflows, and evaluate digital tools for applications such as medical imaging, clinical decision support, computational biology, bioinformatics, digital pathology, multi-omics integration, precision medicine and drug discovery.

The track combines advanced methodological training with a critical understanding of the specific constraints of health data: heterogeneity, limited annotation, bias, interpretability, reproducibility, privacy and clinical relevance.

Who should apply?

AIH is suited to students with backgrounds in computer science, data science, applied mathematics, physics, engineering, biomedical sciences, quantitative life sciences as well as health sciences (medicine, pharmacy, etc), who want to apply computational approaches to biomedical and clinical questions.

What you will learn

Students develop specialized skills in:

- Machine learning and deep learning for health
- Biomedical and clinical data analysis
- Medical image processing
- Bioinformatics and computational biology
- Multimodal and multi-omics data integration
- Responsible and interpretable AI for healthcare

Research & career opportunities

The Master thesis is a 5–6-month research internship in a laboratory, hospital, institute or innovation environment. Projects may focus on AI for medical imaging, digital pathology, foundation models for health, clinical decision support, precision medicine, drug discovery or computational biology.

Graduates may pursue careers as health data scientists, AI engineers for healthcare, computational biologists, bioinformatics specialists, medical imaging scientists, digital health specialists or research engineers. The track also provides strong preparation for PhD studies in AI, biomedical engineering, bioinformatics, computational biology or digital health.

Biomaterials & Engineering for Health (BEH Track)

A hands-on bioengineering program focused on the design of materials, devices, and technologies that interact with living systems for medical applications. The BEH track prepares students to develop biomaterials and therapeutic and diagnostic technologies by connecting scientific approaches with engineering creativity, biological complexity, and unmet clinical needs.



Engineering materials and devices for tomorrow's healthcare

The BEH track focuses on the design of materials, devices and engineering strategies for biomedical and healthcare applications. Students explore how materials interact with living systems and how these interactions can be controlled to develop innovative solutions for diagnosis, therapy, regeneration, monitoring and biomedical research.

The track connects material properties, biological responses, medical needs and technological constraints. It provides a strong scientific and engineering foundation for students interested in developing tangible health technologies, from biomaterials and implants to diagnostic tools and biomedical imaging systems.

Who should apply?

BEH is designed for students with backgrounds in engineering, physical sciences, life sciences, or health sciences (medicine, pharmacy, etc.) who wish to address healthcare challenges through the development of innovative materials and devices interfacing with biological systems.

What you will learn

Students develop specialized skills in:

- Biomaterials and biointerfaces
- Materials–biology interactions
- Tissue engineering and regenerative medicine
- Implantable and medical device engineering
- Nanomedicine and diagnostic technologies
- Biomedical imaging and health-oriented engineering design

Research & career opportunities

The Master thesis is a 5–6-month research internship. Projects may involve biomaterial and implant engineering, surface engineering for medicine, biointerfaces, tissue engineering, nanomedicine, biomedical imaging, diagnostic technologies, or physics and chemistry applied to health.

Graduates are prepared for careers in biomaterials engineering, medical device R&D, MedTech and BioTech industries, diagnostic technology development, biomedical imaging, tissue engineering, research engineering, innovation management or technology transfer. The track also prepares students for PhD studies in biomaterials, biomedical engineering, medical physics, chemistry, materials science or related fields.

Digital Mental Health (DMH Track)

An interdisciplinary program combining neuroscience, artificial intelligence, and cutting-edge technologies to address the growing mental health crisis in France and worldwide. This unique master's track trains experts who can harness advanced technologies to explore the complex connections between brain activity, cognition, and behavior, whilst placing human experience at the center of mental health challenges.



Science and technology for the future of mental healthcare

In response to the growing mental health crisis, the DMH track explores how neuroscience, psychiatry, psychology, artificial intelligence, computational approaches, neurotechnology and digital health can contribute to better understanding, assessing, monitoring and supporting mental health.

The track is designed around a balanced view of digital mental health: technologies are studied not only as tools, but also in relation to clinical practice, lived experience, ethics, society and patient-centered innovation. Students learn to critically evaluate digital mental health solutions and to contribute responsibly to innovation in this rapidly evolving field.

Who should apply?

DMH is suited to students interested in mental health, neuroscience, psychology, psychiatry, cognitive science, biomedical engineering, data science or digital health, and who wish to work at the interface between brain sciences, behaviour, care and technology.

What you will learn

Students develop specialized skills in:

- Psychiatry and mental health research
- Advanced neuroscience and brain–body interactions
- Computational psychiatry and AI for mental health
- Neurotechnology, neuroimaging and neural data analysis
- Connected devices, digital interventions and neurofeedback
- Ethical, participatory and patient-centred design

Research & career opportunities

The Master thesis is a 5–6-month research internship. Projects may focus on computational psychiatry, digital phenotyping, AI-based mental health data analysis, neurofeedback, brain-computer interfaces, connected devices, virtual reality, neuromodulation, neuroscience data analysis or digital therapeutics.

Graduates may pursue careers as digital mental health specialists, neuroscience data analysts, research engineers in neurotechnology, digital health innovation specialists, clinical research associates, mental health technology consultants or AI and mental health researchers. The track also provides a strong foundation for PhD studies in neuroscience, psychiatry, cognitive science, computational psychiatry, digital health or neurotechnology.

Practical information

Program format

- **Degree:** Master's degree in Science & Technology for Health
- **University:** Université PSL
- **Language of instruction:** English
- **Duration:** Two years (possibility to enter in M2 year)
- **ECTS credits:** 120 ECTS (60 ECTS per year)
- **Mode of study:** Full-time
- **Main teaching locations:** PariSanté Campus, ESPCI Paris – PSL and partner institutions
- **Specialization tracks:**
 - AI & Digital Health
 - Biomaterials & Engineering for Health
 - Digital Mental Health

Who should apply?

ST4Health is intended for motivated students with a strong academic background in science, engineering or health-related disciplines. The program is particularly suitable for students trained in:

- engineering;
- physics, chemistry or materials science;
- biology, biotechnology, neuroscience, or life sciences;
- mathematics, computer science or data science;
- medicine, pharmacy or other health sciences.

Applicants should be interested in interdisciplinary work and motivated to address health challenges through scientific and technological innovation.

Teaching locations

Courses are mainly delivered in Paris, within PSL's academic and innovation ecosystem. Key locations include:

- **PariSanté Campus** [\[map\]](#), a major hub dedicated to digital health, health innovation and interdisciplinary collaboration;
- **ESPCI Paris – PSL** [\[map\]](#), a leading engineering and research institution within PSL;
- partner institutions and research sites depending on courses, projects and internships.

International environment

ST4Health is taught in English and welcomes students from diverse academic and geographical backgrounds. The program prepares students to work in international research and innovation environments, where collaboration across disciplines and cultures is essential.

Student support

Students benefit from academic guidance throughout the program, including support for course selection, track orientation, project definition and internship preparation. PSL also provides services for student life ([Campus life@PSL | PSL](#)), international students ([PSL Welcome Desk | PSL](#)), administrative support and well-being.

Welcome to the ST4Health Community

By joining ST4Health, you become part of a vibrant and diverse community of students, researchers, clinicians, engineers and innovators working together to shape the future of healthcare.

Over the next two years, you will develop scientific expertise, technical skills and an interdisciplinary mindset that will enable you to address complex healthcare challenges and contribute to meaningful innovations. Beyond the courses themselves, ST4Health offers opportunities to engage in research, collaborate across disciplines, interact with healthcare professionals and participate in a dynamic ecosystem of innovation.

The program will challenge you to step outside your comfort zone, explore new fields, work in multidisciplinary teams and transform ideas into solutions with real-world impact.

Whether your future lies in research, industry, entrepreneurship or clinical innovation, we hope that ST4Health will provide the foundations, inspiration and network to help you achieve your ambitions.

We look forward to accompanying you on this exciting journey.

Welcome to ST4Health. Welcome to Université PSL.

The ST4Health Team



Contacts

For general information, admissions and administrative questions, please contact:

ST4Health Master Program

Université PSL

Email: admin@st4health.fr

Website: [ST4Health website](https://st4health.fr)

For track-specific information:

- AI & Digital Health — AIH: aih@st4health.fr
- Biomaterials & Engineering for Health — BEH: beh@st4health.fr
- Digital Mental Health — DMH: dmh@st4health.fr

ST4Health In Details



General presentation

ST4Health: Science & Technology for Health



The **Master of Science & Technology for Health — ST4Health** is PSL University's master's program in biomedical and health engineering. Taught in English, the program offers a two-year interdisciplinary curriculum at the interface of **engineering sciences, biomedical sciences, medicine, digital technologies and health innovation**.

ST4Health trains students to understand complex health challenges and to develop innovative scientific and technological solutions for prevention, diagnosis, treatment, rehabilitation and patient care. The program combines rigorous academic training with hands-on projects, research internships, and close interaction with PSL's health innovation ecosystem, including laboratories, hospitals, start-ups, public institutions and industrial partners.

The program is designed for students from diverse backgrounds — engineering, physics, chemistry, biology, computer science, mathematics, medicine, pharmacy and health sciences — who wish to acquire a strong multidisciplinary profile and contribute to the future of healthcare.

Aims of the program

ST4Health aims to train a new generation of scientists, engineers, clinicians and innovators able to work across disciplinary boundaries and translate scientific advances into concrete healthcare applications.

Students will learn to:

- master the core scientific and technological concepts needed in biomedical & health engineering;
- work at the interface between engineering, life sciences, clinical medicine and digital health;
- analyse health challenges from a systems perspective, integrating biological, technical, clinical, ethical and societal dimensions;
- design, evaluate and communicate innovative solutions for biomedical research, health technologies and care pathways;
- develop autonomy, scientific rigor, teamwork and project-management skills through research and innovation projects.

Three specialization tracks

The ST4Health curriculum is structured around three complementary tracks:

AI & Digital Health — AIH This track focuses on the use of data science, artificial intelligence, computational modelling and digital technologies to address major challenges in healthcare. Students acquire the tools needed to analyse biomedical and clinical data, design digital health solutions, and contribute to the transformation of medicine through data-driven approaches.

Biomaterials & Engineering for Health — BEH This track explores the design and development of materials, devices and engineering strategies for biomedical applications. It covers topics such as biomaterials, tissue engineering, biomechanics, biofabrication, medical devices and regenerative medicine, with a strong emphasis on the link between material properties, biological interactions and clinical needs.

Digital Mental Health — DMH This track addresses the emerging field of digital technologies for mental health. Students learn how neuroscience, psychology, data science, connected devices and digital interventions can be combined to improve assessment, prevention, monitoring and care in mental health, while considering ethical, clinical and societal dimensions.

A Unique PSL Ecosystem for Health Innovation

Learning at the heart of PSL

ST4Health is embedded in the exceptional scientific and academic environment of **Université PSL**, bringing together leading schools, research centers and institutes across science, engineering, humanities, medicine and innovation. This environment gives students access to a broad range of expertise and to a strong culture of research, interdisciplinarity and entrepreneurship.

The program is affiliated with PSL's graduate programs in **Engineering** and **Life Sciences**, and relies on the complementary strengths of PSL institutions involved in health, biomedical research, engineering, data science and innovation:

- **ESPCI Paris – PSL** [\[link\]](#)
- **MINES Paris – PSL** [\[link\]](#)
- **CHIMIE ParisTech – PSL** [\[link\]](#)
- **EPHE – PSL** [\[link\]](#)
- **ENS – PSL** [\[link\]](#)
- **Institut Curie – PSL** [\[link\]](#)

Students are affiliated with **ESPCI Paris-PSL**, which handles administrative coordination.

Key partners of research and innovation for health

The ST4Health program benefits from the contribution of major partners in health research, digital health, oncology, and artificial intelligence.



PariSanté Campus [\[link\]](#) is a major digital health ecosystem dedicated to research, training, innovation, and entrepreneurship in health. It brings together public research and innovation actors, including PSL, Inserm, Inria, the Health Data Hub, and the Agence du Numérique en Santé, together with private partners, start-ups, and healthcare stakeholders. Its mission is to accelerate the use of health data, support excellence in digital health training, and foster innovations for healthcare.



The Institute of Women's Cancers [\[link\]](#), co-founded by Institut Curie, Université PSL, and Inserm, is a University Hospital Institute dedicated to better understanding, preventing, & treating women's cancers. It develops a holistic and personalized approach to breast and gynecological cancers, combining clinical care, research, data science, humanities and social sciences, and patient-centered innovation.



The Paris School of AI [\[link\]](#) is PSL's interdisciplinary initiative in artificial intelligence and data science, created within the France 2030 PR[AI]RIE-PSAI cluster. It offers ambitious training programs from undergraduate to doctoral level and places research at the core of education. By connecting AI with fields such as health, cognitive sciences, humanities, ethics, regulation, and sustainability, it contributes to training the next generation of AI experts for science and society.

Why study ST4Health at PSL?

ST4Health offers:

- a highly interdisciplinary curriculum connecting sciences, engineering, medicine and data-based technologies;
- training through research, with strong links to PSL laboratories and partner institutions;
- project-based learning inspired by real biomedical and clinical challenges;
- exposure to health innovation through PariSanté Campus and PSL's entrepreneurial ecosystem;
- small cohorts and close academic guidance;
- an international learning environment, with courses taught in English;
- three specialization tracks addressing major areas of transformation in healthcare.

Building Your Curriculum

A flexible and coherent academic pathway

ST4Health offers a structured yet flexible curriculum. Students follow a combination of **core and track-specific courses**, **electives**, **projects**, and **internships**. This allows them to build a coherent academic profile while adapting the program to their background and career goals. The core courses and activities provide the general knowledge and transversal skills that are essential for a career in health research and innovation.

Students select one of three specialization tracks: **AI & Digital Health**, **Biomaterials & Engineering for Health**, or **Digital Mental Health**. Through specific courses and a major research internship, these tracks provide advanced specialization in some of the most active and critical areas of biomedical engineering and healthcare innovation.

This balance between common foundations and specialization is consistent with those of leading biomedical engineering programs, in which students progressively transition from broad, interdisciplinary training to focused expertise and research practice.

Track selection

For students entering the first year of the program, the M2 track is preselected during the recruitment process. This means that M1 students register for the prerequisite courses required for their intended M2 track. If their background allows, they may complete their curriculum with additional courses to be eligible for two different M2 tracks. After completing the first year, M1 students continue in their intended track for the second year.

Students entering directly into the second year of the program select their track during the recruitment process. Each track has specific admission criteria and a limited number of seats. Admission offers are made for a specific track in the program.

Course selection and credit validation

The ST4Health program combines mandatory and elective courses. Students must validate at least 30 ECTS per semester, although they may earn additional credits and are encouraged to attend extra courses to broaden their knowledge and skills.

As ST4Health welcomes students from diverse academic backgrounds, course selection is tailored to individual profiles and validated according to four criteria:

- **Professional goals:** elective courses are selected with the guidance of the program chairs to support each student's career plan.
- **Track coherence:** the chosen courses must collectively cover the essential concepts of the selected track.
- **Prerequisites:** some courses require prior knowledge acquired either within the program or through previous studies.
- **Schedule compatibility:** given the wide range of available courses, classes taken outside a track may overlap in the timetable.

Learning by Doing

Project-based training

ST4Health emphasizes hands-on learning through projects that apply scientific and technical knowledge to real biomedical and healthcare challenges. Students develop autonomy, creativity, teamwork, and problem-solving skills through activities such as literature analysis, experimentation, data analysis, modelling, prototyping, feasibility studies, and interactions with researchers, clinicians, and external partners.

This project-based approach reflects biomedical innovation in laboratories, hospitals, start-ups, and industrial R&D teams, while helping students gain confidence in working across disciplines.

The M1 Biomedical Engineering Project

Throughout the first year, all M1 students develop research and engineering skills through the **State-of-the-Art (SoA)** activity and the **Biomedical Engineering Project (BME Project)**.

The BME projects are open-ended health engineering challenges proposed by ST4Health partners, including research laboratories, hospitals, and start-ups. Aligned with one or more program tracks, they may involve design frameworks, software or program development, practical experimentation, prototype fabrication, dataset analysis, or dedicated studies.

Student teams of three are formed in September and select one project.

During **Semester 1**, each student individually addresses a specific question related to the team project and prepares a state-of-the-art review under the supervision of the program faculty and project mentor. This work leads to the definition of a research direction.

During **Semester 2**, students work as a team to define and achieve a realistic project objective within the semester. They work independently, with access to the **FabLab PSL network**, and receive guidance from the program faculty and project mentor.

The M2 Research Internship (Master Thesis)

In the second year, ST4Health students complete a full-time **5–6 month research internship** as their master's thesis. Hosted by an academic laboratory, hospital research group, start-up, or industrial R&D team, the internship offers students the opportunity to contribute to an original research project aligned with their chosen track.

Internships are selected during Semester 3 from program-approved opportunities or proposed independently by students, subject to validation by the track chairs. This experience strengthens scientific expertise, professional autonomy, and advanced research skills, while preparing students for doctoral studies, research careers, industrial R&D, or innovation-driven roles in health.

Skills developed through projects and internships

By the end of the program, students will have developed:

- scientific reasoning and critical analysis;
- experimental, computational or design skills;
- teamwork in multidisciplinary settings;
- project planning and time management;
- scientific writing and oral communication;
- awareness of ethical, clinical, regulatory and societal dimensions of health innovation.

ST4Health

Detailed syllabus

Master 1 (M1)

Semester 1

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S1_EC01	Lang	Language (English, French)	Mandatory	-	1	~ 24h
ST4H_S1_EC02	Sem	Seminars	Mandatory	-	-	~ 15h
ST4H_S1_01	SciComm	Scientific communication & Soft skills	Mandatory	-	3	~ 20h
ST4H_S1_02	SoA	State-of-the-Art study	Mandatory	-	6	~ 36h
ST4H_S1_03	PSLwk1	PSL week (Fall)	Elective	-	3	~ 30h
ST4H_S1_04	Biol1	Biology for biomedical engineers (basics)	Elective	-	3	~ 20h
ST4H_S1_05	Math1	Linear algebra & multivariate calculus for health sciences	Elective	-	3	~ 20h
ST4H_S1_06	Prog1	Computer programming (basics)	Elective	-	3	~ 20h
ST4H_S1_07	Neuro1	Neuroscience (basics)	Elective	-	3	~ 20h
ST4H_S1_08	StrsPhysio	Stress & Brain-body physiology	Elective	-	3	~ 20h
ST4H_S1_09	Mech	Mechanics and device engineering	Elective	ST4H_S1_05	3	~ 20h
ST4H_S1_10	MolMeth	Molecular methods for biomedical engineering	Elective	ST4H_S1_04	3	~ 20h
ST4H_S1_11	Biol2	Biology for biomedical engineers (adv.)	Elective	ST4H_S1_04	3	~ 20h

Each student must select and validate **at least 7 elective courses** during Semester 1.

The following electives are mandatory prerequisites* for the M2 tracks:

AIH track: Biol1, Biol2, Prog1, Math1

BEH track: Biol1, Biol2, Prog1, Math1, Mech, MolMeth

DMH track: Biol1, Biol2, Prog1, Math1, Neuro1, StrsPhysio

** A mandatory prerequisite may be replaced by another course provided that the student has already validated an equivalent course in his/her previous studies. This possibility is discussed and validated by the M1 co-chairs at the beginning of the year.*

Master 1 (M1)

Semester 2

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S2_EC01	Lang	Language (English, French)	Mandatory	-	1	~ 24h
ST4H_S2_01	BMEProj	Biomedical engineering project	Mandatory	-	8	~ 50h
ST4H_S2_02	PSLwk2	PSL week (Spring)	Elective	-	3	~ 30h
ST4H_S2_03	Prog2	Computer programming (adv.)	Elective	ST4H_S1_06	3	~ 20h
ST4H_S2_04	Math2	Probability, statistics & optimization for health sciences	Elective	-	3	~ 20h
ST4H_S2_05	Neuro2	Neuroscience (adv.)	Elective	ST4H_S1_07	3	~ 20h
ST4H_S2_06	Biolm	Modalities of biomedical imaging	Elective	ST4H_S1_10, ST4H_S1_11	3	~ 20h
ST4H_S2_07	Psycho	Psychology	Elective	-	3	~ 20h
ST4H_S2_08	Mater	Materials engineering	Elective	ST4H_S1_09	3	~ 20h
ST4H_S2_09	PhysBiol	Physics of biological systems	Elective	-	3	~ 20h
ST4H_S2_10	Sleep	Sleep	Elective	ST4H_S1_07 ST4H_S1_08	3	~ 20h
ST4H_S2_11	SigProc	Signal Processing	Elective	ST4H_S1_05	3	~ 20h

Each student must select and validate **at least 7 elective courses** during Semester 2.

The following electives are mandatory prerequisites* for the M2 tracks:

AIH track: Prog2, Math2, Biolm, SigProc

BEH track: Prog2, Math2, Biolm, Mater, PhysBiol, SigProc

DMH track: Prog2, Math2, Neuro2, Psycho, Sleep, SigProc

* A mandatory prerequisite may be replaced by another course provided that the student has already validated an equivalent course in his/her previous studies. This possibility is discussed and validated by the M1 co-chairs at the beginning of the year.

Master 2 (M2)

Common Core Courses

Semester 3

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S3_TC_EC01	BasBiol	Basics in cell and tissue biology	Depend on background	-	-	~ 15h
ST4H_S3_TC_EC02	BasProg	Basics in programming	Depend on background	-	-	~ 15h
ST4H_S3_TC_EC03	Sem	Seminars	Mandatory	-	-	~ 15h
ST4H_S3_TC_EC04	Lang	Language (English for science, French)	Mandatory	-	1	~ 24h
ST4H_S3_TC_01	HealthChal	ST4Health Research & Innovation challenge	Mandatory	-	3	~ 30h
ST4H_S3_TC_02	ResMeth	Research methodology	Mandatory	-	3	~ 30h
ST4H_S3_TC_03	MedSci	Medical sciences for biomedical engineering	Mandatory	-	3	~ 30h
ST4H_S3_TC_04	SocInno	Society & Innovation for health	Mandatory	-	3	~ 30h

Semester 4

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S4_TC_01	HealthOrg	Health system & Development of health products	Mandatory	-	3	~ 24h
ST4H_S4_TC_02	HealthEntr	Entrepreneurship in health and medtech	Mandatory	-	3	~ 24h

A part from the refresher courses (BasBiol & BasProg), all the common core M2 courses are mandatory.

Master 2 (M2)

Artificial Intelligence & Digital Health (AIH) Track Courses

Semester 3

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S3_AIH_01	MLAI	Machine Learning & Artificial Intelligence	Mandatory	-	3	~ 20h
ST4H_S3_AIH_02	BioinfOmics	Bioinformatics & Multi-omics data analysis	Mandatory	-	3	~ 20h
ST4H_S3_AIH_03	BiomedImg	Biomedical image analysis	Elective	-	3	~ 20h
ST4H_S3_AIH_04	StatGenom	Statistics for genomics	Elective	-	3	~ 20h
ST4H_S3_AIH_05	Cheminf	Cheminformatics & drug design	Elective	-	3	~ 20h
ST4H_S3_AIH_06	MLBioNetw	Machine learning for biological networks	Elective	-	3	~ 20h
ST4H_S3_AIH_07	MedInfo	Electronic Health Records & Medical Informatics	Elective	-	3	~ 20h

Semester 4

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S4_AIH_01	AIHResProj	AIH Research Project (Master thesis)	Mandatory	-	24	5-6 months

During Semester 3, each student must complete the mandatory courses with elective courses to validate a minimum number of at least 30 ECTS. It is possible and encouraged to take up to 3 extra elective courses within the selected track or in other tracks, provided that the schedule allows it.

Master 2 (M2)

Biomaterials & Engineering for Health (BEH) Track Courses

Semester 3

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S3_BEH_01	MatSurfMed	Materials & Surface sciences for medicine	Elective	-	3	~ 20h
ST4H_S3_BEH_02	EngBioInterf	Engineering of biofunctional interfaces	Elective	ST4H_S3_BEH_01	3	~ 20h
ST4H_S3_BEH_03	TissEng	Tissue engineering & Cell-laden devices	Elective	ST4H_S3_BEH_01	3	~ 20h
ST4H_S3_BEH_04	NanoMed	Nanomedicine: design & applications	Elective	-	3	~ 20h
ST4H_S3_BEH_05	NanoMat	Nanomaterials for diagnostics & theranostics	Elective	ST4H_S3_BEH_04	3	~ 20h
ST4H_S3_BEH_06	OptImg	Optical imaging for biology & health	Elective	-	3	~ 20h
ST4H_S3_BEH_07	USImg	Ultra-sound systems for imaging & therapeutics	Elective	-	3	~ 20h
ST4H_S3_BEH_08	BiosenLOC	Biosensors & Lab-on-a-chip technologies for clinical diagnostics	Elective	-	3	~ 20h

Semester 4

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S4_BEH_01	BEHResProj	BEH Research Project (Master thesis)	Mandatory	-	24	5-6 months

During Semester 3, each student must complete the mandatory courses with elective courses to validate a minimum number of at least 30 ECTS. It is possible and encouraged to take up to 3 extra elective courses within the selected track or in other tracks, provided that the schedule allows it.

In particular, the MLAI course “[Machine Learning & Artificial Intelligence](#)” (ST4H_S3_AIH_01) proposed in the AIH track is accessible to all M2 students.

Master 2 (M2)

Digital Mental Health (DMH) Track Courses

Semester 3

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S3_DMH_01	MentDigiTech	Mental health & Digital technology : concepts, practices and perspectives	Mandatory	-	3	~ 20h
ST4H_S3_DMH_02	AdvNeuroSc	Advanced neuroscience for the understanding of behavior and mental health	Mandatory	-	3	~ 20h
ST4H_S3_DMH_03	RealLifPsysc	Real-life psychiatry : from the validity of research methods to incorporating emotions and bodily reactions	Mandatory	-	3	~ 20h
ST4H_S3_DMH_04	CompAppMent	AI-inspired computational approaches to mental health and their applications	Mandatory	-	3	~ 20h
ST4H_S3_DMH_05	TherStratMent	Innovative therapeutic strategies for mental health	Mandatory	-	3	~ 20h
ST4H_S3_DMH_06	AniModMent	Animal models of mental disorders	Elective	-	3	~ 20h
ST4H_S3_DMH_07	ResProjCogSc	Research projects in cognitive neuroscience and mental health	Elective	-	3	~ 20h
ST4H_S3_DMH_08	AIMent	Artificial intelligence applied to neurosciences and mental health	Elective	-	3	~ 20h

Semester 4

Reference	Short title	Full title	Selection status	Prerequisite	ECTS	Contact hours
ST4H_S4_DMH_01	DMHResProj	DMH Research Project (Master thesis)	Mandatory	-	24	5-6 months

During Semester 3, each student must complete the mandatory courses with elective courses to validate a minimum number of at least 30 ECTS. It is possible and encouraged to take up to 3 extra elective courses within the selected track or in other tracks, provided that the schedule allows it.

In particular, the MLAI course “[Machine Learning & Artificial Intelligence](#)” (ST4H_S3_AIH_01) proposed in the AIH track is accessible to all M2 students.

ST4Health

Courses description

Master 1
Semesters 1 & 2
Mandatory courses

ST4H_S1_EC01 ST4H_S2_EC01	Language - English for Science and Academic Communication
Lang	

Coordinator(s)	Daria Moreau (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
1	English	0 h	24 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 20% / Oral presentation 20% / Continuous assessment (tests & assignments) 40%					
Prerequisites	B2+ level in English					

Course description

English for Science and Academic Communication is an advanced academic English course designed for Master HealthTech students preparing for communicating effectively in international scientific and technical environments. The course develops the language and communication skills needed to engage with scientific literature, express complex ideas clearly, participate in academic discussions, with a strong emphasis on conference-style communication.

Students work with authentic scientific materials such as research articles, laboratory reports, lectures, and scientific presentations and also with their own research projects. Through practical workshops, they develop skills in academic writing, oral presentations, including structuring arguments, describing data, and presenting research findings.

Particular attention is given to clarity, precision, and rhetorical effectiveness in scientific English. The course culminates in a mini conference where students present, defend, and discuss their research in English. This simulation of a real academic conference includes presentations, Q&A sessions, and panel-style discussions, allowing students to apply all communication skills in an integrated, professional setting.

Learning objectives

- **Know**
 - Recall and memorise key scientific vocabulary and terminology
 - Identify common academic phrases used in scientific writing and presentations
 - Recognise standard structures of scientific texts (e.g., abstract, introduction, methodology)
- **Understand**
 - Paraphrase scientific information using appropriate academic language
 - Summarise key points from scientific texts and lectures
 - Translate scientific ideas accurately into clear English
 - Demonstrate understanding of data, diagrams, and experimental descriptions
- **Apply**
 - Use scientific vocabulary and structures in written and spoken tasks
 - Apply language knowledge to write lab reports and short research summaries
 - Transfer theoretical knowledge to practical academic tasks (e.g., explaining experiments or procedures)
- **Analyse**
 - Identify key elements in scientific texts (hypothesis, methods, results, conclusions)
 - Examine logical relationships between ideas in research articles
 - Distinguish between main arguments and supporting evidence
 - Analyse data descriptions and interpret their meaning in context

- **Synthesize**
 - Combine information from multiple scientific sources to produce coherent summaries
 - Create structured academic texts such as mini research reports or presentations
 - Integrate language, data, and concepts to produce original scientific explanations
- **Evaluate**
 - Assess the clarity and reliability of scientific texts and arguments
 - Make justified decisions based on scientific information
 - Defend a point of view in academic discussions using evidence and reasoning
 - Critically evaluate research findings and methodological approaches

ST4H_S1_EC01 ST4H_S2_EC01	Language - French as a Foreign Language (FLE)
Lang	

Coordinator(s)	Daria Moreau (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
1	English	0 h	24 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 20% / Oral presentation 20% / Continuous assessment (tests & assignments) 40%					
Prerequisites	-					

Course description

French as a Foreign Language (FLE) is designed for international students enrolled at Mines Paris – PSL and other PSL institutions who wish to develop their French language proficiency and intercultural competence. The course supports students in their academic, professional, and social integration into the French higher education environment.

Aligned with the levels of the Common European Framework of Reference for Languages (CEFR), the course develops the four core language skills—listening, speaking, reading, and writing—through authentic materials and interactive activities. Particular emphasis is placed on communication in academic and scientific contexts, enabling students to participate effectively in university life, understand lectures, interact with peers and faculty, and navigate professional situations in France. PSL's language offerings are specifically adapted to scientific and engineering profiles and are coordinated through the PSL Language Center hosted by Mines Paris – PSL.

Through a combination of language practice, cultural exploration, and task-based learning, students strengthen their ability to communicate confidently in French while developing a deeper understanding of French academic culture and society.

This course contributes to the development of the linguistic, academic, and intercultural skills necessary for successful study and professional engagement within the international environment of PSL and the broader French-speaking world.

Learning objectives

- **Know**
 - Recall & use essential vocabulary and grammatical structures appropriate to their CEFR level.
 - Recognize common expressions used in academic, professional, and everyday situations.
 - Identify key features of French academic and cultural practices.
- **Understand**
 - Demonstrate comprehension of spoken and written French in academic and social contexts.
 - Paraphrase and summarize texts, lectures, and discussions.
 - Explain information, opinions, and cultural concepts using appropriate language.
 - Interpret the meaning and purpose of different types of written and oral communication.
- **Apply**
 - Use French effectively in academic, professional, and everyday interactions.
 - Produce coherent written texts such as emails, reports, summaries, and reflections.
 - Apply grammatical and lexical knowledge in authentic communication tasks.
 - Participate actively in classroom discussions, presentations, and collaborative activities.

- **Analyze**
 - Identify the structure and main ideas of written and spoken documents.
 - Distinguish between facts, opinions, arguments, and supporting evidence.
 - Analyze linguistic and cultural differences between French and other languages.
 - Recognize relationships between language use, context, and audience.
- **Synthesize**
 - Combine information from multiple sources to produce coherent oral and written outputs.
 - Develop and present original viewpoints on academic, cultural, and societal topics.
 - Create structured presentations, reports, and projects in French.
 - Integrate linguistic & intercultural knowledge to communicate effectively in diverse situations.
- **Evaluate**
 - Assess the effectiveness and appropriateness of oral and written communication.
 - Critically evaluate arguments, sources, and cultural perspectives.
 - Defend a point of view using clear reasoning and supporting evidence.
 - Reflect on personal language development and identify strategies for continued improvement.

ST4H_S1_EC02	ST4Health Seminars
Sem	

Coordinator(s)	Eloïse Berson (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
-	English	0 h	0 h	0 h	15 h	0 h
Assessment	Class participation 100%					
Prerequisites	-					

Course description

The ST4Health seminar series is a weekly forum designed to expose students to the diversity of contemporary health science and technology. Each Friday, invited speakers from academia, clinical practice, industry, engineering, entrepreneurship, and health institutions share their research, professional trajectories, and perspectives on the role of science and technology in addressing major healthcare challenges.

Through these seminars, students gain insight into emerging biomedical innovations, translational research, clinical needs, health systems, and career pathways at the interface between science, engineering, medicine, and society. The series also encourages students to critically reflect on how interdisciplinary approaches can contribute to improving prevention, diagnosis, treatment, and patient care.

Learning objectives

- **Know** the diversity of scientific, clinical, technological, entrepreneurial, and institutional actors involved in health innovation.
- **Understand** how science and technology contribute to addressing healthcare challenges and improving patient care.
- **Apply** insights from invited speakers to connect academic learning with real-world clinical, industrial, and societal contexts.
- **Analyse** the opportunities, constraints, and stakeholder perspectives involved in translating research and technology into healthcare applications.
- **Synthesise** multidisciplinary viewpoints to build an integrated understanding of the health innovation ecosystem.
- **Evaluate** the relevance, impact, and limitations of scientific and technological approaches for improving health and shaping future professional pathways.

ST4H_S1_01	Scientific Communication & Soft Skills
SciComm	

Coordinator(s)	Thierry Gallopin (ESPCI Paris PSL); Sofia Carrion (ESPCI Paris PSL); Paul Moore (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
2	English	14 h	0 h	5 h	0 h	0 h
Assessment	Class participation 30% / Written exam 35% / Oral presentation 25% / Report 10%					
Prerequisites	-					

Course description

This course is designed to give students the theoretical knowledge and tools of written and oral scientific communication. The course will be based on lectures and exercise to learn how to structure and analyse scientific arguments and communicate them efficiently, identify and use cognitive biases and manage stress. We will investigate what modern tools are available to assist in research, including bibliographic searches, and artificial intelligence tools. Finally, this course aims to teach how to effectively communicate the results of research, both to an audience of peers, and to a lay audience who may have minimal understanding of the topic.

- **Session 1: Structured Scientific Thinking**
 - Learning the different types of reports and the IMRaD structure.
 - Scientific approach to reading and noting information.
 - Exercise focused on extrapolating a scientific narrative from a figure or data.
- **Session 2: Critical Analysis of Media and Bias in knowledge**
 - Identification of the limiting points of an experiment (unreasonable perseverance)
 - Analysis of interpretation biases (statistical, economic, political).
 - Exercise focused on debunking scientific claims in non-scientific media.
- **Session 3: Communication with Digital Tools.**
 - Study of convergence and hallucination biases, especially in the use of technological tools.
 - How can digital tools be used to acquire and synthesize novel information?
 - Exercises in using search terms as well as testing results presented from search engine and large language model outputs.
- **Session 4: Stress Management through Cognitive, Behavioral and Emotional Approaches**
 - Neuroscience of stress: brain circuits, phases of the stress response, and the role of subjective perception in performance anxiety.
 - Cognitive strategies: reframing automatic stress responses, goal-setting, and mental imagery applied to oral presentation preparation.
 - Behavioural and somatic strategies: cardiac coherence, meditation, and progressive muscle relaxation, with in-session practice.
 - Emotional regulation: identifying and managing emotions before and during a presentation; somatic markers as a self-monitoring tool.
- **Session 5: Presenting Complex Concepts to New Audiences**
 - How to present results orally in a concise way.
 - Practical exercises to adapt a complex scientific discourse to an audience.

- How to adapt presented information appropriately for their audience.
- Assertion - Evidence presentation style.

- **Session 6: Oral Exam : 3 min presentations + questions**

- Without note the student will have to present a scientific article to an unfamiliar scientific audience, the presentation will be followed by an open question period aimed towards the same unfamiliar audience.
- Present in groups of 2, with 6 minutes per presentation, and 6 minutes for questions.
- Evaluate students on quality of questions: critical/skeptical, pertinent, etc.

Learning objectives

- **Know:** How scientific information is organized and how to quickly read it.
- **Understand :** How personal stress can influence ones understanding of information and ones work. How search terms can be used to broaden research.
- **Apply :** Critical tools to scientific facts presented in both scientific and non-scientific media.
- **Analyse :** Scientific articles and identify sources of bias and conflicts of interest.
- **Synthesize :** Scientific information into an easily presented format for unfamiliar audiences.
- **Evaluate :** Information for likely sources of bias, and even falsehood.

ST4H_S1_02	State-of-the-Art Study
SoA	

Coordinator(s)	Sofia Carrion (ESPCI Paris PSL); Paul Moore (ESPCI Paris PSL) ; Laurent Corté (MINES Paris)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
6	English	6 h	12 h	0 h	0 h	18 h
Assessment	Class participation 10% / Oral presentation 25% / Report 45% / In-class assessment 20%					
Prerequisites	-					

Course description

The goal of this course is to teach students to perform an autonomous state of the art research project. Students will be expected to conduct a comprehensive and analytical bibliographic study related to a scientific question, or novel technology. The subject chosen will link up with the design and engineering project undertaken in the following semester in order to provide a deeper understanding of their chosen project.

The state of the art study will teach students to narrow a broad field of study down to a set of specific questions, how to find trustworthy sources, and how to critically evaluate the informations. Along with reports on individual aspects of their state of the art question, students will also be expected to compile a master report which will summarize their findings.

- **Session 1: Choosing study question**
 - Introduce topics of study and future engineering projects
 - How to choose a subject to study
- **Session 2: Broad Literature Search**
 - Identify relevant questions pertaining to a broad research question
 - Use research tools to find new information
 - How to structure research note taking/bibliographic tools
 - Review articles and textbooks as jumping off points.
- **Project 1: Literature Search**
 - Use bibliographic and keyword search tools to find relevant research.
- **Session 3: Systematic Research**
 - Define scope of research
 - Find a relevant scientific source on the state of the art topic
- **Project 2: Article Selection**
 - Identify and select a strong and relevant article to begin in depth research.
- **Session 4: Narrowing Research**
 - How to narrow a literature review
 - Using a review article to answer specific questions
 - Identify a specific research question
- **Session 5: Critical Scientific Reading**
 - How to critically evaluate a scientific source

- Verifying citations in literature.

- **Project 3: Bibliography Building**

- Collect a wide array of reliable sources of information and organize the information such that it is understandable.

- **Session 6: Synthesize Research**

- Basics of report structure for literature reviews.
- How to organize facts into coherent information.
- Basics of presentation structure.

- **Project 4: Research Report 1**

- Organize research notes into a coherent structure

- **Project 5: Research Report 2**

- Organize research notes into a coherent structure

Learning objectives

- **Know:** Know the best practices in report writing and critical analysis of scientific works.
- **Understand :** Understand the rationale behind the determination of a state-of-the-art; Understand what makes a source of information reliable.
- **Apply :** Read and understand scientific writing; Manipulate libraries and artificial intelligence tools to synthesize information; Use bibliographic and organization tools.
- **Analyse :** Read and analyze scientific literature addressing a question of interest.
- **Synthesise :** Write reports summarizing and synthesizing research on a question of interest.
- **Evaluate :** Assess the state of knowledge on a question of interest.

ST4H_S2_01	Biomedical Engineering Project
BMEProj	

Coordinator(s)	Sofia Carrion (ESPCI PSL Paris); Paul Moore (ESPCI PSL Paris)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
8	English	18 h	0 h	30 h	0 h	150 h
Assessment	Class participation 20% / Oral presentation 10% / Report 70%					
Prerequisites	State-of-the-Art study (SoA)					

Course description

This course is designed around the completion of projects on a topic of engineering in healthcare, such as design of a medical device, development of an analysis pipeline, or optimization of a process. Groups of three students will undertake projects proposed by partners in industry, academia and clinical practice. Projects will be evaluated in three phases: problem definition, solution analysis, and a final design.

Students will be given access to lab facilities in order to undertake their different projects, depending on what materials are actually needed. In addition to lectures, this course will include basic training in using lab facilities in order to develop prototypes for their final design. Furthermore, students will be expected to undertake self-directed learning for tools that may be specific to their individual projects.

- **Lecture 1: Project Definition and Team Leadership**
 - How to organize and delegate responsibilities in a large team-based project.
 - Identifying key deliverables and prioritizing output
 - Project planning, time and resource management.
- **Lecture 2: Regulations in Biomedical Engineering**
 - Ethical frameworks in engineering and medicine.
 - Medical and biomedical regulatory bodies and how to research regulations.
 - Intellectual property considerations.
- **Lecture 3: Brainstorming and Idea evaluation**
 - Brainstorming strategies for idea generation.
 - How to develop an idea to maturity.
 - Failure mode consideration.
 - Objective strategies for evaluating potential solutions to a problem.
- **Lecture 4: Troubleshooting and Risk Management**
 - Failure mode effects analysis.
 - Contingency planning and adapting for failure
 - Common prototyping pitfalls.
- **Lecture 5: Technical Reporting**
 - Best practices for report organization.
 - Figure and data presentation strategies.
 - Technical writing standards.

- **Lecture 6: Presenting a Product**

- Slide design for product presentation.
- Storytelling with data strategies.
- Preparing for question and answer sessions.

Learning objectives

- **Know:** Core concepts in project planning, design process, documentation, and technical communication.
Basic safety, ethics, and regulatory principles relevant to the lab spaces and project domain.
- **Understand:** How project scope, constraints, risks, and timelines shape design decisions and deliverables.
How effective teamwork, organization, and documentation support an engineering design project.
- **Apply:** Use planning tools such as work breakdown structures, Gantt charts, logbooks, and design matrices.
- **Analyze:** Break down an open-ended problem into needs, constraints, risks, and design requirements.
- **Synthesize:** Combine research, brainstorming, technical training, and feedback into a coherent design plan.
- **Evaluate:** Critically assess one's own work and team process, including contribution, organization, and revision decisions.

Master 1

Semesters 1 & 2

Elective courses

ST4H_S1_03 ST4H_S2_02 PSLwk1; PSLwk2	PSL week (Fall & Spring)
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Coordinator(s)	Laurent Corté (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English/French	Depends on the selected course				
Assessment	Depends on the selected course					
Prerequisites	Depends on the selected course					

Course description

PSL University proposes a list of one-week courses in the Fall (late November) and in Spring (early March). Those courses are accessible to all PSL graduate students and cover a broad range of topics in science, engineering, arts and humanities. Courses may be taught in French or English. Numbers of seats for each course is limited and prerequisites vary according to each course. Several courses generally address topics of interest for the ST4Health training.

The list of PSL week courses and the detailed syllabus are updated every year and can be consulted here: [PSL-week](#). Registration is done online and opens in September.

Learning objectives

Depends on the selected course – See [PSL-week](#)

ST4H_S1_04	Biology for Biomedical Engineers (basics)
Biol1	

Coordinator(s)	Dominique Bluteau (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	0 h	0 h	0 h
Assessment	Class participation 30% / Written exam 70%					
Prerequisites	-					

Course description

This course is a general introduction to biology providing a set of essential notions to have general understanding of biological systems and techniques (esp. in a biomedical context). It is structured as lectures interspersed with exercises. The content will be assessed through a written exam consisting of course questions and small exercises. The course is organized as follows:

- **Session 1: General Introduction**
 - Levels of biological organization
 - Prokaryotic vs. eukaryotic cells
 - Introduction to human tissues
- **Session 2: Broad Literature Search**
 - Eukaryotic Cell Compartmentalization and Traffic
 - Eukaryotic Cell Activity
- **Session 3: Biomolecules & Molecular biology**
 - Proteins
 - Lipids & membranes
 - Glucids & energy
 - Nucleic acids
- **Session 4: Biomolecules & Molecular biology**
 - DNA packaging / Transcription / mRNA modification / Translation / Transcriptional regulation
- **Session 5: How to analyse DNA/RNA/Proteins**
 - WGS, WES, WTS
 - Western Blot, Immunoprecipitation, Mass spectrometry
- **Session 6: General introduction to physiology and homeostasis**
 - Homeostasis / Major systems / Basic signaling
 - How to visualize the structure of cells/organs
 - Imaging/Microscopy/Spatial transcriptomics-proteomics

Learning objectives

- **Know:** Recall fundamental biological concepts, including levels of organization, cell types (prokaryotic vs. eukaryotic), biomolecules (proteins, lipids, carbohydrates, nucleic acids), and key analytical techniques (WGS, WES, WTS, Western blot, mass spectrometry).
- **Understand:** Explain the structure and function of biological systems, including cell compartmentalization, molecular processes (DNA packaging, transcription, translation), and the principles of physiology, homeostasis, and basic signaling pathways.
- **Apply:** Use foundational biological knowledge and experimental techniques to interpret molecular and cellular data, and address basic biomedical questions.
- **Analyze:** Examine biological data and experimental outputs (e.g., sequencing results, protein analyses, imaging data) to identify patterns, relationships, and functional insights across different levels of biological organization.
- **Synthesize:** Integrate concepts from molecular biology, cell biology, and physiology to build a coherent understanding of biological systems and propose explanations for observed phenomena.
- **Evaluate:** Assess the strengths and limitations of experimental approaches (e.g., sequencing, imaging, proteomics) and critically interpret results in a biomedical context.

ST4H_S1_05	Linear Algebra and Multivariate Calculus for Health Sciences
Math1	

Coordinator(s)	Maxime Ferrer (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	-					

Course description

This course introduces the mathematical language used to represent, analyze, and model multidimensional data in health sciences. Students learn how vectors and matrices describe datasets and transformations, and how multivariate calculus provides the tools to quantify variation and sensitivity in complex systems. Emphasis is placed on geometric intuition, computational implementation, and applications relevant to data science, biomedical engineering, and artificial intelligence.

- **Lecture 1 : Vectors and Matrices and Linear Systems**
 - Scalars, vectors and matrices
 - Matrix operations
 - Dot products and norms
 - Matrix-vector multiplication
 - Systems of linear equations
- **Practicals 1 : Linear Algebra with Data**
 - Matrix manipulations in Python
 - Solving linear systems
 - Dataset representation
 - Geometric visualization of vectors
- **Lecture 2 : Linear Transformations and Data Representation**
 - Linear combinations
 - Span and basis
 - Rank and dimensionality
 - Change of coordinates
 - Introduction to eigenvalues and eigenvectors
 - Covariance matrices and principal directions
 - Dimensionality reduction (PCA)
- **Practicals 2 : Eigenvectors and Data Analysis**
 - Covariance matrices
 - Principal directions
 - Simple PCA implementation
 - Interpretation of high-dimensional data
- **Lecture 3 : Multivariate calculus**
 - Partial derivatives
 - Gradient vectors
 - Jacobian matrices

- Hessian matrices
- Chain rule
- Directional derivatives

- **Practicals 3 : Multivariate Calculus**

- Computing gradients and Jacobians
- Visualization of multivariate functions
- Gradient descent and variants
- Implementation of gradient-based optimization algorithms
- Convex versus non-convex optimization problems

Learning objectives

- **Manipulate** vectors and matrices and perform basic linear algebra operations.
- **Interpret** linear transformations geometrically and algebraically.
- **Solve** systems of linear equations.
- **Represent** health datasets using matrix notation.
- **Compute** partial derivatives, gradients, Jacobians, and Hessians.
- **Apply** the chain rule in multivariate settings.
- **Interpret** derivatives as measures of sensitivity and change.
- **Use** matrix and differential calculus tools in simple modelling problems.

ST4H_S1_06	Computer Programming (basics)
Prog1	

Coordinator(s)	Aina Gari-Soler (Paris Dauphine PSL & INRIA Paris)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Class participation 10% / Written exam 60% / Assignment 30%					
Prerequisites	Basic mathematics (calculus, functions, algebra)					

Course description

This course provides an introduction to computer programming for students in health-related scientific and technological fields. The focus is on developing algorithmic thinking as well as practical programming skills using Python.

Students will learn how to write simple programs, structure code using functions, manipulate core data structures, reading and writing data files, and perform basic numerical tasks. The course is designed to serve as a foundation for the advanced course in computer programming, as well as later courses in data analysis, artificial intelligence, and digital health technologies.

The course is organized into six sessions, each split into a theoretical half introducing the relevant concepts and a practical half with exercises to put them into practice.

- **Session 1: Fundamentals and Setting up**
 - Course organization, objectives, evaluation
 - What is programming? Algorithms and computational thinking
 - Role of programming in health, biomedical research, and digital health
 - Introduction to Python and the scientific Python ecosystem, setting up Anaconda
 - Working environments: scripts, command line, Jupyter notebooks
 - Variables, basic data types and arithmetic
 - String manipulation and string formatting
- **Session 2: Data Structures**
 - Lists, tuples, dictionaries and sets
 - Indexing, slicing and common methods on these structures
 - (Im)mutability
 - What is an object? Attributes and methods
 - Booleans and comparison operators
- **Session 3: Control Flow**
 - Conditional statements and logical operators: implementing simple decision rules
 - Loops and iteration: range, break, continue
 - Typical logical errors and how to avoid them
- **Session 4: Functions and Modularity**
 - Defining functions: (default) arguments, return values, scope
 - Writing readable and reusable code
 - Creating and importing your own modules

- **Session 5: Basic Handling of Data Files**
 - Reading and writing data files (CSV, text files)
 - Basic introduction to NumPy and Pandas: arrays and DataFrames
 - Basic data inspection, summary statistics
- **Session 6: Basic Debugging**
 - Types of errors and exceptions: interpreting and tracing them
 - Anticipating problems: Try, except, assert
 - Good programming habits

Learning objectives

- **Explain** the fundamental principles of programming and algorithmic thinking.
- **Write, read, and understand** simple, well-structured Python scripts.
- **Manipulate** numerical and textual data.
- **Use** appropriate data structures to organize experimental or clinical data.
- **Read and write** data files commonly used in health sciences (CSV, text files).
- **Apply** good practices in scientific programming, including code readability, reusability and basic debugging.

ST4H_S1_07	Neuroscience (basics)
Neuro1	

Coordinator(s)	Sophie Pezet (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	18 h	0 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 90%					
Prerequisites	-					

Course description

This course introduces the foundational concepts of neuroscience to students with limited background in the field. It covers the structure and function of the nervous system, from the neuron to large-scale brain organisation, with a focus on mechanisms that will be further developed in subsequent DMH-track courses. It introduces the organisation of the nervous system, neuronal signalling, synaptic transmission, neurotransmitter systems, brain regions, and large-scale principles of brain function. Topics include sensory systems, vision, audition, somatosensation, and pain, attentional modulation, the dopaminergic reward and motivation circuit, the neurobiological basis of addiction, and the principles of neuroplasticity.

Emotion regulation, stress physiology, memory, and higher cognitive functions are intentionally left to Neuro2, StrsPhysio, and Sleep, for which this course provides the necessary biological grounding. The goal of this course is to provide the biological vocabulary and conceptual framework that students will need to engage critically with the neuroscientific literature and with the concepts covered in the other course units.

Learning objectives

- **Know:** Identify the main components of the nervous system, including neurons, glial cells, synapses, major brain regions, and central versus peripheral divisions. Recall the basic effects of major neurotransmitter systems. Locate and distinguish primary, secondary, and associative cortical areas. Identify the key structures of the reward and motivation circuit.
- **Understand:** Explain the mechanisms of electrical signal generation (action potential) and chemical transmission (synaptic transmission), and how these can be modulated. Describe how sensory systems (vision, audition, somatosensory, pain) process and transmit information hierarchically to the cortex, and how attentional mechanisms modulate this processing. Explain the neurobiological basis of reward and motivation.
- **Apply:** Use concepts covered in the course to identify the biological mechanisms underlying a digital mental health intervention, for example, explaining how a pain management app targets somatosensory and attentional pathways, how a craving-reduction tool relates to the reward circuit, or how a neurofeedback device exploits neuroplasticity mechanisms.
- **Analyse:** Distinguish between levels of explanation in neuroscience (molecular, circuit, systems) and assess what each implies for the design or evaluation of a DMH tool. Distinguish between correlation and causation in neuroscience claims frequently cited in DMH product development.
- **Evaluate:** Judge whether the neuroscientific rationale provided for a digital mental health intervention is credible and internally consistent.

ST4H_S1_08	Stress & Brain-body physiology
StrsPhysio	

Coordinator(s)	Karim Benchenane (ESPCI Paris PSL), Thierry Gallopin (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	0 h	6 h	0 h	0 h
Assessment	Class participation 10% / Report 90%					
Prerequisites						

Course description

This course examines stress as a biological system, how the brain detects threat, activates the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system, and how chronic dysregulation of these systems produces physical and psychiatric pathology.

Students will study the physiology of cortisol, the role of the vagus nerve, heart rate variability (HRV), and the bidirectional relationship between body signals and mental states, including interoception and the physiological basis of emotion and somatic markers.

The course also covers the pathological consequences of chronic stress (glucocorticoid dysregulation, allostatic load), psychosomatic disorders, and the differential diagnosis between functional and organic conditions. The course also addresses the neurobiology of placebo effects and hypnotic states, illustrating how beliefs and suggestion can directly modulate brain and body physiology.

This is directly actionable knowledge for DMH: most physiological biomarkers currently used in wearables and mental health sensing (HRV, skin conductance, respiratory rate) derive their meaning from the stress physiology framework taught here. These topics provide the physiological grounding for subsequent courses on sleep, psychology, and digital biomarker interpretation.

A dedicated practical session uses the Cold Pressor Test (hand immersion in cold water at varying temperatures) to simultaneously record heart rate, respiration, and brain activity (EEG). The objective is to give students direct experience of measuring and interpreting physiological stress responses in a controlled experimental setting, and to understand how attentional modulation and suggestion can alter these signals, directly connecting theoretical content on the HPA axis, interoception, and placebo mechanisms to real biosignal data.

Learning objectives

- **Know:** Identify the main components of the HPA axis and the autonomic nervous system. Name the key physiological markers of stress (cortisol, HRV, heart rate, respiration, skin conductance). Define interoception, allostatic load, and somatic markers.
- **Understand:** Explain the sequence of the acute and chronic stress response and its physiological consequences. Describe how interoceptive signals contribute to emotional states. Explain how chronic glucocorticoid dysregulation leads to psychiatric and somatic pathology. Describe how suggestion can modulate brain and body physiology through placebo and hypnotic mechanisms.
- **Apply:** Interpret physiological signals (HRV, heart rate, respiration) recorded during an acute stress experiment. Identify which body-brain mechanisms a given digital health intervention (e.g. HRV biofeedback, relaxation app) claims to target.

- **Analyse:** Distinguish between functional and organic conditions in a clinical vignette. Examine the assumptions embedded in a digital biomarker against the underlying physiology covered in the course.
- **Evaluate:** Judge whether the physiological rationale of a digital mental health tool is credible, identifying gaps between the claimed mechanism and the evidence.

ST4H_S1_09	Mechanics & Device Engineering
Mech	

Coordinator(s)	Paul Moore (ESPCI Paris PSL), Laurent Corté (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 70% / Weekly assignment 20%					
Prerequisites	Basic mathematics (vectors, matrices operations) (Math1)					

Course description

This course provides an introduction to mechanics with a focus on biomedical applications. The focus will be on applying broad principles in kinematics, solid mechanics and fluid mechanics, to physiological systems or the medical devices that support them. The focus of this course will be on the application of analysis tools, such as system energy minimization, scaling laws, nondimensional analysis and failure criterion.

Students will be expected to take the complex and realistic physiological systems, simplify them to their essential physics, and use this to solve specific problems. Case studies include comparing arterial pressure with and without a blood clot, estimating gait during walking, and design of a pair of crutches.

- **Session 1 : Newton's laws, Forces and Moments**
 - Modeling ideas and units of measurement.
 - Forces, moments vectors and sign conversions.
 - How to draw a free body diagram.
 - Equilibrium conditions
- **Session 2 : Static Equilibrium**
 - Support types and 2-dimensional bodies.
 - Reaction forces and moment balance for a rigid body.
- **Session 3 : Stress, Strain and Elasticity**
 - What is stress, what is strain, and how are the two related?
 - Axial loading and elastic deformation.
 - Bending and torsion in a 3-dimensional body.
- **Session 4 : Kinematics**
 - Displacement, velocity and acceleration in one and two dimensions.
 - Rotational motion and angular velocity and acceleration.
 - Relative motion and frames of reference.
 - Energy conservation as a method of analyzing motion.
- **Session 5 : Fluid Statics and Dynamics**
 - What makes a fluid: pressure, viscosity and convection.
 - Fluids at rest: hydrostatic forces, and buoyancy.
 - Conservation of mass and continuity.
 - Internal flow and the Bernoulli equation.

- **Session 6 : Dimensional Analysis in Fluid Mechanics**
 - Continuity equation (extended).
 - Dimensional analysis and Buckingham Pi theorem.
 - Examples of fluid properties beyond flow and pressure.

Learning objectives

- **Know:** Know the definitions of key mechanics concepts: force, moment, stress, strain, pressure, velocity, acceleration, equilibrium, and free-body diagram.
- **Understand :** Understand the link between force and the reaction it creates in a body.
- **Apply :** Apply basic mechanical principles in the design of simple biomedical devices.
- **Analyze :** Free-body diagrams, and the relationship between various mechanical properties of a given system, such as pressure, flow, velocity, and deformation.
- **Synthesize :** Synthesize mechanical, kinematic, and fluid-mechanics reasoning to evaluate components, devices, and simple biomedical systems.
- **Evaluate :** Evaluate whether a mechanical or fluid-based design is likely to meet performance requirements based on forces, deformation, motion, or flow behavior.

ST4H_S1_10	Molecular Methods for Biomedical Engineering
MolMeth	

Coordinator(s)	Emmanuel Belamie (EPHE PSL), Marie-Noëlle Labour (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	18 h	0 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 90 %					
Prerequisites	Basics in biology (Biol1) and in chemistry in solution.					

Course description

This course is devoted to provide a general overview about the molecular chemistry and biochemistry of biomolecules and the experimental tools used to characterize them and their interactions in biomedical engineering. The students will discover the main biomolecules, their physico-chemical behavior and their interactions through various characterization tools based on chemical, biological and biophysical techniques.

Teaching will be provided in different pedagogic formats including interactive lectures to understand the main theoretical concepts, case studies and guided exercises will be provided to facilitate understanding and illustrate theoretical concepts.

- **Session 1: Structural analysis and interactions**
 - Spectroscopy : Fluorescence, Infrared, Raman
 - Electron microscopy
 - Near-field AFM, SPR
- **Session 2: Basics in aqueous chemistry equilibrium**
 - pH, complexation, solubility, ionic strength, electroactive species
- **Session 3: Advanced analytical methods**
 - Analytical electrochemistry
 - Capillary electrophoresis
- **Session 4: Magnetic Spectroscopy to imaging**
 - Basic magnetic resonance spectroscopy, NMR spectroscopy (1D, 2D, 3D),
 - Application to the study of biomolecular structure and ligand-protein interactions
 - From spectroscopy to Imaging (MRI) for biomedical applications
- **Session 5: Separation and detection methods**
 - Dialysis and filtration (AF4), chromatography (SEC, ion-exchange, affinity, electrophoresis
 - Detection: UV, Fluorescence, DLS, MALLS
- **Session 6: Biomolecules engineering**
 - Recombinant proteins, nucleic acid, antibodies
 - Production/extraction, purification, quality control

Learning objectives

- **Know:** Proficiency in the fundamentals of molecular chemistry and biochemistry
- **Understand:** Understanding of the key concepts in the interactions of biological macromolecules and analytical methods.
- **Apply:** Be able to apply this knowledge to the characterization of molecules, macromolecules and objects, their interactions, and select the appropriate analytical tools.
- **Analyse:** be able to interpret experimental data obtained using the characterization methods taught
- **Synthesise:** To be able to apply these skills to the design of materials for biomedical engineering
- **Evaluate:** Ability to identify the information needed to characterize macromolecular structures and interactions and to select appropriate experimental methods.

ST4H_S1_011	Biology for Biomedical Engineers (adv.)
Biol2	

Coordinator(s)	Dominique Bluteau (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	0 h	0 h	0 h
Assessment	Class participation 30% / Written exam 70%					
Prerequisites	Basic knowledge in cell biology (Biol1)					

Course description

This course is a general introduction to biology providing a set of advanced notions that are necessary when working at the interface between engineering and biomedical sciences. It is structured as lectures interspersed with exercises. The content will be assessed through a written exam consisting of course questions and small exercises. The course is organized as follows:

- **Session 1: Genomic**
 - Advanced gene regulation (gene regulation, epigenetics, ...)
 - Highthroughput sequencing approaches (ChIP-seq, ATAC-seq, ...)
- **Session 2: Signaling pathways**
 - Pharmacological approaches
- **Session 3: Fundamental immunology**
 - Innate & adaptive immunity
 - Biocompatibility & implant rejection
- **Session 4: Biomaterials & Tissue engineering**
 - Cell-material interactions
 - Extracellular matrices
 - Cell culture & organoids
 - Applications (prosthetics, artificial skin)
- **Session 5: Physiopathology**
 - Cancer
 - Cardiovascular diseases
 - Neurodegenerative disorders
- **Session 6: Group oral presentation**
 - A group oral presentation session, distinct from a formal lecture format, based on topics related to the courses attended.

Learning objectives

- **Know:** Identify key concepts in genomics, signaling pathways, immunology, biomaterials, tissue engineering, and major disease mechanisms (cancer, cardiovascular, neurodegenerative disorders), as well as the principles of high-throughput sequencing technologies.

- **Understand:** Explain advanced mechanisms of gene regulation and epigenetics, fundamental signaling pathways and pharmacological strategies, immune system functions (innate and adaptive), and interactions between cells and biomaterials in physiological and pathological contexts.
- **Apply:** Use biological concepts and experimental approaches (e.g., sequencing techniques, cell culture, immunological assays) to interpret data and address interdisciplinary problems at the interface between engineering and biomedical sciences.
- **Analyze:** Critically examine biological data, experimental methods, and disease models (including omics data and biomaterials applications) to identify key mechanisms, limitations, and relationships between systems.
- **Synthesize:** Integrate knowledge from genomics, immunology, biomaterials, and physiopathology to formulate coherent hypotheses, design interdisciplinary strategies, or propose innovative biomedical applications.
- **Evaluate:** Assess the relevance, strengths, and limitations of experimental approaches, therapeutic strategies, and engineering solutions in biology and medicine, and justify scientific conclusions based on available evidence.

ST4H_S2_03	Computer Programming (adv.)
Prog2	

Coordinator(s)	Aina Gari-Soler (Paris Dauphine PSL & INRIA Paris)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	10 h	0 h	11 h	0 h	0 h
Assessment	Class participation 10% / Assignment 45% / Written exam 45%					
Prerequisites	Basics in computer programming (Prog1)					

Course description

This course builds directly on the Computer Programming (Basics) course to develop more advanced and professional programming practices. Students will transition from writing small and self-contained programs to creating more efficient code taking advantage of existing libraries and utilities, with a focus on data processing and visualization. The course will equip students with the ability to manage code, tools and documentation built by others, and to critically evaluate and debug code using IDEs.

The course will cover object-oriented programming, environments and packages, the scientific Python stack (NumPy, pandas, SciPy) and data visualization, a set of advanced Python idioms and standard library tools, an introduction to regular expressions and web scraping and the use of debugging tools and AI coding assistants.

As in the Basics course, each session combines theoretical and practical halves. Across the course, students will work independently on a coding project which will involve designing and coding, from scratch, a program that processes and analyzes a health-related dataset, drawing on the skills developed throughout both courses.

- **Session 1: Object-Oriented Programming (OOP)**
 - Classes, objects, attributes and methods
 - Inheritance, dunder methods
 - When to use OOP vs procedural programming
- **Session 2: Environments, Packages, and Documentation**
 - Pip and conda
 - Creating and managing isolated environments, requirements files, package versions, reproducibility
 - Reading and understanding package documentation
 - Code versioning and collaboration: brief introduction to git
- **Session 3: NumPy, Pandas and SciPy in depth**
 - Vector operations, broadcasting, reshaping
 - Merging datasets, groupby aggregation
 - Handling missing and inconsistent data
 - Basic statistical functions and tests with SciPy
- **Session 4: Data Visualization**
 - Python visualization libraries: Matplotlib, seaborn
 - Principles of clear data presentation
 - Interactive plots

- **Session 5: Advanced Python Utilities I**
 - List, dictionary and set comprehensions
 - Lambda functions
 - Iterables, iterators and generators
 - Useful modules: collections, itertools, Counter, datetime, and others
- **Session 6: Advanced Python Utilities II: Working with Data**
 - Regular expressions for text pattern matching
 - JSON and XML files
 - Introduction to web scraping and API requests
- **Session 7: Advanced Debugging and AI-Assisted Coding**
 - Using an IDE's debugger: breakpoints, step-through execution, variable inspection
 - The Python debugger
 - AI-assisted coding: automatic code completion, code generation from prompts, AI coding agents
 - Limitations of and advice on AI-assisted coding

Learning objectives

- **Know** the core principles of object-oriented programming, how to use NumPy, pandas and SciPy, what regular expressions are and how to use them in Python, how to deal with internet data, write more efficient code, do advanced debugging and use AI coding assistants.
- **Understand** package documentation, the purpose of having separate environments, when to use OOP or procedural programming, what AI coding assistants can and cannot reliably be trusted to do.
- **Apply** previous and more advanced Python knowledge to create your own program dealing with health-related data, making use of libraries like NumPy, pandas, and SciPy.
- **Analyse** health-related data through different kinds of visualization, and evaluate complex code through advanced debugging practices.

ST4H_S2_04	Probability, Statistics and Optimization for Health Sciences
Math2	

Coordinator(s)	Maxime Ferrer (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	10 h	0 h	11 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	-					

Course description

This course introduces probabilistic reasoning, statistical inference, and optimization methods used throughout health sciences, data science, and artificial intelligence. Students learn how uncertainty is quantified, how conclusions are drawn from data, and how optimization algorithms are used to estimate model parameters and train predictive models. The focus is on interpretation, practical implementation, and critical assessment of results.

- **Lecture 1 : Probability and Random Variables**
 - Events and probabilities
 - Conditional probability
 - Independence
 - Random variables
 - Expectation and variance
 - Common distributions (Bernoulli, Binomial, normal)
- **Practicals 1 : Probability and Simulation**
 - Probability calculations
 - Random sampling
 - Simulating common distributions
 - Monte Carlo intuition
- **Lecture 2 : Statistical Inference**
 - Sampling and bias
 - Descriptive statistics
 - Correlation and association
 - Confidence intervals
 - Hypothesis testing
 - p-values and effect sizes
- **Practicals 2 : Statistical analysis of Health Data**
 - Descriptive statistics
 - Confidence intervals
 - Hypothesis testing
 - Interpretation of published results
- **Lecture 3 : Optimization**
 - Objective functions
 - Stochastic gradient descent
 - Learning rates
 - Linear regression

- Regularization and overfitting

- **Practicals 3 : Optimization and Machine Learning**

- Implement linear regression
- Implementing gradient descent
- Visualizing optimization trajectories

Learning objectives

- **Describe** uncertainty using probabilistic models.
- **Compute and interpret** descriptive statistical measures.
- **Understand** common probability distributions.
- **Interpret** confidence intervals and hypothesis tests.
- **Critically evaluate** statistical evidence.
- **Understand** optimization as a parameter estimation problem.
- **Implement** gradient-based optimization methods.
- **Analyze** convergence and optimization performance

ST4H_S2_05	Neuroscience (adv.)
Neuro2	

Coordinator(s)	Karim Benchenane (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	6 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 60% / Report 30%					
Prerequisites	Basics in neuroscience (Neuro1)					

Course description

Building on Neuro1, this course deepens students' understanding of the neuroscientific methods and functional systems most relevant to mental health research and digital health applications. A first block covers neuroscientific methods: electrophysiology (EEG, implanted electrodes, LFP, volume conduction), brain imaging (fMRI, PET, calcium imaging), optogenetics, and the principles of experimental design in neuroscience (causality vs. correlation, control conditions, animal vs. human models).

A second block introduces analytical approaches, including dimensionality reduction methods applied to EEG, fMRI, and neural population data. A third block covers brain oscillations and their functional interpretation. A fourth block addresses learning and conditioning, Pavlovian and operant paradigms, extinction, and their underlying neural substrates. Throughout, the course emphasises the translational gap between fundamental research and DMH applications: how findings from invasive animal models (optogenetics, calcium imaging) generate the mechanistic knowledge that ultimately informs digital interventions, and where the limits of that translation lie.

Tutorials will introduce dimensionality reduction and supervised classification methods applied to neural population data. Students will work on simplified datasets from electrophysiology, calcium imaging, and functional ultrasound imaging (fUS). Methods will include principal component analysis (PCA), linear discriminant analysis (LDA), visualization of neural population trajectories, and interpretation of low-dimensional representations in relation to behaviour, brain states

Learning objectives

- **Know:** Identify the main neuroscientific recording techniques (EEG, LFP, fMRI, calcium imaging, optogenetics) and their respective spatial and temporal resolutions. Name the major brain oscillation frequency bands and their functional correlates. Identify the key paradigms of learning and conditioning (Pavlovian, operant, extinction).
- **Understand:** Explain the principles of electrophysiological recording in vivo, including volume conduction and the distinction between local and global signals. Describe how dimensionality reduction methods (e.g. PCA, tSNE) are applied to neural datasets. Explain the neural substrates of Pavlovian and operant conditioning and extinction, and their relevance to psychiatric conditions such as PTSD, addiction, and anxiety disorders. Describe how optogenetics and calcium imaging allow causal manipulation of neural circuits, and how this knowledge informs intervention design.
- **Apply:** Select an appropriate neuroscientific method for a given research question in the DMH context, justifying the choice based on spatial/temporal resolution and invasiveness constraints. Apply the logic of experimental design (controls, causal inference) to critically read a neuroscience paper relevant to a digital mental health intervention.

- **Analyse:** Identify the translational limitations of findings obtained in animal models when applied to human DMH contexts. Distinguish between correlational and causal evidence in a neuroscientific study, and assess what this implies for the validity of a derived digital tool.
- **Evaluate:** Judge the scientific credibility of a neuroscientific claim used to justify a digital mental health intervention, identifying methodological weaknesses and translational gaps.
-

ST4H_S2_06	Modalities of biomedical imaging
Biolm	

Coordinator(s)	Bich-Thuy Doan (CHIMIE ParisTech PSL), Charlie Deméné (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	3 h	0 h	0 h
Assessment	Class participation 20% / Written exam 60% / Report 20%					
Prerequisites	Basics in cell biology (Biol2), Basics in molecular sciences and spectroscopy (MolMeth)					

Course description

Medical imaging has become a specialised field of study, with advanced research in physics and chemistry related to this biomedical domain suited to academic, clinical and industrial laboratories. This discipline involves methodological research into imaging techniques such as 3D ultrasound imaging and modern targeted therapy with imaging-guided therapy. The aim is to investigate pathological biological tissue qualitatively and quantitatively for diagnosis or therapy. This diagnosis is evaluated in vitro and in vivo, from preclinical to clinical studies, to enable the accurate and early detection of disease, the assessment of the efficiency of medical treatment and the development of innovative therapeutic strategies using non-invasive, safe in vivo imaging tools.

This course provides a general overview of the different bioimaging modalities, whether or not they are associated with contrast imaging agents, for image-guided diagnosis and therapy:

- the different modalities of MRI, optical, X-ray, PET and ultrasound imaging.
- the molecular or nanoparticulate characteristics of imaging probes;
- how imaging can be used in applications in vitro and in vivo in the biomedical or medical field for the diagnosis of cancer and inflammation.
- how they can be used in the development and evaluation of innovative treatments.

The course will comprise general lectures, practical exercises and visits to bioimaging facilities. The main modern bioimaging modalities will be taught by lecturers who are researchers at PSL University and Paris-Saclay Campus in their respective imaging domains: ultrasound, magnetic resonance imaging, nuclear medicine, optics and X-rays.

Various teaching methods will be employed, including interactive lectures, to help students grasp the key theoretical concepts. Case studies and guided exercises will be provided to illustrate these concepts and facilitate understanding. The ultimate objective of this unit of study (UE) is to provide students with the skills necessary to comprehend the imaging modalities employed and developed in academia, industry, and clinics; evaluate the efficacy of solutions; and design innovative imaging solutions for healthcare.

- **Sessions 1 & 2: Ultrasound imaging, physical basics**
 - Ultrasound basic wave physics: coherent propagation (as opposed to optical imaging),
 - Ultrasound systems: transducers, electronics, imaging systems & therapeutic systems, clinical applications: how and what for?
 - Ultrafast imaging. Focused strategy, plane wave strategy, applications: basic elastography and ultrafast doppler.
 - Contrast imaging in ultrasound: agents.
- **Session 3: Magnetic Resonance Imaging, basics and applications**
 - Physical basics of the NMR signal and MRI reconstruction

- Basics MRI weightings (T1, T2, diffusion)
- Examples of biomedical and medical applications
- **Session 4: Optical microscopy and imaging**
 - Optical spectroscopy: atomic, electronic, vibrational spectroscopy
 - Microscopy: widefield, bright field, confocal
 - Optical imaging probes
- **Session 5: PET and SPECT imaging**
 - Radioactivity for nuclear medicine imaging
 - Radiotracers and radiopharmacy
 - PET imaging
 - SPECT imaging
 - Targeted and therapeutical radiotracers, example of biomedical applications
- **Session 6: Xrays and CT imaging**
 - Basics of the X-rays and CT imaging
 - X-ray contrast agents
 - Diagnosis by X-ray imaging
- **Practicals: Bioimaging facility visits**
 - Visit and hands on demo of US and MRI imaging facility

Learning objectives

- **Know** the main modalities of bioimaging used for diagnosis and evaluation of a therapy.
- **Understand** the spectroscopic or physical signals generating an image.
- **Apply** the theoretical basics for the rational use of any modalities of imaging for biomedical applications.
- **Analyse/Evaluate:** Identify the key modality of biomaging to solve a biomedical problem and be able to evaluate a diagnosis by rational quantitative analysis. Design methodologies combining modalities of imaging for biomedical research and applications

ST4H_S2_07	Psychology (basics)
Psycho	

Coordinator(s)	Alice Einloft Brunnet (CLIPSYD - Paris Nanterre University)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	21 h	0 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 90%					
Prerequisites	-					

Course description

This course introduces the foundational concepts of clinical psychology to students with limited background in the field. It covers the major theoretical approaches, psychological assessment and research in clinical psychology. It also explores the profession and practice of clinical psychologists in France and internationally.

The goal of this course is to provide a brief historical analysis of clinical psychology and an overview of the main therapeutic approaches, including psychoanalytic, psychodynamic, humanistic, cognitive, behavior and acceptance-based psychotherapies. The professional practice of clinical psychologists will also be described: what clinical psychologists do, where they work and how they are trained, both in France and internationally.

The second part of this course focuses on clinical assessment. This section introduces the “measurement problem” in clinical psychology, followed by the main psychological instruments and the professional practice of psychological assessment.

Finally, the course covers the fundamentals of research in clinical psychology. This section highlights essential methodological procedures in this field, the principles of evidence-based practice, and the “common factors” in psychotherapy (empathy, cultural adaptation, therapeutic alliance, among others).

Learning objectives

- **Know:** Identify the different approaches in clinical psychology; Who are clinical psychologists and what they do.
- **Understand :** The main differences between therapeutic approaches; “The measurement problem” in clinical psychology; The common factors in psychotherapy.
- **Apply :** Apply fundamental knowledge in clinical psychology to interpret research studies.
- **Evaluate :** The quality of studies in the field of clinical psychology

ST4H_S2_08	Materials Engineering for Biomedical Applications
Mater	

Coordinator(s)	Paul Moore (ESPCI Paris PSL), Laurent Corté (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 70% / Weekly assignment 20%					
Prerequisites	Basics in chemistry (1 st year undergrad); Basics in solid mechanics (Mech)					

Course description

This course provides an introduction to materials science and engineering, with a focus on biomedical applications. The course will overview a range of material properties, such as strength, conductivity and longevity, and how they may be relevant to the problems in biomedical engineering. The structure of the course will introduce different material properties, and how they relate to different materials at a structural level, as well as what the choice of material will mean in a practical context..

Lectures will be accompanied by a mini-case study, examining how a material was selected for a specific project, highlighting the multitude of design considerations.

- **Lecture 1: Structure, Bonding and Properties**
 - Introduction to material science and its impact in health technologies.
 - Structure-Properties-Processing-Performance framework.
 - Atomic bonding, as well as molecular structures, such as a crystalline, amorphous and hierarchical structures.
 - Introduction to material classes at a structural level
- **Lecture 2: Mechanical properties of Materials**
 - Review of stress, strain and deformation
 - Elastic and plastic behaviour of materials.
 - Toughness, brittleness, and strength.
- **Lecture 3: Failure and Degradation in Biomedical Environments**
 - Brittle and ductile fracture fractures
 - Creep and time dependent failure,
 - Corrosion and material degradation in biomedical environments
- **Lecture 4: Thermal, Electrical, Magnetic and Optical Properties**
 - Thermal properties, including expansion and conductivity.
 - Electrical conductivity, resistivity and charge.
 - Magnetic properties and their relationship to electrical properties.
 - Optical properties and transparency
- **Lecture 5: Polymers, Soft Matter and Fluids**
 - Diffusive and convective transport within a material.
 - Viscoelasticity, glass transition and elastomeric behaviour.
 - Polymer structure and polymer classes.
 - Soft matter categories, such as colloids, hydrogels and emulsions.

- **Lecture 6: Biomaterials and Material Selection**

- Common biomedical restraints.
- Examples of materials suitable for implants, versus wearable materials, sensors etc.
- Manufacturability considerations in design.

Learning objectives

- **Know** the main classes of materials and their key property definitions.
- **Understand** how microstructure determine why certain materials behave in certain ways.
- **Apply** the structure-properties-processing-performance framework for basic material property relationships and select and compare materials in biomedical contexts.
- **Analyze** the behaviour and failure modes of materials for biomedical functions.
- **Synthesize** mechanical, thermal, electrical, optical, and degradation properties into a coherent material-selection argument for a biomedical device.
- **Evaluate** material suitability for biomedical applications based on mechanical, thermal, electrical, optical, transport properties, and trade-offs between competing properties.

ST4H_S2_09	Physics of Biological Systems
PhysBiol	

Coordinator(s)	Terence Strick (ENS PSL), Jean-François Allemand (ENS PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	21 h	0 h	0 h	0 h	0 h
Assessment	Class participation 10% / Oral presentation 90%					
Prerequisites	-					

Course description

The goal of this course is to give some elements of physics required to understand a wide range of biological processes and quantify them. Lectures are organized along the following topics:

- **Sessions 1&2: Thermodynamics/statistical physics**
 - From 1st law of thermodynamics to Boltzmann's law what should be known.
 - Orders of magnitude,
 - Diffusion/Fick's law/polymers
- **Session 3: Enzymology**
 - Linear models, allostery & protein folding
- **Sessions 4&5: Instruments & optics for microscopy**
 - Geometric optics, diffraction, superresolution
- **Session 6: Force spectroscopy**
 - Probing structures and conformations, breaking bonds
- **Session 7: Macromolecular machines**
 - Molecular motors, molecular components of cellular motility

Reading suggestions:

Basic: Thermodynamics by Fermi, A random walk in biology by Berg

Advanced: Statistical Mechanics by van Kampen, Mechanics of Motor Proteins and the Cytoskeleton by J. Howard

Learning objectives

- **Know** key physical concepts, laws and experimental principles required to describe biological systems.
- **Understand** how thermodynamics, statistical physics, diffusion, enzymology, optics, and mechanics contribute to the quantitative interpretation of biological processes.
- **Apply** physical laws, scaling arguments, and simple mathematical models to analyze biological phenomena.
- **Analyse** biological systems by identifying relevant length scales, time scales, energies, forces, and dominant physical mechanisms.

ST4H_S2_10	Sleep
Sleep	

Coordinator(s)	Karim Benchenane (ESPCI Paris PSL), Thierry Gallopin (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	0 h	6 h	0 h	0 h
Assessment	Class participation 10% / Written exam 60% / Report 30%					
Prerequisites	Basic neuroscience (Neuro1), Stress & Physiology (StrsPhysio)					

Course description

This course covers the neuroscience and physiology of sleep from foundational principles to clinical and analytical applications.

A first block introduces sleep physiology: sleep architecture, circadian regulation, the two-process model, and the role of sleep in memory consolidation, emotional regulation, and psychiatric health.

A second block examines the neural networks governing sleep and wakefulness, including monoaminergic systems (noradrenergic, serotonergic, histaminergic), the orexin/hypocretin system, and the flip-flop switch model.

A third block addresses the evolution of brain oscillations across vigilance states, from cortical rhythms (delta waves, sleep spindles, K-complexes) to subcortical oscillations (hippocampal sharp-wave ripples, olfactory bulb gamma oscillations) and their functional significance.

The course then covers the relationships between sleep disruption and psychiatric conditions including anxiety, depression and PTSD. Sleep scoring methods are introduced, from standard criteria (AASM for humans, adapted criteria for rodents) to automated and algorithmic approaches.

A dedicated practical session provides hands-on experience scoring sleep from real EEG/LFP/EMG datasets in both humans and mice, using signal analysis tools to apply and compare manual and automated scoring methods. These topics provide students with the conceptual and technical foundations needed to critically evaluate and design digital sleep monitoring tools.

Learning objectives

- **Know:** Describe sleep architecture and the two-process model of sleep regulation. Identify the main neural systems involved in sleep-wake control (monoaminergic systems, orexin/hypocretin, flip-flop switch). Name the major brain oscillations associated with each vigilance state, at both cortical and subcortical levels (spindles, sharp-wave ripples, theta, gamma). Identify the standard criteria for sleep scoring in humans and rodents.
- **Understand:** Explain how sleep-wake transitions are regulated by competing neural systems and how disruption of these systems contributes to psychiatric conditions including anxiety, depression and PTSD. Describe the functional role of specific oscillations in memory consolidation and emotional processing. Explain the principles of automated sleep scoring and its advantages and limitations relative to manual scoring.
- **Apply:** Score sleep stages from human and rodent EEG/LFP/EMG data using both manual criteria and algorithmic approaches. Identify the appropriate sleep monitoring method and outcome variables for a given DMH research question.

- **Analyse:** Compare the validity of PSG, actigraphy, and consumer wearables across sleep metrics. Identify sources of error in automated sleep scoring pipelines and assess their impact on data quality in a digital health deployment.
- **Evaluate:** Critically appraise the neuroscientific and methodological credibility of a digital sleep tool, assessing whether its claimed mechanisms, outcome measures, and scoring methods are scientifically justified.

ST4H_S2_11	Signal Processing
SigProc	

Coordinator(s)	<i>(To be announced)</i>					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	11 h	0 h	10 h	0 h	0 h
Assessment	<i>(To be announced)</i>					
Prerequisites	Foundation in mathematics (differential calculus) (Math1)					

Course description
<i>(To be announced)</i>
Learning objectives
• Know: • Understand: • Apply: • Analyse: • Evaluate:.

Master 2
Semesters 3 & 4
Common Core courses

ST4H_S3_TC_EC01	Basics in Cell and Tissue Biology
BasBiol	

Coordinator(s)	Dominique Bluteau (EPHE PSL); Diego Garcia-Weber (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
-	English	13.5 h	0 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam at the end of the week (80%)					
Prerequisites	Basic high school knowledge on biology and chemistry					

Course description

This refresher course in biology for master's-level engineering students focuses on the fundamental principles of cell structure and function, as well as tissue organization. Students will study the core components of eukaryotic cells, including the plasma membrane, organelles, the cytoskeleton, and the nucleus, among others.

The course covers cellular processes such as cell division, protein synthesis, and cell signaling pathways. It also explores the classification and structure of tissues, highlighting the relationships between different cell types in tissues.

The course is designed to reinforce foundational knowledge in cell biology, essential for further studies in various scientific and engineering fields. This module will be structured as lectures completed by a few revision exercises. The course titles are as follows:

- **Lecture 1: General Introduction to Cellular Biology:**
 - Eukaryotic and prokaryotic cell structure
 - Molecules of life (nucleic acids, proteins, polysaccharides, lipids)
 - Membranes
 - Enzymes and their properties
 - Bioenergetics and metabolism
- **Lecture 2: Genetics and Expression of Eukaryotic Genes:**
 - Repair, Replication, Recombination
 - Transcription
 - Translation
 - Gene expression control (transcription factors, epigenetics, protein degradation...)
- **Lecture 3: Eukaryotic Cell Compartmentalization and Traffic:**
 - Nucleus and nucleolus
 - Rough and smooth endoplasmic reticulum
 - Golgi apparatus
 - Lysosomes and peroxisomes
 - Active/passive transport (channels)
 - Vesicular traffic (endocytosis/exocytosis)
 - Mitochondria
 - Cellular origin and evolution
- **Lecture 4: Eukaryotic Cell Activity:**
 - Cell cycle and proliferation
 - Mitosis/meiosis

- Stem cells and differentiation
- Senescence and cell death (apoptosis/necrosis)
- **Lecture 5: The Eukaryotic Cell and Its Environment:**
 - Cytoskeleton
 - Intercellular junctions
 - Extracellular matrix
 - Cell motility and migration
- **Lecture 6: Cell Biology of the nervous system**
 - Neurons & other cell types
 - Synapses
 - Action potential
 - Central and Peripheral nervous system
- **Lecture 7: Cell Communication and Signaling:**
 - Ligands/receptors
 - Membrane receptors (GPCR, Tyrosine kinase)
 - Ion channel-coupled receptors
 - Cytoplasmic and nuclear receptors
 - Interactions with microbes and innate immunity
- **Lecture 8: Tissue Description and Organization (Histology) Part I:**
 - Epithelia (covering, endocrine/exocrine glands)
 - Connective tissue (loose and dense)
 - Adipose tissue
 - Cartilage tissue
 - Bone tissue
 - Muscle (striated, skeletal, cardiac, smooth)
- **Lecture 9: Tissue Description and Organization (Histology) Part II:**
 - Vascular and lymphatic endothelium
 - Blood (plasma, erythrocytes, leukocytes, platelets)
 - Lymphoid tissue

Learning objectives

- **Know:** Recall the fundamental structures, processes, and classifications of cell and tissue biology (e.g., organelles, stages of cell division, tissue types).
- **Understand:** Explain and summarize how cellular components and biological processes contribute to cell and tissue function (e.g., protein synthesis, cell signaling, tissue organization).
- **Apply:** Use basic cell biology concepts to interpret and solve simple biological problems (e.g., identifying organelles in microscopy images, predicting cellular responses to signals, relating tissue structure to function).
- **Analyse:** Examine the relationships between cellular structures, processes, and tissues to identify patterns and functional connections (e.g., organelle-function relationships, interactions between cell types, differences among tissue types).
- **Synthesise:** Integrate knowledge from different aspects of cell and tissue biology to construct coherent explanations or models (e.g., integrated descriptions of cell function, models of tissue organization).
- **Evaluate:** Assess and justify biological explanations using evidence and fundamental principles (e.g., evaluating the importance of organelles, judging the consequences of disrupted cell division, defending links between tissue architecture and function).

ST4H_S3_TC_EC02	Basics in Programming
BasProg	

Coordinator(s)	Daniel Stockholm (EPHE PSL); Thijs Stuyver (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
-	English	7 h	0 h	8 h	0 h	0 h
Assessment	Class participation 20% / Assessment at the end of the week (80%)					
Prerequisites	-					

Course description

This refresher course is aimed at students who have no or very little experience in programming. It takes place at the very beginning of the Academic year on a full week and introduces essentials in programming (Python) for engineering and data science applications.

It ensures that all students start the M2 year of the ST4Health programme

- Knowing basic notions in Python programming
- Having a set-up ready to be used for Python coding
- Prepared to use generative AI for Python programming

Learning objectives

- **Know** the basic concepts, syntax, data structures, and tools required to start programming in Python.
- **Understand** how Python code is structured and how programming supports engineering and data science applications.
- **Apply** Python programming basics to write, execute, debug, and document simple scripts or notebooks.

ST4H_S3_TC_EC03	ST4Health Seminars
Sem	

Coordinator(s)	Eloïse Berson (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
-	English	0 h	0 h	0 h	15 h	0 h
Assessment	Class participation 100%					
Prerequisites	-					

Course description

The ST4Health seminar series is a weekly forum designed to expose students to the diversity of contemporary health science and technology. Each Friday, invited speakers from academia, clinical practice, industry, engineering, entrepreneurship, and health institutions share their research, professional trajectories, and perspectives on the role of science and technology in addressing major healthcare challenges.

Through these seminars, students gain insight into emerging biomedical innovations, translational research, clinical needs, health systems, and career pathways at the interface between science, engineering, medicine, and society. The series also encourages students to critically reflect on how interdisciplinary approaches can contribute to improving prevention, diagnosis, treatment, and patient care.

Learning objectives

- **Know** the diversity of scientific, clinical, technological, entrepreneurial, and institutional actors involved in health innovation.
- **Understand** how science and technology contribute to addressing healthcare challenges and improving patient care.
- **Apply** insights from invited speakers to connect academic learning with real-world clinical, industrial, and societal contexts.
- **Analyse** the opportunities, constraints, and stakeholder perspectives involved in translating research and technology into healthcare applications.
- **Synthesise** multidisciplinary viewpoints to build an integrated understanding of the health innovation ecosystem.
- **Evaluate** the relevance, impact, and limitations of scientific and technological approaches for improving health and shaping future professional pathways.

ST4H_S3_TC_EC04	Language - English for Science and Academic Communication
Lang	

Coordinator(s)	Daria Moreau (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
1	English	0 h	24 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 20% / Oral presentation 20% / Continuous assessment (tests & assignments) 40%					
Prerequisites	B2+ level in English					

Course description

English for Science and Academic Communication is an advanced academic English course designed for Master HealthTech students preparing for communicating effectively in international scientific and technical environments. The course develops the language and communication skills needed to engage with scientific literature, express complex ideas clearly, participate in academic discussions, with a strong emphasis on conference-style communication.

Students work with authentic scientific materials such as research articles, laboratory reports, lectures, and scientific presentations and also with their own research projects. Through practical workshops, they develop skills in academic writing, oral presentations, including structuring arguments, describing data, and presenting research findings.

Particular attention is given to clarity, precision, and rhetorical effectiveness in scientific English. The course culminates in a mini conference where students present, defend, and discuss their research in English. This simulation of a real academic conference includes presentations, Q&A sessions, and panel-style discussions, allowing students to apply all communication skills in an integrated, professional setting.

Learning objectives

- **Know**
 - Recall and memorise key scientific vocabulary and terminology
 - Identify common academic phrases used in scientific writing and presentations
 - Recognise standard structures of scientific texts (e.g., abstract, introduction, methodology)
- **Understand**
 - Paraphrase scientific information using appropriate academic language
 - Summarise key points from scientific texts and lectures
 - Translate scientific ideas accurately into clear English
 - Demonstrate understanding of data, diagrams, and experimental descriptions
- **Apply**
 - Use scientific vocabulary and structures in written and spoken tasks
 - Apply language knowledge to write lab reports and short research summaries
 - Transfer theoretical knowledge to practical academic tasks (e.g., explaining experiments or procedures)
- **Analyse**
 - Identify key elements in scientific texts (hypothesis, methods, results, conclusions)
 - Examine logical relationships between ideas in research articles
 - Distinguish between main arguments and supporting evidence
 - Analyse data descriptions and interpret their meaning in context

- **Synthesize**
 - Combine information from multiple scientific sources to produce coherent summaries
 - Create structured academic texts such as mini research reports or presentations
 - Integrate language, data, and concepts to produce original scientific explanations
- **Evaluate**
 - Assess the clarity and reliability of scientific texts and arguments
 - Make justified decisions based on scientific information
 - Defend a point of view in academic discussions using evidence and reasoning
 - Critically evaluate research findings and methodological approaches

ST4H_S3_TC_EC04	Language - French as a Foreign Language (FLE)
Lang	

Coordinator(s)	Daria Moreau (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
1	English	0 h	24 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 20% / Oral presentation 20% / Continuous assessment (tests & assignments) 40%					
Prerequisites	-					

Course description

French as a Foreign Language (FLE) is designed for international students enrolled at Mines Paris – PSL and other PSL institutions who wish to develop their French language proficiency and intercultural competence. The course supports students in their academic, professional, and social integration into the French higher education environment.

Aligned with the levels of the Common European Framework of Reference for Languages (CEFR), the course develops the four core language skills—listening, speaking, reading, and writing—through authentic materials and interactive activities. Particular emphasis is placed on communication in academic and scientific contexts, enabling students to participate effectively in university life, understand lectures, interact with peers and faculty, and navigate professional situations in France. PSL's language offerings are specifically adapted to scientific and engineering profiles and are coordinated through the PSL Language Center hosted by Mines Paris – PSL.

Through a combination of language practice, cultural exploration, and task-based learning, students strengthen their ability to communicate confidently in French while developing a deeper understanding of French academic culture and society.

This course contributes to the development of the linguistic, academic, and intercultural skills necessary for successful study and professional engagement within the international environment of PSL and the broader French-speaking world.

Learning objectives

- **Know**
 - Recall & use essential vocabulary and grammatical structures appropriate to their CEFR level.
 - Recognize common expressions used in academic, professional, and everyday situations.
 - Identify key features of French academic and cultural practices.
- **Understand**
 - Demonstrate comprehension of spoken and written French in academic and social contexts.
 - Paraphrase and summarize texts, lectures, and discussions.
 - Explain information, opinions, and cultural concepts using appropriate language.
 - Interpret the meaning and purpose of different types of written and oral communication.
- **Apply**
 - Use French effectively in academic, professional, and everyday interactions.
 - Produce coherent written texts such as emails, reports, summaries, and reflections.
 - Apply grammatical and lexical knowledge in authentic communication tasks.
 - Participate actively in classroom discussions, presentations, and collaborative activities.

- **Analyze**
 - Identify the structure and main ideas of written and spoken documents.
 - Distinguish between facts, opinions, arguments, and supporting evidence.
 - Analyze linguistic and cultural differences between French and other languages.
 - Recognize relationships between language use, context, and audience.
- **Synthesize**
 - Combine information from multiple sources to produce coherent oral and written outputs.
 - Develop and present original viewpoints on academic, cultural, and societal topics.
 - Create structured presentations, reports, and projects in French.
 - Integrate linguistic & intercultural knowledge to communicate effectively in diverse situations.
- **Evaluate**
 - Assess the effectiveness and appropriateness of oral and written communication.
 - Critically evaluate arguments, sources, and cultural perspectives.
 - Defend a point of view using clear reasoning and supporting evidence.
 - Reflect on personal language development and identify strategies for continued improvement.

ST4H_S3_TC_01	ST4Health Research & Innovation Challenge
HealthChal	

Coordinator(s)	Laurent Corté (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	0 h	0 h	6 h	3 h	21 h
Assessment	Class participation 30% / Oral presentation 50% / Report 20%					
Prerequisites	-					

Course description

The ST4Health Research & Innovation Challenge is an intensive interdisciplinary project-based teaching unit organized at the beginning of Semester 3 of the ST4Health Master's programme. Designed as a call-driven interdisciplinary project sprint, the week places students in teams of 4–5 and invites them to respond to a simulated call for projects addressing a major contemporary health challenge.

Each team must identify a relevant project idea, justify its scientific and/or translational positioning, define a coherent methodological approach, and discuss the anticipated results, feasibility, limitations, and potential impact of the proposed work. The activity combines plenary sessions, ice-breaking scientific exercises, mentored group work, invited conferences, confidential feedback sessions with faculty, and final oral pitches in front of peers and the teaching team.

Students may develop either a fundamental research project, aimed at generating new scientific knowledge, or an innovative translational project, aimed at proposing a pathway toward practical implementation in health. Through this format, the course trains students to transform a broad societal or biomedical issue into a structured, interdisciplinary, and defensible research proposal, while developing collaboration, critical thinking, scientific communication, and project-design skills.

Learning objectives

- **Know** the key components of a research or innovation project proposal in health engineering.
- **Understand** how to transform a broad health challenge into a focused, positioned, and feasible project idea.
- **Apply** scientific reasoning and collaborative working methods to formulate a response to a simulated project call.
- **Analyse** the relevance, originality, feasibility, risks, and expected impact of alternative project strategies.
- **Synthesise** interdisciplinary knowledge into a coherent research or translational project proposal.
- **Evaluate** and defend the scientific quality, positioning, and potential impact of a project in front of peers and faculty

ST4H_S3_TC_02	Research Methodology
ResMeth	

Coordinator(s)	Charlie Demené (ESPCI Paris PSL); Marie Verbanck (Curie PSL); Matthieu Labousse (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	19 h	8 h	2 h	1 h	0 h
Assessment	Class participation 10% / Written exam first half of semester (statistics) 30% / Written exam 2 nd half of semester (soft skills and scientific writing) 60 %					
Prerequisites	Undergraduate level in analysis, algebra and probability; Basics in Python (Prog1, BasProg); Computer equipped with reference management tools (Zotero)					

Course description

This course provides a comprehensive foundation in research methodology, covering key statistical concepts such as random variables, probability laws, hypothesis testing, regression analysis, and principal component analysis. Students will learn how to process and curate data, reducing complexity while maintaining meaningful insights, and apply effective data visualization techniques to enhance clarity and readability.

A strong emphasis is placed on scientific communication, guiding students through the structure of research papers, from crafting well-constructed paragraphs to understanding different types of scientific publications. We will focus on how critically evaluating scientific literature. Students will learn to navigate the publication process, assess the quality of research articles, and analyze methodologies, results, and conclusions to ensure scientific rigor. The course also delves into effective scientific presentations, teaching strategies for engaging audiences, structuring narratives, and using graphics to reinforce key messages.

Finally, students will explore best practices for managing references and citations using bibliographic tools, ensuring their research is both rigorous and well-documented. Through case studies and practical applications, this course equips students with essential skills to analyze data, communicate findings, and contribute to the scientific community effectively.

Part 1: Statistics

- **Introduction to statistics**
 - Random variables and probability, transformation laws of random variables, mathematical expectations and standard deviation, median and quantiles, Cumulative distribution function and p-value, Independence vs. correlations, mathematical expectation estimator, unbiased variance estimator, mean square estimator, biased variance estimator
- **Classical laws in probability and statistics**
 - Binomial distribution, Poisson distribution, geometric and exponential distribution, normal distribution (Gaussian), central limit theorem, χ^2 distribution, Student distribution.
- **Confidence intervals, statistical tests**
 - Relative error calculation, Error propagation, confidence interval for the mathematical expectation estimator (large and small sample). Error risk analysis, statistics of false positives and false negatives. Sample comparison: test for identical mathematical

expectation (large and small samples), Statistical testing of outliers, Test χ^2 of shape distributions and independence of two criteria.

- **Dimensionality reduction**

- Principal component Analysis, Singular Value Decomposition.

Part 2: Bibliographical research and critical analysis of scientific articles

This class provides graduate students with the necessary skills to conduct bibliographical research and critically analyze scientific articles. The course combines theoretical foundations with practical exercises to enhance students' ability to evaluate and synthesize scientific literature.

By the end of the theoretical part of the course, students will be able to:

- Understand the principles of bibliographical research;
- Identify and access relevant scientific literature;
- List the different types of scientific articles and their specific characteristics;
- Outline the main stages in the publication of scientific articles and identify the different actors involved in scientific publishing and their interactions;
- Evaluate the relevance and quality of scientific information;
- Evaluate the relevance and good practices of AI tools for bibliographic search;
- Synthesize information from multiple sources to form coherent arguments;
- Practice critical thinking.

By the end of the practical part (article reading) of the course, students will be able to:

- Detail the structure of a research article;
- Read a scientific article;
- Identify the methodology used, the results and their interpretation;
- Identify the limits of research work;
- Critic the article's conclusions by checking the protocol: is it well described, reproducible, and coherent?

Part 3: Data visualization: from the bench to the paper

- **From raw data to curated data**

- intervals in which data are of interest (space, time, physical quantities)
- What to get rid of, under which conditions?
- what are the interesting dimensions
- reduce dimensionality to 2D (in most cases). link with statistical methods.

- **From curated data to the figure** (always keep in mind that scientific data ends up in a figure)

- **Minimize the ink method**

- Pitfalls to avoid: too much data – noise – lack of harmony – readability
- Colors (use it or not use it), colorbars (linearity, perception)
- Case study (the good and the bad)

Part 4: Scientific writing: assert, then prove

- **Scientific paper:**

- Types of scientific papers
- Sections – construction – message – how to build a paragraph
- Case study (the bad and the good)

- **Scientific presentation:**

- Critical steps: know the audience – develop your story – appeal with graphics

- The assertion evidence method
- Case study

- **Bibliography**

- Tools for bibliography

Learning objectives

- **Know:** *Remember* the fundamental concepts of probability and inferential statistics, including probability distributions, random variables, estimators, confidence intervals, and hypothesis testing. *Define* the assertion evidence method and *enumerate* its benefits; *list* the principal search engines for bibliographic research, *acquire* the basics of probability and statistics theory..
- **Understand:** *Understand* the assumptions, scope, and limitations of the main statistical models and methods used for quantitative data analysis. *Establish* a relevant statistical test to compare samples. *Estimate* and *identify* the importance of fluctuations in experimental data.
- **Apply:** *Analyze* datasets by identifying the statistical properties of the data, assessing the validity of model assumptions, selecting appropriate tests, and interpreting multivariate representations such as principal component analysis. *Choose* which data to include and which data to keep supplemental or discard in a scientific communication, *choose and adapt* the graphic representation to the type of data you handle, *construct* a scientific abstract by following a predefined method under a word number constraint, *re-organise* an existing graph or figure to 'minimize ink' and improve visual impact. *Treat* experimental data and compute confidence intervals. *Structure sentences* with known information at the beginning and new information at the end. *Structure article* using paragraphs and their first sentence with an assert/justify method.
- **Analyze:** *Evaluate* the reliability and significance of statistical conclusions by considering sampling variability, type I and type II errors, effect sizes, confidence intervals, and the suitability of alternative statistical approaches. *Detect* 'tortured sentences' and use of generative AI in scientific communications, with or without tools; *Detect* outliers and *analyse* the difference between experimental samples.
- **Evaluate:** *Decide* the risk of a statistical hypothesis. *Evaluate* problems in scientific writing structure and *rephrase* them according to a systematic methodology.
- **Create:** *Create* a rigorous statistical analysis workflow for a research problem by selecting appropriate methods, justifying methodological choices, and communicating statistically sound conclusions. *Discuss and debate* the relevance of experimental control variables.

ST4H_S3_TC_03	Medical Sciences for Biomedical Engineering
MedSci	

Coordinator(s)	Anne Vincent-Salomon (Curie PSL); Paul Cottu (Curie PSL); Aurélie Foucher (Curie PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	30 h	0 h	0 h	0 h	0 h
Assessment	Class participation 10% / Written exam 45% / Oral presentation 45%					
Prerequisites	-					

Course description

This course provides a comprehensive overview of fundamental medical sciences for Master's-level engineering students. Delivered exclusively through lectures, it introduces the key concepts of human anatomy, physiology, pathology, and clinical practice. The module explores the organization of healthcare systems and the medical vocabulary commonly used in clinical environments. Emphasis is placed on understanding the scientific principles underlying disease diagnosis, treatment, and patient care.

Students gain insight into current medical challenges and technological innovations in healthcare. The course aims to develop interdisciplinary literacy and foster effective communication between engineers and healthcare professionals. By establishing a common scientific language, it prepares future engineers to collaborate successfully with physicians and clinical teams throughout their professional careers.

The course is structured around five key thematic areas: Clinical and Health Systems Sciences, Applied Biomedical Sciences, Technical and Diagnostic Medical Sciences, Public Health Sciences, and Emerging Sciences and Innovation.



The course is supported by the Institute of Women's Cancers at Curie Institute. Several examples and case studies will be chosen for their relevance in the treatment of women's cancer.

- **Area 1: Clinical and Health Systems Sciences**
 - Hematology
 - Sensory System – ENT (Ear, Nose and Throat)
 - Sensory System – Ophthalmology
 - Endocrine System
 - Respiratory System
 - Cardiovascular System
 - Nervous System
 - Digestive System
 - Female Genitourinary System
 - Musculoskeletal System
 - Male Genitourinary System
 - Principles of Cancer Management
- **Area 2: Applied Biomedical Sciences**
 - Anatomy
 - Anatomopathology

- **Area 3: Technical and Diagnostic Medical Sciences**
 - Medical Imagery
- **Area4: Public Health Sciences**
 - Epidemiology and socio-economy
- **Area5: Emerging Sciences and Innovation**
 - Psychology and Supportive Care
 - Medical data & AI

Learning objectives

- **Know:**
List the major organ systems of the human body and identify their primary components.
Identify the fundamental steps of a clinical diagnostic process.
- **Understand:**
Explain in engineering terms how a major physiological mechanism works (e.g. cardiac cycle, respiratory gas exchange, neural signal transmission).
Summarize the pathophysiological process underlying cancer
Describe the role and limitations of common diagnostic tools (imaging, biological markers, functional tests).
Paraphrase the clinical needs expressed by a healthcare professional into engineering requirements.
- **Apply:**
Apply knowledge of a physiological system to contextualise the function of a specific medical device (e.g. pacemaker, ventilator, glucose monitor).
Map patient care pathways onto a process flow diagram relevant to a medical technology project.
- **Analyse:**
Break down the interaction between a medical device and the human body in terms of biological response and engineering constraints.
Analyse a clinical use case to identify the medical, ethical, and technical variables at play.
- **Synthesise:**
Design a preliminary set of functional specifications for a medical device by integrating physiological constraints, clinical needs, and user environment.
Construct a structured briefing document that bridges the clinical problem definition and the engineering response.
Propose an innovative technological solution to a current medical challenge, justifying choices based on physiological and pathological knowledge.
- **Evaluate:**
Critically assess the relevance and limitations of a diagnostic or therapeutic technology in a given clinical context.
Defend a design choice in front of a mixed medical-engineering audience, using appropriate scientific justification.
Evaluate the potential clinical impact and risks of a proposed engineering solution, considering patient safety and medical standards.
Judge the quality and pertinence of information exchanged in an interdisciplinary medical-engineering collaboration

ST4H_S3_TC_04	Society & Innovation for Health
SocInno	

Coordinator(s)	Bich-Thuy Doan (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	9 h	0 h	0 h	6 h
Assessment	Class participation 20% / Oral presentation 70%/ Report 10%					
Prerequisites	-					

Course description

The program aims at providing a critical understanding of the societal impact of biomedical and medical innovation. Through a survey of the history and the evolution of biomedical innovation, from surgery, biomaterials, regenerative medicine, psychiatry to data sciences through AI, the courses will analyze the key actors involved in the social acceptance of biomedical innovation (scientists, medical staff, sociologists, patients) in their respective role and function). It will address the importance of the patient/medical practitioner relationship as well as key concepts of medical ethics associated with biomedical research. Through case studies, the students will have the opportunity to analyze the major controversies surrounding biomedical research.



Course created with the support of the Institute for Women's Cancer.

- **Session1: Ethics of Innovation in Health, in medicine and sciences**
 - Presentation and history of ethics institutions, CCNE, CCNEN, CPP.
 - How these committees are working
 - Examples of proposed opinions: 1) ethical opinion on the circulation of health data 2) use of AI for medical diagnosis
- **Session 2: History of Mental Health**
 - Progress in diagnostics and treatment of mental health, underlining the consequence and benefit for Society.
- **Session 3: History of Health data and AI**
 - Latest numerical technologies in health data processing using and developing AI tools, showing the impact in our society and rising our critical use of AI.
- **Session 4: Health and Democracy**
 - How health decisions, policies, and innovations should involve citizens, patients, healthcare professionals, and society through transparent and participatory processes.
 - Equity, access to healthcare, respect for individual rights, informed consent, and collective responsibility in shaping health systems
- **Session 5: History of Innovation in Biomaterials**
 - Research and discovery of novel biomaterials and their applications, consequences of their innovation for Health and Society.

- **Session 6: Ethical thoughts on medicine and medical research**
 - Presentation of the groundwork and principle of ethics in modern medicine for practice and patients.
 - Main ethical questions in medicine ? In what context do we emerge ? Genetic data, patients data, choice in clinical trials ...
 - Human dimension : at the end, and at the beginning, there is a person...
- **Session 7 & 8: Project controversial debate 1 & 2**
 - Analysis and presentation of controversial subjects during debates to solve a biomedical problematics chosen in 3 master tracks domains such as mental health, digital health and biomaterials & engineering for Health. Proposition of the latest technological developments to answer a biomedical problematics, and presentation of the arguments pro and co in regards of the ethics, societal consequences, scientific innovation, patients and medical
 - The oral debates will oppose students groups with questions from them and from the jury composed of teachers, patients association, who will evaluate the teams.

Learning objectives

- **Know:** Be familiar the evolution of biomedical innovations in AI, Biomaterials and engineering, Mental Health, medical practices; learn the evolution of scientific and biomedical ethics.
- **Understand :** Understand the fundamental ethical principles underlying a biomedical innovation.
- **Apply :** Leverage knowledge to propose arguments based on scientific literature, lessons and in the format of debates.
- **Analyse :** Analyse the challenges associated with medical innovations
- **Evaluate :** Promote and defend an innovative scientific and technological project from bibliographic research and with pro and cons arguments during debates.

ST4H_S4_TC_01	Health System & Development of Health Products
HealthOrg	

Coordinator(s)	Line Farah (French Ministry of Health)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	0 h	3 h	3 h	9 h
Assessment	Class participation 20% / Oral presentation 40% / Report 40%					
Prerequisites	-					

Course description

This course gives students a foundational understanding of how health systems are organized, regulated and financed, and of the pathways through which health products — medicines, medical devices and digital or AI-based medical devices — reach patients and are reimbursed.

It combines lectures, institutional and clinical site visits, and a case-study based group project. The course opens with a comparative overview of health system governance in France, Europe and the United States, introducing the respective roles of key institutions such as the Ministry of Health, the National Authority for Health (HAS), the Economic Committee for Health Products (CEPS), the National Agency for the Safety of Medicines and Health Products (ANSM), the French Digital Health Agency (ANS) and the National Health Insurance Fund (CNAM).

Building on this institutional landscape and on field visits to a regulatory/HTA institution and to a healthcare facility, the course examines how health technology assessment, market access, pricing and reimbursement mechanisms operate in practice, with particular attention to the specific evaluation and integration challenges raised by innovative and AI-based medical devices as they move from development to routine use in care pathways.

Students then apply these concepts in small groups to a real-world case study of an innovative health product, analysing its development, regulatory and market access strategy under instructor supervision.

- **Session 1 : Understanding the Health System – Governance, Regulation and Market Access**
 - Healthcare system organization and reimbursement of health products
 - Role of key public institutions (Ministry of Health, HAS, CEPS, ANSM, ANS, CNAM)
 - Market access and health technology assessment, including for medical devices and AI-based medical devices, from product development and evaluation to integration into care pathways
 - Case study briefing and group allocation
 - Afternoon: autonomous group work
- **Session 2: Artificial Intelligence: how can we evaluate AI-based MDs? What healthcare stakeholders need to know?**
 - Definition of how an AI-based health innovation is evaluated, regulated and integrated into care pathways
 - Presentation the specific criteria dedicated to the assessment of AI-based MDs
 - Comparison of international market access strategies of AI-based MDs
 - Afternoon: autonomous group work

- **Session 3 : Digital innovation in Mental Health**
 - Guest lecture (a CEO + MD researcher) illustrating how a digital or AI-based health innovation is developed, designed, evaluated, regulated and integrated into care pathways, taking mental health as a case in point
 - Afternoon: autonomous group work
- **Session 4 : Visit to a health institution (HTA agency or Ministry of Health) or a healthcare facility**
 - Half-day visit to :
a national institution involved in the regulation, evaluation or market access of health products (e.g. Haute Autorité de Santé, Ministry of Health) — scheduled in September or January depending on the academic calendar
=> Meeting with professionals in charge of health technology assessment, pricing or digital health policy
 - Or Half-day visit to :
a hospital or healthcare facility, living lab, Observation of how health products, including AI-based medical devices, are deployed and used within care pathways
=> Discussion with clinical and administrative teams on the practical, organizational and economic conditions of adoption
 - Afternoon: autonomous group work
- **Session 5 (Friday): Final presentations and case studies defense**
 - Written report and oral presentation of the case study market access strategy before a jury

Learning objectives

- **Know:** Identify the key institutions, actors and regulatory bodies that govern the organization, financing, evaluation and market access of health products within the French, European and US health systems.
- **Understand:** Explain the mechanisms of health technology assessment, market access, pricing and reimbursement for health products, including medical devices and AI-based medical devices, and how innovative products are integrated into care pathways.
- **Apply:** Apply market access, regulatory and economic evaluation frameworks to a real-world case study of an innovative health product.
- **Analyse:** Critically analyse the regulatory, economic and organizational challenges raised by the integration of an innovative or AI-based health product into the health system.
- **Synthesise:** Synthesise multidisciplinary considerations — regulatory, economic, clinical and organizational — into a coherent market access strategy presented in a written report.
- **Evaluate:** Defend and justify the proposed market access strategy orally before a jury, discussing its strengths, limitations and alternatives.

ST4H_S4_TC_02	Entrepreneurship in Health & MedTech
HealthEntr	

Coordinator(s)	Anita Kumari (PSL Valo)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	10 h	0 h	0 h	8 h	10 h
Assessment	Class participation 20% / Oral presentation 40% / Project report/business case 40%					
Prerequisites	Basic knowledge of a scientific, engineering, medical, or health-related discipline. No prior entrepreneurial experience is required.-					

Course description

Innovations in health tech and med tech are often driven by innovative start-ups emerging from (academic) research. Those start-ups are also called deeptech start-ups. This course aims to introduce the students of the ST4Health Master to technological entrepreneurship (or deeptech entrepreneurship) with a focus on entrepreneurship in the field of health.

In the beginning of the week, the students, organized in groups, are assigned with case studies. They will work on the case studies along the week and deliver at the end of the week a report and a short presentation in front of a jury of innovation and entrepreneurship experts.

- **Lecture 1: Introduction to Entrepreneurship & DeepTech Innovation**
 - Entrepreneurship and innovation fundamentals
 - Characteristics of DeepTech ventures
 - HealthTech and MedTech ecosystem overview
 - Key challenges and opportunities in healthcare innovation
- **Workshop 1: Team Formation & Project Framing**
 - Identification of healthcare needs
 - Team building and collaboration
 - Project selection and framing
- **Lecture 2: Value Proposition & Market Opportunity**
 - Understanding users and stakeholders
 - Value proposition design
 - Market analysis and segmentation
 - Competitive landscape overview
- **Workshop 2: Business Model Development**
 - Business Model Canvas
 - Customer segments and revenue models
 - Market sizing and validation
- **Lecture 3: Intellectual Property, Technology Transfer & Regulation**
 - Basics of patents and IP
 - Freedom-to-operate considerations
 - Technology transfer process
 - Regulatory pathways in healthcare

- **Workshop 3: IP & Regulatory Strategy**
 - Building an IP strategy
 - Regulatory planning for HealthTech ventures
- **Lecture 4: Financing Innovation**
 - Public funding and grants
 - Venture capital and private investment
 - Non-dilutive funding options
 - Financing roadmap development
- **Workshop 4: Funding Strategy**
 - Funding roadmap design
 - Milestone-based financing planning
- **Seminar: Entrepreneurial Testimonials**
 - Talks from founders, investors, and experts
 - Lessons from HealthTech venture creation
 - Storytelling in DeepTech
- **Seminar: Career Speed Mentoring Workshop**
 - Small-group mentoring with professionals from startups, industry, VC, hospitals, and tech transfer
 - Rotating discussions with mentors across tables
 - Career pathways and networking in HealthTech & MedTech
- **Final Project : Venture Pitch**
 - Team pitch preparation and storytelling
 - Final presentations to expert panel
 - Feedback and evaluation

Learning objectives

- **Know:** Key concepts of entrepreneurship, innovation, and the HealthTech/MedTech ecosystem.
- **Understand:** How healthcare innovations are developed, validated, and brought to market.
- **Apply:** Tools such as business model canvas, market analysis, IP strategy, and funding planning.
- **Analyse:** Market needs, stakeholders, regulatory constraints, and technology opportunities.
- **Synthesise:** Develop a coherent HealthTech venture concept integrating clinical, market, and business aspects.
- **Evaluate:** Critically assess the viability and impact of healthcare startup ideas and strategies.

Master 2
Semesters 3 & 4
AIH Track courses

ST4H_S3_AIH_01	Machine Learning & Artificial Intelligence
MLAI	

Coordinator(s)	Eloïse Berson (MINES Paris PSL) ; Daniel Stockholm (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Written exam 75% / Notebook 25%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Linear algebra & calculus: properties of vectors and matrices (Math1, Math2); Basics in statistics					

Course description

This course provides an introduction to Machine Learning, covering both theoretical foundations and practical applications. The course starts with the problem formulation and the principle of empirical risk minimization, followed by an in-depth exploration of classical Machine Learning algorithms, including linear regression, logistic regression, Support Vector Machines (SVM), Linear Discriminant Analysis (LDA), k-nearest neighbors (k-NN), and tree-based methods such as AdaBoost and Random Forests. Regularization techniques like LASSO and Ridge regression, along with feature selection methods, will also be covered. A particular focus lies on model selection and validation.

The course will further introduce unsupervised learning techniques, including hierarchical clustering, k-means, and DBSCAN, as well as latent variable models and dimensionality reduction techniques such as Principal Component Analysis, Independent Component Analysis, and t-SNE. In the final part, we will introduce Computer Vision and Deep Learning, exploring Convolutional Neural Networks (CNNs) and modern deep learning approaches for image analysis.

Through a combination of theoretical lectures and hands-on programming sessions, students will gain a solid understanding of the foundations of Machine Learning and their real-world applications.

Part 1: Basic Concepts and Traditional Linear Models

- **Fundamental Concepts in Machine Learning** – typology, notation, basic definitions
- **Empirical Risk Minimization**
- **Loss Function and Hypothesis Space**
- **Linear Models**
 - Linear Regression
 - Logistic Regression
 - Linear Discriminant Analysis
- **Regularization and Model Selection**
 - Overfitting and Generalization
 - Bias-Variance Tradeoff
 - Training, Validation, and Test Sets
- **Performance Metrics** – Accuracy, Sensitivity, Specificity, F1-score, ROC, etc.
- **Model Selection** – Cross-validation, Nested Cross-validation, etc.
- **L2 Regularization, L1 Regularization**
 - Ridge
 - Lasso
 - Elastic Net

Part 2: Machine Learning Algorithms (Supervised and Unsupervised)

- **Supervised Methods**
 - Decision Trees
 - Random Forests
 - Boosting
 - Regularization through Ensembling
 - Support Vector Machines (SVM)
 - Kernel Methods (Application to Kernel Ridge Regression)
- **Unsupervised Learning Methods**
 - Dimensionality Reduction: Motivation, Methods, and Limitations
 - Filtering and Wrapper Methods
 - Principal Component Analysis (PCA)
 - t-SNE
- **Clustering**
 - Motivation and Limitations
 - Quality Criteria for Clustering
 - Hierarchical Clustering
 - Concept of Distance Metrics between Observations
 - K-means
 - DBSCAN
- **Final Discussion** – A Practical Guide to Choosing Methods

Part 3: Deep Learning and Computer Vision

- **Introduction** – context, Big Data, Learning Algorithms, representing images
- **Computational Model** – formal neuron, activation function, towards non-linear classification,
- **Supervised learning** – gradient descent, loss functions, backpropagation, model capacity, underfitting/overfitting, data augmentation
- **Convolutional neural networks** – various types of layers
- **Complete CNN architecture**
- **Autoencoders – a special class of networks** – the rationale, different types, and applications
- **Data** – Principal Datasets, Data preparation
- **Principal Backbone Networks** – recognition, classification, detection, image Segmentation,
- **Transfer Learning** – principles and advantages
- **Validation** – understanding model's decision, occlusion sensitivity, activation maps, adversarial attacks and adversarial examples

Learning objectives

- **Know:** Gain an overview of various methods in supervised and unsupervised learning
- **Understand :** Develop a deep understanding of the Machine Learning core concepts and traditional methods in this field; Understand the basics of Deep Learning and Computer Vision;
- **Apply :** Implement, train, validate, and compare machine learning models using standard Python libraries on real-world datasets.
- **Analyse :** Determine the assumptions and limitations of these methods.
- **Synthesise :** Design complete machine learning workflows by selecting appropriate preprocessing, feature engineering, model selection, validation, and interpretation strategies for a given application.
- **Evaluate :** Critically assess model performance, robustness, generalization ability, and suitability for specific biomedical or computer vision problems.

ST4H_S3_AIH_02	Bioinformatics & Multi-Omics Data Analysis
BioinfOmics	

Coordinator(s)	Daniel Stockholm (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Class participation 20% / Written exam 40% / Report 40%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Linear algebra & calculus: properties of vectors and matrices (Math1, Math2);					

Course description

This course offers an overview of bioinformatics and multi-omics data analysis, focusing on genomics, epigenetics and proteomics. Students will learn to clean, analyze, and combine large biological datasets to uncover valuable insights. By blending theory, hands-on coding (including a short introduction to R), and case studies, this course equips students with the skills to conduct multi-omics projects and apply their findings in biomedical research.

Each session includes a short lecture, a hands-on coding exercise, and group discussion

- **Session 1: Introduction to Multi-Omics and R**
 - **Lecture:** Overview of RNA-Seq, Ribo-Seq, Exome, and Proteomics; basic concepts in bioinformatics and the R language. Good Practices
 - **Hands-On Exercise:** Navigating public omics databases and performing a basic data exploration in R
- **Session 2: Sequence Alignments & Similarity Searches**
 - **Lecture:** Sequence Alignments & Similarity Searches. Alignment algorithms (global vs. local) and scoring matrices. BLAST and multiple alignment tools. E-values, identity scores, and biological context (homology, orthologs, paralogs). Briefly discuss clustering/heatmaps for sequence similarity scores (e.g., distance matrices)
 - **Hands-On Exercise:** Run BLAST (command-line or online), Perform multiple alignment, Interpret alignment output and discuss common pitfalls, cleaning and filtering workflows for omics datasets
 - **Goal:** Understand how alignment works, why it matters, and how to interpret alignment results effectively.
- **Session 3: Genomic Variants - Patient Case study**
 - **Lecture**
 - **Hands-On Exercise:**
- **Session 4: Transcriptomics, RNA-Seq and Bias**
 - **Lecture:** Basics of RNA transcription. RNA-Seq data processing steps (trimming, alignment/pseudoalignment). Expression quantification (counts, RPKM, TPM). Differential expression analysis (DESeq2, edgeR). PCA (or MDS) for sample-level QC and clustering. Volcano plots, heatmaps, tSNE for differential expression results. Overview of common sources of bias (biological, technical, computational), their impact on results, and strategies for critical evaluation and mitigation throughout the analysis workflow. Bias and Critical Aspects in Bioinformatics Pipelines.

- **Hands-On Exercise:** RNA-Seq Pipeline in R/Bioconductor. Process FASTQ (using Salmon/Kallisto) to get count data. Differential expression with DESeq2 (normalization, MA plots). Brief pathway/GO analysis for biological context. Identifying and Mitigating Biases in Pipeline Steps (parameter effects, batch effects, reproducibility checks)
- **Goal:** Build a working RNA-Seq analysis pipeline, apply dimensional reduction for QC, and interpret expression result
- **Session 5: Epigenetics & Specialized NGS Approaches**
 - **Lecture:** Basics of epigenetics (DNA methylation, histone modifications). Methylation analysis methods (WGBS, RRBS, ChIP-Seq). Accessibility assays (ATAC-Seq, Hi-C). Ribo-Seq (capturing translating ribosomes). Visualizing epigenetic marks in genome browsers. Possible clustering or UMAP of methylation profiles across samples
 - **Hands-On Exercise:** Epigenetics / Ribo-Seq Data Analysis. Outline a methylation workflow (e.g., Bismark). Basic Ribo-Seq steps (trimming, mapping, footprint detection). Exploratory analysis in R/Bioconductor (e.g., differential methylation)
- **Session 6: Cytometry by Time-Of-Flight (CyTOF)**
 - **Lecture:** This lecture will present the core principles of CyTOF (Cytometry by Time-of-Flight), a high-dimensional single-cell analysis technique that uses metal-tagged antibodies and mass spectrometry. The lecture will also cover the fundamentals of CyTOF data analysis, including preprocessing, normalization, dimensionality reduction, and clustering methods commonly used to interpret single-cell profiles.
 - **Hands-On Exercise:** from data processing to cell type annotation using CyTOF data.

Learning objectives

- **Know:** Gain an overview of the main omics data (genomics, transcriptomics, epigenomics, proteomics, single-cell technologies), their associated data types and analysis workflows.
- **Understand :** Learn how multi-omics data (like RNA-Seq, Exome, etc.) is produced and prepared.
- **Apply :** Do basic analyses, such as finding differentially expressed genes, detecting variants, and running enrichment tests.
- **Analyse :** Combine different omics data types to better understand biological systems and support biomedical research.
- **Synthesise :** Build reproducible bioinformatics workflows to analysis multiple omics datasets and answer biological questions.
- **Evaluate :** Critically assess the quality, reproducibility, limitations, and biological interpretation of multi-omics data and their analyses.

ST4H_S3_AIH_03	Biomedical Image Analysis
BiomedImg	

Coordinator(s)	Thomas Walter (MINES Paris PSL); Daniel Stockholm (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Class participation 20% / Written exam 40% / Report 40%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Linear algebra & calculus: properties of vectors and matrices (Math1, Math2);					

Course description

This course explores state-of-the-art Computer Vision techniques for biomedical image analysis, with applications in microscopy, digital pathology, and radiology. We will cover cutting-edge methods, including advanced segmentation techniques, self-supervised learning, transformers, foundation models, Multiple Instance Learning, cellular phenotyping and radiomics. Through a combination of theoretical lectures and hands-on exercises, students will gain practical expertise in applying these approaches to real-world biomedical imaging challenges.

The course is divided into three sections:

- **Cellular and Subcellular Image Analysis:** Students will be introduced to the field of bioimage informatics, covering various microscopy techniques and the specific challenges associated with their analysis. A broad range of applications will be presented, such as cell and nucleus segmentation and cellular phenotyping.
- **Computational Pathology:** This section will address the challenges of making predictions from Whole Slide Images, focusing on Multiple Instance Learning and self-supervised learning. Additionally, we will explore the analysis of Spatial Transcriptomics and its unique computational challenges.
- **Radiomics and Medical Imaging:** This section will focus on extracting quantitative features from medical images (CT, MRI, PET) to characterize tissue heterogeneity and disease phenotypes. We will cover feature engineering, deep learning-based radiomics, and integration with clinical and molecular data.
- **Lecture 1: Cellular and Subcellular Image Analysis**
 - Introduction to the course (syllabus, grading, contact information, content)
 - Introduction to Bioimage Informatics
 - Cell Segmentation and cellular phenotyping
- **Practicals 1: Cell segmentation and cellular phenotyping**
- **Lecture 2: Computational Pathology**
 - Introduction to Computational Pathology
 - Cutting-edge Technologies for Computational Pathology: Self-supervised learning, Multiple Instance Learning, Foundation Models
 - Applications
- **Practicals 2: Computer Vision for Digital Pathology**

- **Lecture 3: Radiomics**
 - Introduction to radiomics
 - Feature engineering & Deep learning based radiomics
 - Integration with clinical and molecular data
- **Practicals 3: Radiomics**

Learning objectives

- **Understand:** Understand the major biomedical image modalities; Understand the major challenges and opportunities in biomedical image analysis today
- **Apply:** Develop and apply computational pipelines for biomedical image analysis

ST4H_S3_AIH_04	Statistics for Genomics
StatGenom	

Coordinator(s)	Florian Massip (MINES Paris PSL); Chloé Azencott (MINES Paris PSL); Marie Verbanck (Curie PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Class participation 20% / Written exam 40% / Oral presentation 40%					
Prerequisites	Basics in statistics (ResMeth); Linear algebra & calculus: vectors, matrices, linear equations, SVD (Math1, Math2); Basics in genetics (Biol1, Biol2)					

Course description

Over the last fifteen years, genomics have been transformed by high-throughput sequencing technologies, which generate large amounts of complex data that are difficult to interpret. In particular, genomic datasets often comprise a relatively small number of samples described by a large number of features, a statistically challenging setting requiring specific approaches, collectively known as high-dimensional statistics. In this setting, variable selection, clustering and model validation are known to be particularly difficult. This course will present different approaches that have been developed to overcome these difficulties. To this end, we will develop in detail a few classical and successful examples to illustrate both the power and limitations of statistics and machine learning for genomic analyses. The course will combine lectures and hands-on sessions in Python or R.

- **Session 1: High-dimensional statistics**
 - Curse of dimensionality, multiple hypothesis testing, and correction (control of the family-wise error rate or of the false discovery rate)
 - *Hands-on session on simulated data.*
- **Session 2: GWAS and Mendelian randomization**
 - Standard approaches for genome-wide association studies (quality control, association tests, interpretation, population stratification).
 - General principles of causal inference and Mendelian Randomization (MR) and presentation of the general framework (selection of instrumental variables, main approaches, sensitivity analyses)
- **Session 3: Hands-on GWAS and Mendelian randomization**
 - *Hands-on session in Python (+ the command-line software PLINK) covering the material of Session 2.*
- **Session 4: Transcriptomics**
 - General principle of transcriptomic analysis, mathematical models for differential expression analysis, construction of gene signature to classify patients.
 - *Hands-on session in R using the mostly used R packages (DESeq2, edgeR, limma).*
- **Session 5: Dimensionality reduction and clustering**
 - Overview of dimension reduction techniques and its interest in genomic, zoom on a specific example: non negative matrix factorization and its application to the analysis of mutations in cancer
 - Classical applications of clustering in genomics data and frequently used clustering algorithms (hierarchical clustering, Louvain/Leiden, model-based clustering)

- **Session 6: Dimensionality reduction and clustering**
 - *Hands-on session in Python covering the material of Session 5.*

Learning objectives

- **Know:** Challenges of high-dimensionality for statistics (e.g. multiple hypotheses, curse of dimensionality)
- **Understand:** Understand how the specificities of genomics data can impact the application of classical statistical and machine learning techniques
- **Apply:** Run statistical analyses that are standard in genomics (e.g. GWAS, differential expression analysis, matrix factorization, hierarchical or Louvain clustering)
- **Analyse:** Identify, for a given application case, what will be the limitations of generic statistical and machine learning techniques, and which of the techniques presented in the course (if any) can apply.
- **Evaluate:** Determine whether a methodological paper describing a statistical method for genomics data could be relevant for a specific application case.

ST4H_S3_AIH_05	Cheminformatics & Drug Design
Cheminf	

Coordinator(s)	Thijs Stuyver (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Written exam 50% / Report 50%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Linear algebra & calculus: properties of vectors and matrices (Math1, Math2);					

Course description

This course provides an introduction to cheminformatics and the application of machine learning (ML)/artificial intelligence approaches to predictive chemistry tasks, and real-world problems encountered during the process of drug design and development.

In first instance, the drug design pipeline will be introduced, and potential application areas of machine learning will be highlighted. Subsequently, the simplified molecular-input line-entry system (SMILES) will be introduced, and we will discuss how the standardized SMILES format facilitates the definition, storage and analysis of small molecule datasets. Additionally, user-friendly Python toolkits to query and manipulate SMILES, as well as methods to turn them into input representations for ML models, will be presented.

Subsequently, the application of a selection of supervised (linear regression, random forests and graph neural networks), as well as unsupervised (clustering, principal component analysis) ML algorithms to chemical problems will be discussed, with a particular focus on applications related to medicinal property prediction and chemical synthesis.

Finally, a concise overview of Bayesian optimization techniques for experiment design, and generative models for chemical discovery will be provided.

At the end of the course, each student will be tasked with performing a small programming project in which the acquired knowledge will be applied to develop an ML workflow for a predictive chemistry task related to drug design.

- **Lecture 1: Introduction to Drug Design & Cheminformatics**
 - Introduction to the course (syllabus, grading, contact information, content)
 - Introduction to the drug design pipeline
 - Introduction to cheminformatics & common cheminformatics toolkits (RDKit, Pandas, Scikit-Learn)
 - Supervised & Unsupervised learning for chemistry applications: principal component analysis, clustering, linear regression, k-nearest neighbors, random forests
- **Practicals 1: Introduction to Drug Design & Cheminformatics**
 - Hands-on training in SMILES manipulation and querying + analysis
 - Applications of unsupervised learning algorithms with scikit-learn
 - Applications of supervised learning algorithms with scikit-learn
- **Lecture 2: Graph Neural Networks & Generative Modelling**
 - Introduction to molecular graph neural networks & transformers

- Introduction to generative modelling for drug design: recurrent neural networks and variational autoencoders
- **Practicals 2: Graph Neural Networks & Generative Modelling**
 - Applications of graph neural networks
 - Applications of variational autoencoders
- **Lecture 3: Bayesian Optimization**
 - Introduction to Bayesian optimization
- **Practicals 3: Bayesian Optimization**
 - Applications of Bayesian optimization

Learning objectives

- **Know:** Identify opportunities to apply machine learning to problems in drug design.
- **Understand:** Explain and compare applications of machine learning to drug design from the recent scientific literature; Explain and apply Bayesian Optimization frameworks for experiment design within a chemistry context.
- **Apply:** Construct, manipulate, query and process SMILES strings in an automated manner with the help of RDKit; Implement machine learning models to analyze and process data relevant to drug design using Python, in combination with common machine learning frameworks such as Scikit-Learn and Pytorch.
- **Analyse/Evaluate:** Critically analyse/evaluate the choice for a specific machine learning algorithm and input representation based on a task description.

ST4H_S3_AIH_06	Machine Learning for Biological Networks
MLBioNetw	

Coordinator(s)	Hervé Isambert (Curie PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	Class participation 20% / Report 40% / Oral presentation 40%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Linear algebra & calculus: properties of vectors and matrices (Math1, Math2); Basics in statistics (ResMeth); Basics in genetics (Biol1, Biol2)					

Course description

The concept of biological networks is central to biology and biomedical data analysis, and stems from the multiple and combinatorial interactions at all scales of the living world, from genes to cells to patients. After recalling the different types of biological networks, we will review their main topological, dynamic and functional properties.

We will then present the main machine learning and causal inference methods for reconstructing biological networks from biological and biomedical data. These are primarily unsupervised machine learning methods, score-based Bayesian inference and constraint-based causal discovery methods.

Finally, we will present hybrid methods combining causal discovery and information theory to analyze heterogeneous bio-related data, including categorical data (e.g. experimental conditions, treatments), continuous data (e.g. single-cell transcriptomic data), and / or high-dimensional data (e.g. images, sequences, etc.).

Learning objectives

- **Know:** Identify opportunities to apply network inference methods to analyze biological and biomedical data.
- **Understand:** Understand the main network learning methods and explain their specificities, limitations and domain of application. Understand the signature of causality in observational data and in datasets with experimental perturbation. Understand the causal implication of unobserved (latent) variables and the difference between putative and genuine causes in reconstructed networks.
- **Apply:** Perform network reconstruction on different biomolecular datasets (eg single cell transcriptomic data) or biomedical datasets (eg medical records of patients) including the preprocessing of the raw data (eg clustering and annotation of main cell types in scRNAseq data), feature selection using differentially expressed genes or information-based approaches.
- **Analyse/Evaluate:** Critically analyse / evaluate / interpret the reconstructed network models. Review the choice of specific preprocessing steps (input data representation) and the choice of network learning method.

ST4H_S3_AIH_07	Electronic Health Records & Medical Informatics
MedInfo	

Coordinator(s)	Eloïse Berson (MINES Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	0 h	3 h	0 h	0 h
Assessment	Oral presentation 75% / Notebook 25%					
Prerequisites	Basics in Python coding (Prog1, Prog2); Basics in machine learning (MLAI);					

Course description

This course provides an introduction to Electronic Health Records (EHR) data and their use in machine learning for healthcare applications. Students will learn about clinical data types, standards, and data workflows connecting healthcare systems to research environments. Through hands-on sessions with realistic datasets, the course covers data preprocessing, cohort construction, and feature engineering, including raw count representations and embeddings. Students will develop and evaluate machine learning pipelines for disease risk prediction and patient stratification. The course also addresses practical challenges and ethical considerations, such as bias, fairness, interpretability, and patient data privacy.

- **Session 1: Introduction to EHR data and preprocessing**
 - Introduction to the course.
 - What is EHR data? Types & formats (structured, unstructured, time series)
 - Standards and Ontologies (OMOP, ICD, LOINC, FHIR)
 - ML for EHR mining: new opportunities for advancing medical care (risk prediction, treatment recommendation, disease phenotyping)
 - Hands-on using Synthea (<https://synthetichealth.github.io/synthea/>): data science
- **Session 2: Data workflow**
 - Overview of an information system between healthcare and research
 - Health data : what are we talking about?
 - How to “take care” of data?
 - Key role of a health data warehouse
- **Session 3: Machine learning pipeline for disease risk prediction**
 - Task definition
 - Raw counts representation and problems.
 - Baseline model interpretation, evaluation and risk stratification
 - Hands-on session Mimic IV: building a cohort, create raw count matrix, defining a task, training/testing model
- **Session 4: Embedding**
 - Concept of static/dense embeddings.
 - Hands-on using Mimic IV: generate word2vec from EHR data, dimension reduction and embedding evaluation.
- **Session 5: Example of real-world data: The health data hub**

- **Session 6: Temporal models**
 - Temporal models: RNN, transformer
 - Language Models
- **Session 7: Challenges, ethics, and patient privacy**
 - Puzzle class with list of 3 themes and 2/4 articles per themes

Learning objectives

- **Know:** Understand the structure, standards, governance principles, and major AI applications for Electronic Health Records data.
- **Understand:** Understand the structure, standards, and specific characteristics of Electronic Health Records (EHR) data, as well as their major challenges and opportunities in healthcare systems and research.
- **Apply:** Apply appropriate data preprocessing, management, and governance practices for health data, including the use of health data warehouses; Design meaningful representations of clinical data (raw count features, matrices, and embeddings) tailored to machine learning tasks.
- **Analyse:** Identify key methodological challenges, biases, and ethical issues related to the use of machine learning in healthcare, including fairness, interpretability, and patient privacy.
- **Synthesise/Evaluate:** Build, interpret, and evaluate end-to-end machine learning pipelines for healthcare applications, such as disease risk prediction and patient stratification using longitudinal patient data.

ST4H_S4_AIH_01	AIH Research Project (Master thesis)
AIHResProj	

Coordinator(s)	Eloïse Berson (MINES Paris PSL); Daniel Stockholm (EPHE PSL); Thijs Stuyver (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
24	English	0 h	0 h	0 h	0 h	5-6 months
Assessment	Oral presentation 30% / Answers to questions 30% / Report 30% / Supervisor Assessment 10%					
Prerequisites	-					

Course description

Semester 4 is mostly devoted to the Master thesis, in the form of a 5-6 month research internship. During this internship, each student joins individually a research team and works full time on a specific research question in the scope of his/her M2 track.

Students find their internship during Semester 3. For each track, a list of projects submitted to the master program is proposed to the students, who can then apply through a standard interview process. Students can also contact laboratories and propose a project outside of the list. All of these projects are validated by the chairs of the student's track to ensure that they address a research question within the scope of the track and in an appropriate working environment.

AIH research projects span the full spectrum of artificial intelligence in health, including machine learning for medical imaging, computational biology, bioinformatics, multi-modal and multi-omics data integration, digital pathology, clinical decision support, biomedical foundation models, and AI-driven approaches for drug discovery, biomolecular engineering, and precision medicine. Projects typically combine methodological advances in artificial intelligence with applications addressing clinically or biologically relevant research questions.

At the end of their internship, students submit a written manuscript and defend their thesis in front of a jury of experts selected by the track chairs. The duration of the internship is chosen jointly by the student and the host team. Both durations (5 or 6 months) are equally valued. Defenses take place in late June/early July for 5-month internships and in early September for 6-month ones.

Learning objectives

- **Know:** the scientific background, state of the art, and methodological foundations relevant to the internship topic in AI, data science and digital health.
- **Understand:** the research question, objectives, methodological rationale, and biomedical relevance of the internship project.
- **Apply:** appropriate methods to conduct an autonomous research project under supervision, using rigorous and reproducible methodology.
- **Analyse:** results critically considering the project objectives, methodological limitations, and the existing literature.
- **Synthesise:** integrate results into a coherent scientific discussion and produce a structured Master's thesis.
- **Evaluate:** assess the significance and limitations of the work, propose future perspectives, and defend the project during the oral examination.

Master 2
Semesters 3 & 4
BEH Track courses

ST4H_S3_BEH_01	Materials & Surface Sciences for Medicine
MatSurfMed	

Coordinator(s)	Laurent Corté (MINES Paris PSL); Anouk Galtayries (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	16.5 h	0 h	9 h	1.5 h	0 h
Assessment	Class participation 20% / Written exam 80%					
Prerequisites	Basics in materials science (Mater); Basics in cell biology (Biol1, Biol2); Basics in physics and thermodynamics (PhysBiol)					

Course description

This lecture is an advanced introduction to the key-concepts that need to be controlled for the design of materials and devices for in vivo biomedical applications. It aims to provide a fundamental understanding of the phenomena into play at the interface between materials and a living system. These phenomena include protein adsorption, blood-material interactions, inflammatory response and the foreign body response as well as implant-related infections. For each of these phenomena, particular attention will be paid to the key role played by biointerfaces – the interfaces between materials and biological systems. The current associated scientific and medical challenges will be developed and illustrated by case studies showing strategies to make improved functional biomaterials.

- **Session 1: Introductory class**
 - Scope of the class & important definitions
 - Materials for medicine – main materials classes & their properties
- **Session 2: Surface science & Biomaterials**
 - Introduction to surface science – fundamental concepts
 - Protein adsorption – mechanisms and implications for biomaterials design
- **Session 3: Surface characterization**
 - Surface characterization techniques - principles
 - Surface characterization techniques – lab. visit
- **Session 4: Blood-materials interactions**
 - Blood-materials interactions – main phenomena and clinical implications
 - *Case study : design of innovative cardiovascular stents*
- **Session 5: Foreign body response & Immunomodulatory Surfaces**
 - Foreign body response – main phenomena and clinical implications
 - Design of protein adsorption and applications to immunomodulation
- **Session 6: Implant-related infection & Biodegradability**
 - Implant-related infection – main phenomena and clinical implications
 - Biodegradability of biomaterials – mechanisms, applications & design

Learning objectives

- **Know** the main classes of biomaterials used for in vivo applications and the key biological phenomena occurring at material–living system interfaces.
- **Understand** how surface properties and biointerfaces govern protein adsorption, blood compatibility, inflammation, foreign body response, infection, and biodegradation.
- **Apply** surface science and biomaterials concepts to interpret biological responses and guide material or surface design choices.
- **Analyse** the relationships between material properties, surface characteristics, host responses, and clinical performance.
- **Synthesise** knowledge from materials science, surface characterization, biology, and clinical constraints to propose improved functional biomaterials.
- **Evaluate** the relevance, limitations, feasibility, and translational potential of biomaterial design strategies for in vivo biomedical devices.

ST4H_S3_BEH_02	Engineering of Biofunctional Interfaces
EngBioInterf	

Coordinator(s)	Emmanuelle Marie (ENS PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	6 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 80%					
Prerequisites	Basics in chemistry and physical chemistry related to materials science (MolMeth); Materials & Surface sciences for medicine (MatSurfMed)					

Course description

This lecture is an advanced course dedicated to engineers, physicists, physicians, biologists and chemists. During this series of six 3-hour sessions, we will take a brief look at how the body or cells (mammalian cells, bacteria) interact when in contact with a material. We will then focus on the techniques used to chemically modify surfaces, in particular with polymers, and the associated characterization methods. Examples of applications will be detailed (2D and 3D substrates for cell adhesion/migration, implants, colloidal systems). Courses may include tutorials on analysis of scientific papers.

- **Session 1: Introduction to some fundamentals**
 - General introduction: Objectives and expectations
 - Characterization of the interaction of biomolecules with surfaces
 - Fundamentals of cell adhesion
- **Session 2: Introduction to surface modification strategies**
 - Characterization of the interaction of biomolecules with surfaces
 - Surface modification by polymers: polymer adsorption, layer-by-layer approach, grafting of polymers, “grafting from” strategies
- **Session 3: Cell adhesion on substrates**
 - Fundamentals of cell migration, forces exerted by cells on surfaces
 - Control of cell adhesion on polymer functionalized surfaces
- **Session 4 : Surface engineering for biomaterials I**
 - Anti-fouling surfaces
 - Models of controlled 3D substrates for the study of cell adhesion and migration
- **Session 5: Surface engineering for biomaterials II**
 - Modification of colloidal surfaces
 - Antibacterial coatings
- **Session 6: Applications**
 - Surface engineering and medical devices
 - *Tutorials: Analysis of scientific papers, typical exam questions*

Learning objectives

- **Know:** Chemical principles of surface modification and characterization of materials in interaction with living organisms
- **Understand** the mechanisms and parameters influencing cell substrate interactions
- **Apply** surface modification techniques to several applications : 2D 3D culture substrates, implants, colloidal systems
- **Analyse:** Extract scientific data from a scientific article.
- **Synthesise:** Summarize a scientific article addressing surface design for biomedical applications.
- **Evaluate:** Draw conclusions from scientific data related to surface biofunctionalization

ST4H_S3_BEH_03	Tissue Engineering & Cell-laden Devices
TissEng	

Coordinator(s)	Carole Aimé (ENS PSL); Marie-Noëlle Labour (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	1 h	0 h	2 h	0 h
Assessment	Class participation 20% / Oral presentation 40% / Report 40%					
Prerequisites	Basics in materials science (Mater); Basics in cell biology (Biol1, Biol2); Materials & Surface sciences for medicine (MatSurfMed)					

Course description

This course focuses on the application of engineering and materials science principles to the creation of innovative solutions for healthcare challenges. It aims to provide students with an in-depth understanding of advanced materials used in medical devices, microfluidics techniques applied to biology and medicine, and personalized medicine approaches based on biomaterials engineering and advanced technologies.

- **Session 1: General introduction**
 - Properties and class of biomedical materials
 - Materials biocompatibility and biofunctionality
 - Materials applications in medical devices
 - *1h case study/ collective projects*
- **Session 2: Extra-Cellular Matrix**
 - ECM biology (histology, function, pathology)
 - Characterization of ECM (structural, chemical, mechanical, biological)
 - Vascularization & Angiogenesis (basic concepts to be used in organ-on-chip and regenerative medicine sessions)
- **Session 3: Design and fabrication of synthetic ECM (scaffolds)**
 - Materials for scaffolding
 - Fabrication processes (decellularization, foams/textiles, bioimpression,...)
 - Characterization of functionality (gateway to the OptImg course)
- **Session 4: Directing cell behavior**
 - Cellularization (different cell types, cell lines, iPS, MSC)
 - Cell seeding and encapsulation (colonization/perfusion, bioprinting, co-culture)
 - Post-seeding treatment for cell-loaded materials stimulation
 - Cell adhesion, migration, activity and differentiation (chemical, mechanical, physical)
- **Session 5: Organ-on-chip / Cancer-on-chip**
 - Basic concepts of organoids and biomicrofluidics
 - Organ-on-chip models : design, engineering and inputs
 - Cancer-on-chip and medical perspectives
 - Angiogenesis models: The challenge of vascularizing organs-on-chip...
 - *Invited seminar focusing on organ-on-chip research*
- **Session 6: Application to regenerative medicine**
 - In vivo models and their limits

- Introduction to personalized medicine
- Monitoring and activity evaluation (biomarkers), degradation
- Scaffold vascularization
- *Invited seminar focusing on vascularization research*

- **Session 7: Exam**

- written (1p on focus) and oral evaluation of the elaboration of a research project carried out in groups of 3 to 4 students for the development of cell-laden biomaterials

Learning objectives

- **Know** the key concepts and requirements involved in the fabrication and characterisation of tissue engineering approaches and cell-laden devices.
- **Understand:** Gain an in-depth understanding of the interactions between cells, biomaterials, and the extracellular environment.
- **Apply:** Define tissue engineering methodologies to the design of engineered tissues and in vitro models; Work in a multidisciplinary group to tackle a complex research challenge involving tissue engineering and cell-laden devices.
- **Analyse** the performance and limitations of biomaterials, scaffolds, and organ-on-chip systems.
- **Synthesise** multidisciplinary knowledge to develop innovative cell-based biomaterial solutions.
- **Analyse** the scientific, technical, and translational relevance of tissue engineering approaches and cell-laden devices to address a medical challenge

ST4H_S3_BEH_04	Nanomedicine: Design & Applications
NanoMed	

Coordinator(s)	Kawthar Bouchemal (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	18 h	0 h	0 h	0 h	0 h
Assessment	Class participation 20% / Written exam 40%/ Oral presentation 40%					
Prerequisites	Basics in materials science (Mater); Basics in cell biology (Biol1, Biol2); Basics in physical chemistry related to materials science (MolMeth);					

Course description

The Nanomedicine – Design and Applications course provides a comprehensive overview of the rapidly evolving field of nanomedicine, which is transforming modern medical and healthcare solutions. Through a blended learning format combining online preparatory material and interactive in-class sessions, students explore key concepts in the design and characterization of nanomedicines, including nanoemulsions, polymeric and lipid-based nanomaterials, and metal–organic frameworks. Guided by leading researchers, the course also highlights major applications of nanotechnology in drug delivery and therapeutic strategies. Students engage with recent scientific literature, analyzing and presenting research articles to develop critical thinking and scientific discussion skills. The assessment emphasizes oral presentations and active participation rather than a traditional written examination, encouraging deeper engagement with current research and emerging challenges in nanomedicine.

- **Session 1**
 - Nanoprecipitation Techniques for Designing Nanoemulsions and Polymeric Nanomaterials
 - Basic principles of Metal Organic Frameworks (MOF)
- **Sessions 2 & 3**
 - Introduction to nanomedicines
 - Nanomedicines for Navigating Biological Barriers
- **Session 4**
 - Introduction to Metal-organic frameworks (MOFs) and other porous nanocarriers: from basic concepts to cancer treatment
- **Session 5**
 - Targeting strategies in nanomedicines / Focus on surface functionalization
 - Nanomedicines for Infectious Diseases
- **Session 6 & 7**
 - Case studies and written exam

Learning objectives

- **Understand:** Possess a foundational understanding of the role of nanotechnology and nanomaterials in medicine and healthcare.
- **Apply:** Command primary techniques for designing and characterizing nanomedicines.

- **Analyse:** Grasp the inherent limitations of employing nanotechnology and nanomaterials in medical and healthcare contexts.
- **Evaluate:** Comprehend the scientific and regulatory barriers involved in the implementation of nanomedicines

ST4H_S3_BEH_05	Nanomaterials for Diagnostics & Theranostics
NanoMat	

Coordinator(s)	Bich-Thuy Doan (CHIMIE ParisTech PSL); Thomas Pons (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	0 h	12 h	0 h	0 h
Assessment	Class participation 20% / Written exam 20% / TP participation 20%/ Oral presentation 40%					
Prerequisites	Foundations in nanomedicine (NanoMed)					

Course description

This lecture is an advanced course dedicated to engineers, physicists, physicians, biologists and chemists. It brings expertise in the design, synthesis, characterization and functionalization of nanoparticles for bioimaging, image guided diagnosis and therapy.

The evolving field of medical imaging is closely related to the development of new imaging probes for diagnosis or therapy, including nanoparticles presenting unique optical or magnetic properties. These nanoparticles are associated to therapy (nanomedicine) or to targeted therapy guided by imaging (theranostics).

Fluorescent, plasmonic and magnetic nanoparticles, including up to date activable theranostics will be presented together with their biological and biomedical application in cells, preclinical models and towards clinical application. Several modern imaging modalities using nanoparticles will be presented including optical, Raman, thermal, magnetic resonance, US & PET imaging, in single or multi modalities.

The course is divided into general courses including exercises, and 2 practical sessions to learn the synthesis, physicochemical characterisation and optical, thermal to MRI imaging:

- Presentation of “fluorescent, plasmonic, magnetic nanoparticles: their formulation, physicochemical characterization.
- Use and imaging applications in vitro, preclinics to clinics for diagnosis and therapy.
- Practical session for fluorescent, plasmonic and magnetic nanoparticles and imaging in our optical and MRI facilities.
- **Lecture 1: Fluorescent and plasmonic nanoparticles**
 - Fluorescent Nanoparticles for diagnostics and theranostics: definition, formulation, analysis
 - Plasmonic Nanoparticles: definition, formulation, analysis
- **Lecture 2: Magnetic nanoparticles and multimodal probes**
 - Magnetic Nanoparticles for MRI diagnostics and theranostics: definition, formulation, characterization, applications
 - Multimodal imaging probes for diagnostics and theranostics: definition, formulation, applications
- **Practicals 1& 2**
 - Formulation and characterization (physicochemistry and imaging) of fluorescent and plasmonic NPs: NP design and chemical synthesis
 - Bioimaging evaluation of nanotheranostics by MRI and optical imaging

- **Assessment**

- Short written exam
- Preparation and oral presentation presenting the synthesis schemes, properties and applications of a class of nanomaterials prepared during the practical training.

Learning objectives

- **Know / Understand:** Recall and understand the methods of synthesis and characterisation, the properties, and the imaging applications of the main colloidal nanomaterials used for image-guided diagnosis and therapy;
- **Apply:** Characterise and use contrast agents for fluorescence and MRI imaging.
- **Analyse:** Relate the physicochemical characteristics of a nanomaterial to the requirements of a biomedical application.
- **Synthesise:** Combine knowledge to create an original product to address the challenges of diagnostic imaging and new therapies.
- **Evaluate:** : Identify and make decision of the appropriate and efficient nanomaterial to answer a diagnostic and theranostic problematics.

ST4H_S3_BEH_06	Optical imaging for imaging & therapeutics
OptImg	

Coordinator(s)	Ignacio Izeddin (ESPCI Paris PSL); Olivier Thouvenin (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	3 h	0 h	3 h	0 h
Assessment	Class participation 40% / Poster & Short report 60%					
Prerequisites	Basics in signal and image processing (SigProc); Basics in geometrical optics and wave physics (BioIm)					

Course description

This course presents an overview of the main optical imaging techniques for biomedical applications across the variety of spatial and temporal scales of life. It is meant to present the key concepts of optical imaging and briefly introduce many different techniques in order for the students to identify which technique can be best suited for each scientific question or technological challenge. However, it is not meant to go into the specific technical details of the different techniques. The course combines lectures, seminars where applications of a few biophotonic tools will be presented in the context of a research project, and some experimental work in a research lab.

Starting from general optical concepts, the course describes technologies accessible for capturing the different scales of life, from the single molecule to whole organs. Each spatial dimension covers about 2 hours of lecture and one seminar from one PSL researcher introducing their research topic. A special course on eye imaging, the only organ directly accessible to optical imaging, is provided. A small introduction to novel methods for manipulating or stimulating life with light will be covered as well. 3 hours will finally be dedicated to a small group lab visit with a focus on a real photonic experiment, that will be studied in more details and presented and put in context of other technologies to the rest of the class for the exam.

- **Session 1: Optical contrast and image formation (2h Lecture)**

This section recalls the basics of optical imaging, including how to form an image, what spatial and time scales optical imaging can capture, and what information can be obtained.

- How to build a microscope? How to transform your cellphone into a microscope and what compromise in the performances do you have to accept compared to a commercial microscope? Scanning microscope versus widefield imaging
- Endogenous and exogenous contrast: Origin of contrast
- Resolution and penetration depth. The scattering and extinction mean free paths

- **Session 2: Imaging molecules and single cells (2h Lecture + 1h Practicals)**

In diluted solutions and single cells, optical imaging can achieve high resolution and high contrast, making it possible to study the dynamics of life at subcellular scale. This part will introduce the main concepts of imaging proteins and cells at the nano and micro-scale.

- Molecular contrast to find the spatiotemporal patterns of molecular activity + dyes which can measure contacts, and chemical changes in cells. Calcium imaging, voltage imaging, etc...
- Live fluorescence and immunohistochemistry. Introduction to the limits of labeling
- Single particle tracking and super-resolution microscopy, expansion microscopy,
- Quantitative analysis with light: FCS.
- Alternatives of label-free microscopies : DIC and Quantitative phase imaging

- **Session 3: Imaging cell aggregates and tissues (2h Lecture + 1h Practicals)**

When imaging thicker samples, light scattering starts to perturb and complexify the imaging lowering the contrast and accessible resolution. This part will introduce the concept of optical sectioning and imaging in thick samples in the single scattering regime, and will cover the main available techniques

- Axial resolution and optical sectioning
- Classical methods in fluorescence : Confocal, spinning disk, multiphoton, etc...
- Introduction to optical coherence tomography
- Non linear microscopies (SHG, THG, CaRS, etc...) and IR contrast

- **Session 4: In vivo retinal imaging (2h Lecture + 1h Practicals)**

The eye is quite particular as it is the only part of the human body directly accessible for optical imaging. However, the optical properties of the eye and ocular movements make its imaging quite specific and challenging.

- The eye: A transparent window to the brain. Anatomy and constraints of eye imaging
- Adaptive optics
- OCT, autofluorescence imaging of RPE, Scanning light ophthalmoscope, etc...
- Imaging cell photoactivity

- **Session 5: In vivo imagings with recent optical technologies to MRI (2h Lecture)**

At depths larger than a transport mean free path (~1 mm) becomes complicated, light becomes multiply scattered and transverse resolution is lost. However, light is not absorbed and can be transported throughout samples in order to characterize molecular interactions at millimetric resolution. This part will introduce the concept of imaging in the multiple scattering regime and will cover several imaging techniques to image organs and rodents whole body in vivo with light, including a highlight towards multimodal imaging with MRI.

- Diffuse light
- Whole body fluorescence
- Near infrared fluorescence imaging
- Bioluminescence imaging
- Photoacoustic imaging
- Coupling with MRI

- **Session 6: Optical Manipulation and treatments (2h Practicals)**

This part is dedicated to introduce the concept that light can not only be used to image biological samples but also to manipulate cells at the micrometer scale. Two seminars will introduce the key techniques around light tweezers and optogenetics

- Physical manipulation of cells with optical tweezers
- Biochemical manipulation of cells with optogenetics

- **Session 7: Lab visits, Case study & Exam**

By groups of 2-3, students visit one real experiment from a PSL lab, assist and participate to an experiment. For the final exam, each group presents its to the others and to the pedagogical team in their own words, and within the context of the course.

Learning objectives

- **Know:** Describe the different optical imaging systems
- **Understand:** Understand how to choose the right biophotonic tool to answer a problem and estimate the adequate dimensions of a problem.
- **Apply:** Apply biophotonics tools to address a real scientific question during experimental work
- **Analyse:** Critically analyse the experiment and a scientific article related to the experiment.
- **Synthesise:** Present an experiment to other peers
- **Evaluate:** Make constructive feedbacks on others presentation.

ST4H_S3_BEH_07	Ultra-Sound Systems for Imaging & Therapeutics
USImg	

Coordinator(s)	Charlie Deméné (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	12 h	0 h	3 h	3 h	0 h
Assessment	Class participation 20% / Written exam 80%					
Prerequisites	Basics in materials science (Mater); Basics in cell biology (Biol1, Biol2); Basics in physics and thermodynamics (PhysBiol)					

Course description

This course introduces the students to the exciting world of biomedical ultrasound, through the prism of the Physics for Medicine most recent research and developments. It covers the basics (physics, wave propagation, ultrasound systems and hardware) required to understand key concepts in cutting edge ultrasound and then gives a review of the hot topics in ultrasound imaging and ultrasound-based therapies. It includes typical 2h-3h lectures on curated topics (e.g. from basic ultrasound to ultrafast imaging; super-resolution imaging; ultrasound-based therapeutics for brain or cardiac applications; multimodal imaging with ultrasound; brain functional ultrasound imaging), practical hands on work in ultrasound (including programming an ultrasound scanner, post-processing super-resolution ultrasound data, or simulating the thermal ablation of a brain tumor), a group project based on that hands on work, and a constant effort to put this research into perspective for clinical application.

- **Lecture 1: Basics of Medical Ultrasound**
 - Ultrasound basic wave physics: coherent propagation (as opposed to optical imaging), the human body is (almost) transparent to ultrasound, what makes the measured signals, which frequencies & which depths.
 - Ultrasound systems: transducers, electronics, imaging systems & therapeutic systems in terms of spatial and temporal control, clinical applications: how and what for?
 - Ultrafast imaging. Limiting factors to build an ultrasound image, focused strategy, plane wave strategy, applications: basic elastography and ultrafast doppler.
- **Lecture 2: Contrast imaging and ultrasound localization microscopy**
 - Contrast imaging in ultrasound: agents, basic physics, clinical application
 - Diffraction limit: intrinsic limitation when imaging with waves, and super-resolution
 - Ultrasound localization microscopy: principles, applications, perspectives and promises
- **Lecture 3: Therapeutic ultrasound: the clinician's new Swiss army knife**
 - Technology, challenges and promises of therapeutic ultrasound: interaction of ultrasound with tissues (thermal and mechanical effects), transcostal and transcranial focusing, emergence of novel neurosurgical and neurostimulation techniques, multielement arrays vs single element technology.
 - Companies' roadmaps: current and future developments of therapeutic ultrasound: example of MR guided and ultrasound guided systems for tumor ablation; difference in strategy between large multinational companies and innovative startup companies.
- **Practicals: Hands on ultrasound**
 - Basics of ultrasound image reconstruction: build your own ultrasound image OR

- Ultrasound localisation microscopy: beat the diffraction limit and reveal the microvasculature OR
- Ultrasound brain therapy: focus through the skull to burn a tumor
- **Lecture 4: Functional ultrasound imaging & brain machine interfaces**
 - Functional ultrasound: preclinical concepts
 - Functional ultrasound: clinical applications
 - Sonogenetics
 - Towards ultrasound-based brain-machine interfaces
- **Lecture 5: 3D ultrafast systems and cutting-edge cardiac ultrasound**
 - 3D ultrafast ultrasound – applications (Cardiac, brain), system (matrix arrays, RCA), physical principles (ultrafast, coherent compounding, directivity)
 - Applications of Van Cittert Zernike theorem in acoustics (Focusing quality, BTI, sound speed correction, aberration correction)
 - Imaging large volume in ultrasound (multi-lens)
 - Cutting-edge cardiac ultrasound (cardioscope, emyosound)
- **Lecture 6: Combined ultrasound imaging**
 - Ultrasound modalities and their complementarity
 - Combined approaches, opportunities and technical challenges
 - Multimodal imaging, example of PET ultrasound
 - Multimodal analysis, application of machine learning
- **Lecture 7: Innovating in ultrasound: success and pitfalls on the road to clinical application**
 - Physics for Medicine as a world leader in medical ultrasound applications

Learning objectives

- **Know:** Recall the main clinical applications of ultrasound and their typical physical parameters (frequency, resolution, depth, pressure, intensity, used hardware, bioeffects); describe how to create an image from ultrasound measurements; describe how to obtain therapeutic bioeffects with ultrasound; identify and describe hot topics in ultrasound research
- **Understand :** Identify and explain key physical concepts for ultrasound imaging and focusing (coherence, scattering, transduction, antenna gain); distinguish conventional ultrasound imaging and ultrafast ultrasound imaging; explain the principles of ultrasound localization microscopy; classify the available technical solutions for ultrasound 3D imaging; describe the complementarity between ultrasound imaging and other imaging modalities; identify and summarize the challenges associated with focused therapeutic ultrasound.
- **Apply :** Manipulate real ultrasound data and apply post processing techniques covered in the lectures; discover the simulation of acoustic fields; develop a code implementing the key steps of an imaging reconstruction method; plan the allocation of tasks in a group research project;
- **Analyse :** Analyse a scientific article describing an imaging reconstruction method to identify the key steps;
- **Evaluate :** Choose between different approaches to address a clinical question in a personal scientific project; summarize the results of the project and judge their quality and limitations in a scientific article format.

ST4H_S3_BEH_08	Biosensors & Lab-on-chip Technologies for Clinical Diagnostics
BiosenLOC	

Coordinator(s)	Cyrine Slim (CHIMIE ParisTech PSL); Fanny d'Orlyé (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	13 h	3.5 h	0 h	1.5 h	0 h
Assessment	Class participation 20% / Written exam 80%					
Prerequisites	Basics in solution chemistry, separation methods, and electrochemistry (MolMeth)					

Course description

This course integrates the fields of biosensors and miniaturized analytical systems, providing students with a comprehensive understanding of their principles, design, and applications. The course addresses technology transfer challenges and equips students with skills necessary to develop innovative solutions for clinical and medical applications.

Key topics include materials and microfabrication processes for microfluidic chip conception, surface functionalization strategies, affinity ligands and immunoassay, microchip electrophoresis, and sensors technologies. The course also explores the use of nanomaterials for sample preconcentration, separation, and detection within integrated analytical microsystems for biochemical sensing.

Through practical case studies and bibliographic projects, students will focus on developing innovative approaches and technologies in the field of integrated analytical microsystems for detecting cancer biomarkers and diagnosing infectious diseases.

The course addresses technology transfer challenges and equips students with the skills necessary to develop innovative solutions for clinical and medical applications.

- **Session 1: Basics on Miniaturized Analytical Systems**
 - Introduction to the miniaturization of analytical systems and biosensors
 - *Tutorials: Bibliographic projects kick off session in small groups*
 - Chip Design and Microfabrication
- **Session 2: Nanotechnology and Surface Engineering in Biosensing**
 - Nanomaterials and surface functionalization for their use in microanalytical systems
 - Introduction to biosensors
- **Session 3: Advanced Materials and Functionalization Techniques**
 - New affinity ligands and functional materials in molecular diagnostics
 - *Tutorials: Bibliographic project work session in small groups*
- **Session 4: Electrochemical Sensing and Microfluidic Integration**
 - Miniaturization and integration of electrochemical sensing in microfluidic channels
- **Session 5: Micro Total Analysis Systems**
 - Introduction to Micro Total Analysis Systems
 - *Tutorials: Bibliographic project work session in small groups*

- **Session 6: Innovation and Technology Transfer**
 - Case studies (Ebola test, multiplexed biosensing)
 - Problem-solving session: innovation and technology transfer

Learning objectives

- **Know:** Be familiar with the mechanisms of biological recognition, electrochemical transduction, and kinetic laws in miniaturized systems; Master the strategies and techniques of bioelement immobilization for biosensor applications and more widely for the development of analytical systems based on molecular recognition.
- **Understand:** Understand the fundamental principles underlying the selectivity and resolution of analytical separation methods, as well as the sensitivity and reliability of biosensors.
- **Apply:** Leverage knowledge to propose an innovative technological solution (from design to application) in response to a clinical diagnostic challenge, within a collaborative context and based on scientific literature.
- **Analyse:** Analyse the challenges associated with designing, miniaturizing, and integrating analytical systems.
- **Evaluate:** Promote and defend an innovative scientific and technological project both in writing and orally in a group work setting.

ST4H_S4_BEH_01	BEH Research Project (Master thesis)
BEHResProj	

Coordinator(s)	Laurent Corté (MINES Paris PSL); Charlie Deméné (ESPCI Paris PSL); Bich-Thuy Doan (CHIMIE ParisTech PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
24	English	0 h	0 h	0 h	0 h	5-6 months
Assessment	Oral presentation 30% / Answers to questions 30% / Report 30% / Supervisor Assessment 10%					
Prerequisites	-					

Course description

Semester 4 is mostly devoted to the Master thesis, in the form of a 5–6-month research internship. During this internship, each student joins individually a research team and works full time on a specific research question in the scope of his/her M2 track.

Students find their internship during Semester 3. For each track, a list of projects submitted to the master program is proposed to the students, who can then apply through a standard interview process. Students can also contact laboratories and propose a project outside of the list. All of these projects are validated by the chairs of the students' track to ensure that they address a research question within the scope of the track and in an appropriate working environment.

BEH research projects cover a broad range of topics in biomaterials and health engineering, including biomaterial & implant engineering, physics and chemistry applied to health, biointerfaces, tissue engineering, nanomedicine, biomedical imaging, and diagnostic technologies. All projects share a common goal: developing novel concepts, innovative materials, devices, or technologies involving interactions with biological systems for therapeutic, diagnostic or biomedical research applications.

At the end of their internship, students submit a written manuscript and defend their thesis in front of a jury of experts selected by the track chairs. The duration of the internship is chosen jointly by the student and the host team. Both durations (5 or 6 months) are equally valued. Defenses take place in late June/early July for 5-month internships and in early September for 6-month ones.

Learning objectives

- **Know:** the scientific background, state of the art, and methodological foundations relevant to the internship topic in biomaterials and engineering for health.
- **Understand:** the research question, objectives, methodological rationale, and biomedical relevance of the internship project.
- **Apply:** appropriate methods to conduct an autonomous research project under supervision, using rigorous and reproducible methodology.
- **Analyse:** results critically considering the project objectives, methodological limitations, and the existing literature.
- **Synthesise:** integrate results into a coherent scientific discussion and produce a structured Master's thesis.
- **Evaluate:** assess the significance and limitations of the work, propose future perspectives, and defend the project during the oral examination.

Master 2
Semesters 3 & 4
DMH Track courses

ST4H_S3_DMH_01	Mental Health & Digital Technology: Concepts, Practices & Perspectives
MentDigiTech	

Coordinator(s)	Margot Morgiève (INSERM); Nancy De Jesus (Paris Est Val de Marne Hospital)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	18 h	0 h	3 h	3 h	0 h
Assessment	Class participation 10% / Oral presentation 90%					
Prerequisites	-					

Course description

This course explores contemporary issues in psychiatry and mental health, with a particular focus on the applications of digital technology in this field. Students will begin by reflecting on the boundaries of mental health and psychiatry, critically examining concepts such as well-being and empowerment. The main psychiatric disorders will be studied, with an emphasis on their classification, symptoms, and epidemiology. Special attention will be given to obsessive-compulsive disorders (OCD), through the shared testimonies of a psychiatrist and a person affected by the disorder who founded an association.

This approach will be enriched by a historical perspective on the theoretical debates associated with psychiatric classifications. The course will also address both traditional and non-conventional treatments, as well as mental health promotion and prevention approaches. Historical developments in therapeutic practices and the controversies surrounding them will also be considered. Finally, students will explore participatory methodologies for designing and evaluating ethical and inclusive digital tools, focusing on the real needs of users. Three inspiring stories from developers of digital tools in psychiatry/mental health will illustrate the opportunities digital technology offers to transform care and support practices.

- **Lecture 1: Redefining health: from psychiatry to well-being**

This course explores the redefinition of the concept of health, going beyond the simple absence of illness to include a positive approach to mental health, even well-being. Students will examine the concepts of positive mental health and empowerment. Particular attention will be paid to a critical reflection on these definitions and their application in the context of mental health practices, while questioning the social and individual implications of a form of contemporary injunction to well-being.

- **Lecture 2: Major mental pathologies**

This course examines major mental pathologies through a clinical approach, focusing on nosography, symptoms and epidemiology. Students will understand the manifestations of disorders and their psychological, emotional and functional impacts on individuals, their loved ones and society.

- **Lecture 3: History of mental disorder treatments**

This course traces the history of mental disorder treatments. Students will explore the evolution of theories and practices. Emphasis will be placed on the theoretical disputes that have marked each era, by questioning the debates between these different approaches and their impacts on the management of mental disorders.

- **Lecture 3: Psychiatric classifications: issues and controversies**

This course examines the evolution of mental disorder classification systems, with an emphasis on the main classifications such as the DSM (Diagnostic and Statistical Manual of Mental Disorders),

the ICD (International Classification of Diseases) and the RoCs (Research Domain Criteria). Students will analyze the principles and issues of these classifications, as well as the theoretical and practical debates they give rise to.

- **Lecture 4: Health Promotion and Prevention: Concepts, Practices and Methods**

This course explores the concepts and approaches of health promotion and prevention, with an emphasis on the development of psychosocial skills throughout the life course. Students will discover the different strategies of primary, secondary and tertiary prevention, and learn how psychosocial skills can be integrated into public health programs.

- **Lecture 5: Psychosomatics: Body and Mind**

This course explores the interaction between the body and the mind in the context of psychosomatics. Students will analyze the mechanisms by which mental disorders influence physical health and vice versa. The course will cover the main psychosomatic disorders, their diagnosis, as well as therapeutic approaches. Particular attention will be paid to multidisciplinary management strategies and recent advances in the understanding of the links between psyche and somatics.

- **Lecture 6: Conventional treatments**

This course examines conventional treatments used in the management of mental disorders, addressing the main pharmacological and psychotherapeutic approaches. The course will also highlight the integration of these treatments into a comprehensive care approach, taking into account ethical aspects, side effects and adaptation to the specific needs of patients.

- **Lecture 7: Unconventional treatments in mental health**

This course examines unconventional treatments in mental health, focusing on alternative approaches to traditional medicine. It explores the motivations of individuals to turn to these treatments and analyzes the associated ethical issues. The course will also focus on their possible integration into traditional care pathways.

- **Lecture 8: Statistical evaluation methodology for treatments**

This course focuses on methodologies for evaluating the effectiveness of treatments for mental disorders, addressing the statistical techniques and tools used to measure clinical outcomes. Students will learn how to design and analyze clinical studies, use statistical models adapted to the evaluation of mental health interventions, and interpret data from this research.

- **Lecture 9: Obsessive Compulsive Disorders (OCD): Clinical and Lived Perspectives**

This course focuses on obsessive-compulsive disorders (OCD) by addressing both a clinical perspective and a lived experience. On the one hand, students will explore the clinical and neurobiological advances in OCD, particularly through the eyes of a psychiatrist-researcher specializing in deep brain stimulation, who will present his research on innovative treatments. On the other hand, the voice of a person affected by OCD, founder of an association, will offer a unique insight into the daily experience of this disorder.

- **Lecture 10: New participatory design methodologies**

This course addresses the methodology of participatory design in the development of technological tools in mental health, with an emphasis on ethical and social issues. Students will learn to use co-design to create inclusive technological solutions, adapted to the needs of vulnerable populations, particularly in the face of social and territorial inequalities. The course will explore collaborative processes between health professionals, researchers and users, in order to guarantee the effectiveness, accessibility and equity of the digital tools developed.

- **Lecture 11: Patient-Centered Assessment: PreMS and PROMS**

This course explores patient-centered assessment methodologies, with a focus on the PreMS (Patient-reported experience measures) and PROMS (Patient-reported outcome measures) tools, which represent a major challenge in the evolution of traditional assessments. Students will

address the conceptual, ethical, and methodological aspects of measuring patient experience and outcomes in healthcare.

- **Lecture 12: Virtual Reality for Mental Health**

This course explores the use of virtual reality in the field of mental health. It presents innovative technological devices and applications for creating immersive environments dedicated to the treatment and prevention of disorders.

- **Lecture 13: From Suicidology to Social Media: Story of a Child Psychiatrist**

This course is led by a child and adolescent psychiatrist and researcher who designed a suicide prevention tool for young people, based on social media. He explores the various challenges encountered during the development of this tool, whether financial, technical, ethical or clinical. Students will also discover the process of evaluating this tool through a clinical trial.

- **Lecture 14: A Chatbot for Mental Health: Story of an Entrepreneur**

This entrepreneur will share his journey of creating a chatbot dedicated to mental health, highlighting the motivations and challenges that marked his project. Students will discover the technical, ethical and financial issues, as well as the strategies used to meet the real needs of users.

- **Lecture 15: From experience to innovation: Designing an app for eating disorders**

This course is led by a person living with an eating disorder (ED) who has used her experience to design a therapeutic innovation. The course focuses on the process of creating this tool.

Learning objectives

- **Know:** Know the major classifications of psychiatric disorders.
- **Understand :** Understand the methods and challenges involved in evaluating the effectiveness of treatments and care approaches; Understand participatory, ethical design methods centered on the perspective of those affected
- **Synthesise :** Identify the scope of mental health and psychiatry
- **Evaluate :** Take a critical look at contemporary classifications and treatments by incorporating a socio-anthropological perspective

ST4H_S3_DMH_02	Advanced Neuroscience for the Understanding of Behavior and Mental Health
AdvNeuroSc	

Coordinator(s)	Karim Benchenane (ESPCI Paris PSL); Thierry Gallopin (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	0 h	3 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Anatomy of the Nervous system (Physio1); Bases in neurophysiology (neuron, action potentials, ...) (Neuro1) ; Cell Biology (DNA, RNA, protein, receptor, signal transduction,...) (Biol1); Main physiological functions (Biol1, Physio1)					

Course description

This teaching unit provides an in-depth exploration of the neural mechanisms underlying behavior and mental health disorders, integrating theoretical foundations with hands-on neuroscience skills. Students will examine key cognitive and emotional processes—including memory, sleep, neural oscillations, and attention—investigating their roles in both normal function and pathological conditions such as depression, anxiety, PTSD, and addiction. The course will emphasize the brain as a predictive machine, exploring how it generates and refines predictions for motor control, perception, cognition, and decision-making.

A central focus will be on synaptic plasticity and its link to memory, covering encoding, storage, consolidation, extinction, and reconsolidation, as well as neuroplasticity's role in emotional adaptation. Students will also study vigilance states, from sleep to attention, analyzing the neural regulation of sleep, the impact of stress on sleep architecture, and the continuum of vigilance states ranging from wakefulness to focused attention. Theories of learning and conditioning—including the opponent process theory—will provide insights into how the brain processes emotional experiences and stress.

The course will delve into the neuroscientific basis of mental disorders, addressing fear systems, anxiety, defense mechanisms, and motivation. The study of pain will include distinctions between acute and chronic pain, the neural basis of nociception, tolerance, and sensitization, as well as changes observed in the central nervous system during pain and pain chronification. Finally, students will explore how individual differences in neural functioning shape personality and behavior, as well as the principles of homeostasis and allostasis in stress adaptation.

Students will gain hands-on experience with advanced neuroimaging techniques, including electrophysiology (EEG, MEG, LFP), calcium and voltage imaging, fMRI, and functional ultrasound (fUS). The functioning of brain-computer interfaces will also be covered. Practical sessions will involve coding and data analysis using Python (or MATLAB), where students will analyze raw data obtained from the different methods described (electrophysiology, calcium imaging, and fUS hemodynamic signals) and perform spectral analysis, classification, and decoding based on neural activity.

By the end of the unit, students will have developed the ability to critically assess neuroscientific theories and their clinical applications, as well as proficiency in analyzing complex neural data. They will be well-prepared to contribute to mental health research and innovative treatment strategies, leveraging a deep understanding of the brain's role in behavior, emotion, and mental disorders.

- **Lecture 1 : The brain as a predictive machine**
 - Prediction for motor action
 - Perception and action

- Prediction and cognition
- **Lecture 2 : Main methods to study Neuroscience**
 - Electrophysiology (neurons, LFP, EEG, MEG)
 - Imaging (calcium, voltage)
 - fMRI and fUS
- **Lecture 3 : Vigilance states from sleep to attention**
 - Bases of sleep
 - Sleep regulation
 - Stress and sleep
 - Difference sleep human/animal
 - From Vigilance to Attention
 - Attention and neuronal activity
 - Attention and neuromodulation
 - Attentional disorders
- **Lecture 4 : Synaptic Plasticity and memory**
 - Main forms of plasticity
 - Main memory notions: Encoding, Storage, Consolidation, Extinction, Reconsolidation
 - Main forms of memory
 - Link between plasticity and memory
- **Lecture 5 : Neural representation the case of spatial navigation**
 - Spatial decoding
 - Network activity analysis and representation
 - Role of oscillation
 - Network activity
 - Stability of memory representation
- **Lecture 6-7 : Learning and memory**
 - Pavlovian conditioning
 - Instrumental conditioning
 - Role of Dopamine in Reward
 - Motivation and drives
 - Exposure therapy (from extinction to reconsolidation)
- **Lecture 8 : Emotion and personality theory**
 - Defense reaction
 - Fear/anxiety
 - Gray and McNaughton theory
 - Personality theories (inverted classroom)
- **Lecture 9 : Addiction**
 - Decision making and addiction
 - Dopamine and addiction
 - Reward versus pleasure
 - Homeostasis/allostasis
 - Opponent processes
- **Lecture 10 : Pain acute and chronic**
 - Main concepts: tolerance sensitization
 - Nociception
 - Brain mechanisms for pain
 - Difference between acute and chronic pain
 - Placebo and pain

- Social pain

- **Lecture 11 : Pharmacology and circuits approach of neuropsychiatric disorders**

- Antidepressant
- Anxiolytics
- Neuroleptics
- Psychedelic
- Mood stabilizers

- **Practicals:**

- Analysis of continuous data versus discrete data
- Bayesian Decoding
- Spectral analyses
- Dimensionality reductions PCA/ICA
- Linear classification LDA
- GLM

Learning objectives

- **Know** the principal neural mechanisms underlying cognition, emotion, learning, memory, attention, pain, and mental health disorders.
- **Understand** how brain circuits and neural dynamics generate behavior and adapt to environmental challenges.
- **Apply** neuroscience methods and computational tools to process and interpret neural and behavioral data.
- **Analyse** neural activity and experimental results using contemporary theoretical and quantitative frameworks.
- **Synthesise** knowledge from cognitive, systems, and clinical neuroscience to address complex research questions.
- **Evaluate** neuroscientific theories, experimental methodologies, and their implications for understanding and treating mental health disorders.

ST4H_S3_DMH_03	Real-Life Psychiatry: From the Validity of Research Methods to Incorporating Emotions & Bodily Reactions
RealLifPsysc	

Coordinator(s)	Bérengère Guillery-Girard (EPHE PSL); Karim Benchenane (ESPCI Paris PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	3 h	0 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	-					

Course description

The "Real-Life Psychiatry: From the Validity of Research Methods to Incorporating Emotions and Bodily Reactions" teaching unit offers a comprehensive, multidisciplinary exploration of how emotions, brain-body interactions, and psychiatric disorders intersect in real-world clinical practice. The course bridges the gap between scientific research and clinical applications, examining how physiological and emotional responses shape mental health conditions and influence diagnostic and treatment strategies. Students will critically assess the validity of research methods in psychiatry, exploring how emerging neuroscientific findings translate into practical approaches for understanding and managing psychiatric disorders.

Students will engage with core theories and controversies in the study of emotions, delving into the physiological and behavioral mechanisms underlying emotional responses in both humans and animals. The intricate relationship between the brain and body will be examined in depth, with a focus on how physiological signals influence mental states and psychiatric conditions.

A key component of the course addresses the role of physiological and bodily measures in psychiatry, highlighting biomarkers of mental health conditions and their implications for diagnosis and treatment. Students will also explore social neuroscience, covering topics such as mirror neurons, empathy, social hierarchy, and social pain—essential for understanding psychiatric conditions with a social dimension.

The course further examines therapeutic approaches, including cognitive-behavioral therapy (CBT), EMDR, hypnosis, and other psychiatric interventions, analyzing their effectiveness in treating disorders such as anxiety, depression, and PTSD. A debate session will challenge students to engage with contrasting perspectives on psychiatric disorders, featuring viewpoints from biologists/neuroscientists, CBT psychologists, and sociologists.

Students will gain insight into real-world psychiatric treatment through a case study on PTSD and the aftermath of the November 13 attacks in Paris. This session will be led by the team responsible for treating patients suffering from PTSD following the terrorist attack.

The course also critically assesses the intersection of scientific research and clinical applications, addressing the limitations of recent discoveries and emerging fields in terms of real-world applicability. A key issue is that while some methods used to identify deficits in mental disorders may be highly sensitive, they often lack sufficient specificity, significantly limiting their clinical utility.

A prime example is the rapidly growing field of computational psychiatry, which will be examined through the lens of psychometric validity—including test-retest reliability and predictive accuracy—to evaluate its feasibility for clinical use. Additionally, the course will address the Research Domain Criteria (RDoC) framework, a novel approach to classifying mental disorders based on neuroscientific findings rather than traditional symptom-based categories. Students will critically analyze the strengths

and limitations of RDoC, particularly its implications for diagnosis, treatment, and the broader understanding of psychiatric disorders.

Throughout the course, students will work with data analysis tools to classify emotional responses and assess psychiatric symptoms. They will also gain practical experience through engagement with psychiatric services and patient interviews, culminating in a report that integrates scientific theories with clinical realities.

This teaching unit is structured around key themes that integrate neuroscience, psychology, and psychiatry to provide a comprehensive understanding of mental health disorders and their real-world implications.

- **Lecture 1: Emotion: Core Concepts and Controversies**
This module explores fundamental theories of emotion and key controversies, such as the debate between universal and culturally shaped emotions and the role of cognition in emotional processing.
- **Lecture 2: Brain-Body Interactions**
This module examines the dynamic interplay between the brain and physiological states, exploring how bodily signals shape cognition, emotion, and mental health.
- **Lecture 3: Physiological Measures in Psychiatry.**
This module focuses on the role of physiological biomarkers in diagnosing and understanding psychiatric disorders. It covers methods for measuring autonomic responses, hormonal changes, and neural activity in mental health research.
- **Lecture 4: Social Neuroscience.**
This module explores key concepts in social neuroscience, including the mechanisms of mirror neurons in action understanding and imitation, the neural and psychological foundations of empathy, the impact of social hierarchy on mental health, and the overlap between physical and emotional pain processing in the brain.
- **Lecture 5: Cognitive-Behavioral Therapy (CBT), EMDR, Hypnosis, and Psychiatry.**
This section covers the principles of Cognitive Behavioral Therapy (CBT) and its applications in psychiatric treatment, as well as the use of Eye Movement Desensitization and Reprocessing (EMDR). It also explores hypnosis as a therapeutic tool, examining its mechanisms, efficacy, and limitations in psychiatric care.
- **Lecture 6: Placebo Effects in Psychiatry.**
This section explores the neurobiological and psychological mechanisms underlying the placebo effect, and its implications for treatment outcomes and the design of clinical trials.
- **Lectures 7-8: Debate – Perspectives on Psychiatric Disorders.**
Contrasting perspectives from different disciplines on the nature and treatment of psychiatric disorders, including those of a biologist/neuroscientist, psychiatrist, psychologist, and sociologist. The discussion will cover:
 - *Neural and Genetic Mechanisms*: Understanding psychiatric disorders through biological factors.
 - *Learned Behaviors and Cognitive Patterns*: The role of experience and cognition in mental health.
 - *Societal and Cultural Influences*: How social structures and cultural factors shape psychological well-being.
- **Lectures 9-10: Psychiatric Treatment in Real Life – PTSD and the November 13 Attacks.**

This section presents a case study on PTSD treatment following the Paris terrorist attacks, offering insights from clinicians and researchers who have worked closely with the affected patients.

- **Lecture 11: Influence of sleep on Psychiatric disorders.**

This course explores the critical role of sleep in psychiatric disorders, examining how sleep disturbances can exacerbate conditions like depression, anxiety, and PTSD. It will focus on the bidirectional relationship between sleep and mental health, highlighting how poor sleep can contribute to the onset or worsening of psychiatric symptoms, while mental health disorders can also disrupt sleep patterns. Understanding this relationship is crucial for developing more effective treatment strategies that address both sleep and psychiatric conditions simultaneously.

- **Lecture 12: Scientific Research and Clinical Applicability.**

This part of the course explores computational psychiatry, focusing on the real-world applicability of computational models, including their psychometric validity, test-retest reliability, and predictive power. It also examines the Research Domain Criteria (RDoC) approach, evaluating its strengths and limitations as a neuroscience-based classification system for mental disorders.

Learning objectives

- **Know** the main theories, concepts, methods, and clinical approaches linking emotions, brain–body interactions, and psychiatric disorders.
- **Understand** how physiological, cognitive, neural, social, and emotional processes contribute to mental health and psychopathology.
- **Apply** research concepts, clinical frameworks, and data-analysis tools to interpret emotional responses, psychiatric symptoms, and real-life clinical situations.
- **Analyse** the validity, limitations, and clinical relevance of physiological, behavioral, psychometric, and computational methods in psychiatry.
- **Synthesise** multidisciplinary knowledge from neuroscience, psychology, psychiatry, physiology, and social sciences to interpret complex psychiatric disorders.
- **Evaluate** the translational value of scientific findings, therapeutic approaches, and diagnostic frameworks for real-world psychiatric practice.

ST4H_S3_DMH_04	AI-inspired Computational Approaches to Mental Health & their Applications
CompAppMent	

Coordinator(s)	Valentin Wyart (ENS PSL); Valérien Chambon (ENS PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	18 h	0 h	0 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Foundations in statistics (Math2, ResMeth), Basics in AI and machine learning (MLAI)					

Course description

In a world where digital data on mental health is constantly increasing—whether clinical, behavioral, or other forms of data—it is crucial to develop tools capable of extracting actionable insights from these vast datasets. Computational approaches, inspired by artificial intelligence, advanced statistics, and modeling, hold significant potential for unraveling the mechanisms underlying mental disorders. By leveraging these tools, it becomes possible to identify complex patterns with the ultimate goal of personalizing therapeutic approaches and developing more effective interventions.

This course aims to train participants in recent advances in computational modeling and artificial intelligence, with a strong focus on their practical applications in mental health. Guest speakers will demonstrate how these approaches enable a data-driven rethinking of mental disorder classifications, redefining them as clusters of symptoms. The course will also explore how computational tools can identify cognitive strategies characteristic of specific mental disorders, conduct cognitive epidemiology studies to better predict the precipitating factors of mental health conditions, and reconstruct speech from brain activity to restore communication in patients with impaired speech production.

This program provides a unique opportunity to explore cutting-edge methods at the intersection of AI, computational neuroscience, and mental health, equipping participants with the knowledge and skills to address pressing challenges in this critical field.

Learning objectives

- **Know:** Recall and memorise key concepts in artificial intelligence and computational modelling as applied to mental health.
- **Understand:** Understand and explain the links between computational approaches and the mechanisms underlying mental disorders, rephrasing complex concepts in an accessible way.
- **Apply:** Apply artificial intelligence tools to analyse clinical or behavioural data, and transfer this knowledge to real-world situations in mental health.
- **Analyse:** Analyse complex datasets to identify symptomatic patterns or clusters, establishing meaningful logical relationships.
- **Synthesise:** Combine different computational approaches to propose creative and original models, tailored to specific mental health issues.
- **Evaluate:** Assess the relevance of the models or methods used, and advocate for recommendations regarding their clinical or ethical use

ST4H_S3_DMH_05	Innovative Therapeutic Strategies for Mental Health
TherStratMent	

Coordinator(s)	Philippe Domenech (INM Paris)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	15 h	0 h	3 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Advanced neurosciences (AdvNeuroSc); Foundations in psychiatry and mental health (MentDigiTech, RealLifPsys)					

Course description

Psychiatry, a rapidly evolving medical discipline, is particularly well-positioned to benefit from recent neurotechnological advances: innovative neuromodulation techniques, brain-computer interfaces, neurofeedback, connected devices, and the prospective multimodal collection of behavioral data...

The aim of this course is to introduce students to the latest therapeutic innovations in psychiatry and to explore promising areas of future development. It will also address the process of transforming prototypes and concepts developed in research laboratories into therapies suitable for large-scale deployment and daily clinical use, drawing on the experience of researchers who have founded neurotechnology and digital health startups. This course will equip students with essential skills to understand the technological, neuroscientific, and clinical challenges associated with current neurotechnological advancements, which foreshadow the therapeutic strategies of tomorrow's psychiatry.

Part 1: Neuromodulation and Brain-Computer Interfaces (BCI) – This section covers the latest advances in neuromodulation techniques, their mechanisms, and their applications in mental health disorders. Students will explore the intersection of neuroscience, engineering, and computational modeling in developing therapeutic interventions.

- **Session 1 : Physical Neuromodulation Methods**

Therapeutic Transcranial Magnetic Stimulation (TMS) & Precision Neuronavigation

- Principles of TMS: single-pulse, repetitive TMS (rTMS), theta burst stimulation (TBS)
- Functional connectivity and neuronavigation for targeted TMS
- Clinical applications: depression, OCD, addiction treatment
- Ethical and safety considerations of TMS in psychiatry

Deep Brain Stimulation (DBS) & Vagus Nerve Stimulation (VNS) for Depression and OCD, Closed-Loop BCI Systems

- Mechanisms of DBS and VNS: stimulation parameters and neurophysiological effects
- Neural circuits involved in depression and OCD: role of the prefrontal cortex, amygdala, and striatum
- Closed-loop neuromodulation: adaptive DBS and real-time neural monitoring
- Challenges and limitations in clinical applications

Transcranial Ultrasound Stimulation (TUS)

- Mechanism of action: neuromodulation through low-intensity focused ultrasound
- Applications in treating psychiatric disorders and cognitive enhancement
- Safety, risks, and future potential in non-invasive brain stimulation

- **Session 2 : Brain-Computer Interfaces (BCI) & Neural Decoding**

Neuroprosthetics and Decoding Principles

- Understanding neural signals: EEG, ECoG, LFP, and single-unit activity
- Decoding motor and cognitive functions using machine learning algorithms
- Applications in assistive technologies: brain-controlled prosthetics and communication devices

Low-Dimensional Representation of Neural Activity

- Dimensionality reduction techniques: PCA, t-SNE, UMAP
- Identifying stable neural representations for cognitive and motor processes

Decodable Visual Representations

- Neural mechanisms of vision and perception
- Brain decoding of visual stimuli: applications in BCIs and neuroimaging

High-Level Cognitive Information Processing

- Decoding complex cognitive processes (e.g., memory, decision-making)
- Applications in cognitive neuroscience and neurotechnology

- **Session 3 : Neurofeedback & Virtual Reality**

Neurofeedback with fMRI

- Fundamentals of real-time fMRI neurofeedback
- Applications in self-regulation, anxiety, and depression treatment
- Machine learning approaches for personalized neurofeedback

EEG & Virtual Reality (Neuromind)

- EEG-based neurofeedback training in virtual environments
- Applications in anxiety, PTSD, and cognitive rehabilitation
- Integration of VR and BCI for immersive mental health interventions

Part 2: Digital Mental Health – This section explores how big data and digital health technologies are transforming mental health diagnostics, treatment, and research.

- **Session 4: Big Data & Encrypted Data Analysis (Caliopé)**

Data Mining Techniques for Mental Health Research

- Introduction to big data in neuroscience and psychiatry
- AI and machine learning approaches for mental health diagnostics
- Ethical considerations in handling patient data

- **Session 5: Connected Devices for Real-Life Data Collection (2h)**

Wearable and IoT-based Diagnostics

- Smart devices for mental health tracking (e.g., smartwatches, biosensors)
- Continuous monitoring of physiological and behavioral data
- Challenges in data privacy and clinical validation

Part 3: Practical Session – Roundtable with an Entrepreneur

- Discussion on innovation and real-world applications in digital mental health
- Case studies on successful startups in neurotechnology and mental health AI
- Career paths in digital mental health and neurotechnology

Learning objectives

- **Know:** Memorise the key concepts of innovative neurotechnologies, connected devices, and digital approaches in psychiatry.
- **Understand:** Understand and explain the scientific, clinical and technological challenges associated with the use of neurotechnologies in therapeutic contexts.
- **Apply:** Apply the knowledge acquired to analyse prototypes of neuropsychiatric technologies and consider their adaptation for large-scale clinical use.
- **Analyse:** Analyse the critical stages in the transition from laboratory innovations to clinical solutions, identifying potential obstacles and possible solutions.
- **Synthesise:** Synthesise information from different disciplines (neuroscience, engineering, psychiatry) to propose original strategies for technological and clinical development.
- **Evaluate:** Evaluate the relevance and feasibility of technological innovations in psychiatry, and justify strategic choices whilst taking into account ethical and practical considerations.

ST4H_S3_DMH_06	Animal Models of Mental Disorders
AniModMent	

Coordinator(s)	Eric Burguière (Paris Brain Institute)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Basics in programming (Prog1, BasProg), Advanced neuroscience (AdvNeuroSc), Foundations in psychiatry (MentDigiTech, RealLifPsyc)					

Course description

This course offers an in-depth exploration of animal models used to study neuropsychiatric disorders, emphasizing their translational relevance, ethical considerations, and methodological approaches. Participants will learn the principles of model validity, the range of species used (rodents, primates, invertebrates), and the challenges of bridging experimental research with clinical applications.

Theoretical sessions cover specific disorders such as obsessive-compulsive disorder (OCD), anxiety, depression and addiction, while practical sessions focus on advanced behavioral and neuro-physiological analyses in rodent models, including tools like DeepLabCut and experimental setup creation using Arduino.

Designed for students seeking hands-on experience and theoretical insights, this course provides essential knowledge for leveraging animal models to understand mental disorders and develop innovative therapeutic strategies.

- **Session 1: Translational Approach to Neuropsychiatric Disorders – Advantages & Limitations**
 - Principles of Valid Animal Model Design
 - Different Animal Species Used (primates, rodents, invertebrates)
 - Ethical Framework and Legal Considerations in Experimental vs. Clinical Research
 - From bed to bedside: promoting translational research
- **Session 2: Modeling mental disorders in animals**
 - OCD
 - Anxiety/fear and depression
 - Addiction
- **Session 3: Advanced behavioral and neurophysiological analyses of rodent models**
 - Mouse City / Behavioral chamber
 - Classifier / Deep Lab Cut
- **Practical sessions**
 - Creating your own experimental setup for animals using an Arduino and managing synchronization issues – accelerometer
 - Alternative: Introduction to behavior tracking/classification software

Learning objectives

- **Know:** Recall the principles governing the validity of animal models and the specific characteristics of the different species used in neuropsychiatric research.
- **Understand:** Understand the advantages, limitations and applications of animal models within a translational approach to mental disorders.
- **Apply:** Apply experimental tools, such as Arduino or behavioural tracking software, to design and synchronise experimental setups in animals.
- **Analyse:** Analyse behavioural and neurophysiological data from rodent models to identify significant relationships and establish links with human pathologies.
- **Evaluate:** Propose ethical and scientific improvements or alternatives to existing models, and defend their relevance in translational approaches.

ST4H_S3_DMH_07	Research Projects in Cognitive Neuroscience & Mental Health
ResProjCogSc	

Coordinator(s)	Karim N'Dyaye (Paris Brain Institute)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	3 h	6 h	9 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Basics in programming (Prog1, BasProg), Advanced neuroscience (AdvNeuroSc)-					

Course description

This course provides a hands-on approach to experimental research in cognitive neuroscience, psychophysiology, and mental health. Over nine sessions, students will design, program, and execute an experiment aimed at replicating a well-documented effect from the scientific literature, such as the Stroop effect, N-back performance, behavioral priming, or the startle response. Through a structured, project-based approach, students will gain practical experience in experimental psychology and neuroscience by implementing research protocols, collecting behavioral and physiological data, and analyzing their findings.

Students will work with open-source tools and established experimental systems, utilizing programming languages such as Python (or MATLAB), or JavaScript. They will also integrate physiological measurements—including heart rate, muscle activity, and EEG—using equipment such as Biopac systems and eye trackers. A strong emphasis is placed on reproducibility, real-world research constraints, and ethical considerations, including GDPR compliance and budget management.

By the end of the course, students will have developed proficiency in experimental design, data collection, and analysis, equipping them with essential technical and critical-thinking skills for future careers in neuroscience, psychology, and mental health research. The course culminates in a group presentation where students assess the validity and limitations of their replicated findings, fostering a deeper understanding of the complexities of experimental research in cognitive neuroscience.

- **Session 1: Introduction and Task Presentation**
 - Overview of psychophysics and psychophysiology paradigms.
 - Assignments: Select a paper for replication by the next session.
- **Session 2: Presentation of Chosen Effect**
 - Students present their selected publication, including the target effect, associated protocols, and expected outcomes.
- **Session 3: Programming Workshop**
 - Introduction to experimental programming in Python, MATLAB, or JavaScript.
 - Hands-on demos with Biopac systems and eye trackers.
- **Session 4: Independent Work**
 - Students refine their scripts based on class feedback.
- **Session 5: Debugging and Consultation**
 - One-on-one sessions with the instructor for troubleshooting and finalizing protocols.

- **Session 6: Data Collection Preparation**
 - Finalize scripts and acquire subjects.
 - Ethics, GDPR compliance, and platform access.
 - Budget calculation for participant compensation.
- **Sessions 7-8: Data Collection and Analysis**
 - Conduct experiments and analyze data using statistical tools.
 - Explore online deployment for larger datasets.
- **Session 9: Group Presentations**
 - Presentation of results, discussion of reproducibility challenges, and implications for mental health research.

Learning objectives

- **Know:** Identify classic paradigms from the literature in psychophysics and psychophysiology. Identify the fundamental concepts in neuroscience and psychology involved in these paradigms.
- **Understand:** Analyse experimental protocols and associated results in the scientific literature. Explain the theoretical principles underlying experimental tasks, such as Stroop, N-back, or startle.
- **Apply:** Design and programme an experimental protocol to replicate a classic effect (in Python, MATLAB or JavaScript for tests conducted on online platforms). Be able to use simple data acquisition systems (Arduino, etc.). Be able to carry out classic psychophysical measurements (eye movements, heart rate, electrodermal response).
- **Analyse:** Interpret experimental data in relation to theoretical knowledge.
- **Evaluate:** Discuss the validity of the results obtained and propose avenues for further research or clinical application. Discuss these results in the context of the reproducibility crisis in the field of experimental psychology.

ST4H_S3_DMH_08	Artificial Intelligence Applied to Neuroscience & Mental Health
AIMent	

Coordinator(s)	Ania Gari-Soler (Dauphine PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
3	English	9 h	0 h	9 h	0 h	0 h
Assessment	<i>(to be announced)</i>					
Prerequisites	Basics in programming (Python, Colab notebook) (Prog1, BasProg)					

Course description

This course trains students in essential data analysis techniques applied to mental health research, with a focus on extracting insights from complex datasets and effectively communicating results. The program covers both fundamental statistical methods and advanced machine learning approaches, ensuring students can handle real-world data challenges in digital mental health.

More specifically, this course will focus on datasets collected from mice undergoing aversive learning. The animals' brain activity, breathing, and heart rate are continuously recorded, providing a rich, multimodal dataset for analysis. The goal is to establish precise links between behavior and brain activity while considering the temporal dynamics of learning, rather than relying solely on averages over an entire session. Students will develop computational skills to analyze how neural and physiological responses evolve over time and across individual animals, integrating behavioral and physiological markers of learning and stress adaptation.

Part 1: Data Representation and Visualization

Students will learn to visualize complex, time-dependent data, moving beyond static summary statistics. The course introduces techniques for dynamically representing brain activity, physiological responses, and behavior using heatmaps, time-series plots, and phase-space representations. Selecting the optimal visualization format is essential to reveal patterns that emerge over learning stages and across individual animals.

The course emphasizes best practices for visualization, including how to avoid misleading representations and how to tailor figures for different audiences, whether they are researchers, clinicians, or policymakers. A particular focus is placed on selecting the most appropriate visualization methods—such as scatter plots, boxplots, or heatmaps—depending on the nature of the data and the message being conveyed.

Extracting key insights from data goes beyond visualization; students will also learn to summarize complex datasets through exploratory analysis, identifying trends, patterns, and anomalies.

A key aspect of the course is teaching students how to structure data to account for the fact that animals learn at different speeds and do not necessarily reach the same learning stage at the same time.

Extracting insights from such datasets requires aligning brain and body responses with behavioral events, considering both short-term fluctuations and long-term trends. Students will work with real experimental data to explore how breathing and heart rate changes correlate with behavioral transitions, assessing their role in tracking stress responses and learning progress.

Part 2: Statistical and Computational Methods of Analysis

Traditional approaches that average data across an entire session may obscure critical variations in learning dynamics. This course emphasizes time-sensitive analyses that take into account the stage of learning and inter-individual differences in acquisition speed. Students will learn fundamental statistical methods such as mean analysis and comparison (t-tests, ANOVA, non-parametric tests) but will move beyond them to incorporate time-resolved analyses such as sliding window statistics and event-related measures.

Correlation analysis will be explored in depth, with a strong focus on distinguishing correlation from causation. Students will investigate Simpson's paradox in the context of behavioral data and brain activity, where aggregating across time may lead to misleading conclusions. They will learn how to control for confounding factors through partial correlation and multiple regression models, particularly when examining how body reactions (e.g., respiratory fluctuations) influence both behavior and neural dynamics.

Multivariate methods such as generalized linear models (GLM) and linear discriminant analysis (LDA) will be applied to predict behavioral states from neural and physiological signals. Principal component analysis (PCA) and independent component analysis (ICA) will be used to decompose large-scale neural activity, helping students understand how different components of brain function relate to distinct behavioral phases.

Part 3: Machine Learning and Deep Learning for Time-Resolved Analysis

Beyond classical statistical approaches, students will explore machine learning techniques for behavioral and physiological data analysis. They will implement deep learning models, including artificial neural networks (ANNs), convolutional neural networks (CNNs) (usefull for imaging data), and recurrent neural networks (RNNs) for time-series analysis (usefull for physiological and speech data), to classify learning stages based on brain-body interactions. These methods will allow for the prediction of future behavioral states from ongoing physiological signals, shedding light on how stress and body responses dynamically influence learning.

A critical component of the course is understanding the bidirectional relationship between behavior and brain activity. Students will analyze how behavioral constraints affect what can be inferred from neural signals, considering how movement artifacts, decision-making strategies, and physiological adaptations impact interpretation. By the end of the course, students will be equipped with the analytical tools necessary to extract meaningful insights from complex neurophysiological datasets and contribute to the study of learning, stress, and brain-body interactions.

Learning objectives

- **Know:** Recall the main statistical and computational analysis methods applied to time series and experimental data.
- **Understand:** Explain the challenges involved in data representation and in accounting for inter-individual and temporal variability in the analysis.
- **Apply:** Apply methods of exploratory analysis, statistical modelling and machine learning to experimental data.
- **Analyse:** Identify and interpret relationships between different dimensions of the data (behaviour, physiology, neural activity) using appropriate methods (GLM, PCA, ICA, deep learning).
- **Synthesise:** Construct a data analysis pipeline integrating multiple levels of information and enabling the extraction of relevant trends.
- **Evaluate:** Justify the choice of analytical methods and critically interpret the results, taking into account methodological limitations and data uncertainties.

ST4H_S4_DMH_01	DMH Research Project (Master thesis)
DMHResProj	

Coordinator(s)	Karim Benchenane (ESPCI Paris PSL); Thierry Gallopin (ESPCI Paris PSL); Bérengère Guillery-Girard (EPHE PSL)					
ECTS	Language	Lecture	Tutorial	Practicals	Seminar	Project
24	English	0 h	0 h	0 h	0 h	5-6 months
Assessment	Oral presentation 30% / Answers to questions 30% / Report 30% / Supervisor Assessment 10%					
Prerequisites	-					

Course description

Semester 4 is mostly devoted to the Master thesis, in the form of a 5-6 month research internship. During this internship, each student joins individually a research team and works full time on a specific research question in the scope of his/her M2 track.

Students find their internship during Semester 3. For each track, a list of projects submitted to the master program is proposed to the students, who can then apply through a standard interview process. Students can also contact laboratories and propose a project outside of the list. All of these projects are validated by the chairs of the student's track to ensure that they address a research question within the scope of the track and in an appropriate working environment.

DMH research projects cover a wide range of research questions at the intersection of science, engineering, and mental health. Projects can be at various levels of translational research, from early concept exploration to clinical research and preclinical modelling and validation. Projects may involve a combination of experimental, numerical and theoretical approaches, making use of cutting-edge neuroscience and psychiatry methodologies, artificial intelligence and biomedical technologies.

At the end of their internship, students submit a written manuscript and defend their thesis in front of a jury of experts selected by the track chairs. The duration of the internship is chosen jointly by the student and the host team. Both durations (5 or 6 months) are equally valued. Defenses take place in late June/early July for 5-month internships and in early September for 6-month ones.

Learning objectives

- **Know:** the scientific background, state of the art, and methodological foundations relevant to the internship topic in neuroscience, data science and engineering applied to mental health.
- **Understand:** the research question, objectives, methodological rationale, and biomedical relevance of the internship project.
- **Apply:** appropriate methods to conduct an autonomous research project under supervision, using rigorous and reproducible methodology.
- **Analyse:** results critically considering the project objectives, methodological limitations, and the existing literature.
- **Synthesise:** integrate results into a coherent scientific discussion and produce a structured Master's thesis.
- **Evaluate:** assess the significance and limitations of the work, propose future perspectives, and defend the project during the oral examination.

