

## Sensory and Motor Systems

# Functional Recovery of a Locomotor Network after Injury: Plasticity beyond the Central Nervous System

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**Abstract**

Many animals depend on descending information from the brain for the initiation and proper execution of locomotion. Interestingly, after injury and the loss of such inputs, locomotor function can sometimes be regained without the regrowth of central connections. In the medicinal leech, *Hirudo verbana*, we have shown that crawling reemerges after removal of descending inputs. Here, we studied the mechanisms underlying this return of locomotion by asking if central pattern generators (CPGs) in crawl-recovered leeches are sufficient to produce crawl-specific intersegmental coordination. From recovered animals, we treated isolated chains of ganglia with dopamine to activate the crawl CPGs (one crawl CPG per ganglion) and observed fictive crawl-like bursting in the dorsal-longitudinal-excitator motoneuron (DE-3), an established crawl-monitor neuron. However, these preparations did not exhibit crawl-specific coordination across the CPGs. Although the crawl CPGs always generated bidirectional activation of adjacent CPGs, we never observed crawl-appropriate intersegmental phase delays. Because central circuits alone were unable to organize crawl-specific coordination, we tested the coordinating role of the peripheral nervous system. In transected leeches normally destined for recovery, we removed afferent information to the anterior-most (lead) ganglion located below the nerve-cord transection site. In these dually treated animals, overt crawling was greatly delayed or prevented. After filling the peripheral nerves with Neurobiotin tracer distal to the nerve-root lesion, we found a perfect correlation between regrowth of peripheral neuronal fibers and crawl recovery. Our study establishes that during recovery after injury, crawl-specific intersegmental coordination switches to a new dependence on afferent information.

**Key words:** CPG; dopamine; homeostatic plasticity; locomotion; spinal cord injury; crawling

**Significance Statement**

In the field of motor control, a pressing issue to resolve is how the central and peripheral nervous systems become refuned and work together to establish functional locomotor patterns after descending signals are chronically removed after injury. The work we have presented, in the medicinal leech, clarifies that central pattern generator (CPG) neural networks are highly plastic in their ability to incorporate different timing elements for their intersegmental coordination after descending-coordinating information is removed. Essentially, the crawl CPGs switch their dependence on descending-timing cues to those originating from proprioceptive neurons in the muscular body wall. Results from our experimentally tractable preparation may provide a platform to guide future studies of locomotor recovery in vertebrate animals after spinal cord injury.

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Author contributions: J.P., A.W.B., M.C.P.R., and K.A.M. designed research, performed research, and analyzed data; J.P., A.W.B., and K.A.M. wrote the paper.

# Plasticity And Recovery Of Function In The Central Nervous System

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