Cracking the Linear Lens

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For more than a century, medicine has been transfixed by the Biomedical Model, convinced that illness and disease are the sole result of pathological processes. Consequently, physicians adhere to more than the Hippocratic Oath; they are devoted to the linear tenets of a Biomedical Creed:

1. We believe in the truth of the Biomedical Model to account for pathology and disease.

2. We believe that "population health" is defined by the sum of the illness burden of its component individuals, "individual health" is defined by the sum pathology of its component cells, and "cellular health" is defined by the sum of its genetics and exposures.

3. We believe that healthy physiology is reflected in "homeostasis."

4. We believe that the gold standards for research are the Randomized Clinical Trial (RCT) and its overlying meta-analysis.

5. We believe that this reductionistic research can be translated into predictable treatment response, reflected in "evidence-based medicine" and its clinical guidelines.

Under this paradigm, the greater the genetic-exposure burden, the greater the disease burden of individuals and eventually populations. This linear framework continues to dominate medical thought and health policy. Consequently, "homeostasis" characterizes "health," the ultra-controlled RCT typifies "good research," and clinical outcomes are considered a simple matter of applying the right RCT-based treatment to the disease. Such a linear, "point-in-time" emphasis discounts the multifactorial, longitudinal reality of health status, limiting our understanding of illness evolution and treatment response.

Yet, despite such slavish devotion to the Biomedical Model and its linearity, islands of nonlinear thought have emerged. While practitioners are familiar with unpredictable responses to medication (Rado, 1976) and spontaneous remissions in cancer (Challis & Stam, 1990), mavericks have

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espoused the virtues of the expanded Biopsychosocial Model (Engel, 1977). Since Goldberger, Rigney, Mietus, Antman and Greenwald (1988) first reported on the association between loss of heart rate variability (HRV) and sudden death, and West (2006) described the ubiquitous nature of power law distributions in medical populations, evidence has existed for a nonlinear reality in medicine. Such a nonlinear perspective could revise our diagnostic approach to focus on symptom dynamics rather than static severity, our treatment approach to focus on interventions which target dynamics rather than symptoms, and our perspective to focus on the whole patient rather than her disease. However, such prophets continue to be relegated to the medical fringe by the establishment.

This issue of *Nonlinear Dynamics, Psychology and Life Sciences* seeks to build on these "small voices in the wilderness," affirming their nonlinear message at all levels of the biomedical hierarchy. Nonlinear dynamical systems theory (NDS) is a subset of general systems theory, and overlaps with both chaos theory and complexity science (see January 2007 issue of *Nonlinear Dynamics, Psychology and Life Sciences*). NDS describes the changes in systems over time and includes such phenomena as attractors, bifurcations, catastrophes, and self-organization. As such it confers unpredictability, and action-response disproportionality upon its systems.

The issue begins with a conceptual article by Pincus and Metten bridging the gap between the constructs of complexity science and analytic techniques used in nonlinear dynamics and demonstrating how such disparate methods can be joined within a common framework underlying resilience. Following this overarching paper, the issue considers a series of studies applying nonlinear approaches to sequentially greater magnifications, showing the scale-free nature of nonlinear medical systems. Sabelli and Lawandow begin by challenging the traditional homeostatic understanding of HRV, suggesting that HRV may be better characterized as both homeostatic and biotic (homeobiotic) and applicable from newborns to elders. This implies that HRV is produced by combining bipolar feedback with negative feedback. Similarly, in the subsequent article by Good et al., the potential for nonlinear analysis of EEG tracings to predict, and potentially prevent, seizures is demonstrated. Their optimized algorithm applied to seizure-prone rats had a sensitivity of 86% with a prediction time of over 67 minutes prior to seizure onset. In a further application of nonlinear dynamics, Sleimen-Malkoun, Temprado, Jirsa and Berton show their potential application in understanding and treating problems with post-stroke inter-limb coordination. Such nonlinear applications use dynamic pattern theory to elucidate directions for both therapeutics and research.

At the level of the individual, two articles use nonlinear dynamics to understand sexual behavior. Renaud et al. studied pedophiles and controls to characterize their gaze dynamics, finding that perceptual-motor fractal dynamics parallels sexual arousal and differs in the two groups. Hence, nonlinear dynamics analysis can provide a tool to better understand normal and pathological sexual behavior. Similarly, Chen et al. modeled sexual initiation

behavior of young adolescents, finding that cusp catastrophe models accounted for considerably more variance than did the linear models. Understanding such dynamics could have significant implications for intervention programs targeting teen pregnancy.

Across individuals, Katerndahl, Burge, Ferrer, Becho and Wood used orbital decomposition to analyze the day-to-day reports of intimate partner violence among victimized women, finding that not only did violence one day beget violence the next, but that verbal abuse rarely led to subsequent physical abuse. Despite the variety of daily violence-environmental patterns seen, the paucity of patterns observed on days of violence suggests that research has the potential to further our understanding of violence dynamics.

Finally, Sturmberg and Martin conclude the issue by using the nonlinear dynamical constructs inherent in complexity science to assess health care reform strategies and outcomes. Such system level change, seen through the lens of nonlinear dynamics, could guide future reform efforts. As the capstone of this issue, this article reaffirms the general systems nature of nonlinear phenomena in medicine. Whether considering the microlevel events of heart rate or brain wave variability, the macrolevel events of normal and abnormal sexual behavior or the system level events that define reform strategies, nonlinear dynamics better characterize medical reality than the linear perspective underlying the Biomedical Model.

If the nonlinear framework is indeed a better lens through which to view medical phenomena, then the Biomedical Model will ultimately prove inadequate for understanding health and illness. If true, then cellular, individual, and population health are emergent properties that are greater than the sum of their components. Decoding the human genome, while valuable, will prove of limited benefit in promoting the health of individuals and populations due to the complex, multiscale nature of the gene-environment interactions which facilitate and inhibit gene expression. If true, then "health" will be increasingly recognized as a product of variability as well as stability. If true, then RCTs and meta-analyses will play a decreasingly important role in understanding illness and health in individuals and populations, resulting in the increased use of alternative designs and nonlinear approaches. If true, then the importance of clinical guidelines will be increasingly recognized as limited in their application, often irrelevant to the unique context of the individual doctor-patient dyad. As a first step to cracking the linear lens through which modern medicine views phenomena and research, we offer this issue.

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