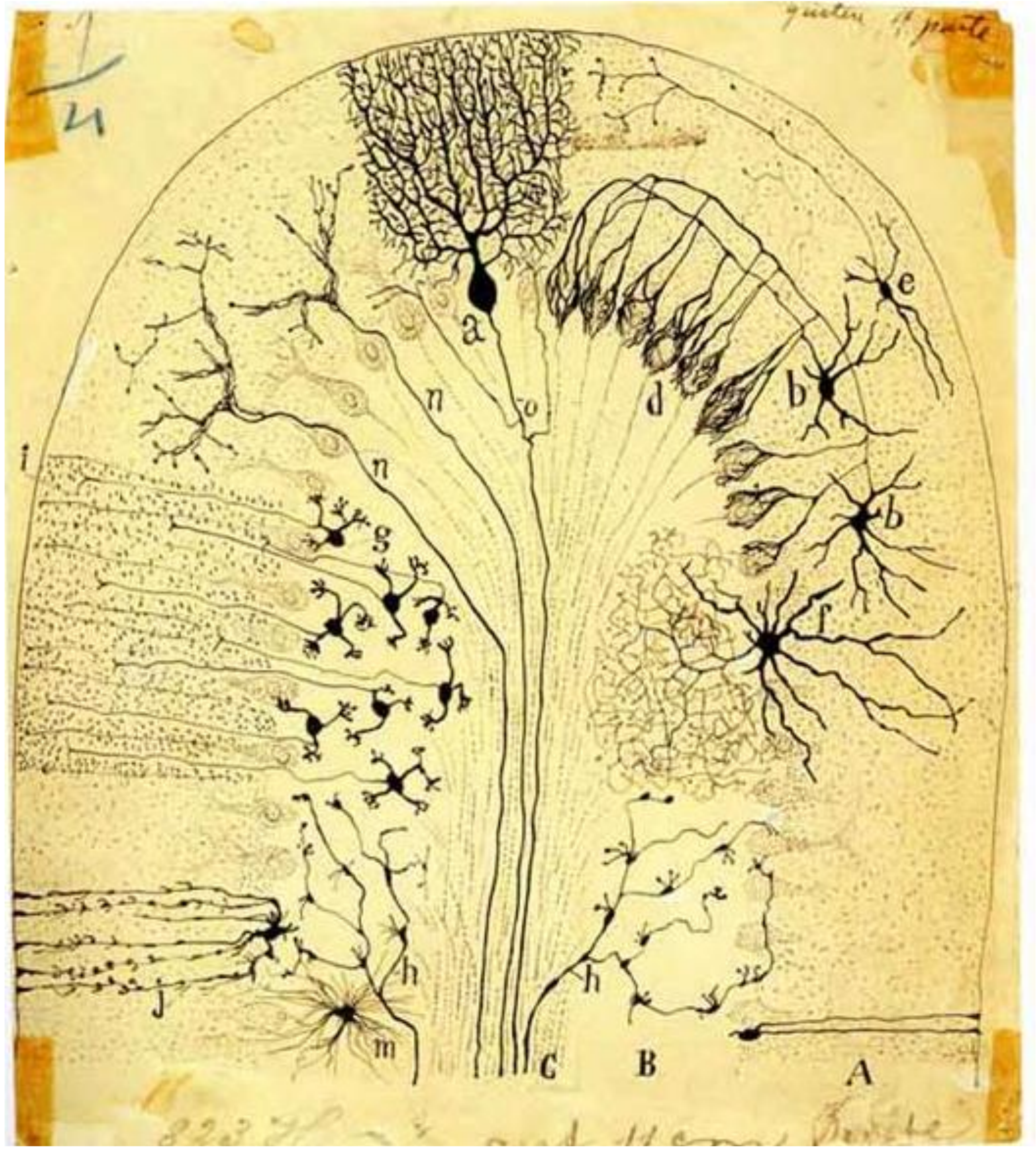
Motor control II



1. The cerebellar circuitry
2. The “future” of motor control research

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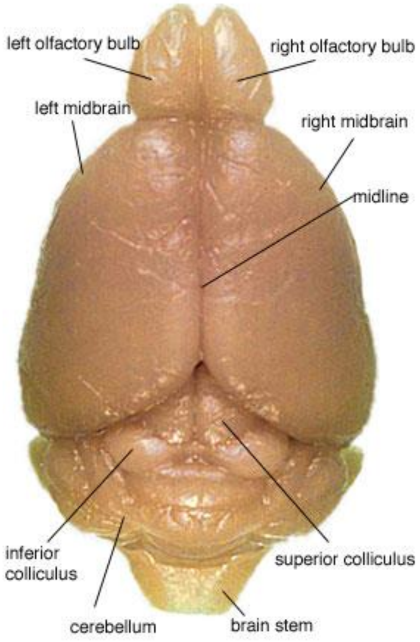
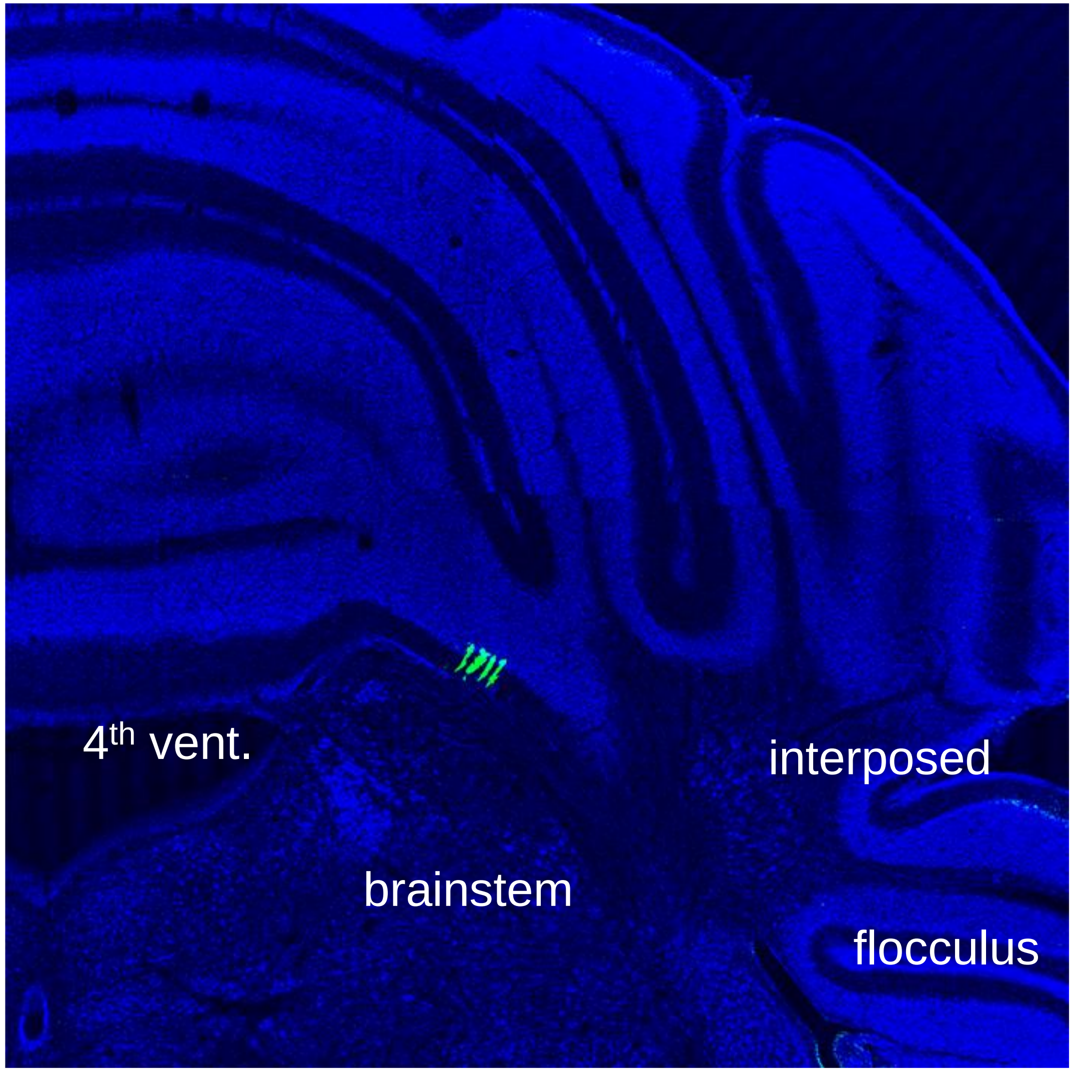
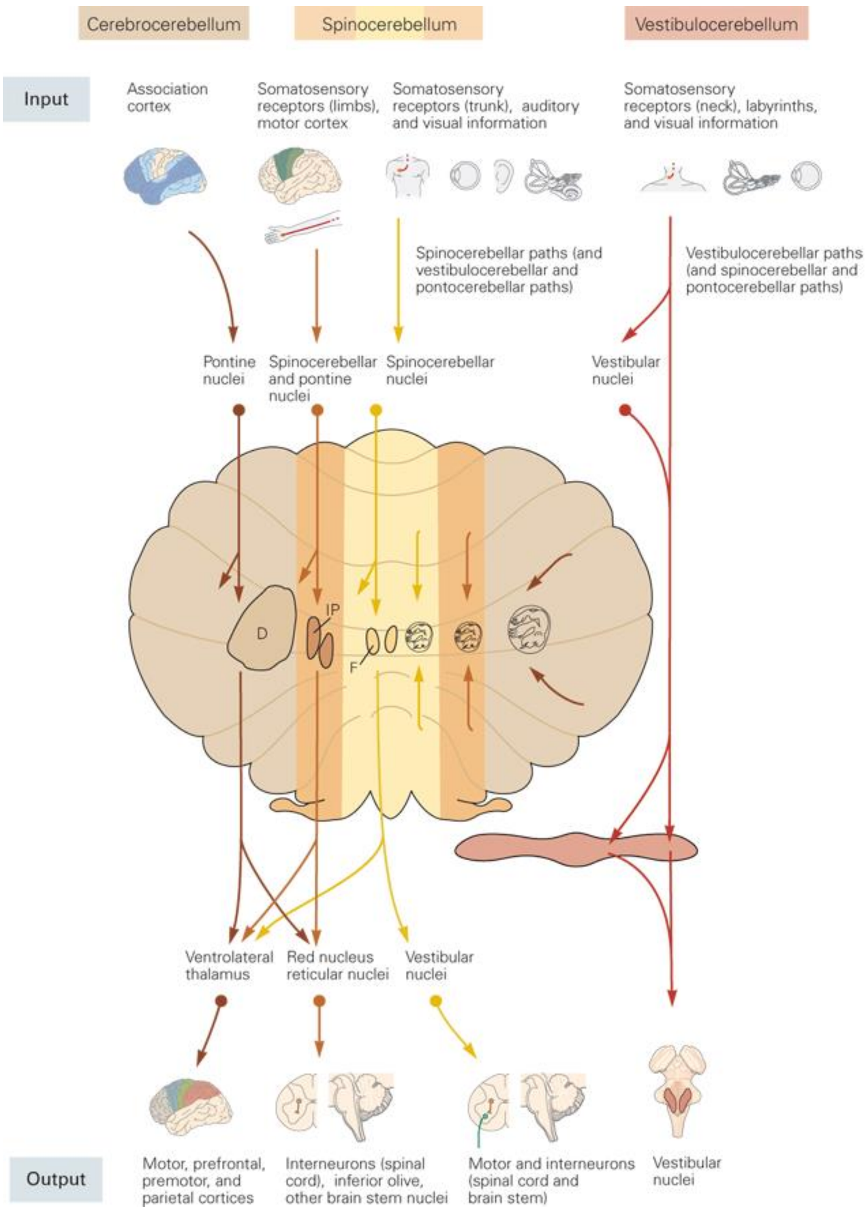
The cerebellum

"It seems likely that the cerebellum may be the first fragment of the higher levels of the nervous system to be understood in principle, all the way from peripheral input to peripheral output".
Eccles, 1973





The cerebellum is functionally organised



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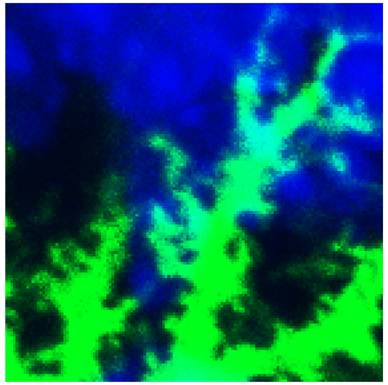
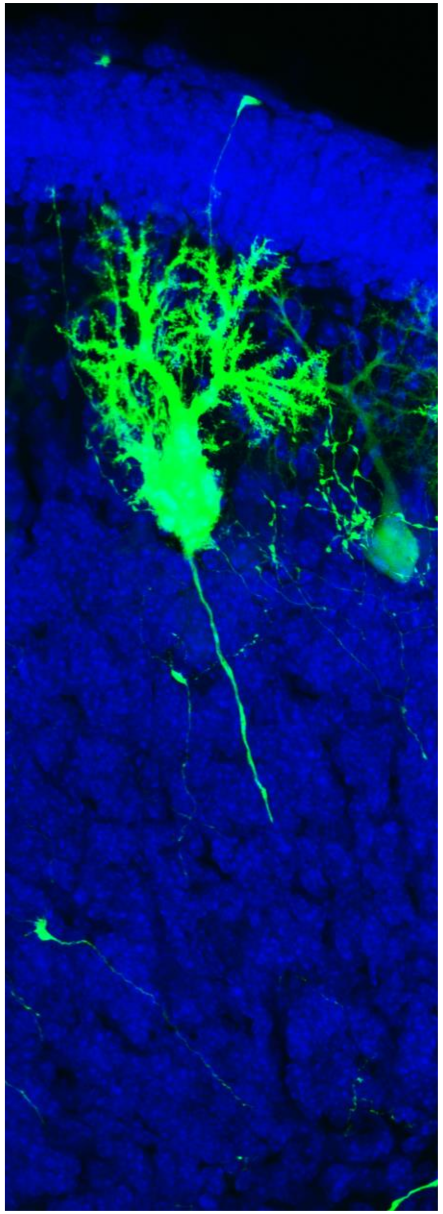
The cerebellum





molecular layer

Purkinje cell layer

granule cell layer

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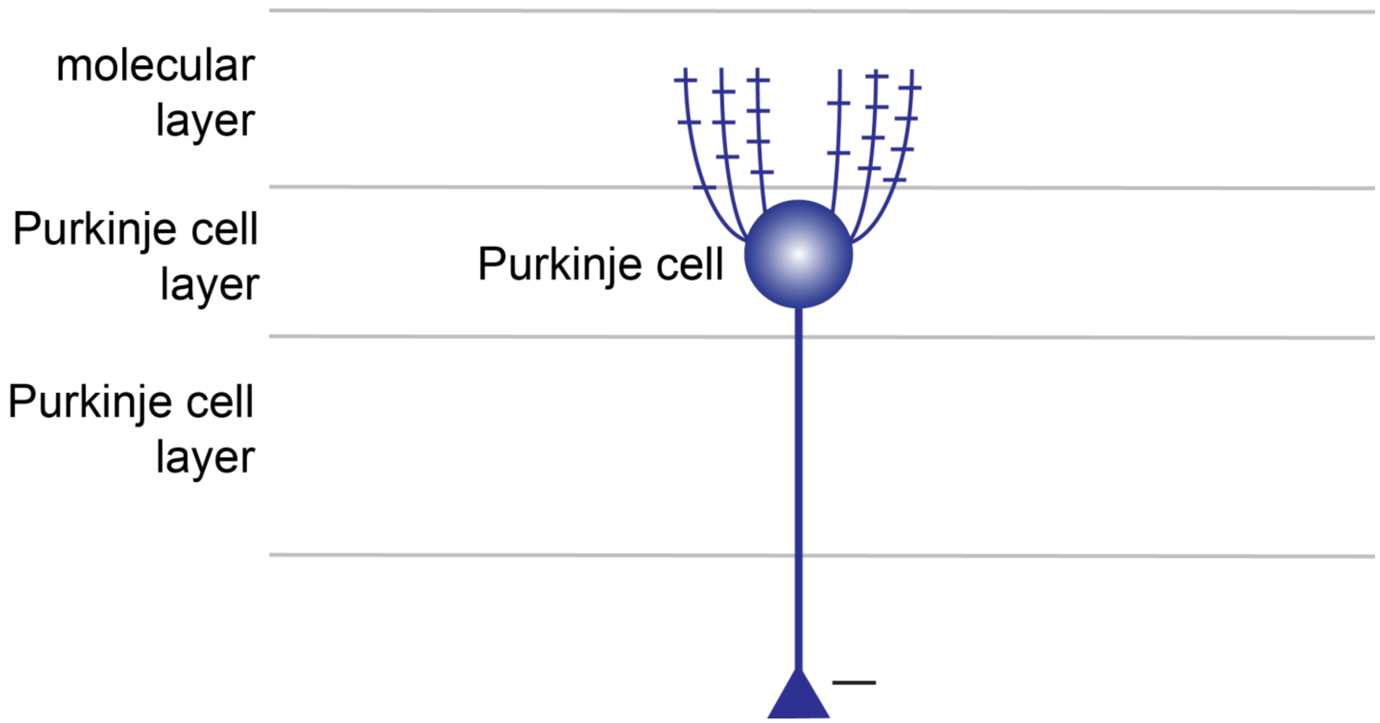
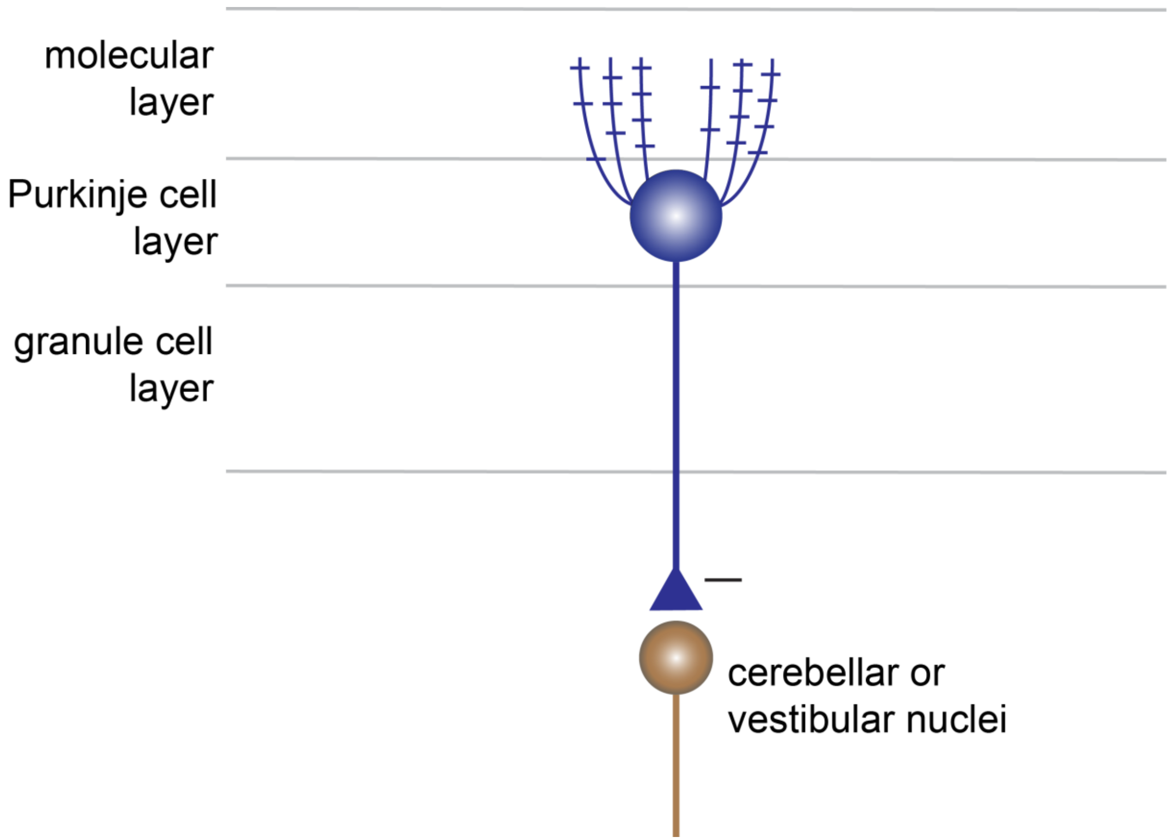
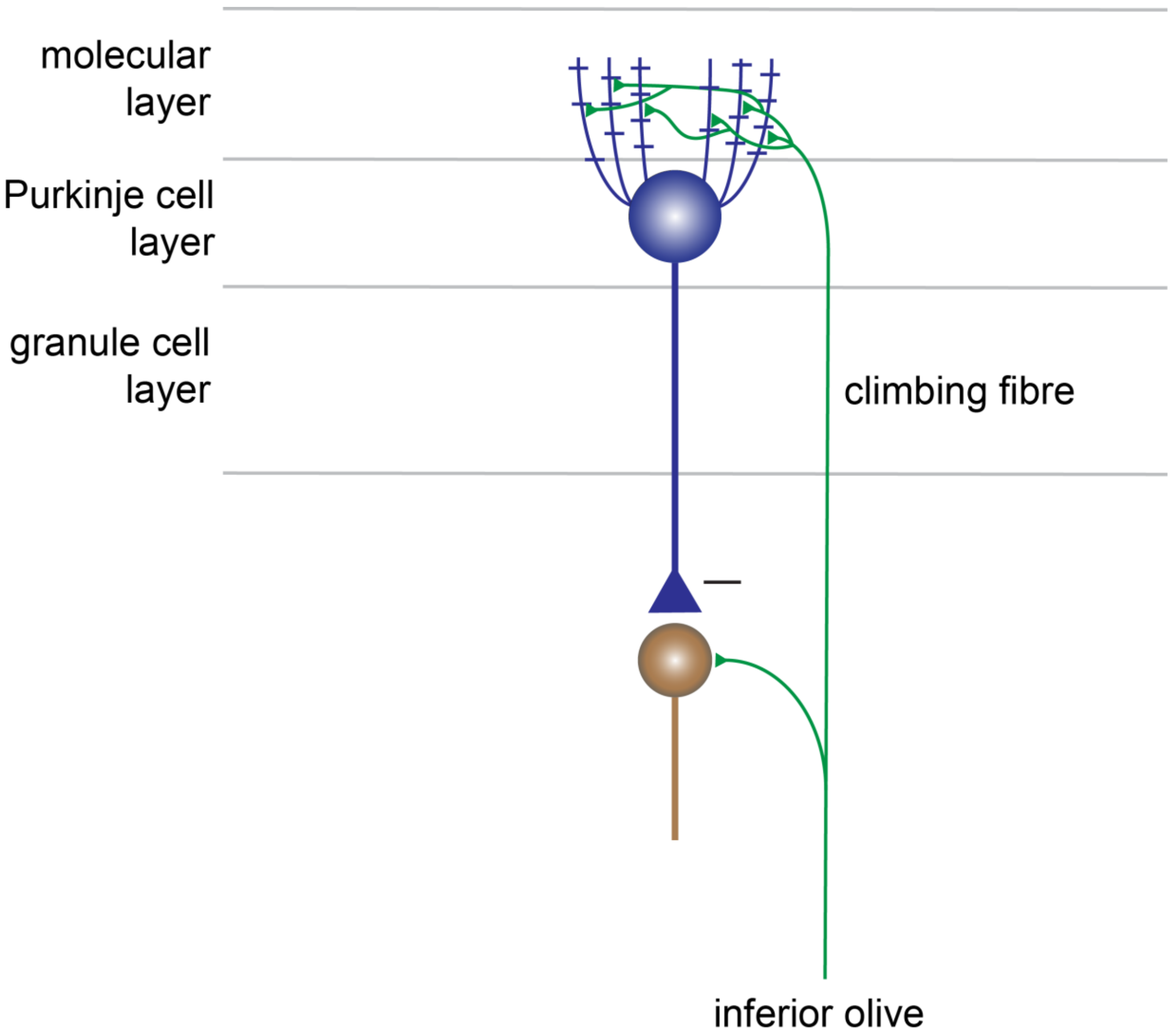
The cerebellum – cell types



Purkinje cells output to cerebellar nuclei and vestibular nuclei



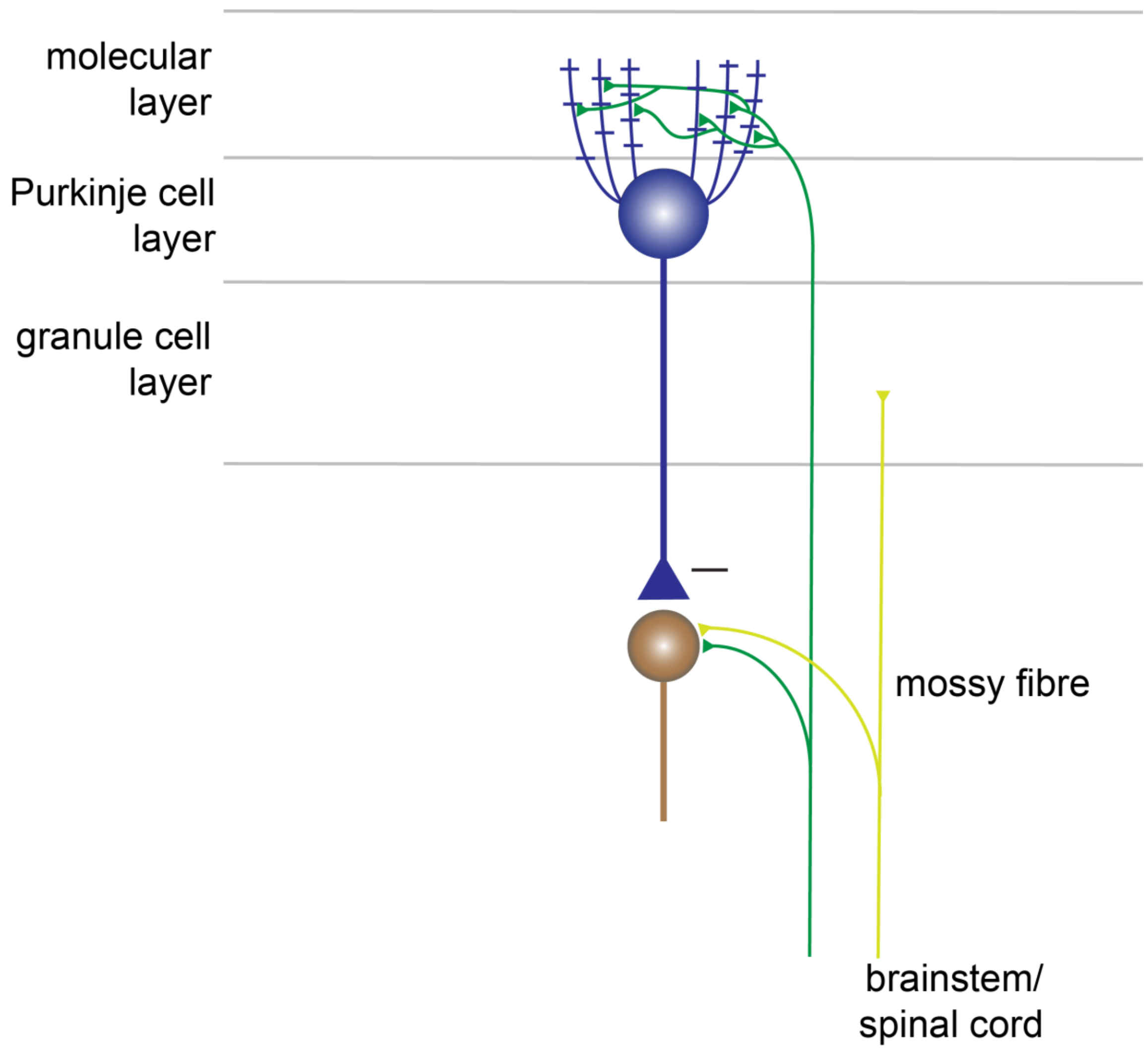
Each PC receives input from 1 climbing fibre



~2000-10,0000 synapses from Climbing fibre to Purkinje cell

1 climbing fibre per Purkinje cell

Mossy fibres provide sensory information



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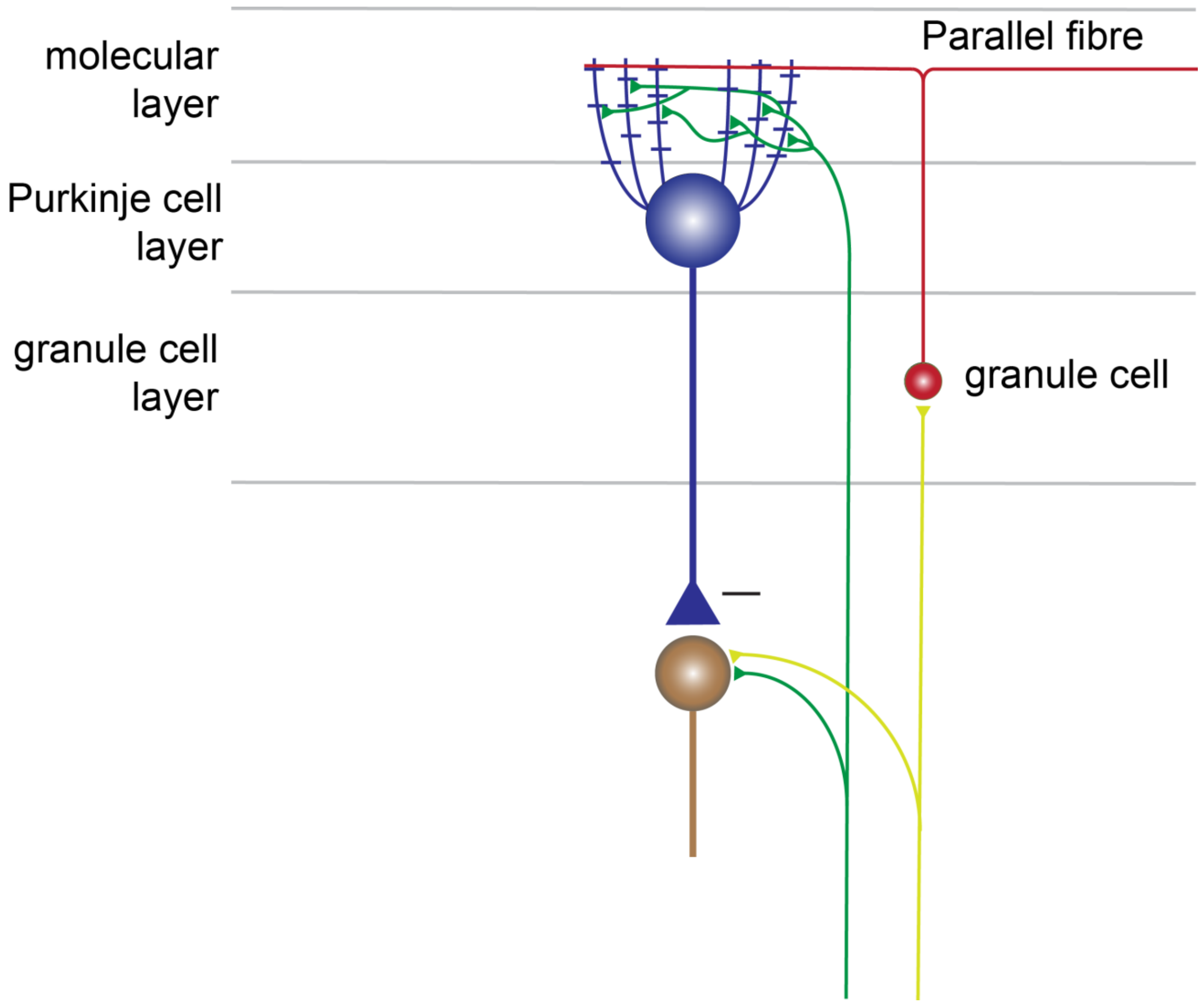
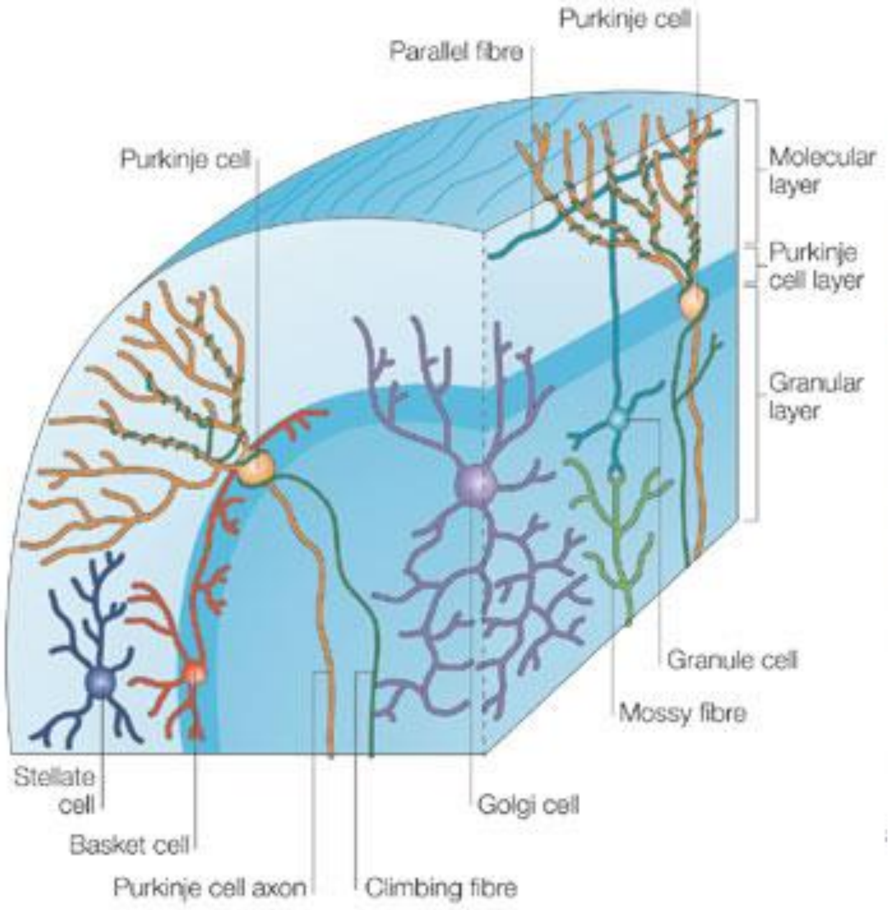
Granule cells give rise to parallel fibres



Granule cells receive input from 1-10 mossy fibres

Each PC contacted by between 200,000 and 1,000,000 granule cells

Cerebellar anatomy in numbers



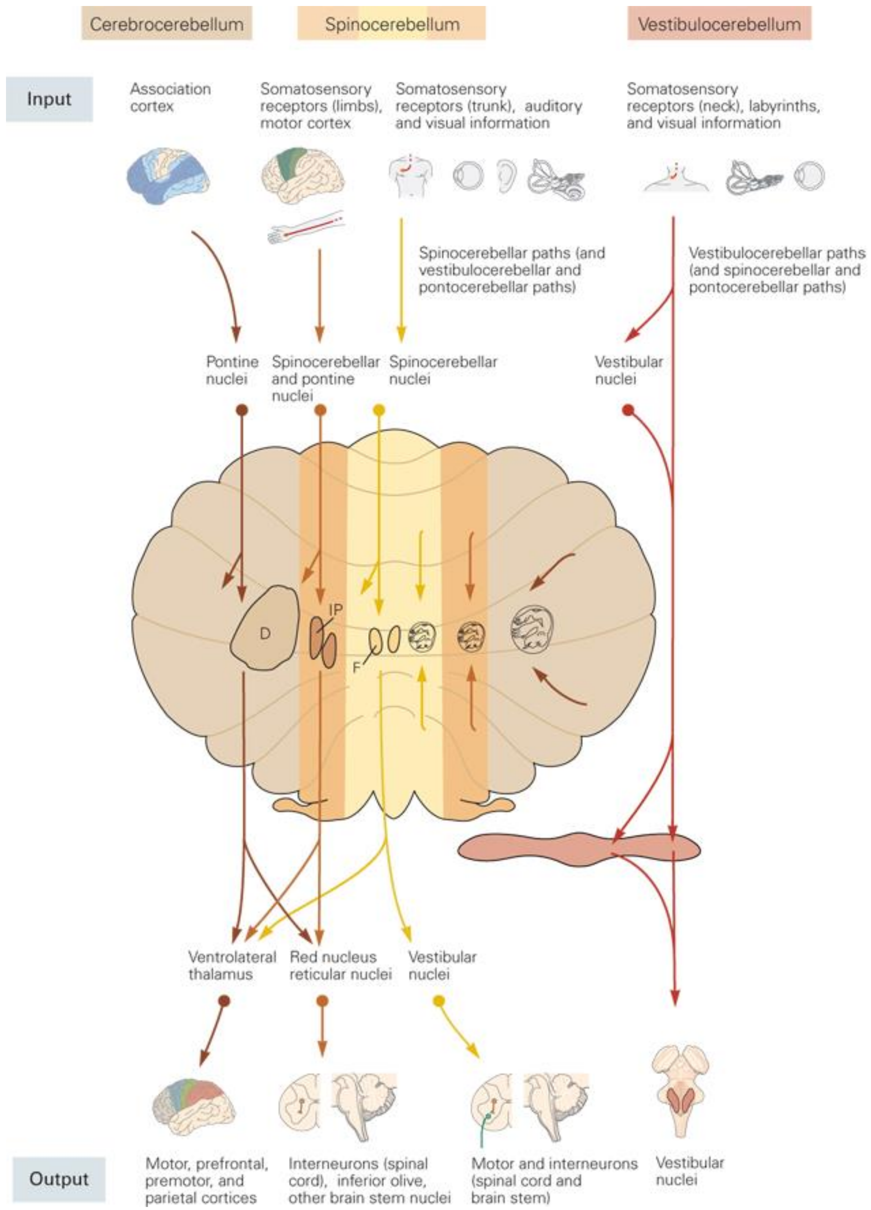
~2000-10,0000 synapses from Climbing fibre to Purkinje cell

1 climbing fibre per Purkinje cell

Granule cells receive input from 1-10 mossy fibres

Each PC contacted by between 200,000 and 1,000,000 granule cells

Cerebellar output is anatomically matched to the input



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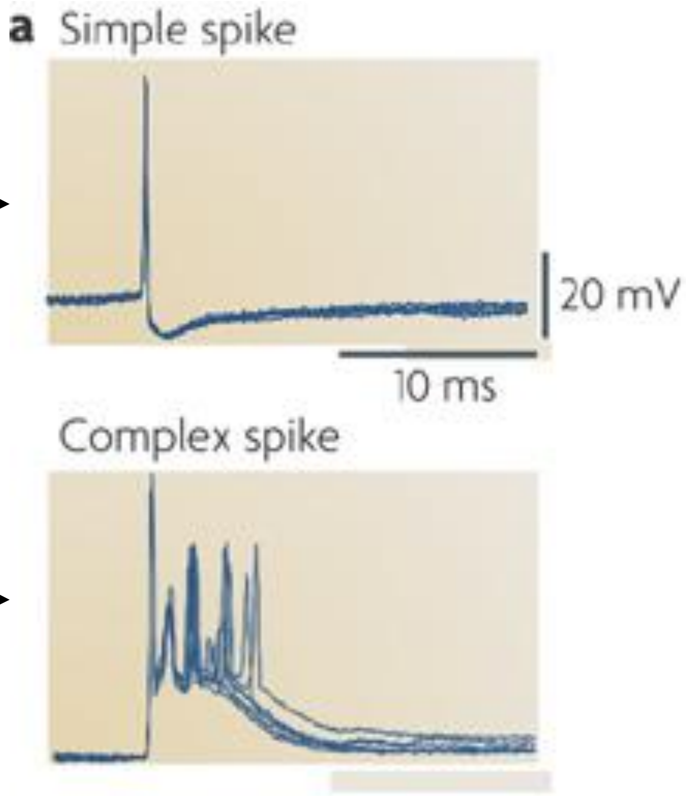
Purkinje cells generate two types of spike

Spontaneous or parallel fibre

~20-150 Hz



Climbing fibre input

Suppress simple spikes

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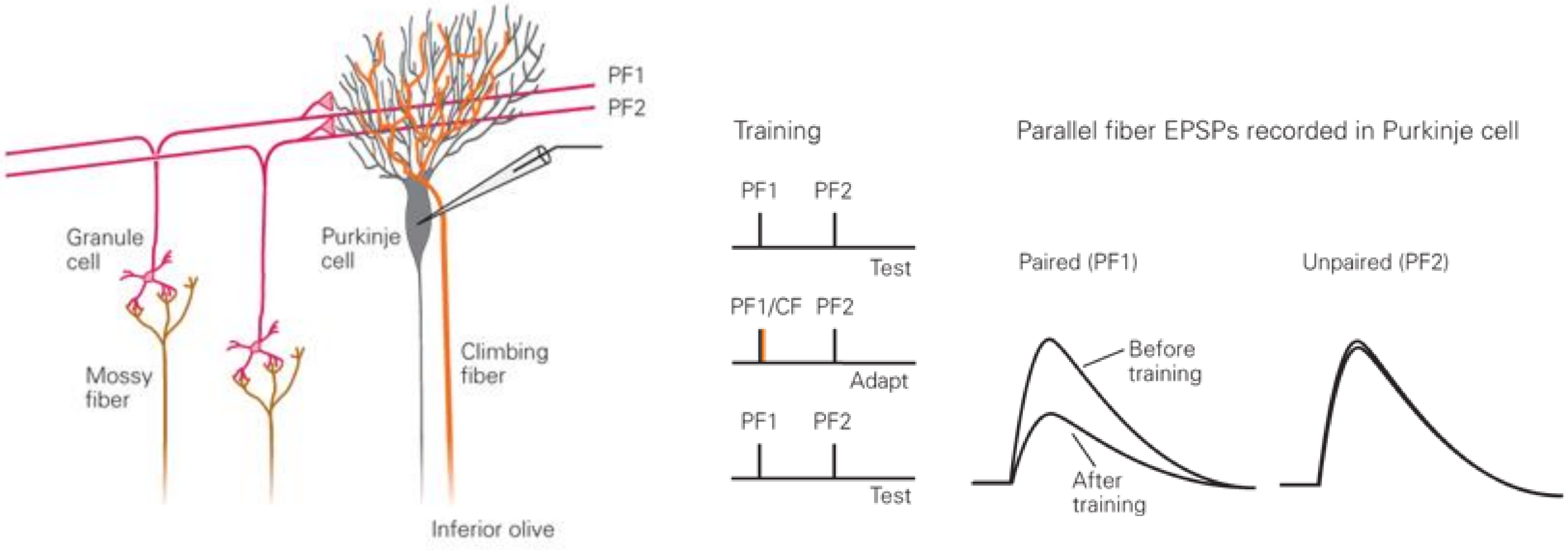
Simple and complex spikes as a possible basis for motor learning

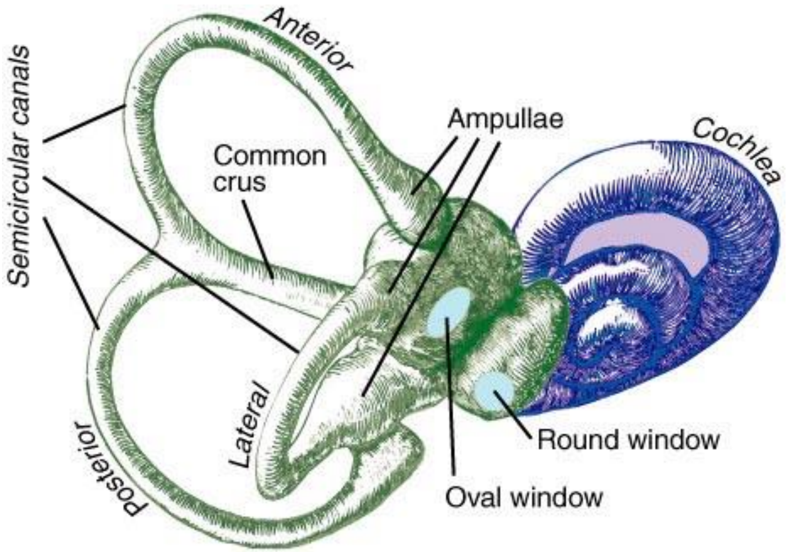


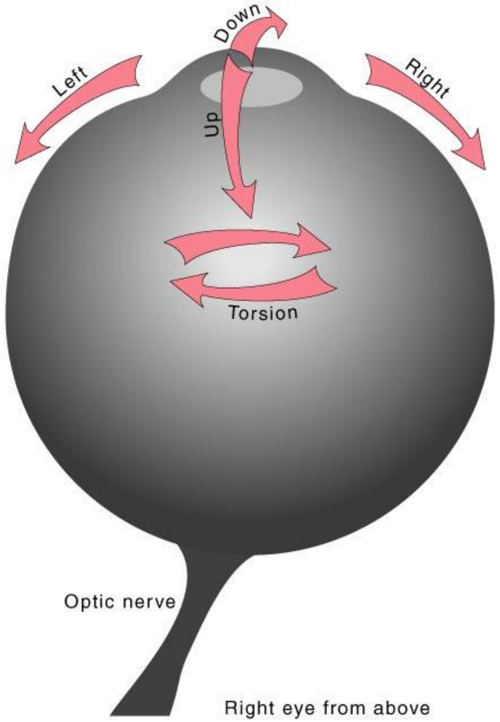
The Vestibulo-ocular reflex (VOR)

Why can you read better when your head is rotating, vs. the page rotating?

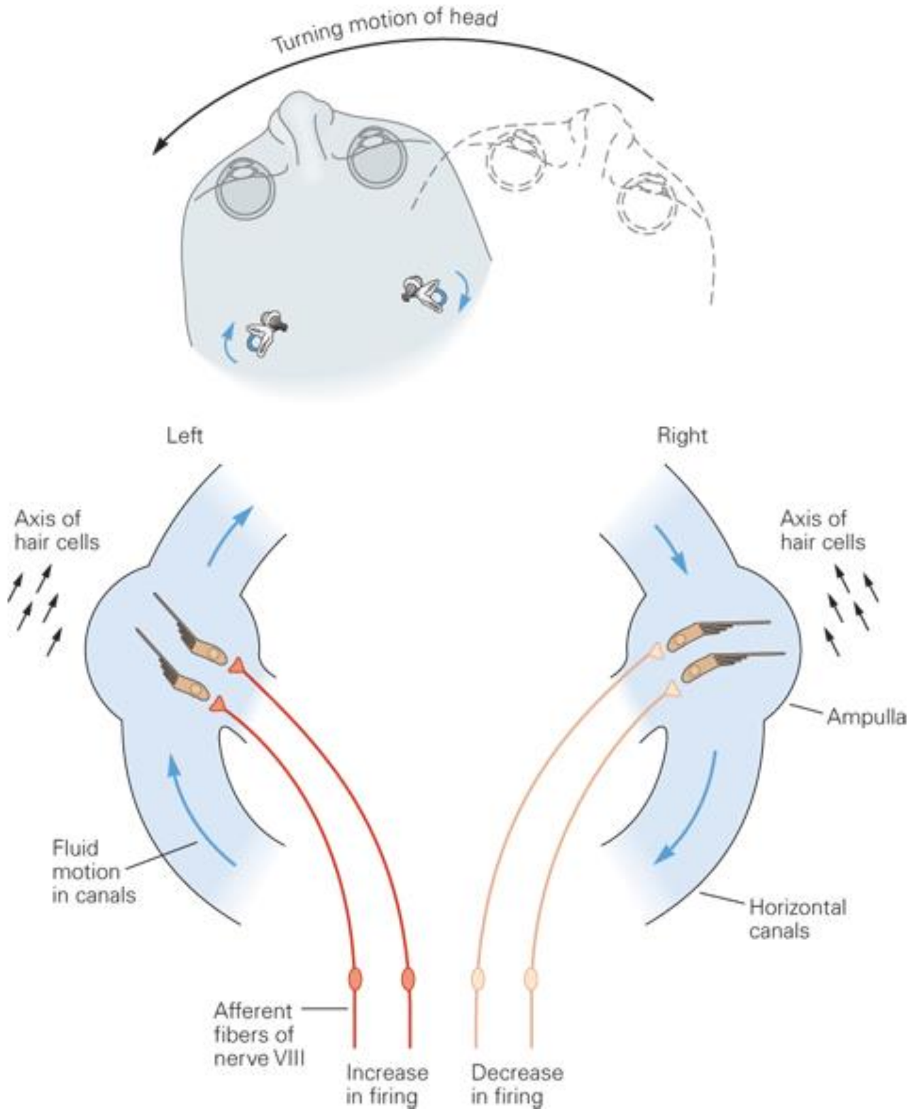
Goal: Stabilise gaze during eye movement
Input: Head motion

The Vestibulo-ocular reflex (VOR)





The VOR

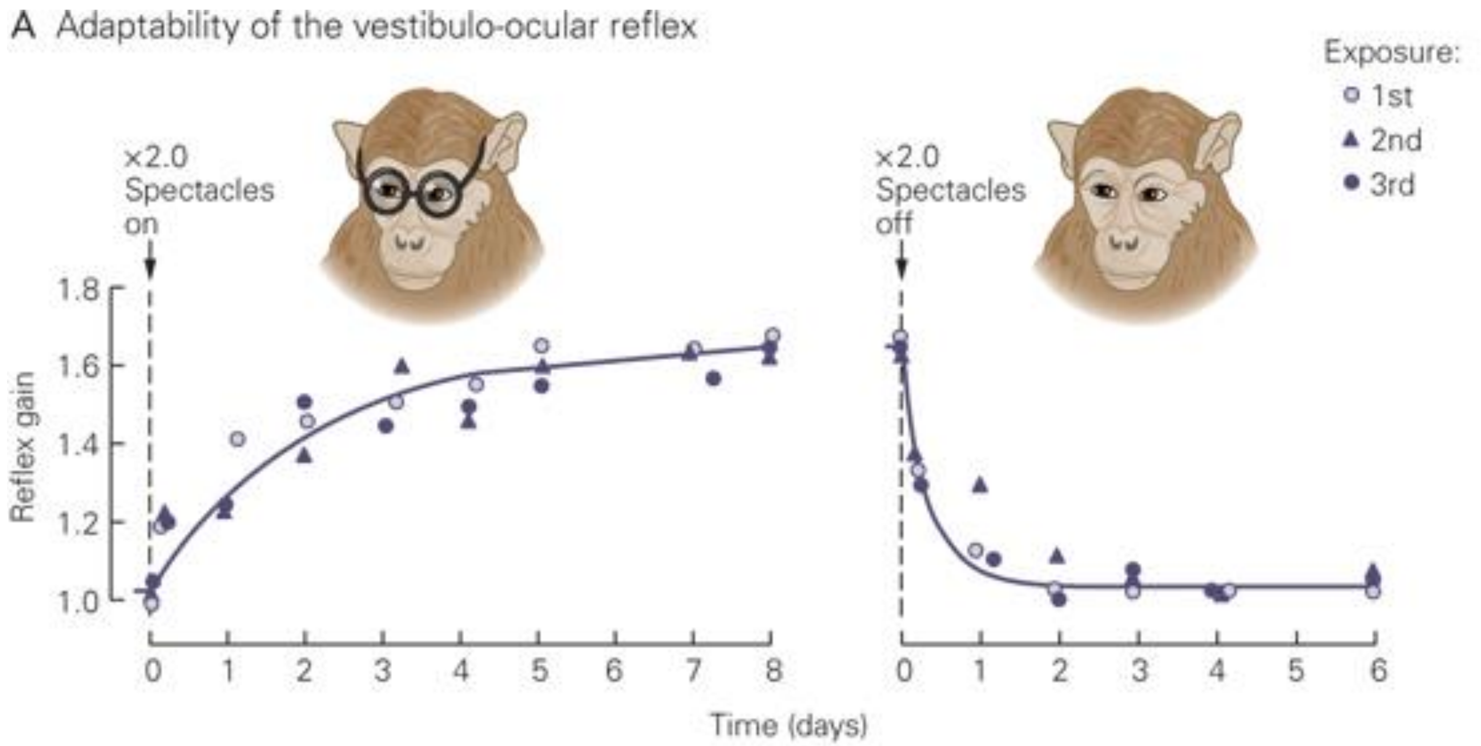


Turning motion of head
Left
Right
Axis of
hair cells
Axis of
hair cells
Ampulla
Fluid
motion
in canals
Horizontal
canals
Afferent
fibers of
nerve VIII
Increase
in firing
Decrease
in firing

The VOR in mouse

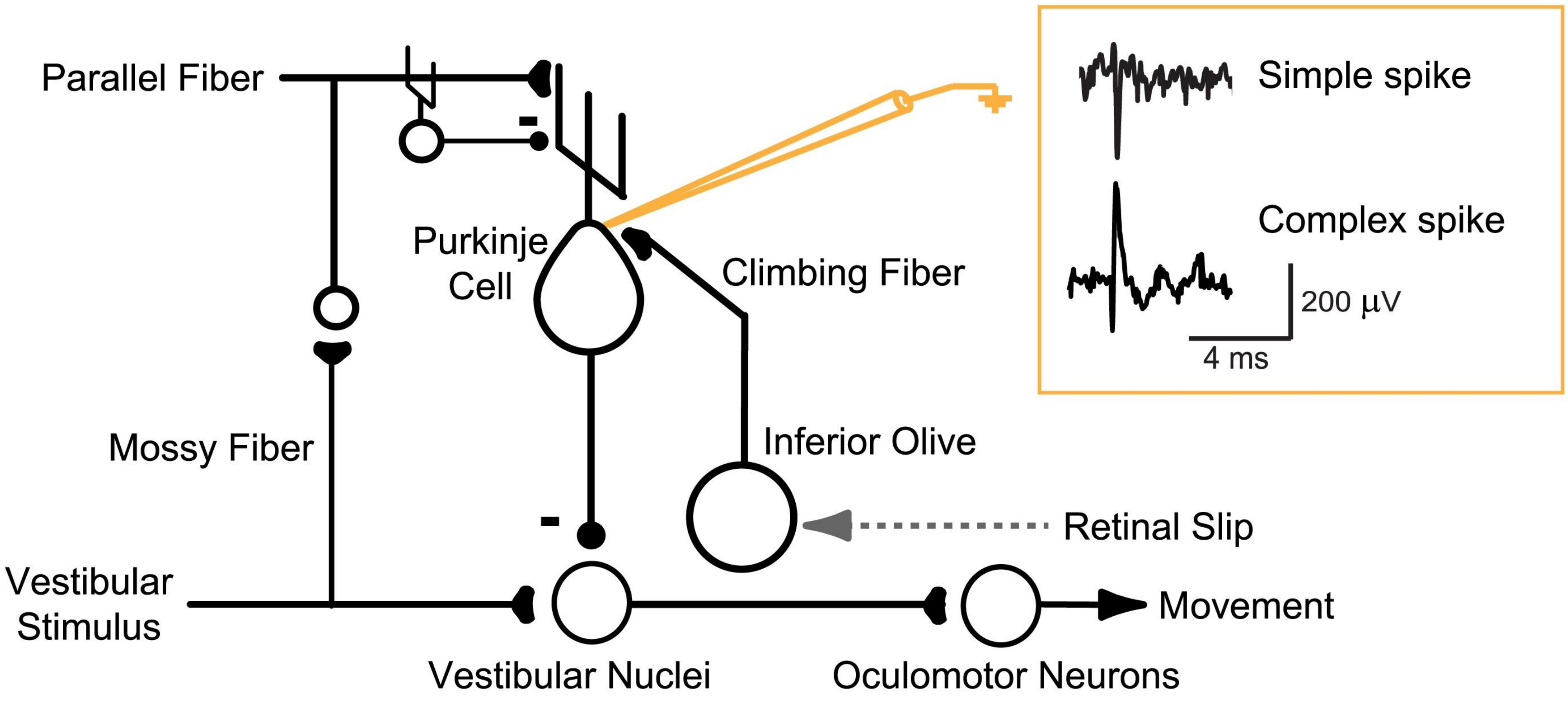
https://www.jove.com/video/3971/video-oculography-in-mice

The VOR is a form of motor learning



Miles and Eighmy, 1980

The VOR



Kimpo et al., 2014

The future of motor control

My opinion…

1. Natural behaviours

2. Integrated quantification and analysis

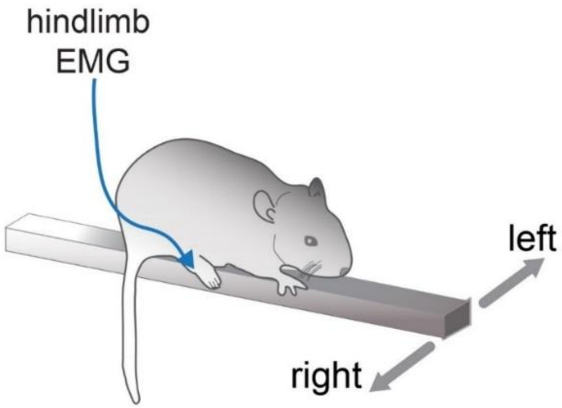
Your assignment:

In your opinion what new directions should motor control research take?

(1 page max. What are the important steps that motor control researches should take to advance the field in the next 5-10 years).

We require better technical advances in measuring behaviour

Motor control research is based around (low throughput) behavioural tasks…



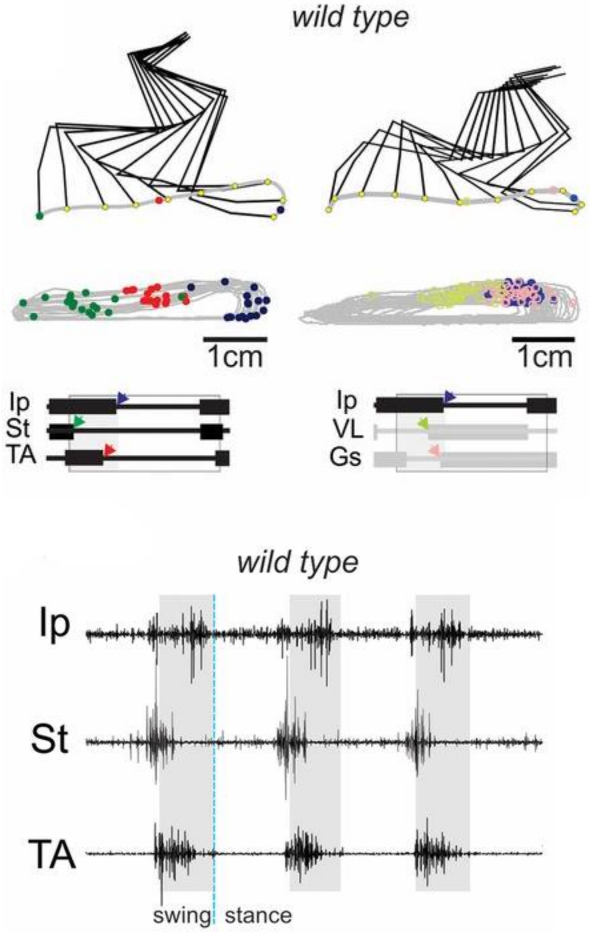
Akay et al., 2014

We require better technical advances in measuring behaviour

Two-dimensional analysis of gait during treadmill walking

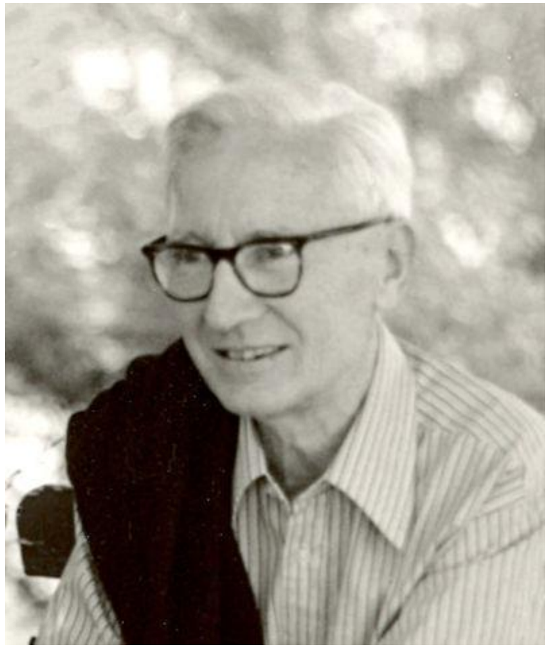
Reflective markers &
High speed camera

Semiautomatic scoring



Akay et al., 2014

An example of “future” directions in motor control



Nikolaas Tinbergen

“The brain builds coherent behaviours by expressing stereotyped modules of simpler action in specific sequences”

‘How’ (Proximate) questions

•Mechanism (Causation) – how does the behaviour get elicited? What signals are required and what pathways within the animal (for example neural pathways) are involved?

•Development (Ontogeny)- how does the behaviour change with age, experience and environment?

‘Why’ (Ultimate) questions

•Evolution (Phylogeny) – how did evolution and earlier generations/species contribute to this certain behaviour?

•Function (Adaptation) – how does this behaviour help the organism/species survive?

Depth imaging and modelling to identify behaviour "modules"

Neuron
NeuroResource

CellPress

Mapping Sub-Second Structure in Mouse Behavior

Alexander B. Wiltschko,[1,2] Matthew J. Johnson,[1,2] Giuliano Iurilli,[1] Ralph E. Peterson,[1] Jesse M. Katon,[1]
Stan L. Pashkovski,[1] Victoria E. Abraira,[1] Ryan P. Adams,[2] and Sandeep Robert Datta[1,*]
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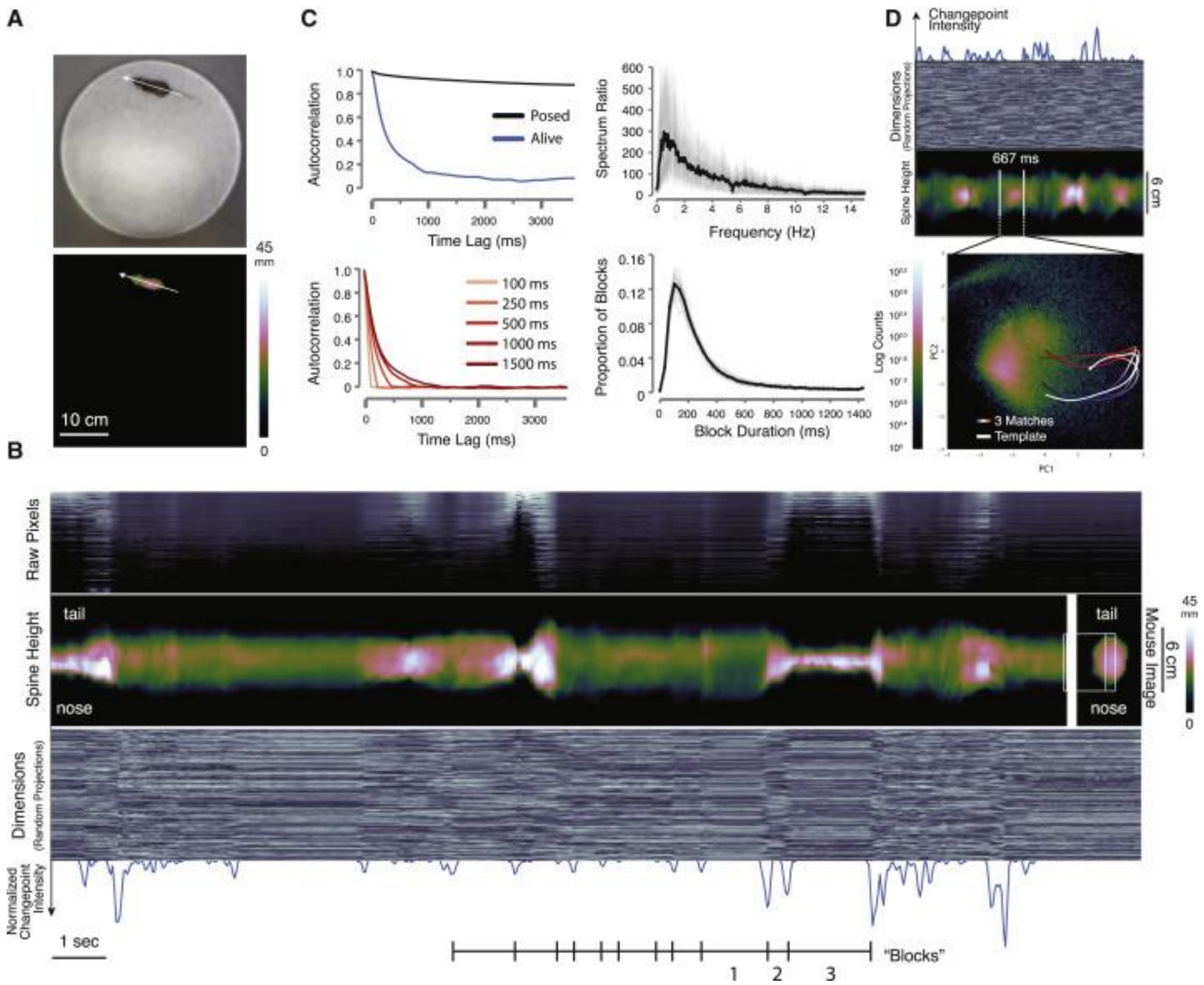
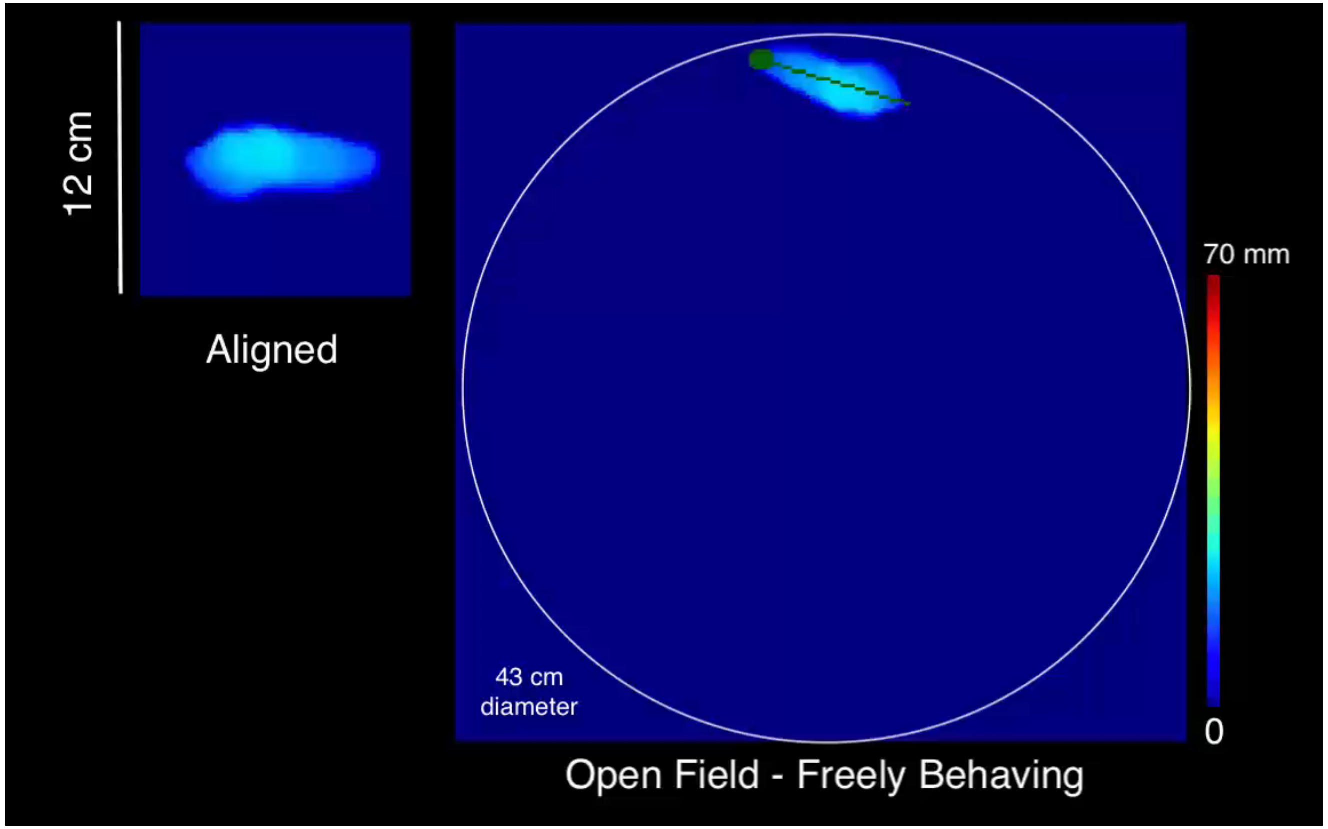
http://dx.doi.org/10.1016/j.neuron.2015.11.031

Wiltschko et al., 2015, Neuron *88*, 1121–1135
December 16, 2015

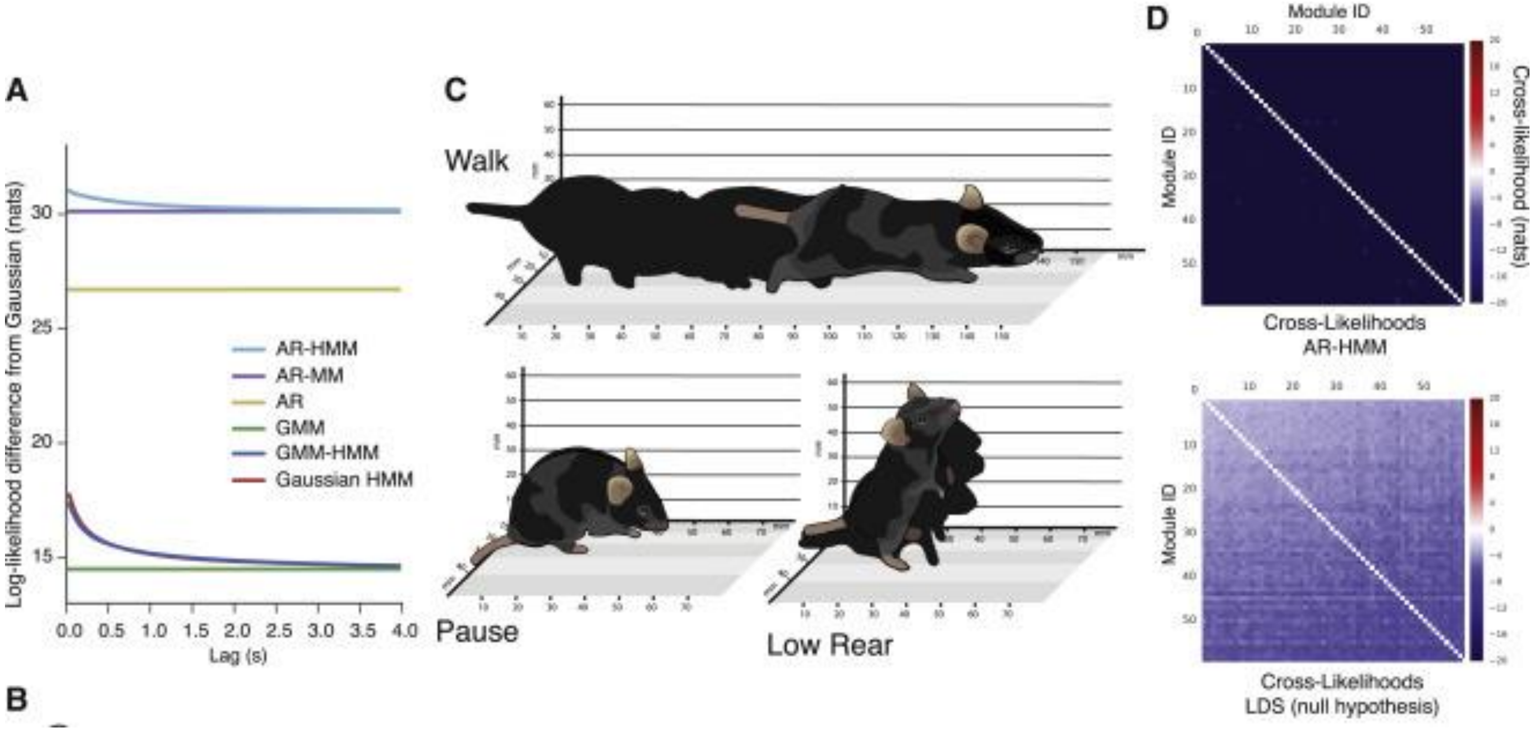
What are the fundamental units of mouse behaviour?



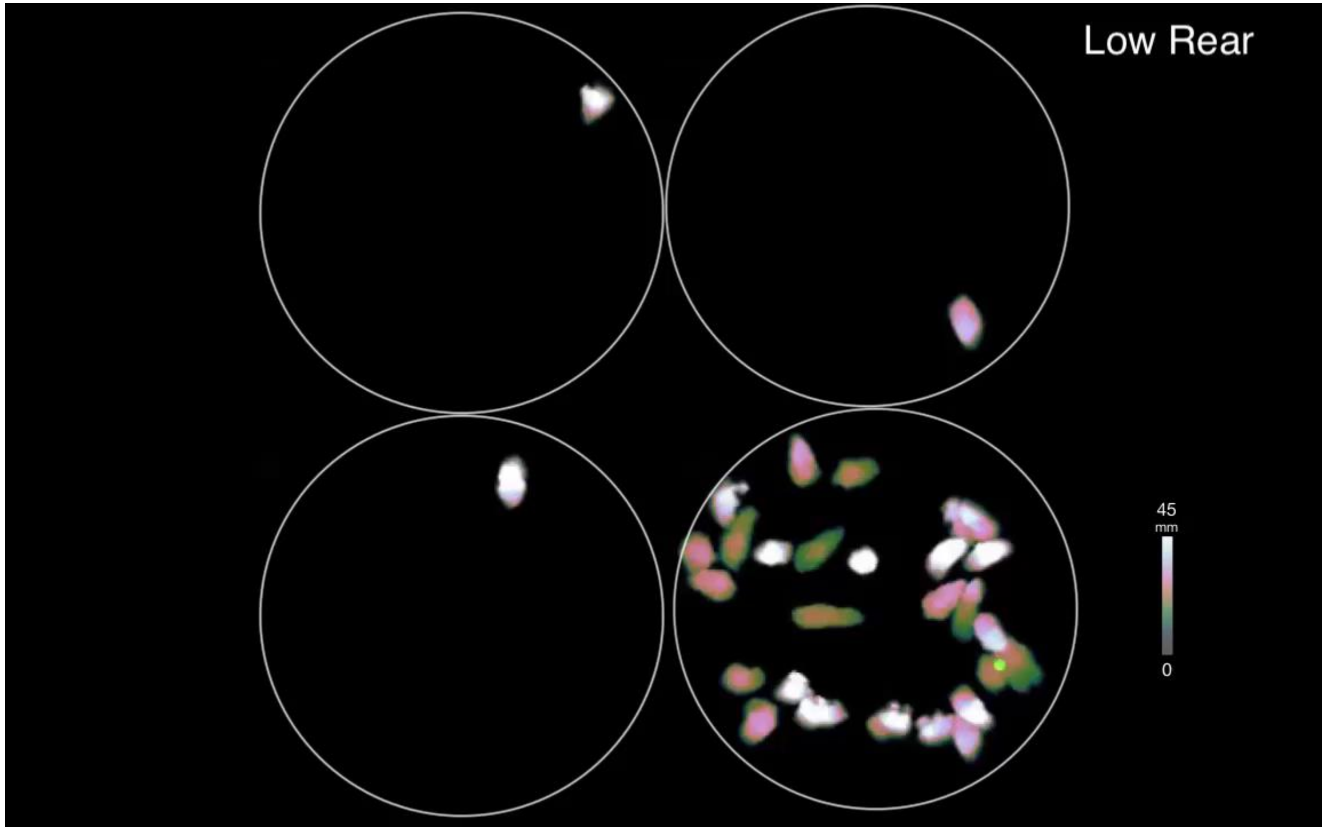
Behavioural "blocks" last ~200-900 ms


12 cm
Aligned
70 mm
0
43 cm
diameter
Open Field - Freely Behaving

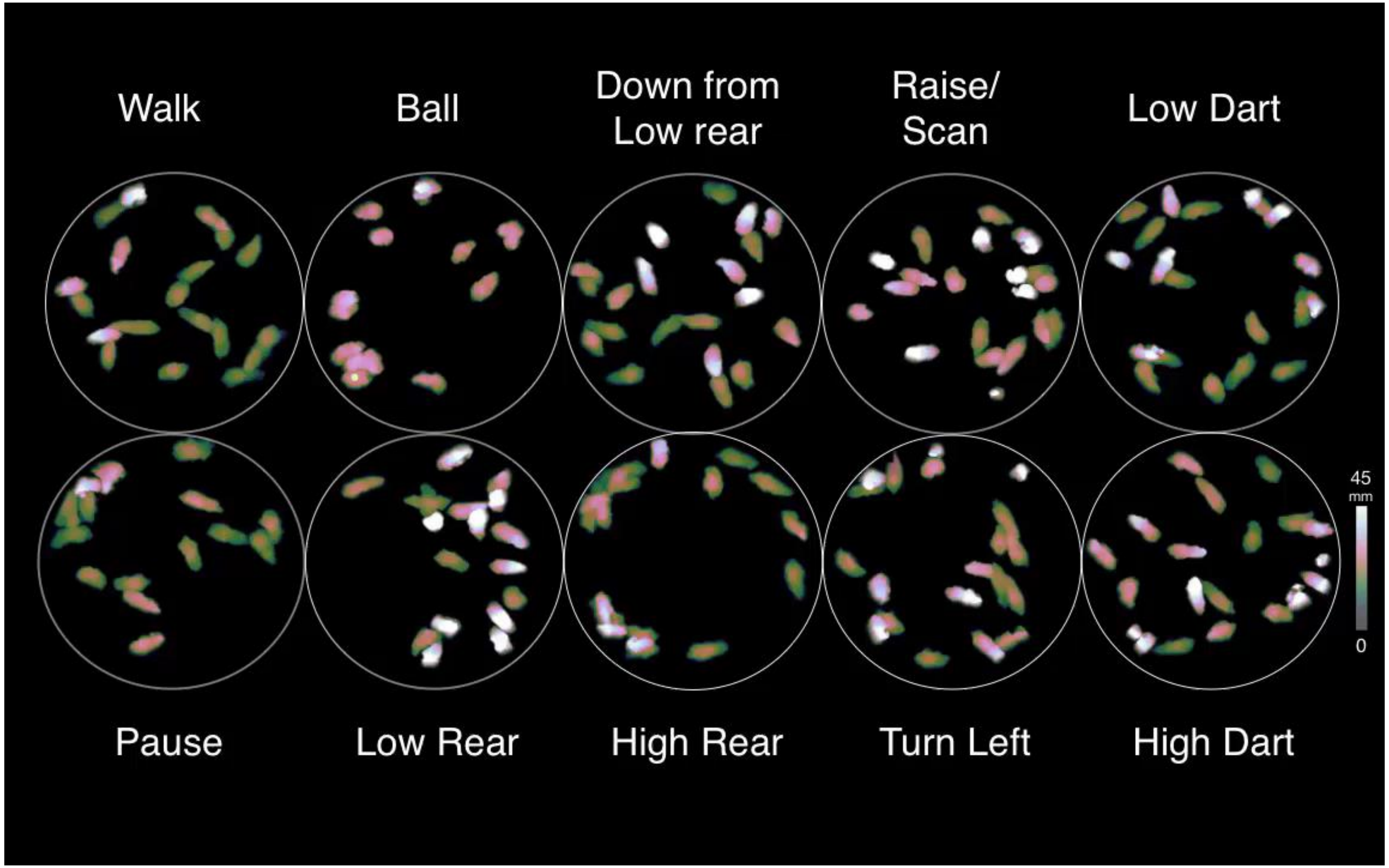
Modelling of pixel data identifies simple behavioural modules



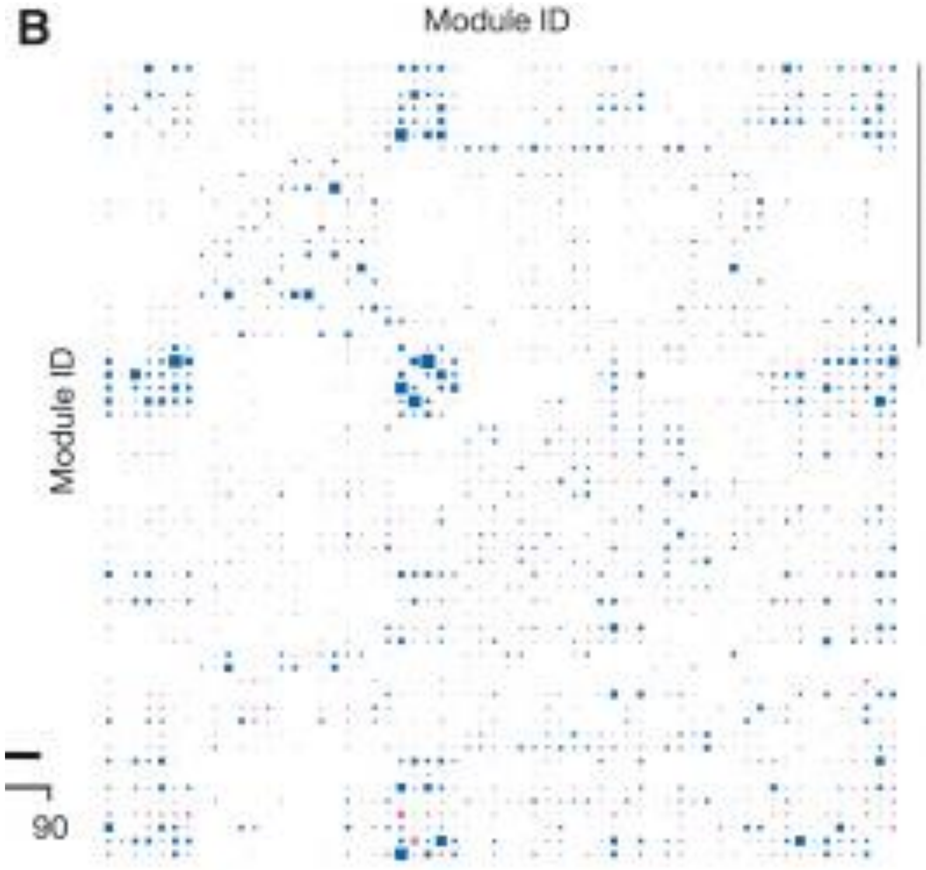
Modelling of pixel data identifies simple behavioural modules that can be identified online



Additional behavioural modules identified by 3D imaging



Transitions between behavioural states are predictable



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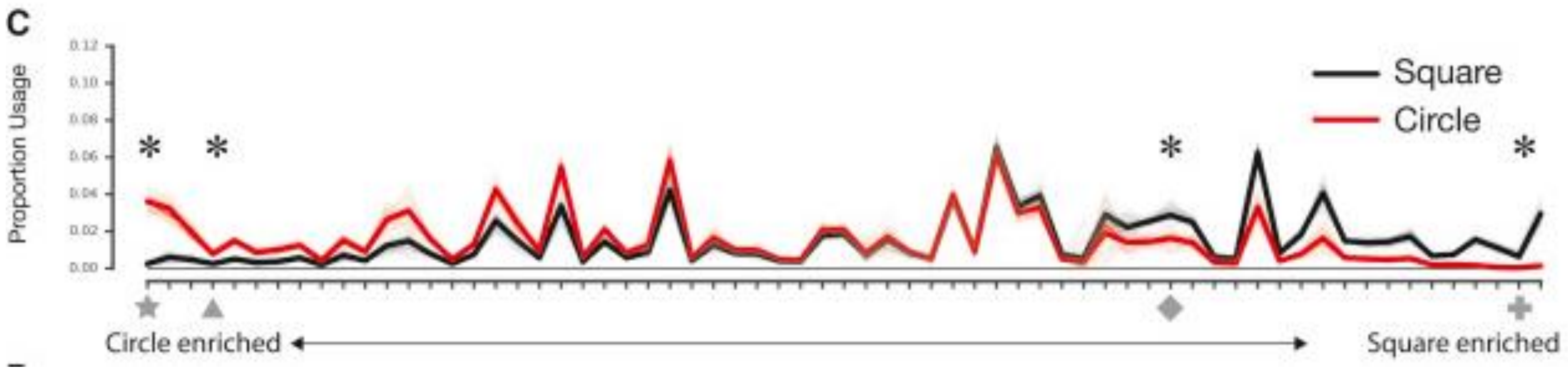
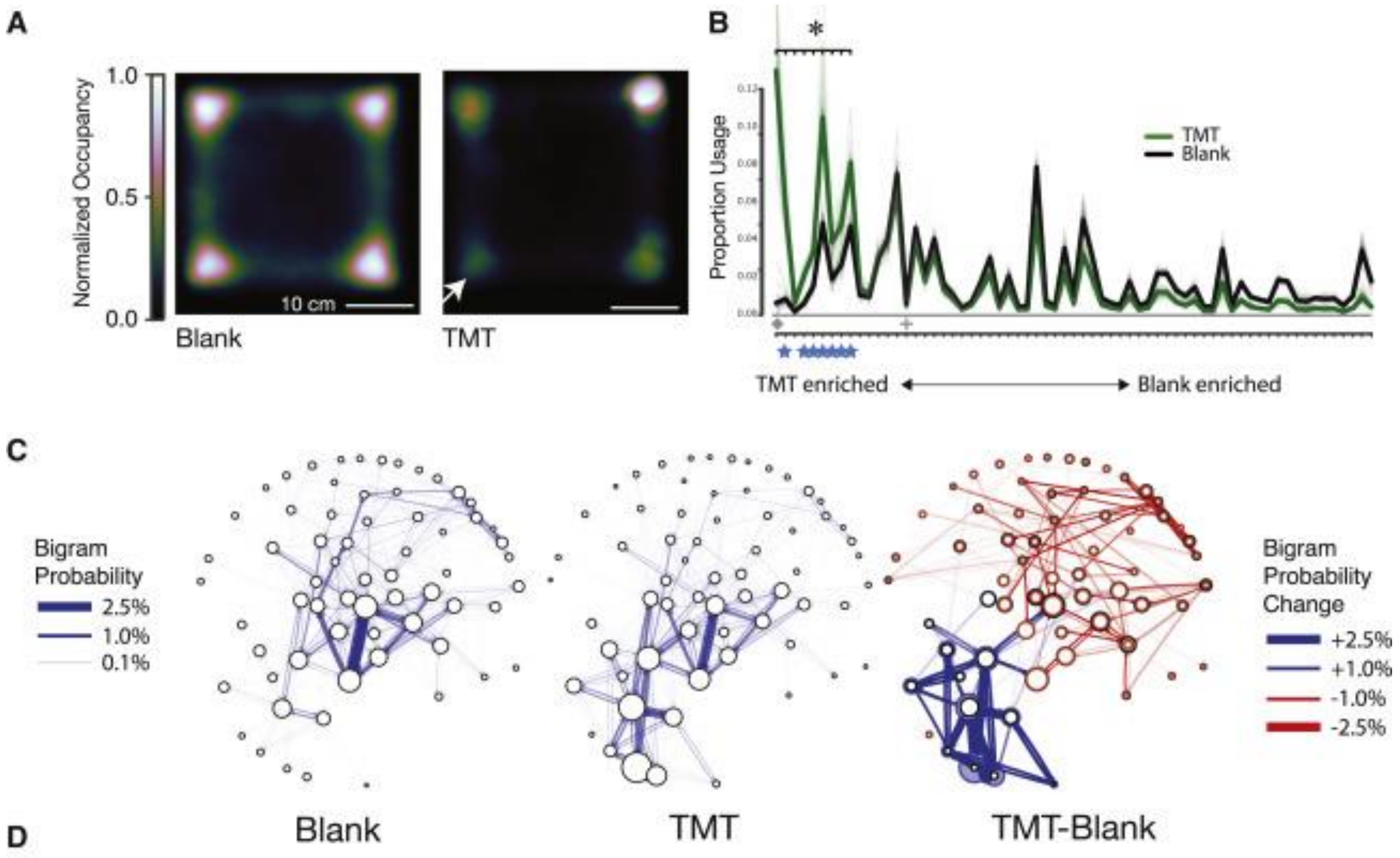
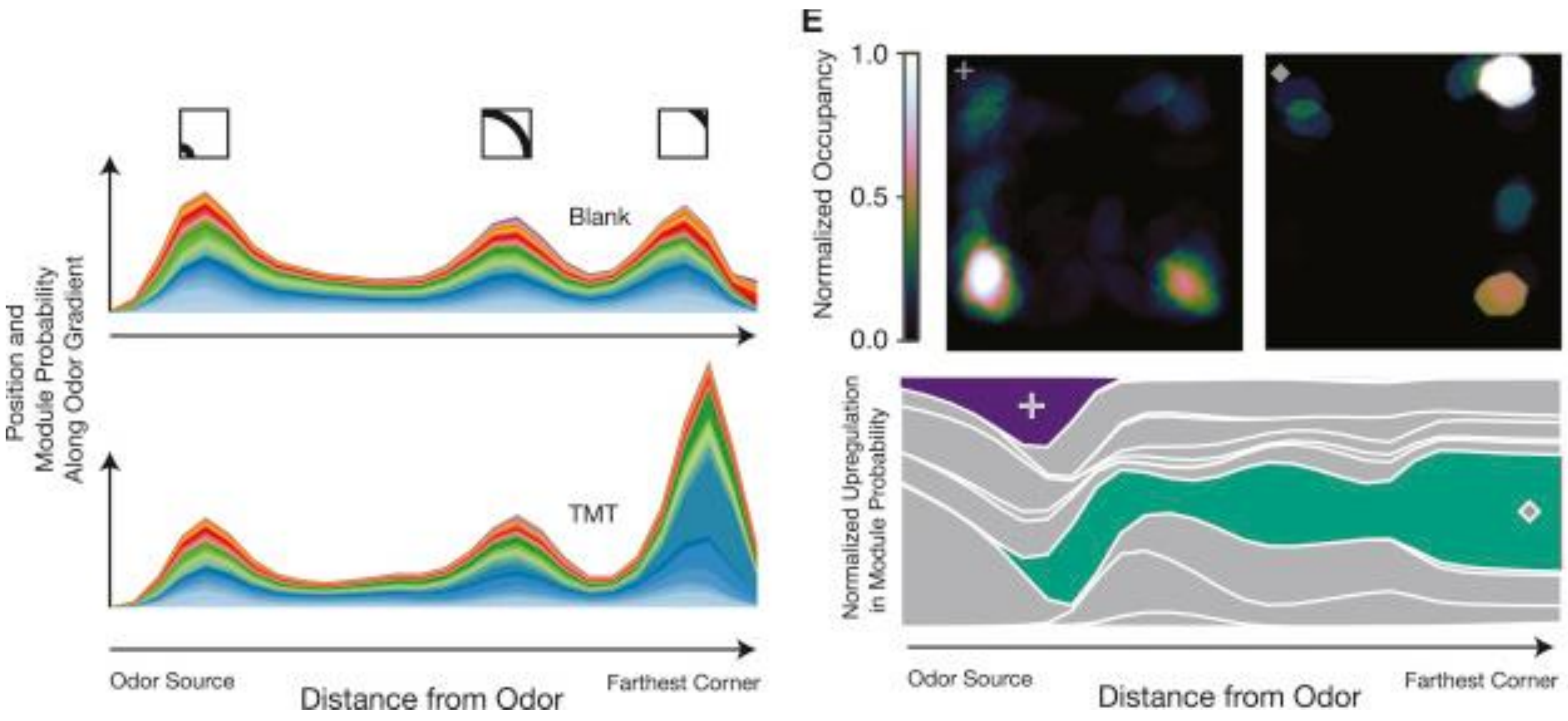
Altering arena shape alters a subset of behavioural modules



Behavioural state changes in response to fox odour



Location determines frequency of module use



Mice alter the frequency that they use each module in different environments – but don't add or change the order of the modules to their behaviour

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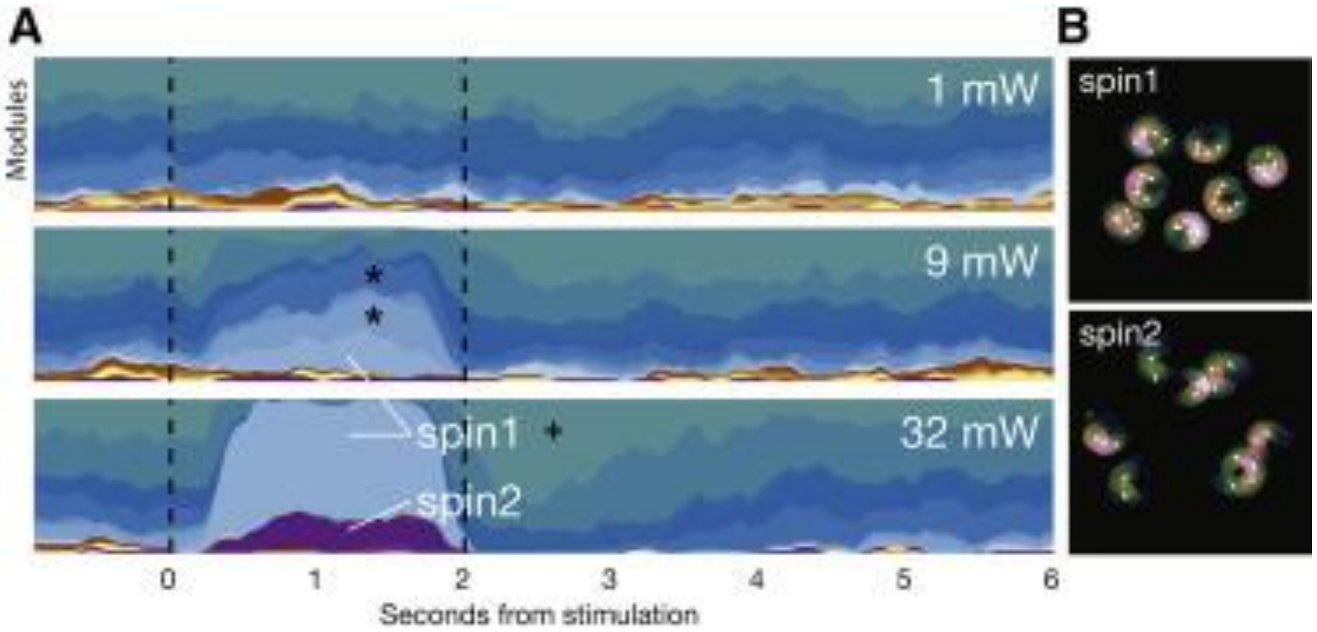
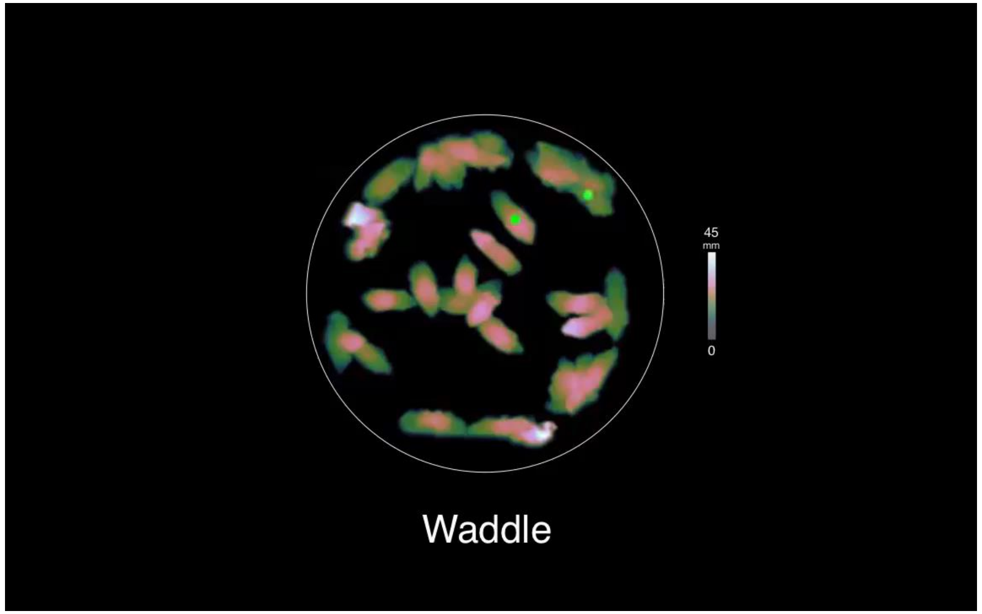
Circuit manipulation also alters module use but does not add new modules

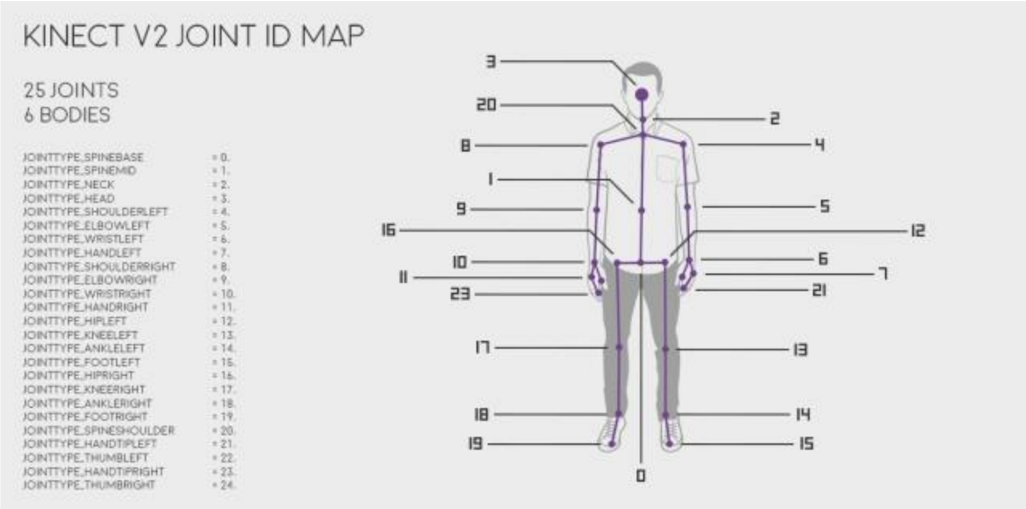


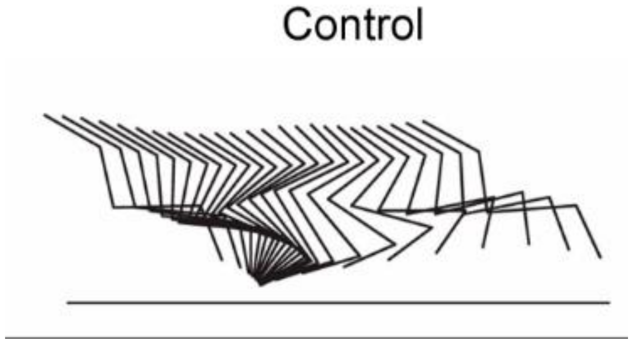


Why am I talking about this?

- A “grammar” is an attractive way of describing behaviour
- Shows that machine learning can be used to “decode” aspects of behaviour
- The key is the 3D imaging of behaviour from above with a Kinect
  - This is also the weakness

How can we expand this technique to examine motor behaviour?





Can we build a standard wireframe model of a mouse? Allowing reconstruction of each joint during behaviour to understand modules of motor behaviour

Can we incorporate this with behavioural tasks presented in a more natural environment?

Can this be combined with (wireless) EMG recordings and “perturbations”?

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