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Theoretical Physics and Cancer Research

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Cancer is a multifaceted disease which involves profound disruptions to biological mechanisms and structures that have evolved since the beginning of life. The most dramatic change is the failure of multi-cellularity and organ homeostasis. Time and time again, this complex disease has evaded the silver bullet cure attempts that rely on simple strategies including targeting dividing cells with broad acting chemotherapies, using radiation to cause DNA damage, and using molecular targeting agents. Even the most recent efforts, such as using immune stimulating agents and activated immune cells, are missing the mark. Against all these efforts, the cancer, even if it retreats, usually returns and often then does not respond to any of our available arsenal. The origin of this persistence is the robustness of life itself. During the past 4 billion years, life has survived many dramatic events and living organisms can be found in the most hostile places on Earth. Based on my research and on analysis of outcomes from several meetings between physicists and cancer researchers, organized by the National Science Foundation, I will argue that we need to integrate theoretical physics approaches to understand the emergence of resistance to treatment and to develop robust and curative interventions in cancer. The adaptive response of living systems to external and internal changes involve many interacting parts and networks. Phenomenological and reductionist approaches must be used synergistically to understand the phenomena at the appropriate spatial and temporal scales. This approach has been successful in understanding inanimate mater in the Universe and should be used in understanding animate matter as well and in particular cancer. I will also argue that public-private partnerships can speed up the process and bring innovation to transform the field.