Protein Synthesis with Various Microbial Gene Sequence

to Develop Unknown Functional Materials

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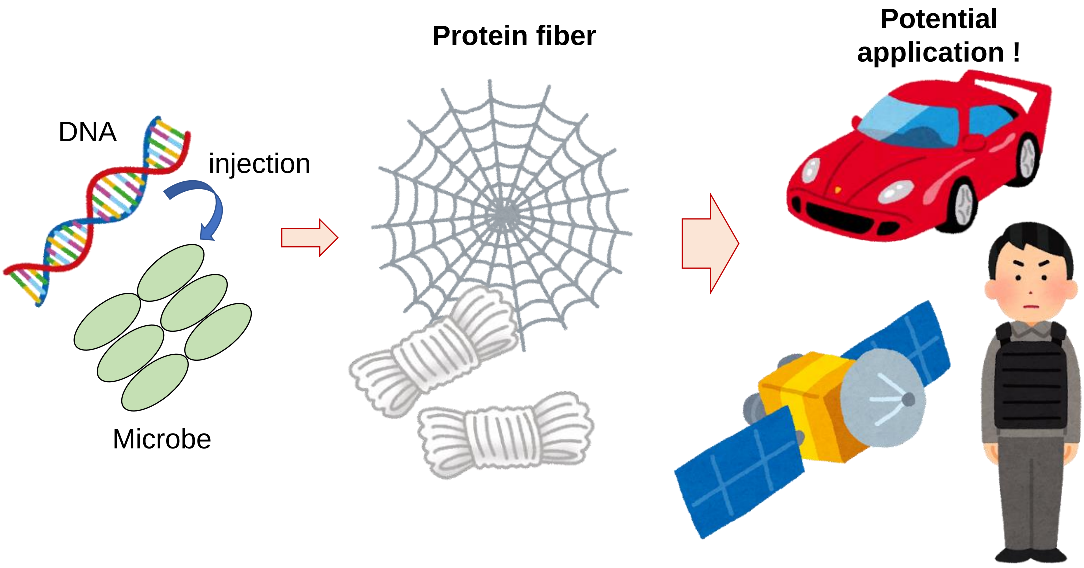

What do you think of when you hear the word protein? Is it the milk you drank this morning? Or maybe it's the "protein" you drink at the gym every day. Now think of our bodies. They may be hair, hard nails, or elastic muscles. All of these are made of protein, and they are composed of 20 types of amino acids. Amino acids can be hydrophilic, hydrophobic, or charge-bearing. They are combined and connected in many different ways to form proteins with a wide variety of functions as described above. Moreover, depending on the combination of amino acids, there is a great potential to create materials with unlimited functions. Furthermore, materials made of proteins do not depend on depleting resources such as oil and steel, and have a low environmental impact because protein materials tend to be decomposed by microorganisms [1]. Therefore, they are expected to be applied as "fiber" materials for a sustainable world.

In fact, protein fibers have been used in the past. Typical examples are silk made from silkworm cocoons and wool from sheep. However, many of these materials do not have enough strength and elasticity to be used in the aerospace or construction industries. There are also concerns about the greenhouse effect of methane gas emitted by wool.

Spider silk has attracted attention as a dream material that overcomes these difficulties. The main component of spider silk is a protein called fibroin. This protein is also found in silkworm cocoon silk, but spider silk is particularly tough. The toughness of spider silk (the energy that can be absorbed by a material before it breaks) is tens of times higher than that of steel, and its elasticity is comparable to that of nylon [2]. Moreover, it also has high thermal conductivity [3]. Due to these extraordinary properties, spider silk is being considered for a wide range of applications, such as materials for artificial satellites that are difficult to break, automobile materials that are difficult to injure pedestrians in collisions, and artificial blood vessels and catheters with excellent compatibility with human body [4].

However, for a long time, the mass production of spider silk has been difficult by major problems. First, spiders are highly territorial, and they begin to cannibalize each other within their territory. Second, the amount of thread produced by a single spider is small, so mass production of spider silk requires a tremendously large area. Third, spiders produce seven different types of threads, making it difficult to obtain spider silk of a certain strength. These problems made spider silk unsuitable for practical production.

Sekiyama and his colleagues at *Spiber*, which is the biotech company founded by Sekiyama in 2007, have succeeded in artificially synthesizing spider silk at a practical level for the first time in the world. They utilized a completely new method that optimizes amino acids and gene sequences to facilitate the production of spider silk by microorganisms with excellent growth and division speed [1]. This method is called "microbial fermentation technology”. After repeatedly incorporating new genes into the microorganisms and applying feedback based on the results of the quantity and quality of spider silk obtained, they eventually succeeded in producing 2,500 times as much spider silk as they had initially. The only source of nutrition for the microorganisms is sugar, which needs no petroleum resources and emits little carbon dioxide. In addition, the company's efforts were also groundbreaking in that they made it possible to spin the yarn without the use of toxic solvents.

Spiber's achievement is important not only because of the powerful protein material "spider silk," but also because the company has developed a database of genes to be introduced into microorganisms in the course of their basic research. With this approach, the company aimed to map the relationship between gene and fiber functions. This method is not limited to protein "spider silk," but can also be applied to protein materials that are still unknown. For example, it may be possible to create materials in combination with fluorescent proteins.

The method mentioned above could also be used in collaboration with the rapidly growing field of machine learning, etc. [5], and there is a possibility that it will continue to develop at an accelerated pace. If machine learning technology and big data can be utilized, it will be possible to more accurately predict what genes can be added to a microorganism to extract the characteristics of the material sought.

Another possibility is to use quantum computing technology, which has been rapidly developing in recent years. Quantum computers can perform parallel computations not only in the 0 and 1 states of classical computers but also in their "superposition" states. This has the potential to realize protein design and optimization of microbial gene sequences at overwhelmingly faster computation speeds compared to conventional methods. These synergistic effects may even make it possible to remove the assumptions made so far and develop completely unknown functional protein materials from exhaustive calculations. In the future, we will be free to discover very usable materials, which may include proteins that have never existed in nature before. I have great expectations that many fields such as genetic engineering, materials chemistry, and information science will be linked like "spider silk" to form a sustainable society on a global scale.

Reference

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