invited editorial

The new kid on the airway smooth muscle block: plasticity theory and series-to-parallel filament transition

N. L. STEPHENS, A. J. HALAYKO, AND X. MA
Departments of Physiology and Paediatrics, Faculty of Medicine, University of Manitoba, Winnipeg, Manitoba, Canada R3E 3P5

THE STUDY OF SEOW ET AL., “Series-to-parallel transition in the filament lattice of airway smooth muscle” (9), in this issue of the Journal of Applied Physiology provides an opportunity for us to review the status of the plasticity theory, which Seow and colleagues published 5 years ago (8). Plasticity may be regarded as deviation of muscle force or shortening behavior from that mandated by static isometric force-length curves.

Dr. Seow and his colleagues used their eminently reliable data to formulate their plasticity theory, which postulated a mechanistic series-to-parallel transition in filament lattice. They speculated that, during the process of adaptation, induced by multiple stimulations at any given length, more myosin filaments are added in series in the muscle cell. The mechanical consequences of this are easy to deduce; isometric force will increase at the expense of shortening velocity as a result of the series-to-parallel transition. Furthermore, because of adaptation, force becomes independent of length, and more myosin filaments are added in series in the muscle cell. Velocity and compliance, however, become dependent on length.

Several mechanisms have been put forward (1–4, 6–9) to explain this phenomenon. Ford’s group (8) provided the best phenomenological data on force that is length independent and on velocity and compliance that are length dependent, as a base for the mechanistic theory just cited. The crucial evidence needed is structural data demonstrating elongation of the filament during adaptation at long lengths. The mechanism for adjustment in filament length at short muscle length, as required by the theory, appears more complex.

Others have provided work on this theory that, although suggestive, is not definitive. One example is the birefringence data of Gillis et al. (3), which were not sufficiently altered to account for the magnitude of the plasticity changes.

With respect to the plastic behavior of smooth muscle, several new broad avenues have opened up. Gunst et al. (4) reported that plasticity is the result of phosphorylation-dependent structural changes in membrane and cytoskeletal proteins. However, their interpretation did not account for the velocity and compliance behavior reported by Ford’s group. Furthermore, the effects they observed on the force-length curve were small. Meiss (6) provided force-length evidence of plasticity; he reported that his data, obtained from load-clamped contractions, demonstrated reconfiguration of the contractile apparatus. However, he indicated that, because the time taken for this was only 2 s, it would not allow for addition of monomeric myosin units to the thick filament, as required in Ford’s theory.

A very recent paper from Hai and colleagues (1) also provided experimental evidence of smooth muscle plasticity; they reported that muscle plasticity was due to the muscle’s ability to retain relatively precise memory of past strain. Whether this could account for the force velocity and compliance behavior reported by Ford is moot. A study, hot off the press, by Morano et al. (7) suggests another explanation that is based on knock-out of smooth muscle-type myosin heavy chain in mice; this group studied the effect of this knock out on contraction. Normally, smooth muscle contraction consists of a phasic response followed by a tonic one. If this transition is taken to represent plasticity behavior, then the explanation of Morano et al. that the transition represents a switch in regulation from that exerted by smooth muscle-type myosin heavy chain to that exerted by non-muscle myosin heavy chain provides yet another explanation for plasticity.

Xu et al (11) observed thick filament lengthening during contraction in anococcyogens muscle but not in taenia coli. It appears, therefore, that different smooth muscles possess different degrees of plasticity and that plasticity theory itself is very plastic.

Presently, it seems that too many pros and cons exist for the emergence of a consensus regarding plasticity theory, but that theory does seem to have the inside track.

An issue that begs attention is determination of how well conserved is the phenomenon of plasticity. Thus far it has been reported for canine and bovine tracheal...
smooth muscle (9). Our laboratory (10) has confirmed its presence in canine tracheal muscle but not in bronchial muscle, for which, although present, it is not so well defined (unpublished observations). Richard Murphy (Univ. of Virginia Health Sci. Center) also did not observe mechanical plasticity in the porcine carotid (personal communication).

A provocative corollary to plasticity theory is that it does away with the latch-bridge hypothesis, since it accounts for the decrease in velocity and increase in force as direct consequences of the series-to-parallel transition.

Perhaps we should close this essay on a historical note. The first time plasticity theory was presented was at a symposium organized on Smooth Muscle Contraction in Minaki, Ontario, in 1993. Dr. Seow, who made the presentation then, recently reminded me that we had a lot of discussions about the impact this new theory was going to make in the coming years, as we rowed our canoes, “fishing,” and on the porch as we puffed our postprandial stogies. “Man,” he recently opined, “that was almost 10 years ago.” Acceptance has been slow!

REFERENCES


