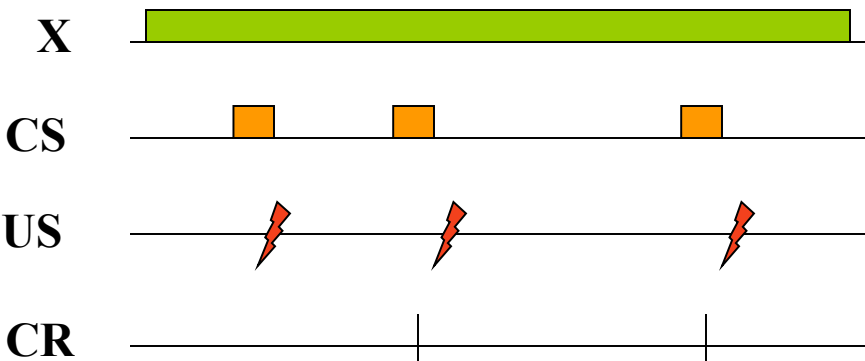


Brain mechanisms of fear conditioning

Fear conditioning: a reminder

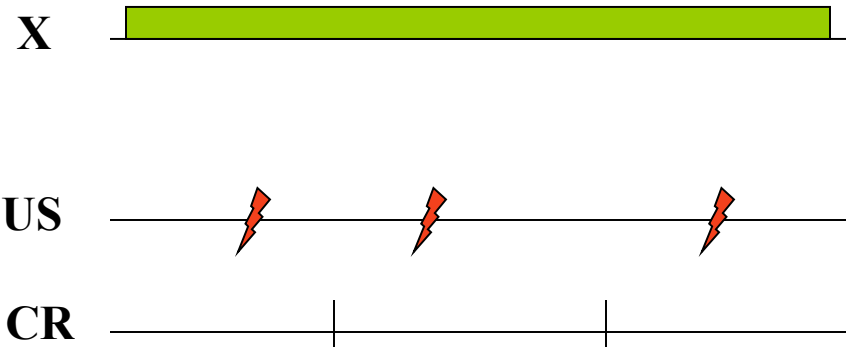
CS training procedure

Group 1 Day 1: Training

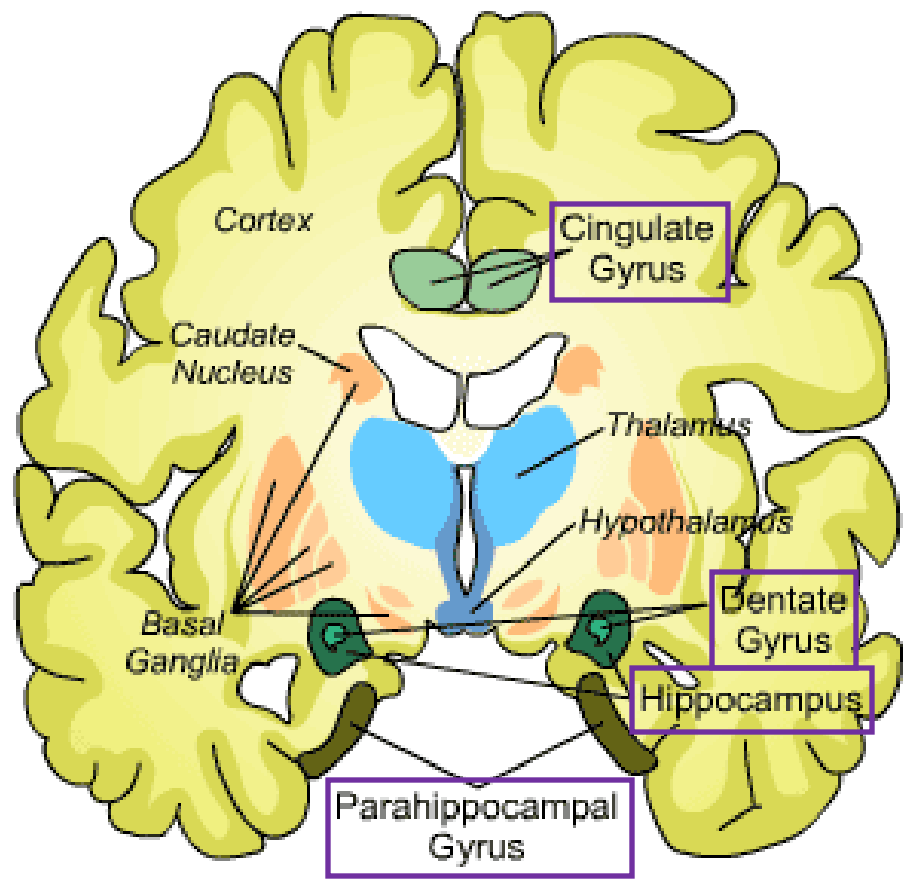
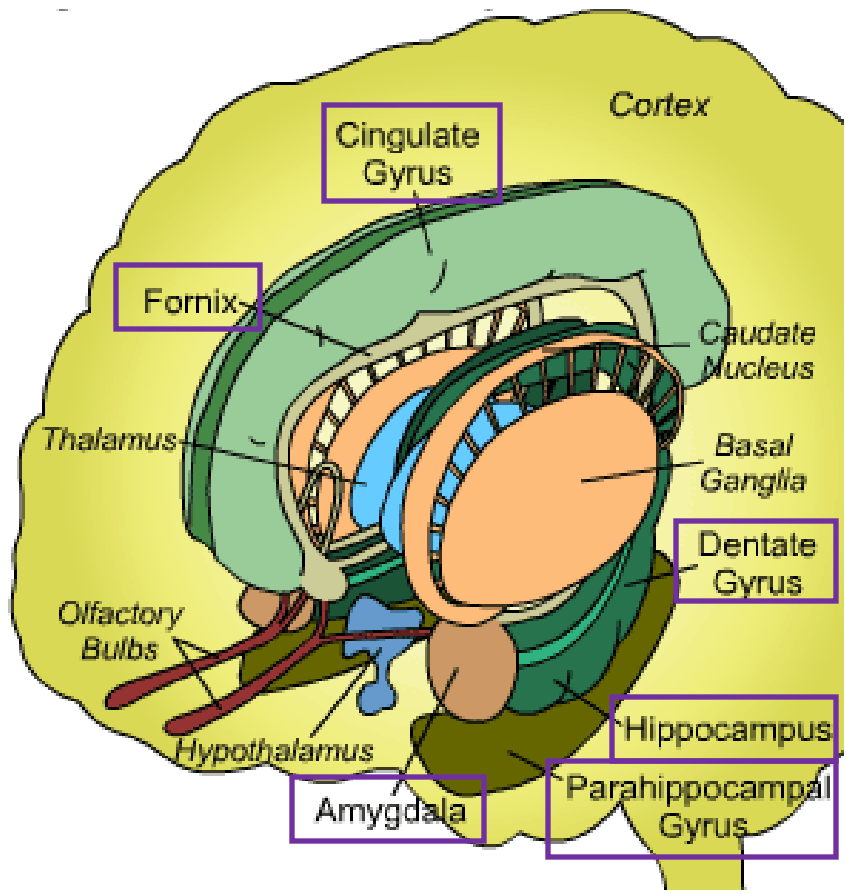


Context training procedure

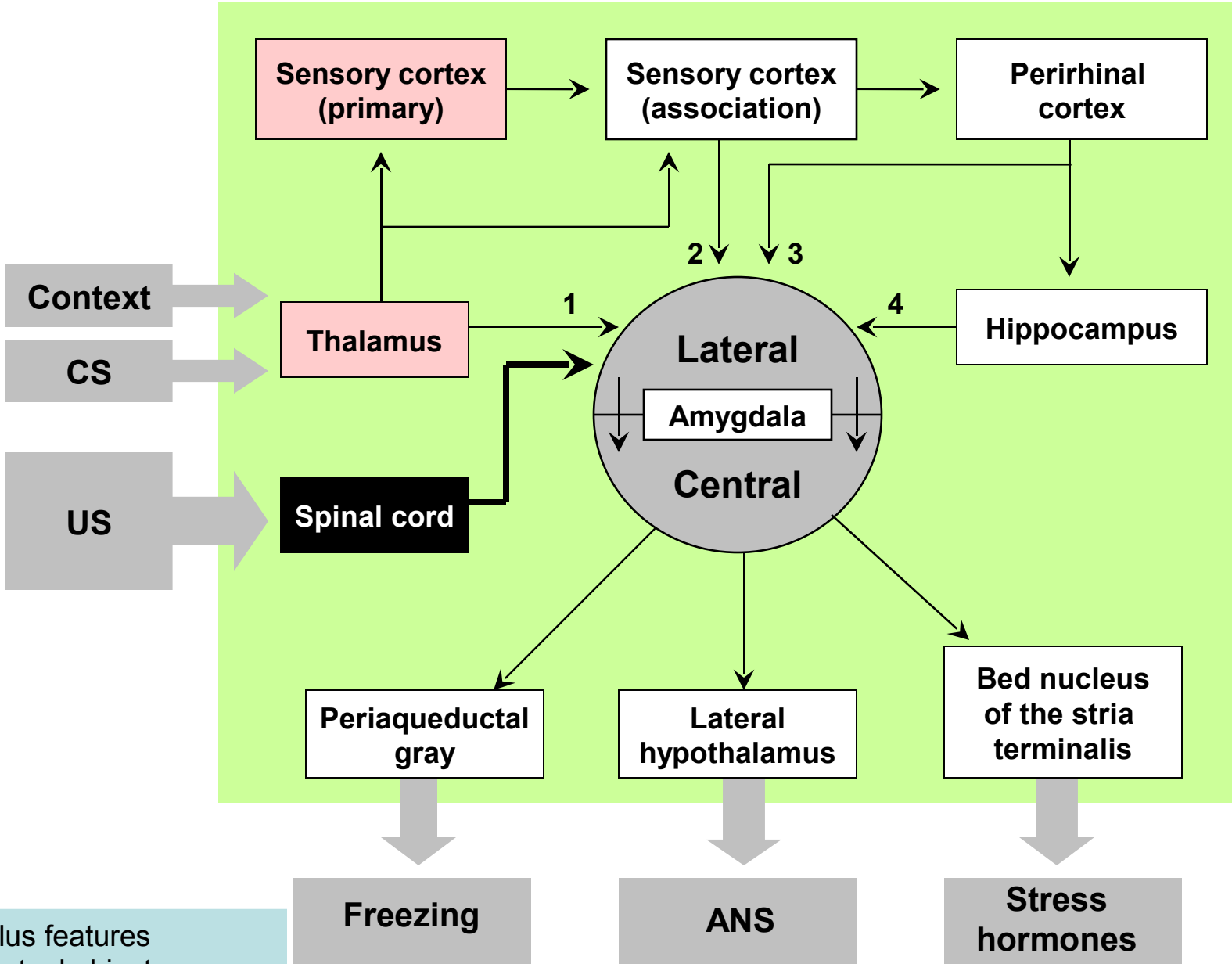
Group 1 Day 1: Training



The limbic system (human brain)

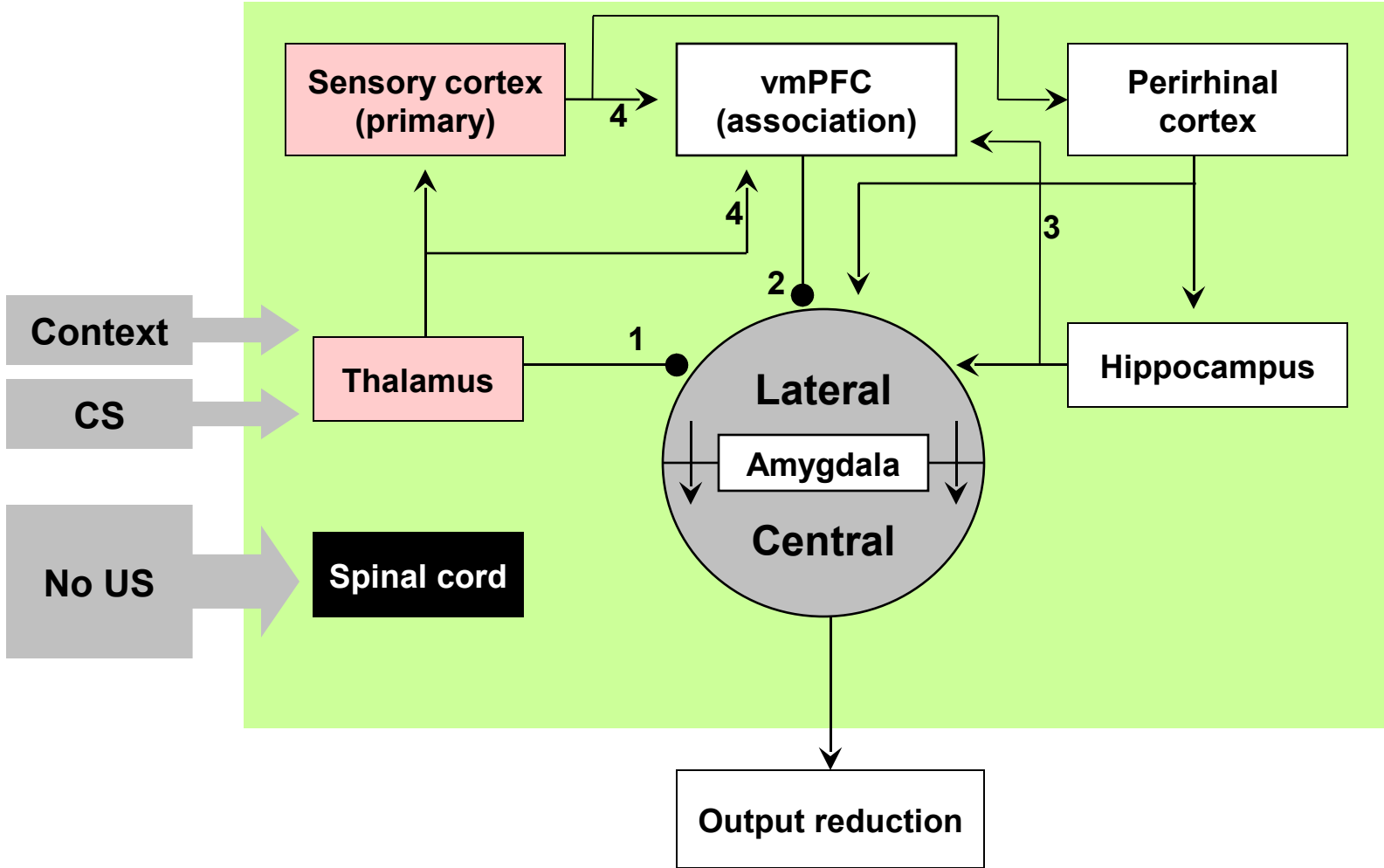


Acquisition of fear conditioning: brain circuit



- 1: stimulus features
- 2: perceptual objects
- 3: polymodal representations
- 4: context

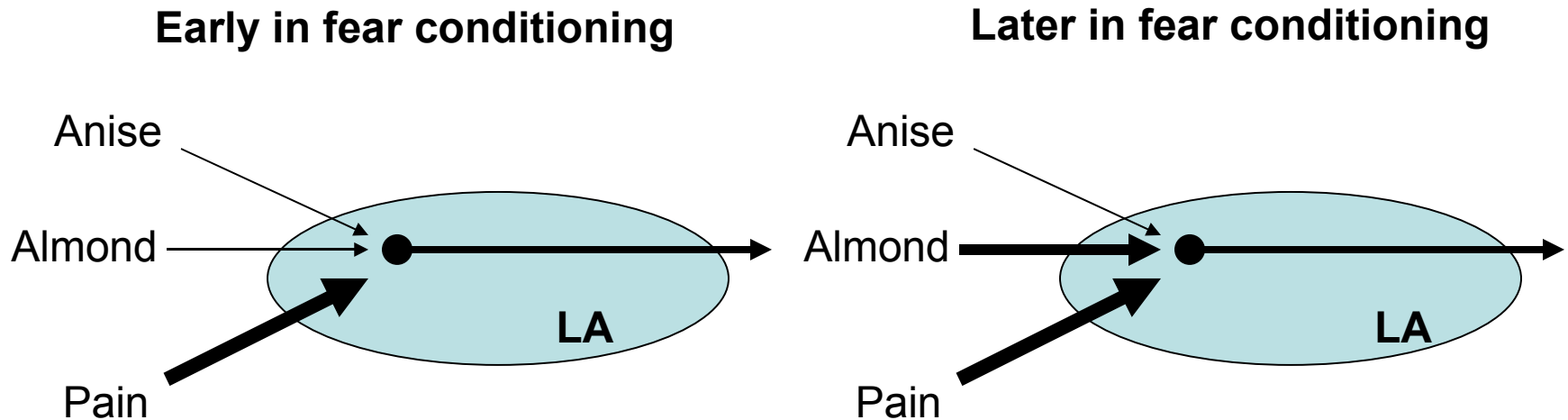
Extinction of fear conditioning: brain circuit



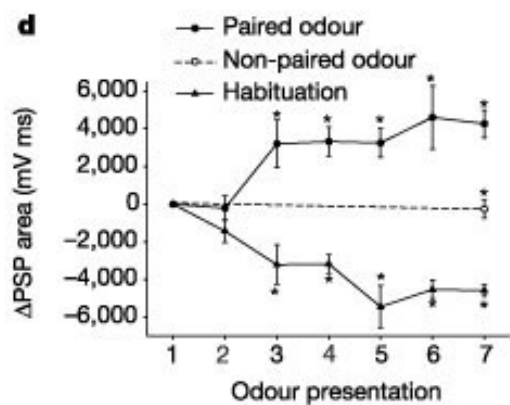
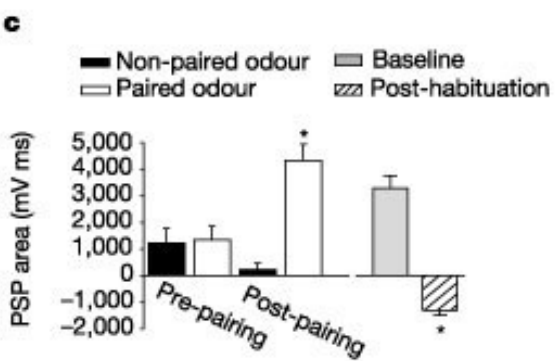
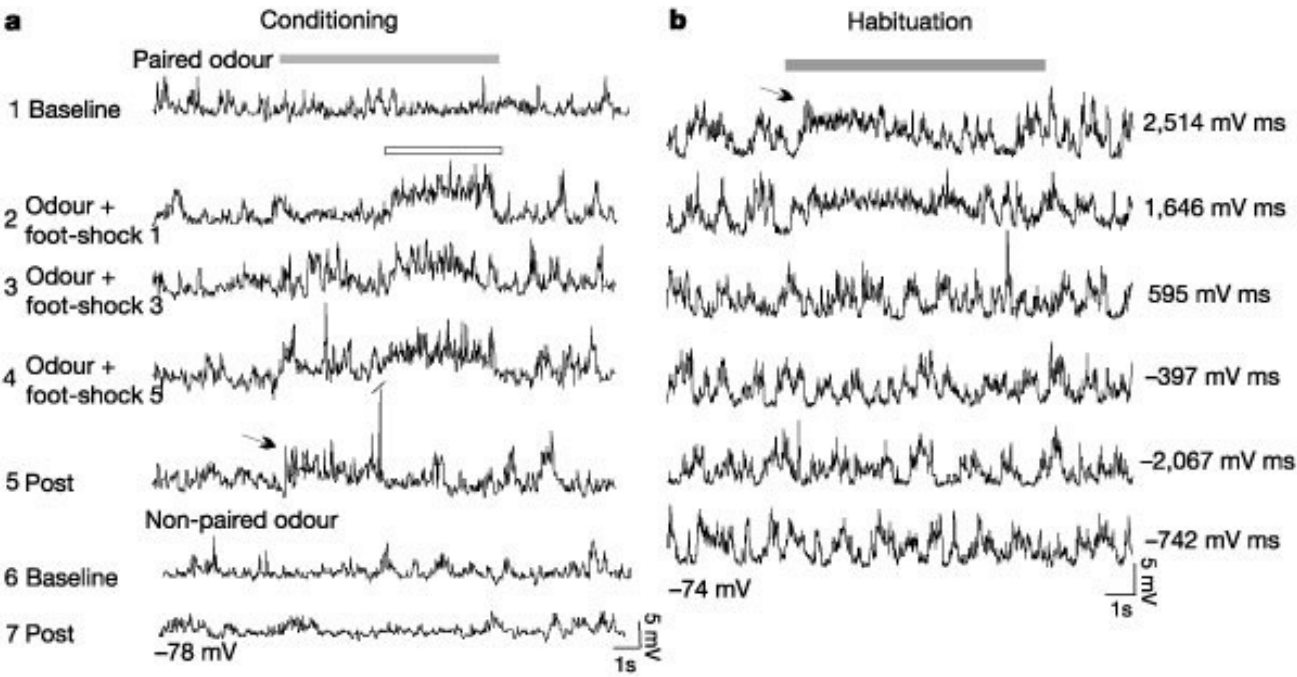
- 1: reduction in LA activity in early extinction
- 2: inhibitory input from the vmPFC, consolidation of extinction memory
- 3: hippocampal input activates vmPFC neurons
- 4: CS input activates vmPFC neurons

Cellular mechanisms of fear acquisition in the amygdala

- Rats were implanted electrodes into the amygdala.
- Unit activity was recorded during Pavlovian fear conditioning.
- Almond → Pain, Anise-only (A+/B- training).
- Unit activity was higher during A tests, than during B tests.



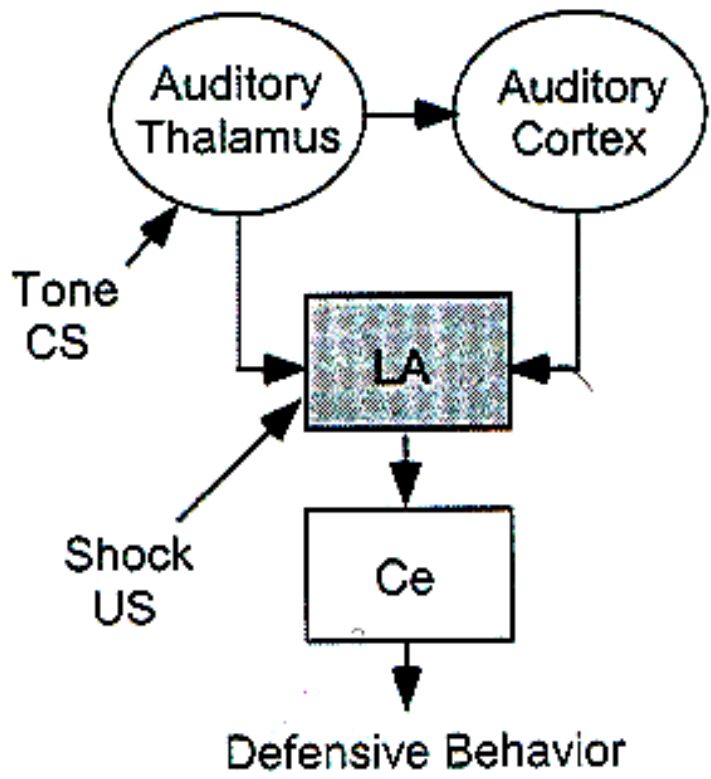
Cellular mechanisms of fear acquisition in the amygdala



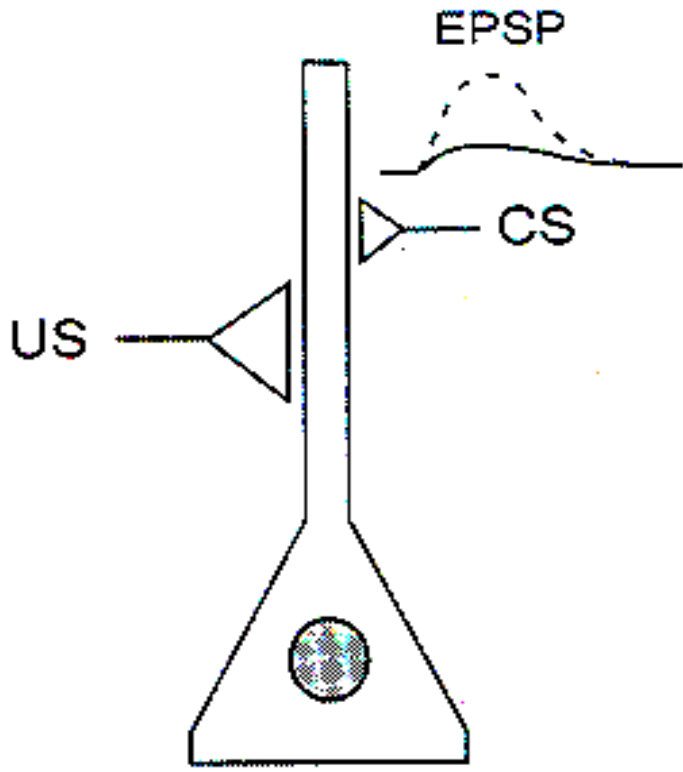
a, Before pairing an odour with foot-shocks, the odour (grey bar) does not evoke a response in this LAT neuron (1). Throughout the course of pairings of the odour with the foot-shock (white bar) a response to this odour begins to emerge, as represented by enhanced deflections of the membrane potential (2–4). After conditioning, the paired odour alone evokes a response (5, arrow), whereas the response to the non-paired odour remains minimal (6, 7). All traces of odour-evoked responses show a 5-s epoch immediately before the odour, the odour presentation itself, and approximately 5 s after odour presentation. **b**, Repeated presentation of an odour (grey bar) in the absence of a foot-shock attenuates the odour-evoked response, quantified as area under PSP, on the right (arrow indicates baseline response to odour). **c**, **d**, Foot-shock-paired odours evoke significantly greater responses compared to their baseline response, and compared to the non-paired odour ($P < 0.01$ for both). In **d** the x axis represents the odour presentation procedure. Two consecutive odour presentations are averaged for the baseline (1) and testing phases (7). The remainder are single odour presentations. After the baseline response was determined (after 1 on the x axis) the conditioning or habituation procedures were initiated. Odours presented without foot-shock ('habituation'; triangles) display a significant attenuation of response to below baseline-response amplitude, while paired odours (filled circles) display enhancement ($P < 0.01$ both). Non-paired control odours do not significantly change (dotted line, open circles).

Cellular mechanisms of fear acquisition in the amygdala


Input convergence



Coincidence detector



Amygdala, hippocampus, conditioning, and declarative knowledge

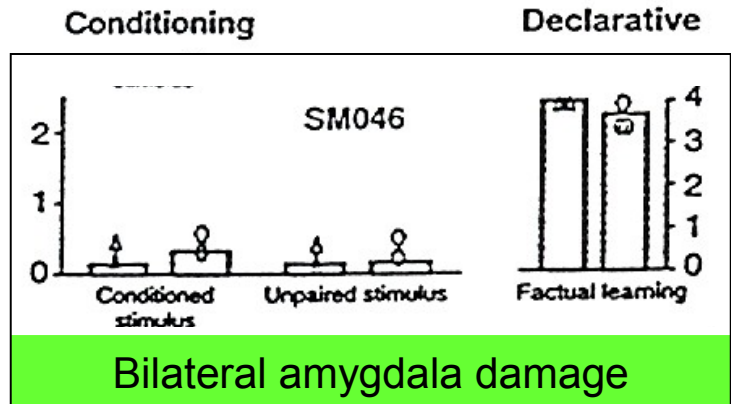
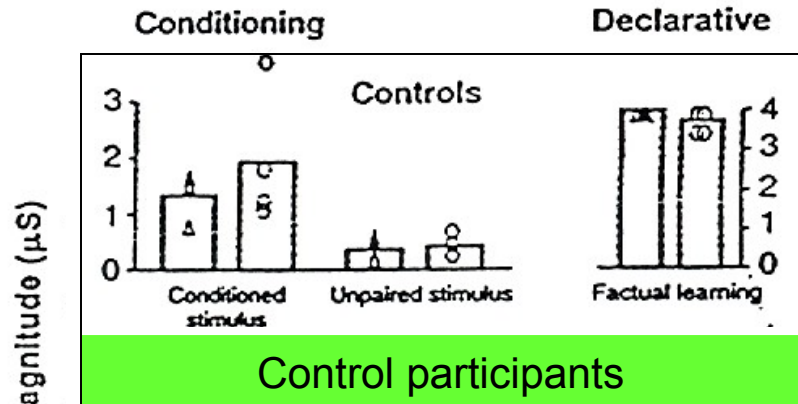
Participants	Training			Declarative knowledge
	Habituation	Acquisition	Extinction	
Amygdala lesion	<div style="border: 1px solid green; padding: 5px;"> Blue Red Yellow Green </div>	<div style="border: 1px solid blue; padding: 5px;"> Blue → Horn Red – only Yellow – only Green – only </div>	<div style="border: 1px solid magenta; padding: 5px;"> Blue – only </div> 	<div style="border: 1px solid red; padding: 5px;"> 4 questions </div>
Hippocampal lesion				
Both areas lesioned				
Controls (n=4)				

DV: skin conductance response

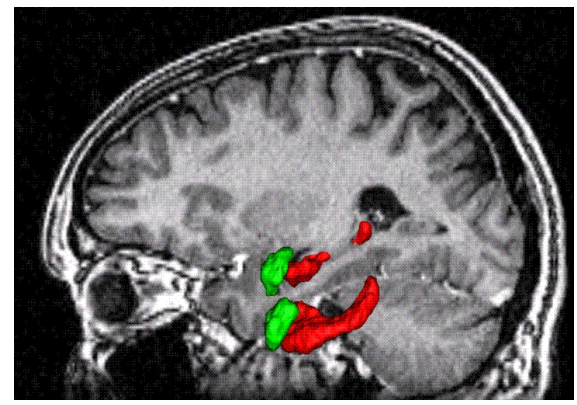
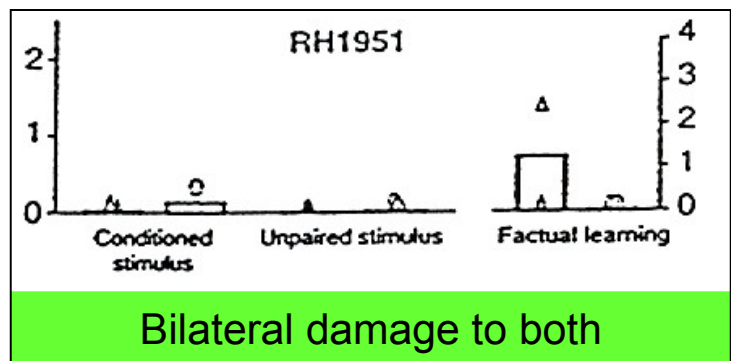
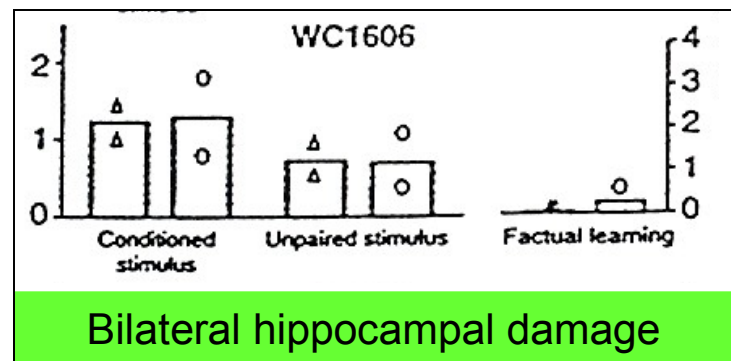
Declarative knowledge questionnaire (max score = 4):

- How many different colors did you see? (max = 0.5)
- Tell me the names of those colors. (max = 0.5)
- How many different colors were followed by the horn? (max = 2.5)
- Tell me the name (or names) of the color (or colors) that were followed by the horn. (max = 0.5)

Double dissociation data



Total score



Memory modulation: posttraining manipulations

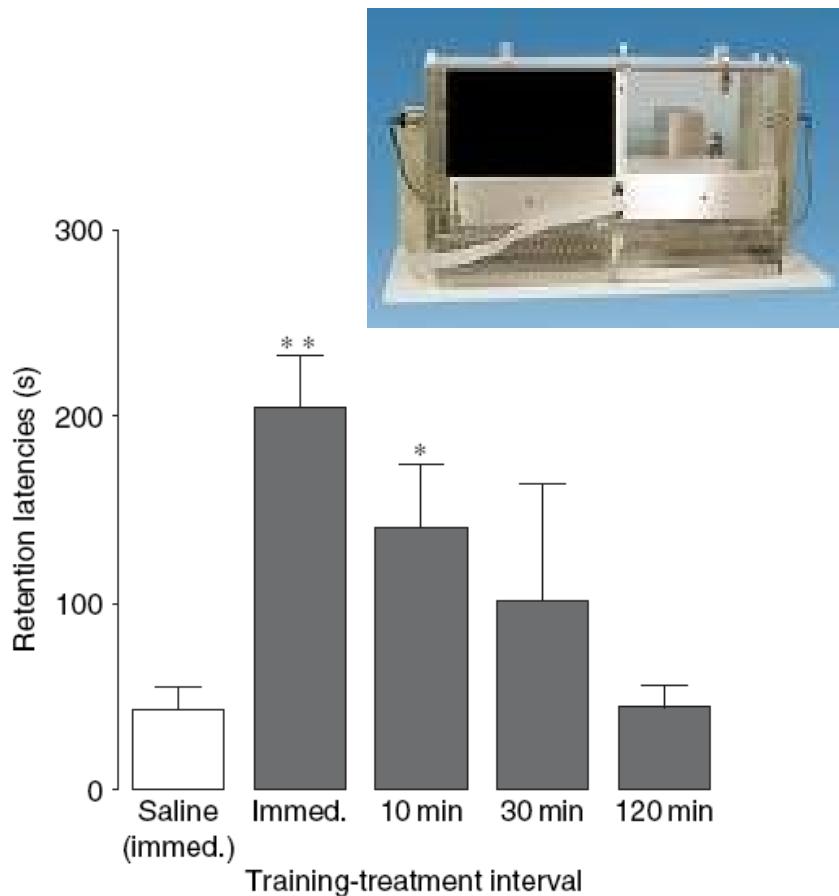


Figure 1 Posttraining systemic injection of epinephrine induces time-dependent memory enhancement. Epinephrine (0.1 mg/kg, ip) enhanced 24-h retention performance on an inhibitory avoidance task when injected either immediately or 10 min after training but was ineffective when given 30 or 120 min after training. Results represent retention latencies (mean + SEM) in seconds. *, $p < .05$; **, $p < .01$ as compared with the saline group. From Gold PE and van Buskirk R (1975) Facilitation of time-dependent memory processes with posttrial epinephrine injections. *Behav. Biol.* 13: 145–153.

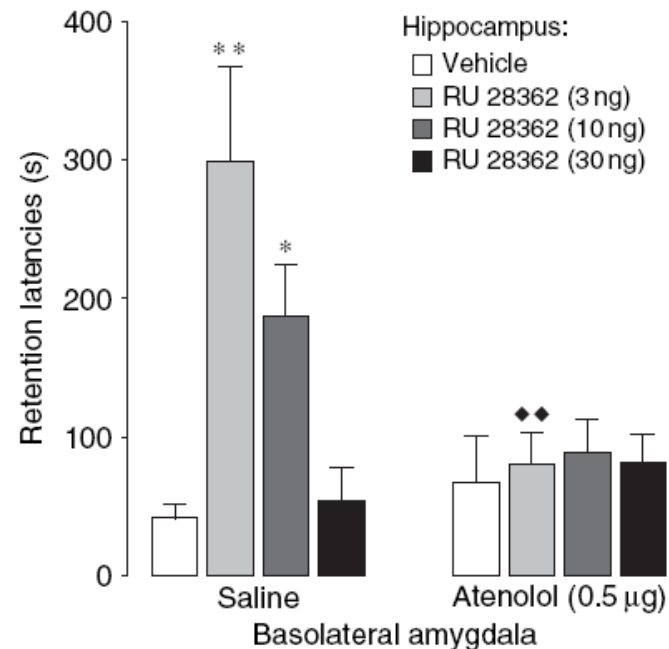
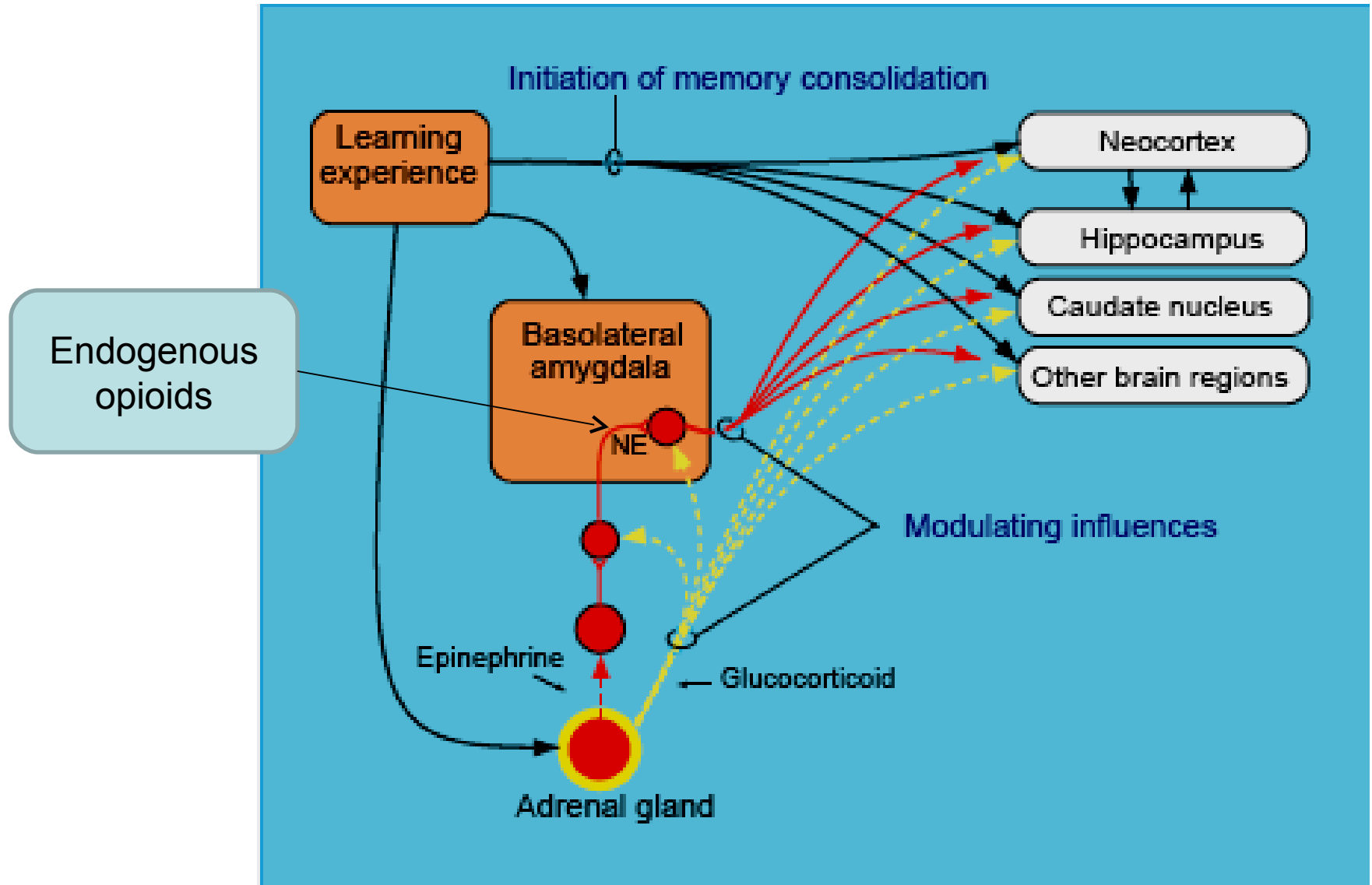
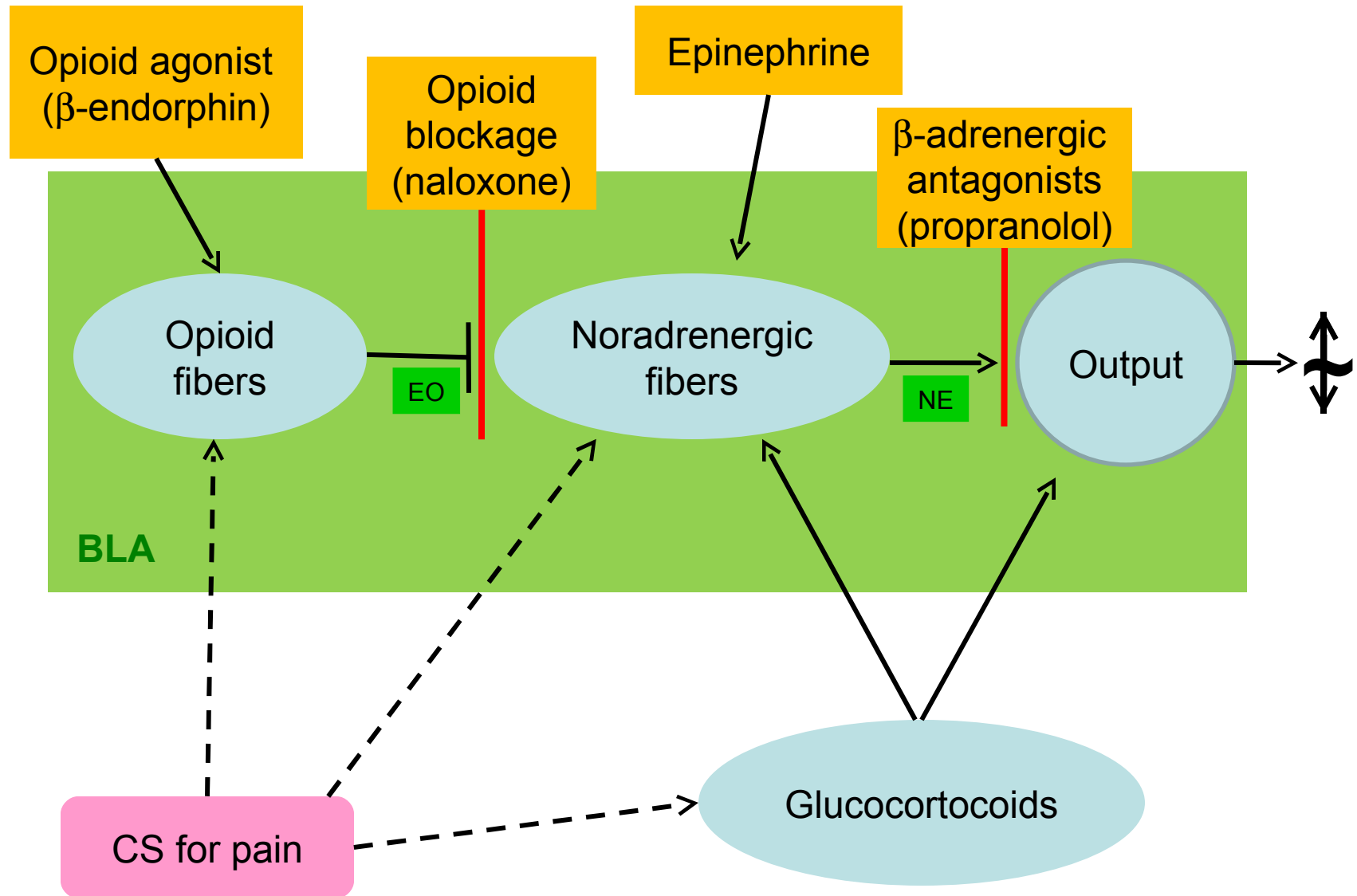


Figure 6 Glucocorticoid effects in the hippocampus on memory consolidation require noradrenergic activity of the basolateral amygdala. Immediate posttraining unilateral infusions of the glucocorticoid receptor agonist RU 28362 (3, 10, or 30 ng in 0.5 μl) induced dose-dependent enhancement of 48-h inhibitory avoidance retention latencies in rats given saline infusions into the basolateral amygdala concurrently. Ipsilateral infusions of the β -adrenoceptor antagonist atenolol (0.5 μg in 0.2 μl) into the basolateral blocked the memory enhancement induced by the glucocorticoid receptor agonist. Results represent retention latencies (mean + SEM) in seconds. *, $p < .05$; **, $p < .01$ compared with the corresponding vehicle group. ♦♦, $p < .01$ compared with the corresponding saline group. From Roozendaal B, Nguyen BT, Power A, and McGaugh JL (1999a) Basolateral amygdala noradrenergic influence enables enhancement of memory consolidation induced by hippocampal glucocorticoid receptor activation. *Proc. Natl. Acad. Sci. USA* 96: 11642–11647.

Modulation of aversive memories: opioids, stress hormones, and catecholamines



Modulation of aversive memories: opioids, stress hormones, and catecholamines



EO : endogenous opioids
NE : norepinephrine