



# The Chilean Neuromorphic Computing Initiative (CLNCI)

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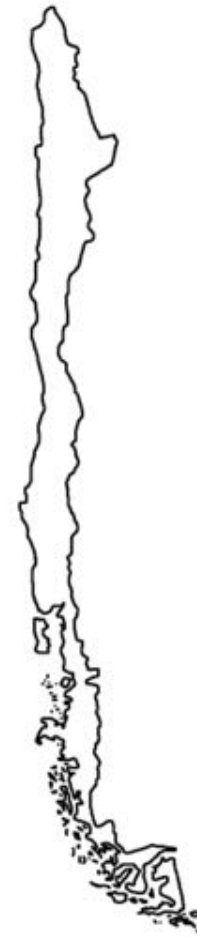
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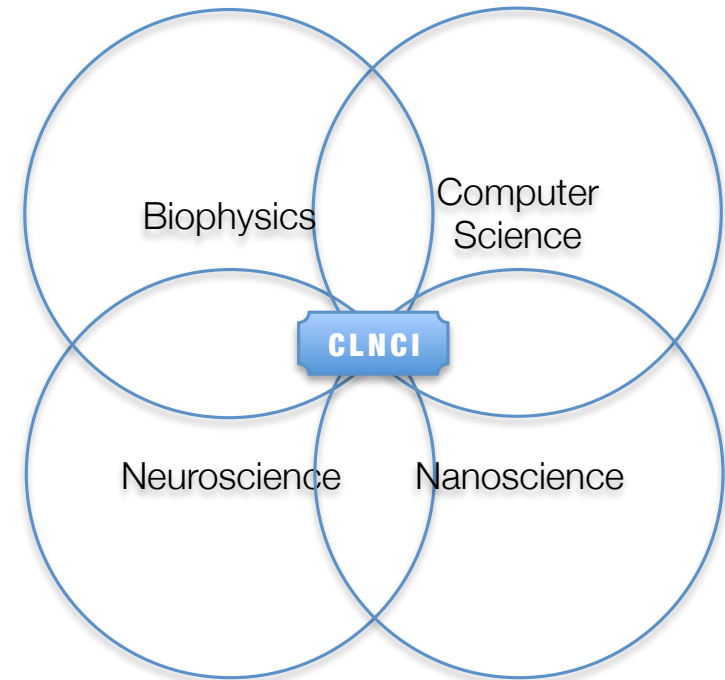
# Chile... in a nutshell

- An almost one dimensional south american country with >4,400 Kms of shoreline
- Largest GDP per capita in South America: ~14,000 USD
- $17 \times 10^6$  people, GDP 250B USD
- Diverse and unique natural labs:
  - The driest desert in the world: Atacama
  - One of the deepest oceanic trenches: Atacama ~8,900 mts
  - The clearest skies: ALMA, VLT, APEX, Gemini, Paranal, LSST and E-ELT
  - The largest number of active volcanoes: >500
  - The most seismic country in the world: Avg. 8 per decade over 7 Mw



# The Chilean NC Initiative (CLNCI)

- A transdisciplinary research initiative aimed at developing fundamental scientific knowledge supporting the advancement of **Neuromorphic Computing (NC)**
- A multi-institutional effort joining research teams from the main Research Institutions in Chile, including FACH (Chilean Air Force)
  - Center for Bioinformatics and Integrative Biology (CBIB)
  - Center for Research in Nanotechnology and Advanced Materials (CIENUC)
  - Biomedical Neuroscience Institute (BNI)
  - Geroscience Center for Brain Health and metabolism (GERO)
  - Center for Development of Nanoscience and Nanotechnology (CEDENNA)
  - Center for Interdisciplinary Neuroscience (CINV)
  - Fundación Ciencia & Vida (FCV)



Transdisciplinary Research



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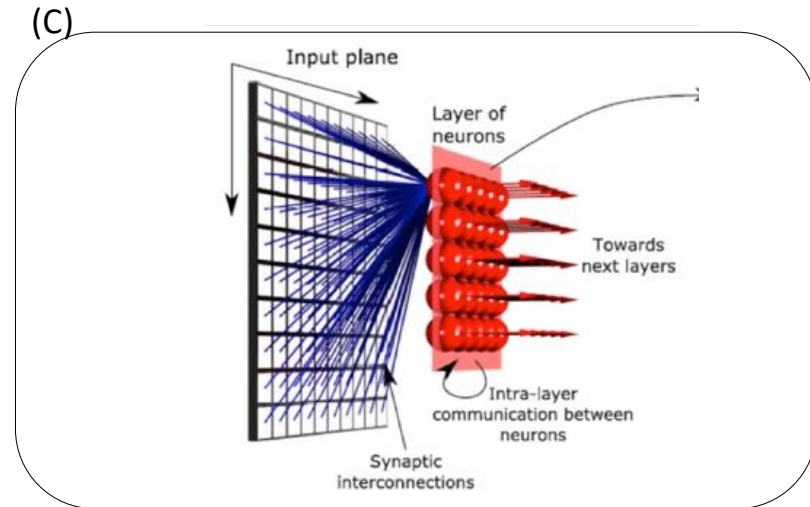
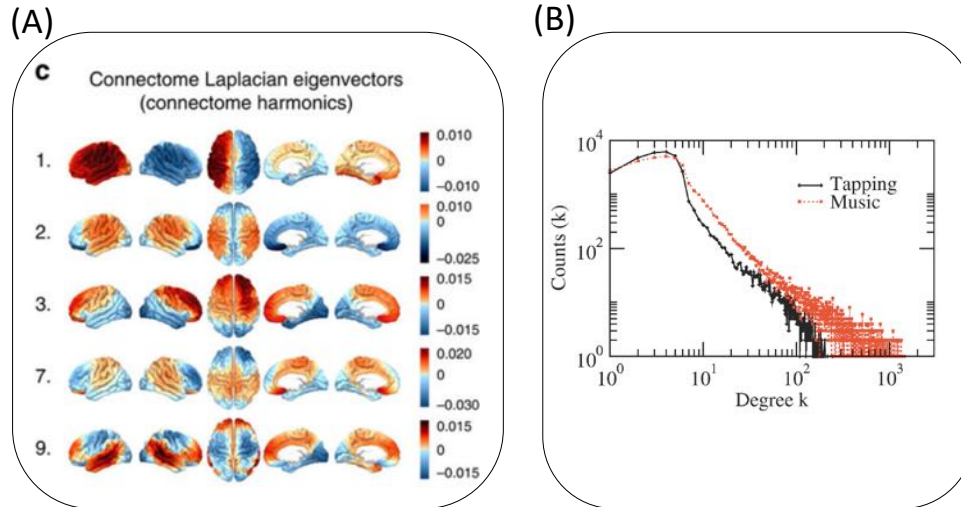


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# Neuromorphic Computing (NC)

A concept developed by Carver Mead<sup>1</sup> describing very-large-scale integrated (VLSI) systems containing electronic circuits mimicking the architecture of the nervous system



## A. Plasticity<sup>3</sup>:

- Neural connections and neural functions
- Signalling-censoring (or integration)

## B. Criticality<sup>4</sup>:

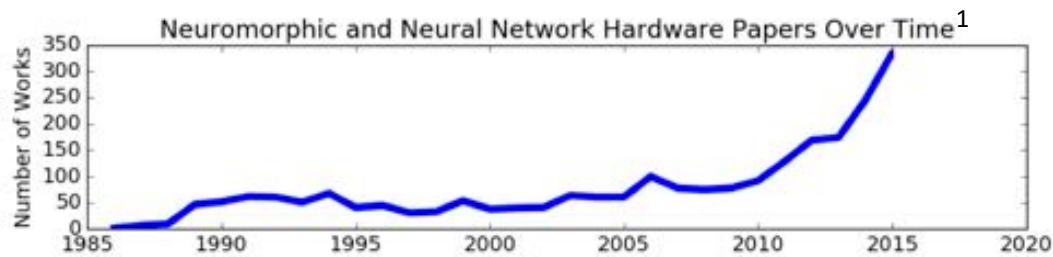
- Metastable solutions
- Continuous adaptation and learning

## C. Topology<sup>5</sup>:

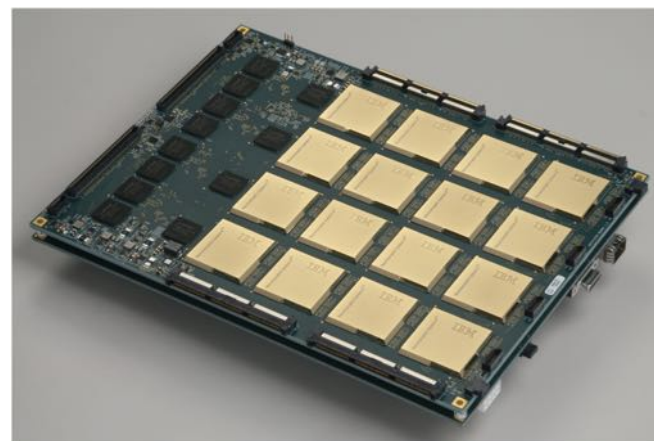
- Multiple layers
- Modularity
- Scale-free architecture

- (1) C. Mead, Proceedings of the IEEE, 78(10):1629–1636 (1990)  
(2) Schuman C.D. et al, arXiv:1705.06963 [cs.NE] (2017)  
(3) Eguiluz V. et al. Physical Review Letters 94, 018102 (2005)  
(4) Sporns O. Dialogues Clin Neurosci. 15(3): 247–262 (2013)  
(5) Merolla P.A. et. al., Science 345(6197): 668–673 (2014)

# From Mead's concept to the IBM TrueNorth chip



- Funded by DARPA and developed by IBM
- Neuromorphic chip (CMOS) whose architecture is inspired in the human brain
- A fine-graining highly parallel and event-driven, non-von Neumann architecture to execute neural network operations (NNOPS)
- 4096 cores, >1 million neurons, 256 millions synapses, 5,4 B transistors<sup>2</sup>



(1) Schuman C.D. et al, arXiv:1705.06963 [cs.NE] (2017)  
(2) Merolla P.A. et. al., Science 345(6197): 668-673 (2014)



# How does the nervous system responds to external stimuli?

## Processing:

- Feature detection
- Pattern recognition
- Spatial/Temporal correlation
- Classification

## Sensing:

- Sight
- Hearing
- Taste
- Smell
- Touch
- Balance
- Acceleration
- Proprioception
- Pain
- Sexual



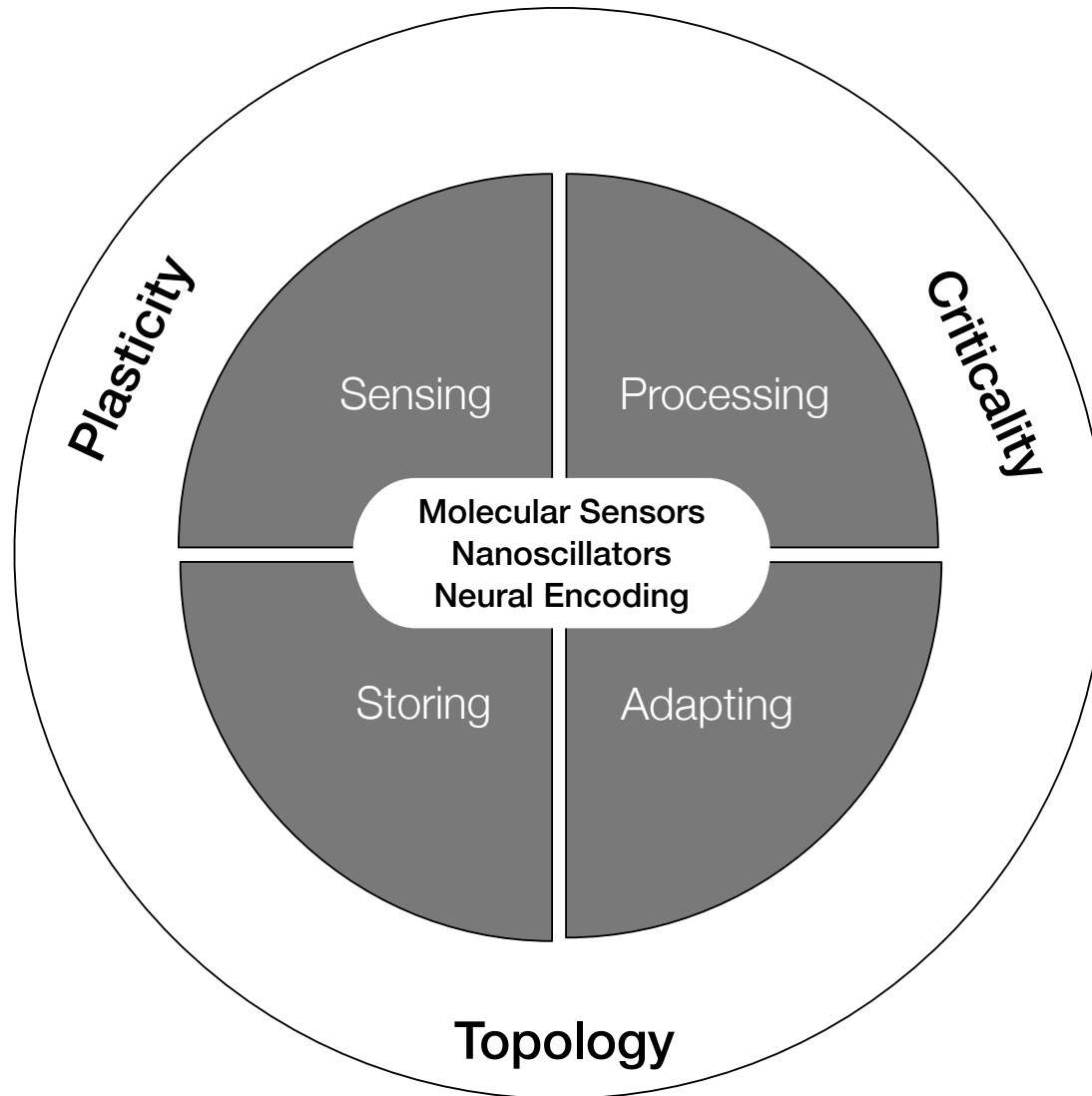
## Storing:

- Synapses formation
- Synapses pruning
- Neuropeptidic signaling
- Chemical signaling
- Myelinogenesis

## Adapting

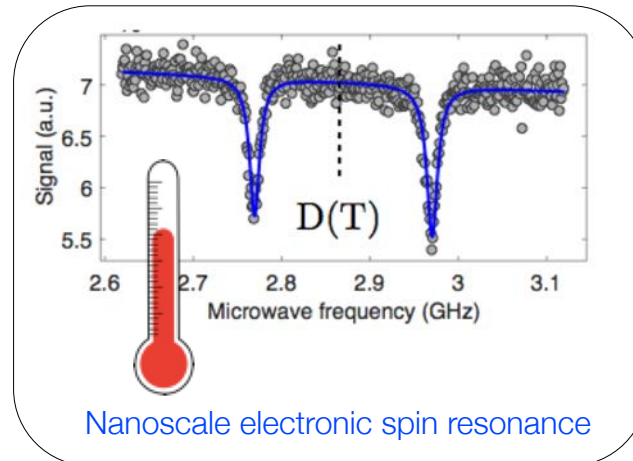
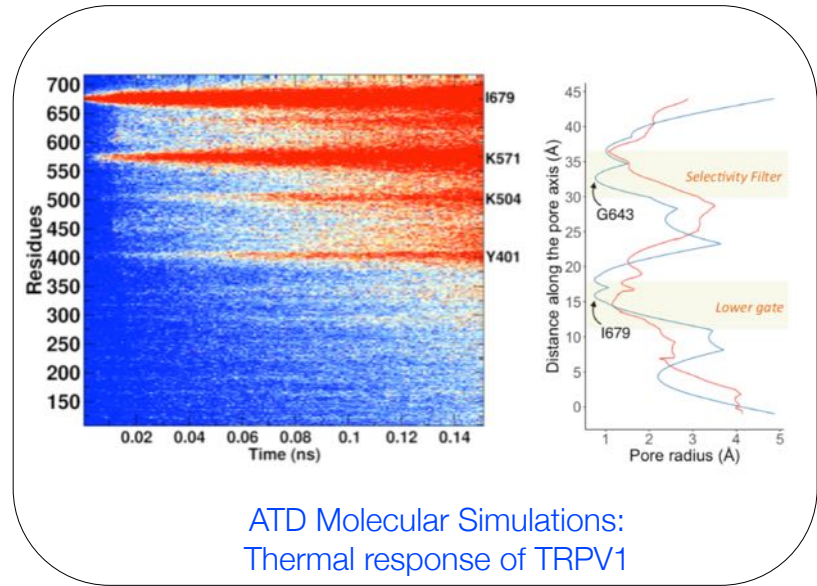
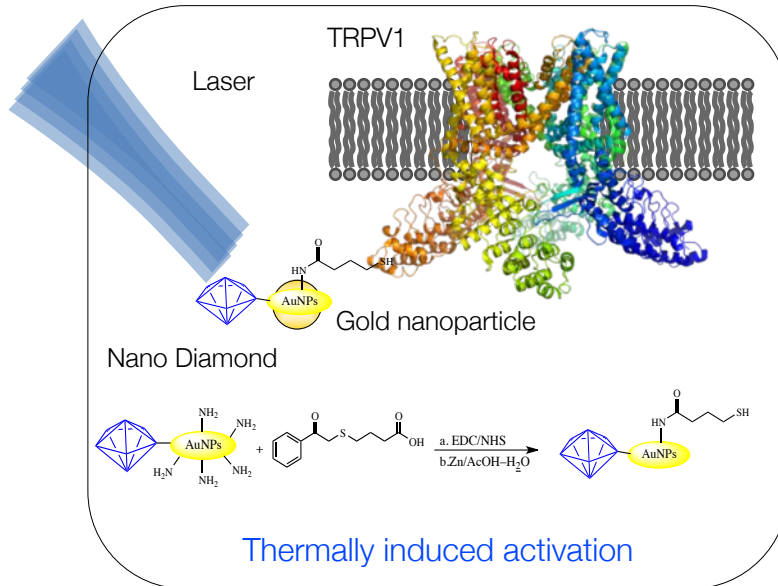
- Neuroplasticity
- Synapses formation
- Synapses pruning
- Neuropeptidic signaling
- Chemical signaling
- Myelinogenesis

# CLNCI Research Focus



# Molecular sensors: fundamentals of plasticity and criticality in thermally regulated ion channels

Danilo González (UNAB), Ramón Latorre (UV), Jerónimo Maze (PUC)



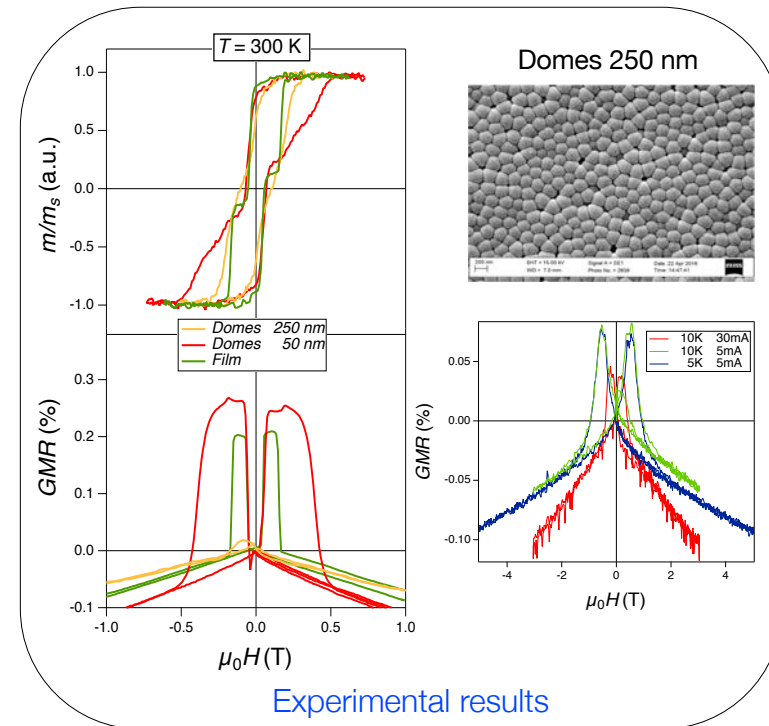
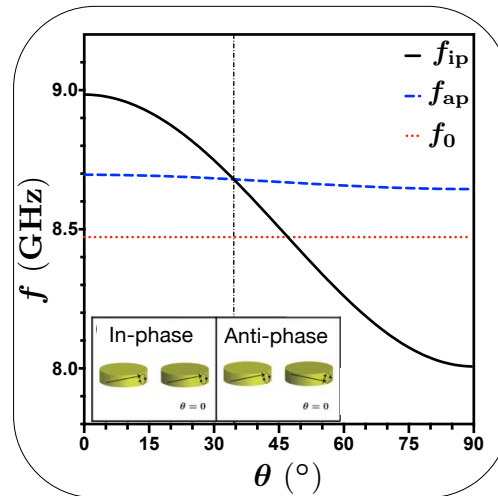
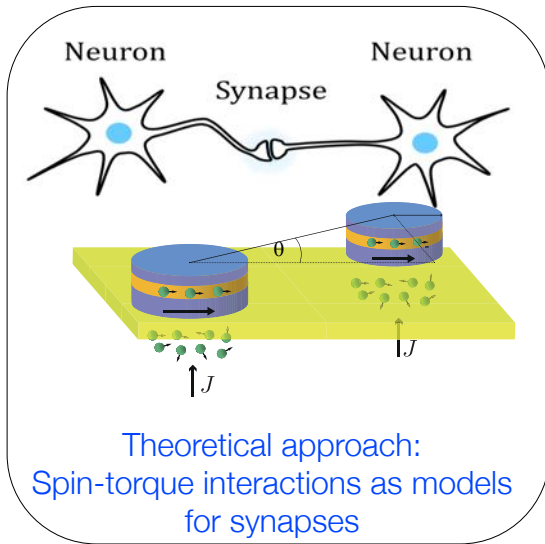
**Criticality:** Neuronal computation relies on multiple available states at around 37° Celsius

**Plasticity:** Ion channel adjustment to repeated stimuli: key for network connectivity and learning



# Spin-torque nano-oscillator for signal processing and storing

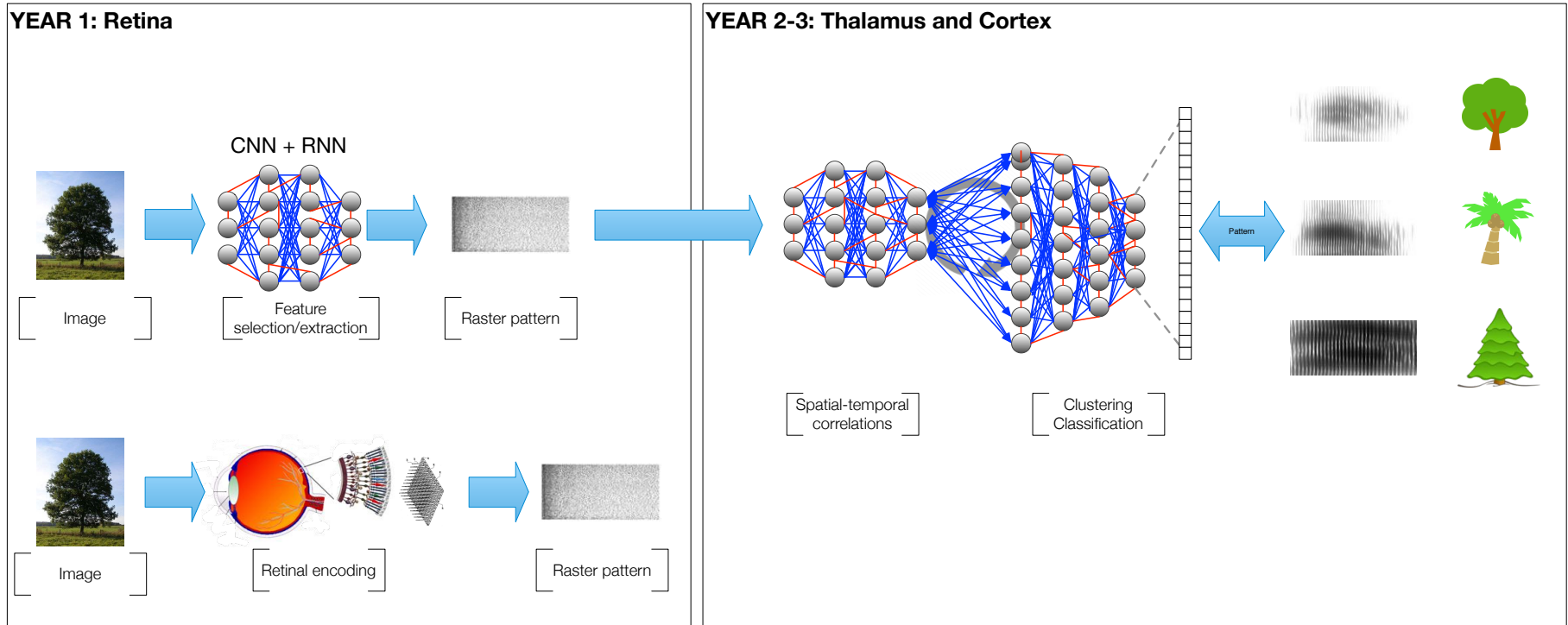
Dora Altbir (USACH), Sebastián Allende (USACH), Julianio Denardín (USACH), Samuel Hevia (PUC), Miguel Kiwi (UCHile),  
Simón Oyarzún (USACH), Juan Alejandro Valdivia (UCHile)



**Criticality:** Magnetic fields promote oscillators array adaptation  
**Plasticity:** Magnetic spins can accommodate multiple meta-states

# Neural Encoding: A dual topology and multilayered hybrid neural network mimicking the retinal encoding of mammals

Claudio Hetz (UCHile), Miguel Kiwi (UCHile), Tomas Perez-Acle (FCV), Adrian Palacios (UV), Juan Alejandro Valdivia (UCHile),



- **Plasticity:**

- Photoreceptors, novel molecular sensors, resonance, programmable neurons/nanoscillators

- **Criticality:**

- Continuous learning by reinforcement

- **Architecture:**

- Modularity, neural network topology

# Outcome... 1 year so far

	Authors	Year	Journal	Status	I.F.
1	Hetz C. & Saxena S.	2017	Nature Reviews Neurology	Published	20.3
2	Hetz C. & Papa F.	2017	Molecular Cell.	Published	14.7
3	Duran-Aniotz C. et al.	2017	Acta Neuropathologica	Published	11.4
4	Mercado G. & Hetz C.	2017	Brain	Published	10.2
5	Pihán P. et al.	2017	Cell death and differentiation	Published	8.2
6	Martínez G. et al.	2017	Aging Cell	Published	6.3
7	Medinas, D.B. et al.	2017	Frontiers in Molecular Neuroscience	Published	5.4
8	Gerakis Y. & Hetz C.	2017	Neurobiology Aging	Published	5.1
9	Rivas A. et al.	2017	Expert Opinion Therapeutic Targets.	Published	4.9
10	Carreras-Sureda A. et al.	2017	Frontiers in Oncology	Published	4.7
11	Gerakis Y. & Hetz C.	2017	FEBS J.	Published	4.2
12	Osvaldo Alvarez and Ramon Latorre	2017	Journal of General Physiology	Published	3.8
13	Cabral-Miranda F. & Hetz C.	2017	Current Topics in Microbiology and I	Published	3.8
14	Carreras-Sureda A. et al.	2017	Cell Calcium	Published	3.2
15	Guerrero N., Meynard M., Borgonov	2017	Curr Mol Med.	Published	2.4
16	Morales-Quintana, L., Faúndez, C., H	2017	Carbohydrate Research	Published	2.1
17	Alberto J.M. Martin, Ignacio Fuenzal	2017	Biophysical and Biological Research C	Published	2.5
18	Sebastian Contreras-Riquelme, Jose-	2017	Bioinformatics	Published	7.3
19	Raul Coto, Vincent Jacques, Gabriel	2017	Physical Review B	Published	3.7
20	Isaac E. García, Felipe Villanelo, Gust	2017	Journal of General Physiology	Published	3.8
1	Martínez G. et al.	2017	Trends in neuroscience	Invited Reviews	14.4
2	Lorenzo Galluzzi et al.	2018	Cell Death Diff.	Invited Reviews	8.2
3	Valenzuela V., Becerra D., and Hetz C	2017	Mol Therapy	Invited Reviews	6.7
1	Hery Urrea et al.	2018	Nature Cell Biology	Under revision	20.1
2	Denisse Sepulveda, Diego Rojas-Rive	2018	Molecular Cell	Under revision	14.0
3	Leslie Bargsted et al.	2018	Sci Reports	Under revision	5.2
4	Bernardo I. Pinto, Amaury Pupo, Isaa	2018	Scientific Reports	Under revision	4.9
21	D. Mancilla-Almonacid, R. E. Arias, S.	2018	Phys Review B	Under revision	3.8
22	Denisse Pasten, Felipe Torres, Benja	2018	Physica A	Under revision	2.2



ER stress and the unfolded protein response in neurodegeneration

Claudio Hetz<sup>1-3</sup> and Smita Saxena<sup>4</sup>



Insights to the mechanisms of voltage gating sensitivity in connexin26 hemichannels revealed by human mutation G12R

Isaac E. García<sup>1</sup>, Felipe Villanelo<sup>1,2</sup>, Gustavo F. Contreras<sup>1</sup>, Amaury Pupo<sup>1</sup>, Bernardo I. Pinto<sup>1</sup>, Jorge E. Contreras<sup>3</sup>, Tomás Pérez-Acle<sup>1,2</sup>, Osvaldo Alvarez<sup>4</sup>, Ramón Latorre<sup>1</sup>, Agustín D. Martínez<sup>1†</sup> and Carlos González<sup>1†</sup>



Tuning the frequencies and auto-oscillations of the normal modes of a nano-pillar oscillator through the magnetostatic interaction

D. Mancilla-Almonacid,<sup>1</sup> R. E. Arias,<sup>2</sup> S. Oyarzún,<sup>1</sup> D. Altbir,<sup>1</sup> and S. Allende<sup>1</sup>

Average I. F. = 7.2

# Acknowledgments: Team and funding



D. Gonzalez-Nilo



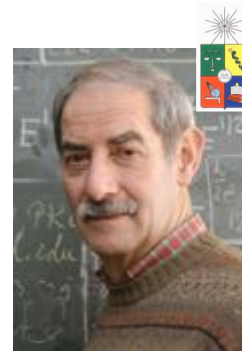
Samuel Hevia



Jeronimo Maze



Claudio Hetz



Miguel Kiwi



Alejandro Valdivia



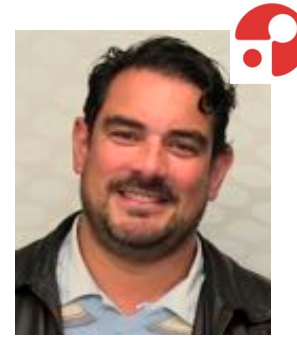
Dora Altbir



Ramón Latorre



Adrian Palacios



Tomas Perez-Acle



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