Detailed neuron models:

Hodgkin-Huxley model

1: Introduction to Hodgkin-Huxley models
2: threshold in the Hodgkin-Huxley model
3. Synaptic input (conductance input)

Wulfram Gerstner
http://lcn.epfl.ch  moodle.epfl.ch

Integrate-and-fire type models

- spikes are events
- threshold
- spike/reset/refractoriness

Hodgkin-Huxley type models

BOOK: Spiking Neuron Models,
W. Gerstner and W. Kistler
Cambridge University Press, 2002

Chapter 2

Chapter 2: Detailed neuron models
Hodgkin-Huxley model

Wulfram Gerstner
http://lcn.epfl.ch
Biophysics of neurons

Cell surrounded by membrane
Membrane contains:
- ion channels
- ion pumps

Ion density:
\[ n \propto e^{-\frac{E}{kT}} \]

Action potential

Concentration difference \( \Delta u = u_1 - u_2 = \frac{kT}{q} \ln \frac{n(u_1)}{n(u_2)} \)

Reversal potential

Exercise 1+2 now:
dynamics of ion channels

Next lecture:
10H15

Hodgkin-Huxley Model
Hodgkin-Huxley Model

**Constant current input**

\[ I_0 \]

**Threshold?**

for repetitive firing

*(current threshold)*

**Threshold?**

- AP if amplitude 7.0 units
- No AP if amplitude 6.9 units

(pulse with 1ms duration)

(and pulse with 0.5 ms duration?)

Where is the threshold?

*question for you!

Where is the firing threshold?

Stimulation with time-dependent input current

Refractoriness! Harder to elicit a second spike

Blackboard

\[
C \frac{du}{dt} = - g_N a m^3 h(u-E_N) - g_K n^4 (u-E_K) - g_L (u-E_L) + I(t)
\]

\[
dm \frac{dt}{dt} = m_m(u) - m_m(u) - \tau_m(u)
\]

\[
dh \frac{dt}{dt} = h - h(u) - \tau_h(u)
\]

\[
C \frac{d\theta}{dt} = - g_K n^4 (u-E_K) + I(t)
\]

---

**Next lecture**

11h15

Exercises 3 now!
**Hodgkin-Huxley Model**

**Where is the firing threshold?**
- **pulse input** \( I(t) \)
- **step input** \( \Delta I \)
- **ramp input**

**There is no threshold**
- no current threshold
- no voltage threshold

'effective' threshold
- depends on typical input

\[
C \frac{du}{dt} = -g_{Na} m^3 h (u - E_{Na}) - \ldots
\]

**Type I and type II models**

**Response at firing threshold?**
- **pulse input**
- **ramp input/constant input**

**Model of Synaptic input: conductance change**

\[
r \frac{d}{dt} = -(u - u_{rest}) - \sum_k g_k (t - t_k') [u - E_k] - \sum_{F} g_{F} (t - t_{F}') [u - E_F]
\]

EPSC  \quad IPSC
**Detailed neuron models:**

Hodgkin-Huxley model

1: Introduction to Hodgkin-Huxley models
2: Threshold in the Hodgkin-Huxley model
3: Synaptic input (conductance input)
4: Variants of the Hodgkin-Huxley model

Wulfram Gerstner
http://lcn.epfl.ch/ moodle.epfl.ch
Hodgkin-Huxley type models

Where is the firing threshold?

There is no threshold
- no current threshold
- no voltage threshold

‘effective’ threshold
- depends on typical input

threshold process not immediate
- delayed AP possible

Hodgkin-Huxley Model

Where is the firing threshold?

There is no threshold
- no current threshold
- no voltage threshold

‘effective’ threshold
- depends on typical input

BUT:
- threshold model is a good approximation
- (voltage threshold)

Exercise 4 now:
~Synaptic input

Computer exercise:
- play with Hodgkin-Huxley model

Next lecture: 11:57

Membrane potential
\[ \frac{d}{dt} u = -(u - u_{rest}) - g_e(t)(u - E_g) \]

Synaptic input
\[ g_e(t)(u - E_g) = g_e(t) v \]

The end