COMS30017
Computational Neuroscience

Week 7 / Video 2 / Cerebellar anatomy, function and microstructure

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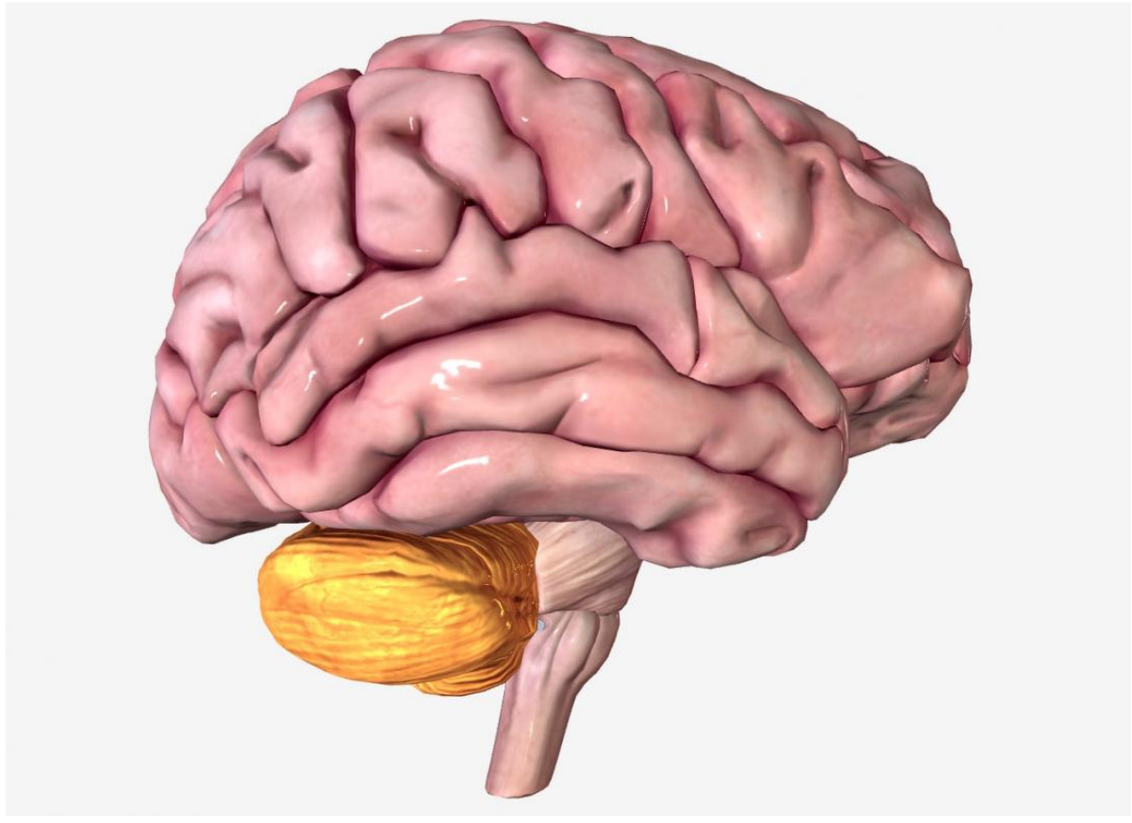
Intended Learning Outcomes

Cerebellar:

- gross anatomy
- microstructure, and the link to supervised learning
- function

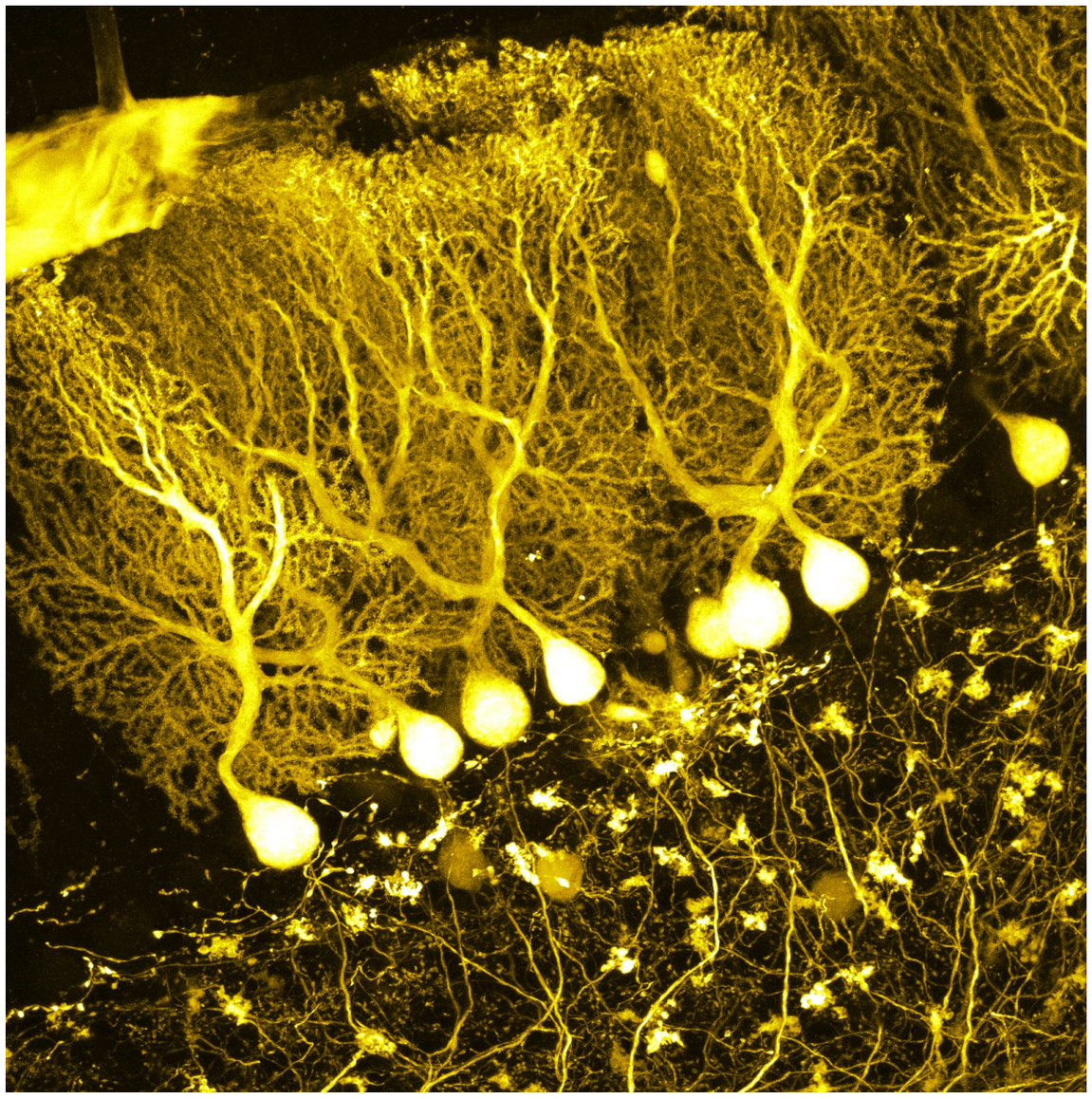
Cerebellar gross anatomy

- Latin for “little brain”
- A large structure, well separated from the rest of the brain.
- More cells than the rest of the brain combined
  - 70 billion cerebellar granule cells (Lange 1975)
  - 25 billion cortical cells (Pelvig et al. 2008)



Cerebellar purkinje cells (PCs)

- Arguably some of the most beautiful cells of the brain
- Dendrites are planar!
- 100,000 input synapses (far more than most other cell types)
- Typical (simple-spike) firing rate = 50 Hz!

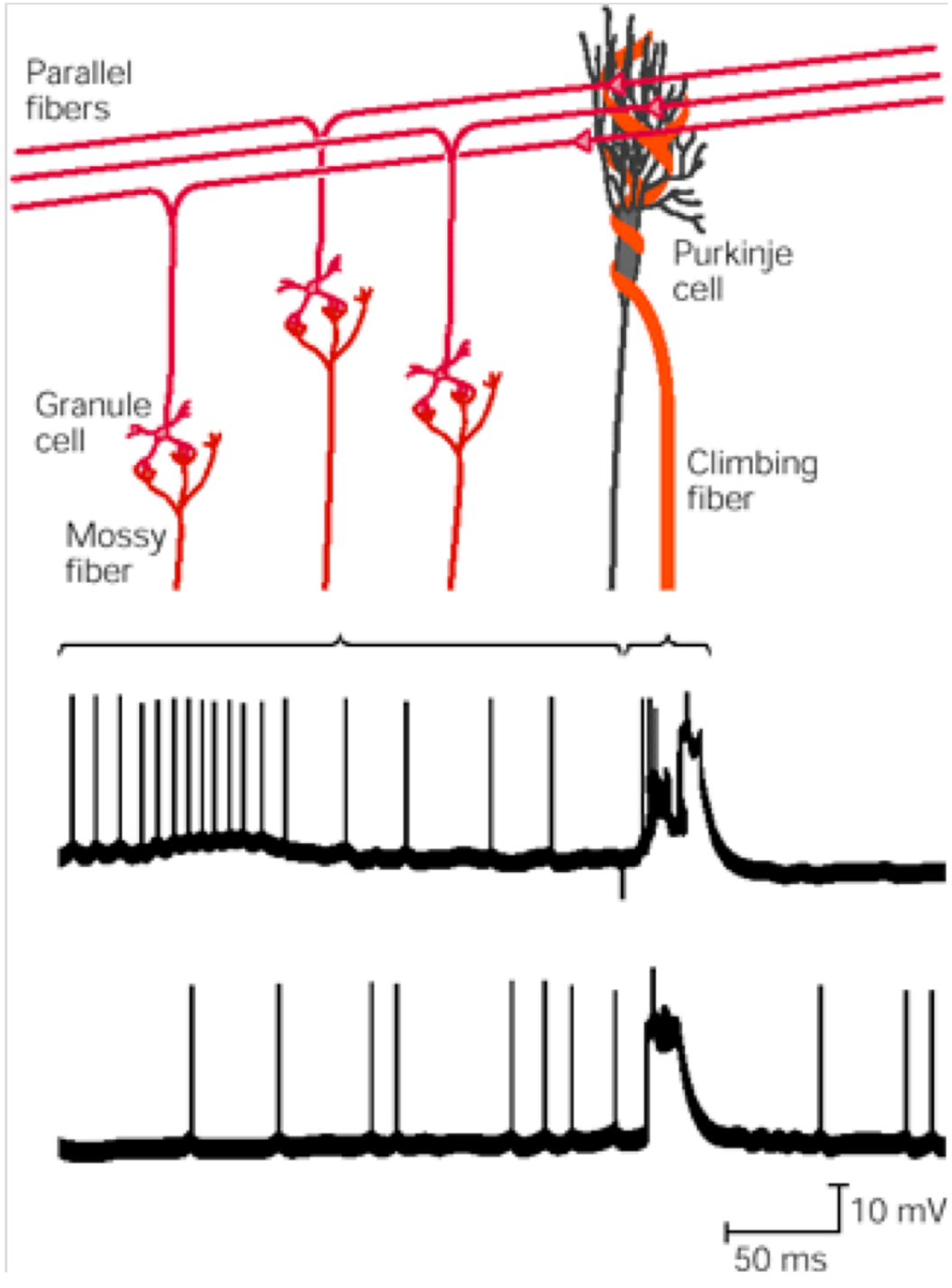


Climbing fibre error signals

- There is one climbing fibre for each Purkinje cell.
- Climbing fibres wrap around the PC and synapse very, very strongly.
- Climbing fibres fire at a low rate ~1Hz
- Climbing fibres originate in the inferior olive.

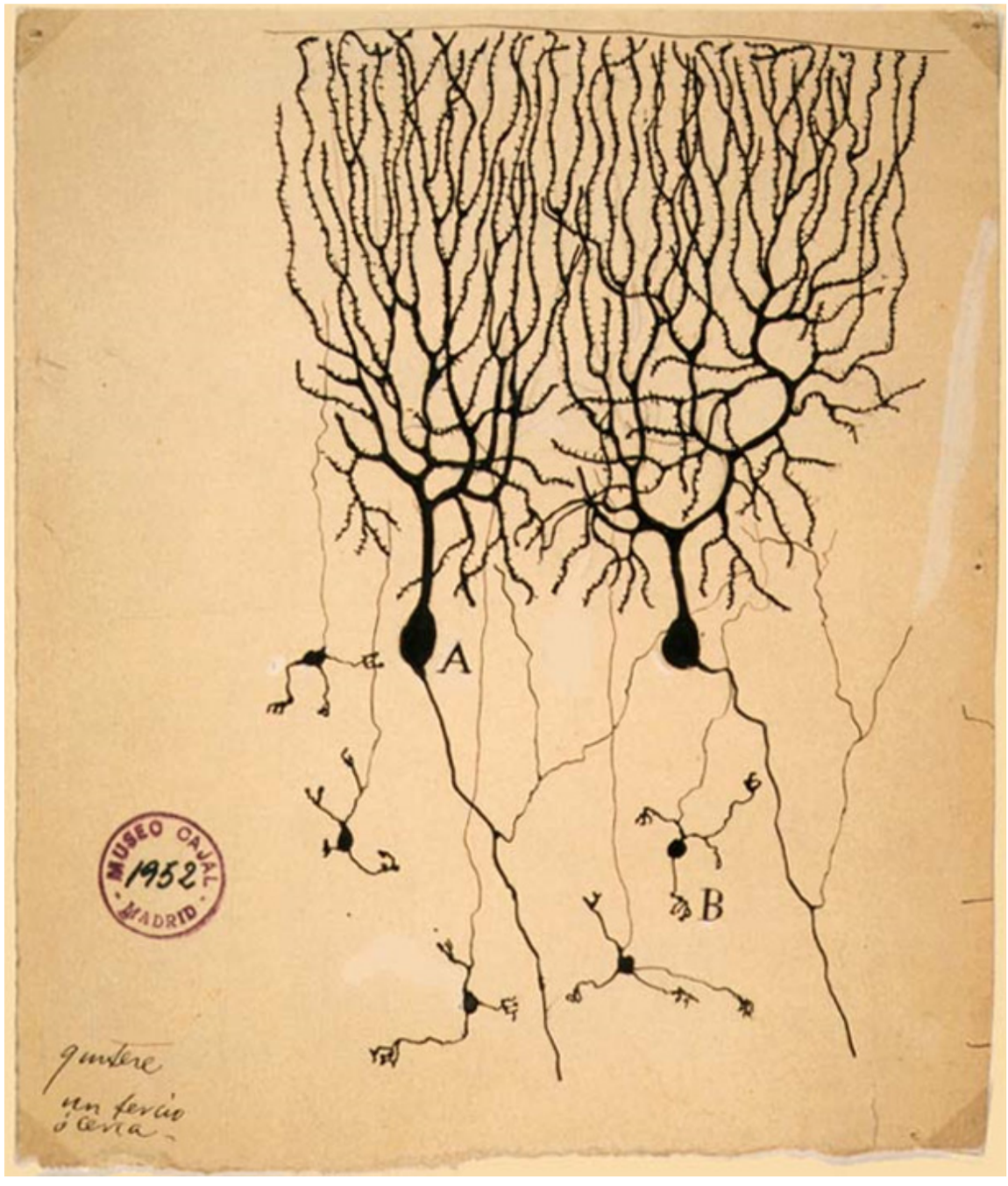
Simple and complex spikes

- Standard PC inputs cause high-frequency (~50 Hz) simple-spikes.
- Climbing fibre inputs causes low-frequency complex spike (~1Hz)
- Complex spikes signal errors, and cause *LTD* (i.e. indicate simple-spike output was too *high*)

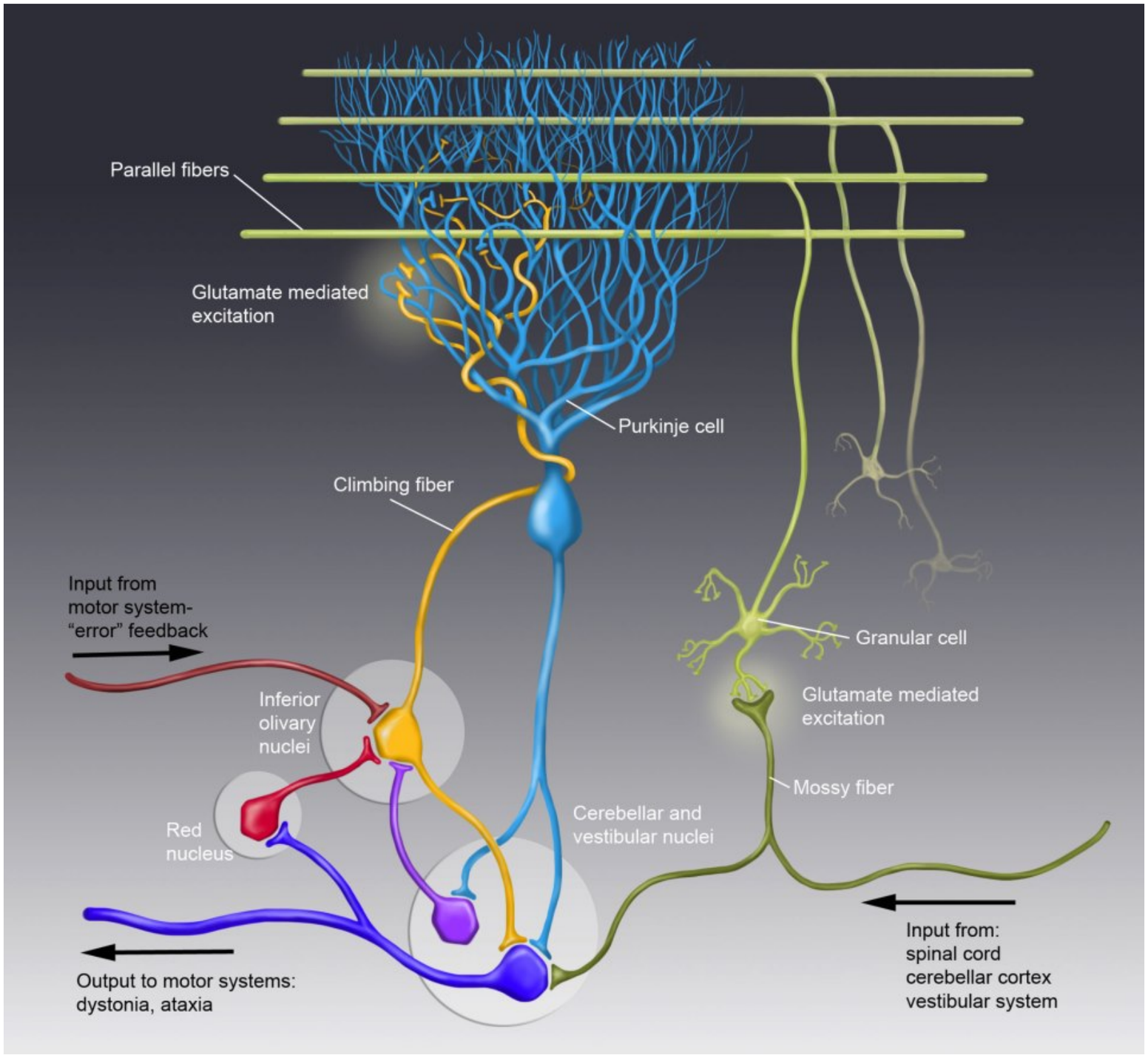


Granule cell inputs

- “B” in the image
- The most numerous cell type in the brain (70 billion cells)
- Only have 1-7 synapses, forming a sparse, decorrelated representation
- Outputs become “parallel fibres”
- Granule cells themeselves take input through the mossy fibres from all over the brain



Overall cerebellar microstructure



Cerebellar modelling

Cerebellum is assumed to do supervised learning:

- Purkinje cell simple spikes = y
- Parallel fibre / granule-cell inputs = x_i
- $y = \sum_i w_i x_i$
- climbing fibre error = $-\delta = -(y^* - y)$ (i.e. climbing-fibre / complex spike indicate output was too large)
- weight update:

$$\Delta w_\alpha = \eta \delta x_\alpha = -\eta(\text{climbing fibre error}) x_\alpha$$

Cerebellar motor deficits

When cerebellum is damaged, we see a variety of deficits, which tend to be in the motor-system:

- A standard test of cerebellar function is to reach with the tip of the finger for a target at arm's length: A healthy person will move the fingertip in a rapid straight trajectory, whereas a person with cerebellar damage will reach slowly and erratically, with many mid-course corrections.
- speech deficits (slow speech, slurring)
- oculomotor deficits (e.g. instability of gaze)
- tremor
- difficulties in balance causing swaying + broad based stance

Cerebellar function

- “Fine-tuning” or direct modifications of the neural motor command.
- Forward modelling: predict the outcome of a given motor command, and therefore pre-emptively modify the command to eliminate predicted errors.
- Doya (1999,2000): the Cerebellum is the brain’s supervised learning module – anytime the brain needs supervised learning it goes to the Cerebellum.
- Cognitive roles “Ito (2008) Control of mental activities by internal models in the cerebellum”

End