Inside Velvet Worm Slime: Rare Protein Modification for Fast Fiber Formation

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Velvet worms eject a sticky and fiber-forming slime for both prey capture and defense. The struggling of the victim to escape the slime network causes the formation of stiff fibers, which results in effective immobilization.

This natural phenomenon of fiber formation is inspiring for biomaterials research. *Induced only by a simple mechanical trigger and the resulting shear forces, the slime instantly turns from a fluid to load-bearing fibers outside of the organism under ambient conditions*. Additionally, fibers can be dissolved, and new fibers made from the solution. Understanding the molecular principles underlying these phenomena can aid in the design of sustainable methods for fabricating advanced polymers.

MagLab users identified a unique post-translational modification of high-molecular weight proteins, a modification that impacts their features and, as a result, the abilities of slime to rapidly assemble into fibers with enhanced toughness. In particular, the MagLab's magic-angle-spinning, dynamic nuclear polarization (MAS-DNP) facility, combined with mass spectrometry, enabled the discovery of the precise structure of a rare phosphonoglycan moiety that is linked to large fiber core building proteins – a striking NMR result that did not require any complicated isotopic enrichment of the samples! Surprisingly, most of the slime's phosphorus is represented in this 2-aminoethyl phosphonate (2-AEP) motif, a chemical moiety that is extremely rare in nature, and especially in land animals.

2-AEP is zwitterionic at the slime's native pH – this adds charges to the proteins. *Thus, researchers assume increased electrostatic protein-protein interactions enable the faster assembly and advanced mechanical properties of fibers. It is anticipated that these findings will help further unravel mechanisms of natural fiber formation and lend insight into future ways to produce polymeric materials*.

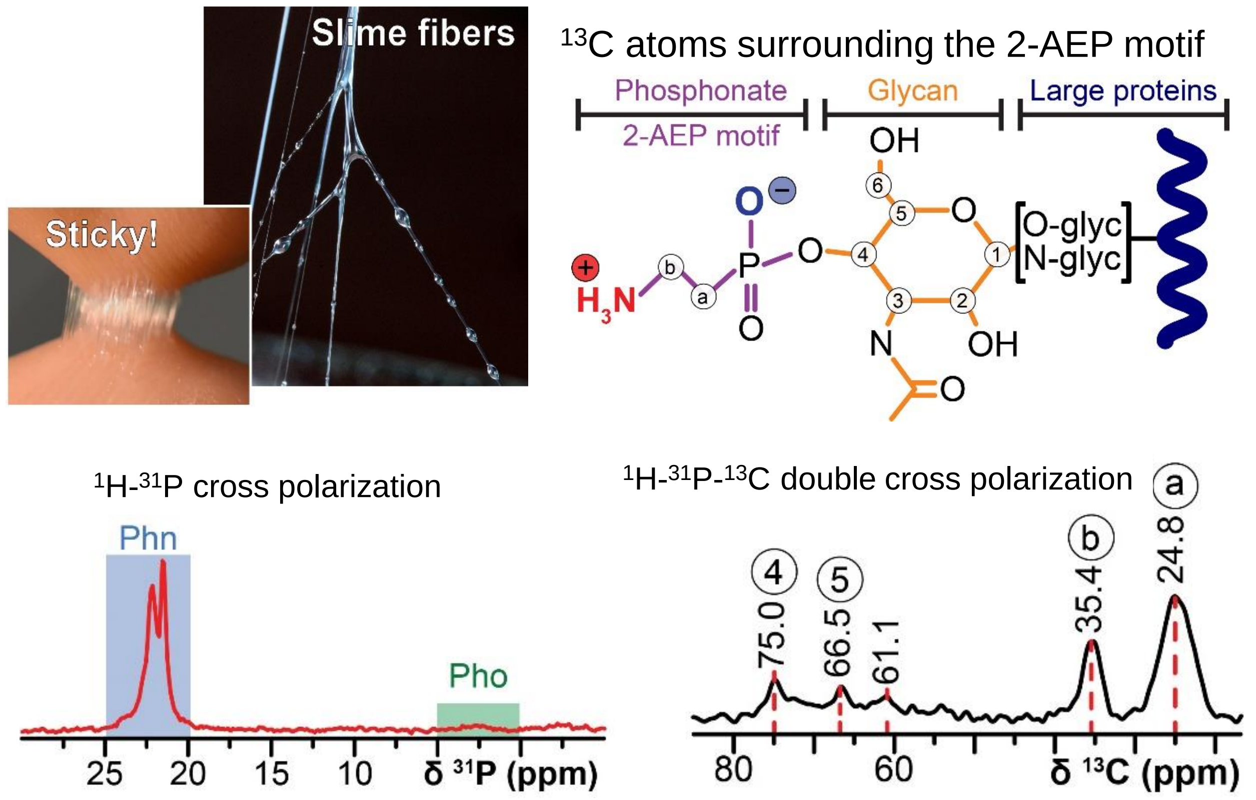

Figure: (top left) The sticky slime fibers from a velvet worm. **(top right)** Schematic representation of the phosphonoglycans that decorate the slime proteins, detected by dynamic nuclear polarization solid-state NMR. **(bottom)** ^{1}H-^{31}P MAS-DNP NMR spectrum showing the predominance of phosphonates in slimes and ^{1}H-^{31}P-^{13}C DNP MAS NMR "double cross polarization" spectrum showing the proximities of key P and C sites.

Facilities used: 600 MHz MAS Dynamic Nuclear Polarization Solid-State NMR instrument.

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