Week 5 – part 2 : Sources of Variability

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 5 – Variability and Noise:
The question of the neural code

Wulfram Gerstner

EPFL, Lausanne, Switzerland

- **5.1 Variability of spike trains**
  - experiments
- **5.2 Sources of Variability?**
  - Is variability equal to noise?
- **5.3 Three definitions of Rate code**
  - Poisson Model
- **5.4 Stochastic spike arrival**
  - Membrane potential fluctuations
- **5.5. Stochastic spike firing**
  - subthreshold and superthreshold

Week 5 – part 2 : Sources of Variability

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5.1 Variability of spike trains

- experiments

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- Is variability equal to noise?

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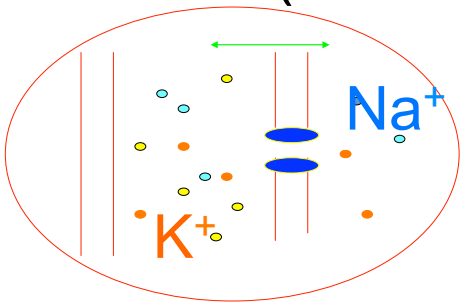
- Membrane potential fluctuations

5.5. Stochastic spike firing

- subthreshold and superthreshold

Neuronal Dynamics – 5.2. Sources of Variability

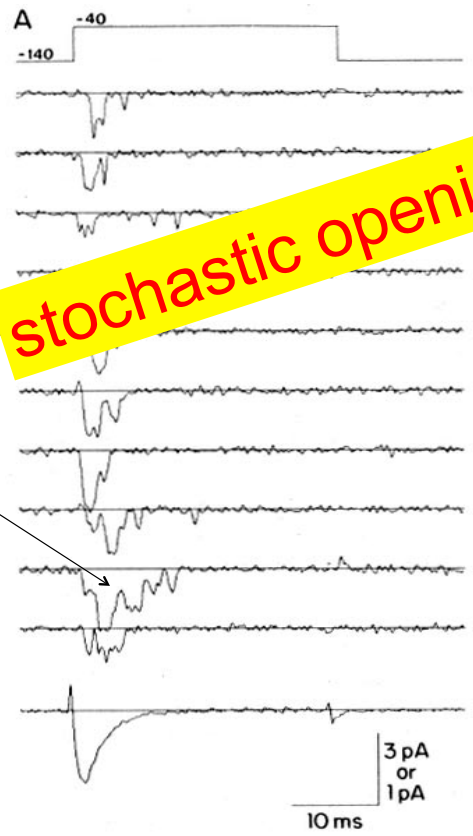
- Intrinsic noise (ion channels)



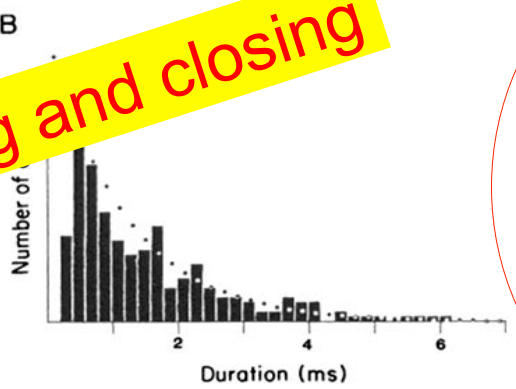
-Finite number of channels
-Finite temperature

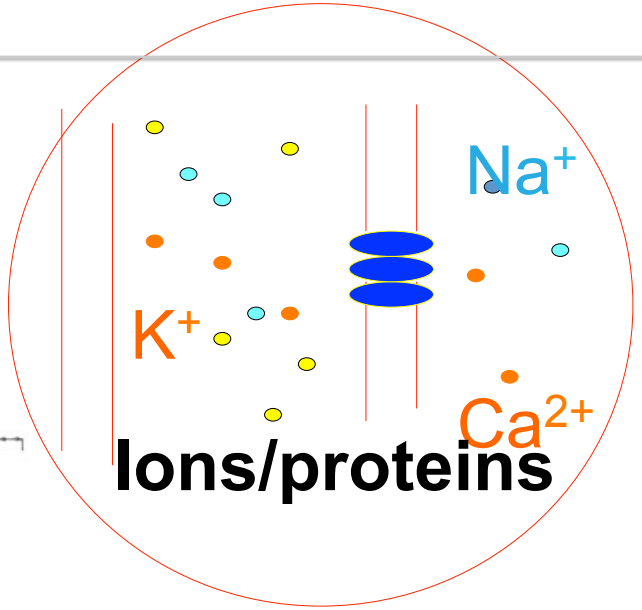
Review from 2.5 Ion channels

Steps:
Different number
of channels



stochastic opening and closing

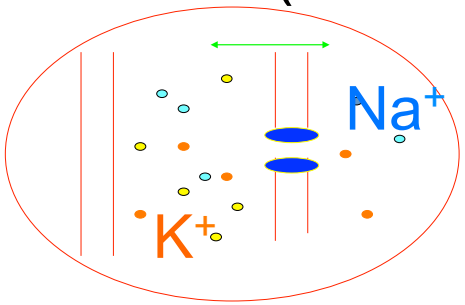




Na+ channel from rat heart *(Patlak and Ortiz 1985)*
A traces from a patch containing several channels.
Bottom: average gives current time course.
B. Opening times of single channel events

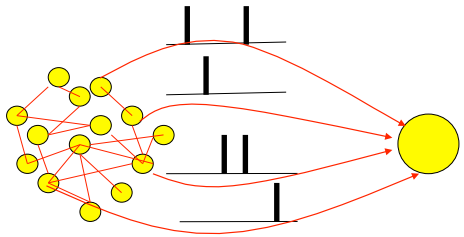
Neuronal Dynamics – 5.2. Sources of Variability

- Intrinsic noise (ion channels)



-Finite number of channels
-Finite temperature

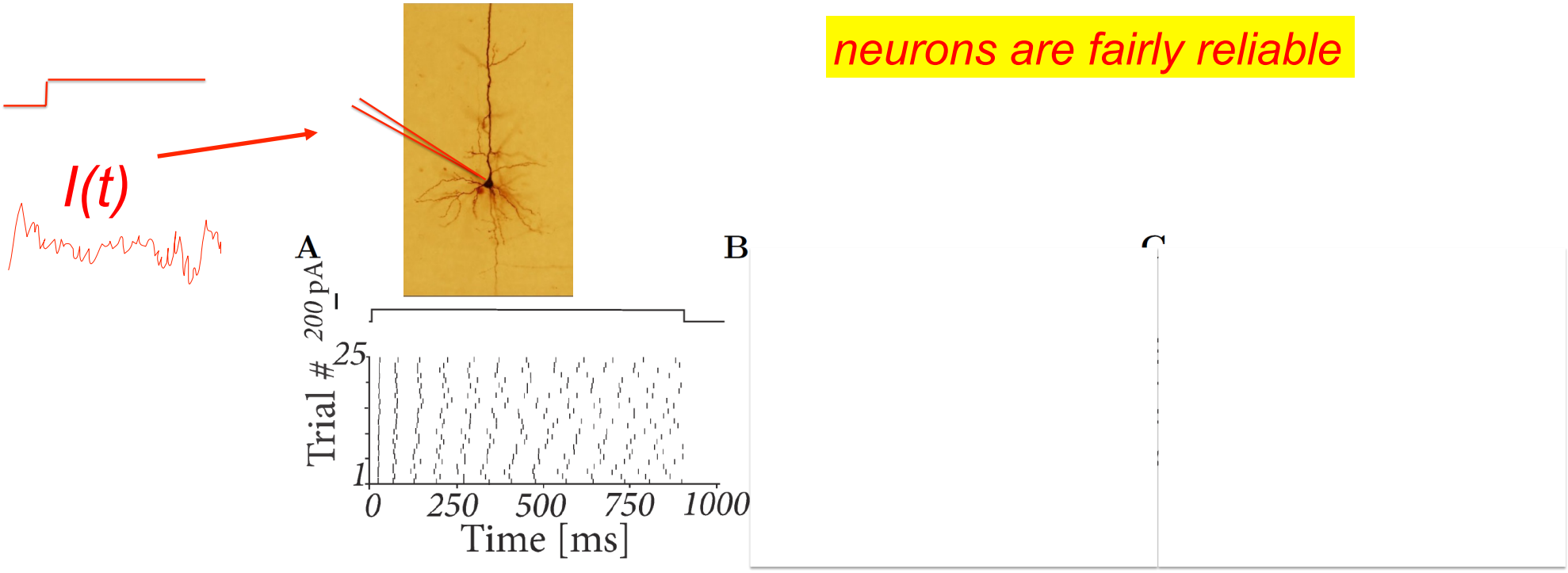
-Network noise (background activity)



-Spike arrival from other neurons
-Beyond control of experimentalist

→ Check intrinisic noise by removing the network

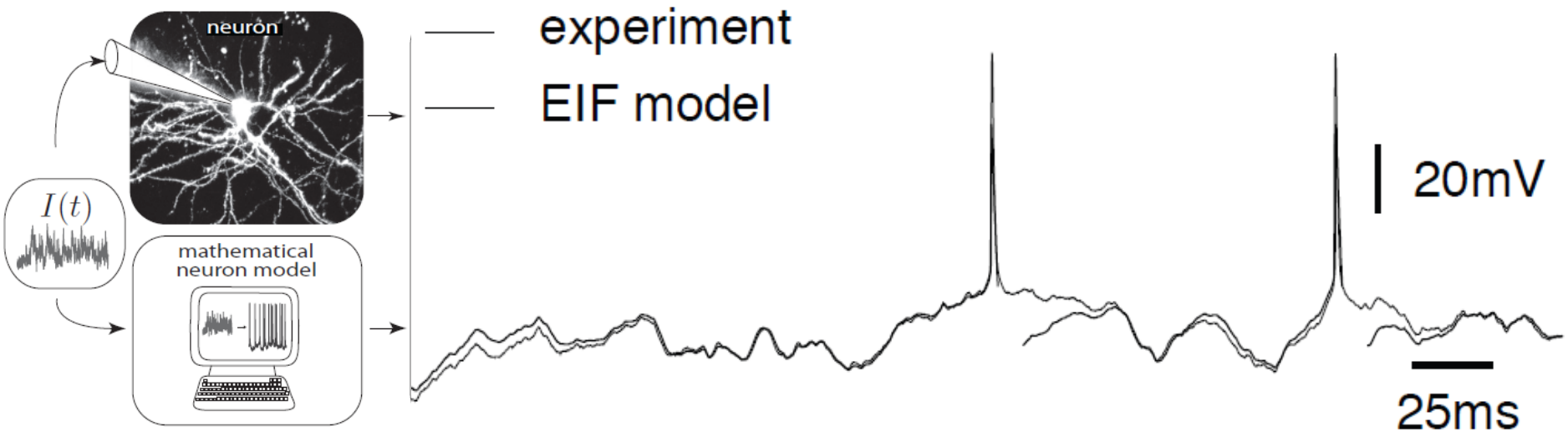
Neuronal Dynamics – 5.2 Variability in vitro



neurons are fairly reliable

Image adapted from Mainen&Sejnowski 1995

REVIEW from 4.5: How good are integrate-and-fire models?



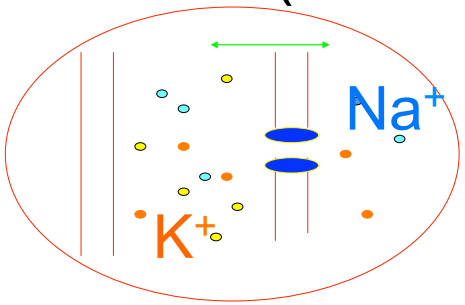
Badel et al., 2008

Aims: - predict spike initiation times
- predict subthreshold voltage

only possible, because neurons are fairly reliable

Neuronal Dynamics – 5.2. Sources of Variability

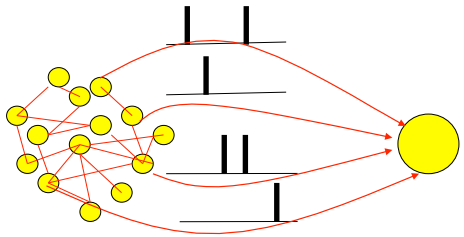
- Intrinsic noise (ion channels)



-Finite number of channels
-Finite temperature

small contribution!

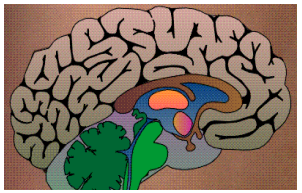
-Network noise (background activity)



-Spike arrival from other neurons
-Beyond control of experimentalist

→ Check network noise by simulation!

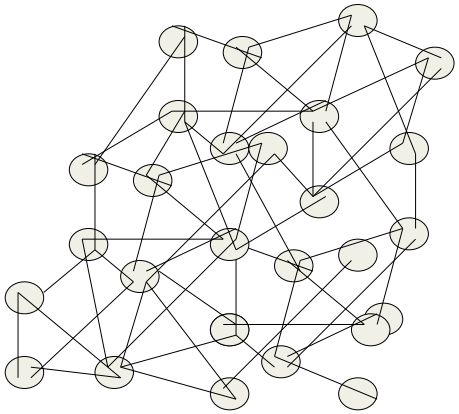
Neuronal Dynamics – 5.2 Sources of Variability



Brain

The Brain: a highly connected system

High connectivity:
systematic, organized in local populations
but **seemingly random**

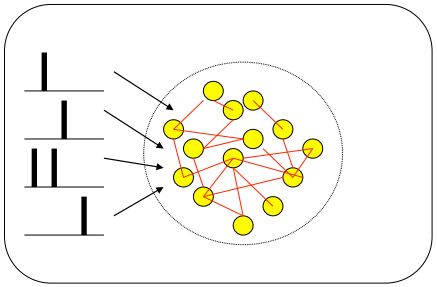


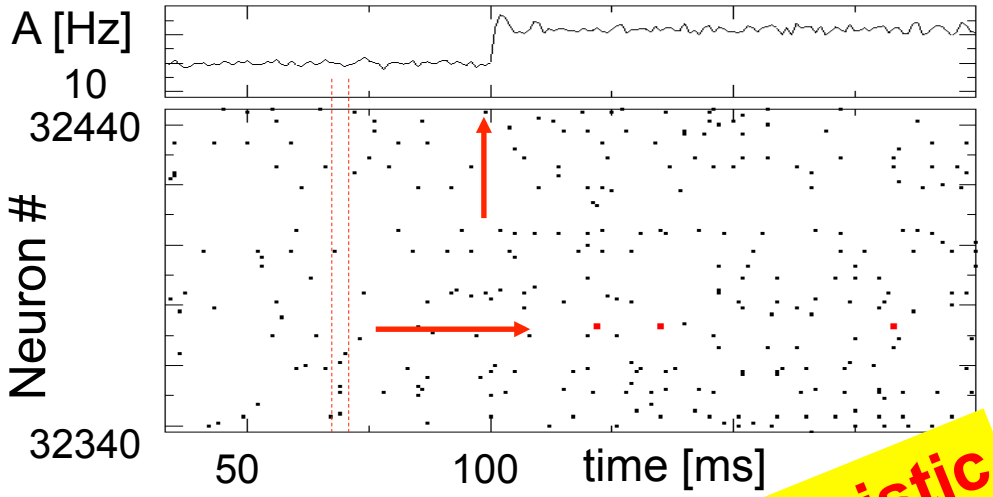
Distributed architecture

10^{10} neurons

10^{4} connections/neurons

Random firing in a population of LIF neurons





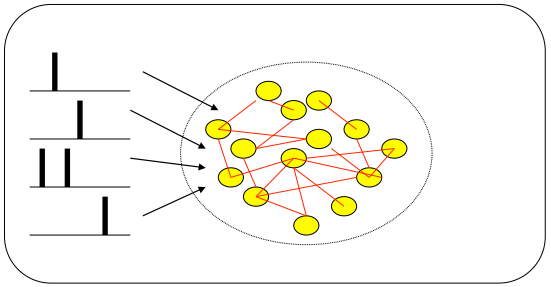
input low rate
high rate

Population
- 50 000 neurons
- 20 percent inhibitory
- **randomly connected**

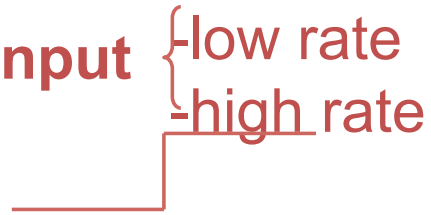
Brunel, J. Comput. Neurosc. 2000
Mayor and Gerstner, Phys. Rev E. 20
Vogels et al., 2005

Network of **deterministic** leaky integrate-and-fire: 'fluctuations'

Random firing in a population of LIF neurons



input low rate / high rate



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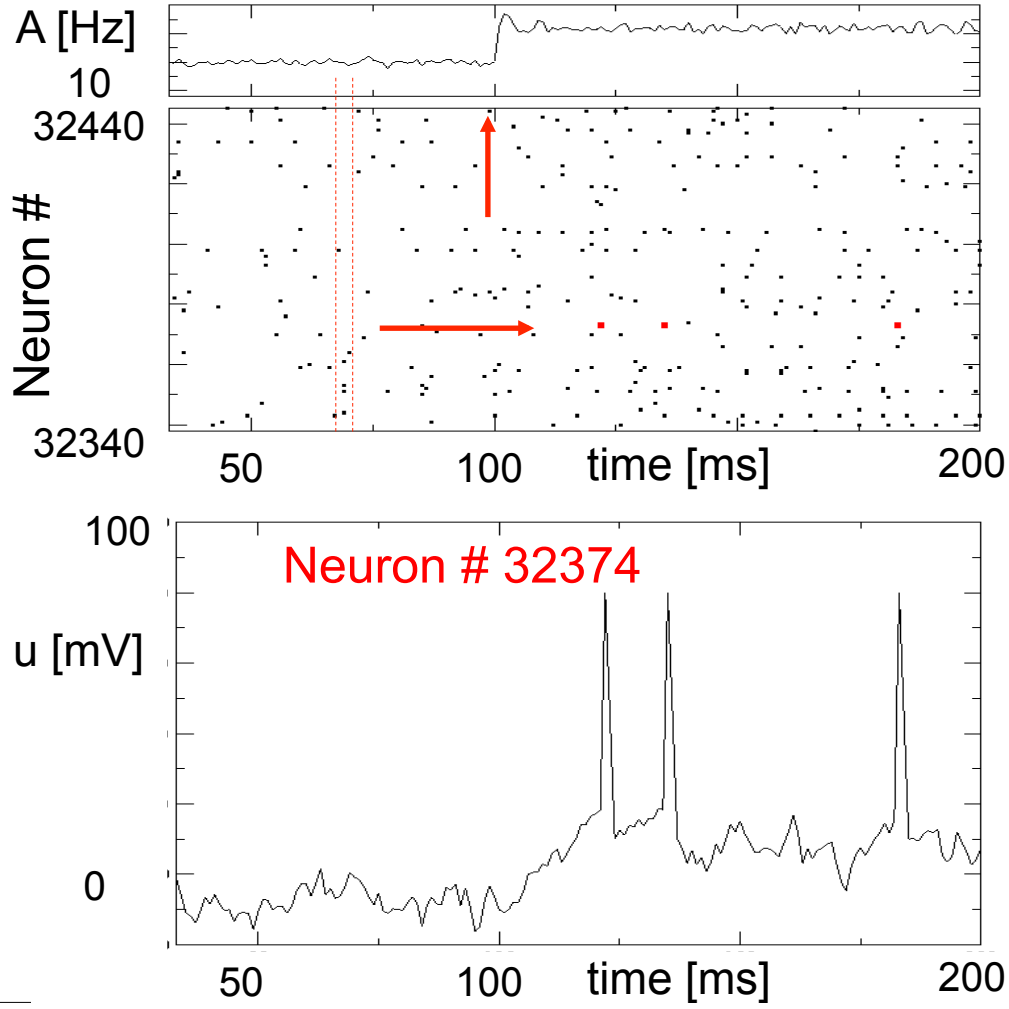
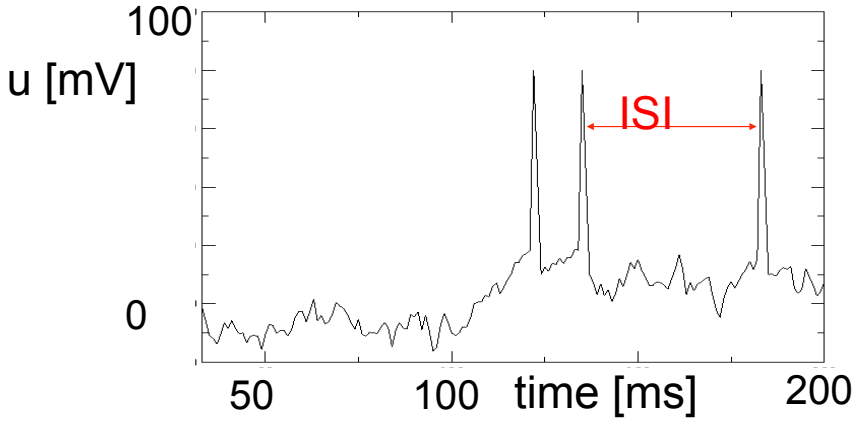
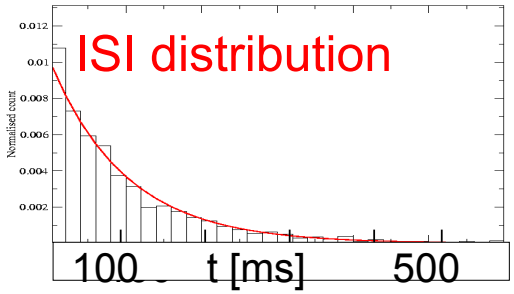


Neuronal Dynamics – 5.2. Interspike interval distribution

- Variability of interspike intervals (ISI)

here in simulations,
but also *in vivo*



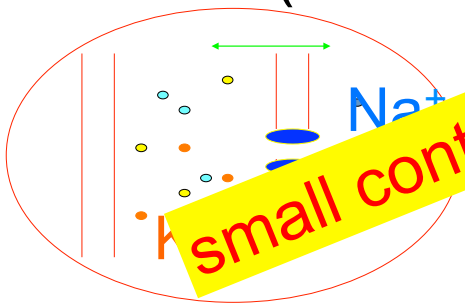


Variability of spike trains:
broad ISI distribution

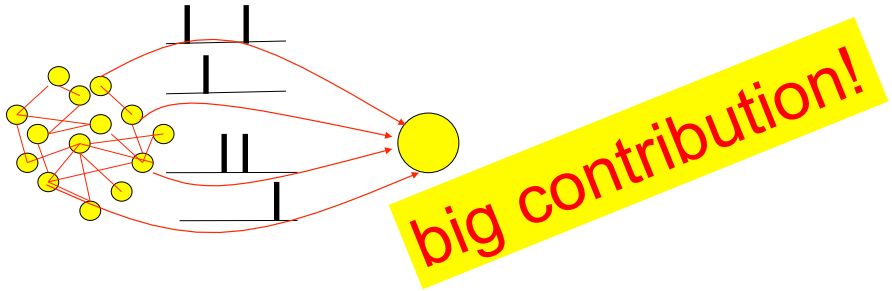
Brunel,
J. Comput. Neurosc. 2000
Mayor and Gerstner,
Phys. Rev E. 2005
Vogels and Abbott,
J. Neuroscience, 2005

Neuronal Dynamics – 5.2. Sources of Variability

- Intrinsic noise (ion channels)



-Network noise



Neuronal Dynamics – Quiz 5.1.

A- Spike timing in vitro and in vivo

[ ] Reliability of spike timing can be assessed by repeating several times the same stimulus

[ ] Spike timing in vitro is more reliable under injection of constant current than with fluctuating current

[ ] Spike timing in vitro is less reliable under injection of constant current than with fluctuating current

[ ] Spike timing in vitro is more reliable than spike timing in vivo

[ ] Nothing is known about spike timing in humans in vivo

B – Interspike Interval Distribution (ISI)

[ ] An isolated deterministic leaky integrate-and-fire neuron driven by a constant current can have a broad ISI

[ ] A deterministic leaky integrate-and-fire neuron embedded into a randomly connected network of integrate-and-fire neurons can have a broad ISI

[ ] An isolated deterministic Hodgkin-Huxley model as in week 2 driven by a constant current can have a broad ISI