The Hodgkin–Huxley model

Conductance models of the action potential

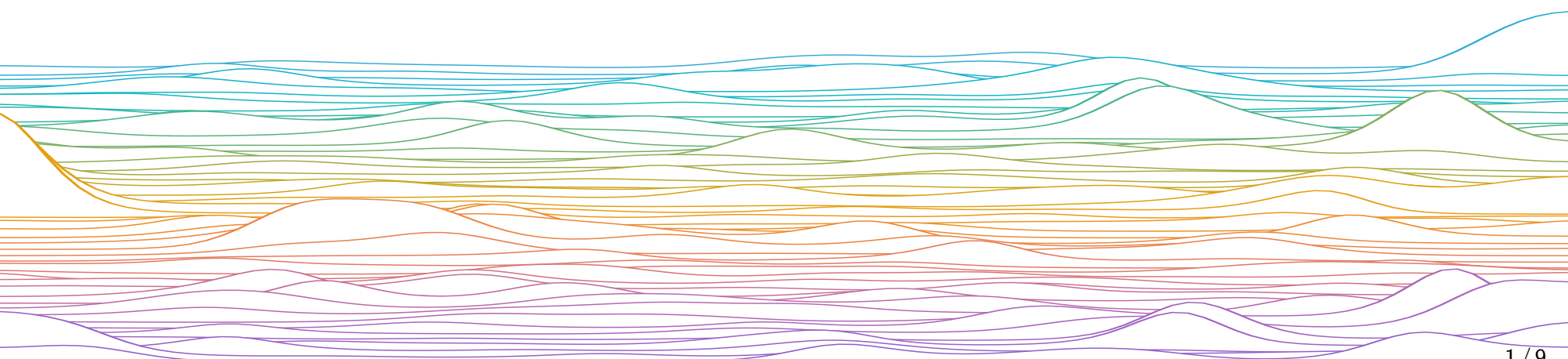
Computational Neuroscience

University of Bristol

M Rule

Learning outcomes:

- Understand and describe a basic voltage clamp setup.
- Be ready to approach exam problems that touch on the voltage clamp.



Hodgkin and Huxley fit them to match their voltage-clamp data.

$$\alpha_m(V) = \frac{0.1(V+40)}{1-e^{-(V+40)/10}} \qquad \beta_m(V) = 4e^{-(V+65)/18}$$

$$\alpha_h(V) = 0.07e^{-(V+65)/20} \qquad \beta_h(V) = \frac{1}{1+e^{-(V+35)/10}}$$

$$\alpha_n(V) = \frac{0.01(V+55)}{1-e^{-(V+55)/10}} \qquad \beta_n(V) = 0.125e^{-(V+65)/80}$$

Neuroscientists say ***"clamped"***

- Voltage clamp
- Current clamp
- Dynamic clamp
- Patch clamp
- Space clamp

What do they mean by that?

Clamp:

- *'We fixed some variables at known values, so that the system is easier to analyze or identify'*
- Experimentally:
  - Using feedback control
- Mathematically:
  - Making assumptions

Voltage Clamp

- Get an electrode connected to the inside of a neuron (somehow?)
- Use a feedback amplifier to hold membrane at some target v_{ref}
- What can we measure?
  - Voltage-gated conductances stabilize at a steady state

Intracellular recording

Sharp Electrode

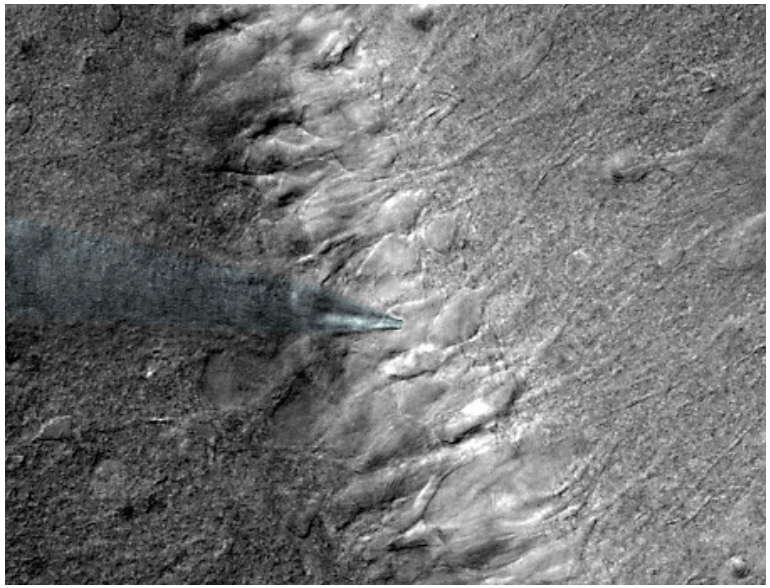
Cell Attached

Whole-Cell

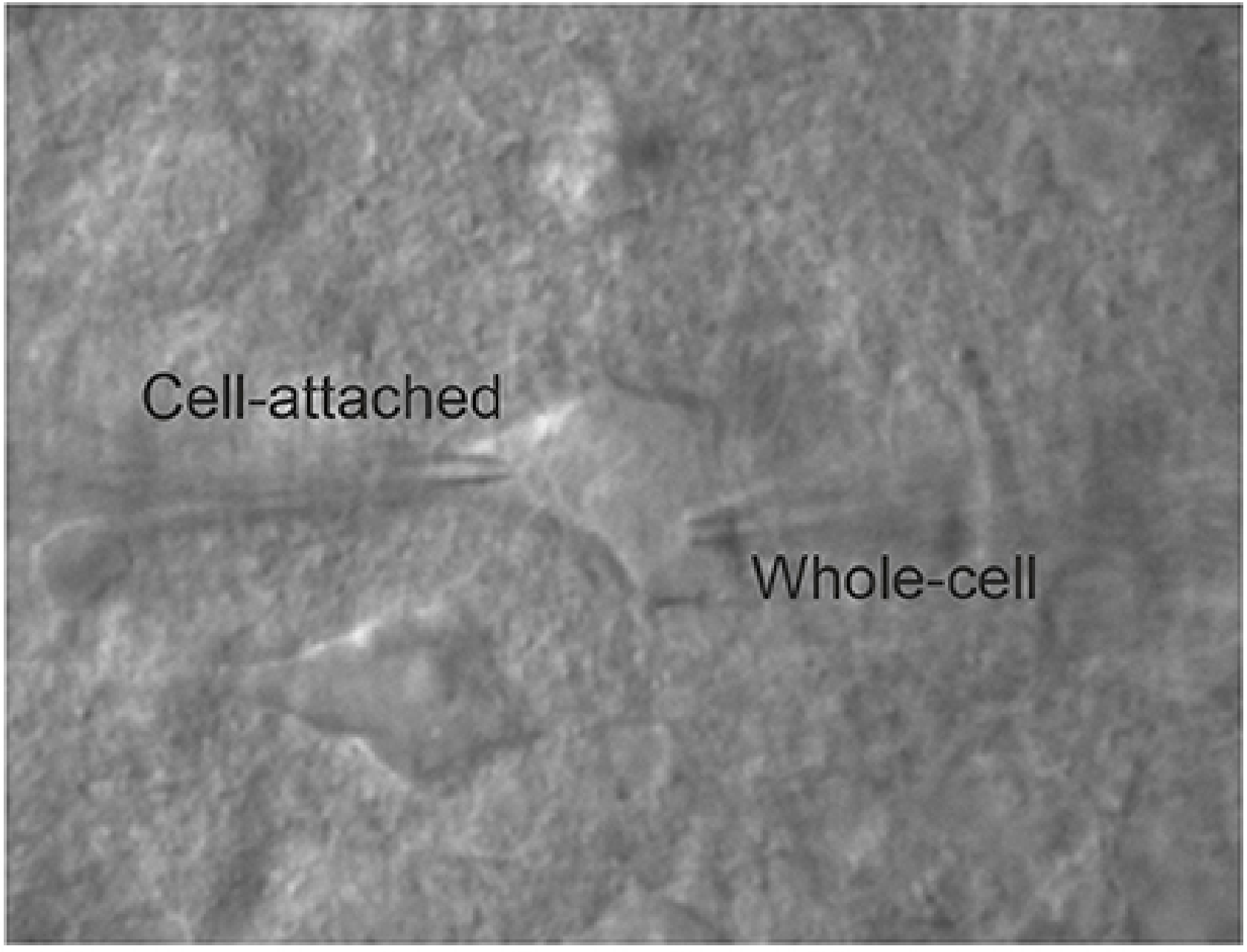
Common misunderstanding: **Patch clamp** refers to a cell-attached recording, combined with the use of a feedback amplifier to "clamp" either the voltage or current (or something more exotic) to a known value to study membrane, channel properties. *Patch clamp ≠ sharp electrode, whole cell*

In vitro electrophysiology: patch clamp

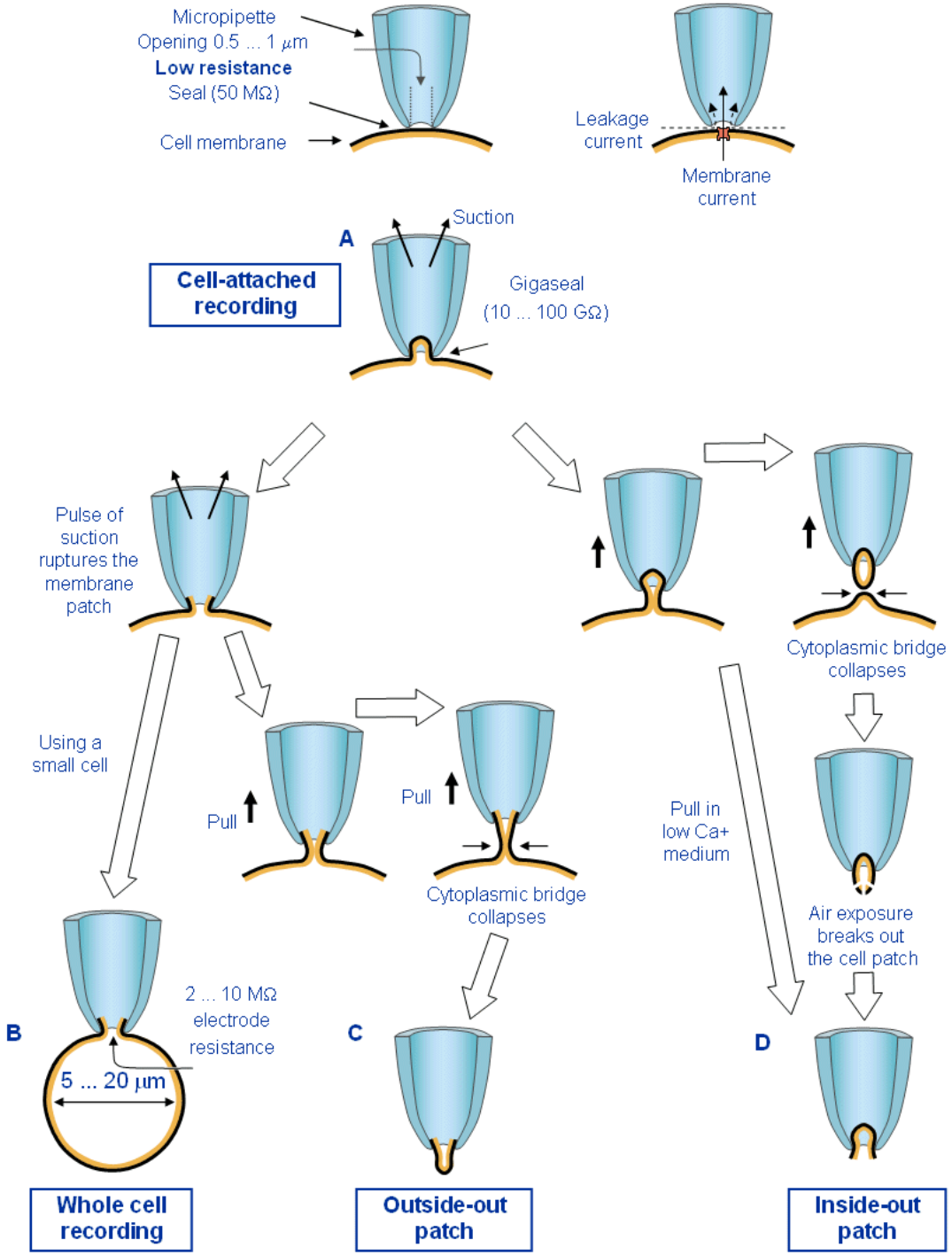
- Extracellular electrophysiology can detect action potentials. But it cannot see 'subthreshold' voltage signals like PSPs.
- To record intracellular voltage researcher use a method called the patch clamp.
- Involves sealing a cylindrical glass pipette (with an electrode inside) onto the neuron's membrane and bursting a small hole through to allow the electrode to measure the intracellular voltage.
- If the seal is not physically stable it will break. So the method is difficult to do in vivo.
- Most often done in *in vitro* brain slices or in neurons grown in a petri dish.



Bonni et al., modified from Rosentod, via wikimedia



Vazetdinova, Alina, et al. (2002)


Micropipette
Opening 0.5 ... 1 µm
Low resistance
Seal (50 MΩ)
Cell membrane
Leakage current
Membrane current
A
Suction
Cell-attached recording
Gigaseal
(10 ... 100 GΩ)
Pulse of suction ruptures the membrane patch
Using a small cell
Pull
Pull
Cytoplasmic bridge collapses
Cytoplasmic bridge collapses
Pull in low Ca+ medium
Air exposure breaks out the cell patch
B
2 ... 10 MΩ electrode resistance
5 ... 20 µm
C
D
Whole cell recording
Outside-out patch
Inside-out patch

end