Box 1 : CA1 region in the rat hippocampus, current injection for 1 ms in blank. Sub-threshold and supra-threshold current injection are shown (red, purple).

$V_{rest} = -62\ mV$, $V_{thres} = -53\ mV$.

Important quantities are the width and $\frac{dV}{dt}$

** note : positive currents are outward flow of + charges (K+, ~~Cl-~~)

Figure 1 : Different types of APs in central neurons

- Purkinje Neuron - GABAergic (inhibitory) neurons, huge dendritic network, important for motor control.
  Narrow APs - 180 μs
- CA1 Pyramidal Neuron - excitatory neurons
- Dopamine neuron - uses dopamine as a neurotransmitter
- Fast-spiking neuron has a more pronounced $\frac{dV}{dt}$ value during repolarization than a regular-spiking neuron.
  However, the $\frac{dV}{dt}$ component during depolarization is similar.
- Increased width of AP in the soma w.r.t. to presynaptic terminal.

Figure 2 : , substantia nigra pars compacta (SNc)
one dopaminergic

- Initial segment (IS) - initial region of the axon (slender) where the AP is initiated.
- Many neurons have APs that are similar when the neurons are dissociated and in brain slices.

- Some do not. Here, the SNc dopaminegic neuron have an IS spike in brain slice but not when dissociated.

- Voltage clamp → control voltage
  current clamp → control current

① current clamp mode → observed V_{comm} (= V_{comm} (AP waveform))
- Capacitance compensation – $I_{cap} = 0$ (I_{ionic} only)
- NO capacitance compensation – $I_{ionic} + I_{cap} \simeq 0$ (equal, opposite)

② voltage clamp mode

purple – action potential
blue – predicted ionic current

Figure 3 : Sodium, calcium, potassium currents during AP.

- Negative current because there is an inward flow of cations during depolarization.

  $|I_{NA}| > |I_{Ca}|$, I_{Ca} is prominent during repolarization.

  measured using voltage clamping.

- Ca^{2+} current activates potassium channels and there is a + potassium current that cancels the Ca^{2+} current during repolarization.

- Iberiotoxin blocks potassium channels widening the AP (cannot dump K^+ into the extracellular space)

Figure 4: Kv3 → fast repolarization potassium currents in fast-spiking neurons

- Voltage clamping w/ const. voltage or AP waveform, measuring potassium current
- voltage clamping AP waveforms, K^+ current is blocked by 4-amino pyridine
- TEA produces AP broadening (is also selective to potassium channels)

  under current clamping you see lower firing frequency after TEA treatment.
- Rescue of firing rate after 4-amino pyridine treatment using dynamic clamping.

  ↓

  simulates adding a conductance

  so they simulate the K^+ conductance blocked by 4-amino pyridine.

Figure 5: Frequency-dependent spike broadening.

- Potassium current (I_{Adepol}) is broken down into delayed rectifier current and Ca^{2+} dependent current
- Frequency dependent spike broadening is the widening of APs at higher firing frequency

  → inactivation of potassium current.

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* Potassium currents control AP width

- Excitatory post-synaptic currents (EPSCs)

  and Broad spikes produce prominent EPSCs

Figure 6: After the spike (After potentials)

- After hyperpolarizations → Voltage is more negative than the resting potential
  After depolarizations → another axial AP after the 1st

- Burst firing results from afterdepolarizations that reach the spiking threshold.
- Afterdepolarizations are driven by persistent sodium currents + calcium channels and others
- TTX application to the dendrite prevents burst firing but maintains the 1st AP
- Nickel also prevents burst firing

  → suggest that

increased neurotransmitter release at high Ca^{2+} concentration.

afterdepolarization → resurgent calcium currents.

TTX — sodium channel (voltage-gated)