Neuronal plasticity in the olfactory bulb during simple and complex learning

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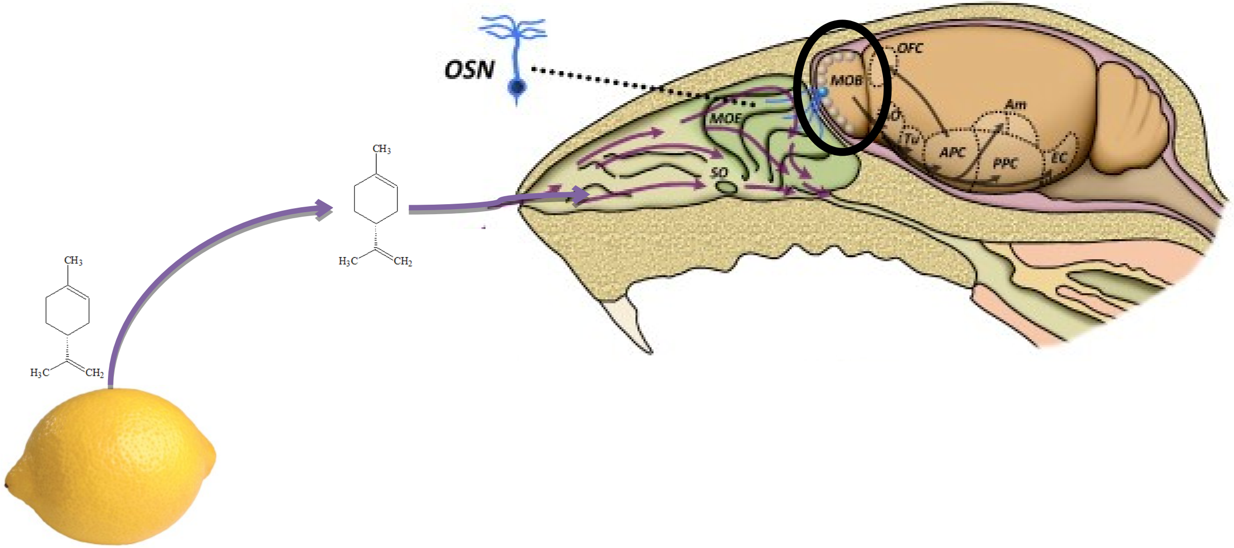
Olfactory system

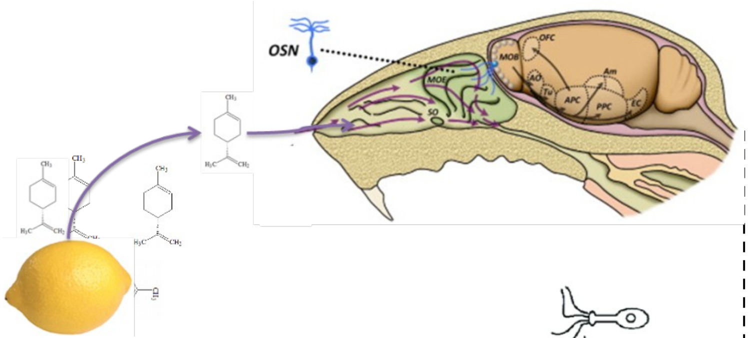
	Food search	Danger avoidance	Social interactions
Human			
Mice			

Olfactory system

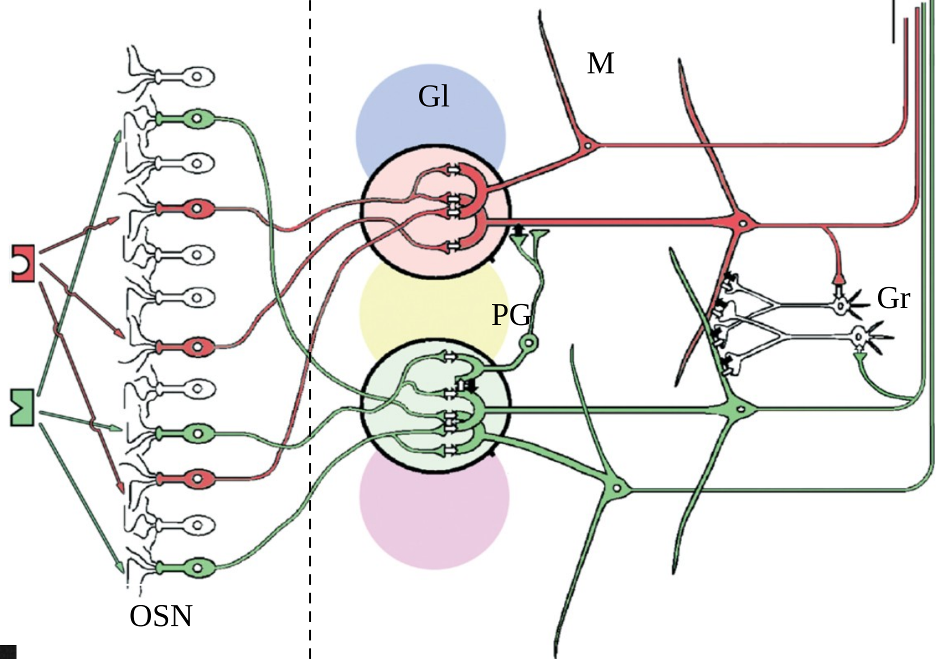
Olfactory system

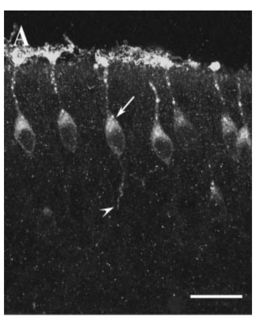


Olfactory system



Higher order olfactory centers

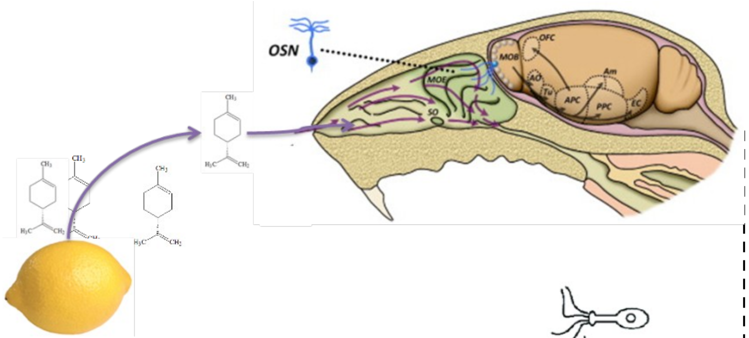


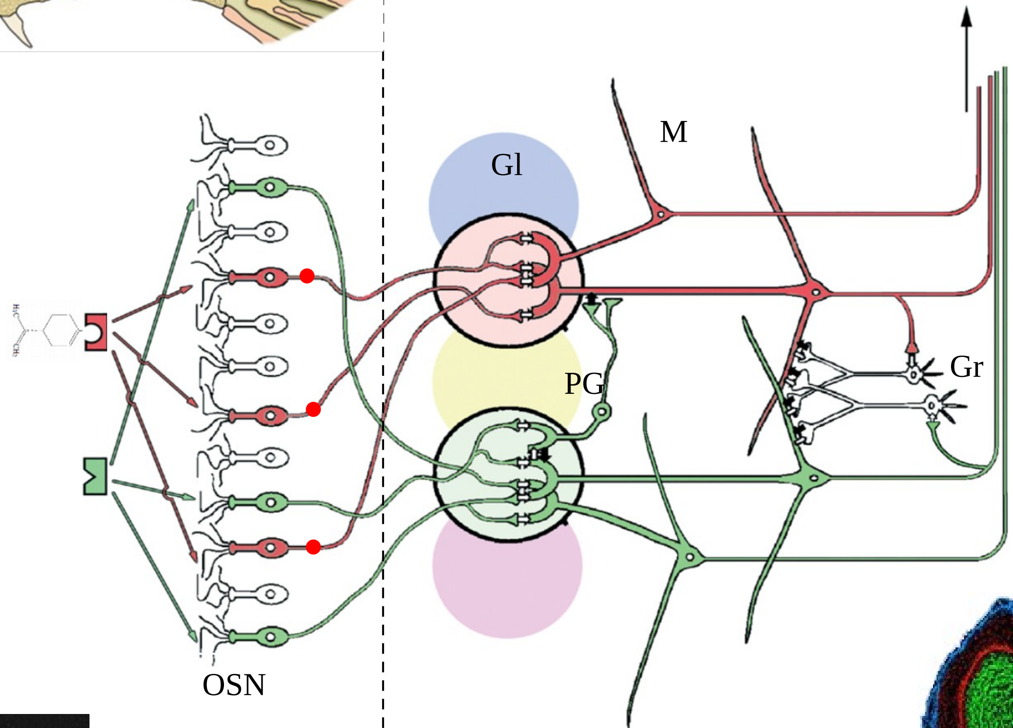


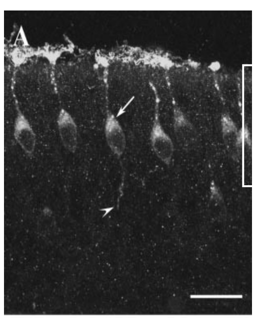
Olfactory epithelium

Olfactory bulb

Olfactory system

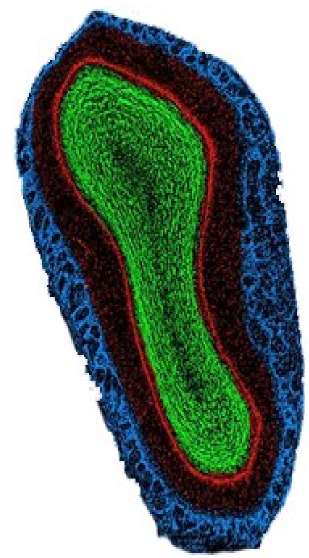




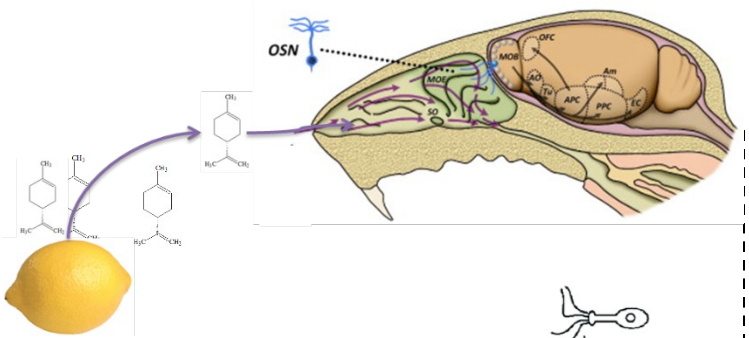


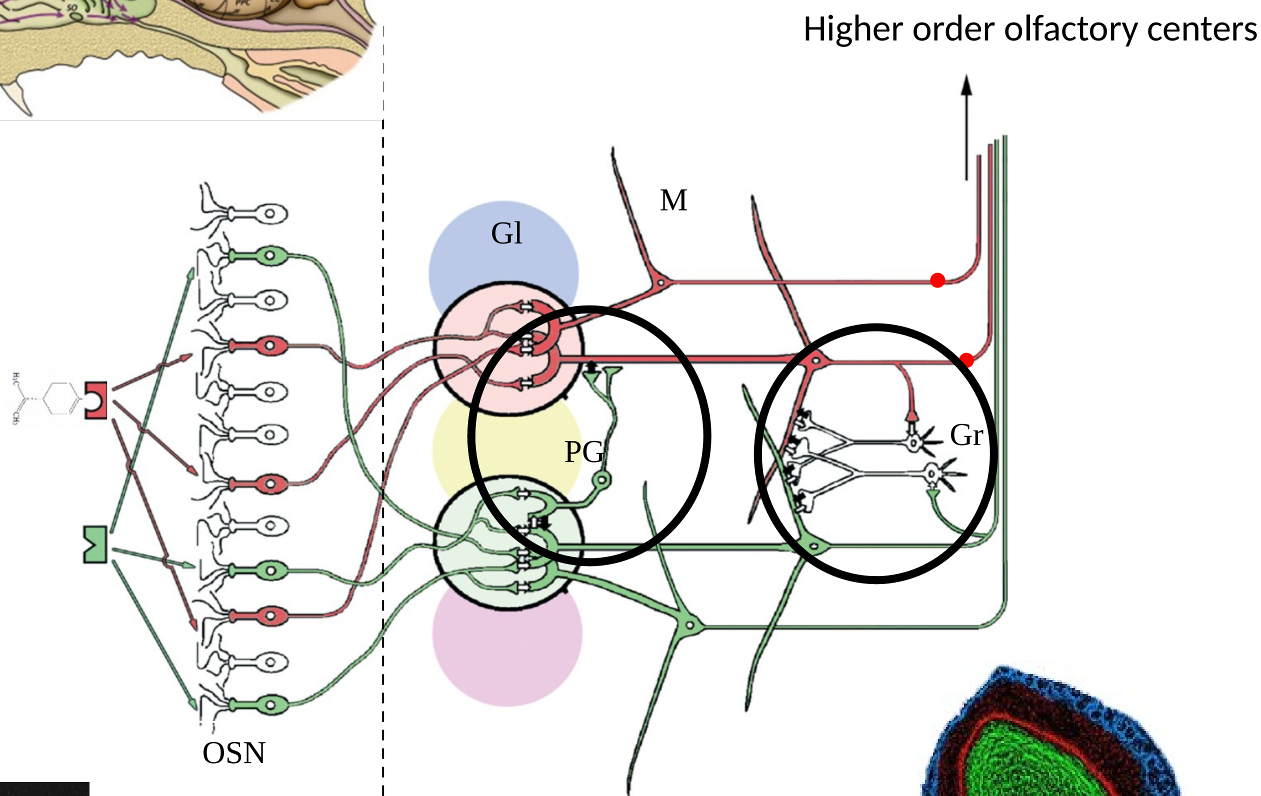
Olfactory epithelium

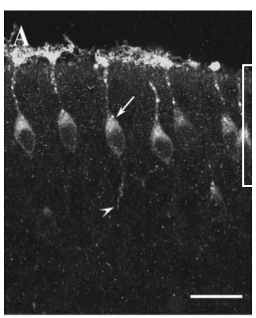
Olfactory bulb



Olfactory system

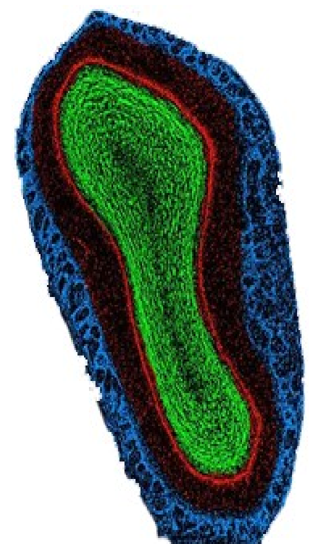






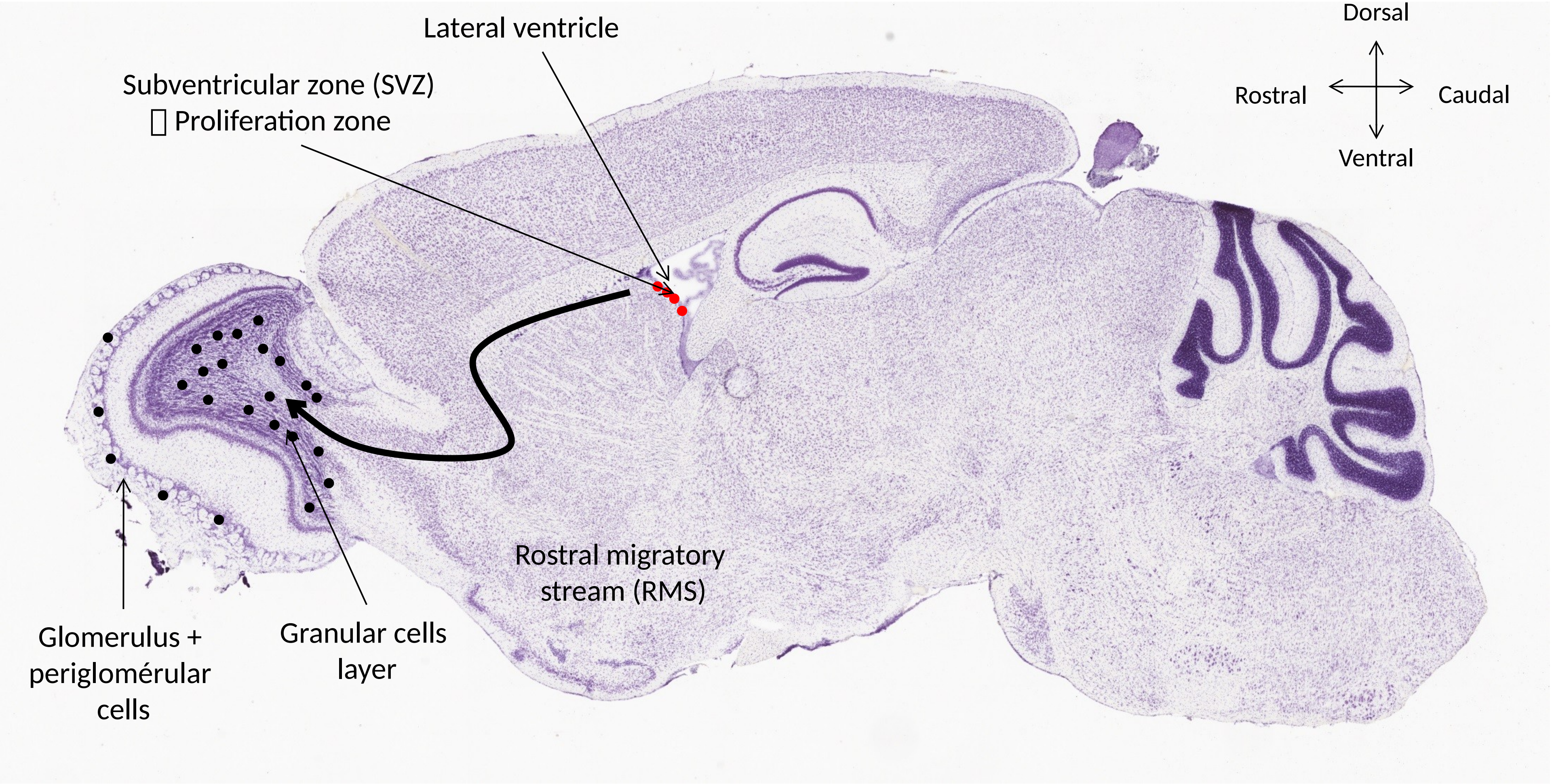
Olfactory epithelium

Olfactory bulb



Buck and Axel, Cell, 1991; Duchamp-Viret et al., Science, 1999; Shepherd, Physiol Rev, 1972

Adult neurogenesis



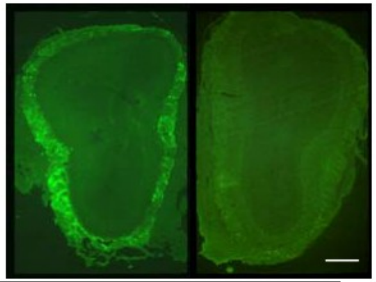
 Adult neurogenesis is a process dependent on sensory experiences

Lledo et al. Nat Neuro 2006 ; Rocherfort et al. J Neuro 2002 ; Mandairon et al. Behav Neuro, 2006; Mandairon et al., J Neuro, 2011 ; Alonso et al., J Neuro, 2006 ; Moreno et al., PNAS, 2009

Adult neurogenesis

LONG-TERM FATE AND DISTRIBUTION OF NEWBORN CELLS IN THE ADULT MOUSE OLFACTORY BULB: INFLUENCES OF OLFACTORY DEPRIVATION

N. MANDAIRON,* J. SACQUET, F. JOURDAN AND A. DIDIER



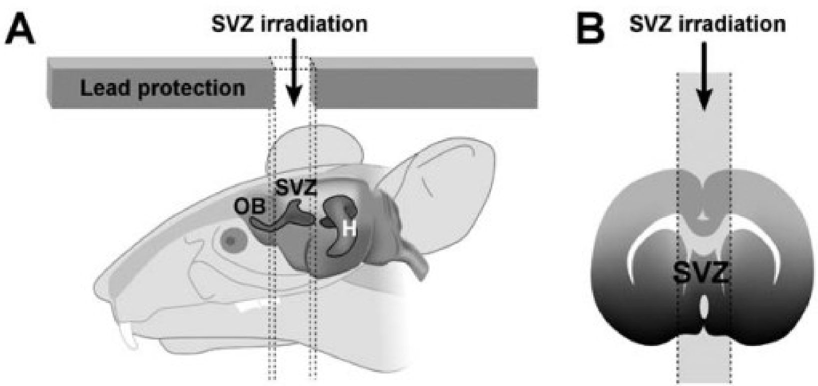
Enriched Odor Exposure Increases the Number of Newborn Neurons in the Adult Olfactory Bulb and Improves Odor Memory

Christelle Rochefort,[1]* Gilles Gheusi,[1,2]* Jean-Didier Vincent,[1] and Pierre-Marie Lledo[1]

Olfactory enrichment
Lavender
Garlic
Paprika
Marjoram
Curry
Rosemary
Nutmeg
Thyme
Basil leaves
Cumin
Cardamom
Tarragon
Whole cloves
Chocolate
Celery
Anise
Ginger
Lemon
Orange
Banana

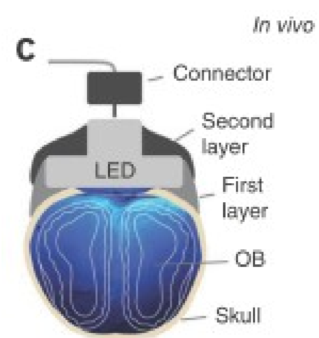
Cellular and Behavioral Effects of Cranial Irradiation of the Subventricular Zone in Adult Mice

Françoise Lazarini[1,2], Marc-André Mouthon[3], Gilles Gheusi[1,2], Fabrice de Chaumont[4], Jean-Christophe Olivo-Marin[4], Stéphanie Lamarque[5,6], Djoher Nora Abrous[5,6], François D. Boussin[3], Pierre-Marie Lledo[1,2]*



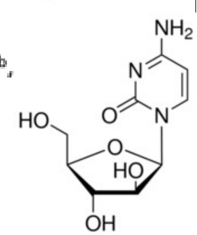
Activation of adult-born neurons facilitates learning and memory

Mariana Alonso[1,2], Gabriel Lepousez[1,2], Sebastien Wagner[1,2,4], Cedric Bardy[1–4], Marie-Madeleine Gabellec[1,2], Nicolas Torquet[1,2] & Pierre-Marie Lledo[1,2]



Olfactory perceptual learning requires adult neurogenesis

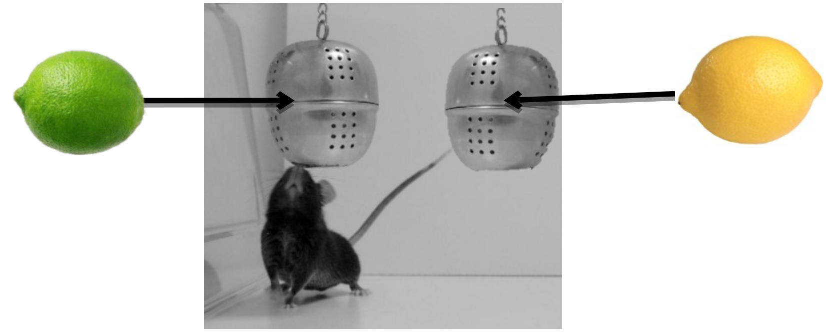
Mélissa M. Moreno[a], Christiane Linster[b], Olga Escanilla[b], Joëlle Sacquet[a], Anne Didier[a], and Nathalie Mandairon[a,1]



AraC

Perceptual learning

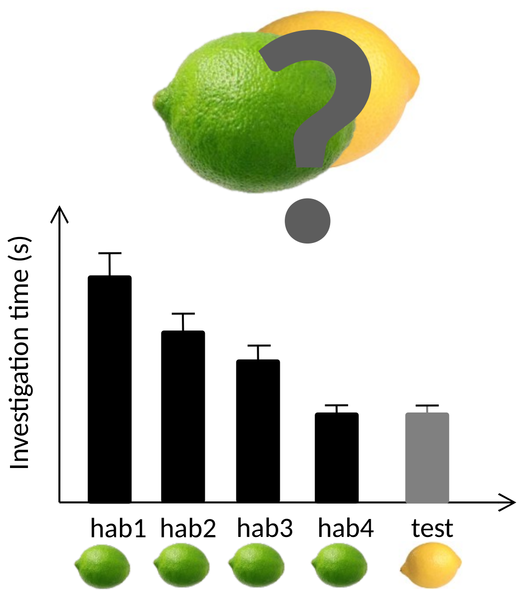
Significant improvement of the discrimination abilities of perceptualy close odorants after repeated exposition to these same odorants(= enrichment).



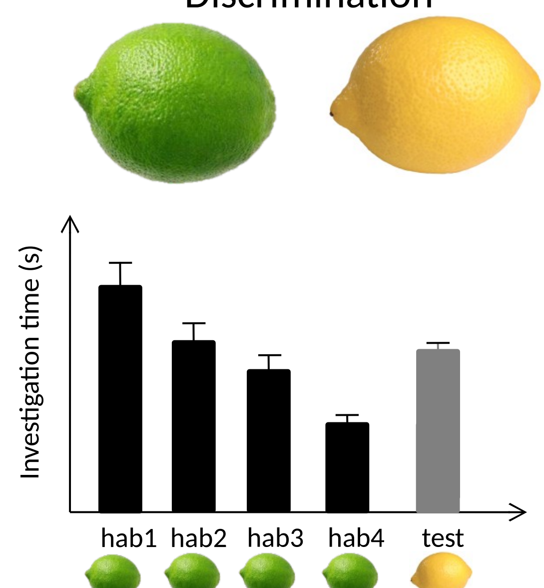
test | enrichment | test

1h/day
For 10 days

No discrimination

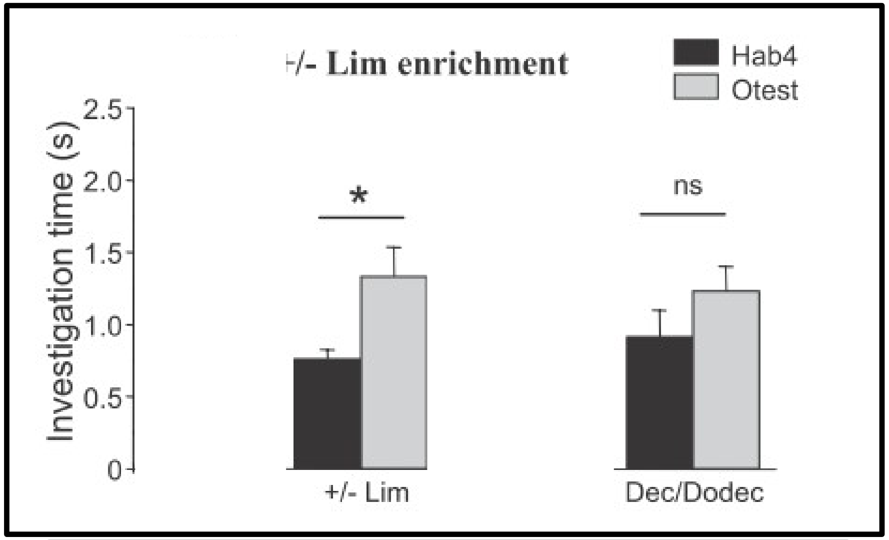


Discrimination

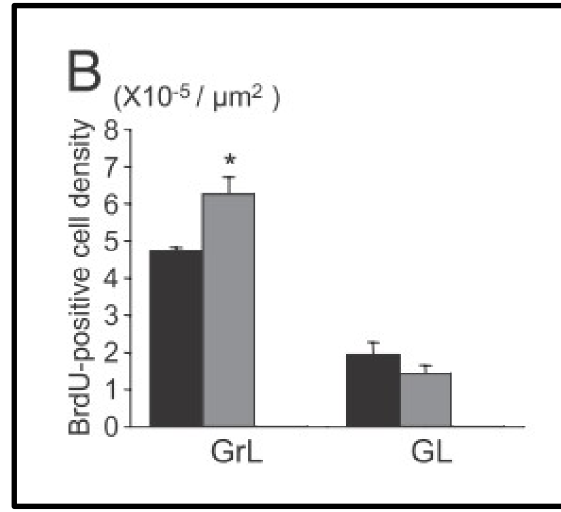


Moreno et al ., PNAS, 2009
Moreno et al ., J Neuro, 2012

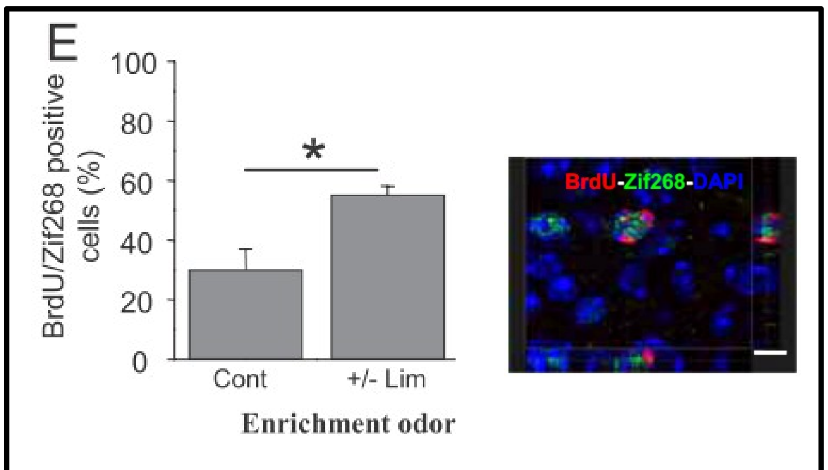
Perceptual learning ...



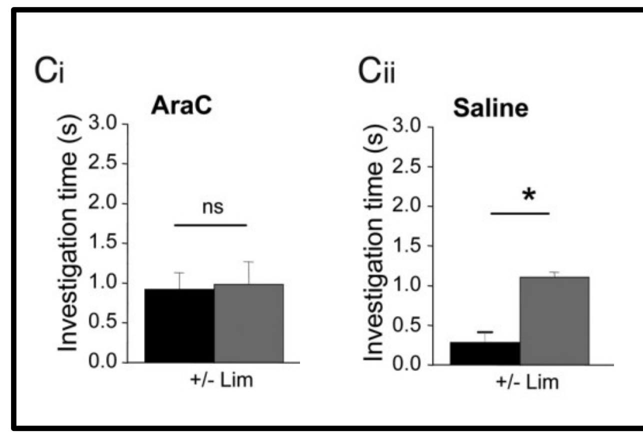
... specificaly improve discimination of learned odorants



... is associated with an increased density of newborn neurons in the granular cell layer ...



... newborn neurons whose contribution to odor processing is increased ...



... and newborn neurons who are necessary for this learning task.

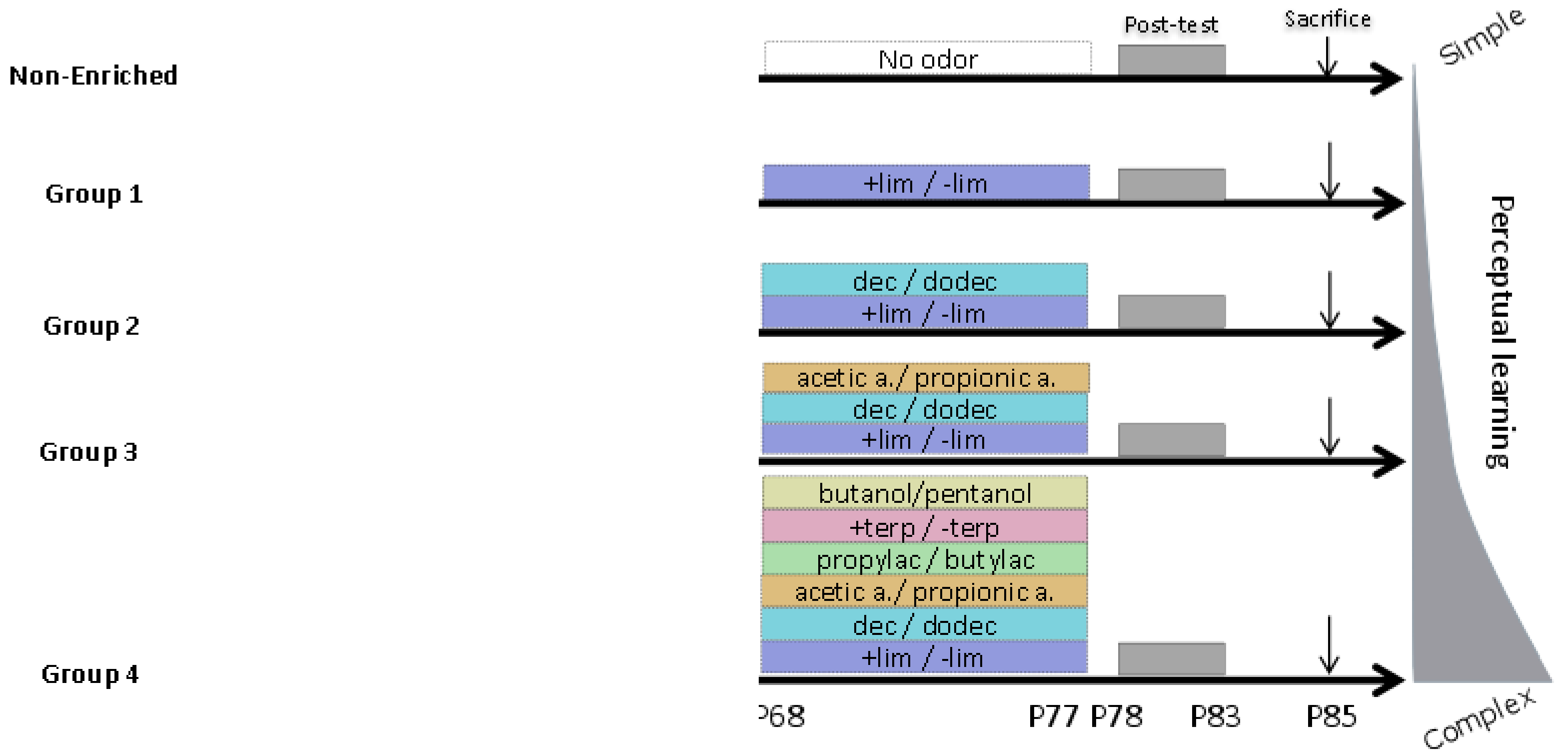
Moreno et al ., PNAS, 2009

Perceptual learning

- Simple perceptual learning paradigm = 1 pair of odorants

- Real olfactory environnement is more complexe = several pairs of odorants

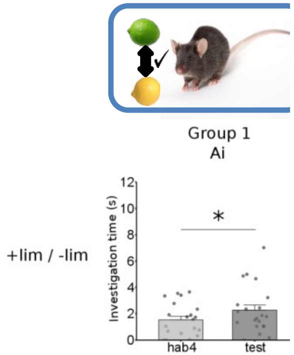
Neuronal plasticity in the olfactory bulb during simple and complex learning



1 – **Discrimination performances** of every couple of odorants
2 – **Neurogenic correlate**: newborn neurons density (BrdU) and cellular activity in response to the learned odorants (Zif268)
3 – **Structural plasticity and specificity of newborn neurons**: study of newborn neurons changing morphological traits as opposed to what happens in preexisiting neurons

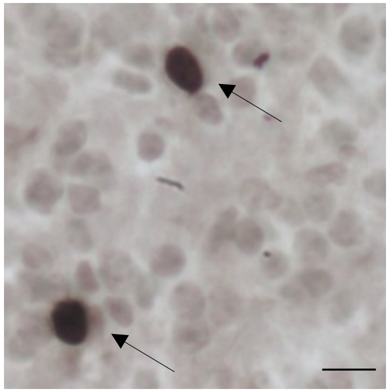
Neuronal plasticity in the olfactory bulb during simple and complex learning

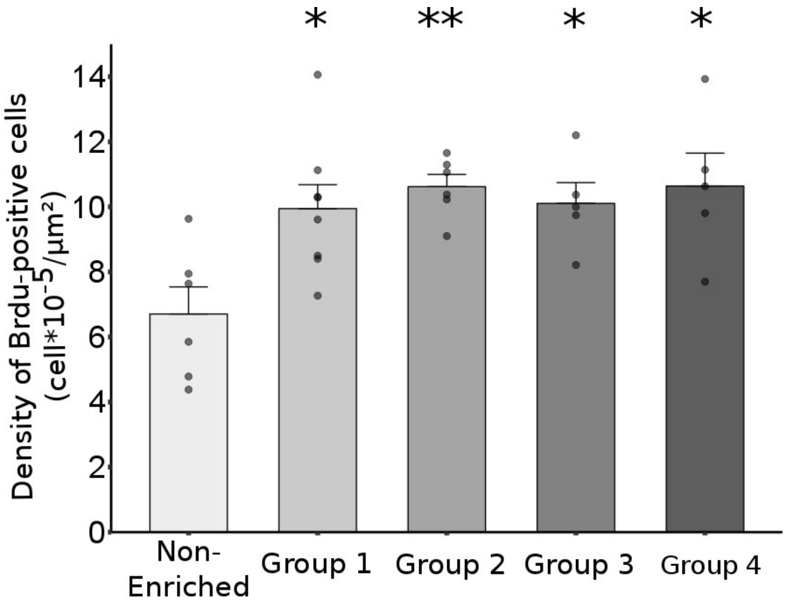
1 – Behavior:



Neuronal plasticity in the olfactory bulb during simple and complex learning

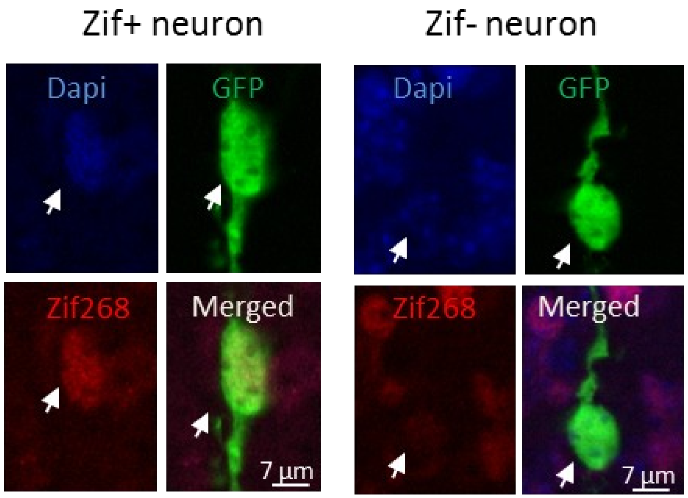
2 – Newborn neurons density:

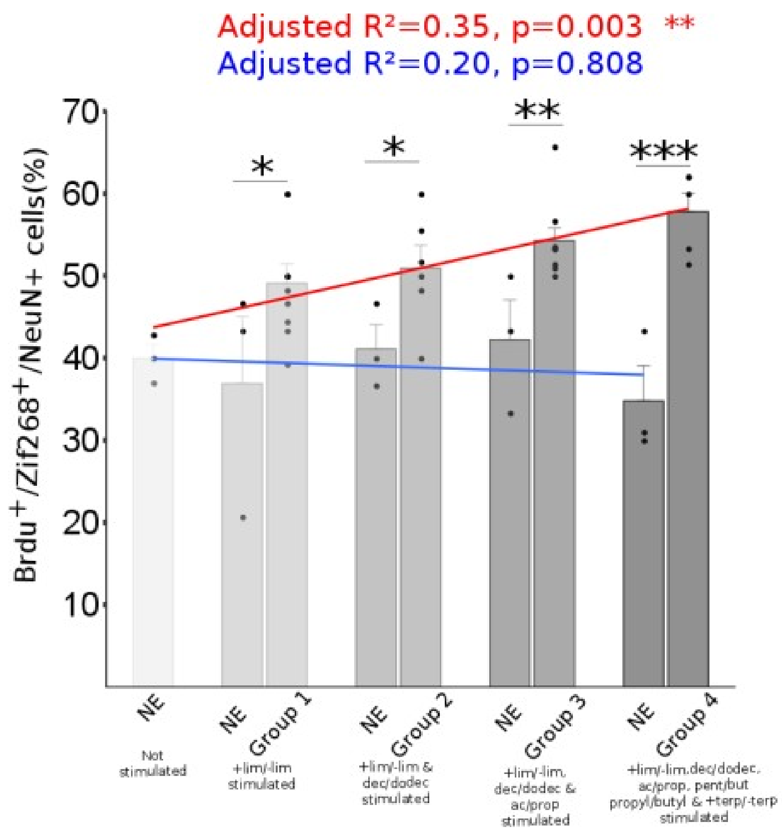




Neuronal plasticity in the olfactory bulb during simple and complex learning

2 – Newborn neurons responsiveness:



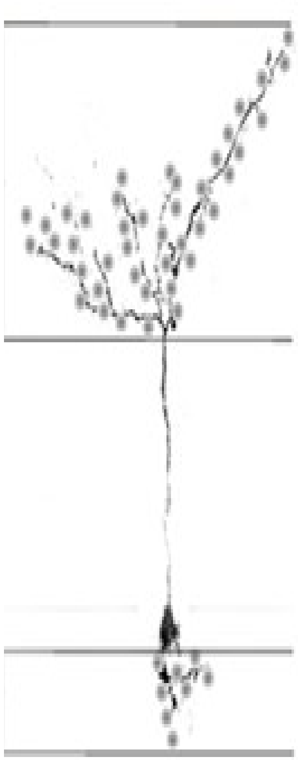


Neuronal plasticity in the olfactory bulb during simple and complex learning

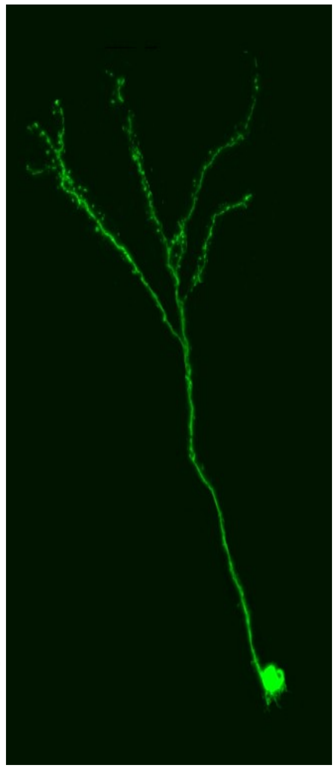
3 – Newborn neurons and preexisting neurons morphology:

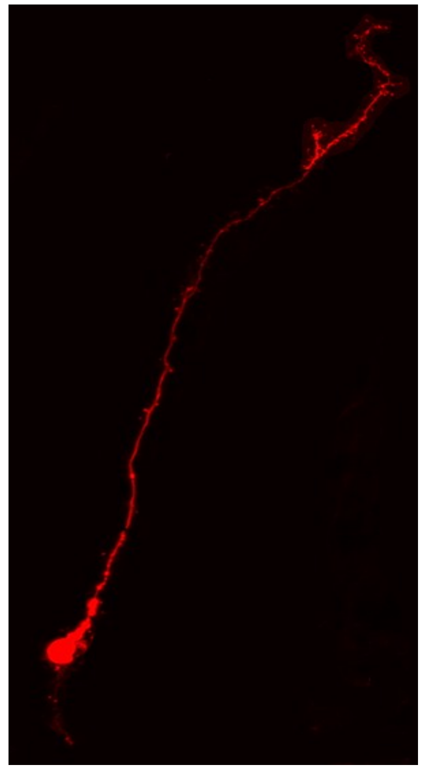
Apical domain

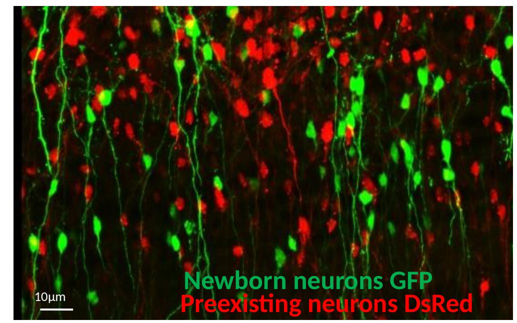
Basal domain



Modified from Kelsh et al. 2009





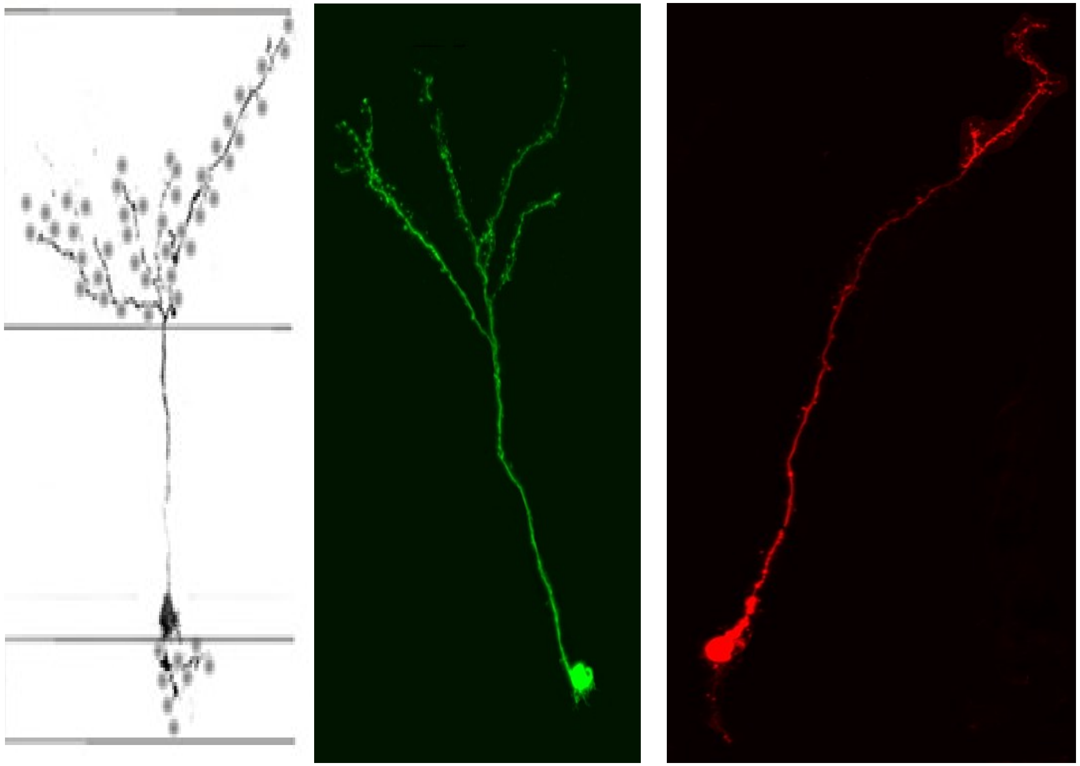


Neuronal plasticity in the olfactory bulb during simple and complex learning

Arborization length

Apical domain

Basal domain



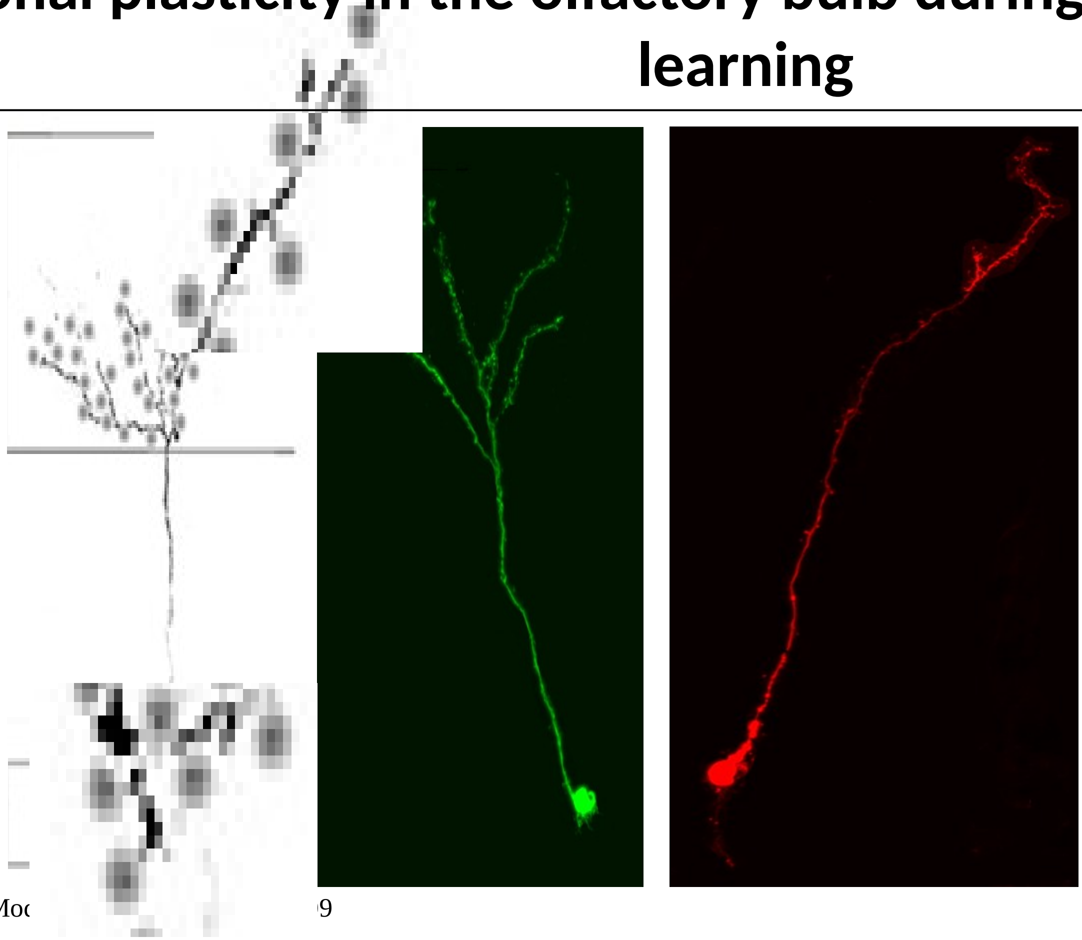
Modified from Kelsh et al. 2009

Primary dendrite length

Basal dendrites length

Neuronal plasticity in the olfactory bulb during simple and complex learning

Apical domain

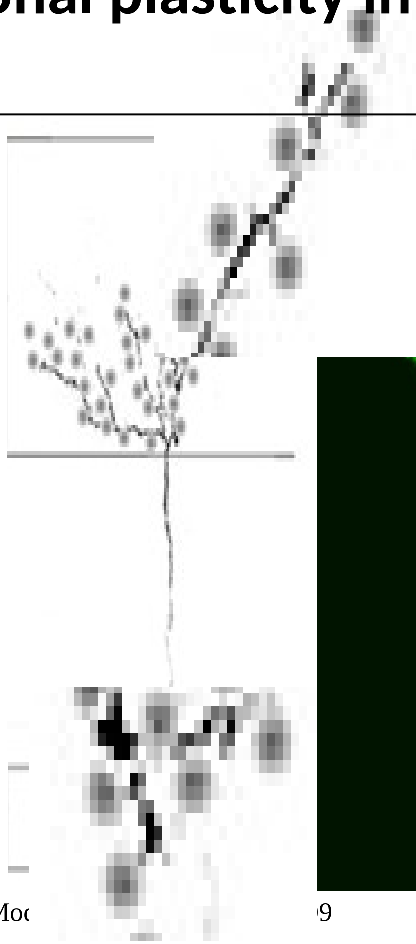


Basal domain

Moc 9

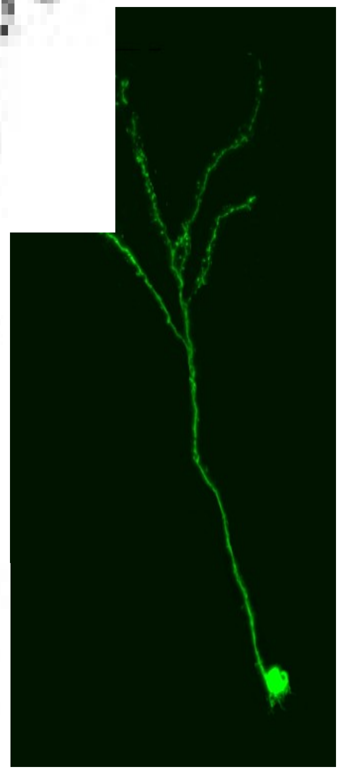
Neuronal plasticity in the olfactory bulb during simple and complex learning

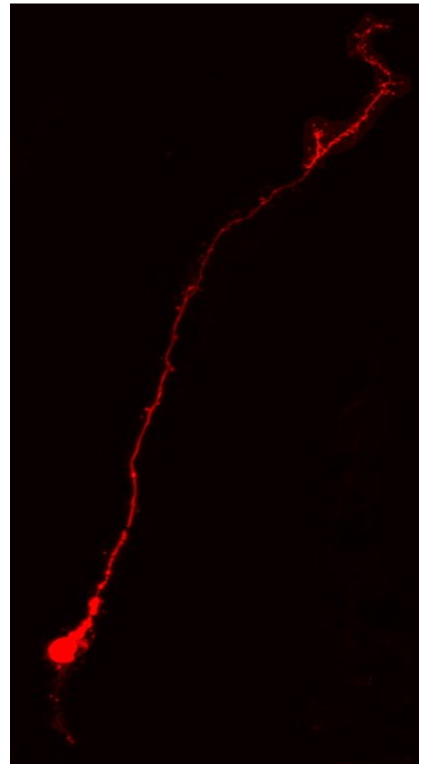
Apical domain

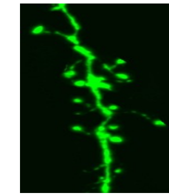


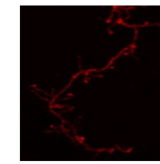
Basal domain

Moc 9



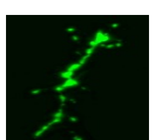


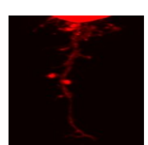




Apical spine density

Basal spine density

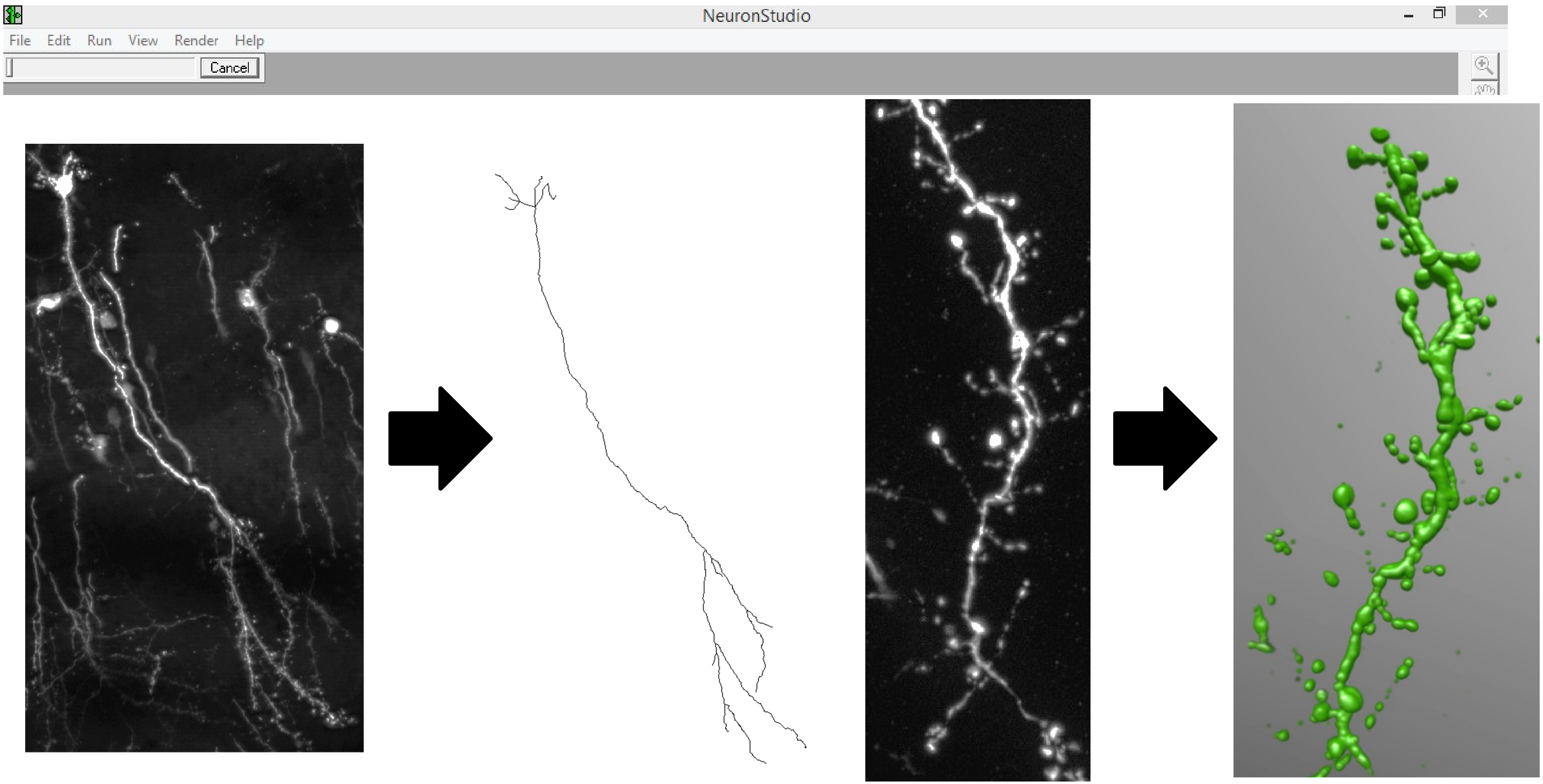


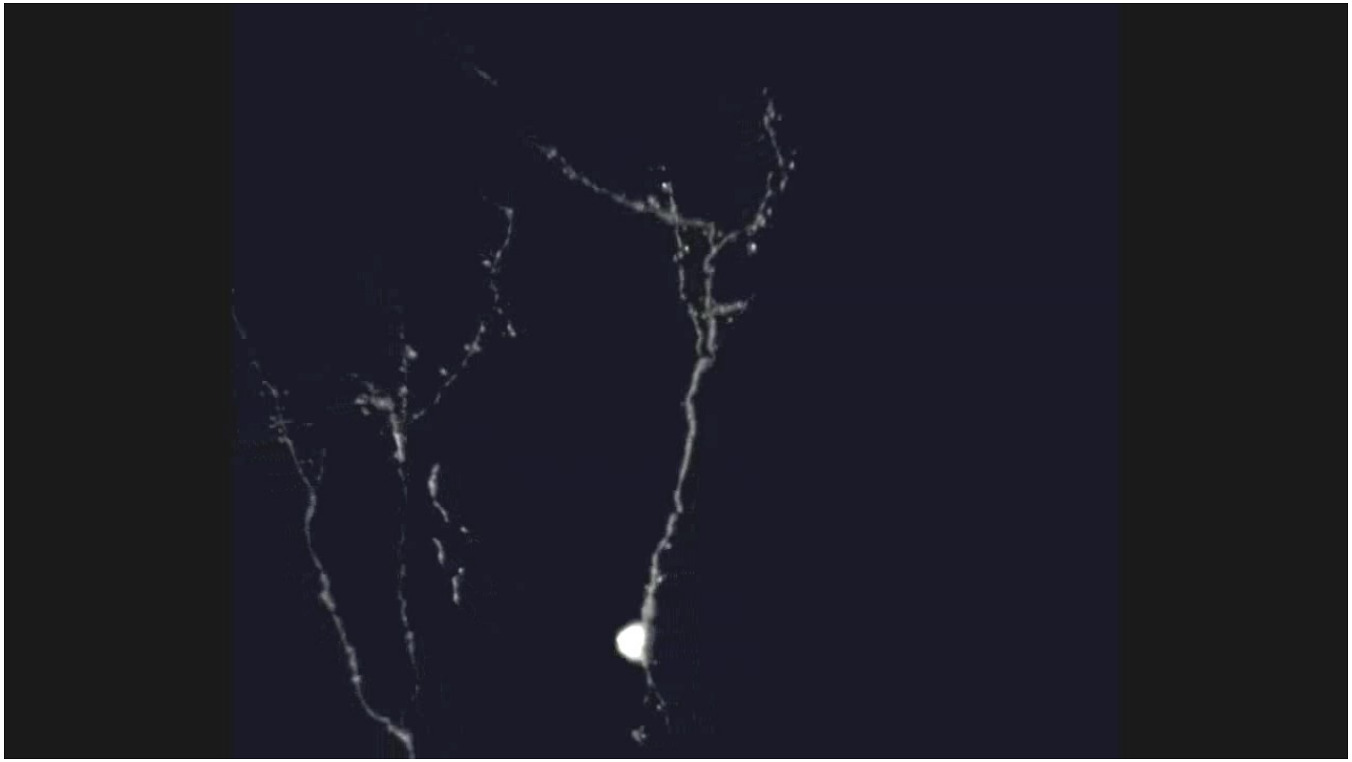


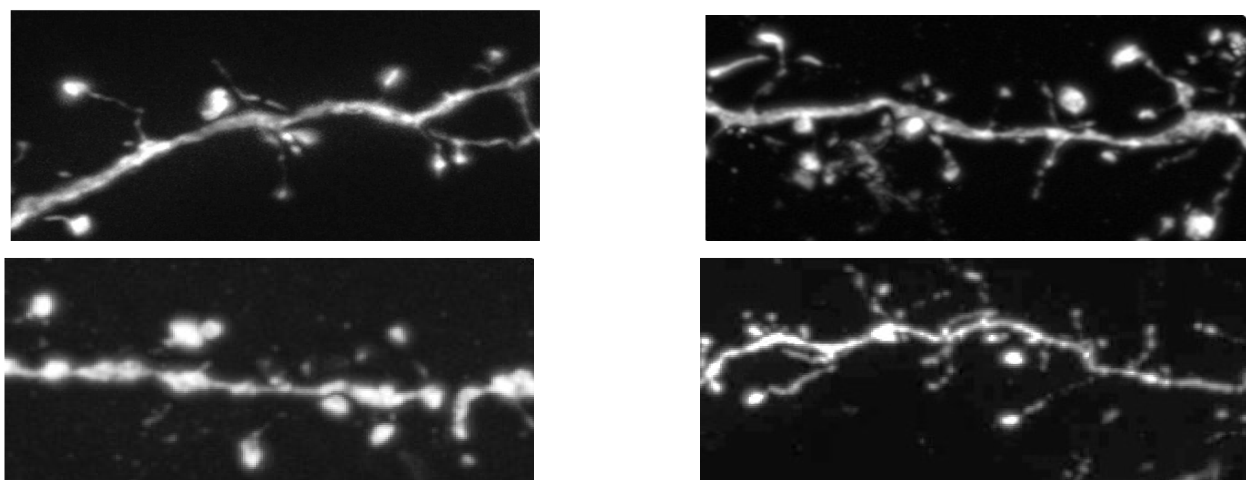
Neuronal plasticity in the olfactory bulb during simple and complex learning

Automated reconstruction of three-dimensional neuronal morphology from laser scanning microscopy images

Alfredo Rodriguez,[a,b] Douglas Ehlenberger,[a,b] Kevin Kelliher,[a,b] Michael Einstein,[a,c,d] Scott C. Henderson,[a,e,f] John H. Morrison,[a,c,d,f] Patrick R. Hof,[a,c,d,f] and Susan L. Wearne[a,b,d,f,*]

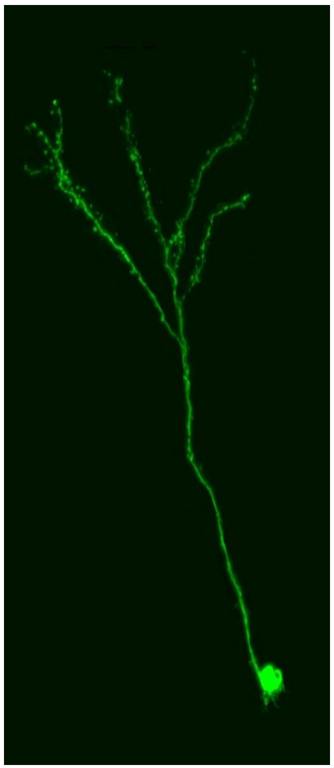


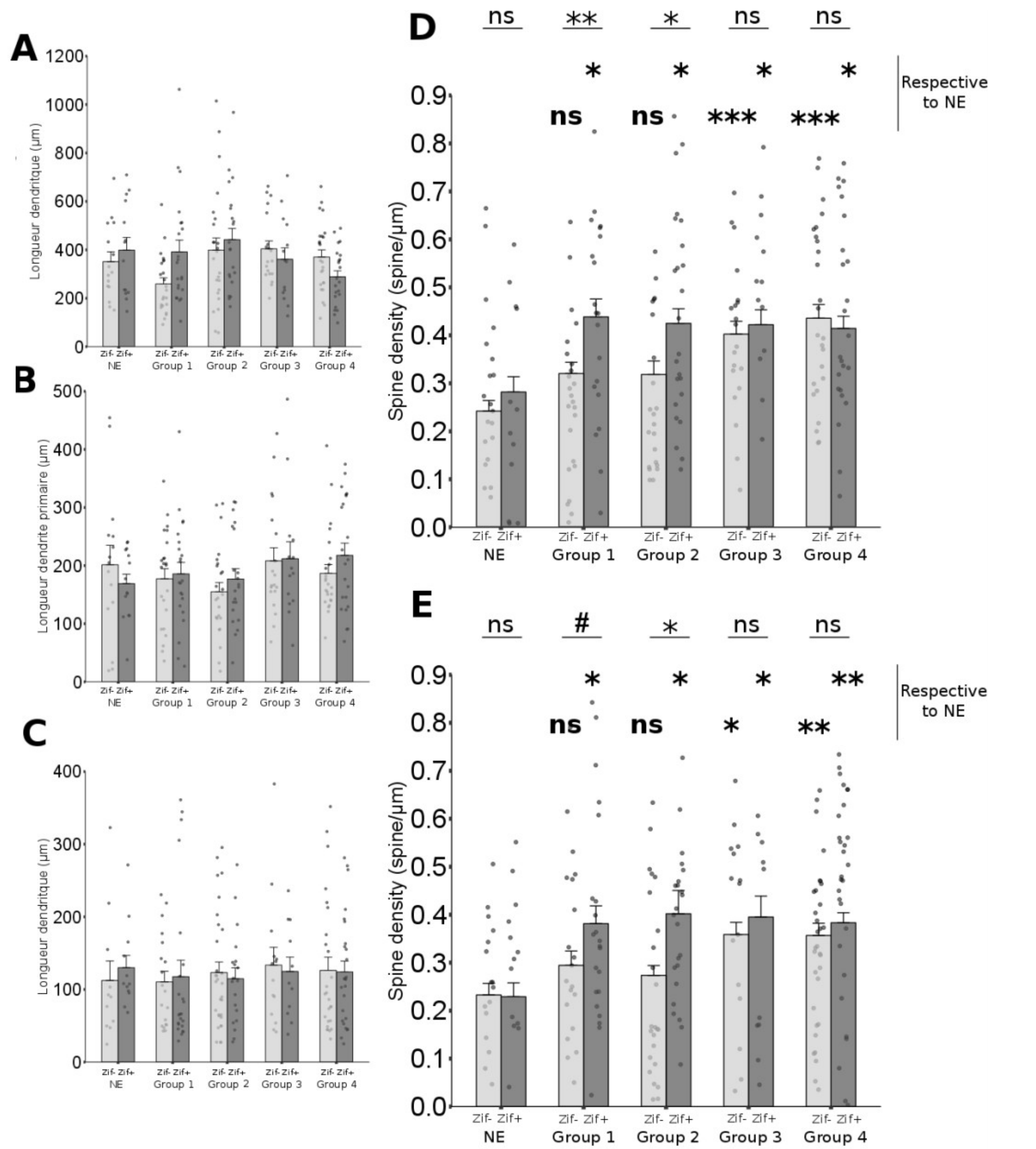




Neuronal plasticity in the olfactory bulb during simple and complex learning

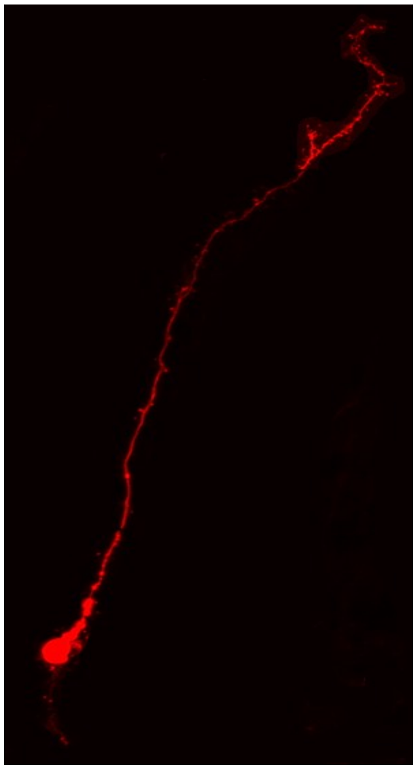
3a – Newborn neurons

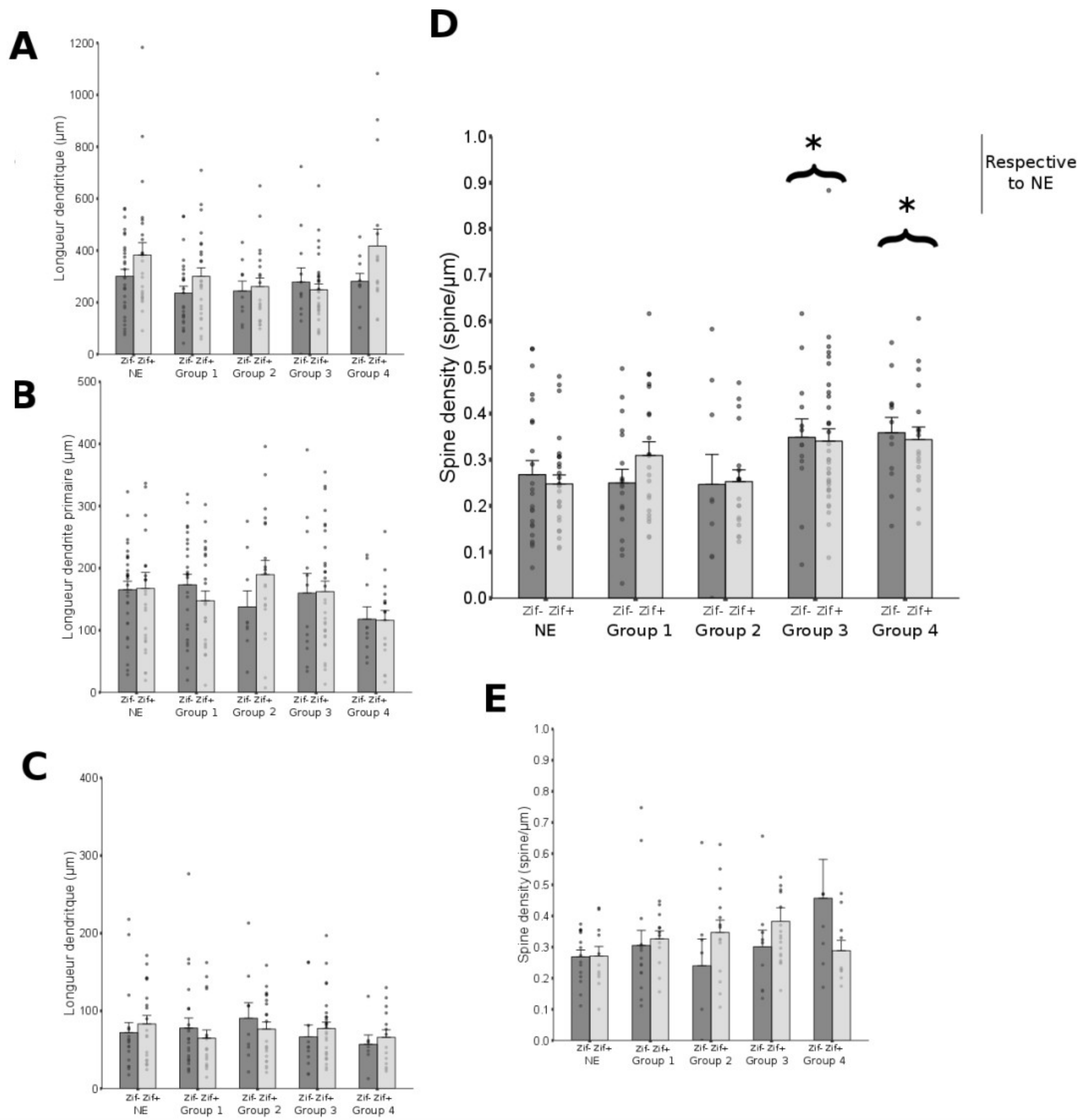




Neuronal plasticity in the olfactory bulb during simple and complex learning

3b – Preexisting neurons





Neuronal plasticity in the olfactory bulb during simple and complex learning

Conclusion

Neuronal plasticity in the olfactory bulb during simple and complex learning

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Perceptual learning is associated with:

- Increased survival of newborn neurons independently of learning complexity

Neuronal plasticity in the olfactory bulb during simple and complex learning

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Neuronal plasticity in the olfactory bulb during simple and complex learning

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Perceptual learning is associated with:

- Increased survival of newborn neurons independently of learning complexity
- Increased recruitment of newborn neurons to the processing of the learned odorants with increased of complexity
- Increased spines density at the apical and basal domains of newborn neurons
  - For the simpler learning, only in Zif268-postive neurons
  - For the more complex learning, in both Zif268-positive and negative neurons

Neuronal plasticity in the olfactory bulb during simple and complex learning

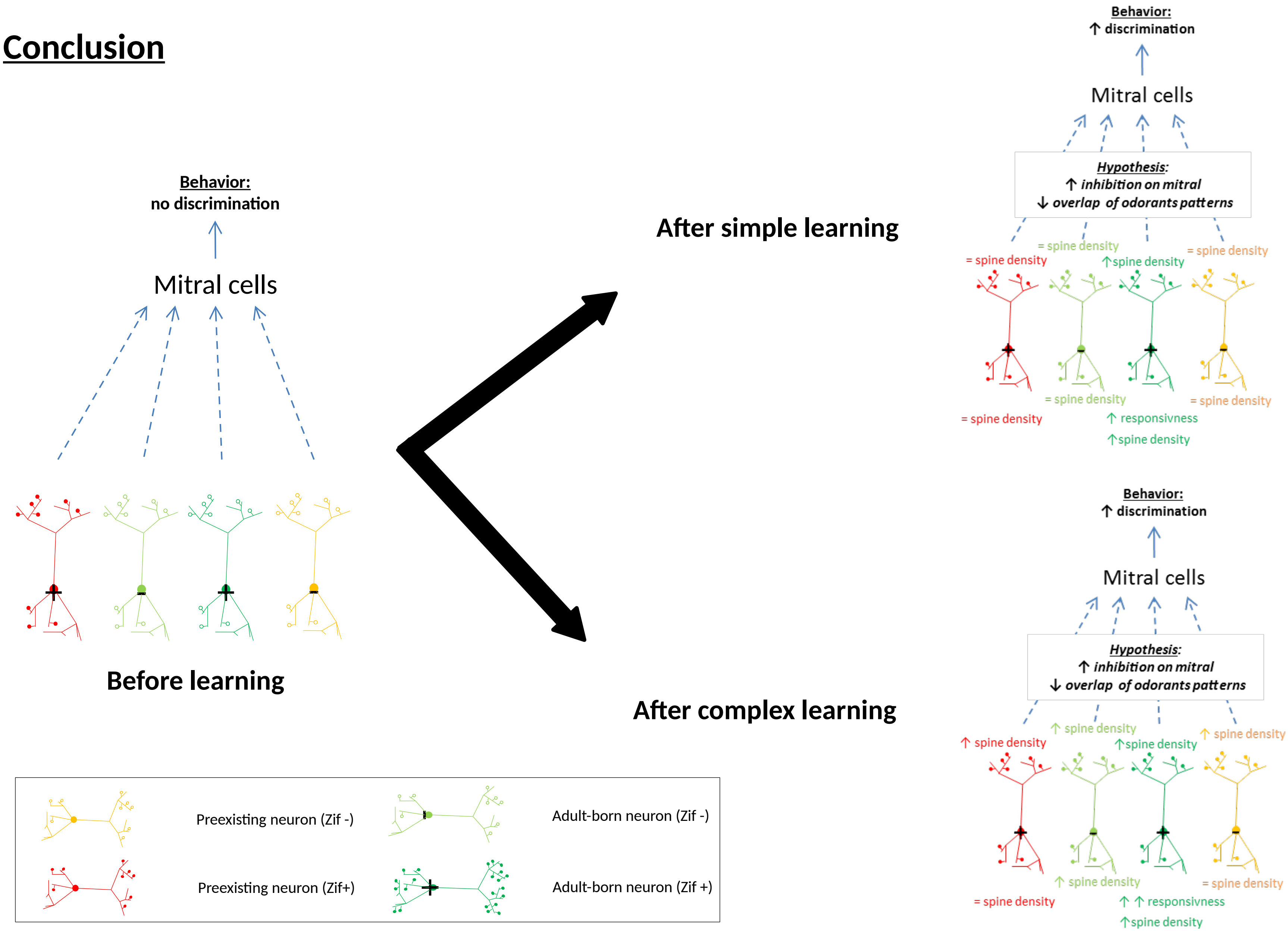
Conclusion

Perceptual learning is associated with:

- Increased survival of newborn neurons independently of learning complexity
- Increased recruitment of newborn neurons to the processing of the learned odorants with increased of complexity
- Increased spines density at the apical and basal domains of newborn neurons
  - For the simpler learning, only in Zif268-postive neurons
  - For the more complex learning, in both Zif268-positive and negative neurons
- Increase spines density at the apical domain of preexisting neurons
  - Only for complex learning and in both Zif268-positive and negative neurons

Neuronal plasticity in the olfactory bulb during simple and complex learning

Conclusion



Project at Cornell

1. Use the integrate and fire model from Licurgo's papers and implement the neurogenesis aspect.
    1. Differences between preexisting and newborn granule cells
    2. Activity regulated survival (derived from Chow's 2012 paper)
2. Implement learning rules within the OB
3. Use natural stimuli (Leon's glomeruli activation maps) to see if the model is able to decorrelate the precedent stimuli and how.
4. From the new model, derive hypothesis to be tested later on (spines type, influence of centrifugal inputs, of top-down processes …)

<u>CRNL - Neuropop Team:</u>

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- Nathalie Mandairon
- Marion Richard
- Nicola Kuczewski
- Joelle Sacquet
- Maellie Midroit
- Xuming Yin
- Claire Terrier