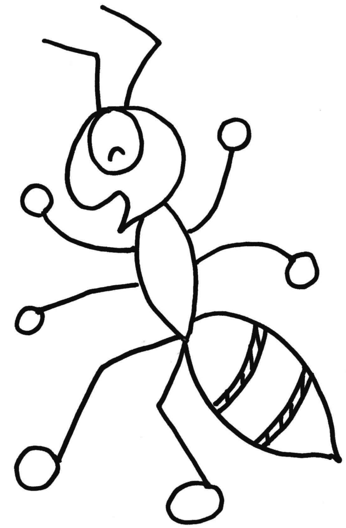


ROBOTICS MEETING
07/03/2007

Carlo Pinciroli

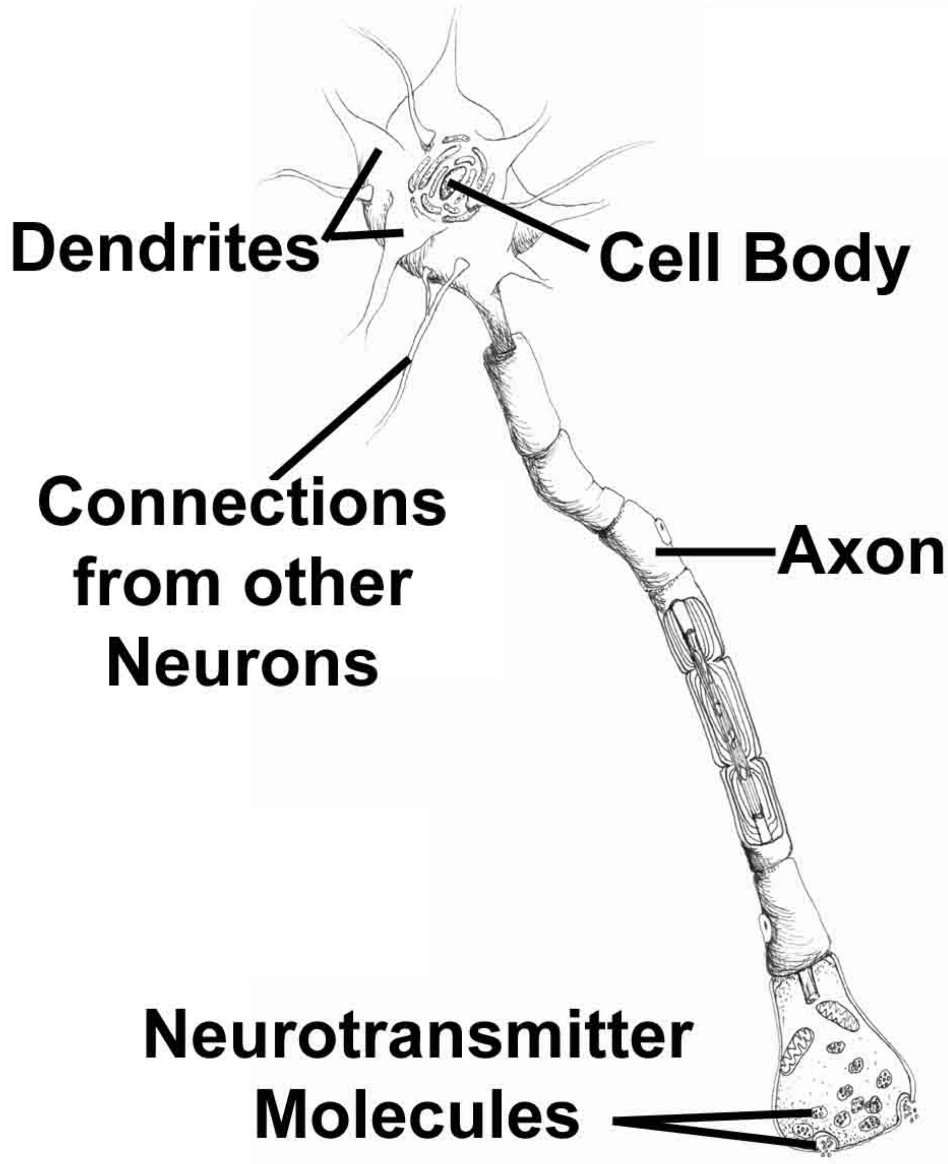
Outline

- Spiking Networks
  - A biological introduction and motivation
  - Applications to Robotics
  - Possible contributions

- A nice application for Collective Robotics
  - The Capture the Flag game

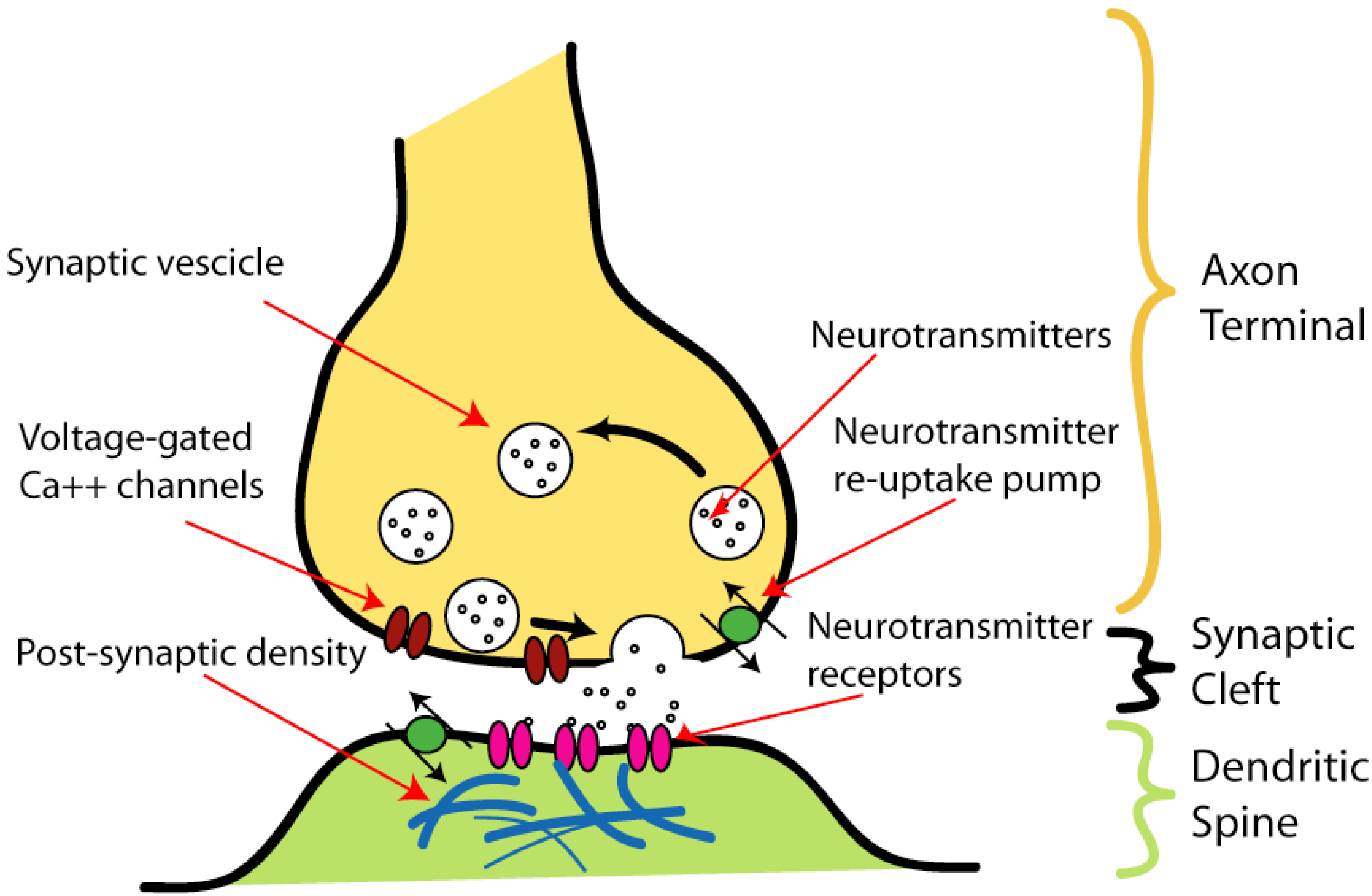
SPIKING NETWORKS

The Neuron



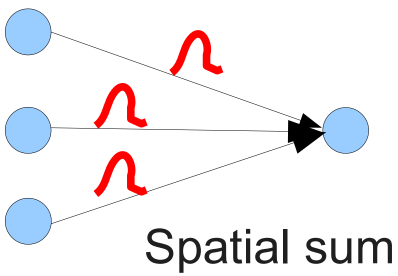
Dendrites
Cell Body
Connections from other Neurons
Axon
Neurotransmitter Molecules

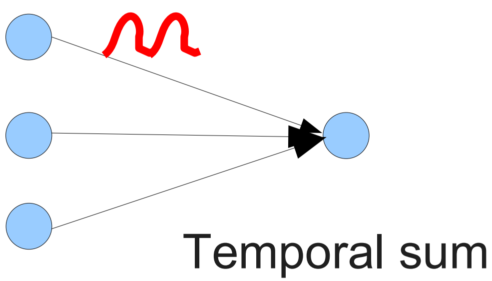
The Chemical Synapse



Processing Synaptic Inputs

- Postsynaptic potentials are summed





- Not only presynaptic firing *rate* influences postsynaptic firing, but also presynaptic firing *time*
  - Synapses are capable of supporting computations based on highly structured temporal codes (Gerstner1997)

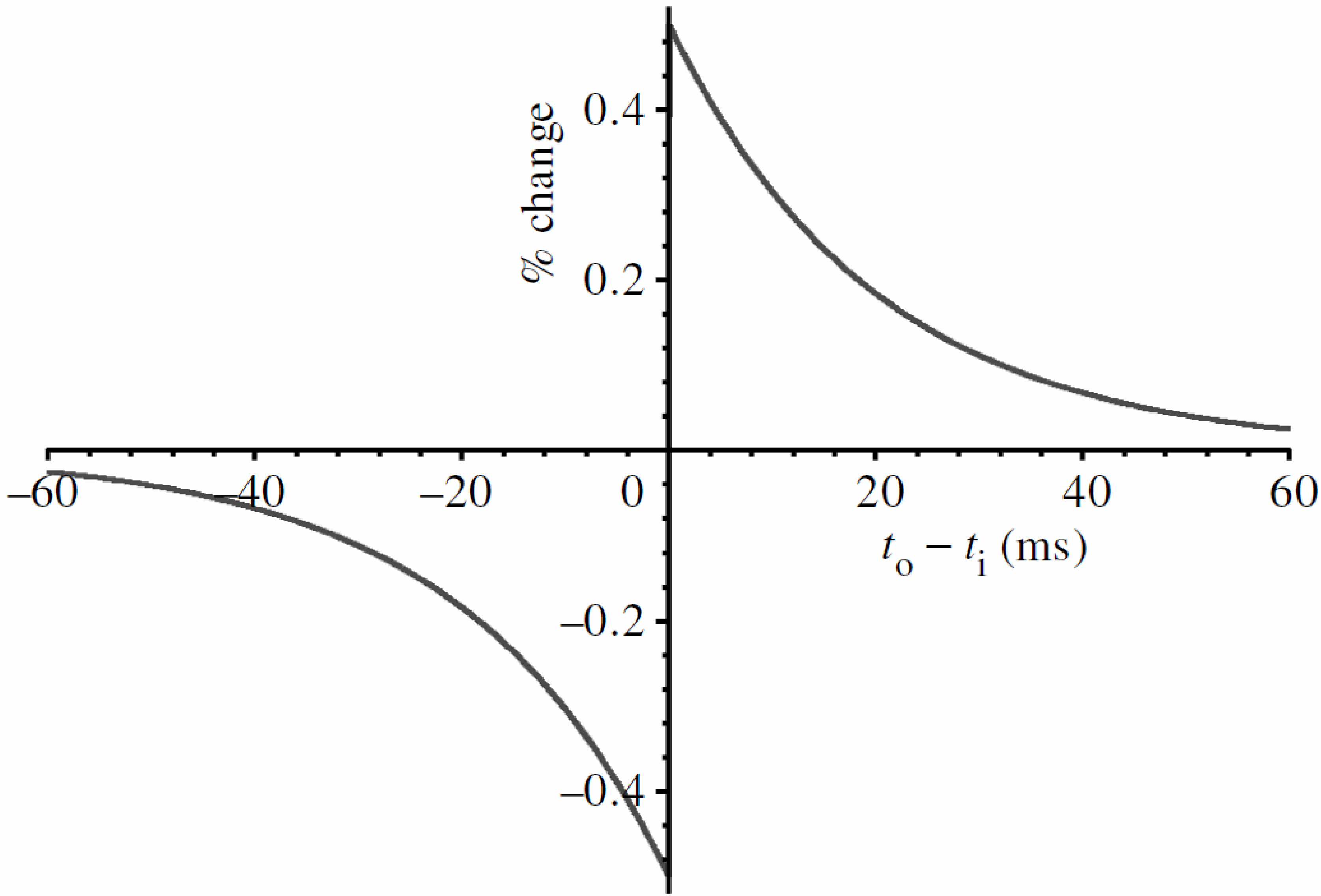
Synaptic Plasticity

- *Synaptic plasticity* is considered one the main mechanisms for learning and memory
- The traditional model of plasticity is the *Hebbian Rule*
  - Positive feedback rule
  - Tends to destabilize postsynaptic firing rates
- *Spiking-Time-Dependent-Plasticity (STDP)* is a Hebbian-like model that overcomes such problem, regulating both rate and variability of postsynaptic firing

STDP Principles

- STDP privileges causal relationships between pre- and postsynaptic firings in a timely manner
  - Synaptic modification is maximal for small differences between pre- and postsynaptic spike times
  - The sign of the difference between pre- and postsynaptic spike times determines the sign of synaptic modification (potentiation or depression)
    - Pre- spike precedes Post- spike potentiates the synapse
    - Post- spike precedes Pre- spike depresses the synapse

STDP Synaptic Modification



Stabilization: an Example

- A neuron receives excessive random input spikes from several synapses (a constant current)
- In response, the neuron fires constantly with no correlation with the inputs
- The synapses are therefore weakened, in fact making the neuron unable to fire for such current
- The neuron still fires if by chance the inputs are clustered in time (coincidence detector)
- As a result, firing is limited but irregular

Applications /1 (Floreano2001)

- First application to interface a spiking network to a robot for a task of simple vision-based navigation
- They have used an evolutionary algorithm to evolve the network, but without plasticity (no STDP)
- Comparison between the resulting spiking network and a classical sigmoid network shows that the spiking network evolves faster and have better performance

Applications /2 (DiPaolo2003)

- Phototaxis on a series of light sources
  - To study the role of plasticity and exact spike timing
  - To study how fast a network is able to learn new behaviours
  - To compare spiking networks to rate based ones
- Results
  - Plasticity is a key feature for robustness
  - Spike timing need not being precise
  - Spiking networks are faster than CTRNN in learning new behaviours

Applications /3 (Soula2005)

- Obstacle avoidance with visual flow to study behaviour adaptiveness (plasticity vs. rigidity)
- They claim that the variance of the weight distribution drives the network from a *chaotic regime* (complete plasticity) to a *synchronous regime* (complete rigidity)
- To have maximum adaptiveness, learning should occur *at the edge of chaos*

Conclusion

- Drawbacks
  - Very complex model
  - Hard and heavy to simulate
  - Not easy to put in s-bots
- Possible applications
  - Learning, memory and time dependent tasks
  - No application to Collective Robotics so far

A NICE APPLICATION FOR COLLECTIVE ROBOTICS

Capture the Flag

- The game
  - Two nests, two teams, two flags
  - The team that has both flags in its nest wins
- It's an interesting application
  - Simple to understand and code
  - Complex strategies: cooperation vs. competition
  - Fits in object retrieval scenario of Swarmanoid
  - Nobody has tried it in 3D before
  - Outstanding demo (if it works!)

The Arena