Information-Theoretic Analysis of Physiological Networks: a New Approach to Uncover Working and Impaired Homeostatic Regulation

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In the emerging field of Network Physiology, the human organism is viewed as an integrated network where the cardiac, circulatory, respiratory, and cerebral systems, each with its own internal dynamics, continuously interact with each other to preserve the overall physiological function. Devising proper analysis frameworks and providing empirical measures able to describe the joint system behavior and the contribution of the different observed parts to it may yield fundamental insight on the functioning of the networks underlying the regulation of physiological rhythms. In this context, I will present the new framework of Information Dynamics, a set of tools whereby information-theoretic measures are developed to dissect the information contained in a network of multiple interacting dynamic systems into basic elements of computation: the new information produced by a physiological system at each moment in time, the information stored in the system, the information transferred to it from the other connected systems, and the (synergistic or redundant) modification of the information transferred from multiple source systems to a target system. In the lecture, the framework will be formalized theoretically and implemented in practice through the development of linear model-based and nonlinear model-free estimators of the relevant measures. Then, the potential of the framework to assess the human physiological regulation in healthy and diseased conditions will be illustrated reporting examples of applications to cardiovascular and cerebrovascular networks during physiological stress and orthostatic intolerance, brain-heart and cardiorespiratory interactions during sleep-related breathing disorders, and epileptic brain networks.