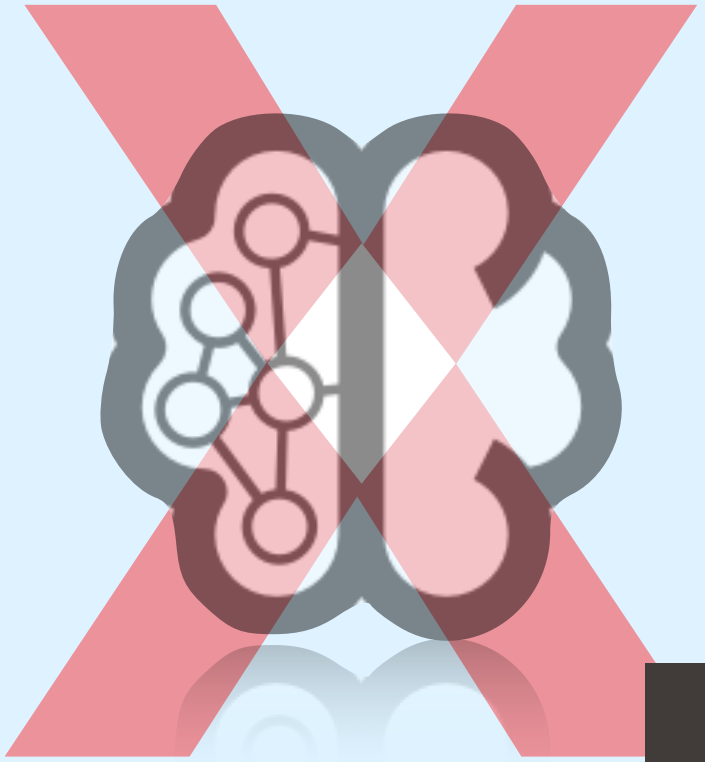
EPFL



Master in Neuro-X

Dimitri Van De Ville

Section Neuro-X

February 28, 2024

SV STI IC

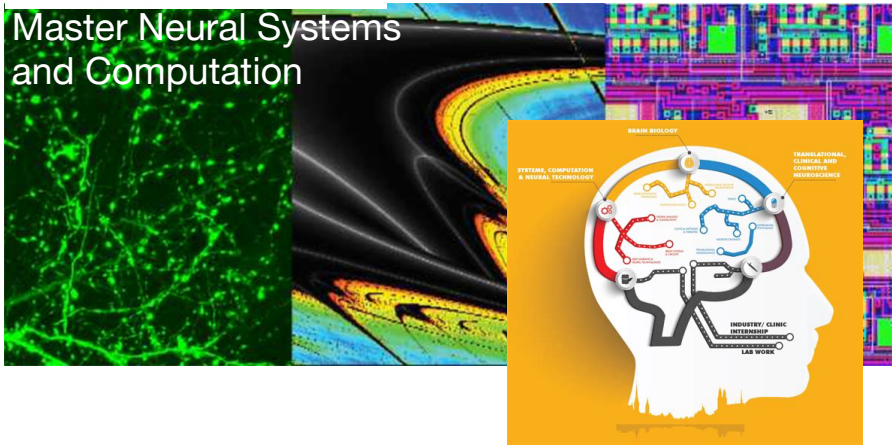
École polytechnique fédérale de Lausanne

Why Master in Neuro-X at EPFL?

- Increasing number of Master programs in neuroengineering at academic institutions

ETH zürich

Master Neural Systems and Computation



Elite Master of Science in Neuroengineering

Imperial College London

MRes in Neurotechnology

Why Master in Neuro-X at EPFL?

- EPFL has strong reputation in neuro-related research activities
- Educate future professionals in the neuro field
  - From *research* to *applications*
  - In industry, healthcare, and academia
- Neuro-X brings together foundational disciplines that shape brain research
  - Science, Engineering, and Computation

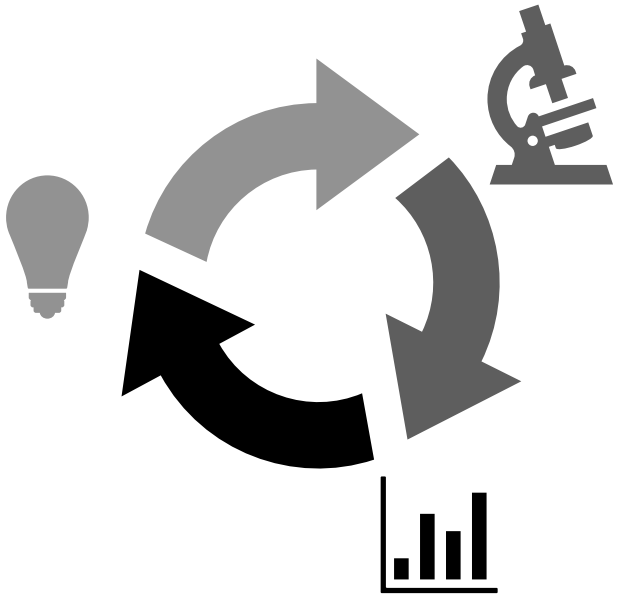
Master in Neuro-X

Science
Engineering
Computation

  - X=intersection: being at the crossroads of disciplines
  - X=eXpansion: exploiting synergies by combining disciplines
  - X=eXploration: explore horizons of what is possible today and tomorrow

Pillars of the Master in Neuro-X

- Discoveries and innovation are driven by the virtuous circle of
  - Curiosity by questioning current knowledge ~ science
  - Tools to pursue measures to test or explore ~ engineering
  - Analysis of measures to extract information ~ computation



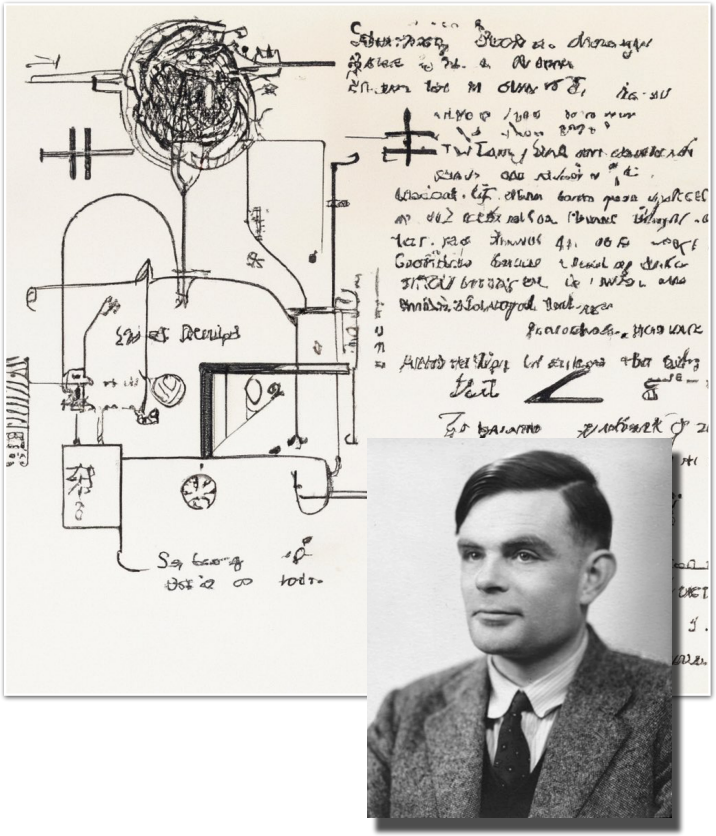
Santiago Ramon y Cajal, 1852-1934

Camillo Golgi, 1843-1926

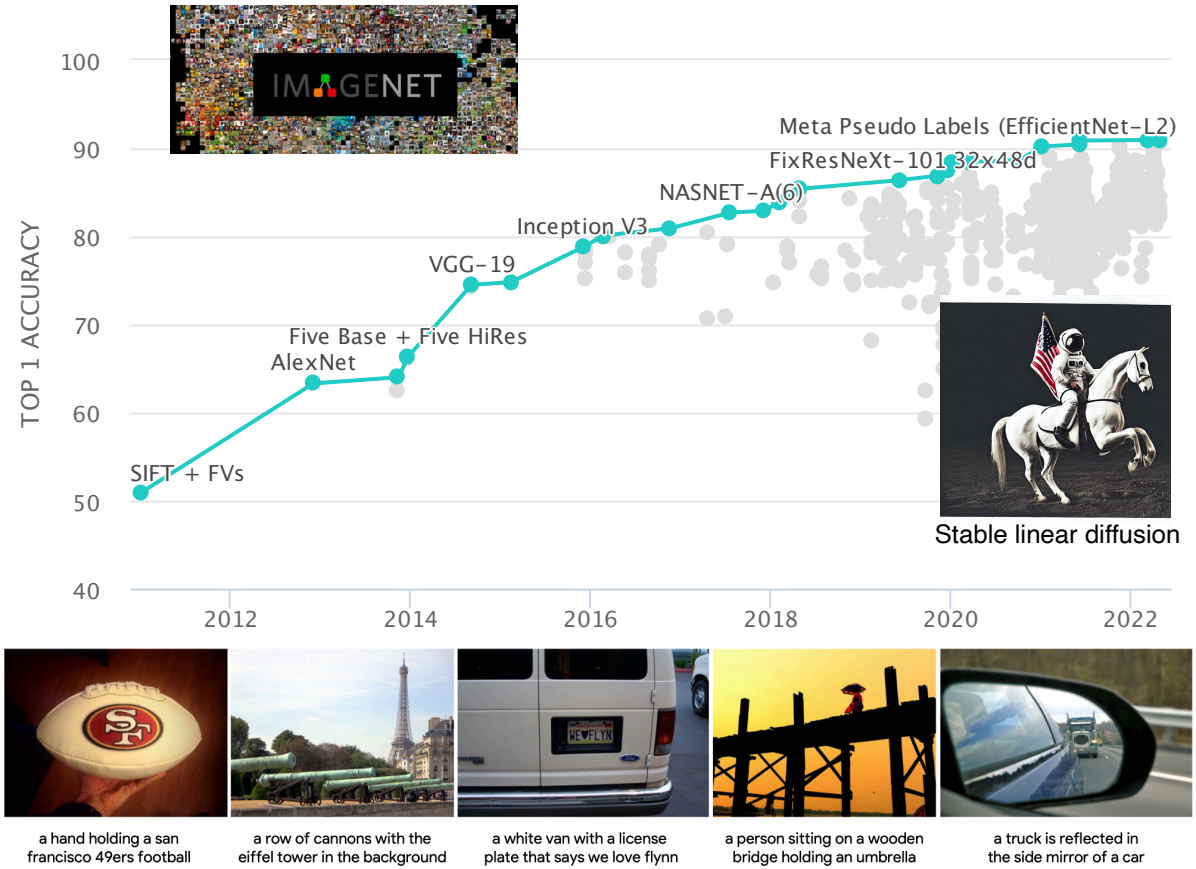
[De Carlos, Borrell, *Brain Research Reviews*, 2007]

Inspiration for brain-like computing

- Computer science learns from neuroscience and vice versa



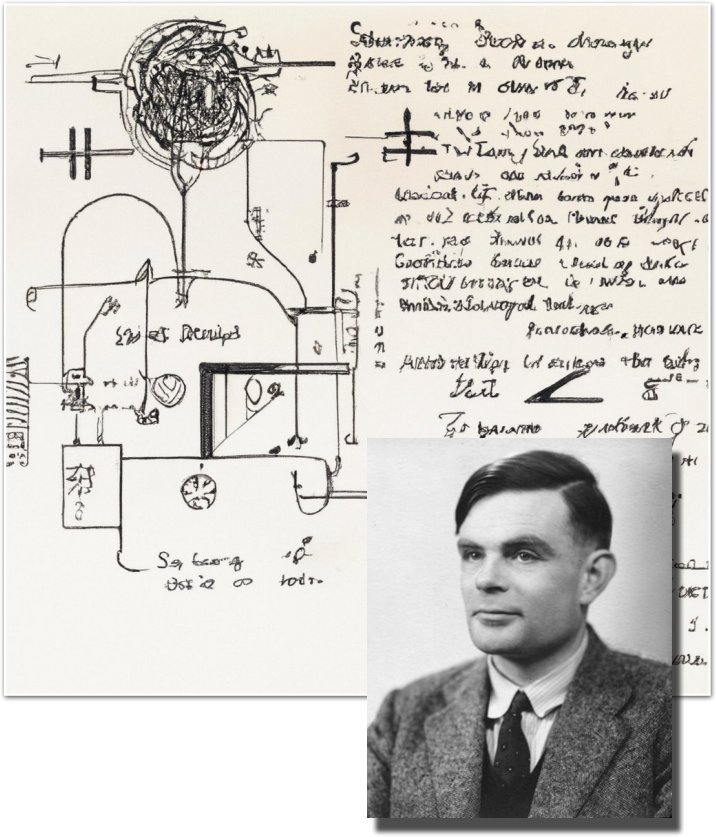
Alan Turing
1912-1954



[https://paperswithcode.com/sota/image-classification-on-imagenet
Yu et al, arXiv 2205.01917, 2022]

Inspiration for brain-like computing

- Computer science learns from neuroscience and vice versa



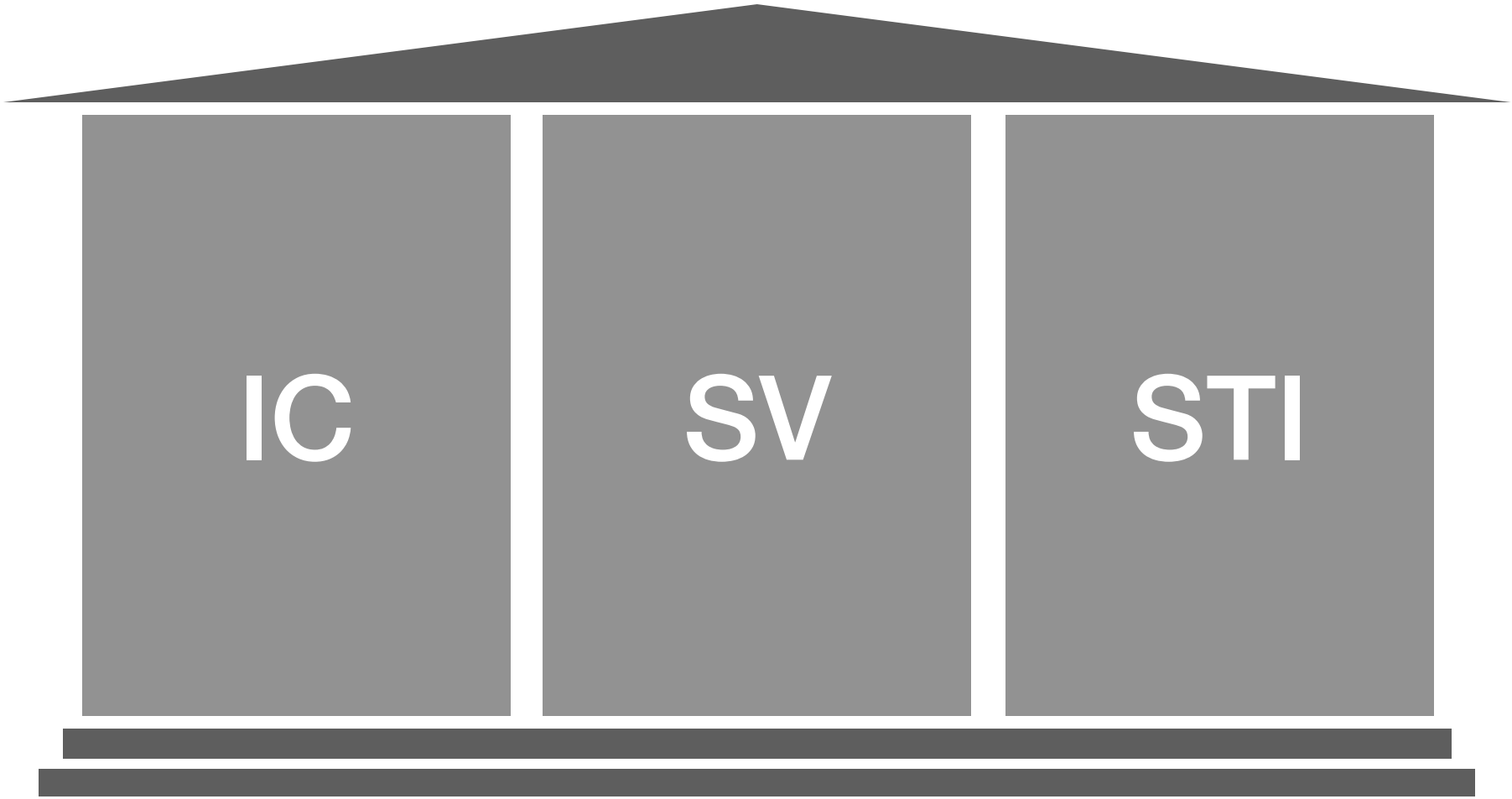
Alan Turing
1912-1954

Why would students opt for the Master in Neuro-X program?

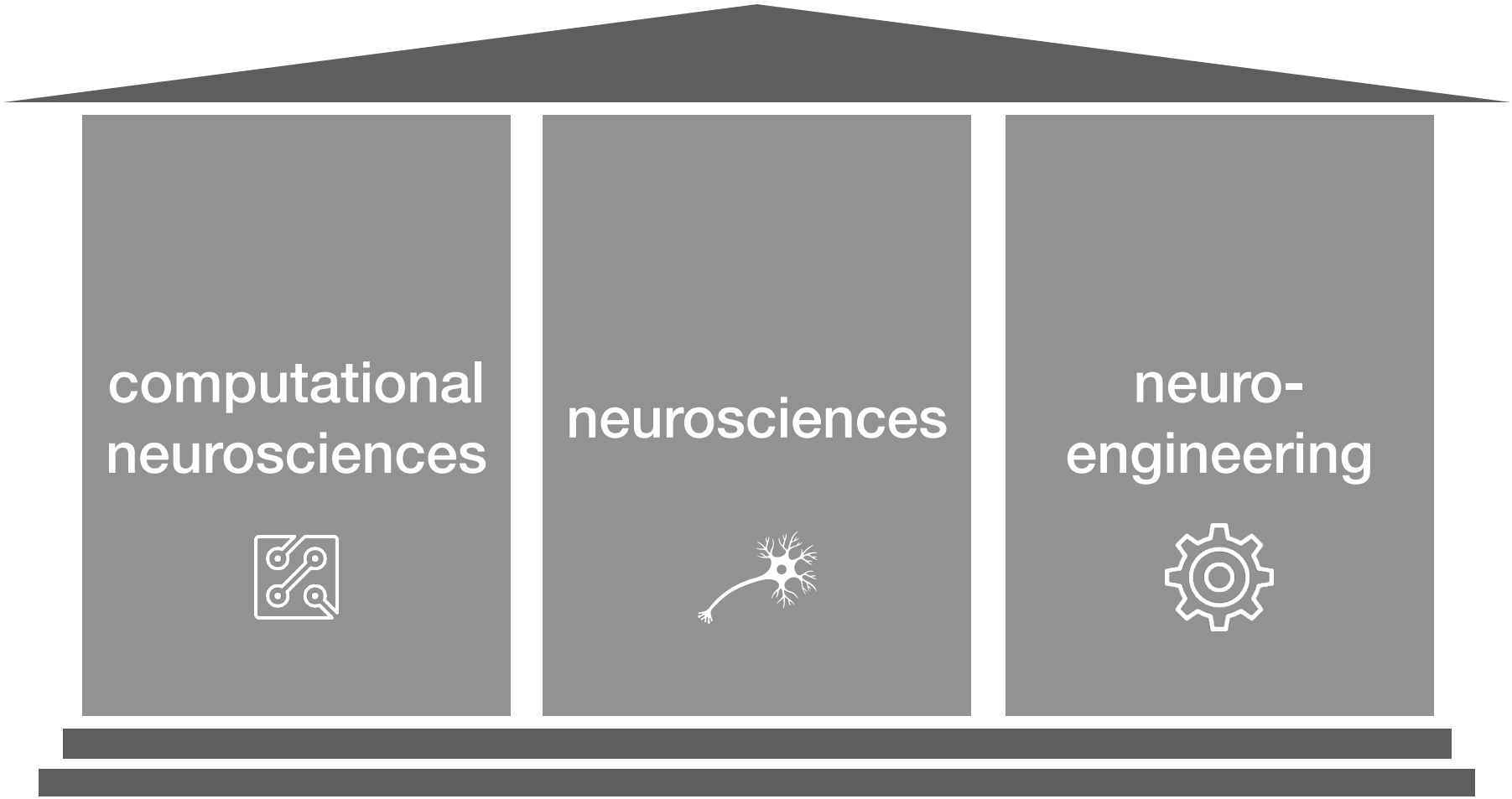
There are several reasons why students might opt for a Master's program in Neuro-X, such as:

1. Interdisciplinary approach: Neuro-X is an interdisciplinary field that combines neuroscience, engineering, and other related fields. Students interested in exploring the intersection of different disciplines and applying a diverse skill set to solve complex problems may find this program appealing.
2. Growing demand: There is a growing demand for professionals with expertise in Neuro-X. As technology continues to advance, there is an increasing need for individuals who can develop new tools and techniques to better understand the brain and nervous system and improve human health.
3. Career opportunities: Graduates of a Master's program in Neuro-X may pursue a wide range of career opportunities in academia, industry, and government. These include roles in research and development, product design, clinical applications, and more.
4. Advancing scientific knowledge: Neuro-X is an exciting and rapidly evolving field, with many unanswered questions about the brain and nervous system. Students interested in advancing scientific knowledge and contributing to breakthroughs in neuroscience may find this program rewarding.
5. Personal interest: Finally, many students may opt for a Master's program in Neuro-X simply because they have a personal interest in the field. The study of the brain and nervous system is fascinating to many people, and a Master's program in Neuro-X provides an opportunity to explore this interest in greater depth.

Affiliated to three faculties



Core disciplines

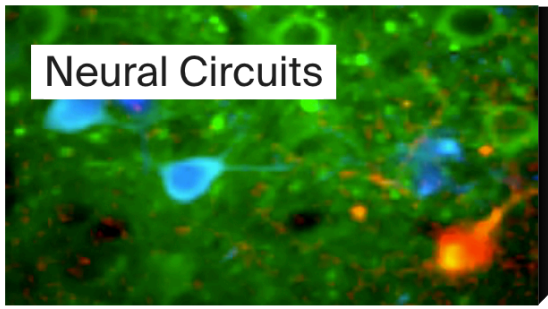


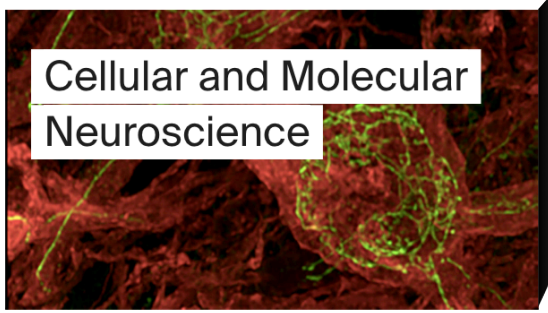
Neurosciences

computational neurosciences

neurosciences

neuro-engineering





5
Neuroscience:
Cellular and Circuit Mechanisms
(**Petersen**/Crochet)
BIO-482

5
Neuroscience:
From Molecular Mechanisms to Disease
(**Graeff**/Schneider/Lashual)
BIO-480

5
Neuroscience:
Behavior and Cognition
(Sandi/Blanke/Herzog)
BIO-483

Computational neurosciences

computational neurosciences | neurosciences | neuro-engineering

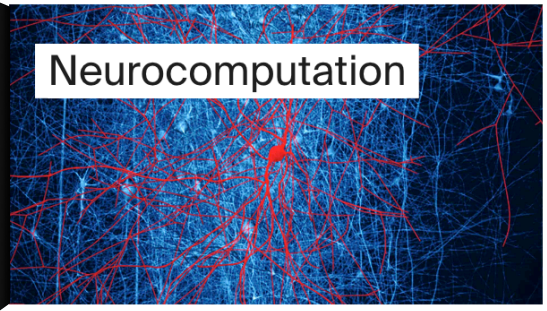
8
Machine Learning
(Jaggi/Flammarion)
CS-433

5
Brain-like computation and intelligence
(Matthis A/Schrimpf)
NX-414

NEW

5
Computational neuroscience: Neuronal Dynamics
(Gerstner)
NX-465

UPDATED



Neuroengineering

computational neurosciences

neurosciences

neuro-engineering

Signals

Interfaces

Translation

NEW

Neural Signals and Signal Processing (**Van De Ville**/Micera) NX-421 — 6

NEW

Neural Interfaces (**Lacour**/Shoaran) NX-422 — 6

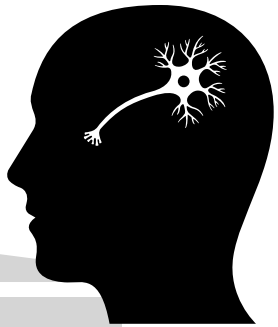
NEW

Translational Neuroengineering (**Hummel**/Blanke/Micera/Courtine) NX-423 — 6

Core courses (31 ECTS)

	computational neurosciences	neurosciences	neuro-engineering
Fall	8 Machine Learning (**Jaggi**/Flammarion) CS-433	5 Neuroscience: Cellular and Circuit Mechanisms (**Petersen**/Crochet) BIO-482	6 Neural Signals and Signal Processing (**Van De Ville**/Micera) NX-421
Spring	5 Brain-like computation and intelligence (**Matthis A**/Schrimpf) NX-414	5 Neuroscience: From Molecular Mechanisms to Disease (**Graeff**/Schneider/Lashuel) BIO-480	6 Neural Interfaces (**Lacour**/Shoaran) NX-422
	5 Computational neuroscience: Neuronal Dynamics (**Gerstner**) NX-465	5 Neuroscience: Behavior and Cognition (Sandi/Blanke/Herzog) BIO-483	6 Translational Neuroengineering (**Hummel**/Blanke/Micera/ Courtine) NX-423

Neuroscience focus



computational neurosciences	neurosciences	neuro-engineering
Machine Learning (**Jaggi**/Flammarion) CS-433	5 Neuroscience: Cellular and Circuit Mechanisms (**Petersen**/Crochet) BIO-482	6 Neural Signals and Signal Processing (**Van De Ville**/Micera) NX-421
5 Brain-like computation and intelligence (**Matthis A**/Schrimpf) NX-414	5 Neuroscience: From Molecular Mechanisms to Disease (**Graeff**/Schneider/Lashuel) BIO-480	Neural Interfaces (**Lacour**/Shoaran) NX-422
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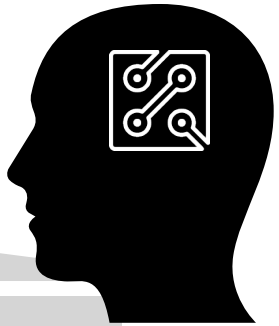
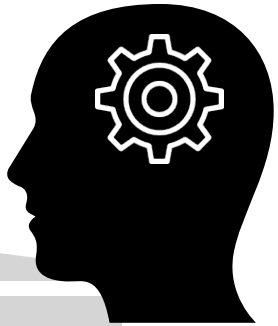
Computational focus



computational neurosciences	neurosciences	neuro-engineering
Machine Learning (**Jaggi**/Flammarion) CS-433 (8)	Neuroscience: Cellular and Circuit Mechanisms (**Petersen**/Crochet) BIO-482 (5)	Neural Signals and Signal Processing (**Van De Ville**/Micera) NX-421 (6)
Brain-like computation and intelligence (**Matthis A**/Schrimpf) NX-414 (5)	Neuroscience: From Molecular Mechanisms to Disease (**Graeff**/Schneider/Lashuel) BIO-480	Neural Interfaces (**Lacour**/Shoaran) NX-422
Computational neuroscience: Neuronal Dynamics (**Gerstner**) NX-465 (5)	Neuroscience: Behavior and Cognition (Sandi/Blanke/Herzog) BIO-483	Translational Neuroengineering (**Hummel**/Blanke/Micera/Courtine) NX-423 (6)

Neuroengineering focus



computational neurosciences	neurosciences	neuro-engineering
8 Machine Learning (**Jaggi**/Flammarion) CS-433	Neuroscience: Cellular and Circuit Mechanisms (**Petersen**/Crochet) BIO-482	6 Neural Signals and Signal Processing (**Van De Ville**/Micera) NX-421
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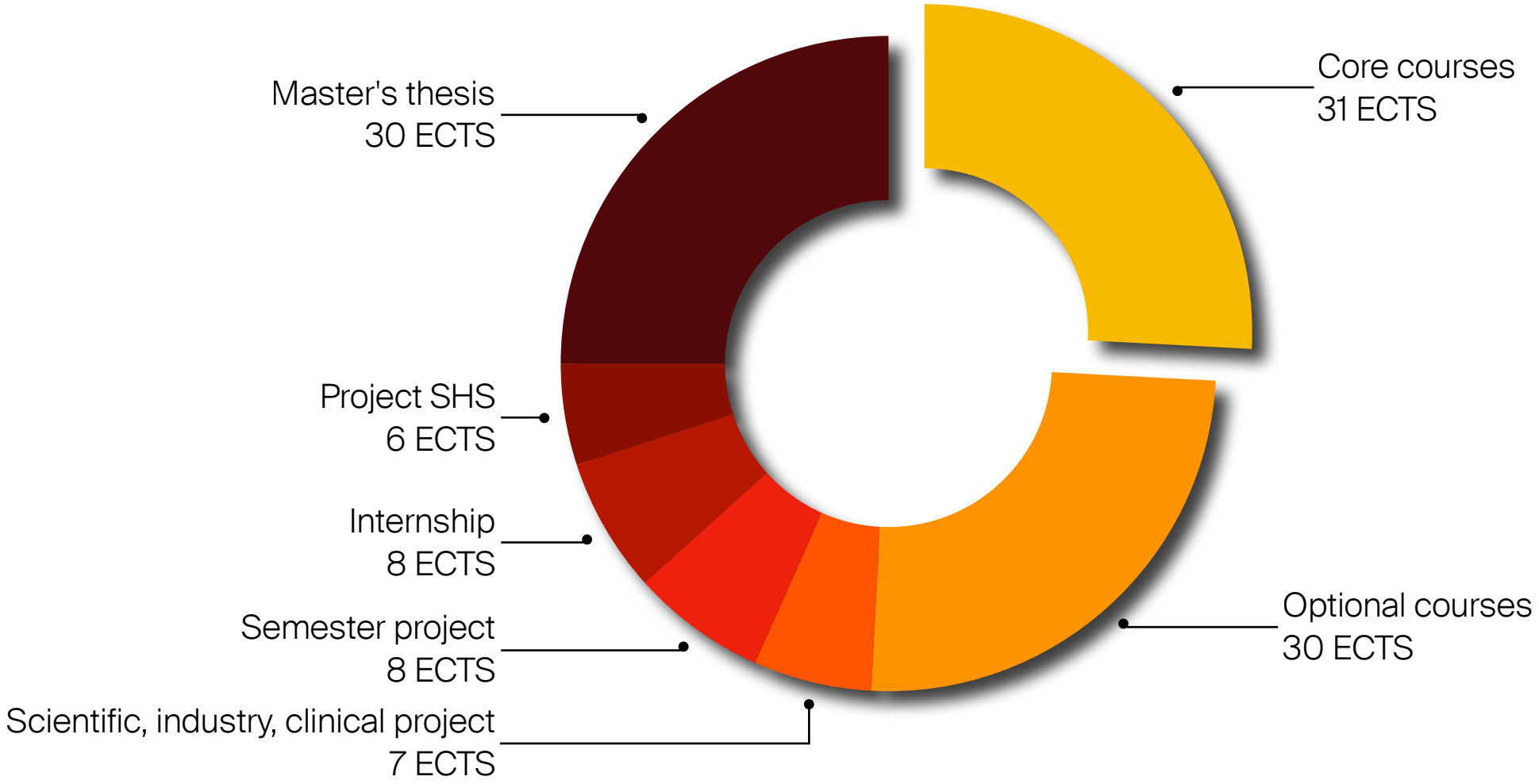
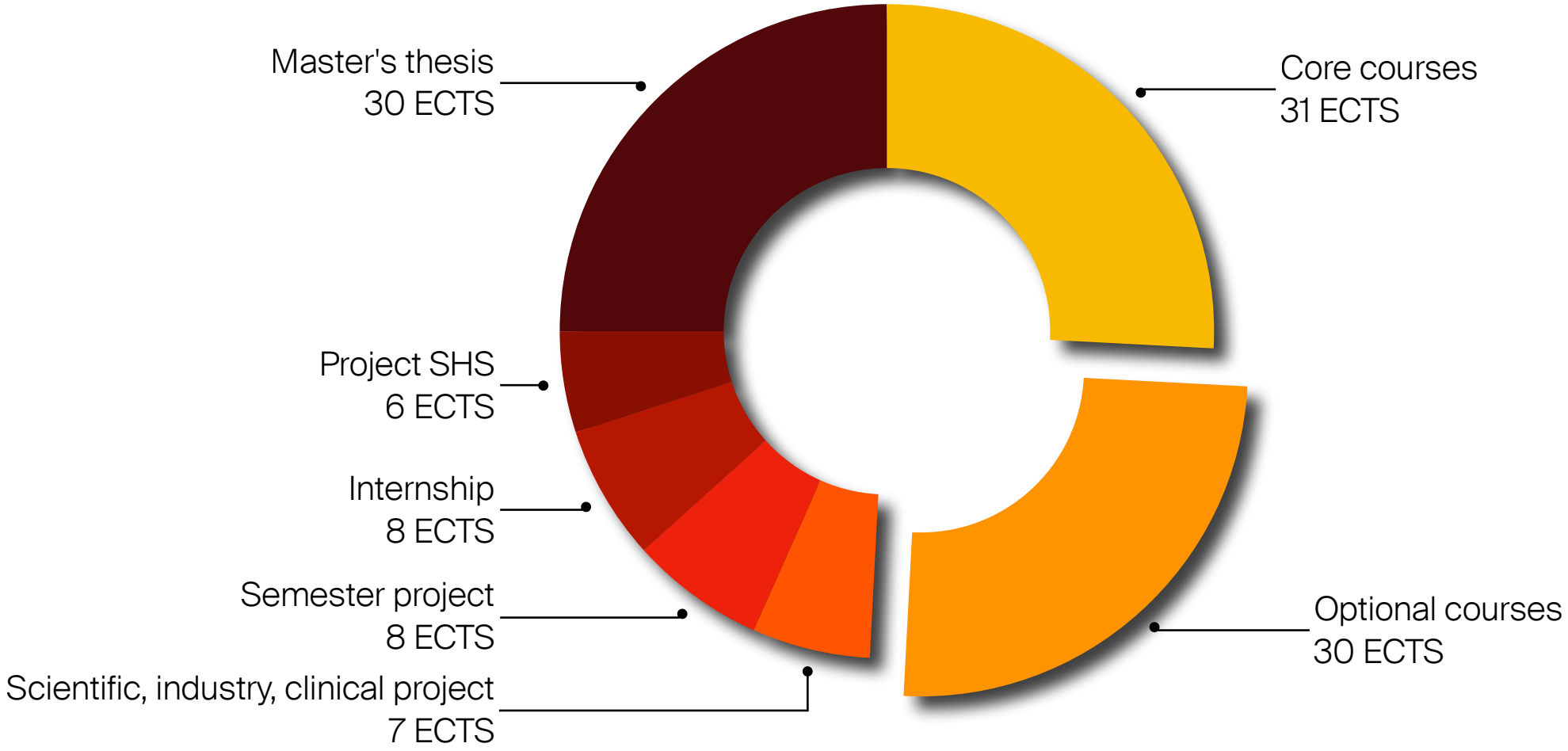
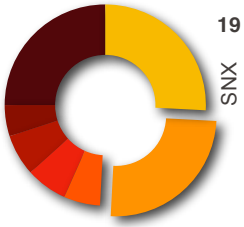
New Master in Neuro-X (120 ECTS)



New Master in Neuro-X (120 ECTS)

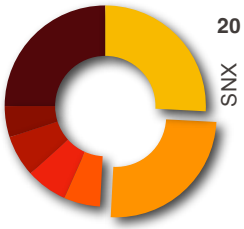


Area: Technology



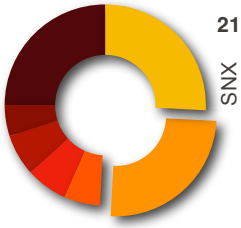
BIOENG-456	4	Controlling behavior in animals and robots (Ramdya)
MICRO-432	6	Computational motor control (Ijspeert)
MICRO-450	3	Basics of robotics for manipulation (Bouri)
MICRO-505	2	Organic and printed electronics (Briand/Subramanian)
MICRO-530	3	Nanotechnology (Boero/Brugger)
MICRO-553	3	Haptic human robot interfaces (Bouri)
MICRO-560	2	BioMEMS (–)
EE-320	3	Analog IC design (Shoaran)
EE-511	3	Sensors in medical instrumentation (Chételat/Ionescu)
EE-515	3	Fundamentals of biosensors and electronic chips (Guiducci)
EE-517	3	Bio-nano-chip design (Carrara)
EE-519	3	Bioelectronics and biomedical microelectronics (Schmid)
CS-444	4	Virtual reality (Boulic)
CS-472	6	Design technologies for integrated systems (De Micheli)
MSE-341	3	Sustainability and materials (Abitbol)

Area: Data Science and Machine Learning



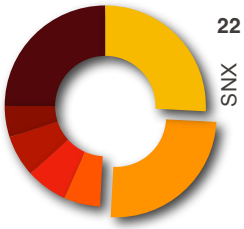
CS-401	8	Applied data analysis (West)
CS-421	6	Machine learning for behavioral data (Käser)
CS-431	6	Introduction to natural language processing (Chappelier/Rajman/Bosselut)
CS-439	8	Optimization for machine learning (Jaggi/Flammarion)
CS-456	6	Deep reinforcement learning (Gulcehre)
CS-4XX	6	Learning in neural networks (Gerstner)
CS-502	6	Deep learning in biomedicine (Brbic)
CS-503	6	Visual intelligence: machines and minds (Zamir)
COM-502	6	Dynamical system theory for engineers (Thiran)
EE-556	6	Mathematics of data: from theory to computation (Cevher)
EE-559	4	Deep learning (Cavallaro)
BIO-449	4	Understanding statistics and experimental design (Herzog)
MICRO-455	4	Applied machine learning (Billard/Polydoros)
MATH-352	5	Causal thinking (Stensrud)
MATH-474	5	Applied biostatistics (Goldstein)
MGT-484	4	Applied probability and stochastic processes (Kuhn)

Area: Imaging and image analysis



BIO-443	3	Fundamentals of biophotonics (Radenovic)
BIOENG-445	3	Biomedical optics (Wagnieres)
MICRO-511	3	Image Processing I (Unser/Van De Ville)
MICRO-512	3	Image Processing II (Unser/Van De Ville/Sage/Liebling)
MICRO-561	3	Biomicroscopy I (Seitz)
MICRO-562	4	Biomicroscopy II (Altug + Seitz)
EE-451	4	Image analysis and pattern recognition (Thiran)
CS-440	6	Advanced computer graphics (Jakob)
CS-442	6	Computer vision (Fua)
PHYS-438	4	Fundamentals of biomedical imaging (Gruetter)

Area: Neuro-exploration

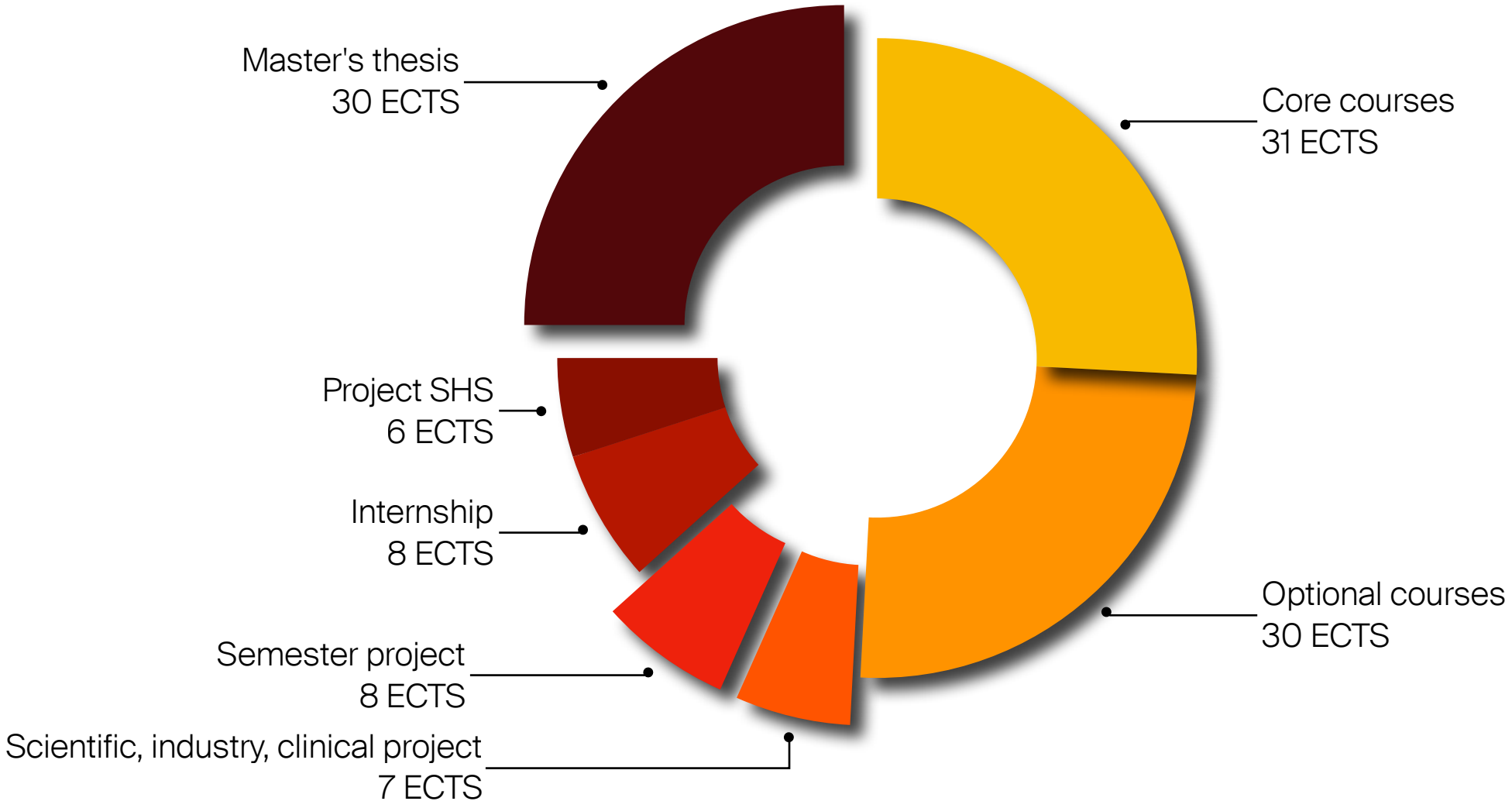


▪ NX-434	4	Computational psychiatry (Graeff)*
▪ NX-435	4	Systems neuroscience (Mathis M)
▪ NX-436	4	Advanced methods for human neuromodulation (Hummel F)
▪ NX-450	5	Computational neurosciences: biophysics (Romani)
▪ BIO-451	4	Scientific literature analysis in neuroscience (Sandi/McCabe)
▪ BIO-493	4	Scientific project design in integrative neurosciences (Petersen)
▪ BIO-487	4	Scientific project design in translational neurosciences (LeCoutre/Graeff)
▪ BIO-499	4	Neural circuits of motivated behaviors (Kochubey/Schneggenburger)
▪ DH-415	4	Ethics and law of AI (Rochel)
▪ NX-4xx	2	Regulatory, quality and clinical affairs (Medidee)

MedTech industry skills

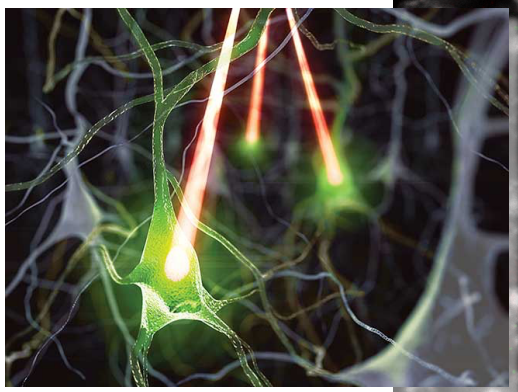
*=starting 2025-2026

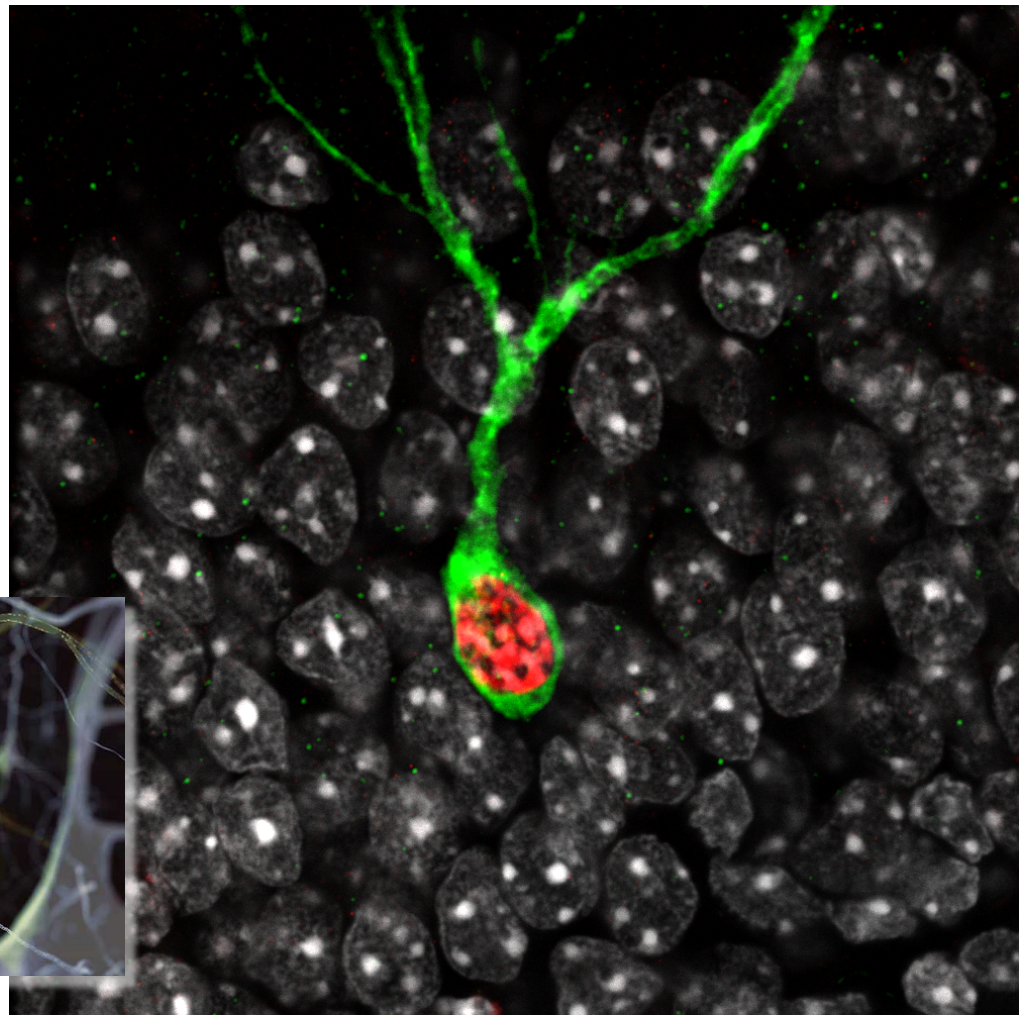
New Master in Neuro-X (120 ECTS)



Traumatic memory formation

- Identify preclinical molecular and cellular mechanisms with translational potential
- Technologies for
  - RNA sequencing
  - Epigenetic sequencing
  - Chromatin accessibility assays
  - Optogenetics to control neuronal function with light

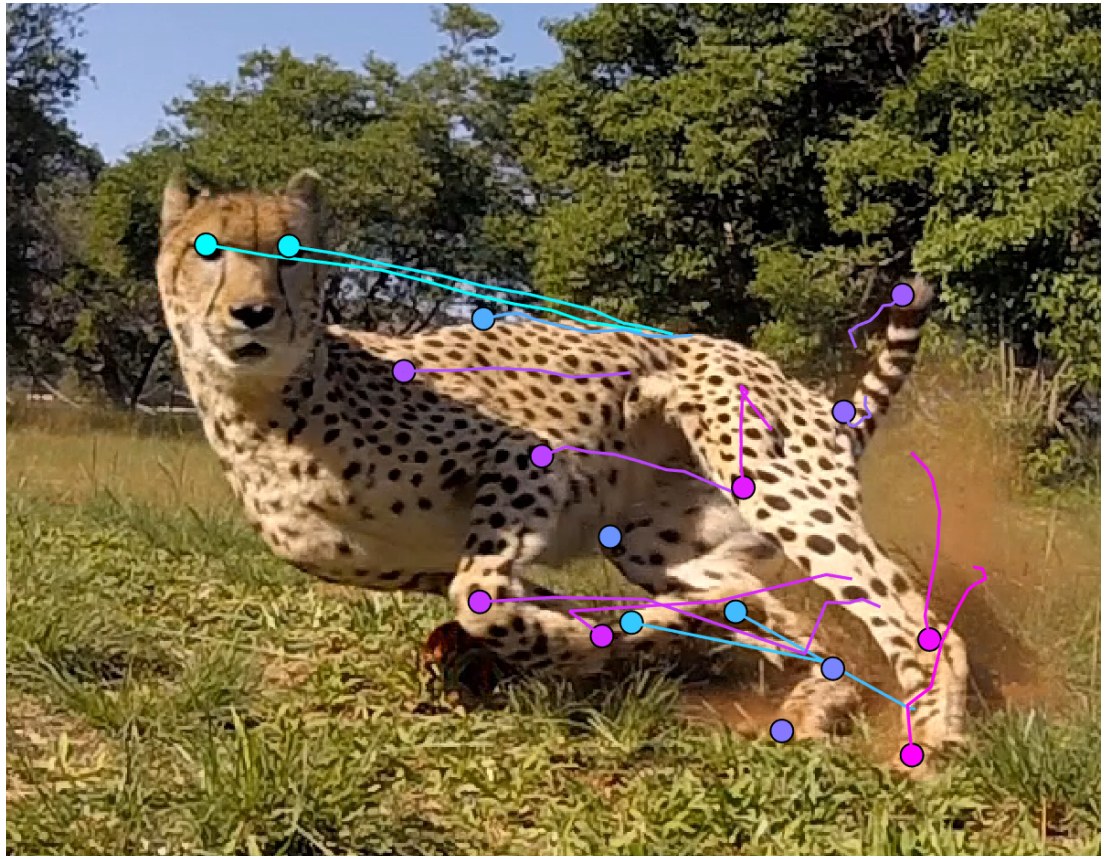




Lab J. Gräff

Deep learning for pose estimation

- How is brain controlling behavior and motor actions
- Inverse dynamics
  - Infer biomechanical torques from video material
  - 2D and 3D pose estimation
- Improve control of prostheses

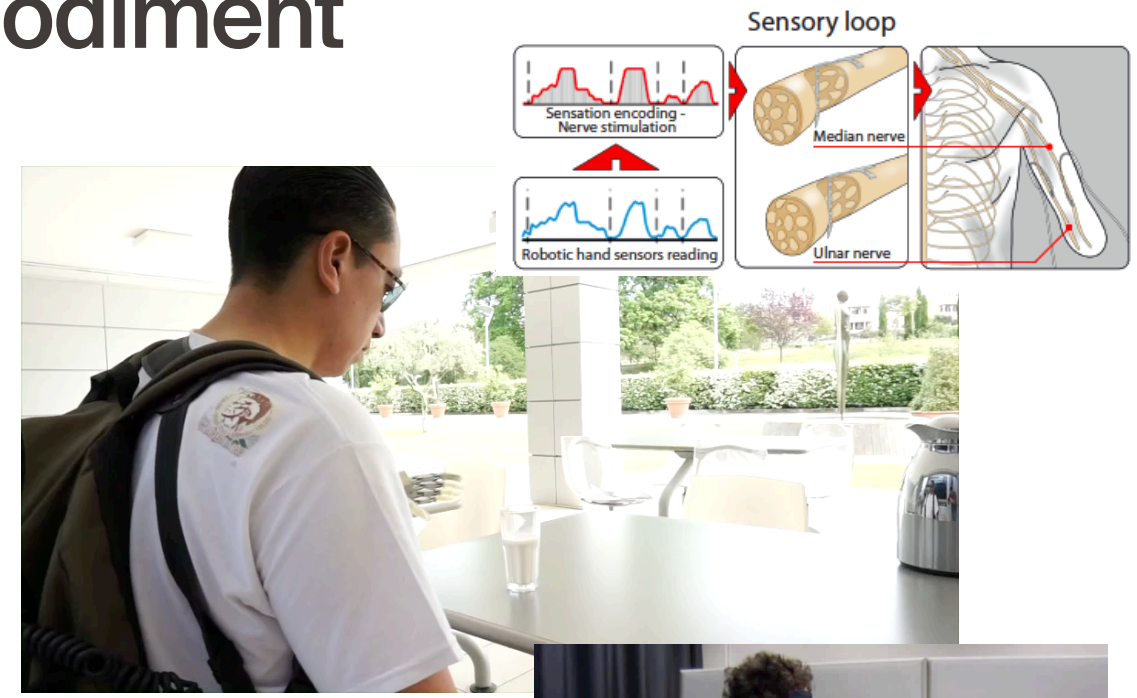


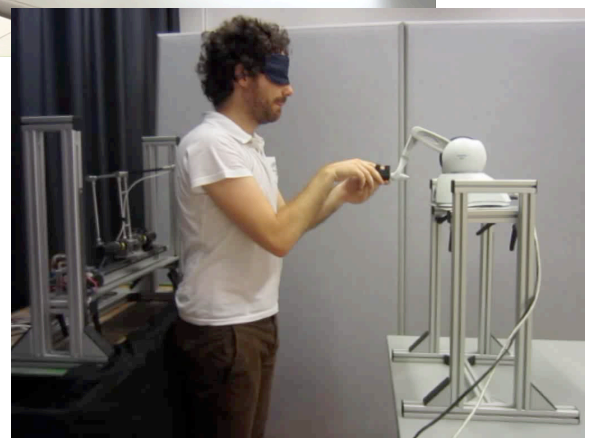
DeepLabCut™:
a software package for
animal pose estimation

Labs A. Mathis, M. Mathis

Prostheses and embodiment

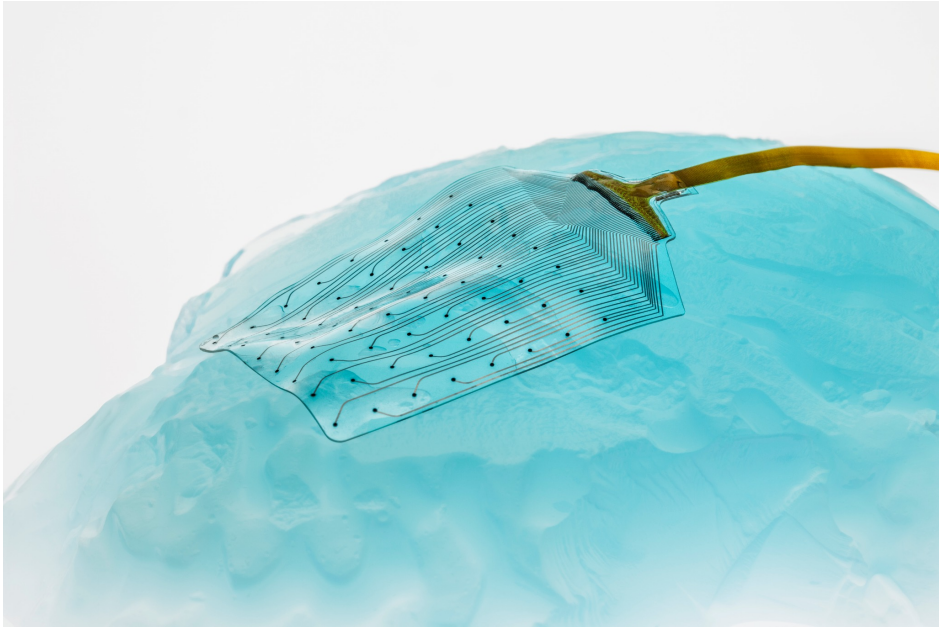
- Improving hand prosthesis with fine force control using sensory-nerve stimulation
- Use of new technologies to study embodiment
  - Virtual reality
  - Robotic stimulation, including inside MRI
- Study presence hallucinations in Parkinson's disease





Labs S. Micera, O. Blanke

Breakthrough neurotechnology for brain communication



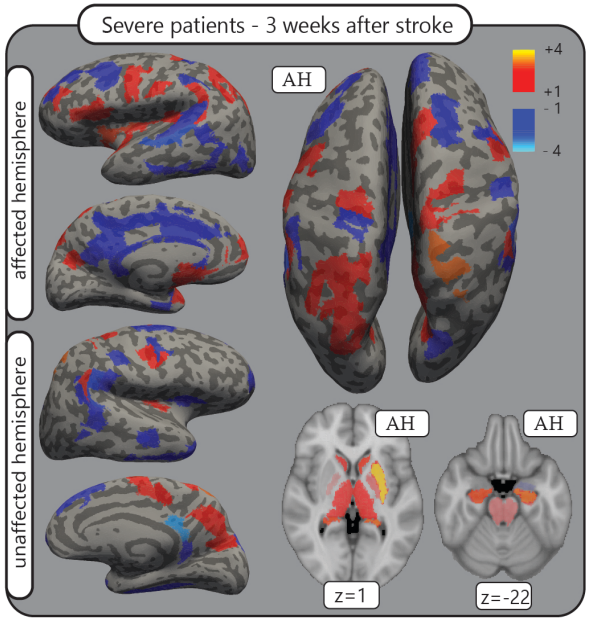
- Restore motor function in chronic spinal cord injury
- Targeted epidural spinal stimulation with implantable pulse generator controlled by AI software

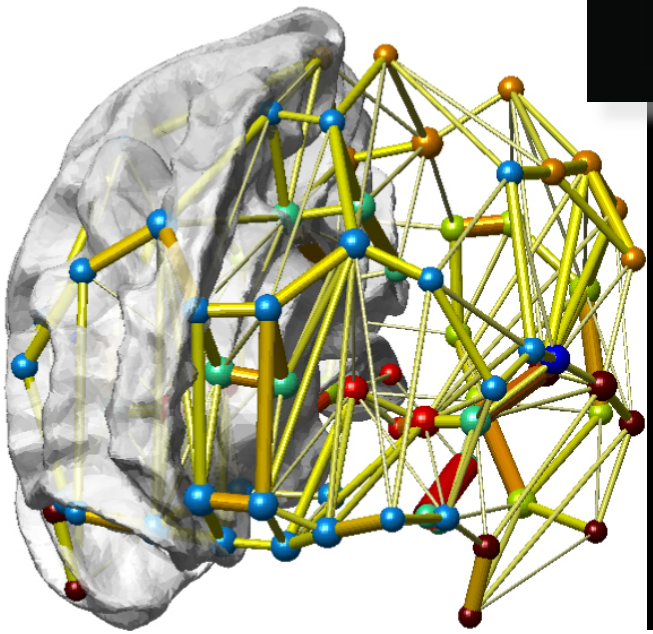
- Open communication channels with the CNS (read+write)
- Develop and validate soft bioelectronic interfaces

Labs S. Lacour, G. Courtine

Imaging and modeling of the central nervous system

- State-of-the-art anatomical and functional neuroimaging
- Imaging-based biomarkers for diagnosis
- Connectomics and brain graphs





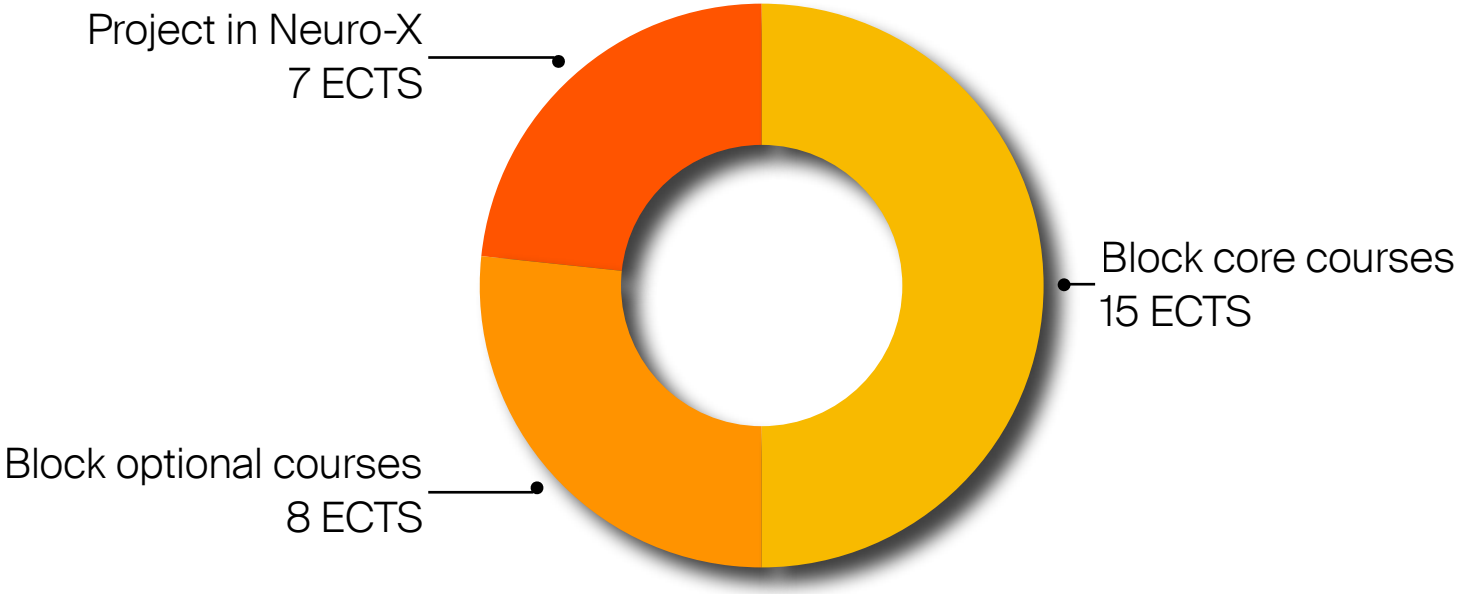
Labs D. Van De Ville, F. Hummel, J.-Ph. Thiran, S. Micera, O. Blanke, G. Courtine

Titles and admission conditions

- Official titles
  - Master of Science (MSc) in Neuro-X
  - Ingénieur en Neuro-X (neuro-X-ing. dipl. EPF)
- Consecutive Master:
  - STI: Microengineering (MT) + Electrical Engineering (EE)
  - IC: Systems and Communications (SC)
  - SV: Life Science Engineering
  - *** Deadline is 2 weeks after start of semester ***
- Admission by application for other sections and external students
  - Two deadlines: December 15 and April 15

Minor in Neuro-X (30 ECTS)

- Coordinators:
  - Silvestro Micera (STI)
  - Friedhelm Hummel (SV)
- Structure



Translation to industry

- Active network of industry partners
- Many start-ups in the Lausanne-Geneva area
- Community-driven events

TOP 100 STARTUP AWARD

#5 MindMaze
#29 Onward Medical
#59 Intento
#94 Sensars

mindmaze

ONWARD

intento

SENSARS
NEUROPROSTHETICS

Translation to clinics

- Outstanding clinical network in western Switzerland

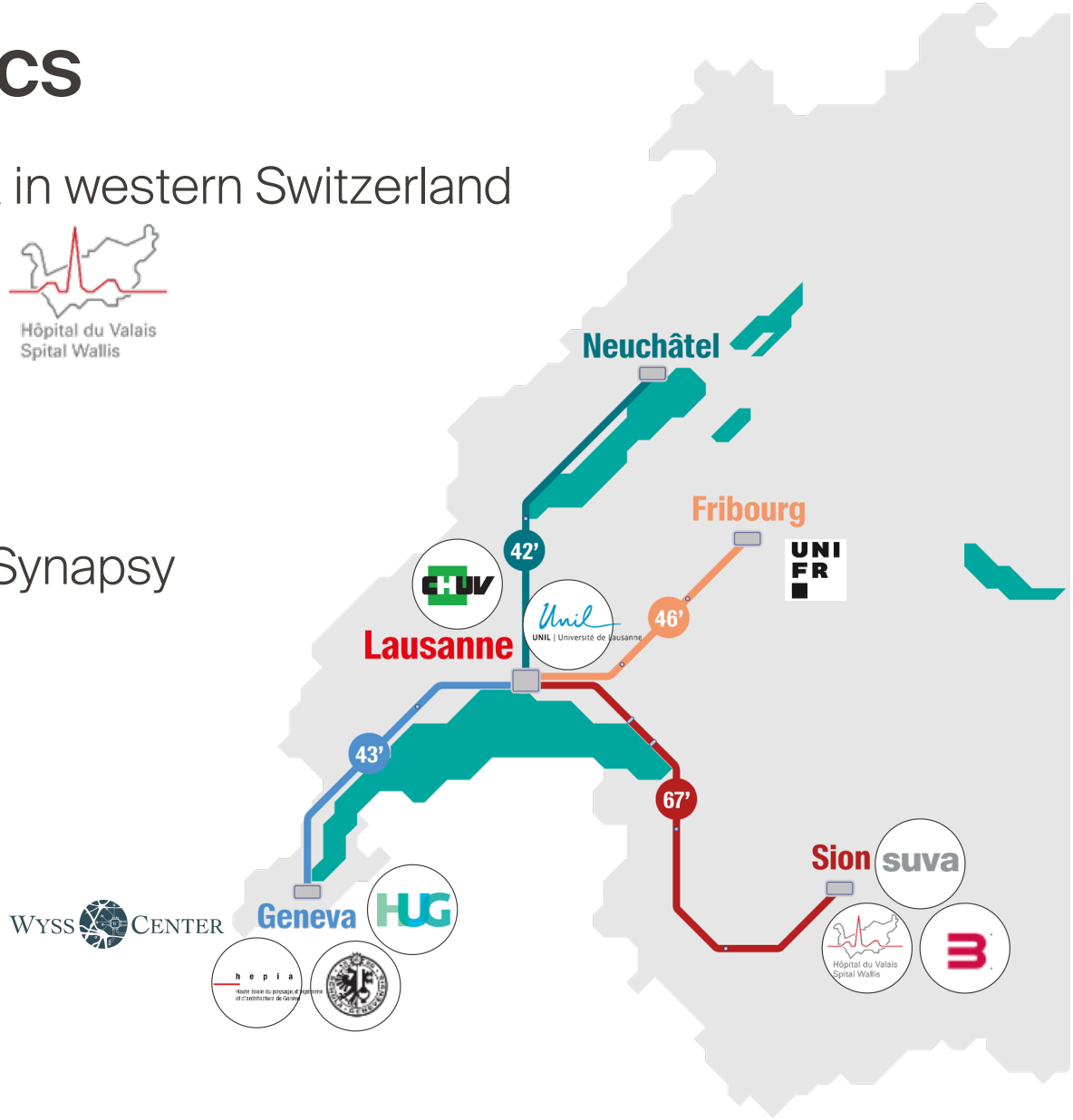
CHUV · HUG Hôpitaux Universitaires Genève · Hôpital du Valais Spital Wallis · suva · Clinique romande de réadaptation

- Strong contributors to NCCR Robotics and NCCR Synapsy

robotics · synapsy

- International partnership

HARVARD MEDICAL SCHOOL



NeuroStudents' Network: NetworX (NSNX)

- Founding members
  - Florence Crozat, Anna Schmitt, Aline Brunner

Committee of 2023

https://www.epfl.ch/campus/associations/list/nsnx/fr/nsnx-neurostudents-networx-2/

Advisory Committee

- Giovanni Cherubini (IBM Zürich)
- Claude Clement* (Consultant)
- Vincent Delattre* (Onward Medical)
- Naveed Ejaz (MindMaze)
- Jean-François Fischer* (Consultant)
- Tobias Kober** (Siemens Healthineers)
- Nathalie Virag* (Medtronic)

*=EPFL alumni, **=EPFL PhD

Meet the *Section in Neuro-X* team

Ms. Hind Klinke
Section's deputy

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Thanks!

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École polytechnique fédérale de Lausanne