Researchers at INL are defining natural adhesive systems at the molecular scale and are exploring ways to recombine proteins to improve adhesives. Such new adhesives may more strongly bond to a wide range of materials and do so in an environmentally friendly and safe manner.

Natural Adhesive Systems

Marine mussels, like *Mytilus edulis*, attach to a variety of surfaces in an aqueous environment using a natural adhesive that is incredibly strong and durable. The properties of this adhesive exceed those of conventional adhesive glues in both strength and environmental acceptability. Research shows that one of the proteins in the adhesive, *Mytilus edulis* foot protein 1 (Mefp-1), bonds to glass, plastic, wood, concrete, and Teflon. Mimicking this bonding capability would yield important, innovative adhesives for such different applications as building and construction, dentistry, surgery, orthopaedics, ophthalmology, electronics, plastics, and wood composites.

A research objective is to develop a biomimetic glue that is environmentally safer, stronger, and less expensive than currently available adhesives.

At least nine different, unique proteins are involved in the formation of the byssus (the adhesive structure formed by the mussel). However, the precise mechanism for assembling the nine proteins is not understood. Additional proteins that have not been identified may also be involved in the formation of the byssus. The byssus components have conventionally been identified by isolating the individual proteins and analyzing their amino acid compositions. The resulting repetitive motifs and modified amino acids present in mussel adhesive proteins are unique to biological systems. Proposed mechanisms for the strength and waterproof properties of the byssus are directly related to the amino acids. Commercial natural adhesive products have consisted of chemically isolated Mefp-1 or Mefp-1 mixed with Mefp-2 from byssus structures. Recombinant products consisting of either the partial amino acid sequence of Mefp-1 or repeats of the unique decapeptide motif have also been marketed in the past. However, no commercial product incorporates any of the other proteins

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Science

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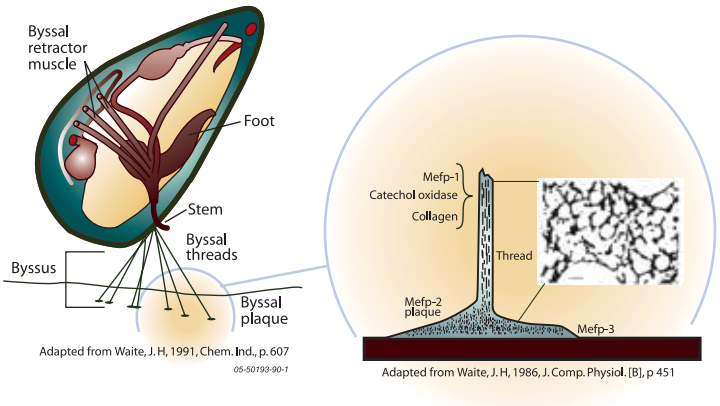

This illustration shows the Atlantic Blue Mussell, Mytilus edulis, and its adhesive structure–the byssus with byssal threads and byssal plaque–and includes a closer look at the byssal thread and plaque and the individual adhesive proteins with respect to a substrate surface.

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known to be involved in underwater adhesion by the *Mytilus edulis* mussel.

Research Focus and Progress

A challenge to further understanding this unique adhesive system is the unavailability of individual protein components. About 10,000 mussels are needed to produce 1 gram of adhesive from byssal structures of the animals. Thus, collecting experimental material from these animals is not practical. Therefore, we have cloned genes into microorganisms for mass production of this natural adhesive material. We have initiated small- and large- scale recombinant protein expression of some *Mytilus edulis* adhesive proteins. In the long range, we want to understand the underwater adhesion mechanisms of the mussel by identifying and producing substantial quantities of the individual protein components.

For more information

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Patents

Silverman, H.G., and Roberto, F.F., "Cloning and Expression of Recombinant Adhesive Protein Mefp-1 of the Blue Mussel, *Mytilus edulis*," *U.S. Patent no. 6,987,170; Jan. 17, 2006.*

Silverman, H.G., and Roberto, F.F., "Cloning and Expression of Recombinant Adhesive Protein Mefp-2 of the Blue Mussel, *Mytilus edulis*," *U.S. Patent no. 6,995,012; Feb. 7, 2006.*

Selected Publications/Presentations

Silverman, H.G., and Roberto, F.F., "Adhesive Proteins From Mussels: Historical Progress and Implications for Materials Applications," *(in preparation).*

Silverman, H.G., and Roberto, F.F., "Adhesive Proteins From Mussels: Current Directions," *(in preparation).*

Silverman, H.G., and Roberto, F.F., "Adhesive Proteins From Mussels: Future Directions," *(in preparation).*

Silverman, H.G., "Identification and Expression of *Mytilus edulis* foot proteins: Insight into Mechanisms of Bioadhesion," *INEEL Biotechnology Seminar Series, June 1999.*

Silverman, H.G., "Identification of Adhesive Protein Clones in the Edible Blue Mussel *Mytilus edulis*," *American Society for Microbiology, Rocky Mountain Region, Idaho Falls, Idaho, April 1998.*

Nicol Narus, E.Y., "Cloning and Expression of *Mytilus edulis* Adhesive Proteins Using cDNA Libraries," *INEEL University Research Consortia Annual Conference, Idaho Falls, Idaho, July 1997.*

Roberto, F.F., "DOE/STP Bioadhesives Project Review," *USSOCOM, McDill Air Force Base, Florida, May 8, 1996.*

Silverman, H.G., "Bioadhesives Project," *INEL Biotechnology Seminar Series, December 1996.*

Silverman, H.G., "Molecular and Biochemical Analysis of Mussel Adhesive Protein in *Mytilus edulis*," *INEL Research Exchange, August 1995.*

Roberto, F.F., "Bioadhesives for Underwater Applications," *OPNAV515, The Pentagon, August 11, 1994.*

Roberto, F.F., "Bioadhesives Project," *U.S. Department of Energy Special Technologies Program Expo '93, Oak Ridge, Tennessee, May 3, 1993.*

Other

GenBank submissions to the National Center for Biotechnology Information
Accession: AY845258 *Mytilus edulis* clone for foot protein 1 (Mefp-1) mRNA, complete cds.
Accession: AY845259 *Mytilus edulis* clone for foot protein 1 (Mefp-1) mRNA, partial cds.
Accession: AY845260 *Mytilus edulis* clone for foot protein 2 (Mefp-2) mRNA, complete cds.
Accession: AY845261 *Mytilus edulis* clone for foot protein 2 (Mefp-2) mRNA, complete cds.
Accession: AY845262 *Mytilus edulis* clone for foot protein 2 (Mefp-2) mRNA, complete cds.

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