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Adhesives Based on and Inspired by Plants and Animals for Use in Medicine

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Introduction

The German Society of Protozoology's selection of the "many-headed" slime mold Physarum polycelphalum as the unicellular organism of the year 2021 serves as a reminder that scientists and the general public alike frequently overlook a significant portion of the vast diversity of life in nature. Even though some animals, like mussels and spiders, have already inspired a lot of scientists to create novel materials with glue-like properties, the flora and fauna have a lot more to offer. The main chemical motifs that convey their stickiness, namely carbohydrate-, protein-, and glycoprotein-based biological glues, are the focus of our discussion of naturally occurring slimy substances with adhesive properties. By either conjugating adhesive motifs found in nature to biological or synthetic macromolecules or by synthetically creating (multi-)functional materials, which combine adhesive properties with additional, problem-specific (and sometimes tunable) features, we also highlight selected recent developments in the area of material design and functionalization that aim to make use of such biological compounds for novel applications in medicine.

Description

Humanity has learned to study and utilize a vast array of natural resources for its own benefit. For example, hunter-gatherer tribes used leftover collagenous meat from the late 4th millennium BC to make hunting weapons and began using adhesives made from natural materials. Natural compounds with adhesive properties have played a significant role in society's evolution ever since. Common uses include animal trapping and home construction. Today, both unmodified and purified bioadhesives are utilized in a variety of industries, including the furniture industry, agriculture, and the cosmetics industry. despite being a relatively recent addition to the list of applications, modern medicine has begun to use them as well: For instance, in the 20th century, a glue made from autologous or heterologous human fibrin was developed. This biomaterial typically serves as an additive to (or substitute for) staples and sutures. In addition, polypeptide mixtures containing gelatin, serum albumin, or collagen have been developed and are now commercially available as injectable hydrogels or adhesive patches for wound healing.

On the other hand, natural glues that have not been altered in any way are frequently incompatible with human use as a material: Although they may have adhesive properties when applied to tissue surfaces, they can be problematic due to their lengthy curing time and the possibility of being contaminated with allergenic or infectious impurities. On the other hand, synthetic alternatives like cyanoacrylate glues offer high mechanical strength; However, the byproducts of their degradation are frequently harmful. As a result, there is still a significant need for a tissue adhesive that meets all mechanical and medical requirements. There are still a number of unanswered questions, particularly regarding the less studied variants of such bio-adhesives, even though our understanding of the main components in natural glues that convey adhesive behavior is continuously improving: What kind of interactions do these various materials have with various surfaces—natural or man-made? How are the chemical properties of the glue/material interface and external factors like changes in moisture content, temperature, or ionic milieu influenced by the adhesive's life time? The ability to recreate a material with such switchable properties for medical or technical applications would be highly desirable because some species of the plant and animal kingdom even produce materials that, depending on their state of hydration, either function as an adhesive or as a lubricant. Researchers have recently been able to create customized, multifunctional glues with a variety of properties thanks to a deeper comprehension of the mechanisms underlying the function of biological adhesives and ongoing advancements in materials science [1-5].

Conclusion

These advancements in the field of bio-derived glues are likely to be beneficial to biomedical applications in the near future. We discuss the biochemical composition of a variety of natural glues and adhesives we use those terms interchangeably here used by animals and plants, as well as the chemical mechanisms and motifs that convey stickiness in the context of biomedical applications, in this review. In addition, we provide a few examples of engineered, bio-derived glues that combine a number of useful functions for biomedical applications. In general, this review article's selected examples fall into one of three categories: bio-based adhesives (conjugates of sticky structural motifs from bioglues with other molecules), bio-inspired adhesives (fully synthetically produced materials that follow, at least in part, the principles of a biological template), and biologically derived materials (biological adhesives).

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