List of courses (with short syllabus) in the Neuroscience Area

PhD in Cognitive Neuroscience
- Cognitive Neuroscience - Intelligence
- How the brain tells time
- Language, Reading and the Brain
- Introduction to Systems and Computational Neuroscience: Evolution of Neural Computation
- Introduction to Systems and Computational Neuroscience: Tactile Perception
- Introduction to Systems and Computational Neuroscience: Visual Perception
- Bayesian modeling and information theory for neuroscience and cognitive science

PhD in Neurobiology
- New technologies for Molecular Neurobiology
- Principles of Computational Neuroscience (blended + hands-on with UniTs)
- Neural Control of Locomotion
- Synaptic plasticity: from an electrophysiological approach to behavioural studies
- Synaptic Function and Nanotools: Physiology at the Nanoscale
- Sensory Systems: Chemical Senses
- Neuroecology – History, Methods and Insights

PhD in Genomics
- Engineering the mammalian genome
- Neurobiology of Neurodegenerative Diseases
- Genomics and Transcriptomics Data Analysis and Mining
- Introduction to RNA structure and Dynamics
- Genomics and genetics of emerging model species
- Evolution and development of macroglia

Methodological courses
- Scientific programming: A crash course
- Data Modelling
- Methodologies of fMRI and TMS
- Statistics
- Scientific writing and communication

Technical courses
- Basic microscopy, fluorescence microscopy and immunofluorescence
- Introduction to Electronics - Theory
- Introduction to Electronics - Practice
- Solidworks and rapid prototyping

Basic Techniques in Cell and Tissue Culture
Organotypic and Dissociated Primary Cultures
Introduction to the Human Cognitive Neuroscience Laboratories
Introduction to the Molecular Biology Laboratories
Introduction to IT services and IT Security

PhD in Cognitive Neuroscience

Cognitive Neuroscience - Intelligence

Teacher: Raffaella Rumiati (office 341, rumiati@sissa.it, https://insula.sissa.it)
Amount of frontal teaching: about 16 h
The course will be held in presence (SISSA, room 139) and online

Description
Typically the field of intelligence has been somewhat detached from general cognitive neuroscience. Thus the main aim of this course is to place this research strand well within the wider umbrella of cognitive neuroscience in order to offer a wider understanding and better explanations of traditional intelligence issues. In this course we will touch upon different definitions of intelligence, the ways in which intelligence has been tested and how tests were used and abused. We will review the neuropsychological and imaging literature investigating the putative mechanisms underlying intelligence. We will also discuss the different factors that might influence intelligence as well as academic and life outcomes. These factors include personality, socio-economic status, family background, social class, gender, and ethnicity. We will introduce the rise and fall of intelligence in normal and pathological level as well as at population level, and we will debate about heritability and genetics.

Brief lists of topics:

1. Introduction to the different models of intelligence and tests including IQ tests and large scale achievement tests, and to concepts of construct validity and construct reliability.
2. Multiple intelligence and different cognitive abilities contributing to intelligence with particular attention to the verbal versus non verbal distinction.
3. Brain and intelligence: brain and head size and IQ, neuroanatomical correlates and neuromechanisms of intelligence.
4. Brain plasticity and cognitive reserve, with also reference to the Flynn effect in intelligence and personality.
5. Intelligence and its deficits in brain damaged patients as well as in normal and pathological aging: the contribution of neuropsychology and neuroimaging.
6. Factors that can influence intelligence: personality, socio-economic status, family background, social class, gender, and ethnicity.

Course Evaluation
How. It will consist in presenting a critical view on one of the topics of the course.
When. To be held in November (date to be decided).

How the brain tells time

Teacher: Domenica Bueti
Amount of frontal teaching: about 20 h

Description:

The ability to tell time is one of the most important functions the brain performs. Tasks such as, understanding/producing language, appreciating music, playing a musical instrument or predicting when an external event will occur rely on the brain's ability to tell time. The course will offer an overview of the state of the art of the neuroscience of time from theoretical models to empirical data. Particular emphasis will be given to the processing and perception of time in a range spanning from a few hundreds of milliseconds to a few seconds.

1. *What* is time? A few specifications to start with.
    a. Milliseconds/seconds, duration perception and processing.
    b. Why is it difficult to study time?
    c. Scalar property and Weber's law (and its violations).
2. *How* and *Where* is Time Represented in the Brain?
    a. Internal Clock and "A-modal" Circuit(s) to tell time.
    b. The role of sensory features and sensory cortex activity in time perception.
        i. Sensory features affecting time perception (distance, speed, contrast, intensity).
        ii. The contribution of sensory cortex activity to time perception.
        iii. The role of visual cortex in time discrimination and its link with spatial representations.
    c. SDN model (time as an object encoded in the context of previous events, temporal dynamics in cortical slices).
    d. Time in the firing rate of neurons
        i. In the slow ramping activity.
        ii. In the speed of the neural network.
        iii. Chronotopy and duration tuning.

Language, Reading and the Brain

Teacher: Davide Crepaldi
Amount of frontal teaching: about 14 h

Description:

The course offers an introduction to how the brain deals with language and reading. It does so by focusing on the relationship between sounds/letters and meaning, and the consequent informational landscape that characterises human languages. These questions will bring us outside of the classic territory that is explored in language courses, to touch upon statistical learning, information theory and neural (deep) networks. We will review experimental and computational evidence at the intersection between Linguistics, Cognitive Neuroscience and Experimental Psychology, to discover that language is a peculiar symbolic system, where fundamental randomness is constrained by the learning capability of the brain, and by the dynamics of human social interactions.

A fairly general syllabus is as follows:
1. what's a human language;
2. arbitrariness and information;
3. word frequency distribution and computational models of word meaning;
4. form-to-meaning mapping (morphology and sound symbolism);
5. neural networks and the geometry of language;
6. statistical and implicit learning;
7. localist, non-learning neural networks;
8. language evolution and cognitive constraints.

Introduction to Systems and Computational Neuroscience: Evolution of Neural Computation

Teacher: Alessandro Treves
Amount of frontal teaching: about 20 h

Description:
The course delineates the evolution of the vertebrate nervous systems, with a particular focus on mammals and among them on the human lineage, contrasting the network organization emerging in different structures, such as the cerebellum, the basal ganglia, the cortex and the hippocampus. Reference is made to abstract styles of neural computation such as reinforcement learning, error-correction and backpropagation of errors, associative memory and self-organizing maps.

Topics:

1. What are we after in the course?
2. Chemical computation – neuromodulators.
3. Elements of information theory. Geometrical computation – early vision in flies, in fish and in mammals

4. Perceptrons and back-propagation. Creative geometry in the basal ganglia and in the cerebellum.
5. Simple models of reinforcement learning,
6. Pyramidal cells, distributed representations, associative plasticity – associative memory for faces with unlabeled data
7. From cortically plausible models to the Hopfield model. Simple associative nets in olfactory cortex, amygdala and orbitofrontal cortex.
8. Competitive nets, extended to the self-organization of cortical maps. Lamination and a realization in sensory cortex.
9. Pure memory in the mammalian hippocampus – David Marr. The statistical physics of flat and curved spatial maps.
10. Random number generators in the Dentate Gyrus, and neurogenesis – analyzing charts and their transitions
11. Memory from statics to dynamics, from semantics to grammar

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Introduction to Systems and Computational Neuroscience: Tactile Perception

Teacher: Mathew Diamond
Amount of frontal teaching: about 15 h

Description:
The course focuses on the basic principles of organization of the sensory pathways and their target regions of cerebral cortex; mechanisms and properties of sensory transduction; psychophysical methods for quantifying sensory perception; methods for quantifying the relationship between neuronal activity and behavioral performance, with a focus on several lines of inquiry spanning tactile, auditory, and visual perception.

Topics:

1. Introduction to the study of the cerebral cortex
2. Sensory maps in the cerebral cortex
3. Transduction
4. Somatosensory system and pain
5. Methods for computational neuroscience of perception 6. Encoding and decoding
6. Perceptual memory
7. Neuroscience of perceptual knowledge

Introduction to Systems and Computational Neuroscience: Visual Perception

Teacher: Davide Zoccolan
Amount of frontal teaching: about 14 h

Description:
The course focuses on the structure and functions of the mammalian visual systems, with a special emphasis on shape processing and object recognition. In addition, the module includes a description of some of the computational approaches that allow modeling and understanding visual functions. In particular, the module introduces the students to: 1) quantitative models of neuronal tuning (e.g., reverse correlation approaches); 2) feedforward neuronal networks for object recognition; and 3) functional models of the visual system using basic machine learning approaches.

More in details, the course is divided into the following sections:
1. Introduction to anatomy and physiology of the visual system
2. A systems/computational approach to the study of the visual system
3. Classic findings about physiology of lower-level visual areas
4. Data analysis approaches in Systems Neuroscience
5. Classic findings about physiology of higher-level visual areas
6. Descriptive models of visual neurons
    a. How to build models of visual neuronal responses (i.e., stimulus/response maps)
7. Mechanistic models of the visual system
    a. Inferring the mechanisms underlying the response properties of visual neurons
8. Functional models of the visual system
    a. Understanding neuronal population codes

Bayesian modeling and information theory for neuroscience and cognitive science

Teacher: Eugenio Piasini
Amount of frontal teaching: about 16 h

Description:
Ideas at the interface of information theory and Bayesian statistics have long been a source of inspiration and of powerful quantitative methods in neuroscience and

cognitive science. This course will focus on some key foundational concepts, and how they are used to formulate and test theories of cognition, perception, and neural processing.

Topics:

1. Introduction to Bayesian inference
2. Perception as Bayesian inference
3. Bayesian inference under sensory noise
4. Cue combination and evidence accumulation
5. Stimulus detection, discrimination and classification
6. Introduction to information theory
7. The efficient coding principle

PhD in Neurobiology

New technologies for Molecular Neurobiology

Teacher: Paul Heppenstall

Amount of frontal teaching: about 15 h

Description: In the last fifteen years, increasingly sophisticated molecular genetic tools have been developed which allow for accurate monitoring and perturbation of the nervous system. The Molecular Neurobiology course gives an introduction to these technologies, focusing on how they were discovered, how they work, and how to use them.

The course covers the following topics:

1. Genome editing and CRISPR: Here I give an overview of genome editing technologies. This is followed by an interactive practical class in which a CRISPR experiment is designed. New CRISPR technologies are then discussed in a journal club.
2. Controlling neuronal activity with optogenetics and chemogenetics: A summary of the principals of optical and chemical methods for manipulating neuronal activity is given. This is followed by a journal club discussing recent advances in these methods.

3. Monitoring neuronal activity with genetically encoded sensors and indicators: An introduction to the biophysical principles of genetically encoded activity probes is given. We then discuss recent advances in a journal club, before benchmarking state of the art probes in a laboratory experiment.
4. Gene delivery using viral vectors. Background in gene delivery technology is given. Recent advances in the field are then discussed in a journal club.
5. Emerging technologies: Recent breakthrough technologies that have emerged in the previous year are discussed in a journal club.

Principles of Computational Neuroscience (blended + hands-on with UniTs)

Teacher: Michele Giugliano

Amount of frontal teaching: about 15 h

Course Website: https://tiny.one/principles

Description: Computational Neurosciences is a multidisciplinary field that studies brain functions and dysfunctions and how information is processed by cells and circuits, by ultimately building mathematical models and numerically simulating them on computers, aiming at tackling scientific questions that are relevant for the understanding of the brain. These models are often, but not always, intimately grounded in first-principle biology, biochemistry, physics, and electromagnetism, so that the processes within individual nerve cells, synapses, and networks are described like a real pendulum can be studied by pen and paper, by a simple formula and a series of parameters.

Through this course, students will increasingly start making quantitative judgements of cell electrophysiology and biophysics, analysing how significant discoveries could be made in these domains and where the availability of solid theoretical and computational tools revealed to be extremely fruitful. Students will become fluent in this language and skills. Students will be presented by a quantitative style of analysis of neural systems, as an opportunity to expand their learning skills towards "synthesis", "quantitative analysis", and "in silico investigation" in Neurobiology.

The course covers the following topics:

1. Introduction
2. Mathematical Refresher
3. Neuroelectronics
4. The Hodgkin-Huxley model

5. Synaptic Transmission
6. Short-term synaptic plasticity
7. Simplified Spiking Neuronal Models
8. Firing-Rate Population Models

Neural Control of Locomotion

Teacher: Giuliano Taccola
Amount of frontal teaching: about 12 h

Description:
The course describes the functional organization of the neuromotor system dedicated to locomotion. Locomotion is introduced as a prototypical function of the central nervous system originating from rhythmogenic neuronal networks that face biomechanical constrains and environmental challenges to express a patterned and flexible motor behaviour. Locomotion is then addressed in more detail, as the continuous processing of volitional brain commands, along with the automatic activity of spinal neuronal circuits and the afferent feedback from the periphery.
Network reconfiguration is described in response to physiological (development and training) and pathological (motor disorders) conditions. Continuous links to experimental studies allow students to become familiar with classical and advanced electrophysiology on in vivo and in vitro rodent preparations.
At the end of the course, translational perspectives for the recovery of motor functions after a spinal cord injury are discussed.

Topics:

1. Basics on spinal infrastructure: spinal cord and spinal motoneurons.
2. Electrophysiological probes to study the function of sensorimotor spinal networks: Hoffmann reflex, F - wave, cord dorsum potentials, spinal reflexes and cortico-spinal responses.
3. Biomechanics of locomotion: the locomotor program.
4. The neural origin of the locomotor program: central pattern generators.
5. Emergent properties of neuronal networks and sensory feedback.
6. In vitro preparations from neonatal rodents to explore the organization of locomotor CPGs.
7. Integrative spinal physiology: A) modulating the excitability of spinal locomotor networks through limb exercise, B) coupling respiratory and locomotor rhythms during physical activity.
8. Updates on motor recovery after spinal injury using neuromodulation.

Synaptic plasticity: from an electrophysiological approach to behavioural studies

Teacher: Giada Cellot

Amount of frontal teaching: about 15 h

Description: Synapses undergo to dynamic changes that depend on their previous history. This issue has been extensively studied through electrophysiological approaches, ranging from the characterization of in vivo long term synaptic potentiation to the development of artificial protocols to induce synaptic plasticity in vitro. In this context, the recent introduction of optogenetic tools combined with electrophysiological and behavioural observations allowed to characterize the functional consequences of synaptic plasticity occurring in specific brain regions.

This course will focus on the following topics:

1. Long term plasticity (LTP): from Hebb's postulate to electrophysiological and behavioural evidence.
2. Hebbian and anti-Hebbian LTP.
3. Spike timing dependent plasticity.
4. Functional implications of hippocampal synaptic plasticity: memory and learning.
5. Plastic changes in the amygdala circuitry. An example of associative learning: fear conditioning.
6. Cellular mechanism underlying fear extinction.

Synaptic Function and Nanotools: Physiology at the Nanoscale

Teacher: Laura Ballerini

Amount of frontal teaching: about 15 h

Description: The course offers an introduction on synaptic physiology approached by microscopy, ultramicroscopy, electrophysiology, live imaging and opotgenetic tools and will review most recent experimental studies contributing to progress in synapse research by advances in superresolution imaging, quantum dot technology, and other super resolution technologies in dissecting presynaptic release machinery and /or dendritic spine dynamics. The focus of these lectures is on synaptic structure and function shifting from the traditional dimension within the micro-world to that at the nano-scale, the general aim is to give hints on how submicron investigations, or changing the dimension of investigation, might provide original views and breakthroughs in addressing current challenges in neuroscience.

Topics:

1. Nanotechnology: a brief overview
2. Introduction to anatomy and physiology of synapses
3. Classic microscopy and electrophysiology findings
4. Live imaging, nanotechnology based and super-resolution approaches
5. The dynamics of synaptic release
6. Transcellular nano-alignment and synaptic function
7. Dendritic spine and voltage compartmentalization
8. Dendritic spine mechanical regulation of presynaptic bouton exocytosis

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Sensory Systems: Chemical Senses

Teacher: Anna Menini

Amount of frontal teaching: about 15 h

Description: Sensory systems allow an organism to get information from the external world and transform it into an internal representation. We will learn general principles of sensory systems' organization and the most recent advances about the mammalian chemical senses. Students will be involved in laboratory experiments with electrophysiological recordings of odor and pheromone responses and in journal clubs discussing the most recently published papers.

The course covers the following topics:

1. Anatomical organization of the olfactory, vomeronasal and taste systems.
2. Olfactory, vomeronasal, taste receptors, their ligands and transduction mechanisms.
3. The family of TMEM16 ion channels and their roles in chemical senses.
4. Chemesthesis and TRP ion channels.
5. From the periphery to the cortex
6. How SARS-CoV-2 infects the chemical senses.

Neuroecology – History, Methods and Insights

Teacher: Katja Reinhard

Amount of frontal teaching: about 15 h

Description:

Neuroecology is the study of how the structure and function of the brain has adapted to specific niches. When animals move into a new habitat, the different evolutionary pressure of that environment may favour changes in appearance and behaviour. Neuroecologists aim to understand neural circuitry by studying how the brain of animals is built to allow for those niche-specific behaviours. This course will provide an introduction to the history of Neuroecology, the methods used to study behaviour and the brain in parallel, and the main insights the science community has gained from this field.

Topics:

1. Definition and history of neuroecology: To start, I will provide an overview of when neurocology started and how it is different from other neuroscience and behaviour fields.
2. Methods to study behaviour: I will give an introduction into the types of behaviours neuroecologists would study. This is followed by an overview of the methods used to analyse behaviour. We will then discuss behaviours and applied methods in a journal club.
3. Methods to study the brain: After an introduction to methods that allow us to study the brain in behaving animals (electrophysiology, imaging,...) and techniques to detect changes in brain structure (viral tracing, antibody stainings,...), we will discuss specific applications in a journal club.
4. Neuroecology vs model organisms: In the final block, I will introduce model organisms in neuroscience. We will then discuss and contrast the use and value of model organisms and ecological approaches.

PhD in Genomics

Engineering the mammalian genome

Teacher: Prof. Mallamaci

Amount of frontal teaching: 25 hours
Description: The Course starts with a general survey of molecular logics, operational gateways and molecular machineries for manipulation of the mammalian genome. Next, it continues with a systematic, in depth analysis of tools and designs employed for functional genome engineering, from classical to state-of-art ones.

This course will focus on the following topics:

1. Experimental goals of genome engineering:
    a. investigating/manipulating regulation of gene expression: cis- and trans-effectors; necessity and sufficiency
    b. investigating biological functions of gene products: limits and caveats of gain- and loss-of-function approaches
    c. exploiting known functions of gene products: "special" applications
2. Gateways to the mammalian genome:
    a. germ-line manipulations
    b. somatic manipulations
3. Endogenous and exogenous recombination machineries (NHEJ, HR, lentiviral integrases, transposases) and their use for:
    a. classical transgenesis
    b. gene trapping
    c. gene knock-out
    d. gene knock-in
4. Site-specific recombinases (Cre, FLPe, FC31, Bxb1), and their use and engineering for:
    a. conditional mutagenesis
    b. fast transgenesis
5. Engineered operons for ligand-controlled transcription
    a. Tet, E, PIP, Lac, QuoRex
    b. RheoSwitch, Rapalog
6. Engineered EndoNucleases (EENs) and nickases, and their use for gene knock-out and knock-in, in rodents and primates:
    a. ZFNs
    b. TALENs
    c. CRISPR-Cas9
7. Sequence editors:

    a. Precision base editors
    b. Base mutators
    c. Prime editors
8. Technologies for precision, scareless manipulation of:
    a. epigenetic state of chromatin (TALE- and dCas9-based)
    b. transcription (RNAa, RNAi, CRISPRa, CRISPRi, NMHV)
    c. translation (ASO, SineUp)
    d. protein degradation (Protac, Smash)

Neurobiology of Neurodegenerative Diseases

Teacher: Prof. Legname
Amount of frontal teaching: 24 hours
Description:
The Neurobiology of Neurodegenerative Diseases course deals with all the major neurodegenerative diseases in humans, with a few exceptions. The course is divided into monographic lessons which alone can be considered seminars that illustrate all the problems related to a certain disease both at the physiological as well as at the molecular level. Students will be trained in interactive lessons discussing with the professor each topic of each lesson.

The diseases considered are:
1. Alzheimer disease, taupathies, Parkinson disease.
2. Multiple sclerosis, amyotrophic lateral sclerosis (ALS).
3. Prion diseases or transmissible spongiform encephalopathies.
4. Frontotemporal dementia and other types of dementia.
5. Chronic traumatic encephalopathy.

Genomics and Transcriptomics Data Analysis and Mining

Teacher: Prof Sanges
Amount of frontal teaching: 35 hours
Description:
The course is an introduction to the experimental design and the data analysis and mining in Genomics made by a mixture of theoretical lessons and practical sessions. Students will also be instructed on the history of molecular biology and the milestones that lead to the sequencing of the human genome and the development of current functional genomics strategies and theories. Evolutionary aspects and the

contribution of non-coding RNA and transposons to the evolution of complexity and the impact of their activity in the brain will be discussed. The course is an open discussion between the teacher and the students.

Specific covered topics are:

1. Cells, genomes, genes and the Central Dogma of molecular biology.
2. Transcription, transposons, non-coding and the evolution of organismal complexity.
3. Transposons and the brain.
4. Bioinformatics databases and tools.
5. Good practices for experimental design.
6. Transcriptome mining and meta analysis with gene expression data.
7. R for dummies.
8. Data exploration and visualization.
9. False discovery rate.

Introduction to RNA structure and Dynamics

Teacher: Prof. Bussi
Amount of frontal teaching: 6 hours
Description:
The course provides an introduction to RNA structure and dynamics. The topics will be covered from an historical and technical point of view. Student will be introduced step by step to secondary structure prediction methods and chemical probing experiments and also to structural molecular biology methods (x-ray diffraction and nuclear magnetic resonance).

The covered topics include:

1. Hierarchical structure annotation (primary/secondary/tertiary).
2. RNA chemical structure.
3. RNA secondary and tertiary structure.
4. Molecular dynamics simulations and integration of simulations and experiments for RNA systems.

Genomics and genetics of emerging model species

Teacher: Dr. Ferrante
Amount of frontal teaching: 10 hours
Description:
The course aims at introducing the genomics and the genetics used when a researcher needs to establish an unknown organisms to the level of a model organisms and perform molecular studies. Students will be introduced to the processes behind the establishment of a new organismal model for functional genomics studies.

The topics treated include:

1. Emerging model organisms.
2. Genomics and genetics techniques and why they matter.
3. Life cycles.
4. Genomics resources for an emerging model species.
5. The genome and the transcriptome.
6. Reverse genetics.
7. Sex determination, sex reversal.

Evolution and development of macroglia

Teacher: Carmen Falcone
Amount of frontal teaching: about 30 hours
Description: The course will provide a general introduction on the functions of macroglia (i.e. astrocytes and oligodendrocytes) in health and disease, and will then focus on the evolution and development of such cells across vertebrates, with special attention to mammals. It will finally provide an overview of the state-of-the-art techniques used in the glial biology field. This course will also contribute to swift the neurono-centric view of brain development and evolution, to a more comprehensive neuro-glia perspective.

This course will include the following topics:

1. Introduction on astrocytes and oligodendrocytes cell functions in mammals
2. The origin of glia: insights from invertebrates, radial glia cells and ependymal cells
3. Astrocytes’ evolution across vertebrates: anatomy, morphology, transcriptome, and functions in health and disease

4. Astrocytes' development in mammals: molecular mechanisms (special focus on mouse and human)
5. Oligodendrocytes' evolution across vertebrates: anatomy, morphology, transcriptome, and functions in health and disease
6. Oligodendrocytes' development in mammals: molecular mechanisms (special focus on mouse and human)
7. Overview on the state-of-the-art techniques used in glial biology

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Methodological courses

[these courses are meant for all students of the Neuroscience Area that are interested in these specific topics]

Scientific programming: A crash course

Teacher: Jon Carr (external teacher)
Amount of frontal teaching: about 14 h

Description:
This course is intended for PhDs who have little to no experience with coding; however, it should also be suitable for people who've done a bit of coding before but who could nevertheless benefit from a refresher course.

We'll start with Python, which is a general-purpose language that is very friendly for beginners. Then, we will switch to the R language, which is pretty-much essential for doing modern statistics. Time permitting, we might also touch on JavaScript too, which is becoming increasingly important as we begin to run more and more experiments online. Finally, I will wrap up the course by discussing some more theoretical issues, such as how good programming practices can support open-science and reproducibility efforts.

The course will consist of eight 2-hour classes with the second hour dedicated to practical activities. In addition to this, you should do several hours of self-directed practice per week on a personal project of your choice. The following schedule is indicative to what I would like to cover in each class; however, I will adapt the material to the needs and pacing of the students.

1. Programming basics
  - What is programming?
  - Interpreter vs. scripting

- Core data types (ints, floats, strings, lists, dicts...)
- Conditional statements
- Loops
- Understanding errors

2. Functions and objects
   - Abstraction in computing
   - Good code organization
   - Built-in functions and objects
   - Defining a function
   - Defining an object

3. Handling files and textual data
   - Reading and writing data
   - Data formats: plain text, CSV, JSON
   - String parsing and manipulation
   - Regular expressions

4. Building experiments
   - Installing and managing packages
   - PsychoPy and how to read an API
   - Coding up a basic experiment

5. The R language
   - Mapping what we've already learned onto R
   - Vectorization
   - Data frames
   - Manipulating data

6. Basic analysis and plotting in R
   - Importing/exporting data
   - Built-in functions
   - Plotting graphs

7. Web programming
   - HTML, CSS, JavaScript
   - Client-side programming with jsPsych
   - Server-side programming
   - Online platforms

8. Good scientific practices
   - Open source / open-access
   - Reproducibility
   - Version control

- Virtual environments
- Documentation
- Code review

Data Modelling

Teacher: Davide Crepaldi
Amount of frontal teaching: about 16 h
NOTE: this is a rather advanced course about statistics, specifically meant for cognitive science.

Description:
In this course we will go together over a set of data from a fairly standard behavioural experiment in human cognition research, trying to extract reliable inferences from it. If it sounds very general, that's exactly it—you can think of this course as a series of hands-on meetings on what is our everyday task as scientists, that is, transforming experimental data into solid science (which is somewhat -- but not perfectly, be advised -- correlated to have a publishable paper, or get a PhD).

The initial example data will come from human cognition, but the process of extracting meaning from these data is general enough that the course will be be useful for people with a different expertise (e.g., animal electrophysiology, circuit analysis). In fact, people who run different kind of experiments are super-welcome — the more diverse the kind of data will have to deal with, the more useful (and fun!) the course will be.

We'll cover: (i) descriptive statistics; (ii) graphical exploration; (iii) data transformation (e.g., standardisation, centering); (iv) modelling; (v) validation and prediction. We'll do our best to touch on all of these issues, but the pace of the course will be determined by you -- your proficiency on the one hand and your curiosity on the other.

Much attention will be given to monitoring our own work on issues such as data overstretch, p hacking, and other bad research practices. Yes, there will be a touch (sometimes a heavy touch) of open and reproducible science.

The software I'll use for the course is R. There's no commitment in this statement however, and students with advanced background are most welcome to explore other options (Python is a very good one).

Methodologies of fMRI and TMS

Teacher: Sandra Arbula (postdoc in Rumiati's lab) Marco Zanon (lab technician at CNS) and Domenica Bueti (Prof.)

Amount of frontal teaching: about 14 h

Description:

Magnetic Resonance Imaging (MRI) and Transcranial Magnetic Stimulation (TMS) are common research tools in neuroscience used to investigate the neural correlates of human cognitive functions.

The first part of the course will focus on the characterization and analysis of MRI data with a special emphasis on functional MRI (fMRI). The course will be comprised of a combination of lectures and hand

Science pipelines. To be able to follow the hands-on tutorials, please download and install all the required software and data as described in the tutorial here.

The course will be held in presence and for those that cannot assist, remotely on zoom. Room number and zoom link will be indicated on the calendar.For those interested in taking the course, please write me an email (saarbul@sissa.it) letting me know in what modality you prefer to follow the course.

Topics covered:

1. The Physics of MRI (basic principles)
2. From Neurons to BOLD
3. Design and Efficiency
4. Preprocessing (hands-on)
5. General Linear Model (First and Second Level Analysis – hands-on)
6. Advanced fMRI Analysis (MVPA, pRF mapping – lectures and tutorials)

The TMS course will be held by Marco Zanon. The two lectures will cover

1. theoretical (basic principles, temporal and spatial resolution)
2. practical (TMS protocols) issues.

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Statistics

Teacher: Michele Allegra (external teacher, University of Padova)
Amount of frontal teaching:

Description:
This is a course about basic statistics, taught by an external teacher.

1. Statistical Testing I.
Null hypothesis; type I errors, sensitivity; p-values. Examples with parametric statistics: Z test, T test, chi2 test;

2. Statistical Testing II.
Non-parametric statistics: Kolmogorov-Smirnov test, Wilcoxon test. Permutation methods.

3. Statistical Testing III.
Alternative hypothesis; type II errors, power. Effect size: difference family (Cohen's d, Hedges' g), correlation family (R2). Confidence intervals. The bootstrap method.

4. Statistical Testing IV. *Multiple testing. Controlling for familywise error rate (Bonferroni); Controlling for false discovery rate (Benjamini-Hochberg). False positive risk. Notes on cluster inference.*

5. Parameter inference I. *Estimators and their properties; maximum likelihood estimation. Simple Linear regression.*

6. Linear models. *Multiple linear regression. Notes on nonlinear regression and logistic regression*

7. Linear models. *ANOVA with one and two factors, F-test.*

8. Reproducibility. *The reproducibility crisis. Bad practice in statistical analysis: p-hacking; double-dipping, publication bias.*

Scientific writing and communication

Teacher: Valentina Parma (external teacher, University of Paris)

Period: one week in the period Feb. 13-24
Amount of frontal teaching:

Description:
This is a course about scientific writing and preparing presentations.
[details still to be added]

Technical courses

[these courses are meant for all students of the Neuroscience Area that are interested in these specific topics]

Basic microscopy, fluorescence microscopy and immunofluorescence

Teacher: Micaela Grandolfo

Amount of frontal teaching: 20 h

Description:

Basic Microscopy: The "basic microscopy" course aims to give students some basic information necessary to understand what a microscope is made of, how it works and how to use it. The intent is to lead the student to know how to choose the microscope most suitable for the type of experiment he/she has to carry out, and to know what equipment it must have and, above all, which objective to use to achieve the desired result. For this purpose the concepts of Numerical Aperture, Resolution, Working Distance, Depth of focus, Point Spread Function, Rayleigh Criterion and Nyquist Criterion are studied in depth. After the lectures are planned practice sessions

Fluorescence Microscopy: The "fluorescence microscopy" course starts from the explanation of the phenomenon of fluorescence to arrive at how it is used in microscopy. The student is explained how a fluorescence microscope works, what its components are, how they are made and how to read the characteristics of the different types of filters. The features of the fluorophores are also studied in depth to allow the student to choose the most suitable one for his/her experiment, to combine them correctly in a multiple staining and, above all, to avoid low-performing fluorophores very present on the market. The second part of this course is entirely dedicated to confocal microscopy and all the peculiarities of this technique are deepened: from the type of light source, to the use of the pinhole, to the functioning of PMTs and sampling in z; deepening how much the regulation of these parameters affect the quality of the final image. After the lectures are planned practice session

Immunofluorescence: In this course all aspects that lead to a good immunofluorescence experiment will be investigated with particular attention to the optimization of the signal-to-noise ratio. We will deal with the various types of fixation, permeabilization, blocking of non-specific signals, analyzing several explanatory examples of how to recognize and avoid possible artifacts due to the use of an incorrect protocol.

Introduction to Electronics - Theory

Teacher: Erik Zorzin

Amount of frontal teaching: 20 h

Description: In this course you will be guided through a rational pathway touching different topics in the field of electronics. By following a theoretical approach with practical examples connected to the scientific laboratory environment, the course is open to everybody who aims to understand and take advantage of electronics as a tool for their research. Some knowledge of mathematics is recommended (algebra, calculus), as it will be necessary to develop the framework that will be explained in the class. There will be an introduction to vectors, complex numbers and Fourier analysis to be able to manage electronic signals and filters. Then there will be a reminder of physics about the fundamental electronics components (resistors, capacitors, inductors and semiconductors). After having developed a theoretical basis, we will move into the real world of electronics: analysing circuits in both analog and digital domain, with examples on amplifiers, CPUs, neural networks and methods to mitigate the electromagnetic noise disturbance when working with real laboratory measurement instrumentation.

The video recordings of the lessons are available online here.

This course is complementary to the "Introduction to Electronics - Practice " course.

Introduction to Electronics - Practice

Teacher: Erik Zorzin

Amount of frontal teaching: 10 h

Description: This course is complementary to the "Introduction to Electronics - Theory" course. It will make use of real electronic components, such as resistors, capacitors, operational amplifiers and an Arduino UNO compatible board. Some experiments will be done according to the topics of the theoretical course, so it will be possible to put hands on real circuits.

A laptop PC of yours (Windows, Mac or Linux) is necessary, with the following open source software installed:

- Arduino
- Processing
- Kicad

as well as other software resources you can find here.

All other materials will be provided by SISSA.

The video recordings of the lessons are available online here.

Solidworks and rapid prototyping

Teacher: Marco Gigante

Amount of frontal teaching: about 12 h

Description: Learn the basics of CAD and Solidworks and start using these softwares in the rapid prototyping. The importance of these tools is growing up, with the new technology making up 3D printers an integral part of our world.

In science, "out of standards" experiments are getting really common. Together with the increasing complexity of the scientific setups, it is very useful to get a new designing approach: building high precision apparatuses from scratch or using available libraries. If you are interested, join the SISSA Solidworks & Rapid Prototyping course and you will learn:

1. Basics of 3D CAD;
2. Solidworks, basics of a parametric CAD;
3. Solidworks 2D Sketches and Relations;
4. Solidworks Parts;
5. Solidworks Assemblies;
6. Solidworks Drawings;
7. Fundaments of Rapid Prototyping;
8. Fundamentals of 3D Printing;
9. File preparation for 3D printing.
10. 3D printing materials

Basic Techniques in Cell and Tissue Culture

Teacher: Federica Ferrero

Amount of frontal teaching: 4 hours

Description:
The short course is an overview on the procedures to maintain cells in culture, basic protocols and needed equipment. Part of the course is a practical demonstration in the SISSA cell culture facility to review the basic rules for working, waste disposal and care of equipment.

The course focuses on the following topics:

1. introduction to cell types and characteristics
2. techniques and requirements needed for sterile working
3. recognition of the most common contaminants
4. startup and routine workflow of a cell culture

Organotypic and Dissociated Primary Cultures

Teacher: Beatrice Pastore

Amount of frontal teaching: 4 hours

Description:
During this course will be shortly explained the techniques used to obtain primary cultures of nervous tissue. Part of the course is a practical demonstration in the SISSA cell culture facility.

The course covers the following topics:

1. the methods that permit to obtain dissociated neuronal cultures, starting from the source of the tissue, the enzymes used for the dissociation, the substrates used for the adhesion, and the culture media.
2. what is an organotypic culture, how to prepare and maintain this kind of cultures for long time
3. when it is better to prefer an organotypic to a dissociated cultures
4. brief introduction to the current legislation regulating the use of the laboratory animals

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Introduction to the Human Cognitive Neuroscience Laboratories

Teacher: Marco Zanon

Amount of frontal teaching: 2 h

Description: The course is an introduction to experimental activities carried out in the Human Cognitive Neuroscience Laboratories (aka Human Labs). The course will describe the laboratories, the available techniques and the guidelines and good practices for carrying out experiments with volunteers.

Furthermore, the course aims to introduce the online systems for booking a lab (see Instrument Booking) and for recruiting the participants and scheduling the experimental sessions (Sona Participant Management System).

In the course the following techniques to investigate the brain in humans will be presented:

1. Transcranial Magnetic Stimulation (TMS);
2. Electroencephalography (EEG);
3. Eye-tracking and pupillometry;
4. Recording of biopotentials (EMG, ECG, EDA):
5. Psychophysics and methods to investigate behavior.

Introduction to the Molecular Biology Laboratories

Teacher: Christina Vlachouli and Helena Krmac

Amount of frontal teaching: 2 hours (frontal teaching and practical session)

Description: The aim of this two-hour module is to familiarize new students with the spaces and instruments present in the common Molecular Biology Laboratories in SISSA. More specifically:

1. to get new operators acquainted with the equipment and instrumentation present in the labs and briefly highlight the possibilities offered by the relevant technologies
2. to point out the guidelines and good practices to be adopted when working in a molecular biology laboratory
3. to introduce operators to the online system for booking an instrument
4. to train operators, during the practical demonstration, to the correct and safe use of common instruments like centrifuges, the sonicator, the cold room etc.

Introduction to IT services and IT Security

Teacher: Andrea Tomicich

Amount of frontal teaching: 2 h

Description: Divided in two parts, the aim of this course is to introduce students to ITCS services and IT security. The first part will explain how IT services (Helpdesk, Printers, plotters, network, email, etc) are organized in Sissa,

The second part is focusing on security. Password importance, wrong behavior, risks of phishing and ransomware, etc.

In closure, a very brief introduction to open source softwares, benefits, pros and cons.