

# Non-auditory projections to the inferior colliculus; a tracing study

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## Introduction

The inferior colliculus (IC; the principal midbrain nucleus in the auditory pathway) processes and integrates ascending auditory streams of information from upstream brainstem structures.

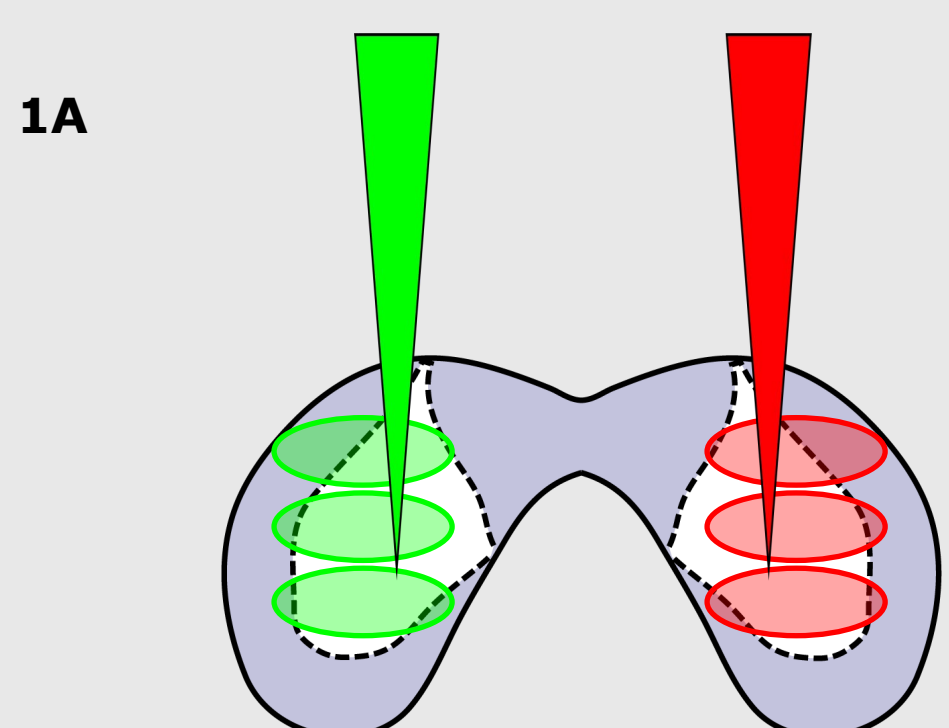
In addition, extensive descending projections from the auditory cortex to the IC have been demonstrated. These cortico-collicular connections modulate sound processing in the IC (Bajo et al. 2013 Frontiers in Neural Circs 6, 114 for review).

It is, however, unknown whether other, non-auditory, cortical and subcortical areas also project to the IC.

To answer this question we used retrograde and anterograde tracers to map descending projections to the IC in rat.

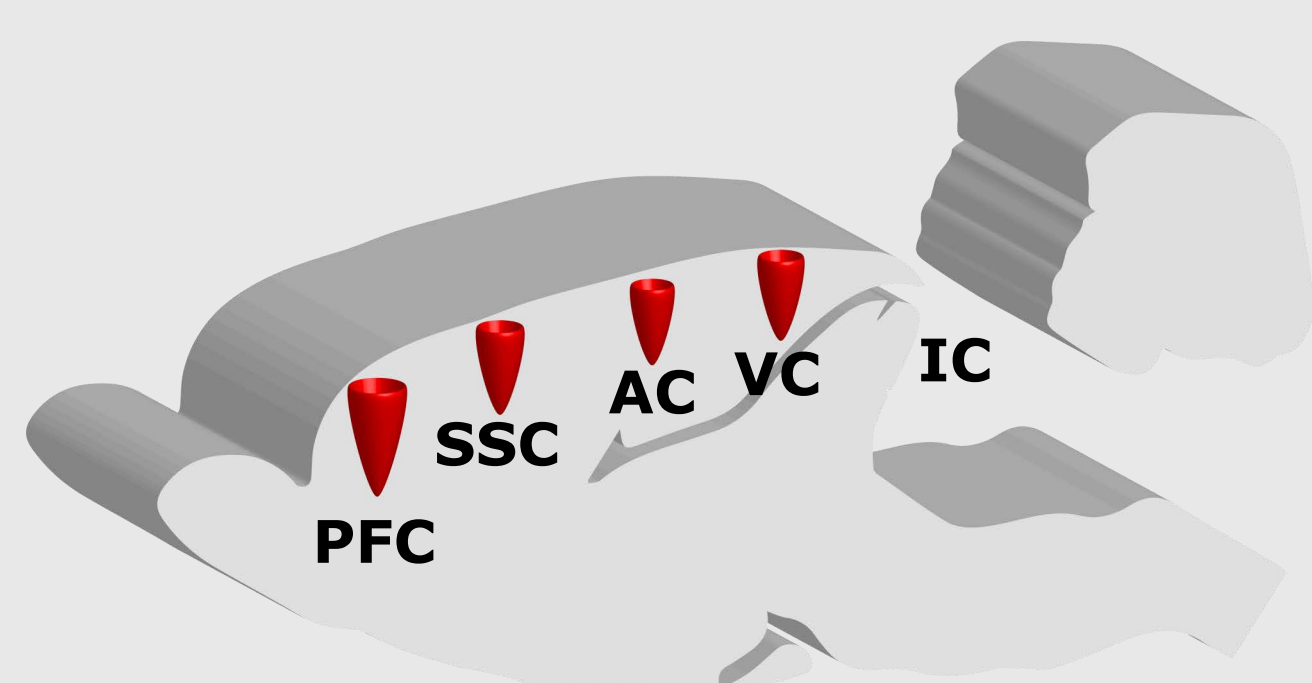
## Methods

- 1 Six Lister Hooded male rats (250-300g) received bilateral RetroBead (Lumafleur ®) tracer injections in each IC: green in the left and red in the right.

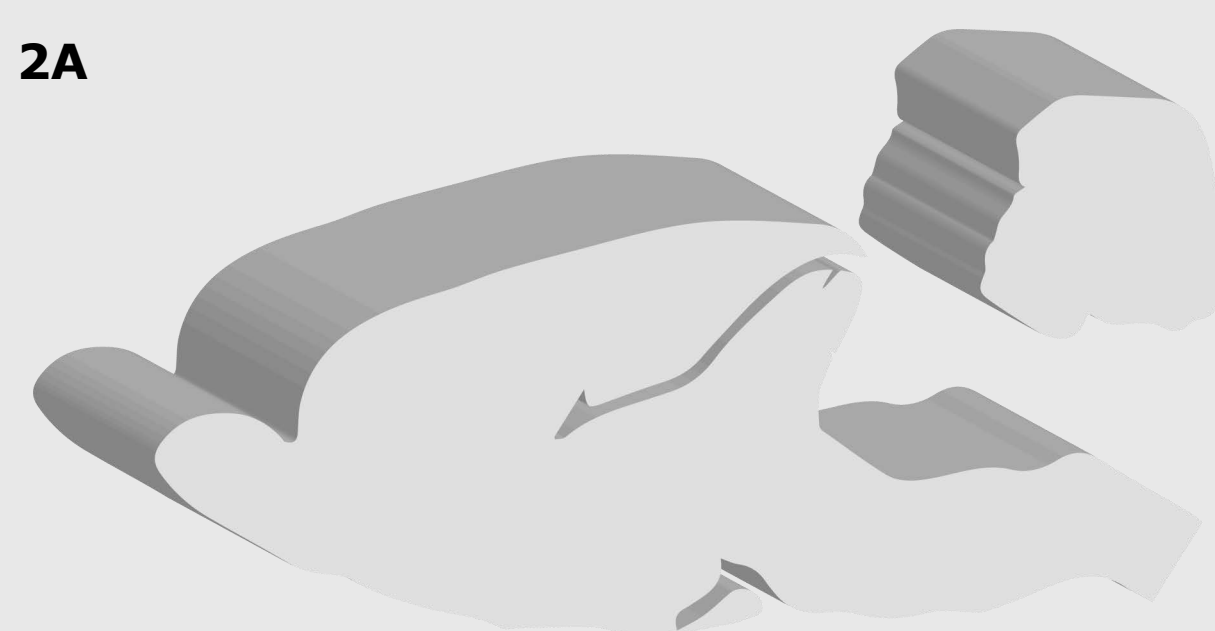


1B

To confirm the retrograde tracing, eight Lister Hooded male rats (250-300g) received injections of anterograde tracer (Dextran) into the prefrontal (PFC), somatosensory (SSC), auditory (AC), visual cortices (VC).



- 2 72 hours post surgery, whole brains were harvested, cryoprotected in 30% sucrose and cut in 40 µm coronal sections.



2B

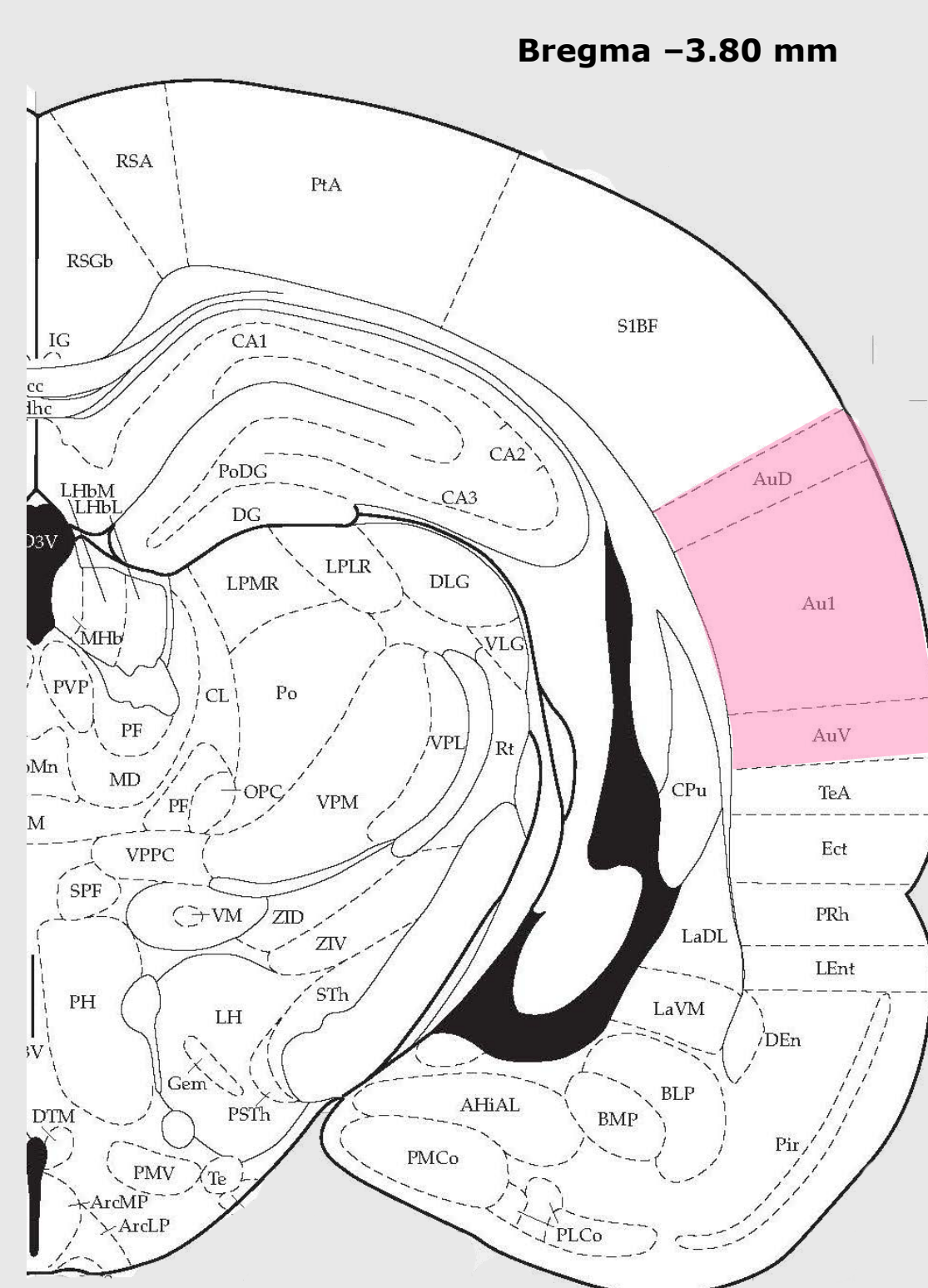


- 3 All sections were visually inspected for the presence of RetroBeads using a wide field microscope with appropriate filters.

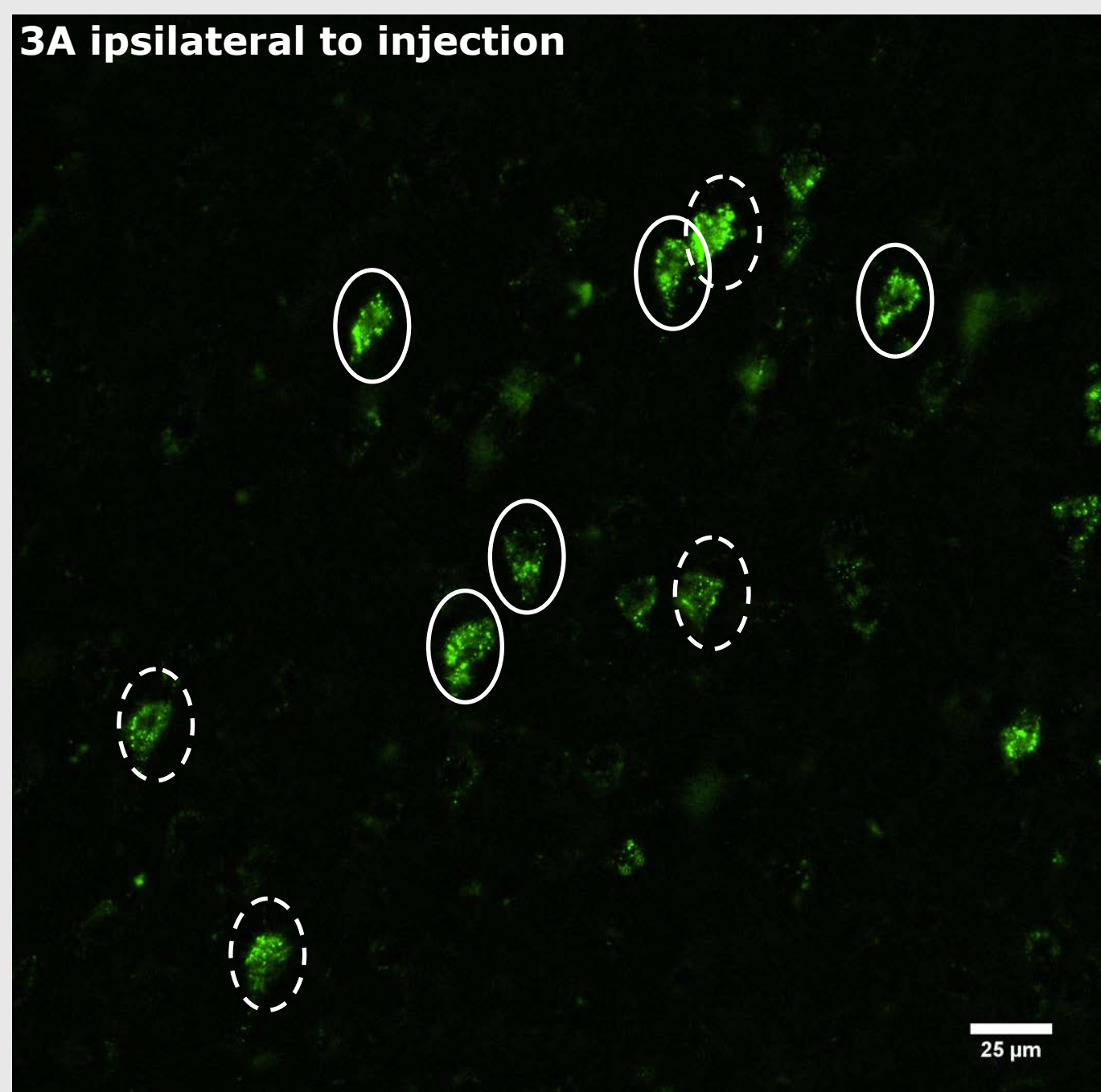
## Results

### Auditory cortex

- an injection of green RetroBeads in the left IC labelled numerous cell bodies in the ipsilateral **auditory cortex** (Fig 3A) confirming previous studies.
- an injection of red RetroBeads in the right IC labelled fewer cell bodies contralaterally in the left cortex (Fig 3B).
- Labelled cells in the auditory cortex had a morphology consistent with pyramidal cells and were distributed in two distinct layers (V & VI).
- Some cells (solid outlines) contain both green and red RetroBeads, indicating that these cells project to both the ipsilateral and contralateral IC.
- Other cells (dashed outlines) contain only green RetroBeads, indicating ipsilateral connectivity.



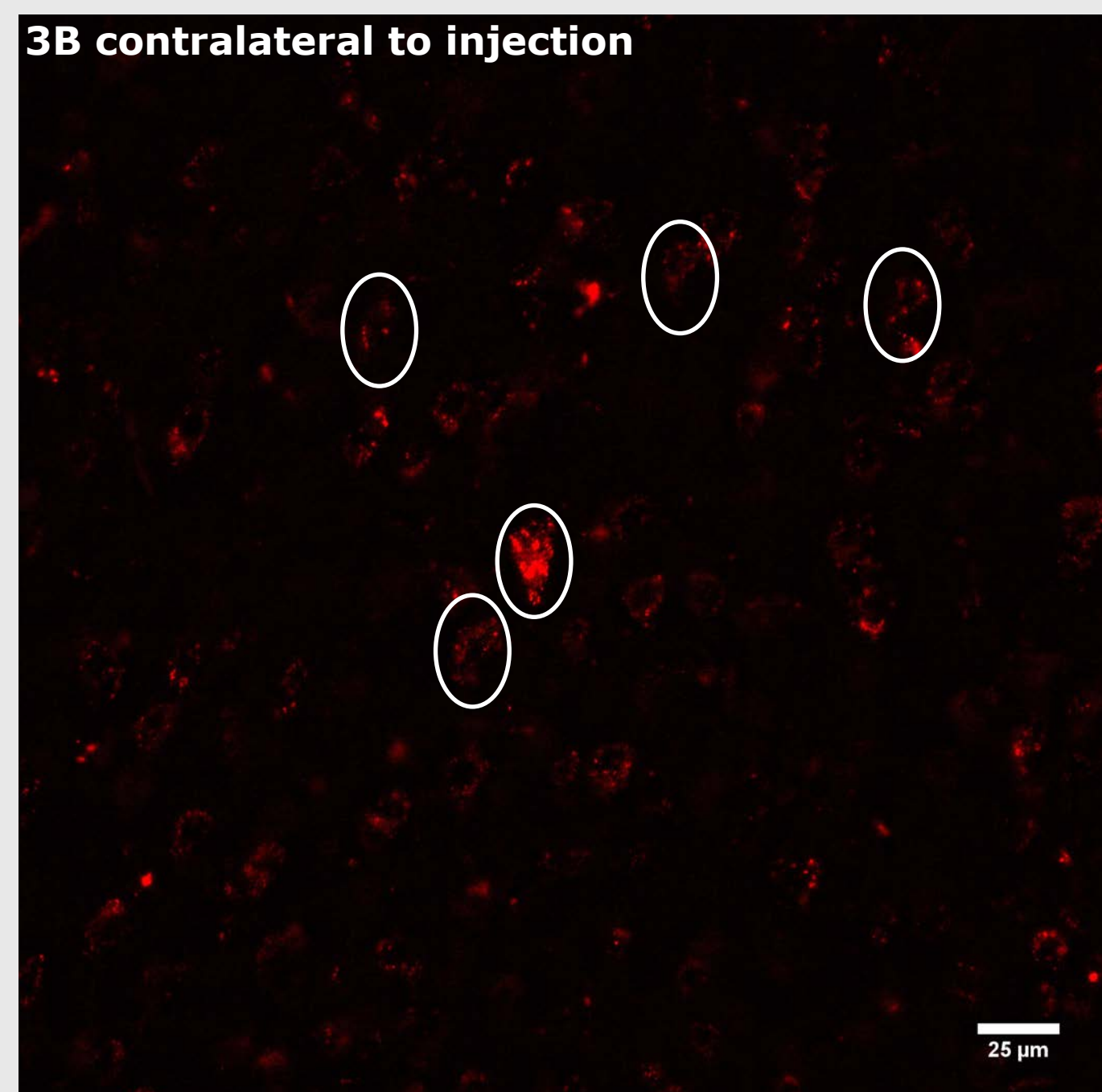
3A ipsilateral to injection



3A Ipsilateral labelling: following an injection of green RetroBeads in the left IC, RetroBeads were observed in the left AC.

Solid outlines denote cells double labelled by ipsilateral and contralateral IC injections, dashed outlines denote cells labelled by the injection in the ipsilateral IC.

3B contralateral to injection



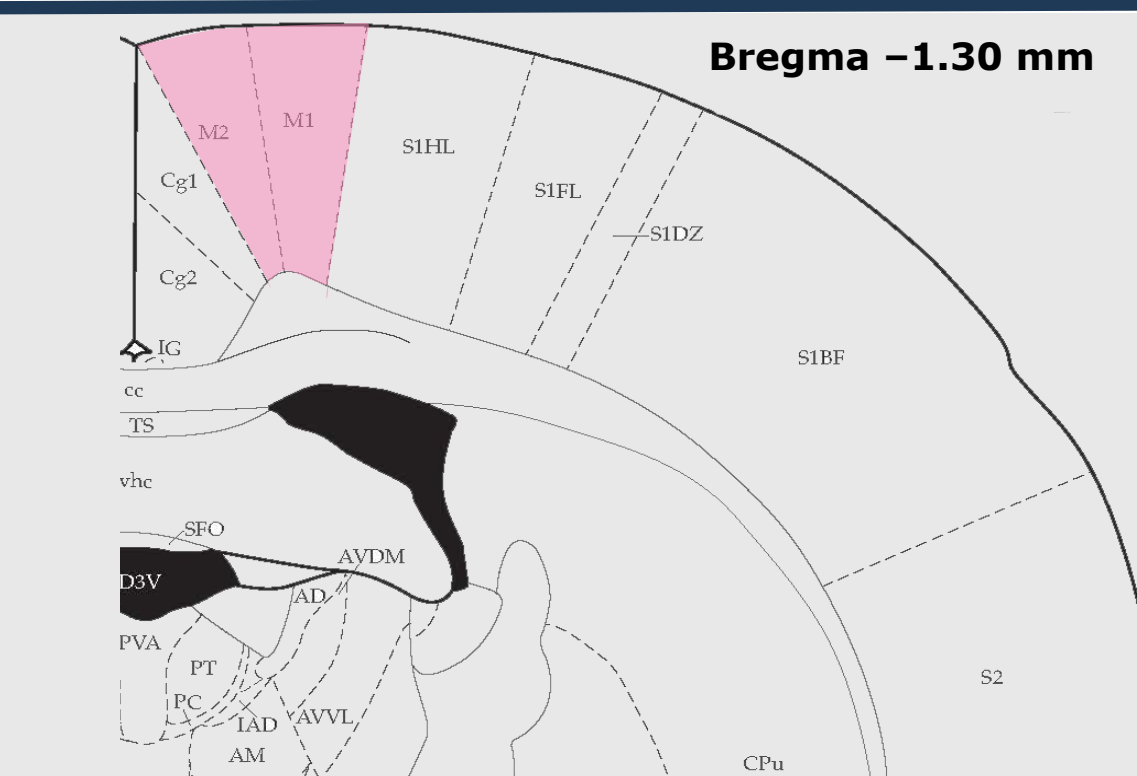
3B Contralateral labelling: following an injection of red RetroBeads in the right IC, red RetroBeads were observed in the left AC.

## Results

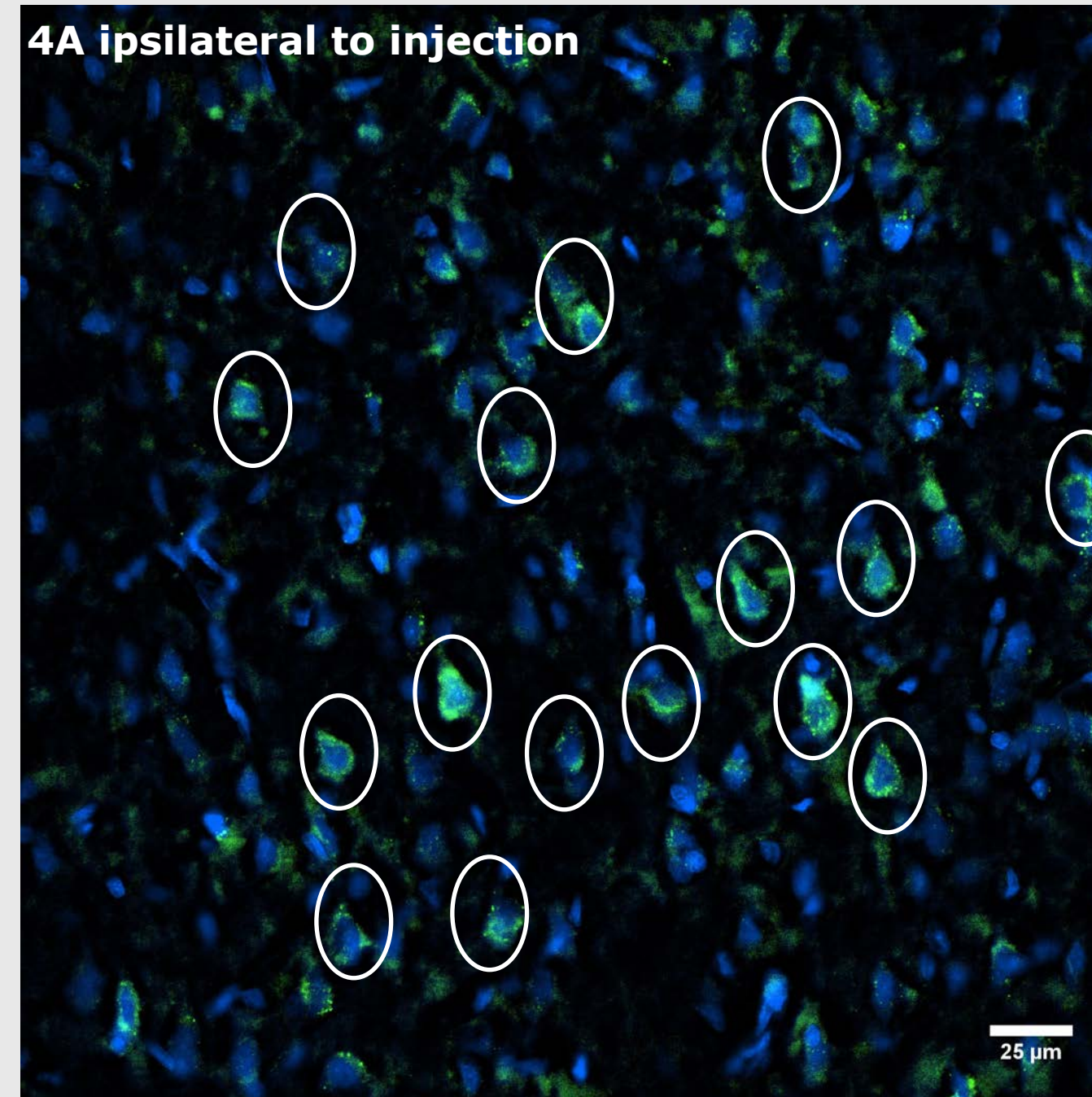
### Motor cortex

RetroBead injections in the IC labelled many cell bodies in ipsilateral and contralateral **motor cortex** (M1 & M2, Fig 4A and 4B).

All labelled cells (solid outlines) contain both green and red RetroBeads, indicating that these cells project to both the ipsilateral and contralateral IC.

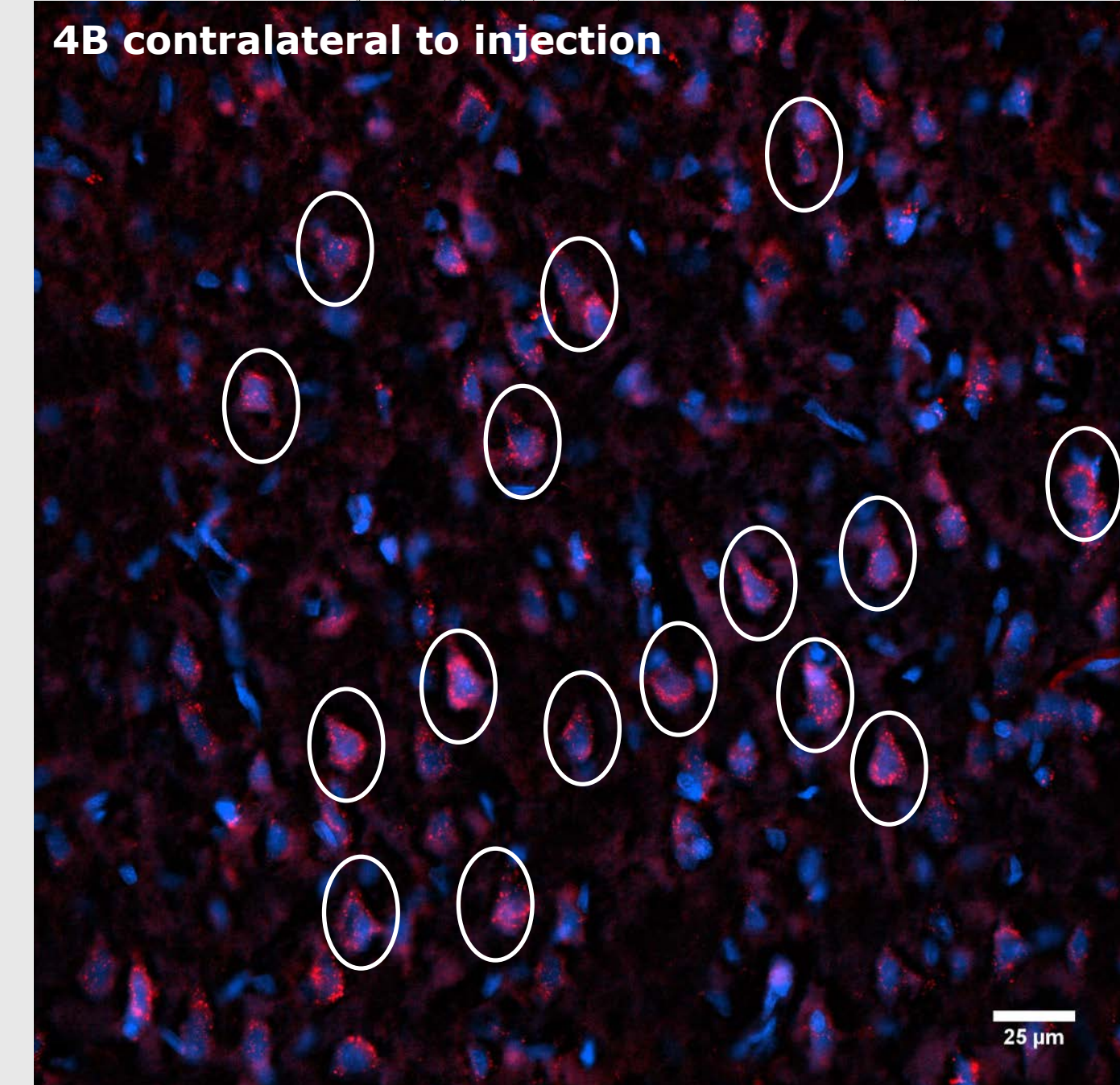


4A ipsilateral to injection



4A Ipsilateral labelling: after injection of green RetroBeads in the left IC green RetroBeads were observed in the left motor cortex.

4B contralateral to injection

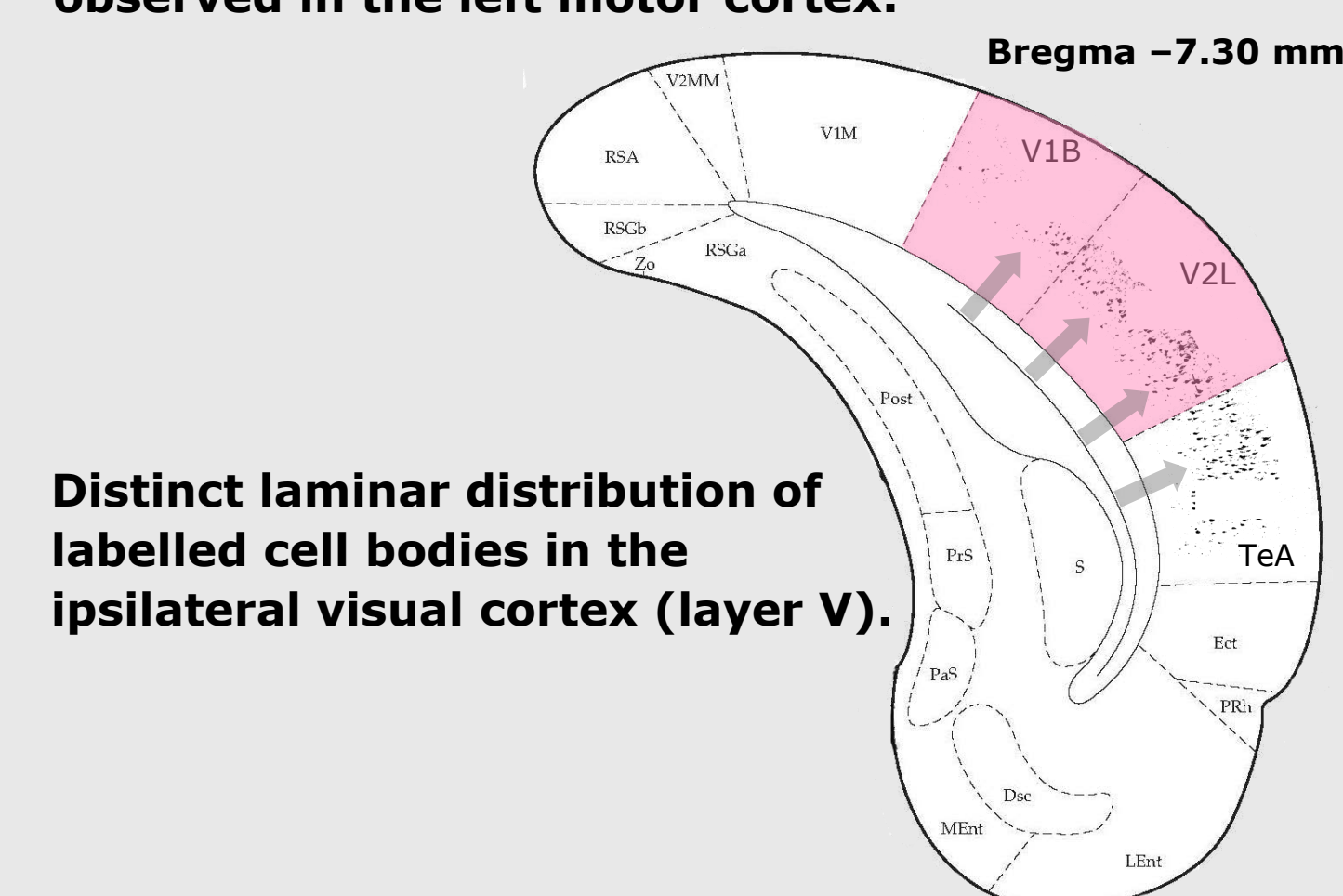


4B Contralateral labelling: after injection of red RetroBeads in the right IC red RetroBeads were observed in the left motor cortex.

### Visual cortex

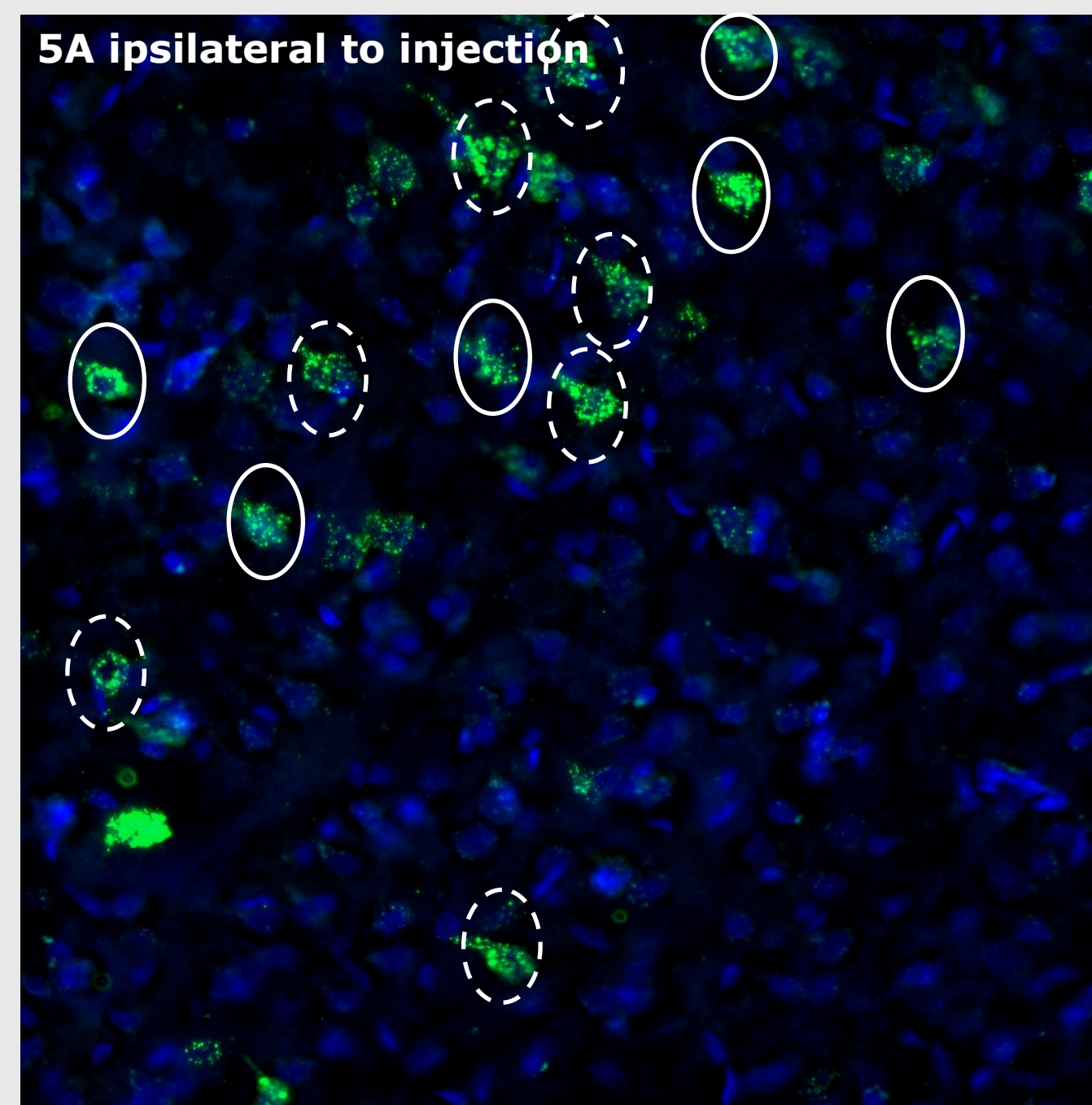
RetroBead injections in the IC labelled many cell bodies in the ipsilateral **visual cortex** (Fig 5A) as well as some in the contralateral **visual cortex** (Fig 5B).

Some cells (solid outlines) contain both green and red RetroBeads, indicating that they project to both the ipsilateral and contralateral IC. Other cells (dashed outlines) contain only green RetroBeads, indicating purely ipsilateral connectivity.



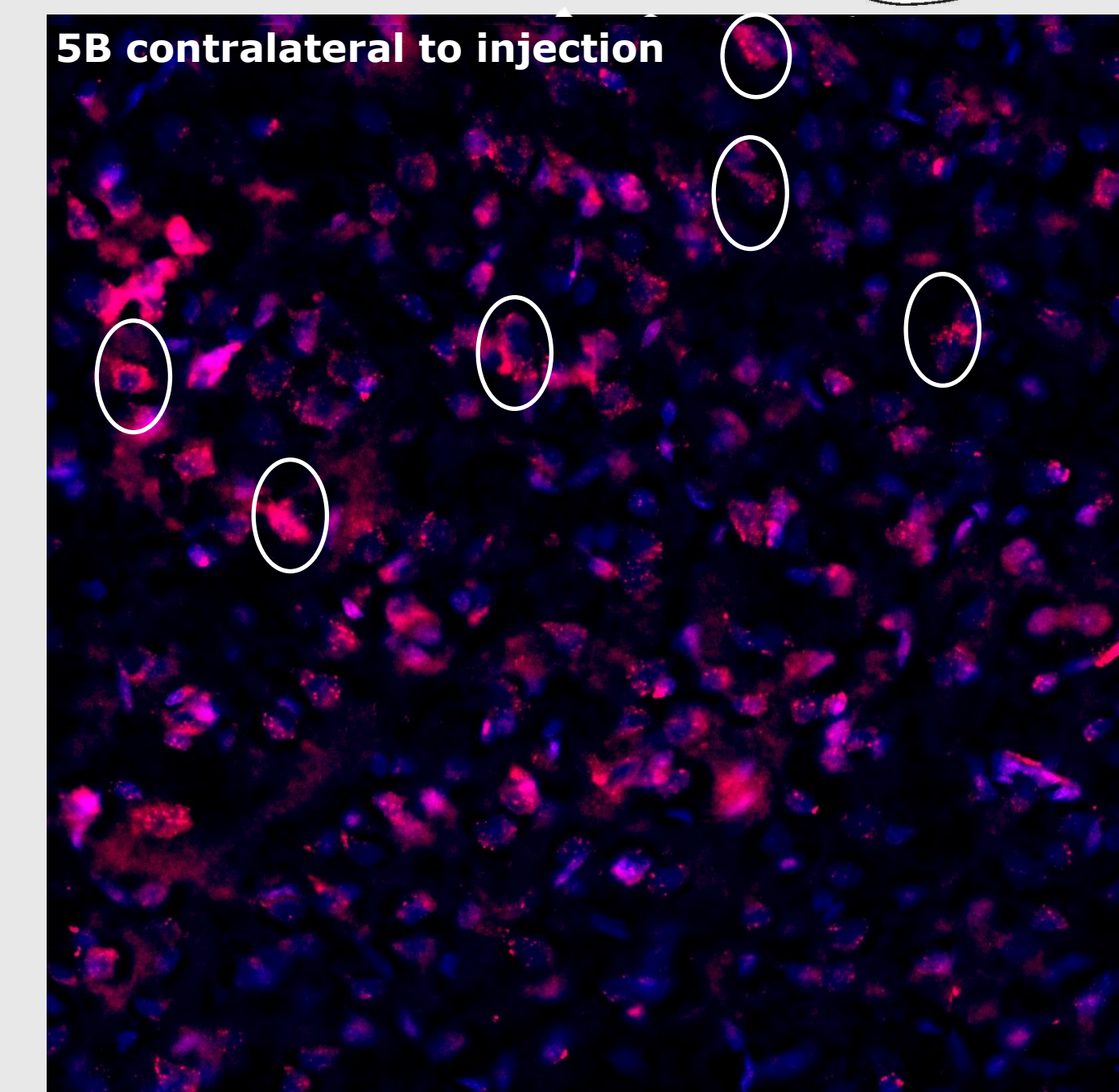
Distinct laminar distribution of labelled cell bodies in the ipsilateral visual cortex (layer V).

5A ipsilateral to injection

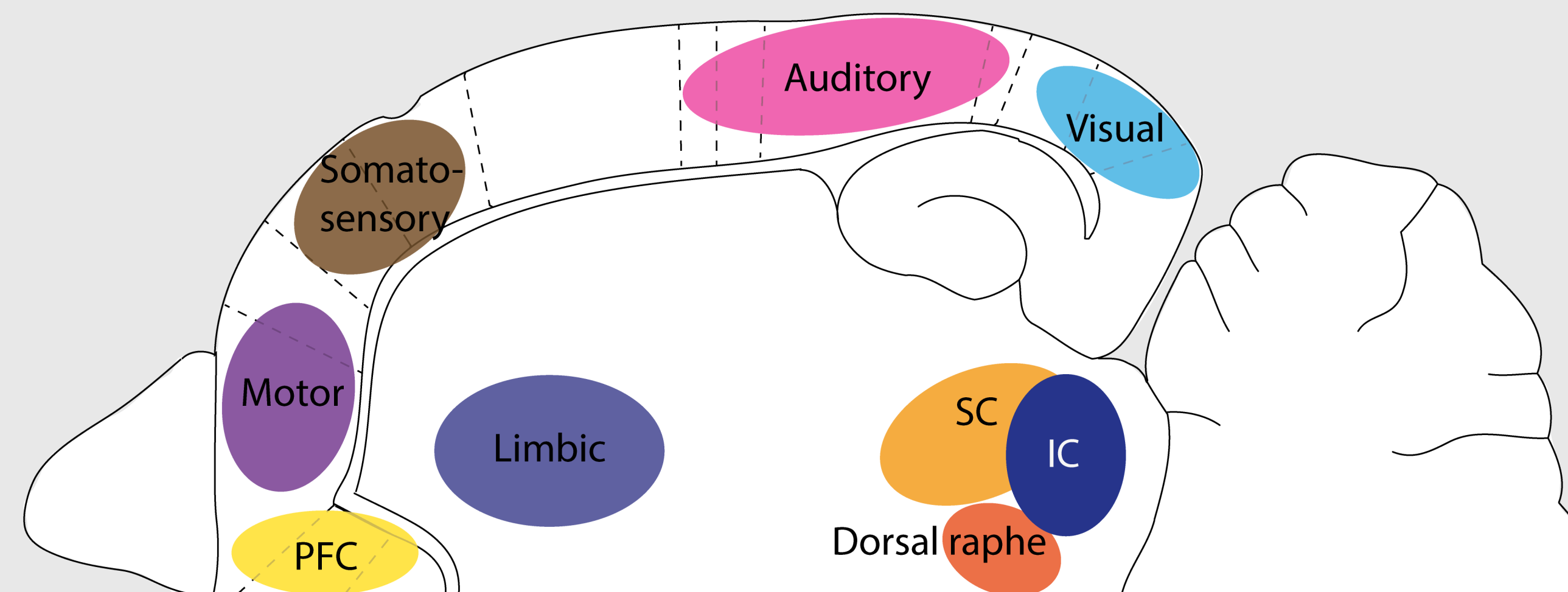


5A Ipsilateral labelling: after injection of green RetroBeads in the left IC green RetroBeads were observed in the left visual cortex.

5B contralateral to injection



5B Contralateral labelling: after injection of red RetroBeads in the right IC red RetroBeads were observed in the left visual cortex.



6. Summary diagram of cortical and non auditory subcortical projections to the IC. For clarity, only the ipsilateral projections are shown.

## Summary & conclusions

- RetroBead labelling indicates the ICs receive projections from the auditory, motor, visual, and (not shown) the prefrontal and somatosensory cortices, excluding the barrel field (Fig 6).
- There are varying degrees of bilateral connectivity from different cortices, but in all areas many individual neurons project to both ICs.
- The majority of cortical labelled neurons were pyramidal cells in the layers (V or VI).
- Anterograde studies confirmed the connections traced retrogradely.
- In addition to the cortical labelling, RetroBeads were also observed in several non-auditory subcortical structures including the amygdala and other limbic structures, hypothalamus, superior colliculus, and dorsal raphe nucleus (Fig 6).

These results show that the IC receives descending projections from more structures than previously known including many outside the auditory pathway. These descending projections to the IC suggest the processing of sound information is influenced by sensory, cognitive, and executive inputs at a much earlier stage than previously believed.