Neurologic Physical Therapy at the Nexus of Recovery, Restoration, and Regeneration

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In the later years of the 19th century, a good deal of evolutionary theory was grounded in zoologist Ernst Haeckel's premise that "ontogeny recapitulates phylogeny,"[1] the idea that human embryonic development mimics the biological evolution of the species. While the veracity of this theory was debated for much of the 20th century, it was finally laid to rest in 1977 with the publication of Stephen Jay Gould's *Ontogeny and Phylogeny.*[2] Gould showed that while ontogeny does not really recapitulate phylogeny, variations in the timing and rate of development are essential to the evolutionary process of adapting to the environment through natural selection.

In our own world of neurorehabilitation, there has been a similar evolution in our understanding of the process of neural recovery and functional restoration. Prior to the 1980s, it was widely believed that functional restoration in individuals with neuropathology required recapitulation of the neurodevelopmental sequence of motor behaviors observed in the typically developing child.[3] This theory was based on a hierarchical model of motor control in which phylogenetically simple behaviors, such as reflexes, were replaced with more complex movements over the course of motor development. With our present understanding, it is clear that motor behavior emerges not from an inefficient, immutable, and unidirectional heirarchy of control, but rather from a flexible, distributed system wherein interactive control is coordinated among subsystems.[4]

As with evolutionary biology, experience is a critical and compelling force driving normal development. Animals deprived of normal experiences during the critical periods of system development never develop the capacity for normal function in that system. As an illustrative case, the 1981 Nobel Prize in Medicine was awarded to David Hubel and Torsten Wiesel, whose work included a demonstration that kittens deprived of vision in one eye during the critical period of visual system development never developed normal binocular vision.[5] While all the necessary structures were in place, the necessary functional development of the cortical binocular cells failed to occur in the absence of visual experience. As is true with normal development, functional restoration of motor control following neuropathology also requires exposure to the requisite experiences. The emergence of task-specific training as a focus of rehabilitation interventions[6] shifted attention away from the postural sequences to the learning experiences provided by the environment in which one moves. Happily for neurologic physical therapists, the timeframe over which these forces have their influence on motor control is much shorter than the timeframe for driving evolution. Also happily and unlike evolutionary environmental influences, we have the capacity to structure the movement experiences to which our patients are exposed.

Over the years, the pages of *JNPT* and other neurology-related rehabilitation journals have been filled with examples of activity-dependent plasticity and the impact of structured motor experiences on the capacity for improved human motor function. On many occasions, articles by basic scientists have offered valuable and relevant insights from animal models. Interestingly, while clinician scientists have long looked to animal models for scientific evidence of interventions that might be applicable to the rehabilitation of people with disability, more and more, science is applying to animal models the lessons that we have learned from functional restoration in people.

The growing recognition that movement experience is a necessary component of optimal neural recovery is evident in the increasing use of "enriched environments,"[7] animal housing that provides opportunities for the animals to run, climb, reach . . . opportunities for movement. The birth of new neurons in adult animals, once thought impossible, has been observed in animals exposed to vigorous exercise;[8] and although the functional relevance is as yet unknown, early evidence suggests that functional electrical stimulation may promote development of progenitor cells in the central nervous system.[9] Not only do exercise and stimulation appear to promote the cellular environment necessary for natural regeneration, evidence indicates that following the transplantation of cells to promote regeneration, this regeneration only results in improvements in function when the animal is exposed, not just to movement, to the appropriate form of task-specific practice.[10]

Neurologic physical therapy is the nexus between the latent potential of the nervous system and the manifestation of that potential. It is heartening to know that basic science is catching up with us.

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