“Mysteries of Muscle Contraction”  
Professor Walter Herzog  
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Biography:

Dr. Herzog did his undergraduate training in Physical Education at the Federal Technical Institute in Zurich, Switzerland (1979), completed his doctoral research in Biomechanics at the University of Iowa (USA) in 1985, and completed postdoctoral fellowships in Neuroscience and Biomechanics in Calgary, Canada in 1987. Currently, Dr. Herzog is a Professor of Biomechanics with appointments in Kinesiology, Medicine, Engineering, and Veterinary Medicine, holds the Canada Research Chair for Cellular and Molecular Biomechanics, and is appointed the Killam Memorial Chair for Inter-Disciplinary Research at the University of Calgary. His research interests are in musculoskeletal biomechanics with emphasis on mechanisms of muscle contraction focusing on the role of the structural protein titin, and the biomechanics of joints focusing on mechanisms of onset and progression of osteoarthritis. Dr. Herzog is the recipient of the Borelli Award from the American Society of Biomechanics, the Career Award from the Canadian Society for Biomechanics, the Dyson Award from the International Society of Biomechanics in Sports, and the Muybridge Award from the International Society of Biomechanics. He is the past president of the International, American and Canadian Societies for Biomechanics. He was inducted into the Royal Society of Canada in 2013.

Abstract:

The sliding filament and the cross-bridge theories have dominated our thinking of how muscles contract for the past half century. This thinking has been so strongly embedded in our minds, in our textbooks, and our teachings, that we often forget that Andrew Huxley, the first to propose and formulate the cross-bridge theory, has warned us that there are many phenomena that remain unexplained with his theory: for example, the stability of sarcomeres on the descending limb of the force-length relationship, the overestimation of the metabolic cost of eccentric muscle work, the stabilization of the myosin filament in the centre of sarcomeres, and the history-dependent properties of force enhancement and force depression, to name just a few of the many unexplained phenomena.

Not satisfied with the lack of explanation for many muscle properties, we attempted to find out how some of these unexplained muscle properties might be explained. Specifically, here, I will focus on eccentric contractions, the associated increase in force during and following eccentric contractions, and the reduced metabolic cost of eccentric compared to concentric and isometric contractions. In search for explanations of these observations, we stumbled across the fact that in eccentric contraction, passive structural elements of the muscle seem to contribute more force than they do during passive elongation. We then identified that the structural filamentous spring protein “titin” might be responsible for these observations. Specifically, we proposed that titin might increase its stiffness in an activation-dependent manner, and that this increase in stiffness produces more force in titin filaments when a muscle is stretched actively (eccentric contraction) compared to when the same muscle is stretched passively.
In my presentation, I will show examples of how we tried to identify the properties of titin in active and passive muscle, how these changed properties might be caused on the molecular level, and what implications such property changes may have for everyday animal movement. Finally, I will propose a three-filament sarcomere model including titin that explains most of the currently unexplained phenomena and properties of muscle contraction, while retaining the predictive powers of the traditional cross-bridge model.