# Table of Content

**List of Tables** **viii**

**List of Figures** **ix**

**1 Introduction** **1**

1.1 Hypothesis . . . . . 6

1.2 Objectives . . . . . 6

1.2.1 General objectives . . . . . 6

1.2.2 Specific objectives . . . . . 6

1.3 Contributions of the thesis . . . . . 6

1.4 Thesis outline . . . . . 7

**2 Background and theoretical framework** **8**

2.1 Neurons . . . . . 8

2.1.1 Hodgkin-Huxley model . . . . . 9

2.1.2 Integrate-and-Fire models . . . . . 11

2.2 Synapses . . . . . 13

2.2.1 Abstract synapses . . . . . 14

2.3 Plasticity in the brain . . . . . 16

2.3.1 Spike-Timing-Dependent Plasticity . . . . . 17

**3 Energy-dependent Leaky Integrate-and-Fire** **20**

3.1 EDLIF formalization and dynamics . . . 21
3.1.1 Energy Dependent Leaky Integrate-and-Fire model . . . 22
3.1.2 Parameter fitting . . . 27
3.1.3 EDLIF evaluation . . . 28
3.2 Results . . . 29
3.2.1 Models performance in predicting real spike trains . . . 29
3.2.2 Neurons energetics and behavior . . . 30
3.2.3 Neurodegeneration and energetics: amyotrophic lateral sclerosis . . . 32
3.3 Discussion . . . 32

**4 Energy-dependent Spike-Timing-Dependent Plasticity 35**

4.1 Synapses and energy consumption . . . 36
4.2 Energy Dependent Spike-Timing-Dependent-Plasticity model . . . 38
4.2.1 Energy-dependent plasticity and equilibrium . . . 40
4.3 Results . . . 42
4.3.1 Two-neurons experiment . . . 42
4.3.2 Bombarding postynaptic neuron . . . 43
4.4 Discussion . . . 46

**5 Energy-dependent Spiking Neuronal Networks 48**

5.1 Network dynamics under the Energy Homeostasis Principle . . . 49
5.1.1 Network's firing-rate . . . 49
5.1.2 Energy dynamics . . . 51
5.2 Results . . . 54
5.2.1 Exploring synaptic energy imbalance sensitivities $\eta$ . . . 60
5.2.2 Including neuronal sensitivities to energy imbalances $\gamma$ . . . 64
5.2.3 Impaired metabolic production . . . 66

5.3 Discussion . . . . . 72

**6 Conclusion and future work** **76**

**Bibliography** **79**