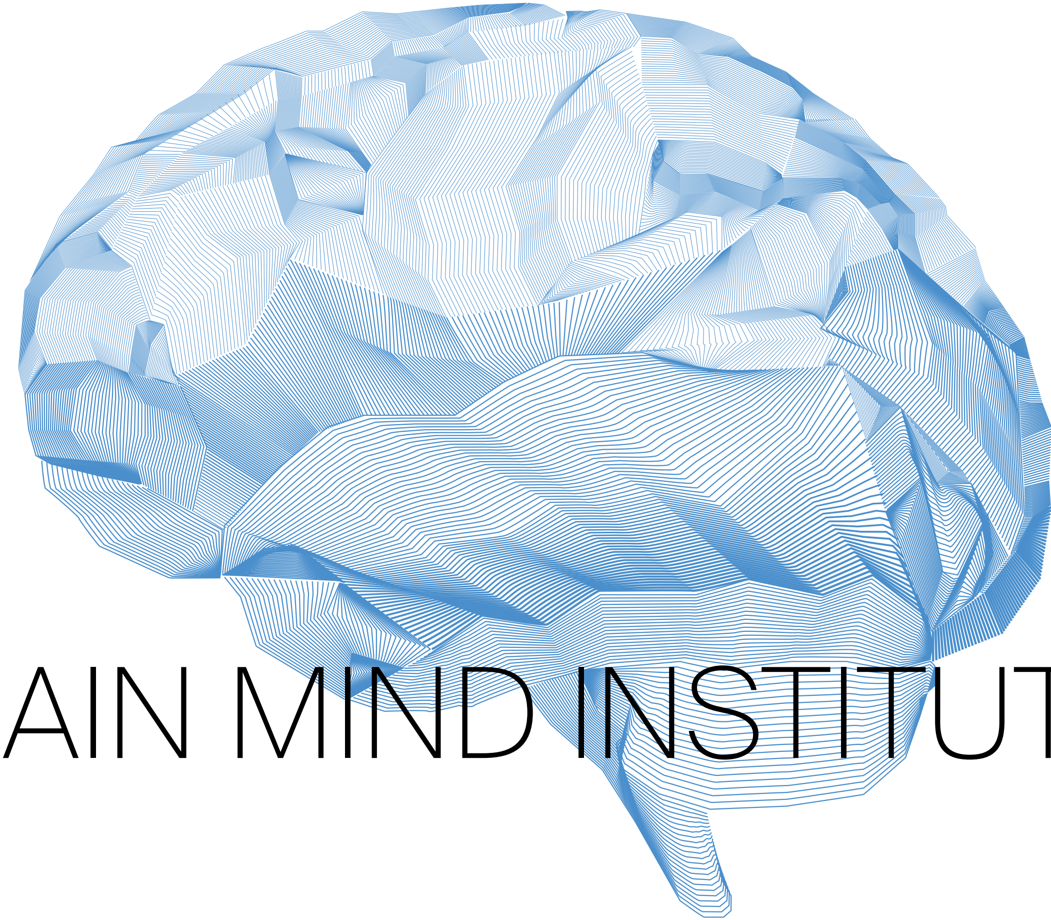
EPFL



BRAIN MIND INSTITUTE


EPFL
#epflcampus

The mission of the EPFL Brain Mind Institute is to advance fundamental understanding of brain function and dysfunction, to educate the next generation of neuroscientists, and to contribute to the development of novel therapies for the many neurodisorders.

Research

The EPFL Brain Mind Institute carries out quantitative multidisciplinary research into neural structure, function, dysfunction and computation through developing and applying cutting-edge technological advances. The Brain Mind Institute is composed of 21 highly collaborative research laboratories encompassing all areas of neuroscience including Neural circuits, Neurocomputation, Neurotechnology, Cellular and molecular neuroscience, Cognitive and behavioural neuroscience, as well as Brain dysfunction and therapy. Researchers from the Brain Mind Institute also contribute to driving several important EPFL Centers, including the Blue Brain Project, NeuroRestore and the Center for Neuroprosthetics. The Brain Mind Institute is at the heart of neuroscience research within the broader EPFL Neuro community with strong links to the universities of Lausanne and Geneva, as well as their associated hospitals. To support and encourage interdisciplinary research, the Brain Mind Institute together with the EPFL Neuro community organize two annual international research conferences and two annual interdisciplinary workshops covering hot topics in neuroscience providing exciting forums for discussion.

Education

Researchers at the Brain Mind Institute are deeply involved in neuroscience teaching at the EPFL by leading courses in NeuroScience, NeuroComputation and NeuroEngineering at the Bachelor, Master and Doctoral levels. The EPFL offers an MA degree in Life Sciences Engineering with specialisations in Neuroscience and Neuroengineering, Computational Neuroscience and Neuroprosthetics.

Innovation

The remarkable progress in the basic understanding of nervous system function and dysfunction has led to the creation of many new companies leveraging the latest advances in brain research to address mental health issues of enormous societal importance. Researchers at the Brain Mind Institute have contributed to founding highly successful new companies including Frontiers (Markram), Amazentis (Aebischer), GTX Medical SA (Courtine), Metaphysiks Engineering (Blanke) and GliaPharm (Magistretti).

Carl Petersen
Director

#

Sensorimotor

Cognition

Consciousness

Robotics

Virtual and augmented reality

Neuroimaging, fMRI

EEG, neurology

Parkinson’s disease

Measuring body perception in virtual reality - © EPFL 2019 / Matthieu Gafsou

COGNITIVE NEUROSCIENCE AND NEUROPROSTHETICS

The Chair in Cognitive Neuroprosthetics studies the multisensory brain mechanisms of body perception (somatosensory, vestibular, motor and visual signals) in cortical networks. For this we apply paradigms from cognitive science, neuroscience, neuroimaging, robotics, virtual reality in healthy subjects and a large range of neurological, psychiatric and orthopedic patients. Our scientific goal is to understand the brain mechanisms involved in multisensory own body perception in order to develop a neurobiological model of self-consciousness. Concerning technology development, we have pioneered the use of digital technologies such as virtual and mixed reality in neuroscience and introduced robotics, haptics, and MRI-compatible robotics to cognitive neuroscience. Our research in cognitive neuroprosthetics applies and translates these neuroscientific insights and technological breakthroughs to develop immersive digiceuticals, novel diagnostics and therapeutics for patients suffering from Parkinson's disease, psychiatric disorders and chronic pain.

Selected publications

Park HD, Barnoud C, Trang H, Kannape OA, Schaller K, Blanke O (2020) Breathing is coupled with voluntary action and the cortical readiness potential. *Nature Communications 11, 289.*

Park HD, Blanke O (2019) Coupling inner and outer body for self-consciousness. *Trends in Cognitive Sciences 23, 377.*

Blanke O, Slater M, Serino A (2015) Behavioral, neural, and computational principles of bodily self-consciousness. *Neuron 88, 145.*

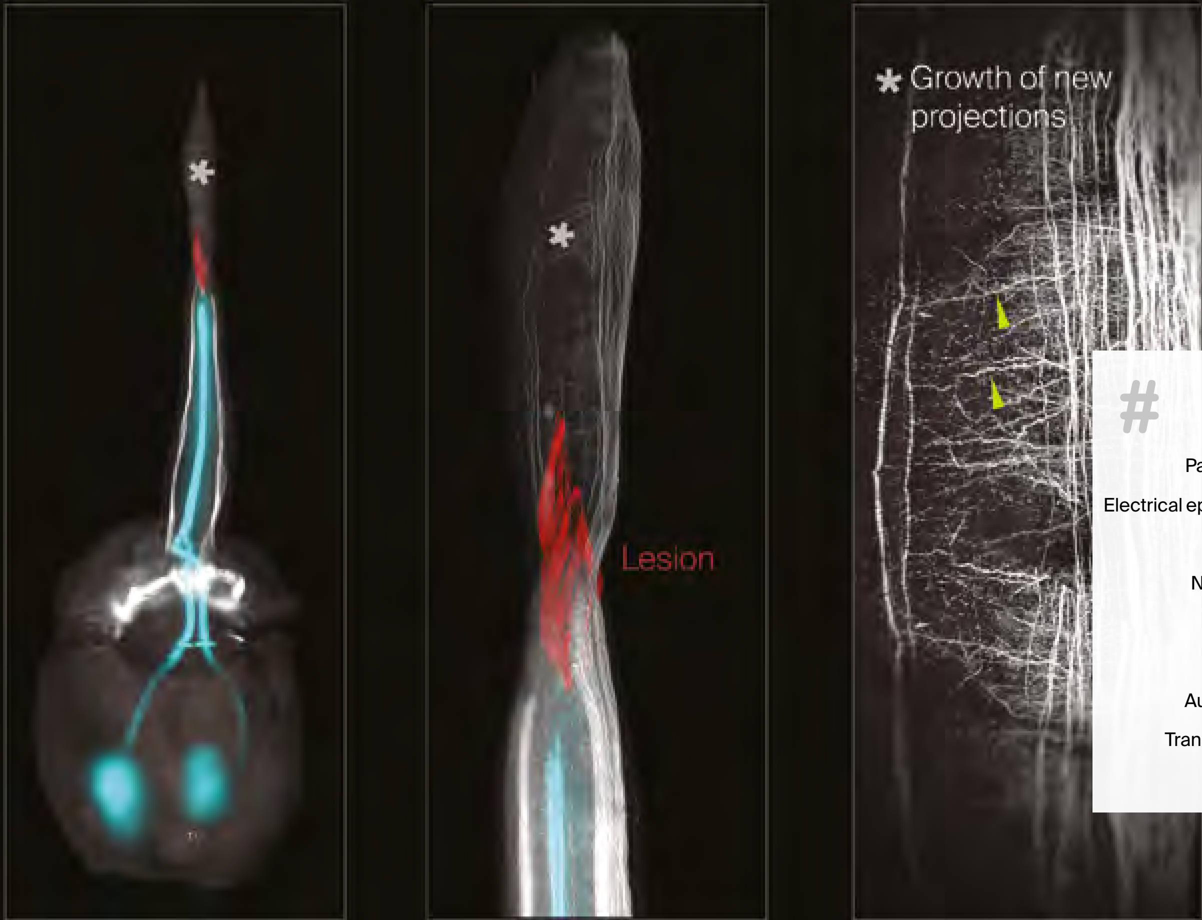
Blanke O, Pozeg P, Hara M, Heydrich L, Serino A, Yamamoto A, Higuchi T, Salomon R, Seeck M, Landis T, Arzy S, Herbelin B, Bleuler H, Rognini G (2014)Neurological and robot-controlled induction of an apparition. *Current Biology 24, 2681.*

Blanke O (2012) Multisensory brain mechanisms of bodily self-consciousness. *Nature Reviews Neuroscience 13, 556.*

Ionta S, Heydrich L, Lenggenhager B, Mouthon M, Fornari E, Chapuis D, Gassert R, Blanke O (2011) Multisensory mechanisms in temporo-parietal cortex support self-location and first-person perspective. *Neuron 70, 363.*

Olaf Blanke

Full Professor
Bertarelli Foundation Chair in Cognitive Neuroprosthetics



#

Spinal cord injury

Stroke

Parkinson’s disease

Electrical epidural stimulation

Rehabilitation

Neuroregeneration

Neuroprosthesis

Motor disorders

Autonomic disorder

Translational research

Clinical study

Cleared mouse spinal cord after an injury and rehabilitation - © EPFL 2021 / Courtine lab

MOTOR CONTROL, NEUROPROSTHETICS AND REGENERATION

Our mission is to develop new treatments for neurological disorders based on a precise understanding of the underlying mechanisms. For this purpose, we conduct projects across three uniquely complementary research platforms. The preclinical neuroscience platform located at Campus Biotech proposes cutting-edge methods to dissect the links between molecules, genes, circuits, and behaviors. These methods involve genetically modified mice, multifaceted neural interfaces, optogenetics, chemogenetics, calcium imaging, single-cell technologies, virus-based gene delivery, whole-organism clearing, and whole-brain imaging. The translational neuroscience platform, located at Fribourg, combines a range of advanced wireless and robotic technologies to conduct research in nonhuman primate models of neurological disorders. The clinical neuroscience platform is located at the Lausanne University Hospital, where we established rehabilitation infrastructures for the locomotor system and upper limb functions. These platforms provide the environments to uncover the mechanisms underlying the control of movement, exploit this understanding to develop neuroprosthetic and biological repair treatments, and realize their translation to humans.

Selected publications

Skinnider M, Squair J, Kathe C, Anderson M, Gautier M, Matson K, Milano M, Hutson T, Barraud Q, Phillips A, Foster LJ, La Manno G, Levine A, Courtine G (2021) Cell type prioritization in single-cell data. *Nature Biotechnology 39, 30.*

Wagner FB, Mignardot JB, Le Goff-Mignardot CG, Demesmaeker R, Komi S, ... Bloch J*, Courtine G* (2018) Targeted neurotechnology restores walking in humans with spinal cord injury. *Nature 563, 65.*

Asboth L, Friedli L, Beauparlant J, Martinez-Gonzalez C, Anil S, ... Schneider BL, Barraud Q, Courtine G (2018) Cortico-reticulo-spinal circuit reorganization enables functional recovery after severe spinal cord contusion. *Nature Neuroscience 21, 576.*

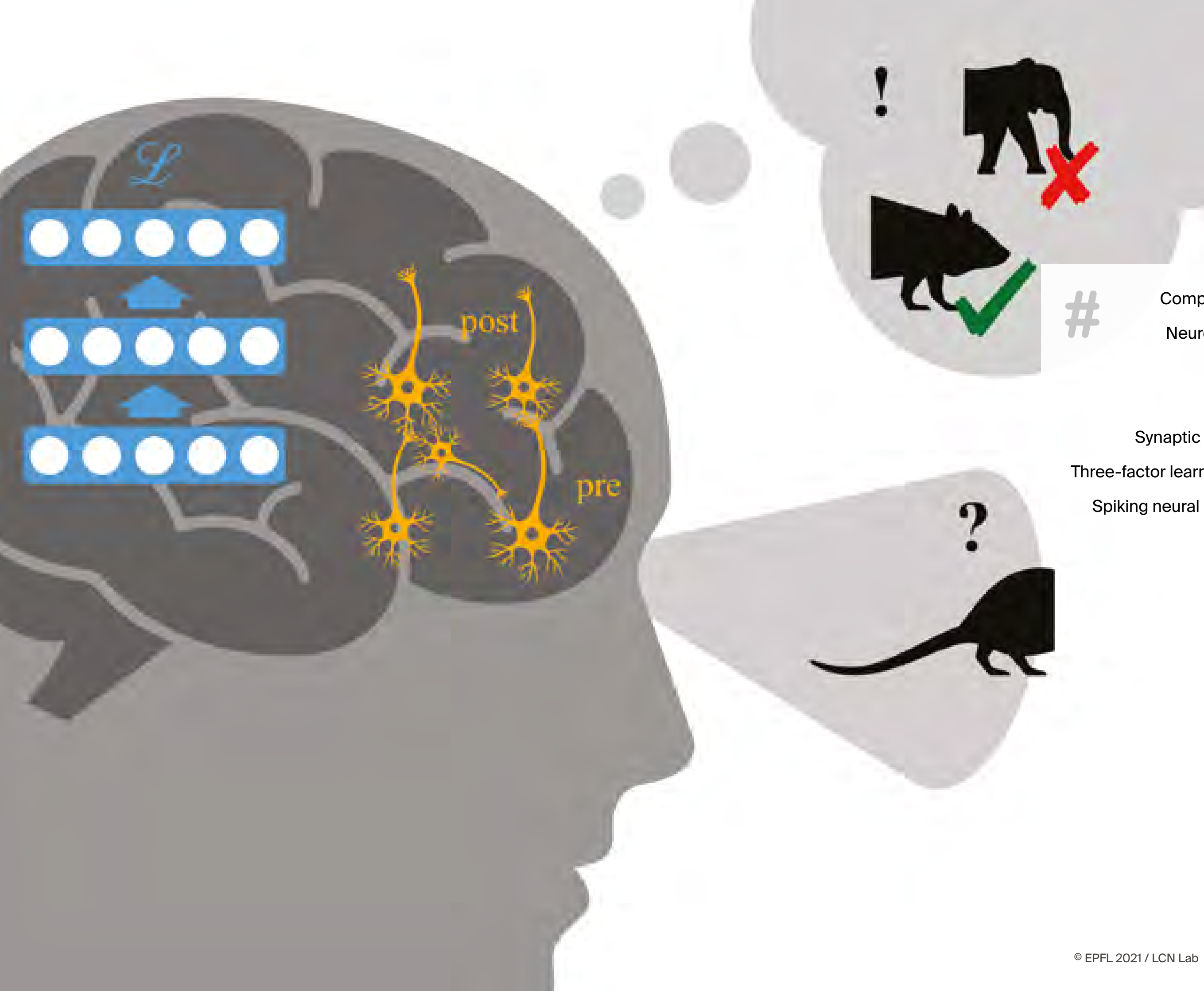
Wenger N, Moraud EM, Gandar J, Musienko P, Capogrosso M, Baud L, ... Courtine G (2016) Spatiotemporal neuromodulation therapies engaging muscle synergies improve motor control after spinal cord injury. *Nature Medicine 22, 138.*

Capogrosso M, Milekovic T, Borton D, Wagner F, Moraud EM, ... Bloch J, Courtine G (2016) A brain-spine interface alleviating gait deficits after spinal cord injury in primates. *Nature 539, 284.*

van den Brand R, Heutschi J, Barraud Q, DiGiovanna J, Bartholdi K, ... Courtine G (2012) Restoring voluntary control of locomotion after paralyzing spinal cord injury. *Science 336, 1182.*

Grégoire Courtine

Full Professor



Computational
Neuroscience
Reward
Surprise
Synaptic Plasticity
Three-factor learning rules
Spiking neural networks

COMPUTATIONAL NEUROSCIENCE

The Laboratory of Computational Neuroscience has a long tradition in modeling spiking neurons, either single neurons or networks thereof, as well as spike-based synaptic plasticity. In recent years, the research has shifted from classical spike timing dependent plasticity, to spike-based three-factor learning rules triggered by reward and surprise. As humans, we are surprised if we experience a stimulus that runs against our expectations. Our hypothesis is that surprise activates neuromodulators in a way similar to reward prediction error. A reward prediction error occurs if you expect a reward and you do not get it (or you get twice as much). Surprise occurs if you expect a next observation and you observe something else. Currently we explore in the lab how surprise can be represented by the activity of spiking neurons, for example through a mismatch between excitation and inhibition. In a collaboration with the laboratory of Michael Herzog, we find that surprise speeds up reinforcement learning. The Laboratory of Computational Neuroscience also collaborates with the labs of Carl Petersen, Henry Markram, and Ralf Schneggenburger at the BMI as well as with Prof. C. Hongler (Department of Mathematics) and Prof. M. Rohrmeier (Digital Humanities) on the EPFL campus for the study of multi-layer neural networks.

Selected Publications

Liakoni V, Modirshanechi A, Gerstner W, Brea J (2021) Learning in volatile environments with the Bayes factor surprise. *Neural Computation 33, 269.*

Lehmann MP, Xu HA, Liakoni V, Herzog MH, Gerstner G, Preuschoff K (2019) One-shot learning and behavioral eligibility-traces in sequential decision making. *eLife 8, e47463.*

Gerstner W, Lehmann M, Liakoni V, Brea J (2018) Eligibility traces and plasticity on behavioral time scales: experimental support of NeoHebbian three-factor learning rules. *Front Neural Circuits 12, 53.*

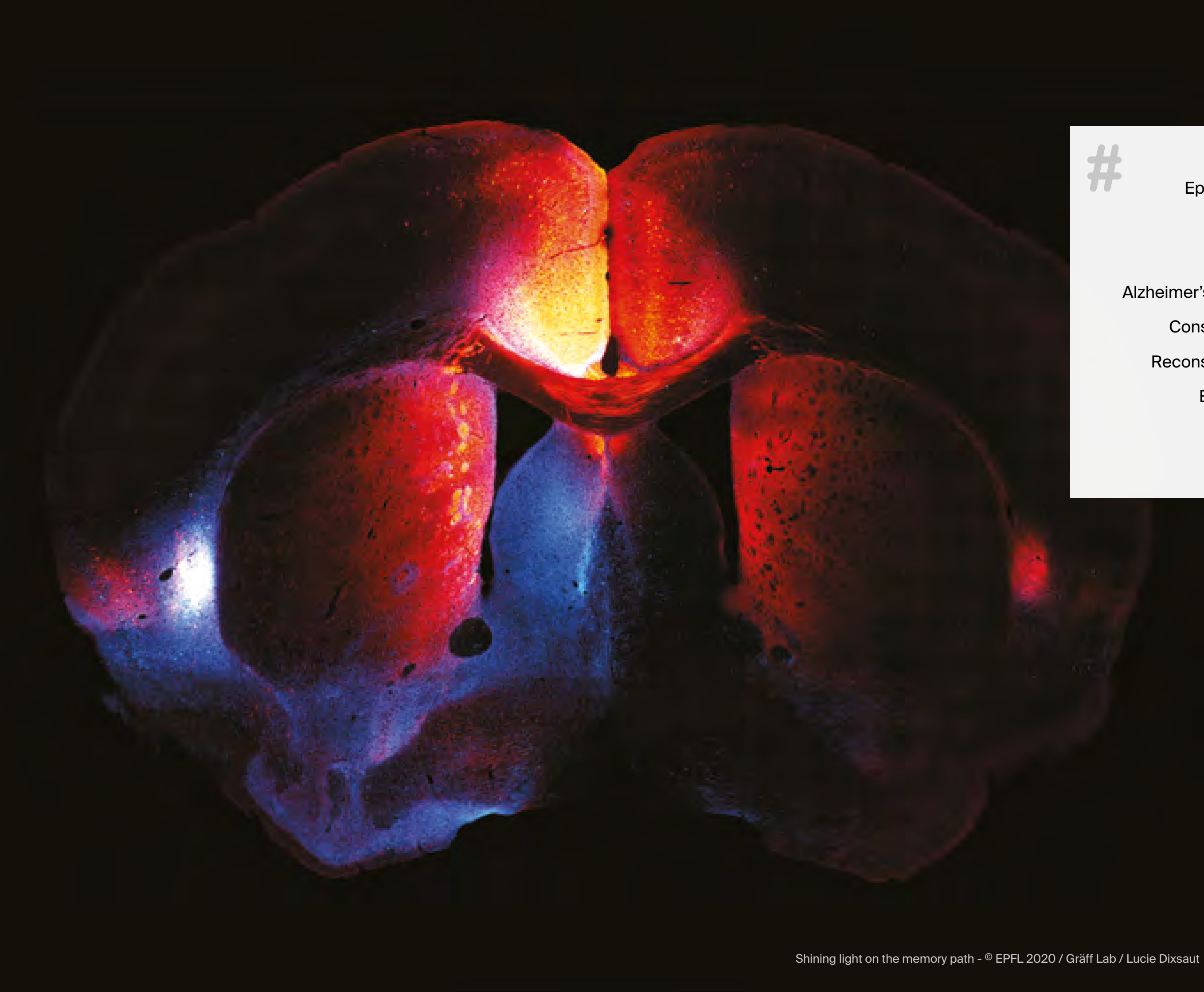
Schwalger T, Deger M, Gerstner W (2017) Towards a theory of cortical columns: From spiking neurons to interacting neural populations of finite size. *PLoS Computational Biology 13, e1005507.*

Pozzorini C, Mensi S, Hagens O, Naud R, Koch C, Gerstner W (2015) Automated high-throughput characterization of single neurons by means of simplified spiking models. *PLOS Computational Biology 11, e1004275.*

Zenke F, Agnes EJ, Gerstner W (2015) Diverse synaptic plasticity mechanisms orchestrated to form and retrieve memories in spiking neural networks. *Nature Communications 6, 6922.*

Wulfram Gerstner

Full Professor



Shining light on the memory path - © EPFL 2020 / Gräff Lab / Lucie Dixsaut

#

Engrams
Epigenetics
Learning
Memory
Alzheimer’s disease
Consolidation
Reconsolidation
Extinction
PTSD
Trauma

NEUROEPIGENETICS

Our lab is interested in the cellular and molecular processes underlying learning and memory, with a particular focus on epigenetic processes. Epi-genetics, derived from the Greek prefix 'επι', refers to changes on the DNA without affecting the genetic sequence itself. These mechanisms have long been known to play a fundamental part in development, where they stably induce cell type-specific gene expression pattern that persist through life. More recently, however, epigenetic mechanisms within the brain have also been found to readily react to changing environmental contingencies, thereby rapidly altering gene expression programs.
With such Janus-faced property of being at once dynamic and stable, we reason that epigenetic mechanisms harbor the potential to better explain the molecular cascades that govern memory formation, storage and change. Our particular interests in the lab are memory allocation, memory consolidation/reconsolidation, memory extinction, Alzheimer's disease, and long-lasting traumatic memories.
Our main discoveries thus far are the identification of the first genetically encoded epigenetic change associated with Alzheimer's disease, as well as the brain areas and the cellular subpopulations important for the extinction of long-lasting traumatic memories.

Selected publications

Burns AM, Gräff J (2021) Cognitive epigenetic priming: Tipping histone acetylation to enhance memory. *Current Opinion in Neurobiology 67, 75.*

Silva BA, Burns AM, Gräff J (2019) A cFos activation map of remote fear memory attenuation. *Psychopharmacology, 236, 369.*

Khalaf O, Gräff J (2019) Reactivation of recall-induced neurons in the infralimbic cortex and the basolateral amygdala after remote fear memory attenuation. *Frontiers in Molecular Neuroscience 12, 70.*

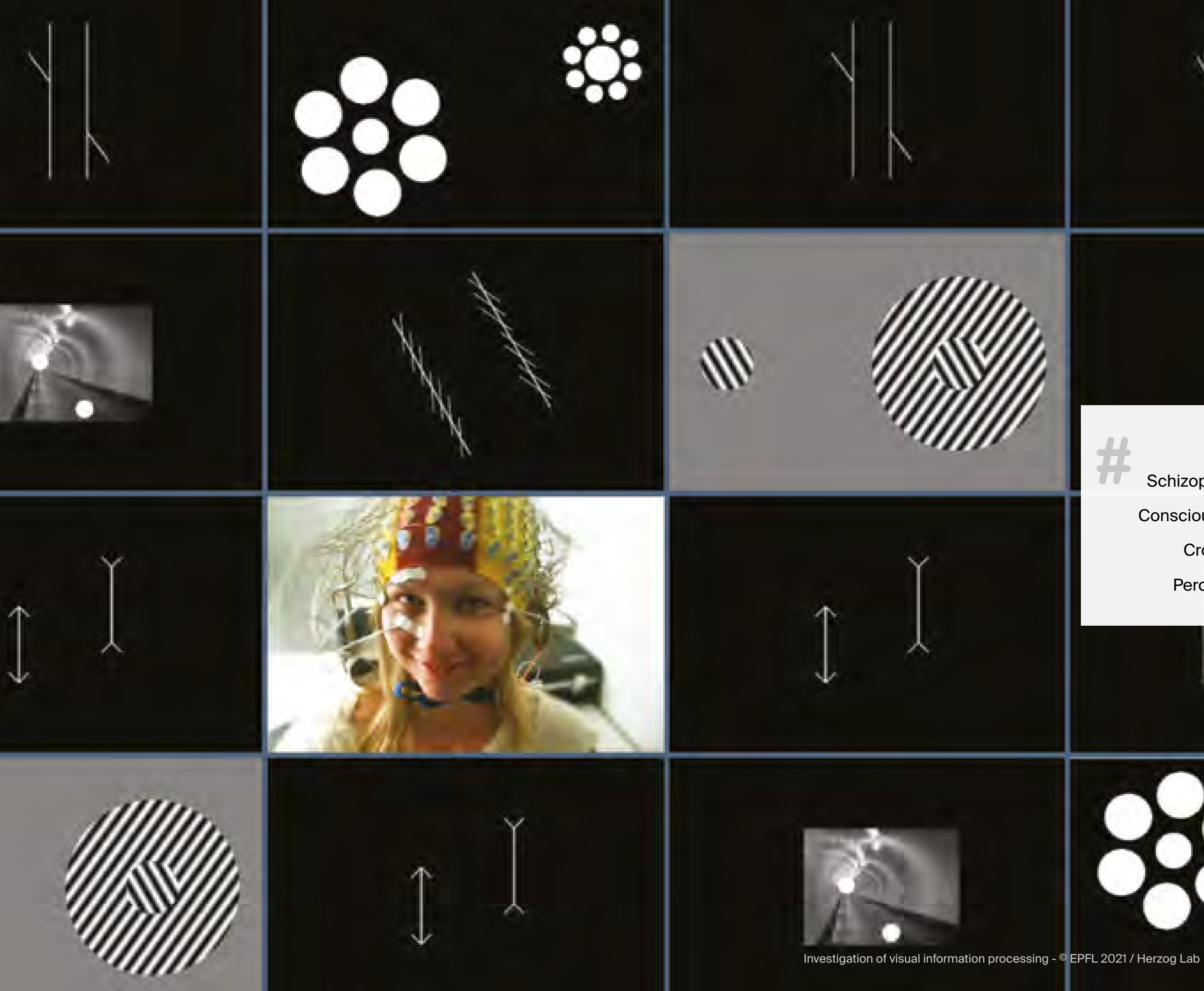
Khalaf O, Resch S, Dixsaut L, Gorden V, Glauser L, Gräff J (2018) Reactivation of recall-induced neurons contributes to remote fear memory attenuation. *Science 360, 1239.*

Sanchez-Mut JV, Heyn H, Silva BA, Dixsaut L, Garcia-Esparcia P, ... Gräff J (2018) PM20D1 is a methylation quantitative trait locus associated with Alzheimer's disease. *Nature Medicine, 24, 598.*

Albo Z, Gräff J (2018) The mysteries of remote memory. *Philosophical Transactions of the Royal Society B, 373, 20170029.*

Johannes Gräff

Associate Professor
Nestlé Chair



Investigation of visual information processing - © EPFL 2021 / Herzog Lab

Aging
Schizophrenia
Consciousness
Crowding
Perception

PSYCHOPHYSICS

In the Laboratory of Psychophysics, we investigate healthy and abnormal visual information processing in human observers with psychophysical methods, TMS, EEG, and mathematical modelling. Main topics of research are: feature integration, contextual modulation, time course of information processing, and perceptual learning.

Particular emphasis is on the temporal aspects of vision and consciousness. For example, intuitively, we feel that we are conscious at each moment of time. However, this view is hard to reconcile with current psychophysical experiments that show that we integrate information unconsciously for several hundreds of milliseconds before a conscious percept emerges (Herzog, Drissi-Daoudi & Doerig, 2020). During this period the brain tries to make sense out of the vast amount of information impinging on the retina. Clearly, the classic feedforward approach to vision falls short to explain these and many more results (Pachai, Doerig & Herzog, 2016; Herzog & Manassi, 2015). In clinical work, we try understand the mechanisms of schizophrenia and healthy aging. One of the surprising insights is that there are no common causes to the deficits in visual perception.

Selected publications

Herzog MH, Drissi-Daoudi L, Doerig A (2020) All in good time: Long-lasting postdictive E effects reveal discrete perception. *Trends in Cognitive Sciences 24, 826.*

Da Cruz JR, Favrod O, Roinishvili M, Chkonia E, Brand A, Mohr C, Figueiredo P, Herzog MH (2020) EEG microstates are a candidate endophenotype for schizophrenia. *Nature Communications 11, 3089.*

Drissi-Daoudi L, Doerig A, Herzog MH (2019) Feature integration within discrete time windows. *Nature Communications 10, 1.*

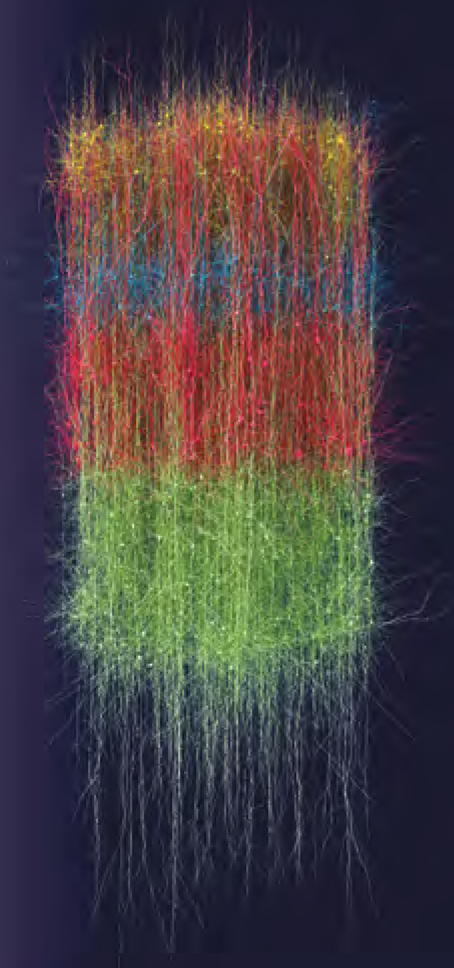
Pachai M, Doerig A, Herzog MH (2016) How best to unify crowding? *Current Biology 26, R352.*

Herzog MH, Kammer T, Scharnowski F (2016) Time slices: What is the duration of a percept? *PLoS Biology 14, e1002433.*

Herzog MH, Manassi M (2015) Uncorking the bottleneck of crowding: a fresh look at object recognition. *Current Opinion in Behavioral Sciences 1, 86.*

Michael Herzog

Full Professor



Topology
Topological data analysis
Connectomics
Neuron morphology
Network dynamics
Biomarkers
Gene expression

Digital reconstruction of mouse brain circuits - © Blue Brain Project EPFL

TOPOLOGY AND NEUROSCIENCE

Our laboratory's research concerns the branch of mathematics called algebraic topology and its applications, primarily to the life sciences, especially to neuroscience. In particular, we apply algebraic topology to the analysis of the structure and function of the connectome, at both the micro and macro levels and in both rodents and Drosophila, in particular to characterize network plasticity. We focus moreover on the analysis of neuronal and glial morphologies, from characterization and classification to digital synthesis, based on methods of topological data analysis (TDA). We employ TDA methods to analyze clinical data as well, with the goal of developing novel biomarkers for psychiatric and neurodegenerative diseases, such as schizophrenia and Parkinson's disease. TDA methods also play an essential role in our analysis of dynamics in networks of neurons, leading to a pipeline for automated classification and detection of dynamic regimes, which we are currently applying to recordings from a mouse model for autism. Beyond neuroscience, we apply TDA methods to gene-expression analysis of the role of hormones in breast cancer.

Our laboratory maintains strong activity in pure mathematics, primarily within homotopy theory and category theory.

Selected publications

Fournier M, Scolamiero M, . . . Conus P, Do Cuénod K, Hess K (2020) **Topology predicts long-term functional outcome in early psychosis.** *Molecular Psychiatry. DOI: 10.1038/s41380-020-0826-1*

Kanari L, Ramaswamy S, Shi Y, Morand S, Meystre J, Perin R, Abdellah M, Wang Y, Hess K, Markram H (2019) Objective classification of neocortical pyramidal cells. *Cerebral Cortex 29, 1719-1735.*

Bardin J-B, Spreemann G, Hess K (2019) Topological exploration of artificial neuronal network dynamics. *Network Neuroscience 3, 725.*

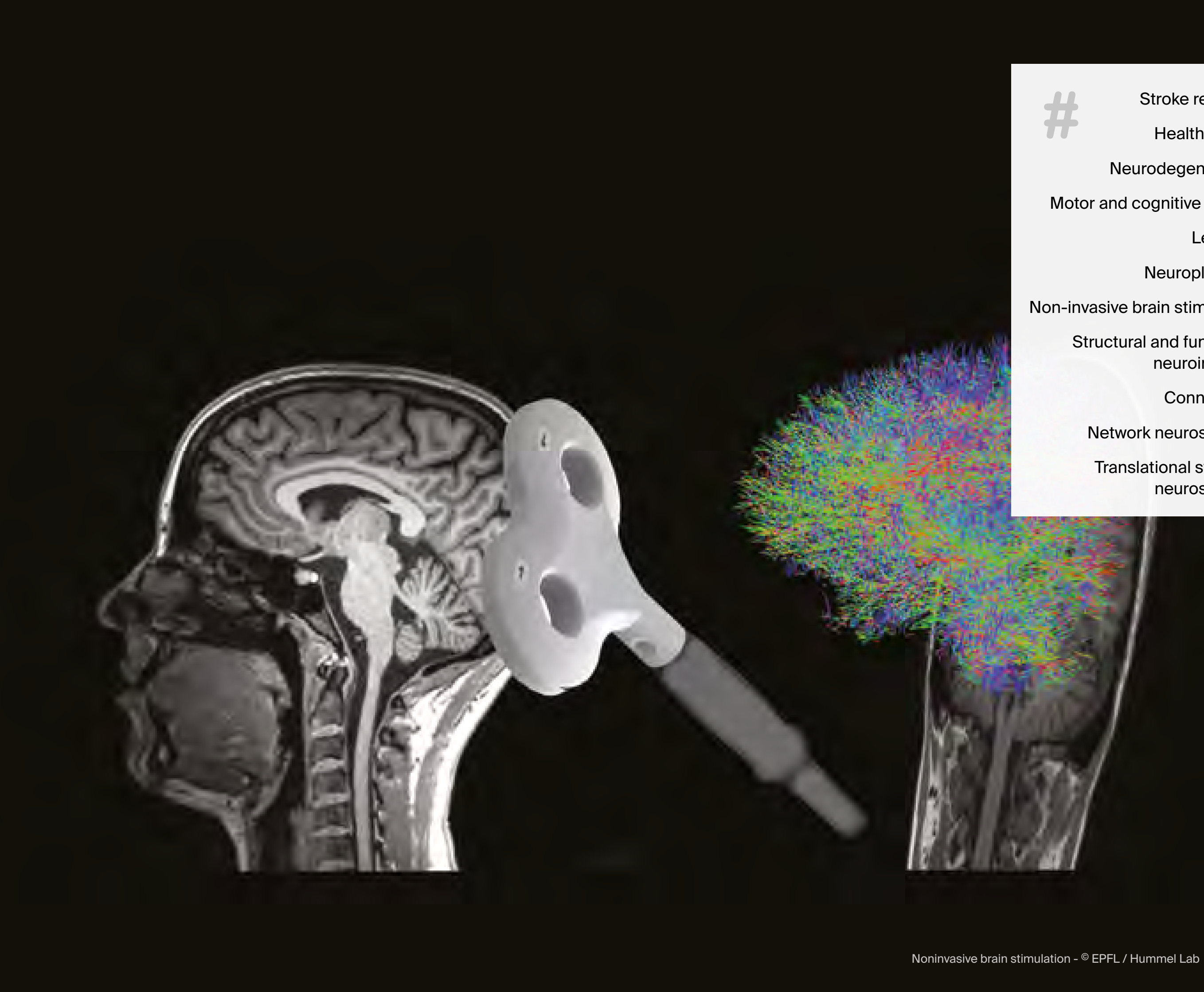
Kanari L, Dłotko P, Scolamiero M, Levi J, Shillcock JC, Hess K, Markram H (2017) A topological representation of branching morphologies. *Neuroinformatics 16, 3.*

Reimann MW, Nolte M, Scolamiero M, Turner K, Perin R, Chindemi G, Dłotko P, Levi R, Hess K, Markram H (2017) Cliques of neurons bound into cavities provide a missing link between structure and function. *Frontiers in Computational Neuroscience 11, 48.*

Lee Y, Barthel S, Mohammad Moosavi S, Dłotko P, Hess K, Smit B (2017) Quantifying similarity of pore-geometry in nanoporous materials. *Nature Communications 14, 4427.*

Kathryn Hess Bellwald

Full Professor



#

Stroke recovery

Healthy aging

Neurodegeneration

Motor and cognitive control

Learning

Neuroplasticity

Non-invasive brain stimulation

Structural and functional neuroimaging

Connectivity

Network neuroscience

Translational systems neuroscience

Noninvasive brain stimulation - © EPFL / Hummel Lab

NEUROTECHNOLOGY FOR NEUROREHABILITATION

The research focus of the Hummel Lab is on systems and translational clinical neuroscience and neuroengineering. The main research topics are targeted towards neuroplasticity, neuronal control and modulation of sensorimotor and cognitive functions, learning, healthy aging and especially on functional reorganization and recovery after focal brain lesions and neurodegeneration by using multimodal systems neuroscience approaches including modern neuroimaging, brain stimulation and psychophysical and clinical evaluations. We are specifically interested in the understanding of underlying systems neuroscience mechanisms of healthy aging, neurodegenerative neurological disorders, stroke and traumatic brain injury, and functional regeneration and recovery and how they can be modulated by neurotechnologies (e.g. brain stimulation). The overarching goal is to translate the knowledge from 'bench' to daily life clinical 'bedside'. One of our main characteristics is the multidisciplinarity and multimodal methodological expertise. Our interdisciplinary team consists of medical doctors, engineers, neuroscientists, mathematicians and therapists. Our research is embedded in internal, national and international collaborations.

Selected publications

Maceira-Elvira P, Popa T, Schmid A-C, Hummel FC (2020) Feasibility of home-based, self-applied transcranial direct current stimulation to enhance motor learning in middle-aged and older adults. *Brain Stimulation 3, 247.*

Coscia M, Wessel MJ, Ujwal Chaudary, Millán JdR, Micera S, Guggisberg A, Vuadens P, Donoghue J, Birbaumer N, Hummel FC (2019) Neurotechnology-aided interventions for upper limb motor rehabilitation in severe chronic stroke. *Brain 142, 2182.*

Quandt F, Boenstrup M, Schulz R., Timmermann JE, Mund M, Wessel MJ, Hummel FC (2019) The functional role of Beta-oscillations in SMA during reaching and grasping after stroke: a question of structural damage to the corticospinal tract. *Human Brain Mapping 40, 3091.*

Schulz R, Park E, Lee J, Chang W, Lee A, Kim Y-H, Hummel FC (2017) Interactions between the corticospinal tract and premotor-motor pathways in stroke recovery. *Stroke 48, 2805-2811.*

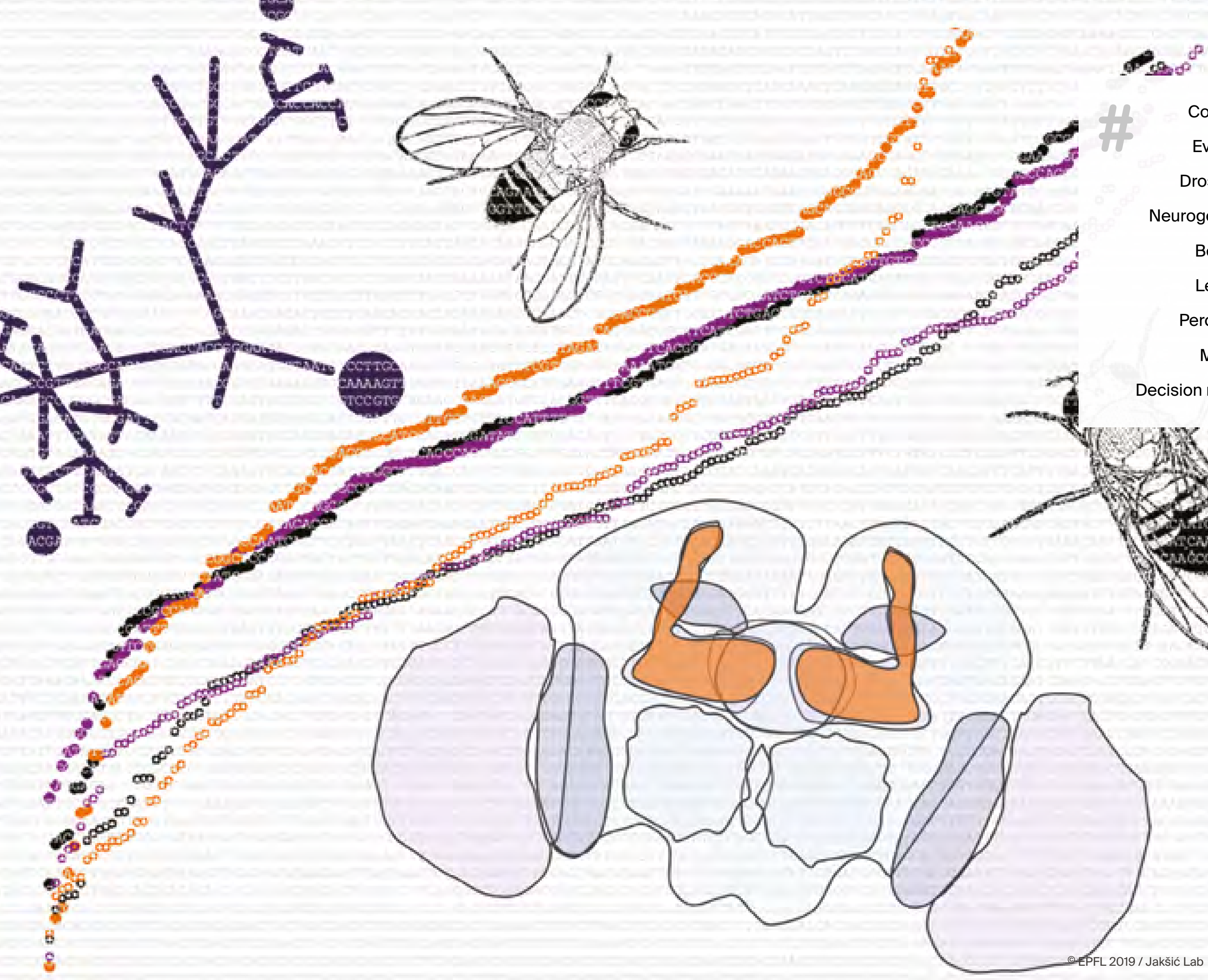
Schulz R, Koch P, Zimerman M, Wessel M, Bönstrup M, Thomalla G, Cheng B, Gerloff C, Hummel FC (2015) Parietofrontal motor pathways and their association with motor function after stroke. *Brain 138, 1949.*

Zimerman M, Nitsch M, Giraux P, Gerloff C, Cohen LG, Hummel FC (2013) Neuroenhancement of the aging brain: Restoring skill acquisition in old subjects. *Annals of Neurology 73, 10.*

Friedhelm Christoph Hummel

Full Professor

Defitech Chair of Clinical Neuroengineering



#

Cognition

Evolution

Drosophila

Neurogenetics

Behavior

Learning

Perception

Memory

Decision making

EXPERIMENTAL EVOLUTIONARY NEUROBIOLOGY

The main distinction between humans and other animals is the human's extreme cognitive ability, yet why did we have to evolve this extreme phenotype is still a mystery buried in our evolutionary past. The main aim of the Laboratory of Experimental Evolutionary Neurobiology is to answer this question in the present using real-time evolution experiments. We use experimental evolution and the power of Drosophila melanogaster genetics to test which genetic and evolutionary conditions are necessary for the evolution of cognition. By applying various environmental selective pressures like imposing complex social structures and challenging environments that require cognitive performance, or simply by using artificial selection for cognition, we can drive the evolution of the brain in real time, and study it as it evolves. To do so we use a panel of Drosophila lines that harbors the vast genetic diversity which has been genetically fully characterized. The same genetic panel is used for mapping the variation in the DNA to variation in cognitive ability in order to pinpoint the genetic substrates of this trait. Our ultimate goal is to characterize the tempo and mode of evolution of cognition, and identify the main evolutionary components necessary for evolving a cognitive brain.

Selected publications

Jakšić AM, Karner J, Nolte V, Hsu S, Barghi N, Mallard F, Otte KA, Svečnjak L, Senti KA, Schlötterer C (2020) Neuronal function and dopamine signaling evolve at high temperature in Drosophila. *Molecular Biology and Evolution 37, 2630.*

Hsu SK, Jakšić AM, Nolte V, Lirakis M, Kofler R , Barghi N, Versace E, Schlötterer C (2019) Rapid sex-specific adaptation to high temperature in Drosophila. *eLife 9, e53237.*

Barghi N, Tobler R, Nolte V, Jakšić AM, Mallard F, Otte KA, Dolezal M, Schlötterer C (2019) Genetic redundancy fuels polygenic adaptation in Drosophila. *PLoS Biology 17, e3000128.*

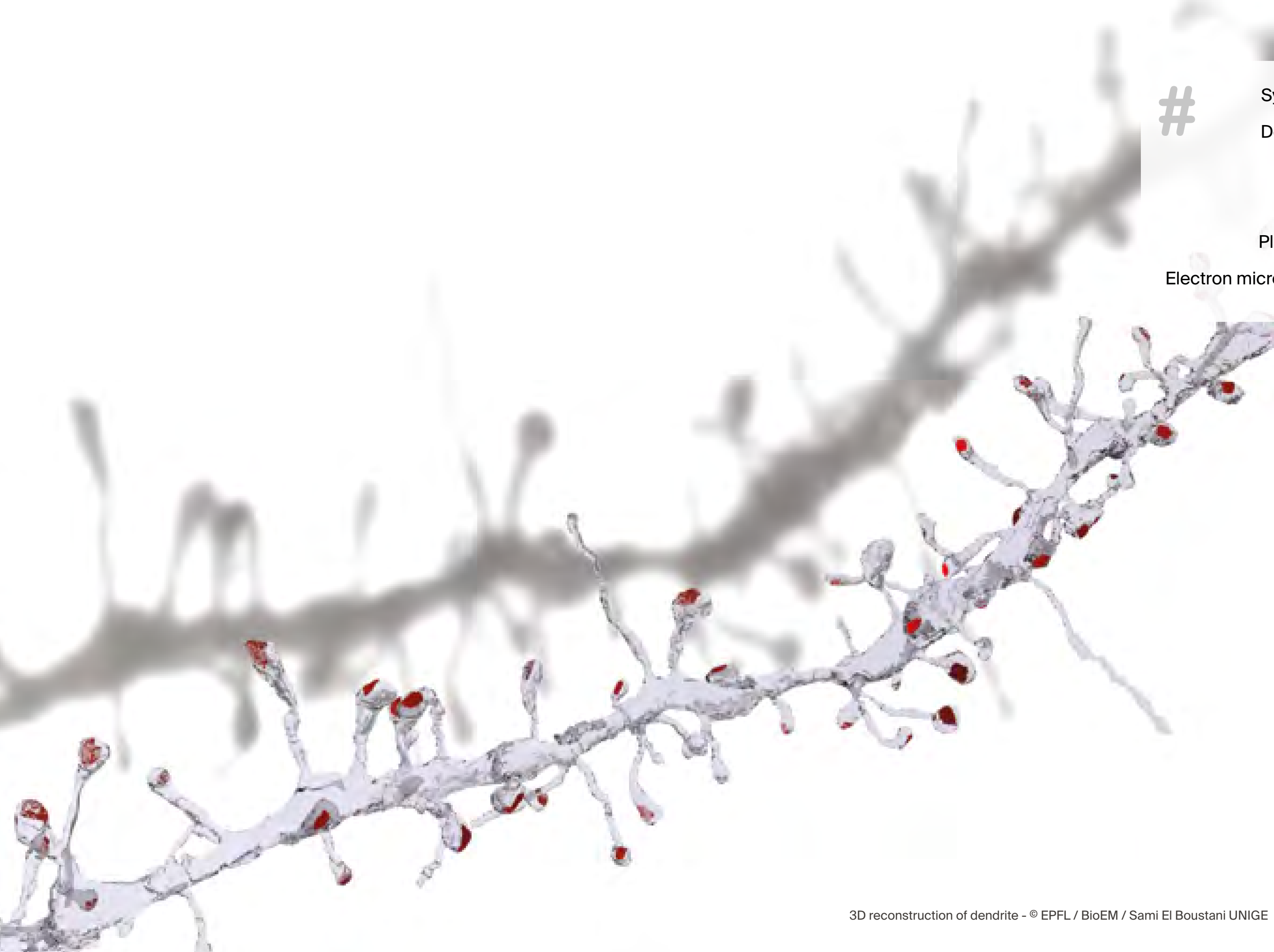
Mallard F, Jakšić AM, Schlötterer C (2018) Contesting the evidence for non-adaptive plasticity. *Nature 555, E21.*

Jakšić AM, Kofler R, Schlötterer C (2017) Regulation of transposable elements: interplay between TE-encoded regulatory sequences and host-specific trans-acting factors in Drosophila melanogaster. *Molecular Ecology 26, 5149.*

Jakšić AM, Schlötterer C (2016) The interplay of temperature and genotype on patterns of alternative splicing in Drosophila melanogaster. *Genetics 204, 315.*

Ana Marija Jakšić

EPFL Life Sciences Early Independent Research Scholar



Synapse

Dendrite

Axon

Cortex

Plasticity

Electron microscopy

3D reconstruction of dendrite - © EPFL / BioEM / Sami El Boustani UNIGE

BIOLOGICAL ELECTRON MICROSCOPY

The Biological Electron Microscopy Platform, headed by Graham Knott is interested in understanding the detailed structure of the different types of connections in the brain, as well as how they are altered through experience and aging. The laboratory has access to a variety of the latest electron microscopy imaging techniques and continues to develop these in a number of different ways. These include projects developing correlative light and electron microscopy methods, to computing projects producing segmentation, reconstruction and analysis software. It is well recognized that to understand the brain's neural processes we must also understand the underlying structures involved. The detailed structure of neuronal connections is only visible with electron microscopy, giving a high-resolution view of the complex circuitry that controls our actions, reactions, and behaviour. The last decade has seen extraordinary advances in electron microscopy technology allowing scientists unprecedented views of the brain's structure and its connectivity. This electron microscopy laboratory has been at the forefront of a number of the technological advances that have shaped this field of brain circuit exploration.

Selected publications

Tamada H, Blanc J, Korogod N, Petersen CCH, Knott GW (2020) Ultrastructural comparison of dendritic spine morphology preserved with cryo and chemical fixation. *eLlife 9, e56384.*

Calì C, Wawrzyniak M, Becker C, Maco B, Cantoni M, Jorstad A, Nigro B, Grillo F, De Paola V, Fua P, Knott GW (2018) The effects of aging on neuropil structure in mouse somatosensory cortex - A 3D electron microscopy analysis of layer 1. *PLoS One 13, e0198131.*

El-Boustani S, Ip JPK, Breton-Provencher V, Knott GW, Okuno H, Bito H, Sur M (2018) Locally coordinated synaptic plasticity of visual cortex neurons in vivo. *Science 360, 1349.*

Jorstad A, Blanc J, Knott G (2018) NeuroMorph: A software toolset for 3D analysis of neurite morphology and connectivity. *Frontiers in Neuroanatomy 12, 59.*

Gala R, Lebrecht D, Sahlender DA, Jorstad A, Knott G, Holtmaat A, Stepanyants A (2017) Computer assisted detection of axonal bouton structural plasticity in in vivo time-lapse images. *eLife 6, e29315.*

Korogod N, Petersen CCH, Knott GW (2015) Ultrastructural analysis of adult mouse neocortex comparing aldehyde perfusion with cryo fixation. *eLife 4, e05793.*

Graham Knott

Adjunct Professor

#

Single-cell biology

RNA-seq

Machine-learning

Neurodevelopment

Radial-glia

Neurogenesis

Gliogenesis

Retina

NEURODEVELOPMENTAL SYSTEMS BIOLOGY

Our research focuses on understanding how the cell types in the nervous system are made. We are particularly interested in describing the sequence of states that progenitors go through during their differentiation towards mature neurons and glia in the central nervous system and the retina. The lab combines computational analysis of genomics data and technique development to answer questions of developmental neuroscience. We generate and analyze comprehensive and biologically complex datasets with different machine learning methods. For example, we have pioneered the quantitative evaluation of in vitro differentiation of neural cell types. We also developed RNA Velocity, a technique that makes it possible to directly measure in static snapshot data the dynamic, time-resolved component of gene expression. Recently we published a comprehensive single-cell molecular atlas of the developing nervous system. Mining this data, we discovered an unexpected heterogeneity of radial-glia-like progenitors. The lab is currently investigating the spatiotemporal patterning of these progenitor subtypes and how teratogenic perturbations can disrupt their organization leading to cognitive disabilities.

Selected publications

Schede HH, Schneider CG, Stergiadou J, Borm LE, Ranjak A, Yamawaki TM, David FPA, Lönnerberg P, Tosches MA, Codeluppi S, La Manno G (2021). Spatial tissue profiling by imaging-free molecular tomography. doi: 10.1038/s41587-021-00879-7. *Nature Biotechnolology.*

Lederer AR, La Manno G (2020). The emergence and promise of single-cell temporal-omics approaches. *Current Opinion in Biotechnology 63, 70.*

La Manno G, Soldatov R, Zeisel A, Braun E, Hochgerner H, Petukhov V, Lidschreiber K, Kastriti ME, Lönnerberg P, Furlan A, et al. (2018). RNA velocity of single cells. *Nature 560, 494.*

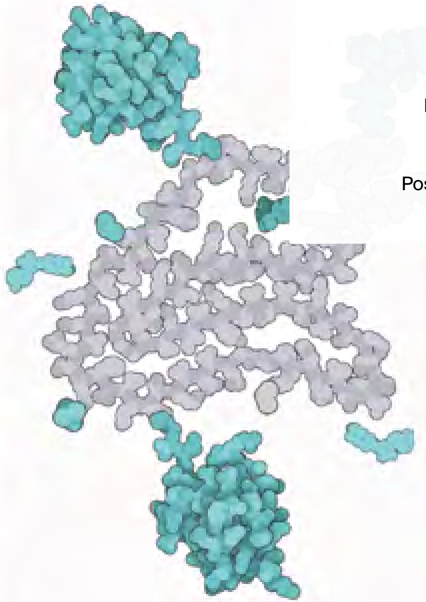
La Manno G, Gyllborg D, Codeluppi S, Nishimura K, Salto C, Zeisel A, Borm LE, Stott SRW, Toledo EM, Villaescusa JC, et al. (2016). Molecular diversity of midbrain development in mouse, human, and stem cells. *Cell 167, 566.*

Furlan A, La Manno, G, Lübke M, Häring M, Abdo H, Hochgerner H, Kupari J, Usoskin D, Airaksinen MS, Oliver G, et al. (2016). Visceral motor neuron diversity delineates a cellular basis for nipple- and pilo-erection muscle control. *Nature Neuroscience 19, 1331.*

Gioele La Manno

EPFL Life Sciences Early Independent Research Scholar

Neurodegeneration
Alzheimer’s disease
Parkinson’s disease
Huntington’s disease
Protein synthesis
Amyloid
Aggregation
Drug discovery
Biomarkers
Post-translational modifications



Degenerating neurons containing neurofibrillary tangles - © EPFL / Lashuel Lab

CHEMICAL BIOLOGY OF NEURODEGENERATION

Research in the Lashuel lab focuses on applying integrated chemical, biophysical, and molecular/cellular biology approaches to elucidate the molecular and structural basis of protein misfolding and aggregation and the mechanisms by which these processes contribute to the pathogenesis of neurodegenerative diseases. More specifically, we aim to

1. Elucidate the sequence, molecular and cellular determinants underlying protein aggregation, pathology spreading, and toxicity.
2. Develop novel chemical approaches and tools to investigate the role of post-translational modifications in regulating the function/dysfunction of proteins implicated in the pathogenesis of Alzheimer's disease (Tau), Parkinson's s (α-Synuclein), Huntington's disease, and Amyotrophic lateral sclerosis (TDP-43).
3. Develop novel cellular models to assess and validate therapeutic targets and to test disease-modifying strategies based on modulating protein post-translational modifications, aggregation, pathology spreading and clearance.
4. Identify biomarkers and imaging agents for early detection, monitoring of disease progression and response to therapies and disease staging.

Selected publications

Mahul-Mellier AL, Burtscher J, Maharjan N, Weerens L, Croisier M, Kuttler F, Leleu M, Knott GW, Lashuel HA (2020) The process of Lewy body formation, rather than simply α-synuclein fibrillization, is one of the major drivers of neurodegeneration. *Proc Natl Acad Sci U S A 117, 4971.*

Hedge R, Chiki A, Petricca L, Martufi P, Arbez N, ... Lashuel HA (2020) TBK1 suppresses mutant HTT induced toxicity and pathology in models of Huntington's disease. *EMBO Journal 39, e104671.*

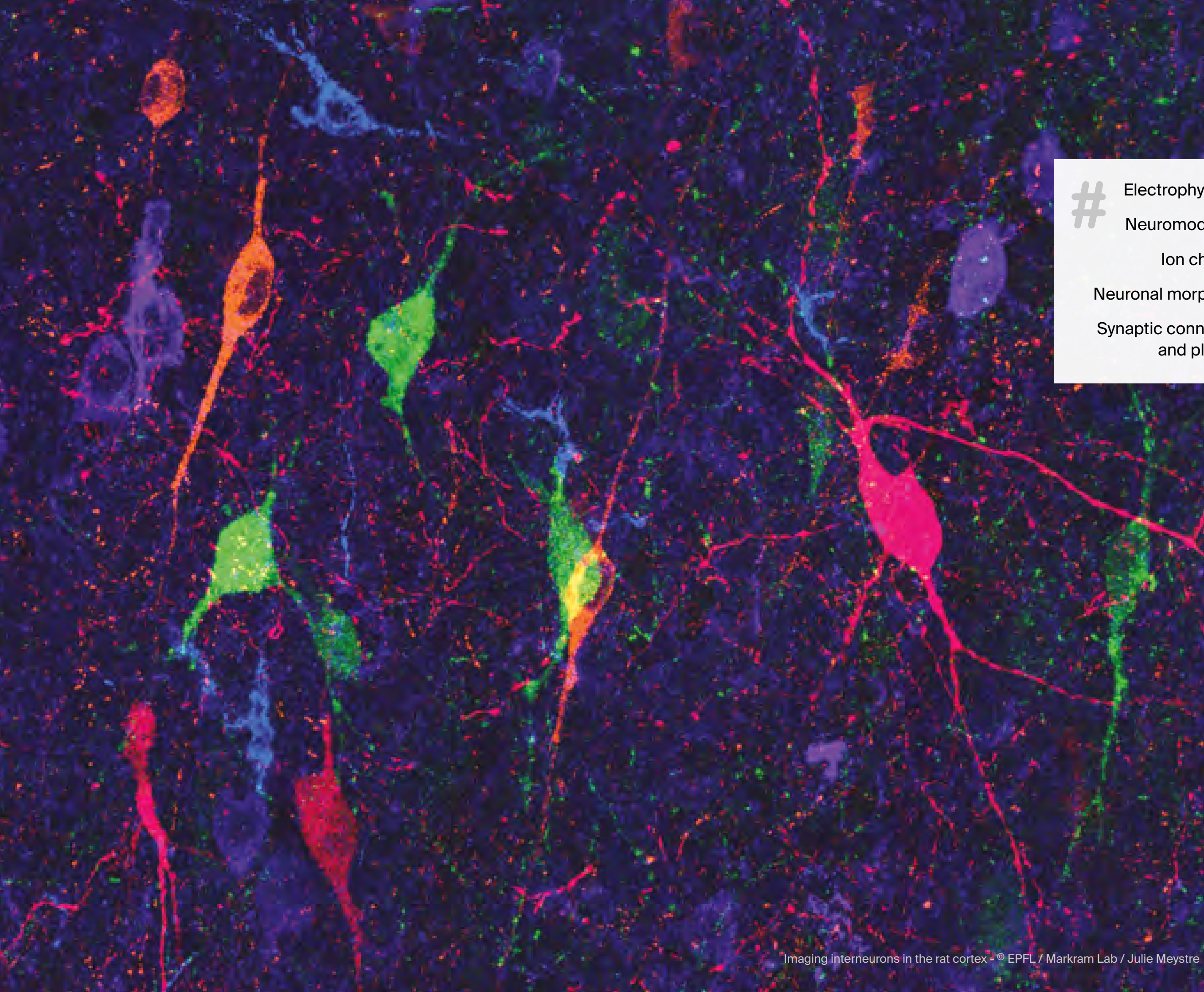
Cendrowska U, Silva PJ, Ait-Bouziad N, Müller M, Guven ZP, ... Lashuel HA (2020) Unraveling the complexity of amyloid polymorphism using gold nanoparticles and cryo-EM. *Proc Natl Acad Sci U S A 117, 6866.*

Haj-Yahya M, Gopinath P, Rajasekhar K, Mirbaha H, Diamond MI, Lashuel HA* (2020) Site-specific hyperphosphorylation inhibits, rather than promotes, Tau fibrillization, seeding capacity and its microtubule binding. *Angew Chem Int Ed Engl 59, 4059.*

Kumar ST, Jagannath S, Francois C, Vanderstichele H, Stoops E, Lashuel HA (2020) How specific are the conformation-specific α-synuclein antibodies? Characterization and validation of 16 α-synuclein conformation-specific antibodies using well-characterized preparations of α-synuclein monomers, fibrils and oligomers with distinct structures and morphology. *Neurobiology of Disease 146, 105086.*

Haj-Yahya M and Lashuel HA (2018) Protein semisynthesis provides access to Tau disease-associated post-translational modifications (PTMs) and paves the way to deciphering the Tau PTM code in health and disease states. *Journal of the American Chemical Society 140, 6611.*

Hilal Lashuel
Associate Professor



Imaging interneurons in the rat cortex - © EPFL / Markram Lab / Julie Meystre

#

Electrophysiology

Neuromodulation

Ion channels

Neuronal morphology

Synaptic connectivity and plasticity

NEURAL MICROCIRCUITRY

The Laboratory of Neural Microcircuitry, headed by Professor Henry Markram, is dedicated to understanding the structure, function and plasticity of neural microcircuits, with emphasis on the neocortex. The neocortex constitutes nearly 80% of the human brain and is made of repeating stereotypical microcircuits composed of different neuron subtypes and takes part in various tasks. Deriving the blueprint of neocortical microcircuits is essential for a comprehensive understanding of its functions, therefore, we systematically characterize the electrophysiological, structural and molecular properties of individual neurons as well as local rules of connectivity and the synaptic properties of interconnected neurons. We also investigate the plasticity and neuromodulation of microcircuit dynamics and continue to work in developing and applying high throughput protocols for thoroughly characterizing and mapping ion channels. The experimental data generated by the Laboratory of Neural Microcircuitry is also used by the Blue Brain Project to build realistic in silico models of many brain regions, providing insights into the function of neuronal circuits through detailed computer simulations.

Selected publications

Iavarone E, Yi J, Shi Y, Zandt BJ, O'Reilly C, Van Geit W, Rössert C, Markram H, Hill SL (2019) Experimentally-constrained biophysical models of tonic and burst firing modes in thalamocortical neurons. *PLoS Computational Biology 15, e1006753.*

Ranjan R, Logette E, Markram H et al. (2019) A kinetic map of the homomeric voltage-gated potassium channel (Kv) family. *Frontiers in Cellular Neuroscience 13, 358.*

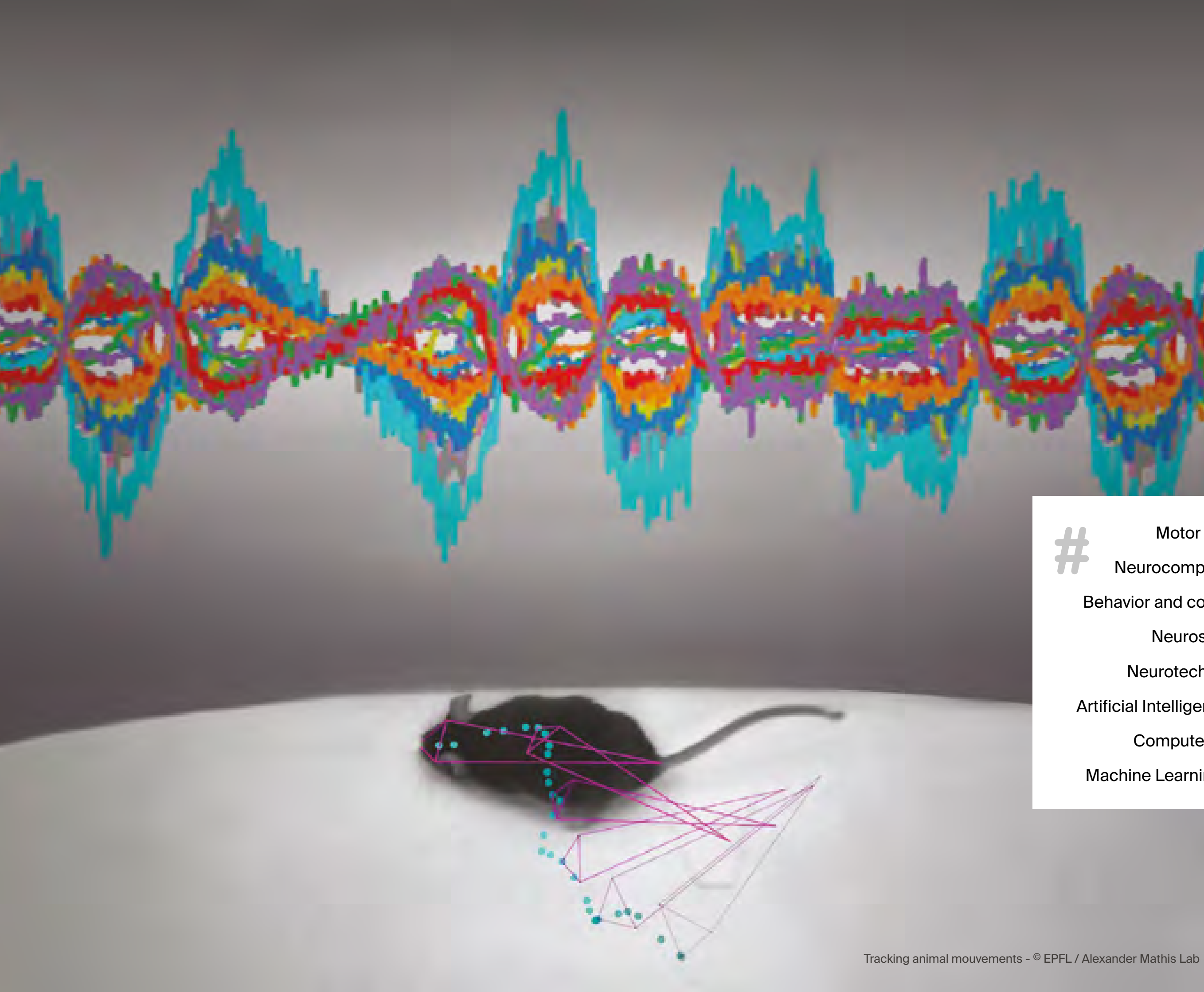
Kanari L, Ramaswamy S, Shi Y, Morand S, Meystre J, Perin R, Abdellah M, Wang Y, Hess K, Markram H (2019) Objective morphological classification of neocortical pyramidal cells. *Cerebral Cortex 29, 1719.*

Markram H, Muller E et al. (2015) Reconstruction and simulation of neocortical microcircuitry. *Cell 163, 456.*

Reimann MW, Anastassiou CA, Perin R, Hill SL, Markram H, Koch C (2013) A biophysically detailed model of neocortical local field potentials predicts the critical role of active membrane currents. *Neuron 79, 375.*

Perin R, Berger TK, Markram H (2011) A synaptic organizing principle for cortical neuronal groups. *Proc Natl Acad Sci U S A 108, 5419.*

Henry Markram
Full Professor



Tracking animal mouvements - © EPFL / Alexander Mathis Lab

#

Motor control

Neurocomputation

Behavior and cognition

Neuroscience

Neurotechnology

Artificial Intelligence (AI)

Computer vision

Machine Learning (ML)

COMPUTATIONAL NEUROSCIENCE AND ARTIFICIAL INTELLIGENCE

Broadly speaking, the group works at the intersection of computational neuroscience and machine learning. We seek to build better models for measuring behavior and develop models of the brain that can reproduce behavior. We strive to develop tools for the analysis of animal behavior. Behavior is a complex reflection of an animal's goals, state and character. Thus, accurately measuring behavior is crucial for advancing basic neuroscience, as well as the study of various neural and psychiatric disorders. However, measuring behavior (from video) is also a challenging computer vision and machine learning problem. Thus, our work will build on advances in machine learning and computer vision to advance the analysis of behavior. To model the sensorimotor system, we explore task-demands, like controlling an arm or learning motor skills, and investigate the emerging representations and computations. Our key hypothesis is that brain circuits for motor control and learning emerge when optimizing circuit models for ethological behaviors. We plan to test and improve those models in collaboration with experimental labs.

Selected publications

Mathis A, Schneider S, Lauer J, Mathis MW (2020) A Primer on motion capture with deep learning: principles, pitfalls, and perspectives. *Neuron 108, 44.*

Mathis A, Mamidanna P, Cury KM, Abe T, Murthy VN, Mathis MW, Bethge M (2018) DeepLabCut: Markerless pose estimation of user-defined body parts with deep learning. *Nature Neuroscience 9, 1281.*

Li Y, Mathis A, Grewe BF, Osterhout JA, Ahanonu B, Schnitzer MJ, Murthy VN, Dulac C (2017) Neuronal representation of social information in the medial amygdala of awake behaving mice. *Cell 171, 1176.*

Mathis A, Herz AV, Stemmler MB (2012) Resolution of nested neuronal representations can be exponential in the number of neurons. *Physical Review Letters 6109, 018103.*

Mathis A, Herz AV, Stemmler M. (2012) Optimal population codes for space: Grid cells outperform place cells. *Neural Computation 24, 2280.*

Alexander Mathis
Assistant Professor

Natural intelligence

Motor control

Artificial intelligence

Systems neuroscience

Sensorimotor control

Motor learning

ADAPTIVE MOTOR CONTROL

The goal of the laboratory is to reverse engineer the neural circuits that drive adaptive motor behavior by studying artificial and natural intelligence. In our lab we develop and utilize new behavioral assays for mice that allow us to study both motor learning in skilled and naturalistic settings. How do animals learn new tasks? How do they adapt to their environment over short and long timescales? To answer these (and related) questions, we believe behavior is an essential component to understanding the underlying neural functions. As part of our quest to better understand behavior, we develop new tools to study complex and natural movements. For example, we developed DeepLabCut, a deep learning-based software package for animal pose estimation, which allows us to record fine motor behaviors noninvasively with high accuracy and speed. We also develop artificial systems that can learn, adapt, and correct motor errors. Lastly, we perform large-scale neural recordings, such that we can combine neural, behavioral, and computational analysis

Collectively, we hope that by understanding the neural basis of adaptive motor control we can open new avenues in therapeutic research for neurological disease, help build better machine learning tools for neuroprosthetics, and provide fundamental insights into brain function.

Selected Publications

Kane GA, Lopes G, Sanders JL, Mathis A, Mathis MW (2020) Real-time, low-latency closed-loop feedback using markerless posture tracking. *eLife 9, e61909.*

Mathis A, Schneider S, Lauer J, Mathis MW (2020) A primer on motion capture with deep learning: Principles, pitfalls, and perspectives. *Neuron 108, 44.*

Mathis MW, Mathis A (2020) Deep learning tools for the measurement of animal behavior in neuroscience. *Current Opinion in Neurobiology 60, 1.*

Mathis A, Mamidanna P, Cury KM, Abe T, Murthy V, Mathis MW*, Bethge M* (2018) DeepLabCut: Markerless pose estimation of user-defined body parts with deep learning. *Nature Neuroscience 21, 1281,* *co-senior.

Mathis MW, Mathis A, Uchida N (2017) Somatosensory cortex plays an essential role in forelimb motor adaptation in mice. *Neuron 93, 1493.*

Cohen JY, Mathis MW, Uchida, N (2015) Serotonergic neurons signal reward and punishment on multiple timescales. *eLife 4, e06346.*

Mackenzie Weygandt Mathis

Assistant Professor
Bertarelli Foundation Chair
of Integrative Neuroscience

Drosophila neuromuscular synaptic terminal - © EPFL 2021/ McCabe Lab / C. Cela

#

Motor

Synapses

Circuits

Genetics

Molecular

Neurotransmission

Neurodegeneration

SMA

ALS

Drosophila

Gene therapy

NEURAL GENETICS AND DISEASE

Our research aspires towards the dual goals of understanding, with molecular and cellular resolution, the neuronal circuit networks and interconnecting synapses that comprise the motor system, and in tandem, to decipher and ameliorate neurodegenerative motor disorders. The vital necessity for precise motor control, the ability to image motor synapses in vivo together with expedient electrophysiological access, coupled with the stringency of locomotor behavioural quantitation, make motor circuits a potent paradigm to allow molecular, cellular and physiological interrogation of the mechanisms through which synapses and circuits develop, adapt and coordinate to produce ensemble activity. Exploiting these advantages can also illuminate how neuronal circuits are depleted by ageing and neurodegenerative disorders including SMA and ALS (motor neuron disease). As the basis for our investigations, we exploit the advanced neurogenetic control enabled by the molecular and genome engineering capabilities of the Drosophila model system. Drosophila share not only extensive genetic conservation with humans but also many morphological, physiological and behavioural similarities. Augmenting this foundation, we extend and validate our studies in rodents in addition to human cellular models.

Selected publications

Chiriboga CA, Marra J, LaMarca NM, Young SD, Weimer LH, Levin B, McCabe BD (2020) Effect on ambulation of dalfampridine-ER (4-AP) treatment in adult SMA patients. *Neuromuscular Disorders 30, 693.*

Choi BJ, Imlach W, Jiao W, Wolfram V, Ying W, Grbic M, Cela C, Baines RA, Nitabach MN, McCabe BD (2014) Miniature neurotransmission regulates Drosophila synaptic structural maturation. *Neuron 82, 618.*

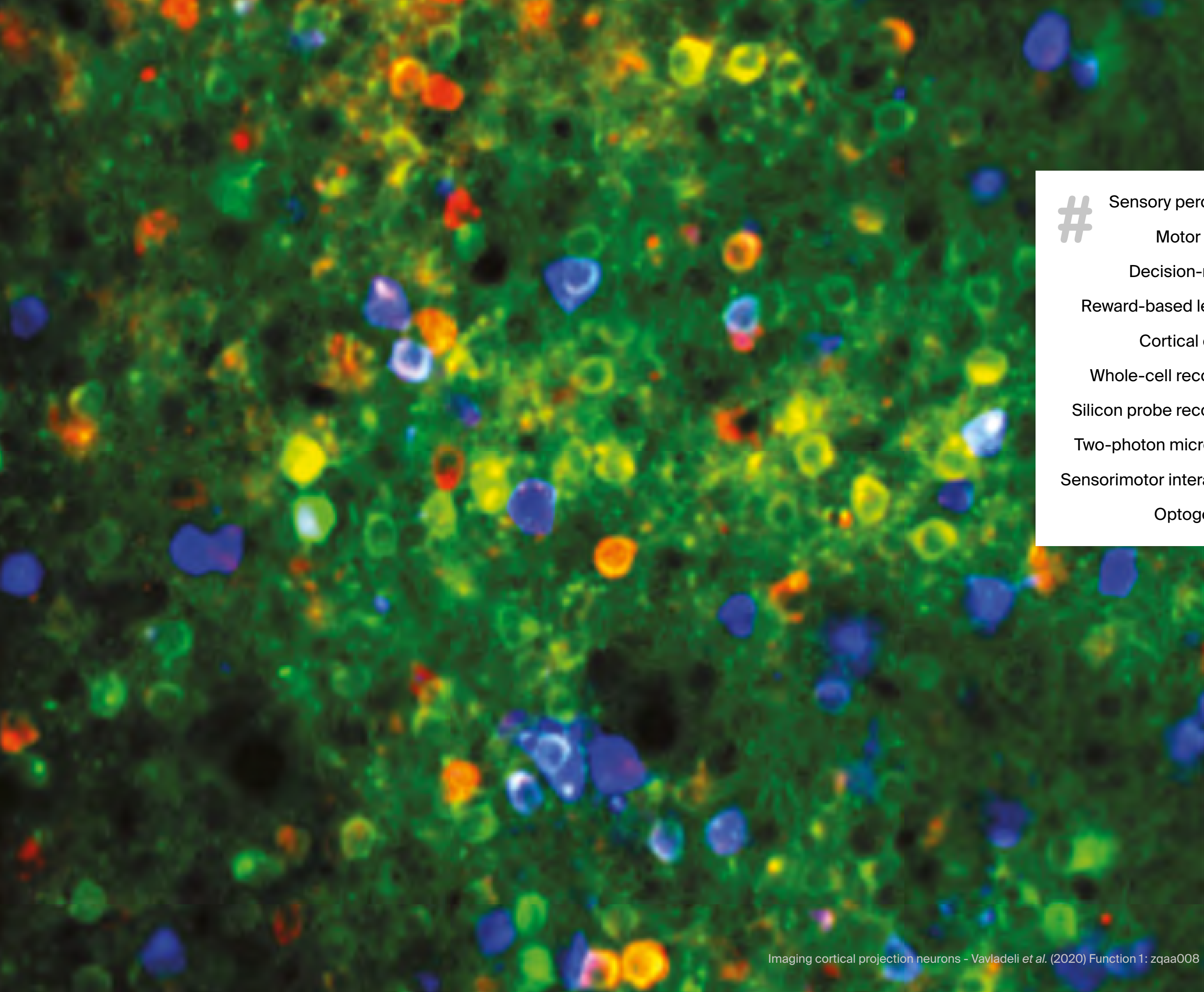
Lotti, F, Imlach, W, Luciano S, H. Le, Beattie CE, Beck E, Pellizzoni L, McCabe BD (2012) SMN-Dependent U12 splicing events are essential for motor circuit function. *Cell 151, 427.*

Imlach W, Beck E, Choi BJ, Pellizzoni L, McCabe BD (2012) SMN is required for sensory-motor circuit function in Drosophila. *Cell 151, 440.*

Beck E, Gasque G, Wu P, McCabe BD (2012) The splicing factor Beag governs synapse growth through the regulation of Fasciclin II. *Journal of Neuroscience 20, 7058.*

Wang JW, Brent J, Schneider N, McCabe BD (2011) The ALS genes FUS and TDP-43 function together to regulate locomotion and longevity in Drosophila. *Journal of Clinical Investigation 121, 4118.*

Brian McCabe
Associate Professor



#

Sensory perception

Motor control

Decision-making

Reward-based learning

Cortical circuits

Whole-cell recordings

Silicon probe recordings

Two-photon microscopy

Sensorimotor interactions

Optogenetics

Imaging cortical projection neurons - Vavladeli *et al.* (2020) Function 1: zqaa008

SENSORY PROCESSING

Carl Petersen's laboratory aims to define the neuronal circuits and synaptic mechanisms underlying sensory perception and reward-based sensorimotor learning in mice. To understand sensorimotor processing at the level of individual neurons and their synaptic interactions within complex networks, we use electrophysiological and optical methods combined with molecular and genetic interventions. We want to know how specific neuronal networks contribute to the processing of sensory information in a learning- and context-dependent manner ultimately leading to behavioral decisions and goal-directed motor output. Current experiments investigate how neuronal circuits in the mouse brain learn to transform whisker sensory information into goal-directed licking motor output through reward-based learning (Petersen, 2019; Esmaeili *et al.*, 2020). Through brain wide measurement and perturbation of neuronal activity correlated with quantified behavior in mice, we find evidence for cell-type-specific contributions in different brain regions for sensory processing, learning, decision-making and motor control (Sippy *et al.*, 2015; Yamashita & Petersen, 2016; Le Merre *et al.*, 2018; Mayrhofer *et al.*, 2019).

Selected publications

Esmaeili V, Tamura K, Foustoukos G, Oryshchuk A, Crochet S, Petersen CCH (2020) Cortical circuits for transforming whisker sensation into goal-directed licking. *Current Opinion in Neurobiology 65, 38.*

Mayrhofer JM, El-Boustani S, Foustoukos G, Auffret M, Tamura K, Petersen CCH (2019) Distinct contributions of whisker sensory cortex and tongue-jaw motor cortex in a goal-directed sensorimotor transformation. *Neuron 103, 1034.*

Le Merre P, Esmaeili V, Charrière E, Galan K, Salin PA, Petersen CCH, Crochet S (2018) Reward-based learning drives rapid sensory signals in medial prefrontal cortex and dorsal hippocampus necessary for goal-directed behavior. *Neuron 97, 83.*

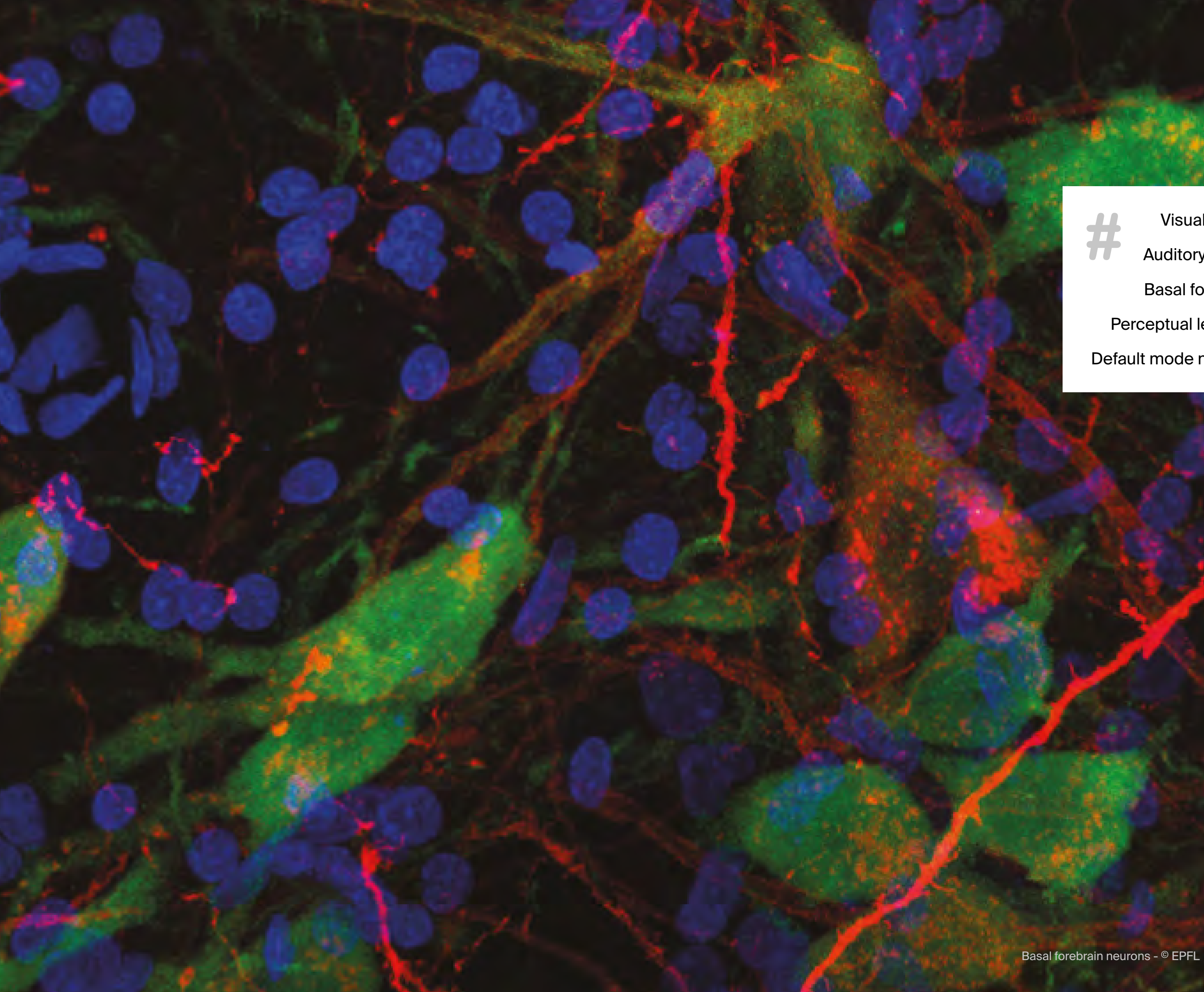
Petersen CCH (2019) Sensorimotor processing in the rodent barrel cortex. *Nature Reviews Neuroscience 20, 533.*

Yamashita T, Petersen CCH (2016) Target-specific membrane potential dynamics of neocortical projection neurons during goal-directed behavior. *eLife 5, e15798.*

Sippy T, Lapray D, Crochet S, Petersen CCH (2015) Cell-type-specific sensorimotor processing in striatal projection neurons during goal-directed behavior. *Neuron 88, 298.*

Carl Petersen

Full Professor



\# Visual cortex
Auditory cortex
Basal forebrain
Perceptual learning
Default mode network

Basal forebrain neurons - © EPFL

VISUAL COGNITION

Our research focuses on the role of basal forebrain nuclei in attention, learning and memory and brain state regulation. We have become interested in the ventral pallidum basal forebrain nucleus, which we have linked to regulation of the default mode network. In particular, pronounced gamma oscillations are apparent in this brain region during quiet wakefulness and self-grooming, two behaviors associated with self-directed, inwardly focused behavior compatible with the default brain state. We have accumulated evidence implicating inhibitory circuits projecting to frontal cortical areas in this regulation of brain function, and are further exploring this using cell-type specific circuit manipulations. We combine sophisticated behavioral training with a number of state-of-the-art experimental techniques, including optogenetics, multi electrode recordings of spikes and local field potentials, deep-brain stimulation, in vivo neurochemical monitoring and optogenetics. We believe in comparative neuroscience, because only mechanisms shared by closely related species are likely to be of general character with excellent translational potential. We therefore perform investigations in several mammalian species in our laboratory, including rat, macaque and tree shrew.

Selected publications

Lozano-Montes L, Dimanico M, Mazloum R, Li W, Nair J, Kintscher M, Schneggenburger R, Harvey M, Rainer G (2020) Optogenetic stimulation of basal forebrain parvalbumin neurons activates the default mode network and associated behaviors. *Cell Reports 33, 108359.*

Azimi H, Klaassen AL, Thomas K, Harvey MA, Rainer G (2020) Role of the thalamus in basal forebrain regulation of neural activity in the primary auditory cortex. *Cerebral Cortex 30, 4481.*

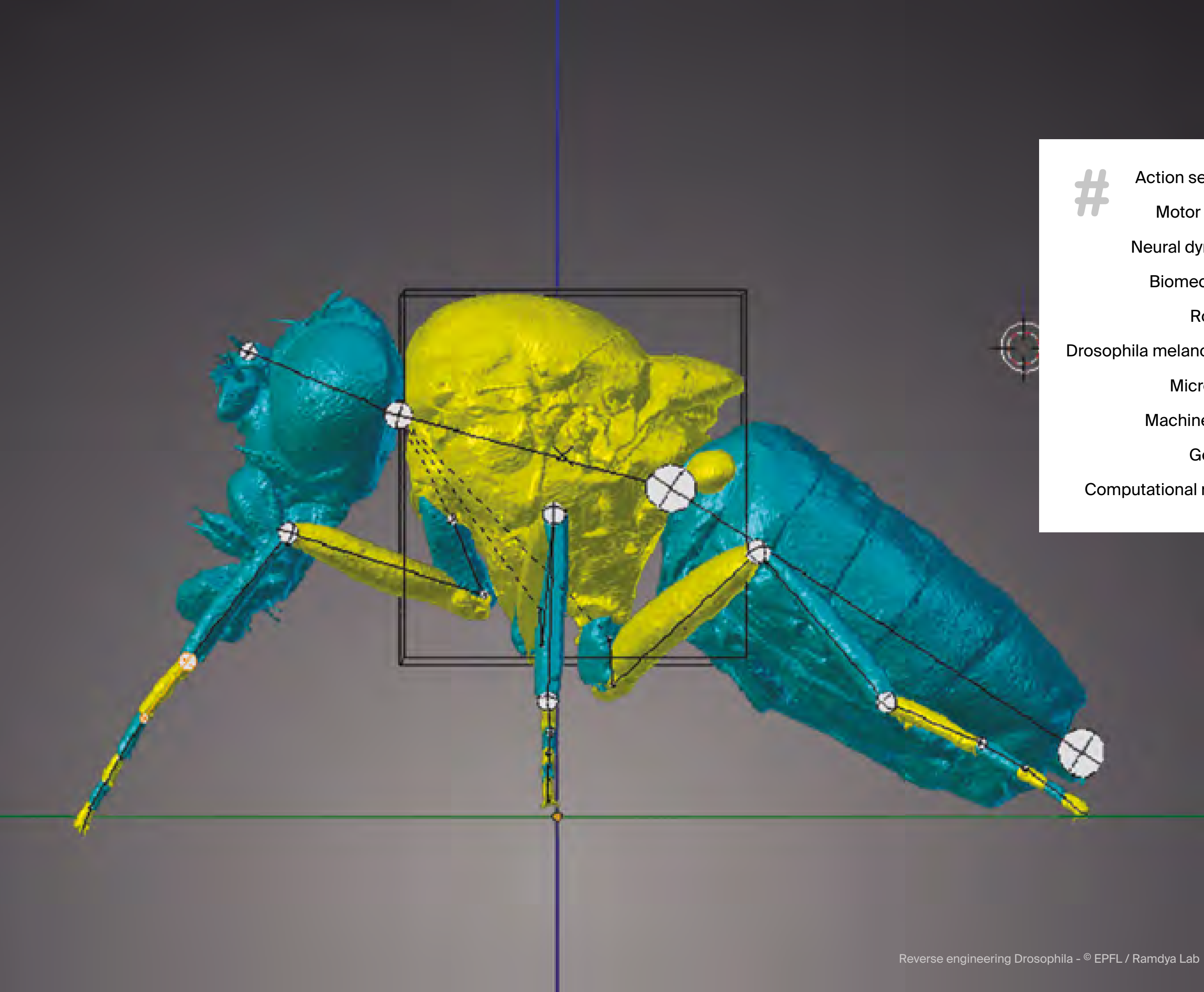
Sonnay S, Poirot J, Just N, Clerc AC, Gruetter R, Rainer G, Duarte JMN (2018) Astrocytic and neuronal oxidative metabolism are coupled to the rate of glutamate-glutamine cycle in the tree shrew visual cortex. *Glia 66, 477.*

Nair J, Klaassen A-L, Arato J, Vyssotski AL, Harvey M, Rainer G (2018) Basal forebrain contributes to default mode network regulation. *Proc Natl Acad Sci U S A 115, 1352.*

Khani A, Mustafar F, Rainer G (2018) Distinct frequency specialization for detecting dark transients in humans and tree shrews. *Cell Reports 23, 2405-2415.*

Mustafar F, Harvey M, Arato J, Khani A, Rainer G (2018) Divergent solutions to visual problem solving across mammalian species. *eNeuro 5, 0167-18.2018.*

Gregor Rainer
Associate Professor at EPFL and Full Professor at the University of Fribourg


Reverse engineering Drosophila - © EPFL / Ramdya Lab

#

Action selection

Motor control

Neural dynamics

Biomechanics

Robotics

Drosophila melanogaster

Microscopy

Machine vision

Genetics

Computational models

NEUROENGINEERING

We are fascinated by how seemingly simple animals achieve rather complex feats. A fly walking upside down on the ceiling, or boxing a sexual competitor may seem mundane until you try to imagine how one would build a robot to do the same. This is our goal: to reverse-engineer living systems in order to understand how to construct similarly agile and flexible artificial systems. We study the fly, Drosophila, because (i) it has relatively few neurons, (ii) each cell can be repeatedly genetically targeted, and (iii) it can generate complex limb-dependent behaviors. Limb dependent actions emerge from a multiscale algorithm comprising molecular gene expression, neuronal population dynamics, and the biomechanics of muscle and exoskeleton. We untangle how these mechanisms contribute to action control by developing and using microscopy and deep network-based analysis to measure neural activity and behavior. We also explore neural network models and physics-based simulations in an ongoing dialogue with real experiments. One test of how well we understand the language of biological control will be the extent to which we can construct artificial systems that can recapitulate the dexterous movements of real animals.

Selected publications

Günel S, Rhodin H, Morales D, Campagnolo J, Ramdya P, Fua P (2019) Deep-Fly3D, a deep learning-based approach for 3D limb and appendage tracking in tethered adult Drosophila. *eLife 8, e48571.*

Chen CL, Hermans L, Viswanathan MC, Fortun D, Aymanns F, Unser M, Cammarato A, Dickinson MH, Ramdya P (2018) Imaging neural activity in the ventral nerve cord of behaving adult Drosophila. *Nature Communications 9, 4390.*

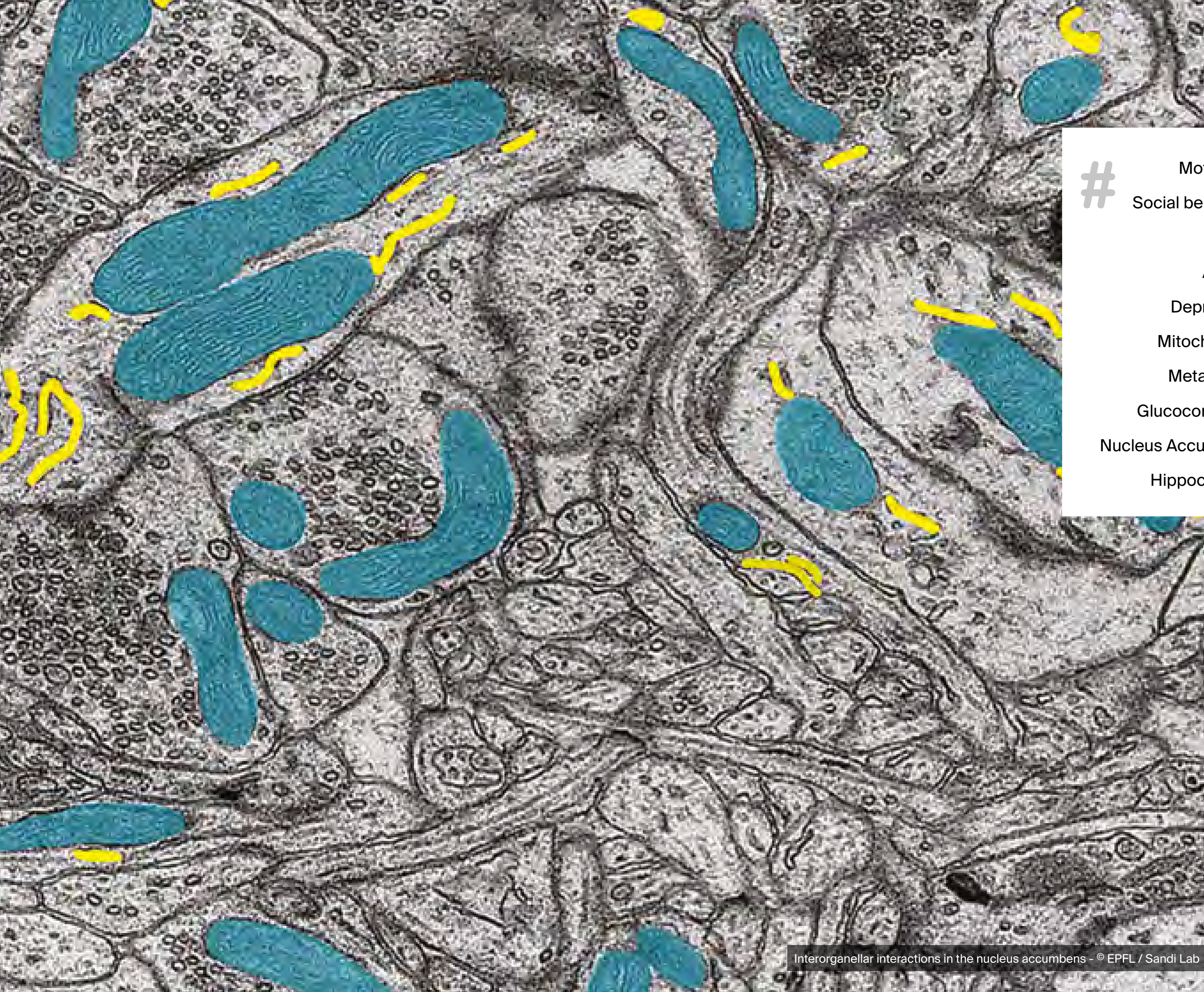
Ramdya P, Thandiackal R, Cherney R, Asselborn T, Benton R, Ijspeert AJ, Floreano D (2017) Climbing favors the tripod gait over alternative faster insect gaits. *Nature Communications 8, 14494.*

Maesani A, Ramdya P, Cruchet S, Gustafson K, Benton R, Floreano D (2015) Fluctuation-driven neural dynamics reproduce Drosophila locomotor patterns. *PLoS Computational Biology, 11, e1004577.*

Ramdya P, Lichocki P, Cruchet S, Frisch L, Tse W, Floreano D, Benton R (2015) Mechanosensory interactions drive collective behavior in Drosophila. *Nature 519, 233.*

Pavan Ramdya

Assistant Professor



Interorganellar interactions in the nucleus accumbens - © EPFL / Sandi Lab

#

Motivation

Social behaviors

Stress

Anxiety

Depression

Mitochondria

Metabolism

Glucocorticoids

Nucleus Accumbens

Hippocampus

BEHAVIORAL GENETICS

We investigate the impact and mechanisms whereby stress and personality affect brain function and behavior, with a focus on motivation and the social domain. Specifically, we investigate: i) The neurobiological mechanisms involved in motivated behavior, and their modulation by stress and anxiety. We focus on the mesolimbic system and the role of mitochondrial function in effort-based motivated behavior and social hierarchy formation and maintenance. ii) The mechanisms whereby early life stress enhances risk to develop psychopathologies, with a main focus on the emergence of sociability deficits and pathological aggression. We investigate the role of glucocorticoids in determining different neurodevelopmental trajectories following exposure to early life adversity. We also ascertaining the fat-to-brain pathways in the mediation of behavioral programming by early life stress. Experimental approaches in the lab include a combination of behavioral, neuroimaging, electrophysiological, neurochemical, pharmacological, metabolic, genetic and optogenetic methods. We perform studies in rodents and translational work in humans using virtual reality, behavioral economics, experimental psychology (eye-tracking, computer-based tests) and neuroimaging (EEG, fMRI, MRI, 1H-MRS) approaches.

Selected publications

Rodrigues J, Studer E, Streuber S, Meyer N, Sandi C (2020) Locomotion in virtual environments predicts cardiovascular responsiveness to subsequent stressful challenges. *Nature Communications 11, 5904.*

Cherix A, Larrieu T, Grosse J, Rodrigues J, McEwen B, Nasca C, Gruetter R, Sandi C (2020) Metabolic signature in nucleus accumbens for anti-depressant-like effects of acetyl-L-carnitine. *eLife 9, e50631.*

Strasser A, Luksys G, Xin L, Pessiglione M, Gruetter R, Sandi C (2020) Glutamine-to-glutamate ratio in the nucleus accumbens predicts effort-based motivated performance in humans. *Neuropsychopharmacology 45, 2048.*

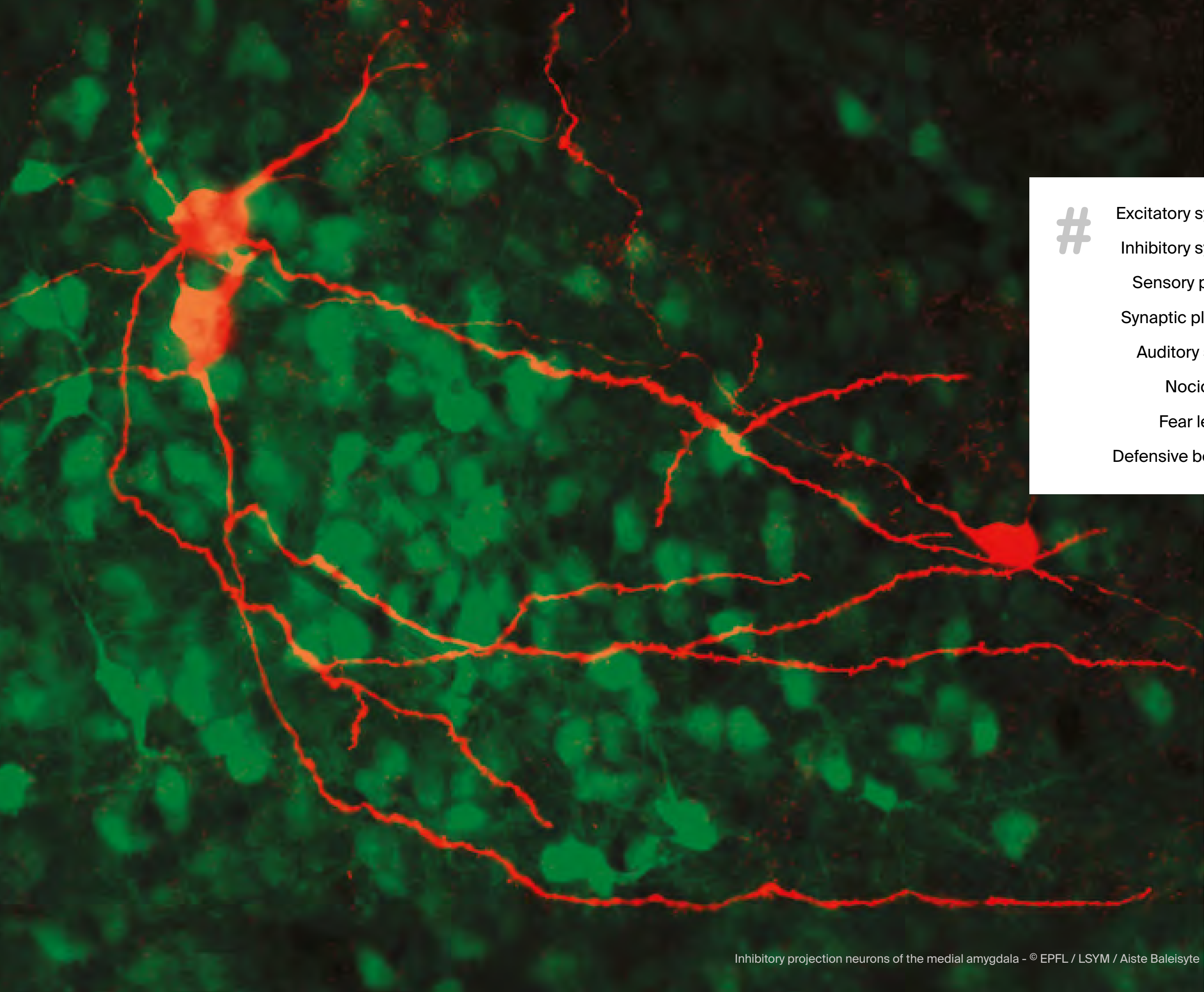
van der Kooij MA, Hollis F, Lozano L, Zanoletti I, Zalachoras I, Abad S, Zanoletti O, Grosse J, Guillot de Suduiraut I, Canto C, Sandi C (2018) Diazepam actions in the VTA enhance social dominance and mitochondrial function in the nucleus accumbens by activation of accumbal dopamine D1 receptors. *Molecular Psychiatry 23, 569.*

Larrieu T, Cherix A, Duque A, Rodrigues J, Lei H, Gruetter R, Sandi C (2017) Hierarchical status predicts behavioral vulnerability and nucleus accumbens metabolic profile following chronic social defeat stress. *Current Biology 14, 2202.*

Hollis F, van der Kooij MA, Zanoletti O, Lozano L, Canto C, Sandi C (2015) Mitochondrial function in the brain links anxiety with social subordination. *Proc Natl Acad Sci USA 112, 15486.*

Carmen Sandi

Full Professor



Inhibitory projection neurons of the medial amygdala - © EPFL / LSYM / Aiste Baleisyte

#

Excitatory synapse
Inhibitory synapse
Sensory percept
Synaptic plasticity
Auditory system
Nociception
Fear learning
Defensive behavior

SYNAPTIC CIRCUITS

Information transfer between neurons happens at synapses, and long-term plasticity at synapses is a key mechanism that enables learning and memory. In the past, the Schneggenburger lab has made important contributions to our understanding of synaptic transmission. In recent years, the lab has become interested to study the relationship between plasticity at synapses in specific brain circuits, and a learned behavior. For this, we employ the paradigm of fear learning, during which an innocuous sensory event like a tone will come to elicit a defensive response after it is paired with an aversive outcome. We use optogenetic tools in mice, in-vivo recordings of neuronal activity, and functional tracing of synaptic connections and their plasticity state, to investigate the role of synaptic plasticity in fear learning. Studying cortical and amygdalar circuits, we want to understand how the aversive quality of a nociceptive event is imprinted onto an initially neutral sensory percept, like a tone. Addressing these processes of aversively motivated plasticity will allow us to gain insights into fundamental mechanisms of brain function, as well as into the pathophysiology of psychiatric disease like anxiety disorders.

Selected publications

Tang W, Kochubey O, Kintscher M, Schneggenburger R (2020) A VTA to basal amygdala dopamine projection contributes to signal salient somatosensory events during fear learning. *Journal of Neuroscience 40, 3969.*

Vickers ED, Clark C, Osypenko D, Fratzl A, Kochubey O, Bettler B, Schneggenburger R (2018) Parvalbumin-interneuron output synapses show spike-timing dependent plasticity that contributes to auditory map remodeling. *Neuron 99, 720.*

Keller D, Babai N, Han Y, Kochubey O, Markram H, Schürmann F, Schneggenburger R (2015) An exclusion zone for Ca^{2+} channels around docked vesicles explains release control by multiple channels at a CNS synapse. *PLOS Computational Biology 11, e1004253.*

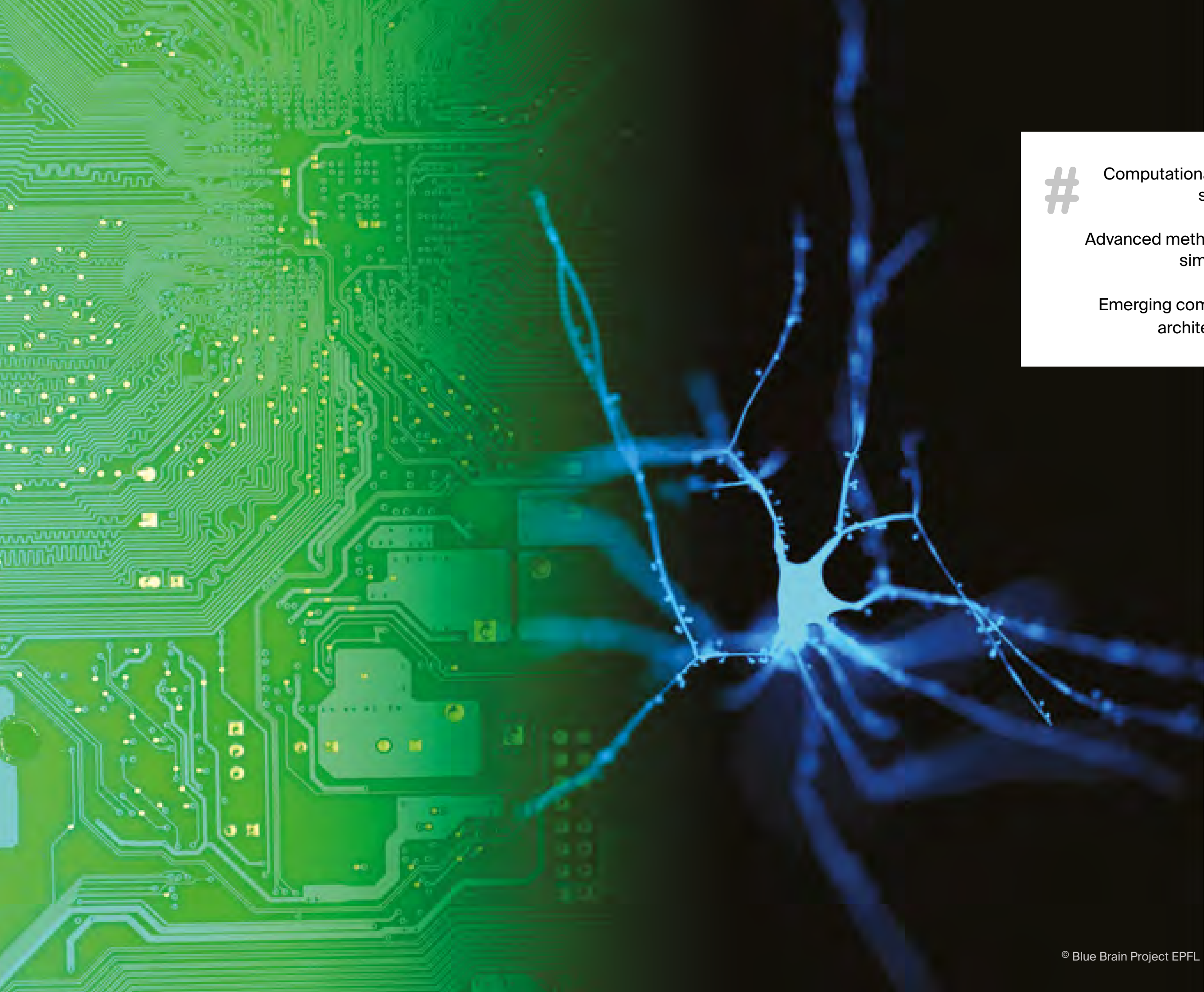
Genc Ö, Kochubey O, Toonen R, Verhage M, Schneggenburger R (2014) Munc18-1 is a dynamically regulated PKC target during short-term enhancement of transmitter release. *eLife 3, e01715.*

Kochubey O, Schneggenburger R (2011) Synaptotagmin increases the dynamic range of synapses by driving Ca^{2+} - evoked release and by clamping a near-linear remaining Ca^{2+} sensor. *Neuron 69, 736.*

Han Y, Kaeser PS, Südhof TC, Schneggenburger R (2011) RIM determines Ca^{2+} channel density and vesicle docking at the presynaptic active zone. *Neuron 69, 304.*

Ralf Schneggenburger

Full Professor



Computational brain science

Advanced methods for simulation

Emerging computing architectures

NEUROSCIENCE AND COMPUTING

Our research takes place at the interface of computing and neuroscience. Computing for Neuroscience - focusing on bringing the toolbox of computational science to neuroscience. In collaboration with the EPFL Blue Brain Project, we develop effective methods for the building of biophysically detailed neuronal models and brain tissue models, which push the boundaries of numerical methods and simulation schemes, making it possible to use massively parallel supercomputers efficiently for neuroscience. Our research looks several years ahead to innovate in our ability to simulate brain tissue and we use analytical performance modelling to understand the limits and opportunities of computing for brain science. Neuroscience for Computing - with the challenges of Moore's law becoming more and more apparent, it will become more difficult to continue to increase computing performance in the future. This requires tailoring computing more specifically for the application, necessitating deep insight of the computational essence of the application and opportunities in computer architecture. We use our insight on the brain and understanding of the computational needs to promote the use of neuromorphic computing elements as a means to complement computing in the future.

Selected publiations

Cremonesi F, Hager G, Wellein G, Schürmann F (2020). Analytic performance modeling and analysis of detailed neuron simulations. *The International Journal of High Performance Computing Applications, 34, 428.*

Cremonesi F, Schürmann F (2020) Understanding computational costs of cellular-level brain tissue simulations through analytical performance models. *Neuroinformatics 18, 407.*

Amsalem O, Eyal G, Rogozinski N, Gevaert M, Kumbha Pr, Schürmann F, Segev (2020) An efficient analytical reduction of detailed nonlinear neuron models. *Nature Communications 11, 288.*

Magalhães BRC, Sterling T, Hines M, Schürmann F (2019). Fully-asynchronous fully-implicit variable-order variable-timestep simulation of neural networks. *In V. Krzhizhanovskaya et al. editors, Computational Science – ICCS 2020. ICCS 2020. Lecture Notes in Computer Science 12141, 94. Springer, Cham.*

Kumbha Pr, Hines M, Fouriaux J, OvcharenkoA, King J, Delalondre F, and Schürmann F (2019) CoreNeuron: An optimized compute engine for the neuron simulator. *Frontiers in Neuroinformatics, 13, 63.*

Einevoll GT, Destexhe A, Diesmann M, Grün S, Jirsa V, de Kamps M, Migliore M, Ness TV, Plesser HE, Schürmann F (2019) The scientific case for brain simulations. *Neuron 102, 735-744.*

Felix Schürmann

Adjunct Professor

SCIENTIFIC ADVISORY BOARD

Barry Everitt
Professor of Behavioural Neuroscience
University of Cambridge, UK
Expert in neural mechanisms of motivation, learning and memory

Christof Koch
Chief Scientist of the MindScope Program
Allen Institute for Brain Science, Seattle, USA
Expert in computer science and the neural basis of consciousness

Sten Grillner
Neurophysiologist and distinguished professor at the Karolinska Institute
Stockholm, Sweden
Expert in the cellular bases of motor behavior

Andreas Meyer-Lindenberg
Professor at the University of Heidelberg and Director of the Central Institute of Mental Health in Mannheim, Germany
Expert in neural mechanisms of psychiatric disorders

Michael Häusser
Professor of Neuroscience at the Wolfson Institute for Biomedical Research
University College London, UK
Expert in the cellular basis of neural computation in the mammalian brain

Carla Shatz
Professor of Biology and of Neurobiology
Stanford University, USA
Expert in development and plasticity of mammalian brain circuits

EPFL NEURO PROFESSORS

Prof. Johan Auwerx
Laboratory of Integrative System Physiology, EPFL SV IBI

Signaling networks, mitochondrial function and metabolism in health, aging and disease

www.epfl.ch/labs/auwerx-lab

Prof. Jocelyne Bloch
Stereotactic and Functional Unit, University Hospital of Lausanne (CHUV) and EPFL SV BMI

Neurosurgery, implantable neuroprostheses, neuroregeneration, neurorehabilitation, neurostimulation

www.chuv.ch/fr/chirurgie-spinale/spi-home/en-bref/notre-equipe/nos-medecins/pre-jocelyne-bloch

Prof. Aude Billard
Learning Algorithms and Systems Laboratory, EPFL STI IMT

Control and design of robotic systems for human interactions

https://www.epfl.ch/labs/lasa/

Prof. Pascal Fua
Computer Vision Laboratory, EPFL IC IINFCOM

Computer vision and neural circuit tracing

https://www.epfl.ch/labs/cvlab/

Prof. Diego Ghezzi
Medtronic Chair in Neuroengineering, EPFL STI IBI and CNP

Neuro-optoelectronic interfaces and visual prosthesis

https://lne.epfl.ch

Prof. Rolf Gruetter
Laboratory of Functional and Metabolic Imaging, EPFL SB IPHYS

Functional and metabolic magnetic resonnance imaging in rodents and humans

https://www.epfl.ch/labs/lifmet/

Prof. Auke Ijspeert
Biorobotics Laboratory, EPFL STI IBI

Locomotion in biologically-inspired robots

https://www.epfl.ch/labs/biorob/

Prof. Stéphanie Lacour
Foundation Bertarelli Chair in Neuroprosthetic Technology, EPFL STI IMT and CNP

Technology of soft bioelectronic interfaces, including ultra-compliant neural electrodes

https://lsbi.epfl.ch

Prof. Pierre Magistretti
Honorary Professor, EPFL SV

Brain energy metabolism, astrocytes, lactate, neuroenergetics, neuron-glia interaction, mood disorders

https://nccr-synapsy.ch/research/axis-2/

Prof. Silvestro Micera
Bertarelli Foundation Chair in Translational Neuroengineering, EPFL STI IBI and CNP

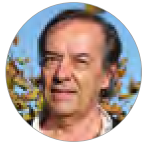
Neural interfaces and robotic systems to restore sensorimotor function in people

https://tne.epfl.ch

Prof. Sahand Jamal Rahi
Laboratory of the Physics of Biological Systems, EPFL SB IPYS

Biophysics, systems biology, computational biology, genetics, microscopy

https://www.epfl.ch/labs/lpbs/



Prof. Philippe Renaud
Microsystems Laboratory 4, EPFL STI IMT

Microfabrication technologies for bioelectronic devices such as micro-electrodes for neural recordings

https://lmis4.epfl.ch/

Dr. Bernard Schneider
Bertarelli Foundation Gene Therapy Platform, EPFL SV PTECH

Production of viral vectors for therapeutic applications in the field of neurological diseases

https://www.epfl.ch/research/facilities/gene-therapy/

Prof. Mahsa Shoaran
Integrated Neurotechnologies Laboratory, EPFL STI IEL and CNP

Neural interface microsystems, neuromodulation and neural data analysis

https://www.epfl.ch/labs/inl/

Prof. Jean-Philippe Thiran
Signal Processing Laboratory 5, EPFL STI IEL

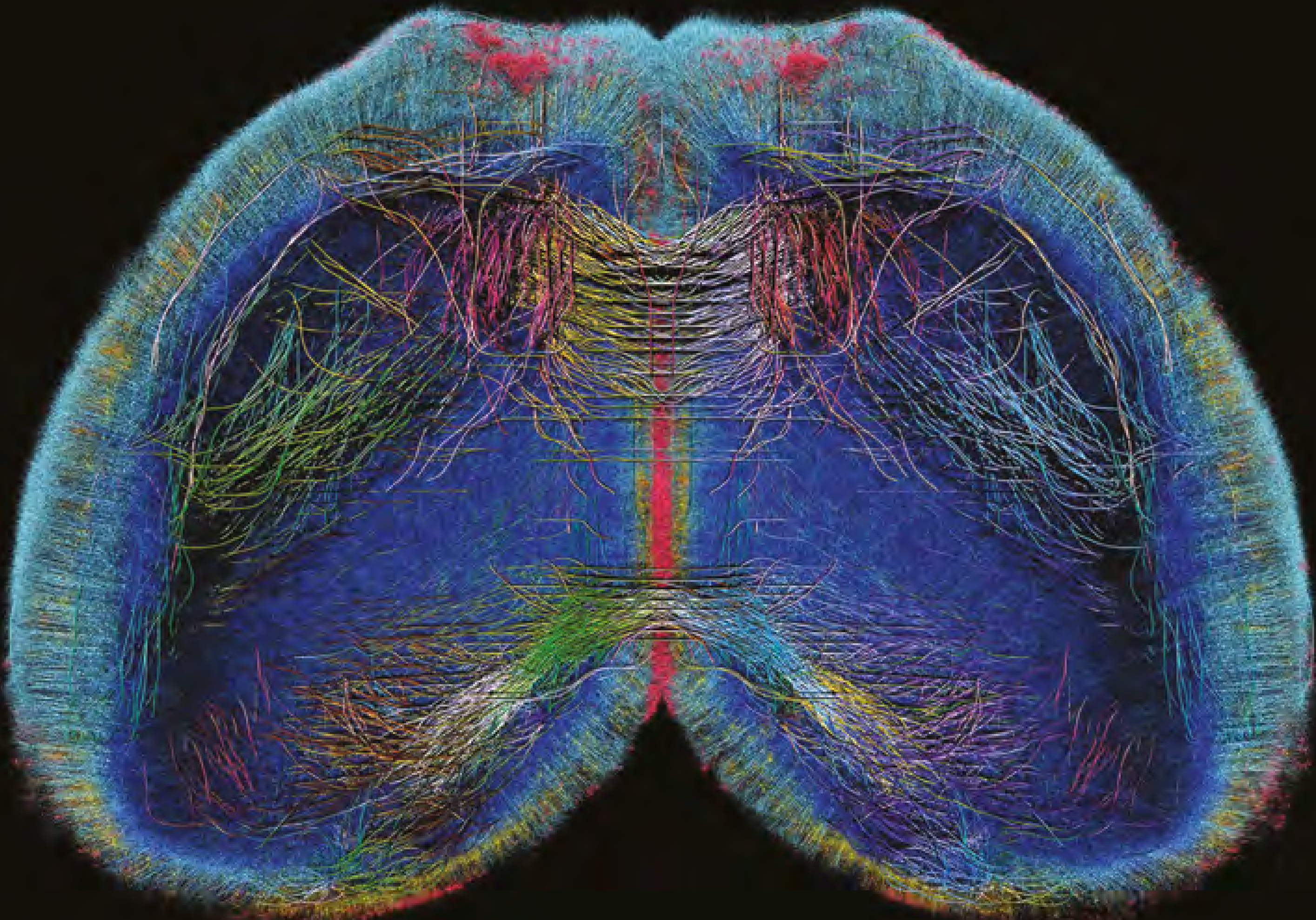
Image processing and diffusion tensor imaging analysis of human brain connectivity

https://lts5www.epfl.ch/

Prof. Dimitri Van De Ville
Medical Image Processing Laboratory, EPFL STI IBI and CNP

Innovative data-processing tools for analysis of human neuroimaging data

https://miplab.epfl.ch/



BLUE BRAIN PROJECT

The aim of the EPFL Blue Brain Project (BBP) is to establish simulation neuroscience as a complementary approach alongside experimental, theoretical and clinical neuroscience to understanding the brain, by building biologically detailed digital reconstructions and simulations of the entire mouse brain.
In 2015, BBP reached a major milestone with the publication of a first draft of the digital reconstruction of neocortical microcircuitry (Markram et al., Cell 2015), representing the most complete description of any neural microcircuit to date. Since then alongside other work, BBP has

- Used the microcircuit model for novel in silico studies, tackling the relationship between structure and function using algebraic topology, studying cortical reliability amid noise and chaos, examining the underpinnings of auditory surprise and taking a fresh look at voltage-sensitive dye imaging
- Produced the first draft model of the rules guiding neuron-to-neuron connectivity of a whole mouse neocortex. Based on these rules, the team has generated dense instances of the micro-connectome of 10 million neurons, a model spanning 5 orders of magnitude and containing 88 billion synaptic connections that will serve as the basis of detailed models of the mouse neocortex
- Released the Blue Brain Cell Atlas, the first digital 3D atlas of every cell in the mouse brain
- Mapped and made publicly available, the kinetic behavior of the largest family of ion channels: Kv channels
- Helped other global groups to build digital copies of other brain regions including first biophysically detailed models of human neurons

Division directors

Prof. Henry Markram
Founder and Director

Prof. Felix Schürmann
Director of Computing

Adriana Salvatore
Director of Operations

Blue Brain Project

CENTER FOR NEUROPROSTHETICS

The Center for Neuroprosthetics (CNP) is a multidisciplinary research center that brings together approximately 200 researchers, engineers, physicians and technicians from the Schools of Life Sciences and Engineering. Its mission is to develop technologies that interface with the nervous system to support, repair or replace neural functions. Based on cutting edge fundamental knowledge of the brain and nervous system (perception, cognition and movement), and on revolutionary technologies (bioelectronics, neural signal recording, processing and control, imaging, AI, computer vision, virtual reality), the Center aims at translating to the clinics revolutionary technologies to alleviate the burden of neural diseases and disorders.
With its main site located at Campus Biotech, CNP has clinical outposts in Sion (at the Clinique Romande de Réhabilitation CRR-SUVA) for the rehabilitation of patients after stroke, in Lausanne at NeuroRestore (a joint initiative between EPFL, CHUV, UNIL and CRR-SUVA) to develop treatment strategies involving neurosurgery to treat spinal cord injuries, and develops strategic partnerships with HUG in Geneva.

CNP is equipped with unique capabilities ranging from world-class engineering resources, to preclinical infrastructures, either internally or in collaboration with other Lemanic Arc actors at Campus Biotech, and in Fribourg. CNP is also part of the Bertarelli program in Translational Neuroscience and Neuroengineering with Harvard Medical School, and has tight connections with the neurotechnology industry, both at the regional and international level.

Director

Prof. Stéphanie Lacour

defitech fondation

fondation bertarelli

Medtronic

www.cnp.epfl.ch

NEUROLEMAN

THE NEUROSCIENCE NETWORK OF THE LAKE GENEVA REGION

The NeuroLéman Network – established in Spring 2018 – brings together neuroscientists and clinicians from the Lac Léman (Lake Geneva) region from all fields of neuroscience within and across universities and disciplines. Our members are faculty members and group leaders at the EPFL, the Universities of Lausanne (UNIL), Geneva (UNIGE), and Fribourg (UNIFR), as well as of the University Hospitals of Lausanne (CHUV) and Geneva (HUG). Our members are neurobiologists, neuroengineers, computational and theoretical neuroscientists, neurologists, psychiatrists and psychologists.

Our overarching goal is to promote innovative and interdisciplinary research to better understand brain function in health and disease. Building upon the rich and diverse neuroscience environment of the Lac Léman region, we aim to further progress in both basic and clinical neuroscience in and between our member institutes. Our network serves as a platform for the open exchange of research and ideas, and acts as a catalyst for new collaborations.

Central to this effort, our network promotes excellence in the education of students and postdocs. We support three neuroscience doctoral programs : The PhD Program in Neuroscience (EDNE), the PhD Program in Biotechnology and Bioengineering (EDBB) and the Lemanic Neuroscience Doctoral School (LNDS) and provide many possibilities for training and scientific exchange through organizing national and international workshops and symposia.

Steering Commitee

Prof. Claudia Bagni (UNIL)
Prof. Olaf Blanke (EPFL)
Prof. Roberto Caldara (UNIFR)
Prof. Andreas Kleinschmidt (HUG)
Prof. Stéfanie Lacour (EPFL)
Prof. Christian Lüscher (UNIGE)
Prof. Brian McCabe (EPFL)
Prof. Carl Petersen (EPFL)
Prof. Gregor Rainer (UNIFR)
Prof. Philippe Ryvlain (CHUV)
Prof. Carmen Sandi (EPFL)
Prof. Ron Stoop (CHUV)
Prof. Patrick Vuilleumier (UNIGE)

Coordination and Communication

Dr. Gabriele Grenningloh (EPFL)
Dr. Ulrike Toepel (UNIL)

NEURORESTORE

NeuroRestore is a new Center set up in December 2019 by the Defitech Foundation, Lausanne University Hospital (CHUV), the University of Lausanne's (UNIL) Faculty of Biology and Medicine (FMB), and EPFL to harness expertise in neurorehabilitation and neurosurgical implant technologies across the four partner institutions. Doctors, engineers and researchers have joined forces to develop 'electroceuticals' – a type of neurotherapy that uses electrical stimulation to help restore motor function in paraplegic and quadriplegic patients, as well as in people suffering from Parkinson's disease or the after effects of a stroke. The NeuroRestore team will trial innovative, personalized treatments that, once proven, will be made available to hospitals and patients. The center also trains a new generation of health-care practitioners and engineers in the use of these breakthrough therapies.

On 1 November 2018, EPFL neuroscientist Grégoire Courtine and CHUV neurosurgeon Jocelyne Bloch published the findings of the STImulation Movement Overground (STIMO) study in the journal Nature. The research established a revolutionary new therapeutic framework to improve recovery from spinal cord injury, combining targeted electrical stimulation of the spinal cord and an intelligent bodyweight-support system. After undergoing the groundbreaking therapy, eight paraplegic patients were able to take a few steps unassisted.
The NeuroRestore team is spread across several sites: CHUV in Lausanne, CRR SuvaCare (a Sion-based rehabilitation clinic and one of the project's financial partners), and EPFL's Campus Biotech in Geneva. The researchers, based at CHUV and EPFL, also work with the Wyss Center for Bio- and Neuroengineering in Geneva. Patients undergo surgery at CHUV, while the rehabilitation sessions take place at either CHUV or CRR SuvaCare.

Co-directors

Prof. Jocelyne Bloch
Prof. Grégoire Courtine

NeuroRestore Science in Motion

defitech fondation

NEUROSCIENCE EDUCATION

Master program

The Brain Mind Institute organizes a curriculum in Neuroscience and Neuroengineering as part of the EPFL Master in Life Sciences Engineering. The program in Neuroscience and Neuroengineering allows students to deepen their knowledge in this interdisciplinary domain at the interface between engineering, biology, medicine and computer science.

The curriculum includes a systematic introduction to the neurosciences and covers disciplines such as molecular and cellular neuroscience, cognitive and behavioural neuroscience, neuronal circuits and computational neuroscience, and neuroengineering and neurotechnology. The goal is to understand the links between brain function and behavior as well as brain disorders, therapies and neuroprosthetics.
The master program finishes with a master thesis in one of our laboratories.

Doctoral program

The EPFL PhD Program in Neuroscience (EDNE) offers training from the genetic to the behavioural level including molecular, cellular, cognitive, computational and therapeutic aspects of neuroscience research.

EPFL Neuroscience PhD students matriculate into the highly dynamic and interdisciplinary environment of the EPFL which includes the Brain Mind Institute (School of Life Sciences), the Blue Brain Project, the Center for Neuroprosthetics and other affiliated research groups.

The program is further strengthened by research and training opportunities in collaboration with the Universities and the associated University Hospitals of Lausanne and Geneva, as well as further research in Sion and Fribourg.

The EPFL Neuroscience PhD doctoral program seeks outstanding applicants holding a Master's degree in a variety of backgrounds including physics, engineering, biology, medicine and psychology. Currently, there are 95 students (44 women, 51 men) representing 28 different nationalities working across 36 affiliated laboratories across the EPFL campus, the Geneva Campus Biotech and the EPFL satellite in Sion.
Application deadlines - April 15th and November 1st.

Summer research program

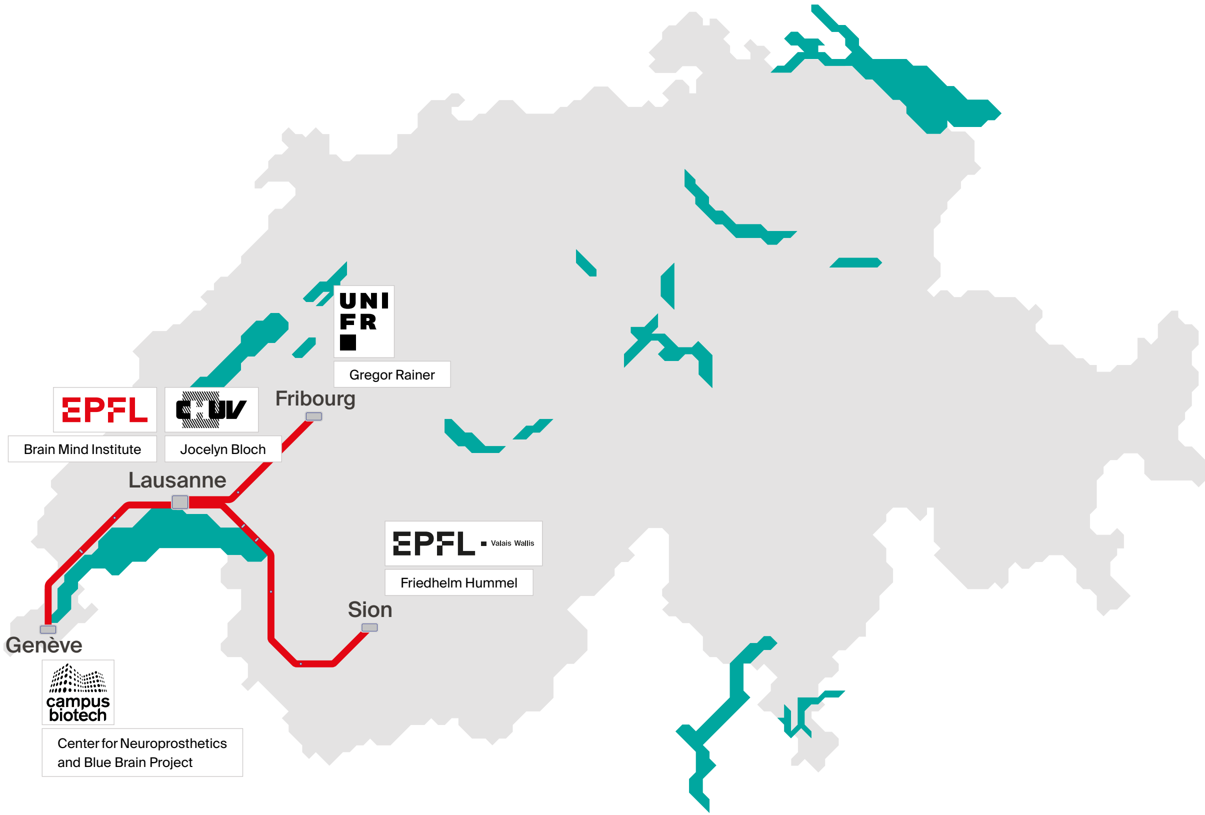
Our laboratories offer talented BA/MA students worldwide a unique research experience every year within the Summer Research Program of the EPFL School of Life Sciences.

www.epfl.ch/schools/sv/education/summer-research-program/

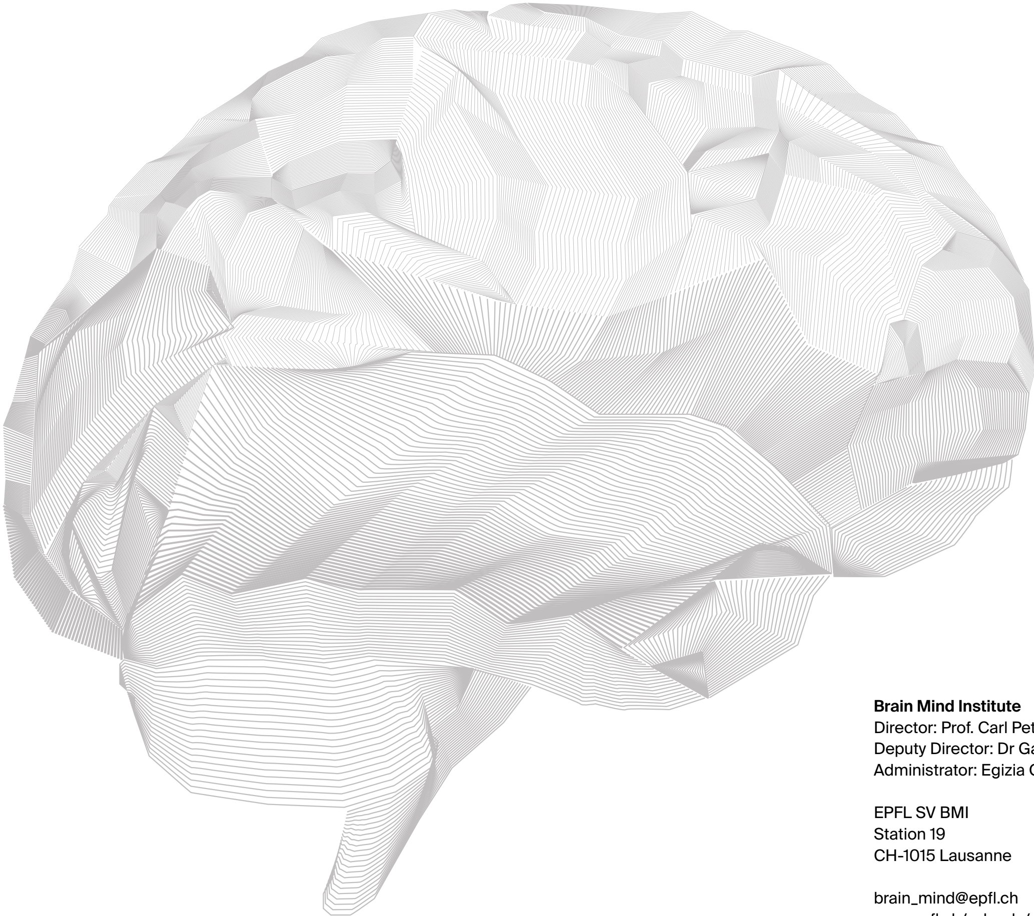
www.epfl.ch/schools/sv/education/master-in-life-sciences-engineering


SV
campus
biotech

WHERE TO FIND US



Published by the Brain Mind Institute / © EPFL - 2021
Images & Layout: E.Ruchti / L.Mauro / T. Veuillet
Printing: Repro Center EPFL



Brain Mind Institute
Director: Prof. Carl Petersen
Deputy Director: Dr Gabriele Grenningloh
Administrator: Egizia Carbone

EPFL SV BMI
Station 19
CH-1015 Lausanne

brain_mind@epfl.ch
www.epfl.ch/schools/sv/bmi