BSB design and usecases

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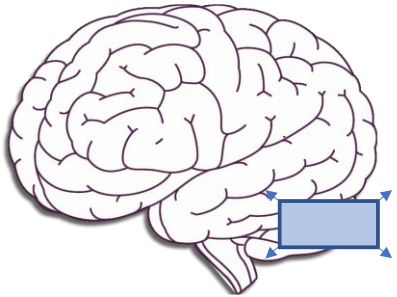
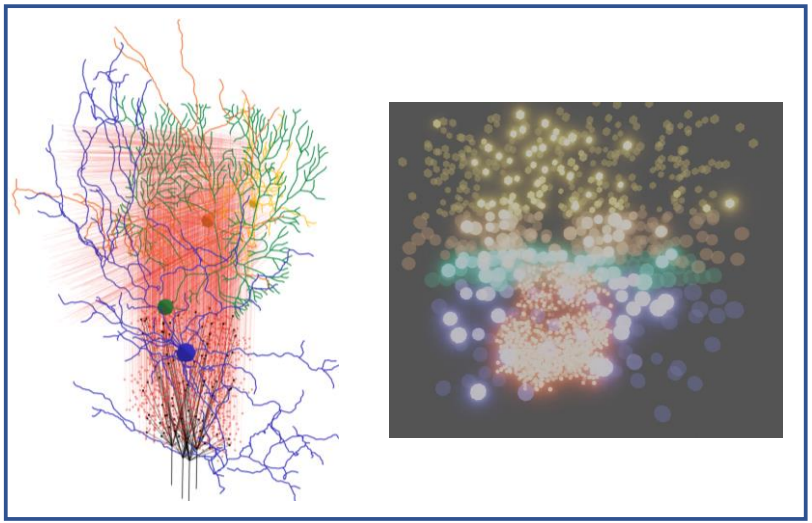
BSB





UNIVERSITÀ DI PAVIA

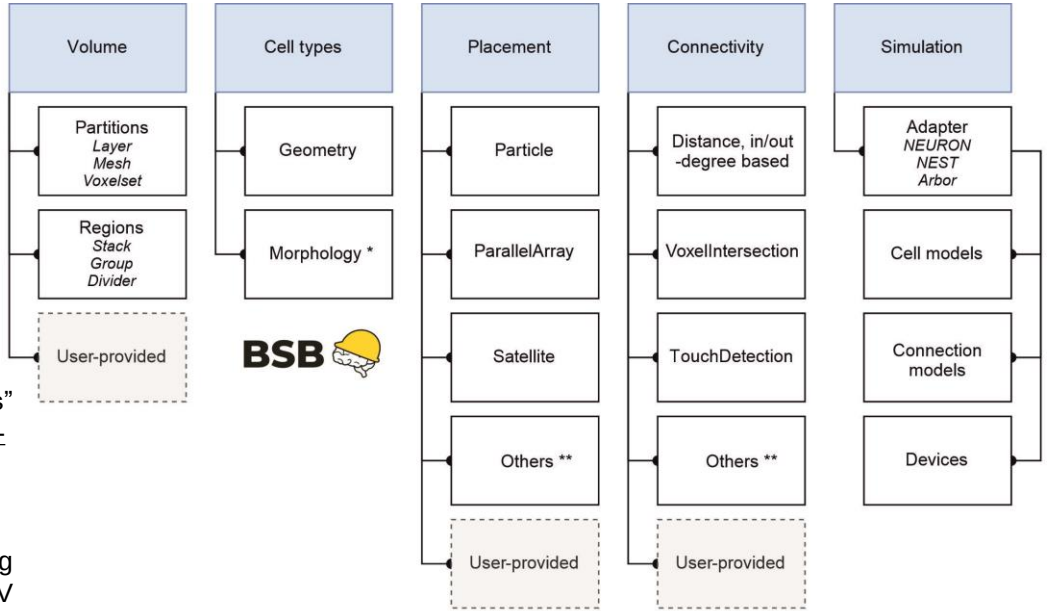
Human Brain Project

EBRAINS

Network reconstruction and simulation

the **Brain Scaffold Builder**, a flexible software package to build and simulate brain models at different levels of complexity, constrained on data

pip install bsb



- https://github.com/dbbs-lab/bsb; https://bsb.readthedocs.io/
- component in "EBRAINS Modelling Workflows" https://wiki.ebrains.eu/bin/view/Collabs/technical-coordination/EBRAINS%20components/Scaffold%20package%20codebase/?srid=ZqoazFyV
- one of the main tools of the "Cerebellar Modelling Hub" at UNIPV [https://www.humanbrainproject.eu/en/collaborate/facility-hubs/]
- Cerebellar usecase: *De Schepper et al.,* https://www.biorxiv.org/content/10.1101/2021.07.30.454314v1

CSCS
Centro Svizzero di Calcolo Scientifico
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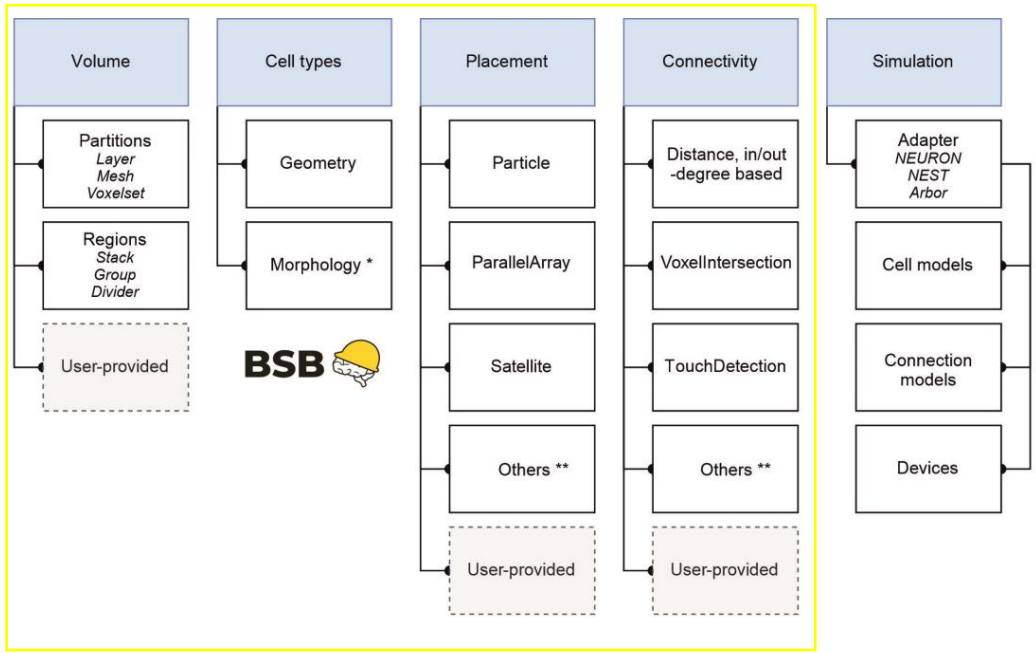
FENIX
RESEARCH INFRASTRUCTURE

Network reconstruction



Volume

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  "store_compound_kd_tree": true,
  "store_pf_kd_trees": true
},
"layers": {
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      "position_in_stack": 0,
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    }
  },
  "purkinje_layer": {
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      "position_in_stack": 1
    }
  },
  "molecular_layer": {
    "thickness": 150.0,
    "stack": {
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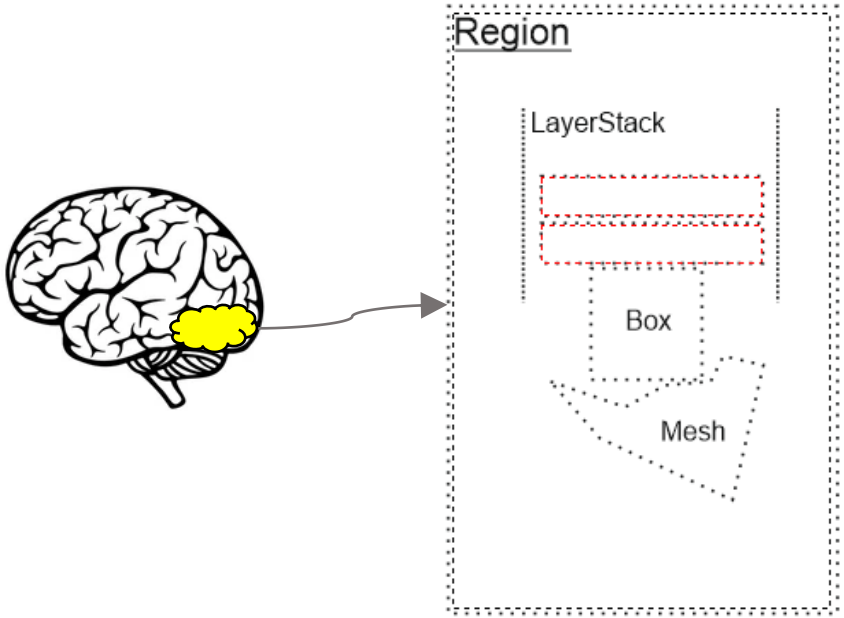
      "position_in_stack": 2
    }
  }
},
```

[µm] x	[µm] z	[µm] y	[µm³]
300	200	295	17700000

x-y (sagittal plane), *x-z* (horizontal plane), *z-y* (coronal plane), *z*-axis (major lamellar axis, along which parallel fibers elongate)



Cell types

- Glomerulus (glom)
- Granule cell (GrC)
- Golgi cell (GoC)
- Purkinje cell (PC)
- Stellate cell (SC)
- Basket cell (BC)

```
"cell_types": {
  "granule_cell": {
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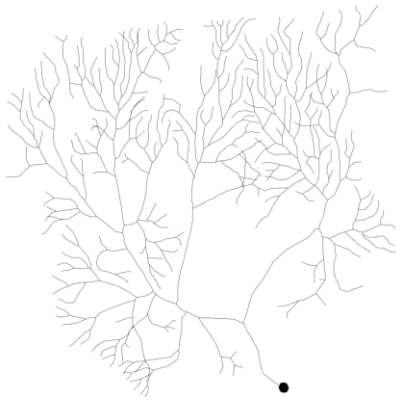

```
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Placement

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    }
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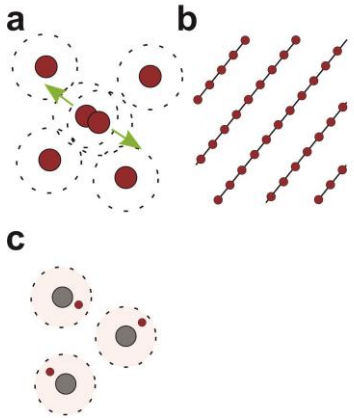
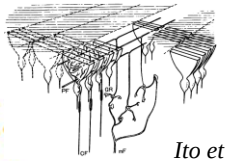
}
```



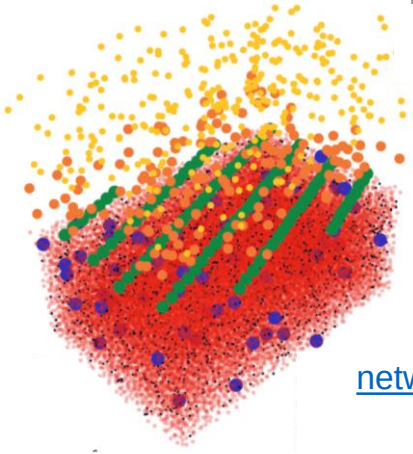
- Neuron densities
- Neuron geometry

- Particle Placement algorithm for all cell types except for PCs (random placement, collisions/replacement, pruning)
- Planar arrays placement algorithm for PCs

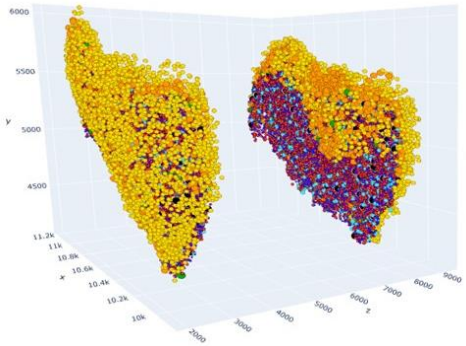


Ito et al., 1984

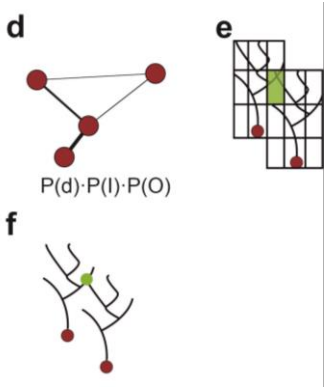
	N
mossy fibers	117
glomeruli	2336
granule cells	28615
golgi cells	70
purkinje cells	99
basket cells	147
stellate cells	299
tot cells	29230
tot entities/relays	2453
TOT elements	31683



network_scene.html



Connectivity




```
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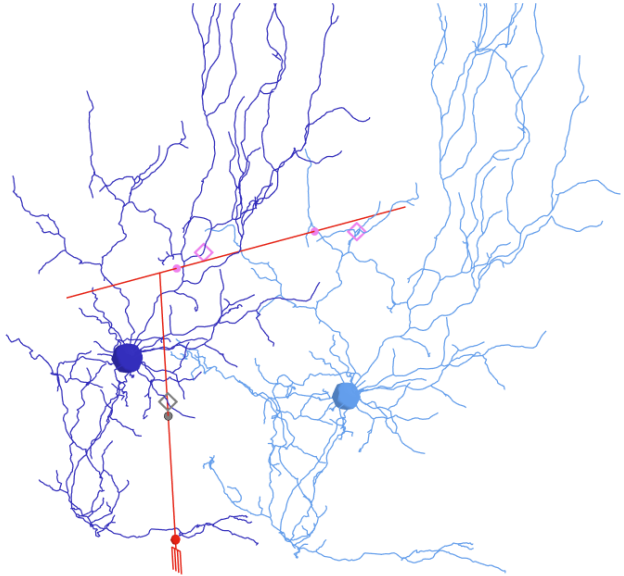

grc_golgi_touch_v2.html

Connectivity

```
{
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    "A_to_B": {
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    },
    "B_to_C": {
      "cls": "bsb.connectivity.TouchDetection",
      "from_type": "cell_type_B",
      "to_type": "cell_type_C",
      "intersection_radius": 2.0
    },
    "A_to_C": {
      "cls": "bsb.connectivity.VoxelIntersection",
      "from_type": "cell_type_A",
      "to_type": "cell_type_C",
      "synapses": {
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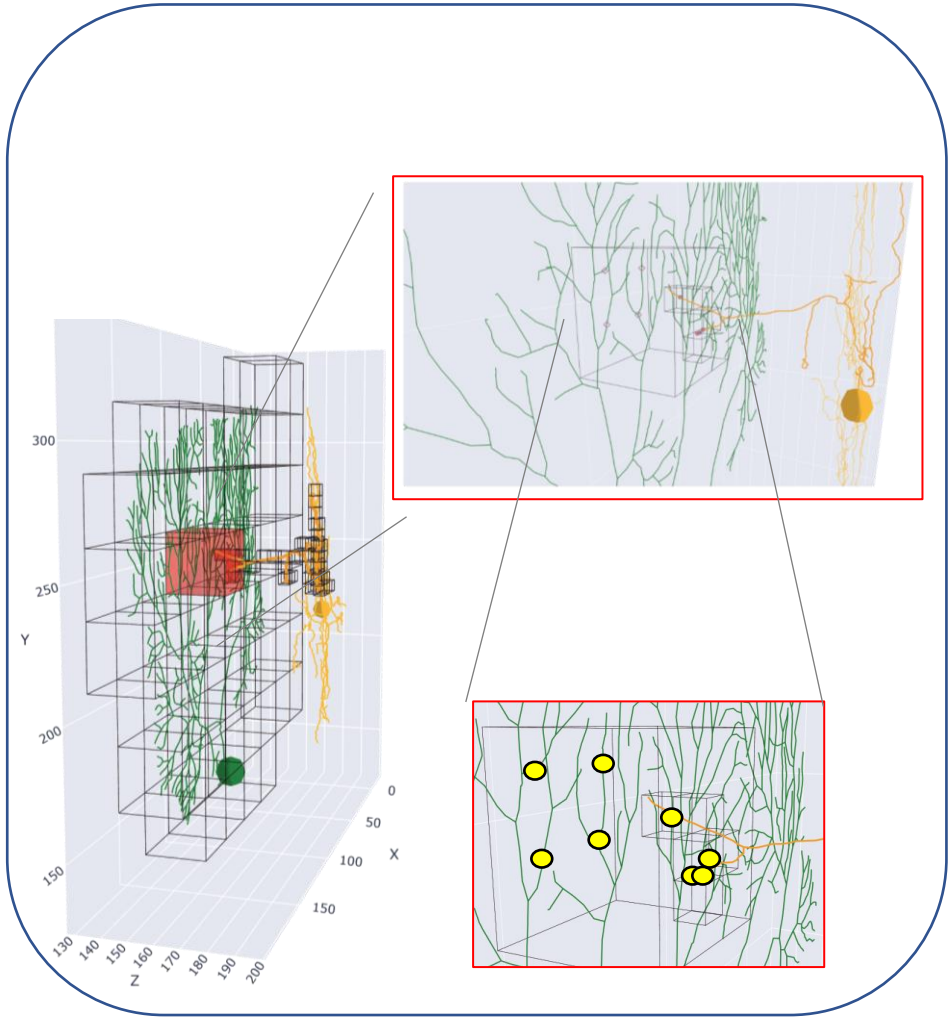
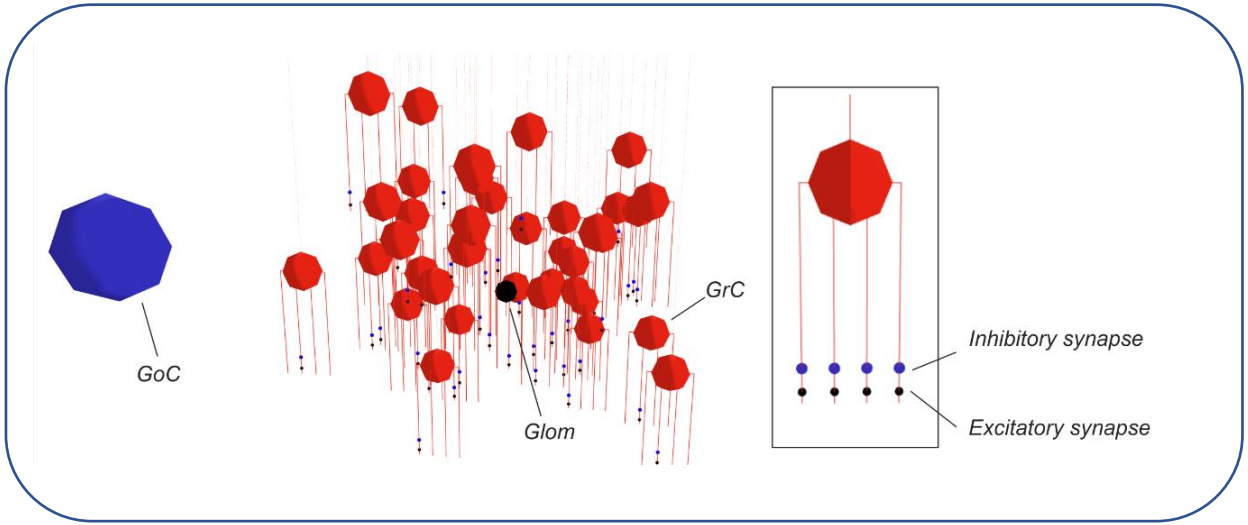
      }
    }
  }
}
```



Connectivity



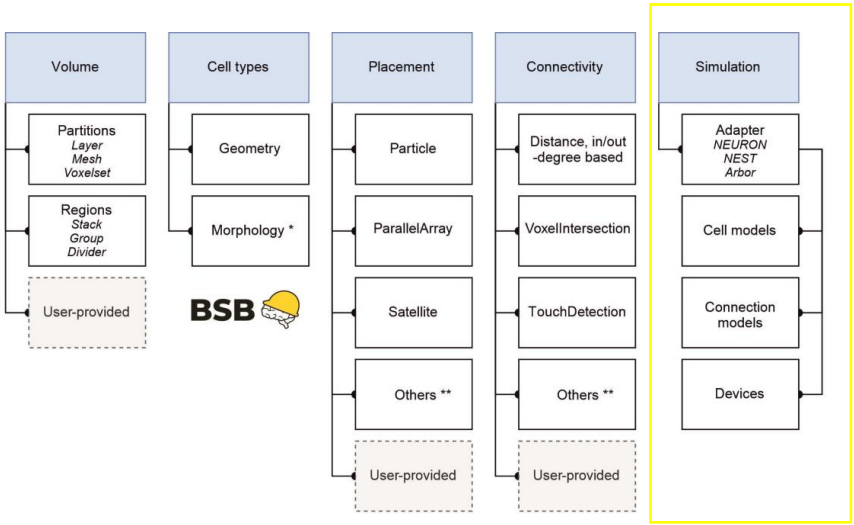
Ad-hoc algorithms, based on experimental evidences (divergence and convergence ratios, and geometrical neuronal features)

	Convergence	Divergence	Synapses	Synapses/pair
mf-Glom	1 ± 0	20 ± 8	2300	1 ± 0
Glom-GrC	4 ± 0	49 ± 26	110000	1 ± 0
Glom-GoC	56 ± 21	1.7 ± 1.4	3900	1 ± 0
GoC-GrC	2.4 ± 0.88	1000 ± 460	97000	1.4 ± 0.66
GoC-Glom	0.84 ± 0.37	28 ± 14	2000	1 ± 0
GoC-GoC	16 ± 6.5	16 ± 7.1	180000	160 ± 5
GrC (*aa*)-GoC	320 ± 230	0.78 ± 1.1	22000	1 ± 0
GrC (*aa*)-PC	82 ± 24	0.28 ± 0.52	20000	2.4 ± 1.1
GrC (*pf*)-GoC	910 ± 360	2.2 ± 1.6	64000	1 ± 0
GrC (*pf*)-PC	1500 ± 300	5.1 ± 2.6	140000	1 ± 0
GrC (*pf*)-SC	480 ± 160	5.1 ± 3.2	140000	1 ± 0
GrC (*pf*)-BC	740 ± 130	3.8 ± 2.1	110000	1 ± 0
SC-PC	5.4 ± 2.7	1.8 ± 1.5	530	1 ± 0
BC-PC	20 ± 9.9	14 ± 8	2000	1 ± 0
SC-SC	14 ± 6.1	14 ± 5.9	430000	100 ± 4
BC-BC	14 ± 6.7	14 ± 6.6	200000	100 ± 4
GoC-GoC (*gap*)	8.4 ± 3.5	8.4 ± 3.5	2100	3.5 ± 1.6

~ 1˙500˙000 chemical synapses and 2˙100 electrical synapses

The **cerebellar connectome** was generated through appropriate connection rules, unifying a collection of scattered experimental data into a coherent construct and providing a **new model-based ground-truth** about circuit organization.

Network simulation



detailed or point-neuron networks

NEURON
for empirically-based simulations of neurons and networks of neurons

nest ::
simulated()

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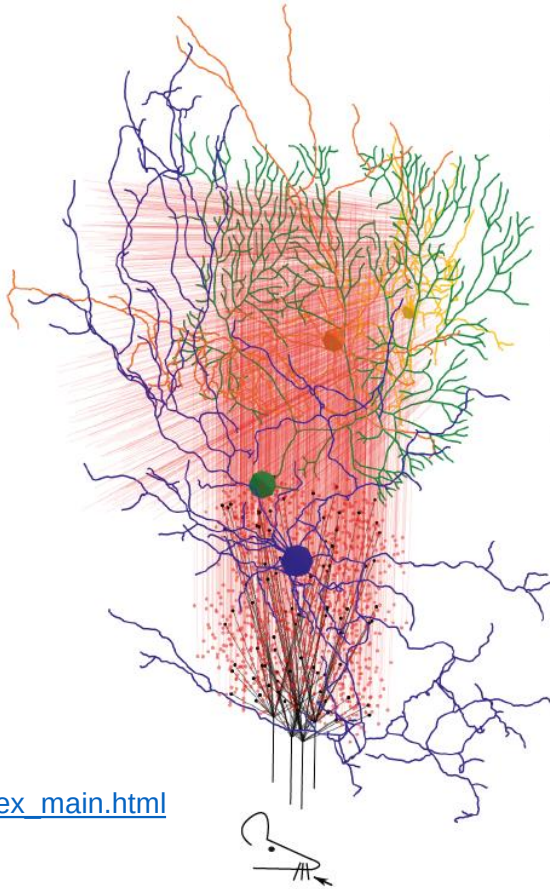
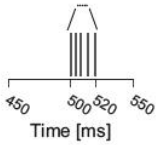
FENIX
RESEARCH INFRASTRUCTURE

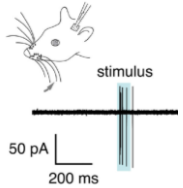
Release probabilities at mf-GrC synapses

LTD **control** **LTP**



cortex_main.html

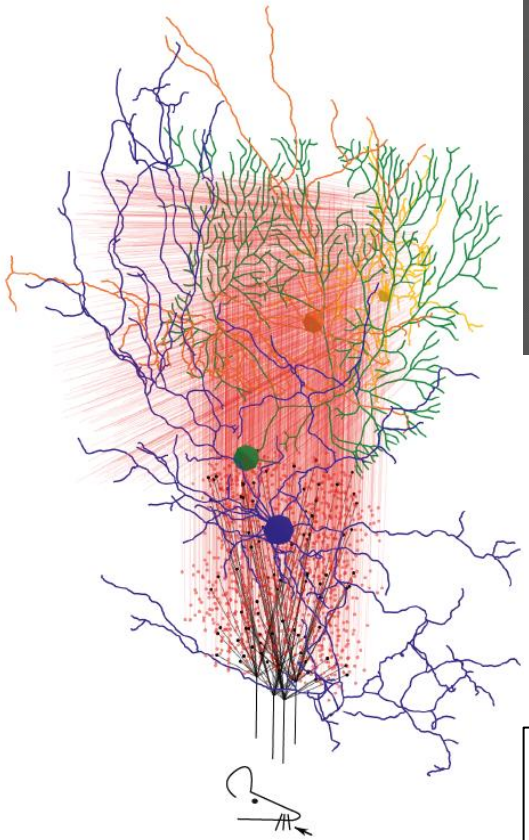


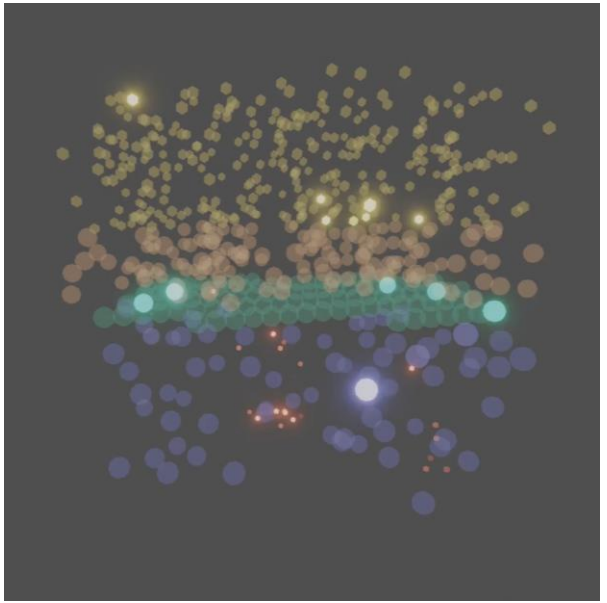


Background noise + whisker air-puff [Rancz et al. Nature 2007]

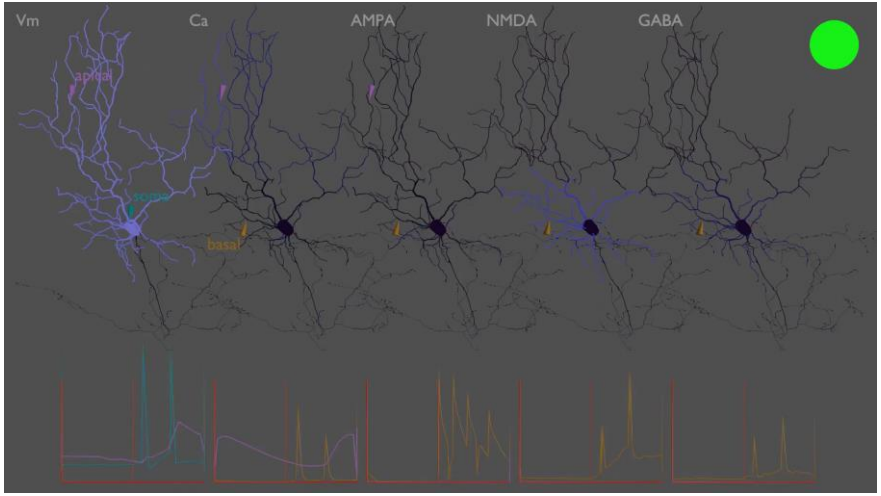
Functional validation against ***in vivo*** **data,** monitoring the impact of subcellular and cellular mechanisms on **spatio-temporal signal processing**

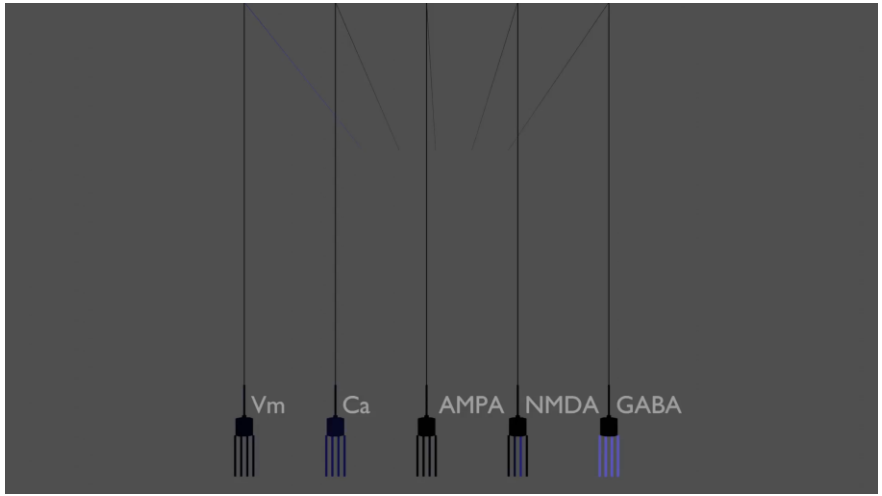
- ✓ Background frequency of all cerebellar neuron types
- ✓ Synchronous oscillatory behaviour in theta band of granular layer in resting state
- ✓ Impulsive responses of all cerebellar neuron types
- ✓ Burst-pause response of Purkinje Cells (PCs)
- ✓ Feedforward and lateral inhibition from Molecular Layer Interneurons (MLIs, i.e. Stellate Cells (SCs) and Basket Cells (BCs)) to Purkinje Cells

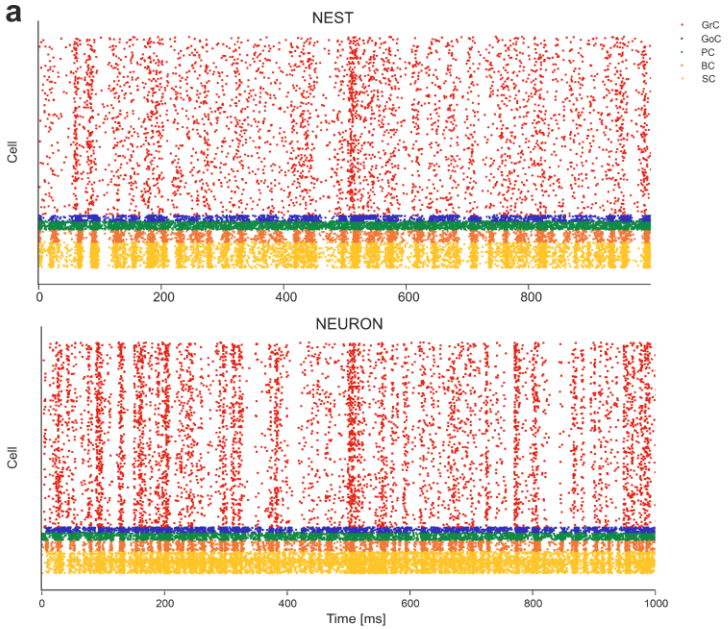


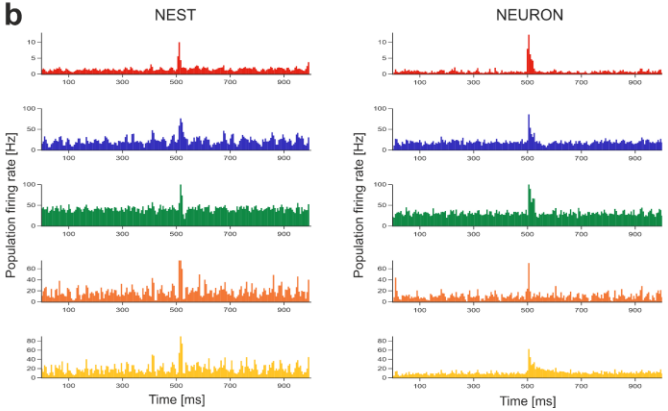


- Formation of **columns of activity** travelling from the granular to the molecular layer
- Prediction of the impact of cellular mechanisms on signal propagation and **spatio-temporal processing**

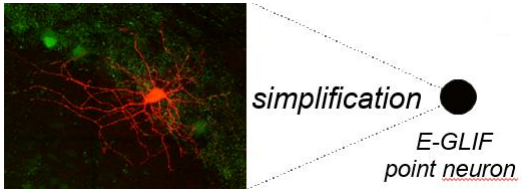

Vm
Ca
AMPA
NMDA
GABA
apical
soma
basal


Vm
Ca
AMPA
NMDA
GABA





The reconstructed cerebellar network was simulated using the BSB NEST and NEURON Adapters. The simulation lasted 1 second, with background at 4Hz on all mfs and a burst on 4 adjacent mfs starting at 500 ms and lasting 20 ms. For NEST version, optimized E-GLIF neuron models and alpha-based conductance synapses (Geminiani et al., 2019a) were inserted. a) Raster plot of all cells; GrCs are undersampled (random 10%) for clarity. b) Peri-Stimulus-Time-Histogram (PSTH) of each population (number of spikes in 5 ms time bins, normalized on the total number of cells)



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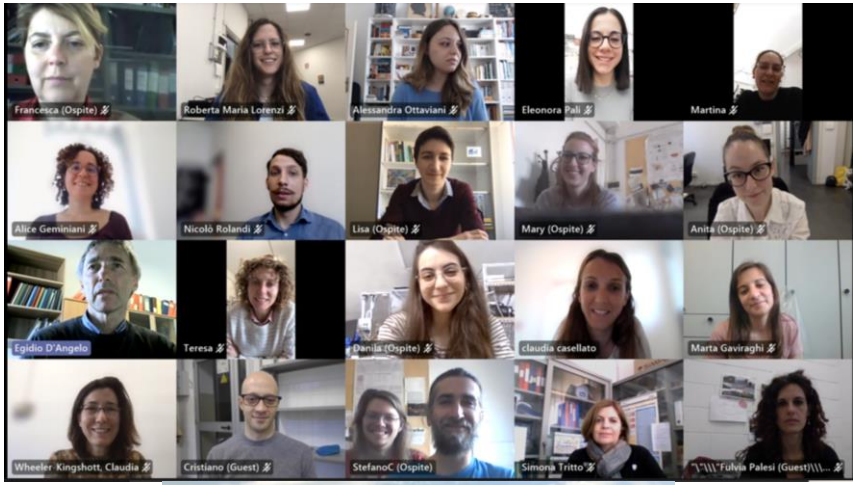

Collaborations

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