

# **A cellular alphabet of honeybee learning: From ion channels to memory recall**

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# Social animals have high learning capacities



- Changing environment, variable social context.
- The brain of social insects is specialized to learning
- Honeybees are a model organism for brain research!

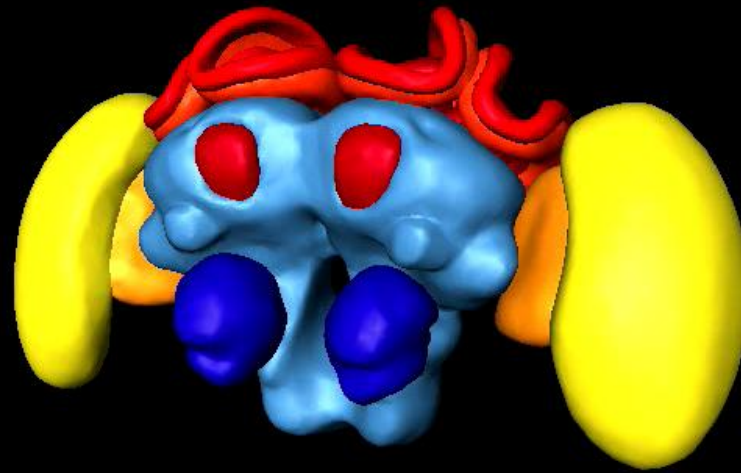


# How do we define learning?

Learning is an enduring change in the mechanisms of **behaviour** that results from **experience** with environmental events. (Domjan & Burkhard, 1985)

Learning **may** result in memory formation.

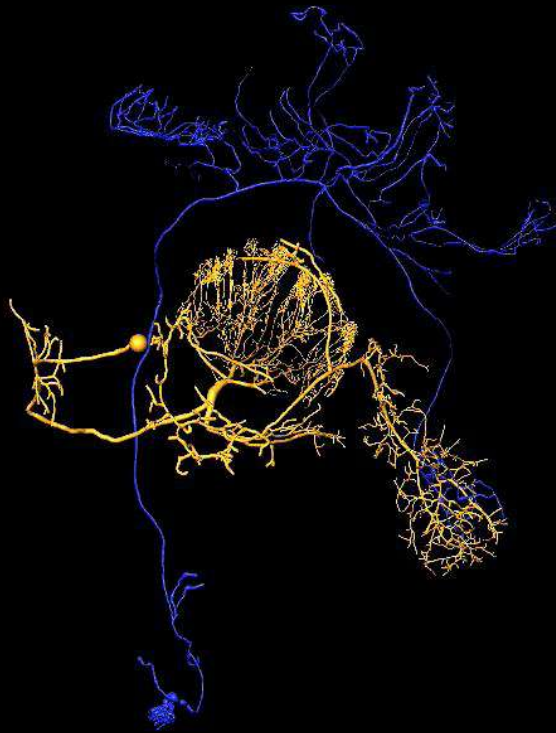




The bee brain is special...  
... It controls learning performance.



# Neural mechanisms of odor learning and memory



Projection neuron (mACT) and PE1-neuron in the 3D atlas



# Classical conditioning of the proboscis extension reflex





# The proboscis extension reflex



Conditioning: acquisition phase



# The proboscis extension reflex



Retrieval of memory: retention test



# During classical conditioning: bees learn a signal for reward



- Associative learning – link between odor and reward.
- Basic learning paradigm – found in almost all animals.
- Universal cellular mechanisms!

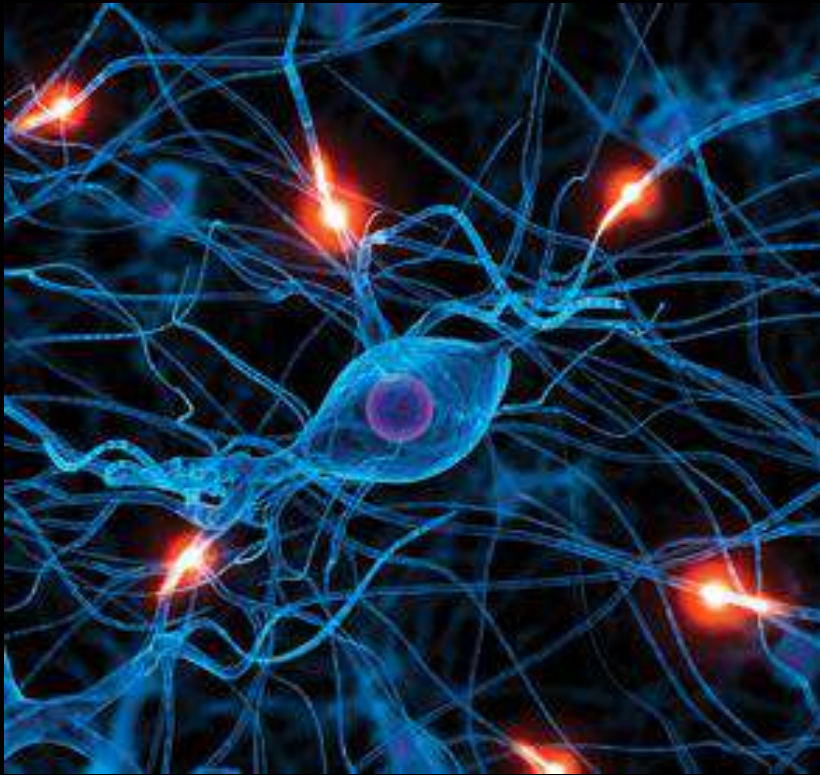


# Cellular Alphabet of Learning

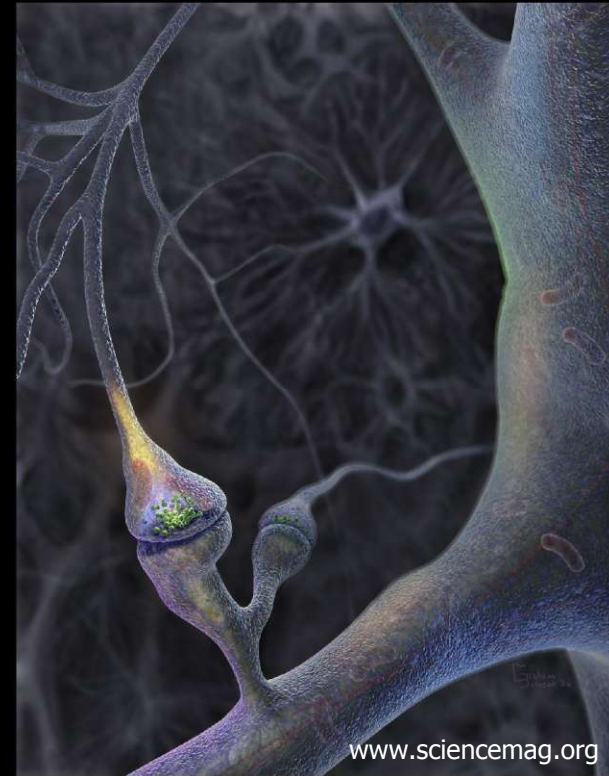
- Odor learning in honeybees
- **Cellular mechanisms of learning-dependent plasticity**



# The nerve cells in the brain translate information from the outside world into neural activity:



Electrically at axons:  
the action potential



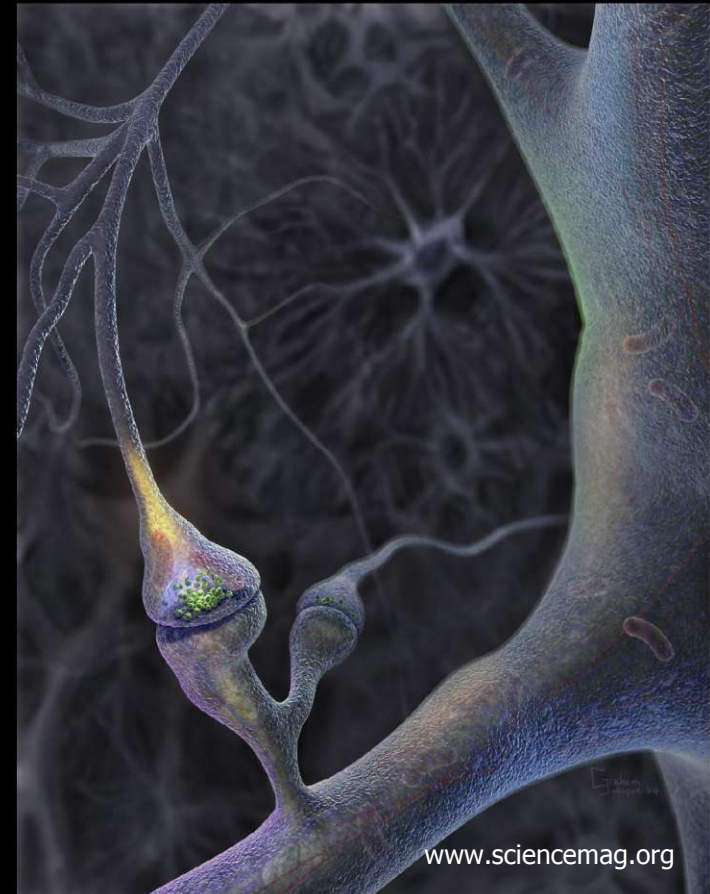
Chemically at synapses:  
neurotransmitters



# Lerning often alters synaptic transmission

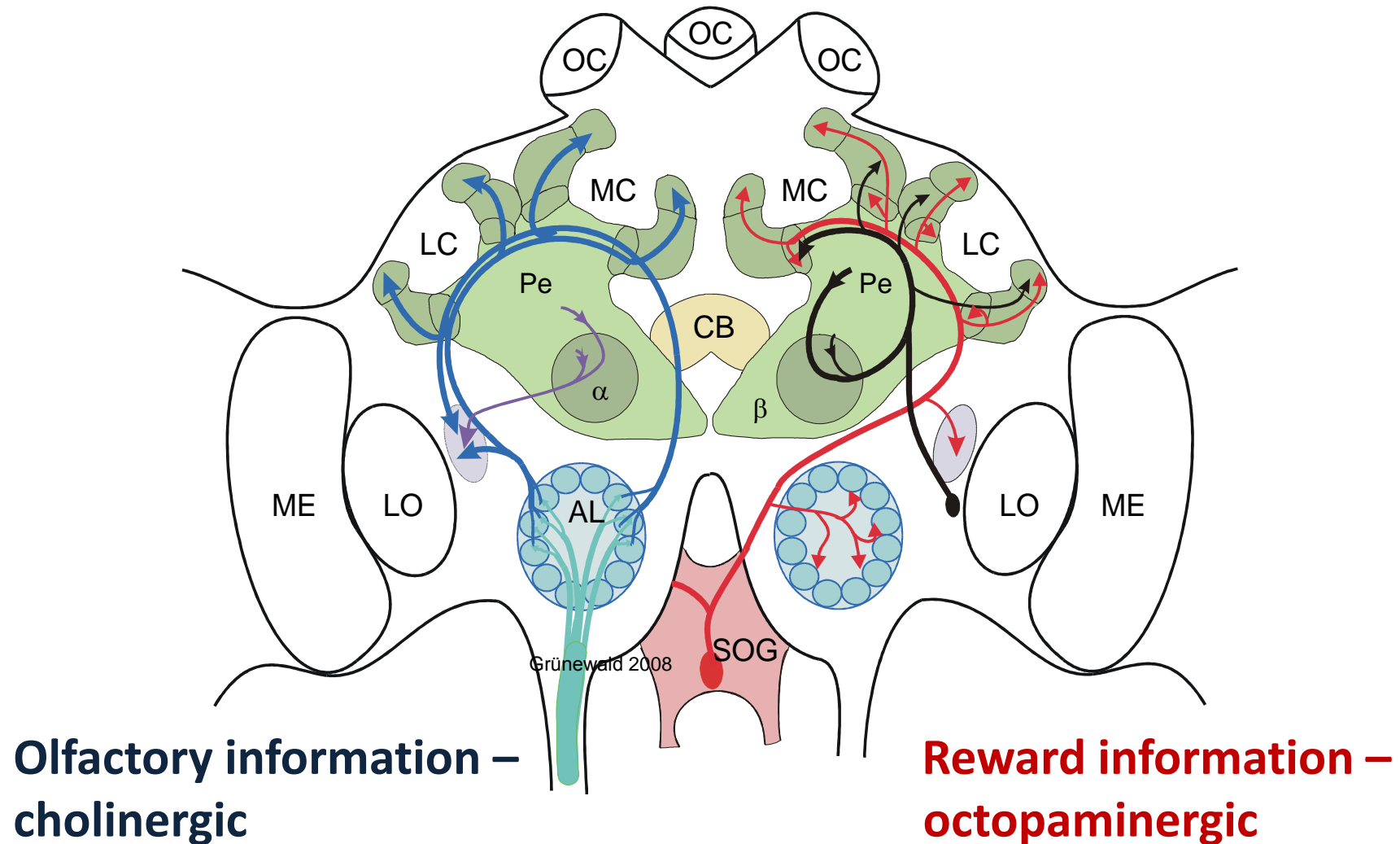
## Study of transmitter receptors in honeybees:

- Physiology
- Pharmacology
- Cellular Interaction
- **Modulation**



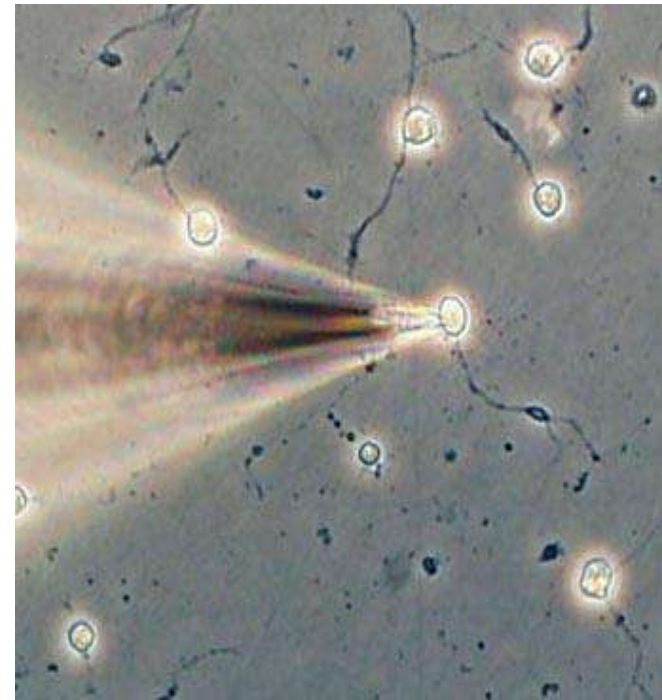
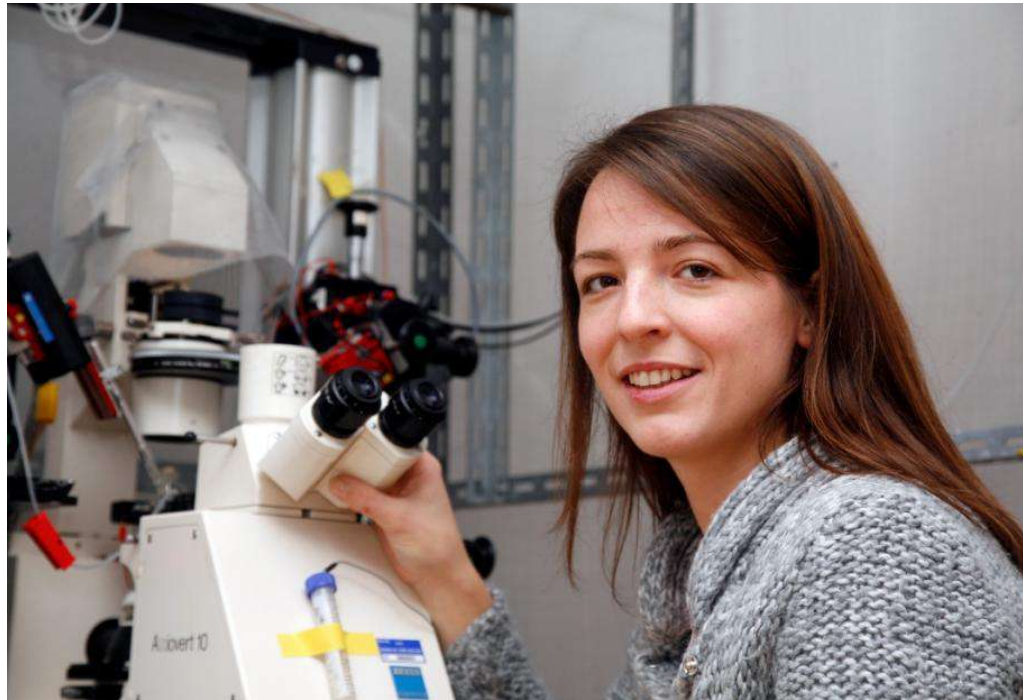


# Neuroanatomy of olfactory information processing within the honeybee brain





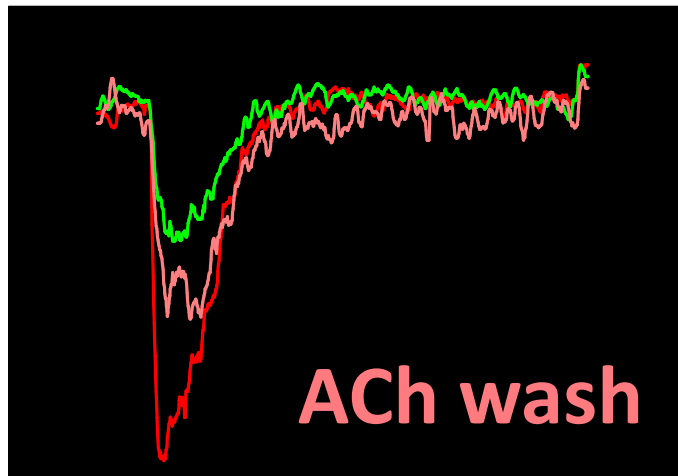
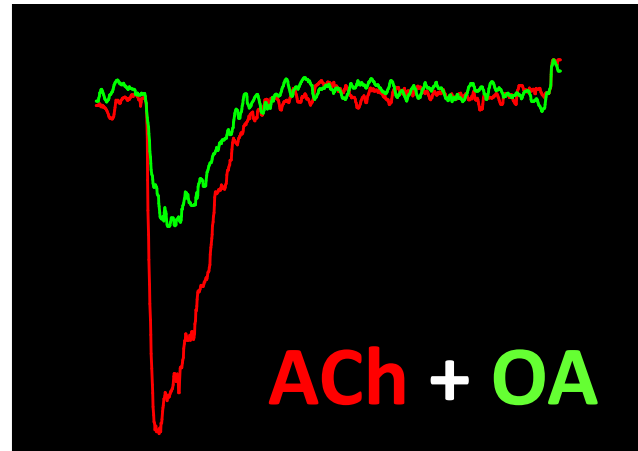
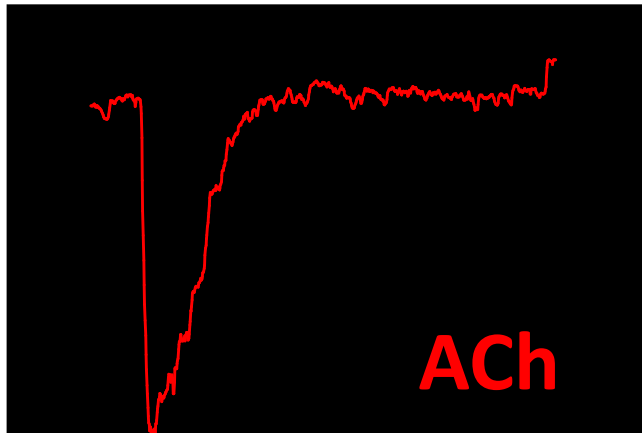
# Modulations of transmitter-gated ionic currents



- Patch Clamp Recordings and Calcium Imaging
- **Modulations by octopamine**
- Interactions between nACh and GABA receptors



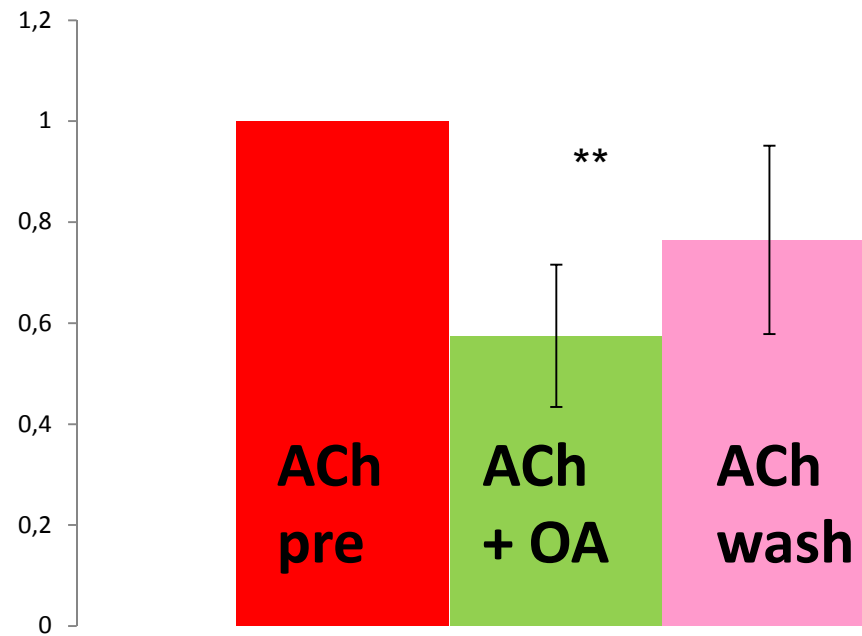
# Reversible modulation of ACh-currents by octopamine



- Antennal lobe neurons
- Bath applications of octopamine
- Reduction of ACh currents
- Partially reversible



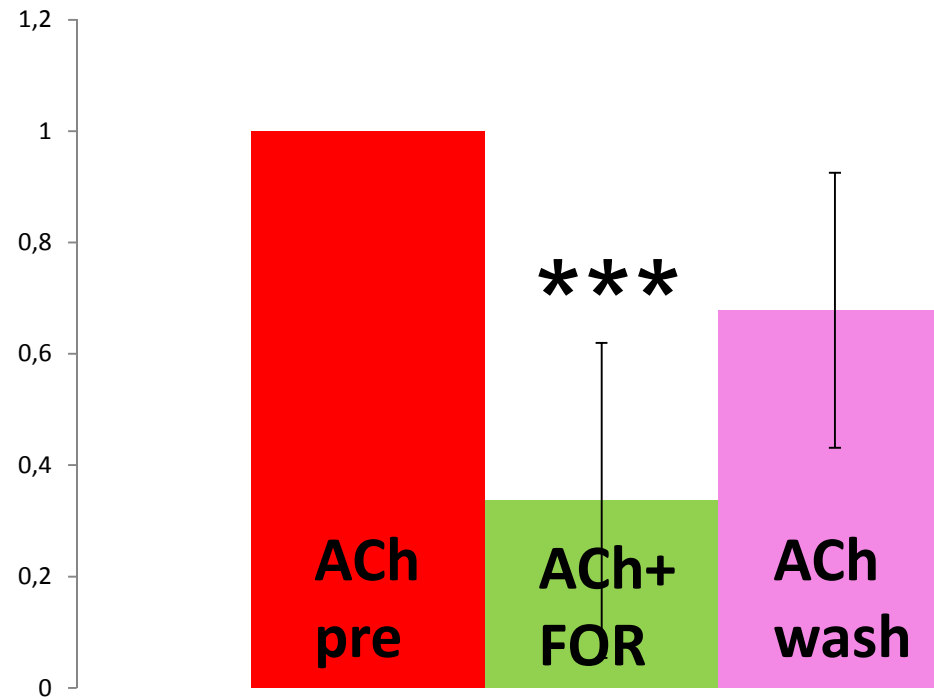
# Reversible reduction of ACh-currents by octopamine in the antennal lobe



N=9, bars = s.e.m.  
Kruskal-Wallis-Test  
\*\*p= 0.01



# Forskolin mimicks the effect of octopamine on ACh-currents of AL neurons



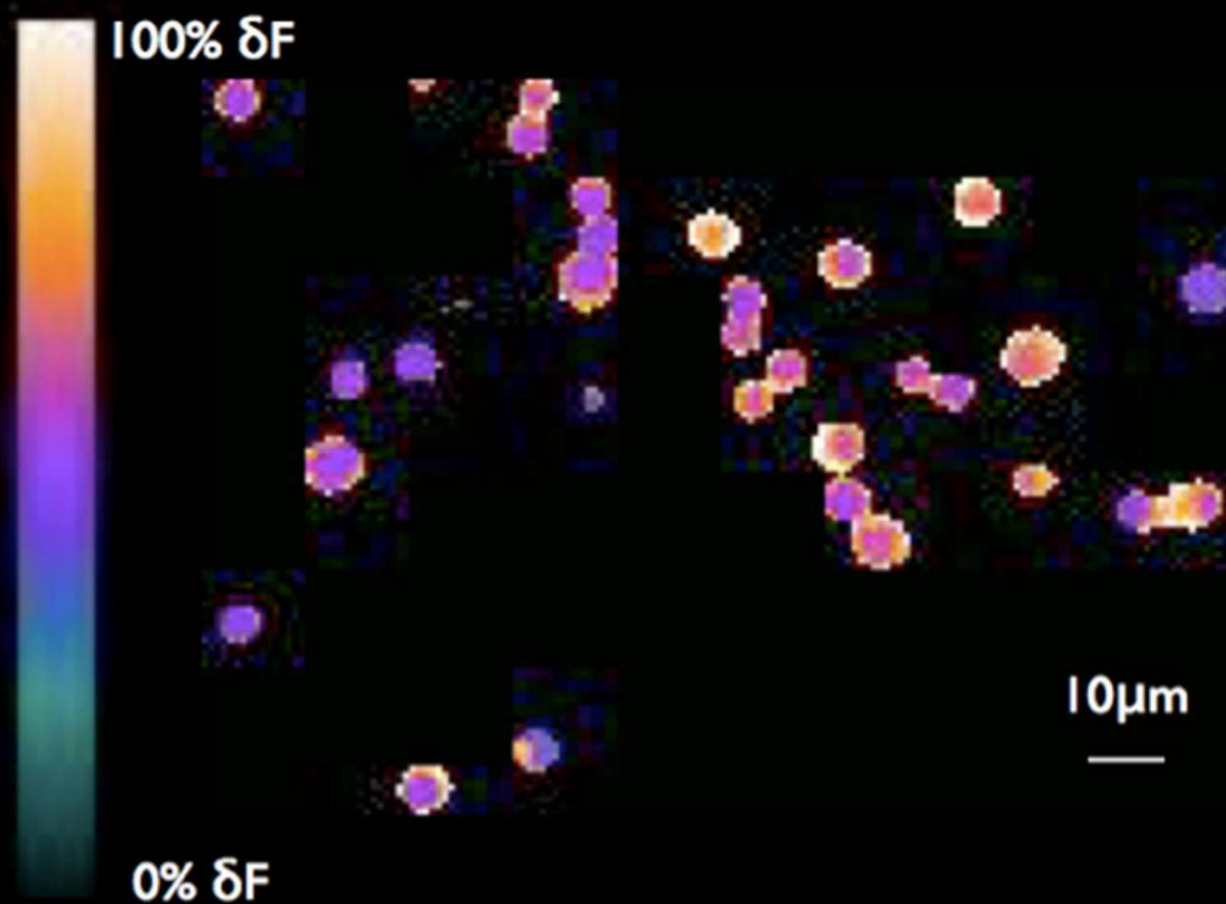
N=5 each, bars = s.e.m.

Kruskal-Wallis-Test

\*\*\* $p < 0.001$



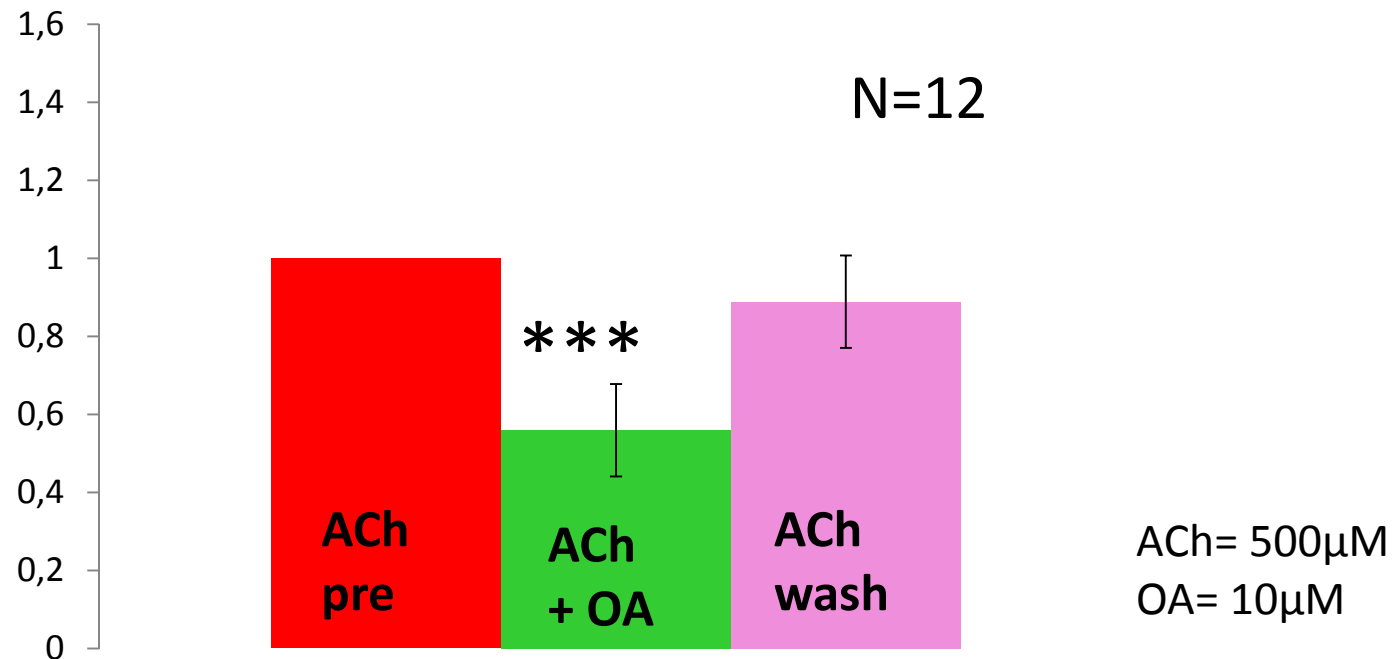
# Calcium imaging reveals similar results on Kenyon cells



10  $\mu\text{m}$   
—  
ratiometric  
measurements  
w/ Fura-2AM



# Octopamine reduces the ACh-induced calcium influx into Kenyon cells

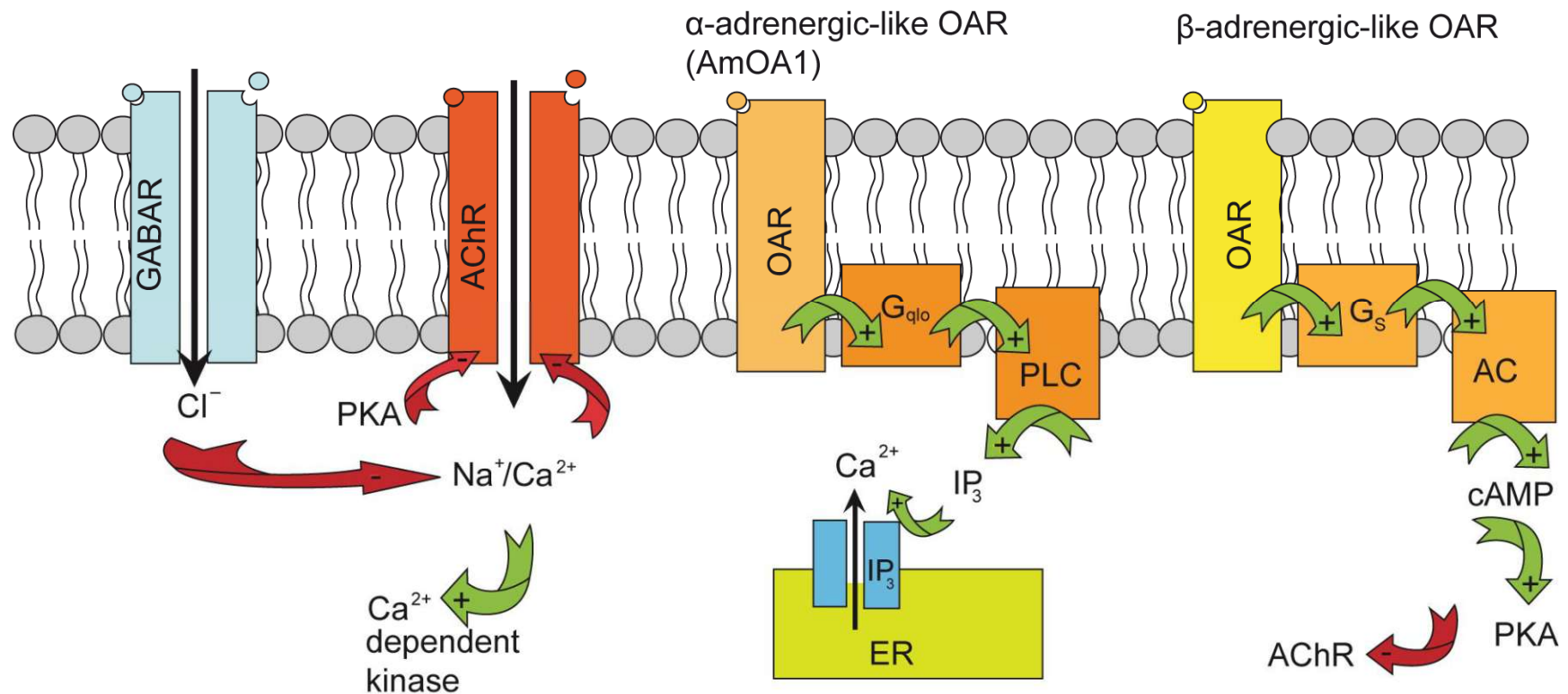


- Bath applications of octopamine or serotonin
- Reversible w/in 5 min of wash



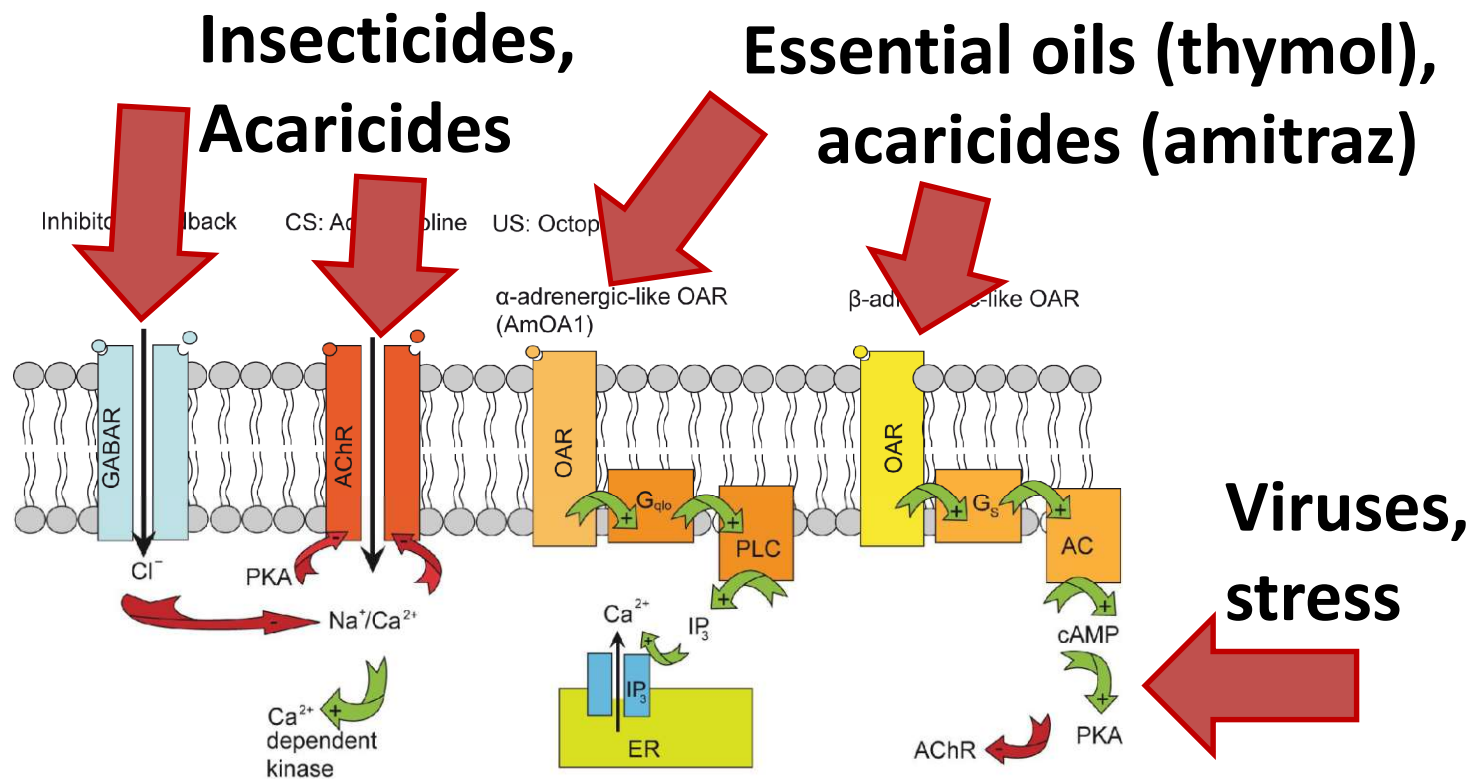
# A cellular alphabet of olfactory learning

Inhibitory feedback      CS: Acetylcholine      US: Octopamine





# Well, but what does that have to do with practical beekeeping?



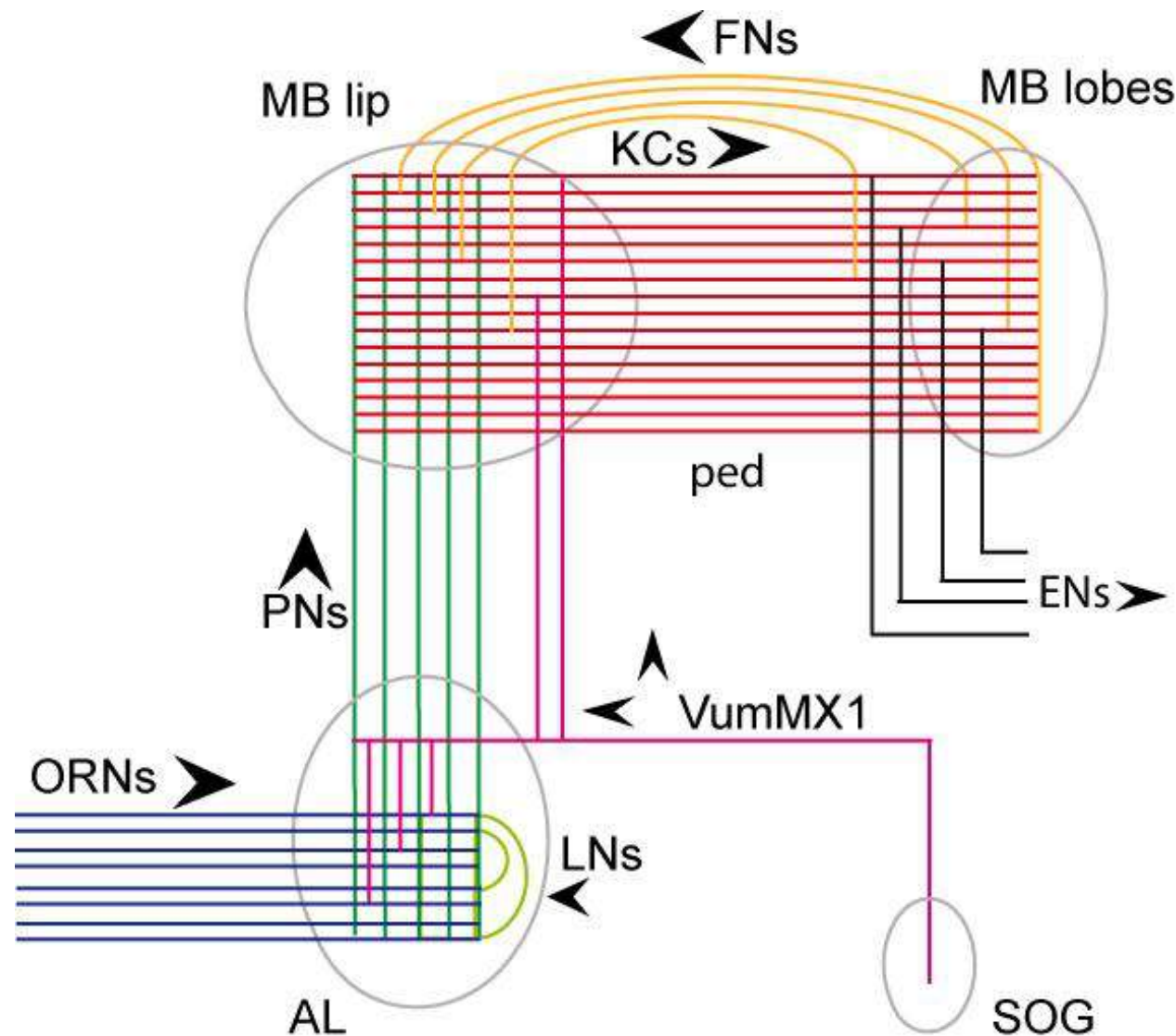




Face it Fred - you're lost.



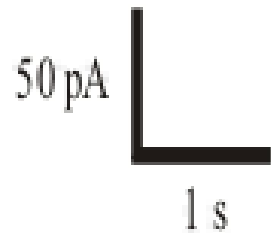
# Synaptic wiring diagram of odor learning





# Nicotinic receptors are central during memory formation

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Ionic currents through the nicotinic ACh receptor

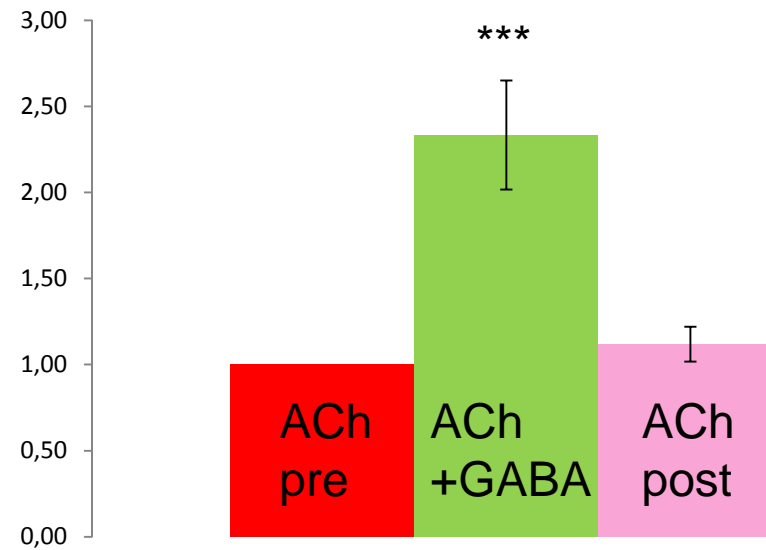


# **Cellular Alphabet of Learning**

- Odor learning in honeybees
- Cellular mechanisms of learning-dependent plasticity



Simultaneous ACh and GABA application enhance the total membrane current

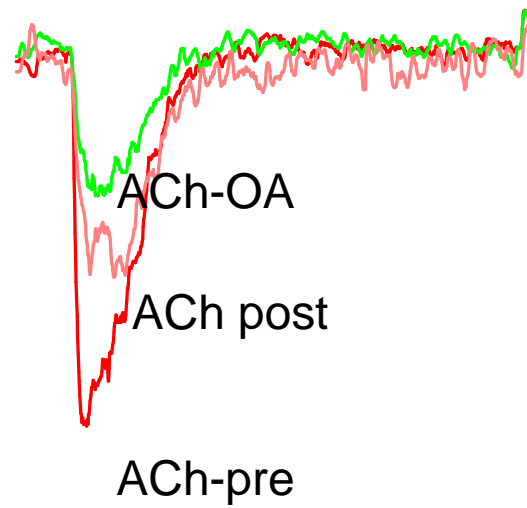


ACh= 500 $\mu$ M  
GABA= 1mM

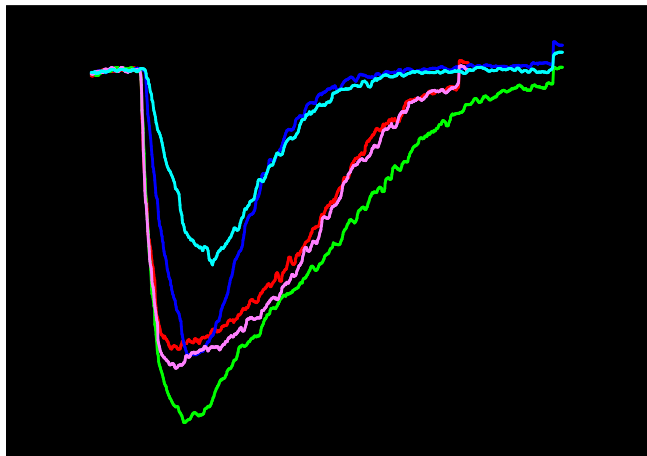
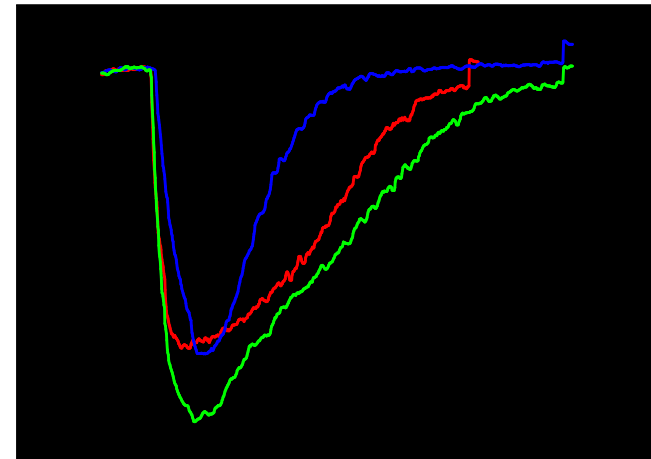
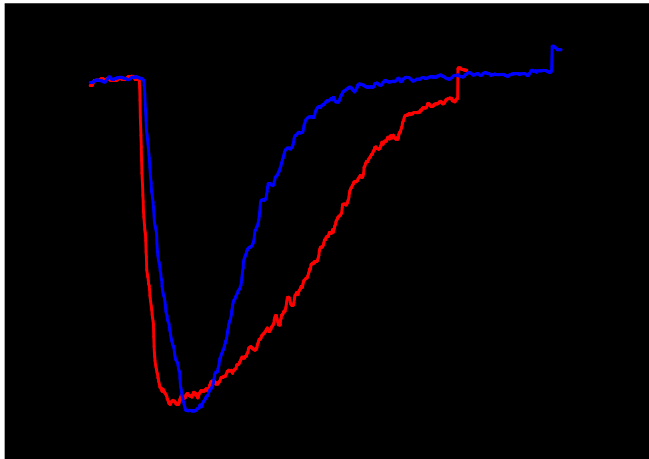


# ACH-OA- modulation

08.12.2010 IV







## GABA-modulation

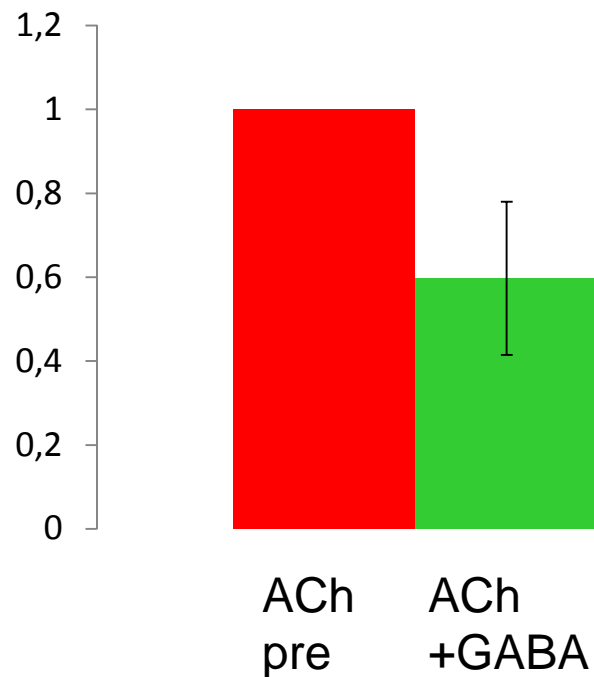
ACh rot - GABA blau –

ACh+GABA grün

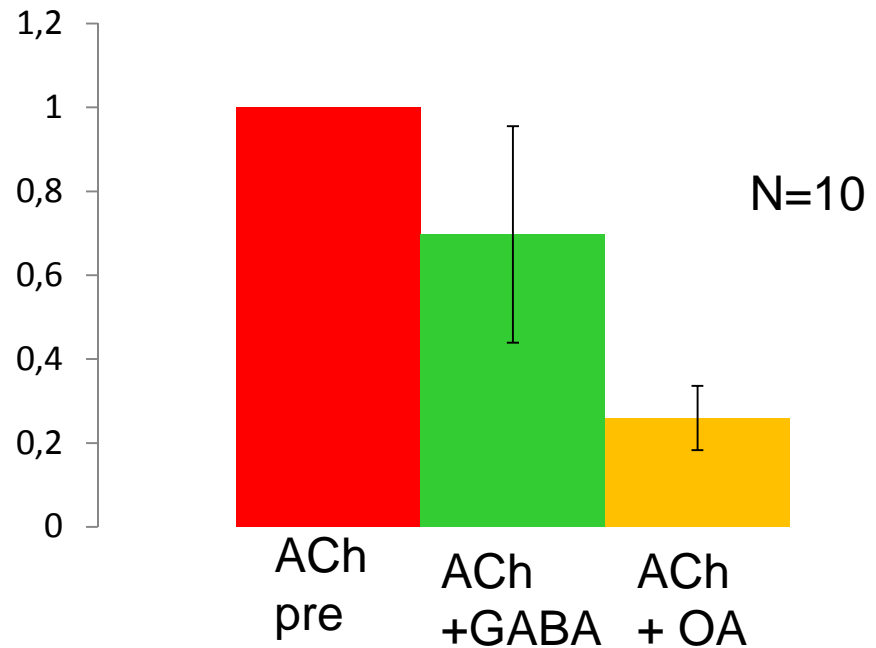
- ACh wash1 rosa – GABA wash2 hellblau



Ca<sup>2+</sup> imaging experiments show decreased Ca<sup>2+</sup> transients by simultaneous ACh-GABA KCs



Ca<sup>2+</sup> imaging experiments show decreased Ca<sup>2+</sup> transients in AL neurons



ACh= 500 $\mu$ M  
OA= 10 $\mu$ M  
GABA=1mM