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「身体・脳・環境の相互作用による適応的運動機能の発現（移動知）」講演会

適応的歩行運動の神経生物学的基盤

Neurobiological basis of adaptive locomotor behaviors

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Neurobiological basis of adaptive locomotor behaviors

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A hallmark of animal locomotion is the capacity to move through complex terrains in a flexible manner. Less obvious is the ability to adapt to injury and to anticipate environmental events based on previous experience. The task of establishing the neurobiological basis for short and long-term adaptive behaviors has emerged as a major goal of contemporary studies on locomotion. A fundamental requirement is knowledge about the organization and functioning of central pattern generating networks, and how these networks are modulated by sensory inputs and by internal signals related to previous experience. Investigations on the lamprey, and recent studies on neonatal rodents, have yielded considerable insight into the functional properties of central pattern generators in vertebrates. Emerging molecular genetic approaches in mice aimed at modifying the properties of specific classes of interneurons in the spinal cord hold considerable promise for further advances.

The basis of short-term adaptation of locomotion in variable environments depends on visual, proprioceptive and cutaneous signals modifying pattern-generating networks to adapt movements to changes in the environment. Over the past 20 years we have gained considerable knowledge about how these signals actually regulate pattern-generating networks. Proprioceptive feedback is used to control the timing of the major phase transitions in limb and body movements in many locomotor systems, and to control the magnitude of ongoing motor activity within a single phase. For example, in the walking system of the cat positive feedback from force sensitive afferents in the ankle extensor muscles contributes significantly to the activation of these muscles. Furthermore, the transition from stance to swing depends on a reduction in force in these muscles near the end of the stance phase. The transition is facilitated by signals from hip afferents activated during the stance phase.

Gaining a full understanding of the complex, flexible interactions between the sensory and motor systems, limb and body mechanics, and the environment requires computer simulations combining all these elements in a realistic manner. Neuro-mechanical simulations of the walking systems of insects, cats and humans, and the swimming system of the lamprey, have been developed and are currently being used to test specific hypotheses about the neuronal and mechanical events underlying locomotion.

Obstacle avoidance is another essential function of locomotor systems. In walking mammals this depends primarily on visual signals guiding leg movements in an appropriate manner. For some time we have known that descending signals from the motor cortex enhance leg flexion when cats use vision to step over obstacles in their pathway. Recently we have found that the memory of obstacle location can be retained for many minutes and used to guide leg movements to avoid the obstacles. Lesion studies and single unit recording from the parietal cortex of walking cats have begun to establish the cortical mechanisms associated with the memory of the location of obstacles relative to the body.