PROJECT DESCRIPTION

Hierarchical Flow and Deformation
as Mechanisms for Bone Adaptation

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Bone adaptation is a phenomenon in which human and/or animal bones slowly add or lose mass and alter their form in response to *modifications* from normal mechanical stimulus conditions. When subjected to prolonged exposure to sustained and semi-intensive cyclic loading *in vivo*, bone systems adapt by adding mass resulting in combined densification and thickening. Conversely, when living bone systems are continuously underloaded over extended periods (as in space travel; fixation; prolonged bed rest; or stress shielding from surgical implants) a fraction of the bone mass is resorbed resulting in diminished capacity from reduced bone densities and thinning. This suggests that the skeletal system senses changes in sustained mechanical load patterns and adapts itself to carry the predominant loads most efficiently using minimal bone mass.

While bone adaptation is well recognized, the specific mechanical stimuli that trigger and sustain it are not well characterized. Furthermore, the underlying biological mechanisms used by skeletal systems both to sense mechanical stimulus and to biologically adapt remain poorly understood. This poor understanding has forestalled progress on a number of positive clinical developments such as: treating bone and skeletal deformities; preventing and treating osteopenias; accelerating fracture healing; and optimizing implant designs. This research program is thus being directed toward obtaining a better fundamental understanding of bone adaptation.

Deformation driven fluid flow in bone is an increasingly hypothesized, but as yet untested, mechanism that appears appears quite capable of explaining the predominant characteristics of bone adaptation. Since compact bone has a hierarchical microstructure, such fluid flow occurs in bone on a spectrum of length scales during mechanical excitation. The specific challenge being addressed in the research program is the development of computational models to accurately predict such flow, both how it is activated by mechanical stimulus, and how it might in turn activate the biological processes of bone adaptation. These models are being developed and verified with the aid of well-conceived experiments. From a scientific perspective, achievement of this objective could lead to an enhanced fundamental understanding of bone adaptation and new experiments to verify this understanding. From a clinical perspective, achievement of this objective could facilitate the knowledgeable usage and control of bone adaptation in a wide range of important orthopaedic applications.