SAND2006-5066P

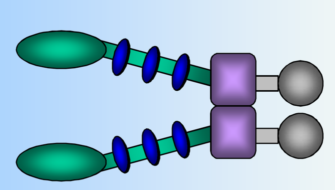
Engineering Structural and Functional Proteins for Integrated Nanomaterials and Nanodevices

Nature provides brilliant examples of multiscale self-assembly of materials and components, which together exhibit a range of emergent phenomena. A fundamental goal of our work is to understand, exploit, and engineer structural and functional proteins to assemble integrated nanomaterials and nanodevices with unique properties.

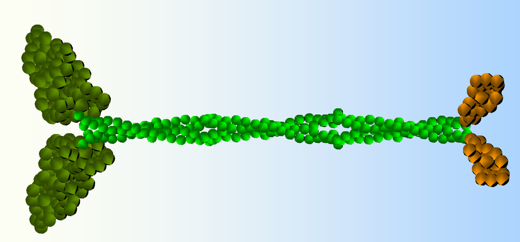
Functional Proteins (actuators and pumps)

Nature provides examples of nanoscale actuators and pumps that can efficiently convert chemical and light energy into mechanical work. These classes of functional proteins may be exploited to incorporate bio-mimetic and inspired functionality into integrated systems.

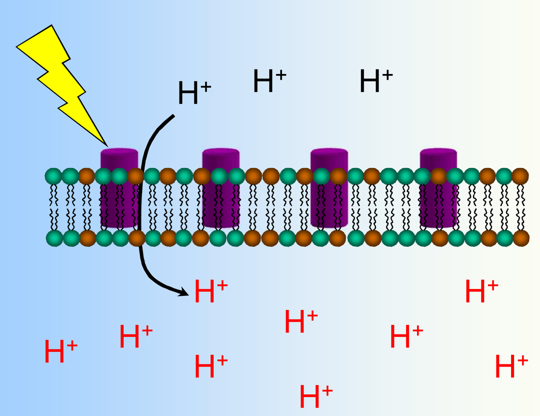
Myosin II (muscle myosin) linear motor



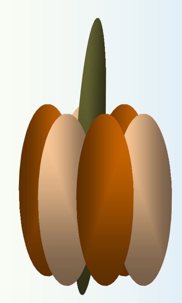
Kinesin (conventional) linear motor



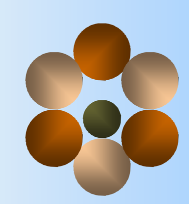
Bacteriorhodopsin light-driven pump



F_1-ATP synthase rotary motor



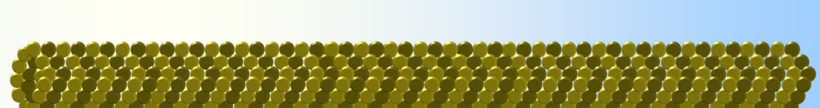
side view



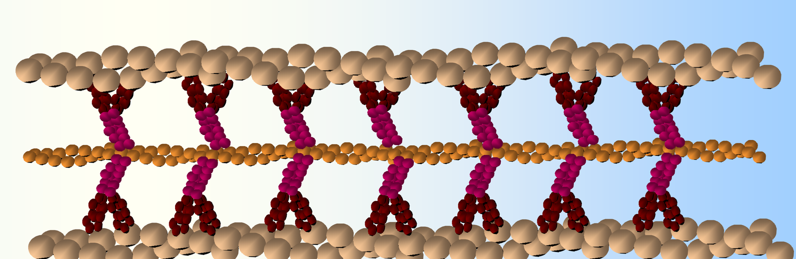
top view

Structural Proteins (filaments and membranes)

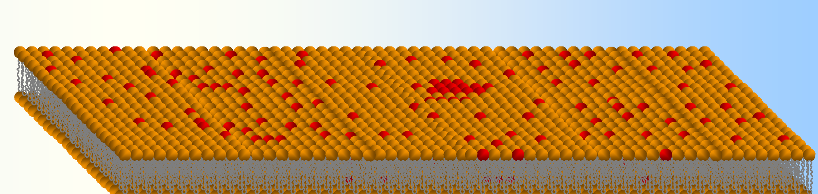
Structural materials in living systems exist in non-equilibrium, dynamic states, which is in contrast to man-made structural materials. The energy-driven assembly, disassembly, and organization of structural proteins enables organisms to readily adapt to changing environmental conditions and physiological needs.



Microtubule filaments



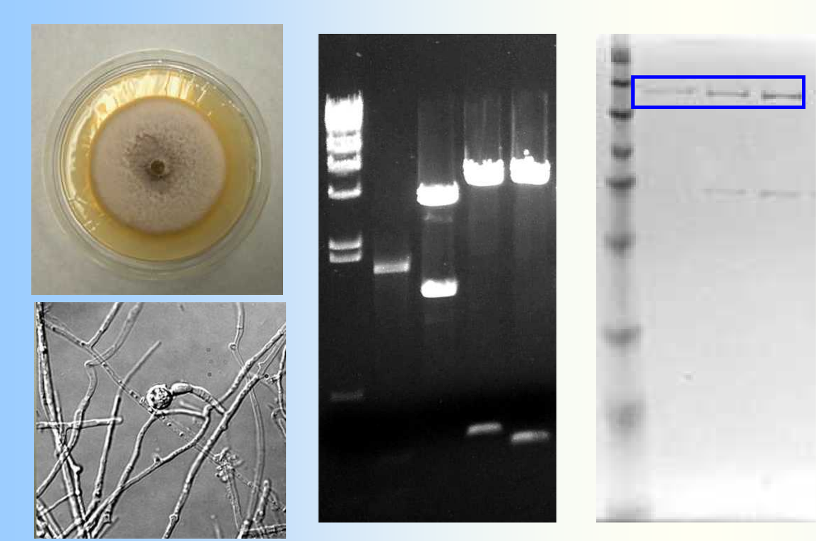
Actin filaments (in muscle architecture)

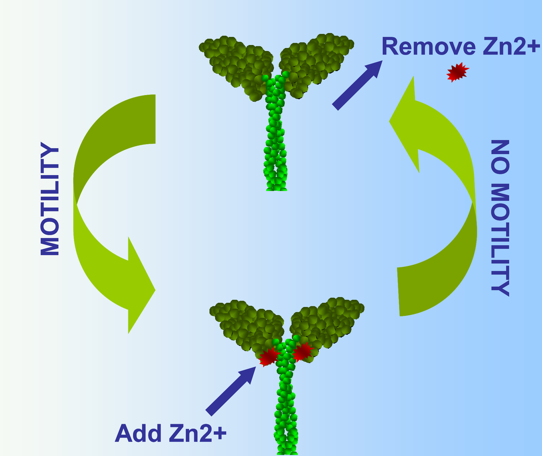


Lipid bilayer membranes

Engineering Functional Biomolecules

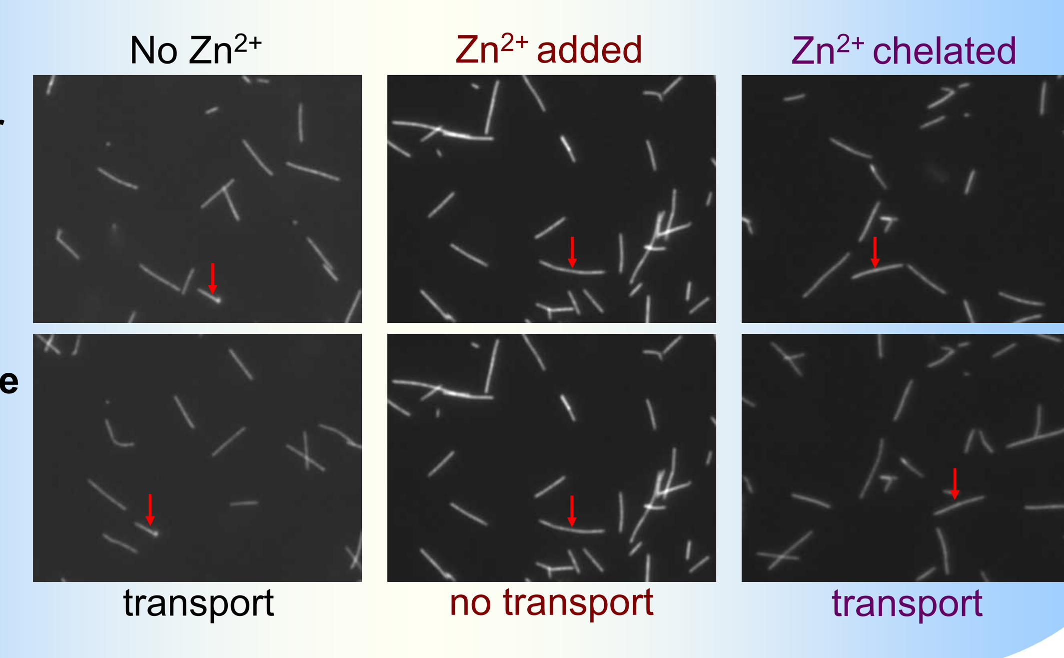
Functional biomolecules such as motor proteins possess a wide range intrinsic properties (e.g., thermostability, energy conversion, actuation, etc). Such proteins be isolated and engineered for integration as structural and functional components of nanoscale materials and systems.



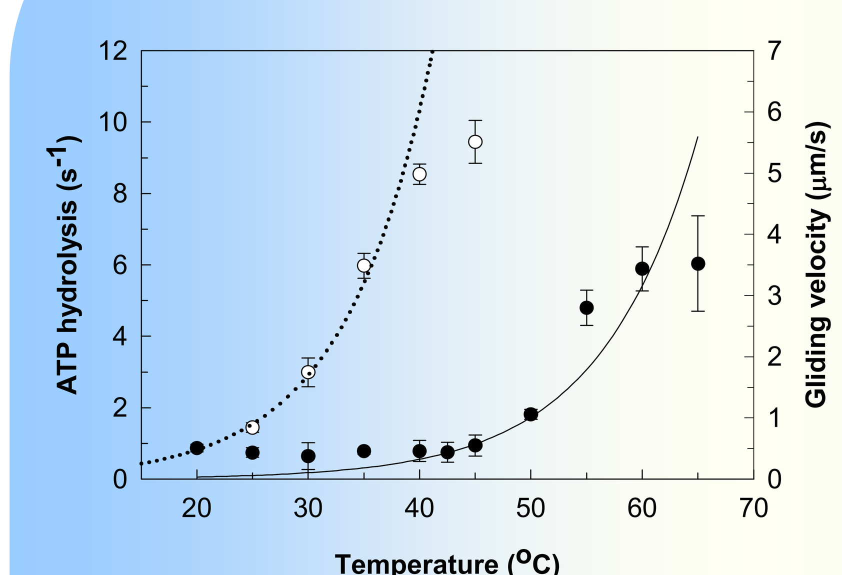


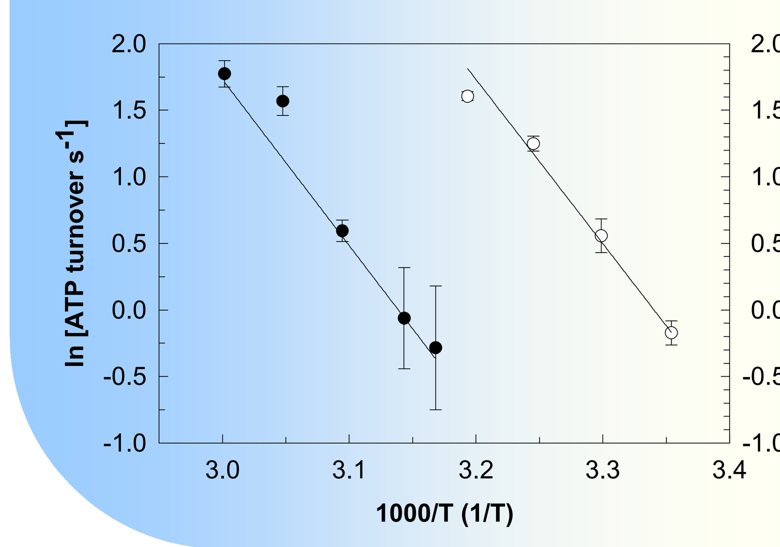
Organism → Gene Isolation & Cloning → Protein Expression → Engineering

Kinesin motor proteins were engineered with a zinc-dependent switch capable of turning the motor on and off,



Characterizing Engineered Proteins





Engineered proteins are characterized with respect to biochemical and biophysical properties, as well as enhanced stability at nano-bio interfaces.

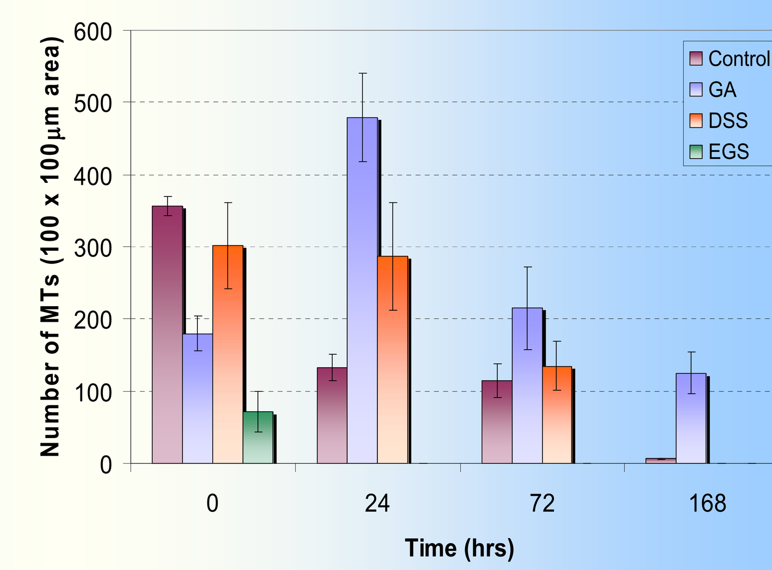
For example, Kinesin motor proteins from *Thermomyces lanuginosus*:

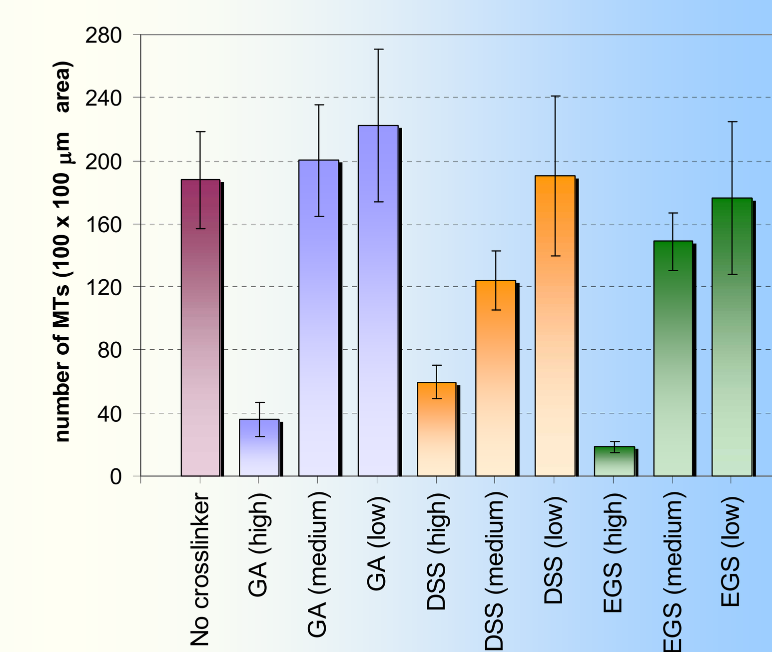
- **are capable of functioning at much higher temperatures compared with mesophilic analogs;**
- **have Arrhenius energy barrier nearly twice that of other kinesin; and**
- **display enhanced stability on hydrophobic surfaces**

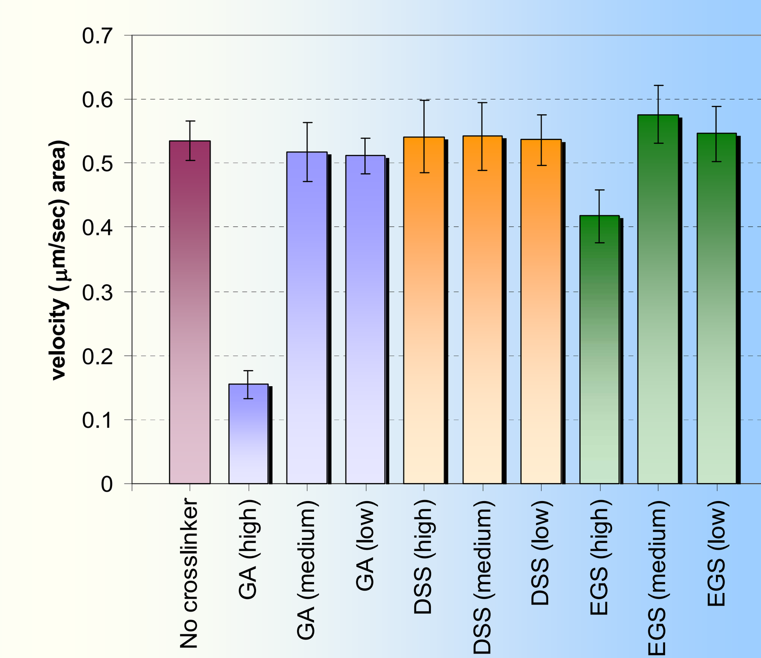
Engineering Structural Biomolecules

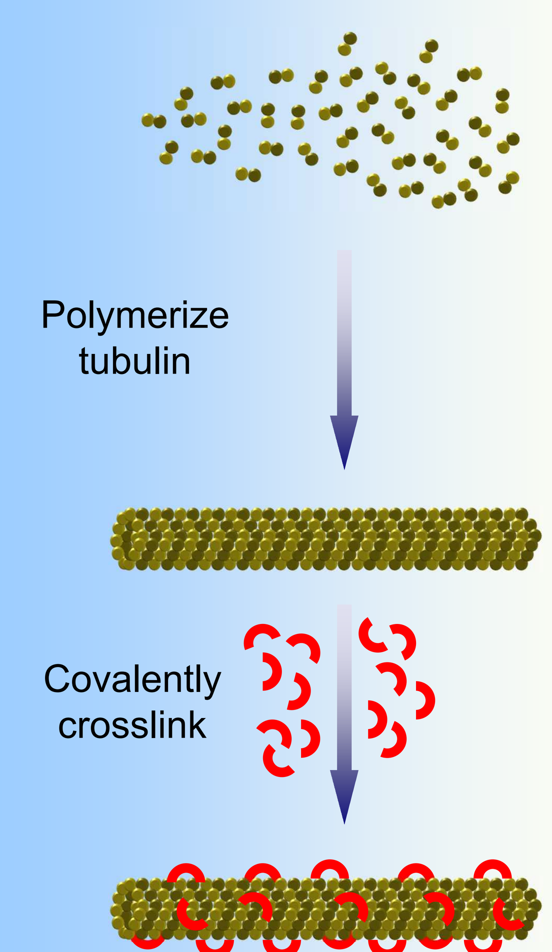
The assembly and organization of structural biomolecules (e.g., cytoskeletal filaments, lipid bilayers, etc) is dynamic and adaptive. This intrinsic property may be exploited for developing integrated materials in which the structures are transient.

In some cases, it may be advantageous to assembly integrated materials in which the structures are more stable than the natural analog. As an example, we have use covalently crosslink microtubule filaments to increase (1) longevity, (2) stability against divalent cations, and (3) thermal stability.









Crosslinking Agent	Metal Ion				
	Ca^{2+}	Cu^{2+}	Ni^{2+}	Zn^{2+}	Co^{2+}
None	<0.1 mM	0.1 mM	<0.1 mM	1 mM	0.1 mM
GA	>100 mM	1 mM	1 mM	1 mM	10 mM
DSS	1 mM	1 mM	1 mM	1 mM	1 mM
EGS	>100 mM	1 mM	1 mM	>10 mM	1 mM

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