Systems consolidation of motor memory in the cerebellar circuits

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Long-term depression (LTD) at parallel fibres (PF) to cerebellar Purkinje cells (PC) synapse is implicated in the output of PC, the sole output of the cerebellar cortex. Besides the synaptic plasticity, intrinsic excitability is also one of the components which determines the PC output. Although long-term potentiation of intrinsic excitability (LTP-IE) has been suggested, it has yet to be investigated how PF-PC LTD modifies intrinsic excitability of PC. Here, we show that pairing of the PF and climbing fibre (CF) for PF-PC LTD induction evokes long-term depression of intrinsic excitability (LTD-IE) in the cerebellar PCs from C57BL/6 mice. We also provide evidence for which this intrinsic plasticity is also required for the long-term memory consolidation. Interestingly, this intrinsic plasticity showed different kinetics from synaptic plasticity, but both forms of plasticity share Ca^{2+} signalling and protein kinase C (PKC) pathway as their underlying mechanism. While small-conductance Ca^{2+}-activated K^+ channels (SK channels) play important roles in LTP-IE, no direct implication was found in LTD-IE. By using consolidation deficit transgenic mice [Purkinje cell-specific stromal interaction molecule 1 (STIM1) knockout; $STIM1^{PKO}$], we found that these mice were not able to induce intrinsic plasticity in the cerebellar Purkinje cell (PC). Interestingly, motor learning is concomitant with synaptic and intrinsic plasticity in PC in wild-type littermates whereas only synaptic plasticity was found in $STIM1^{PKO}$. Furthermore, the absence of intrinsic plasticity in Purkinje cell was reflected to improper plasticity in its relayed neurons in vestibular nucleus (VN). Our results suggest unrevealed circuit mechanism for motor memory consolidation by which newly acquired memory would be transferred to subsequent brain region via intrinsic plasticity.