

## 1 **Engineered proteins stick like glue -- even in water**

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3 Shellfish such as mussels and barnacles secrete very **sticky** proteins that help them cling to rocks or ship hulls, even underwater.  
4 Inspired by these natural **adhesives**, a team of MIT engineers has **designed** new materials that could be used to repair ships or  
5 help **heal wounds** and surgical incisions. To create their new **waterproof** adhesives, the MIT researchers **engineered** bacteria to  
6 produce a hybrid material that **incorporates** naturally sticky mussel proteins as well as a bacterial protein found in biofilms—  
7 slimy **layers** formed by bacteria growing on a **surface**. When combined, these proteins form even stronger underwater adhesives  
8 than those secreted by mussels. This project, described in the Sept. 21 **issue** of the journal *Nature Nanotechnology*, represents a  
9 new type of **approach** that can be **exploited** to synthesize biological materials with multiple components, using bacteria as tiny  
10 factories. "The **ultimate** goal for us is to **set up** a platform where we can start building materials that combine **multiple** different  
11 functional domains together and to see if that gives us better materials **performance**," says Timothy Lu, an associate professor of  
12 Biological Engineering and Electrical Engineering and Computer Science (EECS), and the senior author of the paper.

## 14 **Complex adhesives**

15 The sticky **substance** that helps mussels **attach** to underwater surfaces is made of several proteins known as mussel foot proteins.  
16 "A lot of underwater **organisms** need to be able to stick to things, so they make all sorts of different types of adhesives that you  
17 might be able to borrow from," Lu says. Scientists have **previously** engineered *E. coli* bacteria to produce individual mussel foot  
18 proteins, but these materials do not capture the **complexity** of the natural adhesives, Lu says. In the new study, the MIT team  
19 wanted to engineer bacteria to produce two different foot proteins, combined with bacterial proteins called curli fibers—fibrous  
20 proteins that can clump together and **assemble** themselves into much larger and more complex meshes. Lu's team engineered  
21 bacteria so they would produce proteins **consisting of** curli fibers bonded to either mussel foot protein 3 or mussel foot protein 5.  
22 After **purifying** these proteins from the bacteria, the researchers let them incubate and form **dense**, fibrous meshes. The **resulting**  
23 material has a regular yet flexible structure that **binds** strongly to both dry and wet surfaces. "The result is a powerful wet  
24 adhesive with independently functioning adsorptive and **cohesive** moieties," says Herbert Waite, a professor of chemistry and  
25 biochemistry at the University of California. "The work is very creative, rigorous, and **thorough**." The researchers tested the  
26 adhesives using atomic force microscopy, a technique that **probes** the surface of a **sample** with a tiny tip. They found that the  
27 adhesives bound strongly to tips made of three different materials—silica, gold, and polystyrene. Adhesives assembled from  
28 **equal** amounts of mussel foot protein 3 and mussel foot protein 5 formed stronger adhesives than those with a different ratio, or  
29 only one of the two proteins on their own. These adhesives were also stronger than naturally **occurring** mussel adhesives, and  
30 they are the strongest biologically inspired, protein-based underwater adhesives reported to date, the researchers say.

## 32 **More adhesive strength**

33 Using this technique, the researchers can produce only small amounts of the adhesive, so they are now trying to **improve** the  
34 process and **generate** larger quantities. They also plan to experiment with adding some of the other mussel foot proteins. "We're  
35 trying to **figure out** if by adding other mussel foot proteins, we can increase the adhesive strength even more and improve the  
36 material's robustness," Lu says. The team also plans to try to create "living glues" consisting of films of bacteria that could **sense**  
37 damage to a surface and then repair it by secreting an adhesive. The research was **funded** by the Office of Naval Research, the  
38 National Science Foundation, and the National Institutes of Health.

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40 [Adapted from Science Daily](#)