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# Hagfish slime: The future clothing

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**Abstract**
Synthetic fibers at present dominate the textile industry, which are made of petroleum based materials, that's way; its disposable is a big problem. Synthetic fibres replaced by natural ones, like spider silk, wool, silk etc. Now a new fibre 'hagfish slime thread' (protein based polymer) is invented, which is like spider silk, had exhibit outstanding material properties. Hagfishes (Craniata: Myxini) are an ancient group of benthic marine chordates that are best known for their ability to create large volumes of defensive slime when they are attacked. A wet spinning technique is used to spin Hagfish fibers and weaving is done on the fly shuttle pit looms. The hagfish threads possess intriguing property: they can be pulled 33% longer than their original length and still remain soft and flexible. Hence, it could be said that Hagfish slime threads will be a candidate of high performance eco-friendly clothing and will be fashion for future.

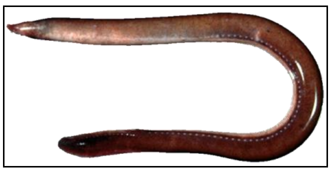
**Keywords:** Hagfish, slime, fibers, eco-friendly

## Introduction

Textile manufacturing is one of the biggest industries in the world, and synthetic fibres signify two-thirds of the global textile market. Synthetic fibres are fabricated from petroleum-based feedstocks, its main problems is disposal and also threat for the environment. Hence, there is a want to replace synthetic fibers with sustainable fibers [6]. Natural materials for example spider silk though demonstrate high performance and ecological sustainability but the way spiders generate their silks is complex, and spiders cannot be farmed to give up high quantities of silk [12]. Hence, an alternative could be the protein based polymer; hagfish slime a thread which is like spider silks. Hagfishes are exclusively marine, bottom dwelling, cold water animals that occur in depths from 2500 m to 30 m and are primarily scavengers, playing important ecological roles. Hagfish standard about 0.5 meters (19.7'') in length. Hagfish have elongated, eel-like bodies. Hagfish differ in color from a mottled grey-brown to a red-grey upper and a white to pale grey on the base or it depends on color of the sea bed. Hagfish Diet is prepared of marine worms and other invertebrates; dead and dying sea life. Large slime glands line their sides along the length of their bodies and can sneeze to clear slime from nostrils [20]. The hagfish slime protein threads have the possible to be spun and woven into new biomaterials. The slime contains myriad protein threads, 100 times thinner than a human hair and 10 times the strength of nylon [18].

There are approximately 67 described species of hagfishes but Pacific hagfish (*Eptatretus stoutii*) and the Atlantic hagfish (*Myxine glutinosa*) are the two most studied species (Figure 1.)

Pacific hagfish (*Eptatretus stoutii*)



Atlantic hagfish *(M. glutinosa)*

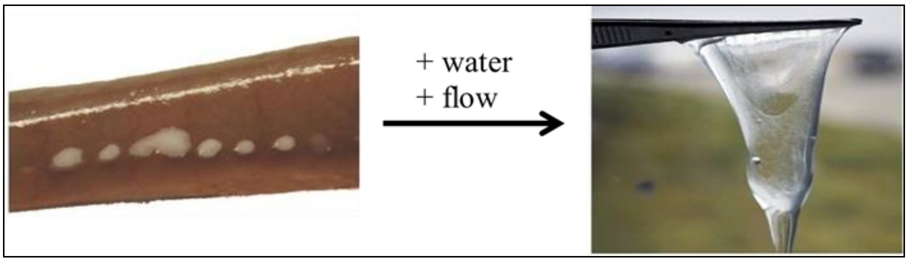
**Fig 1:** Picture of Pacific hagfish and the Atlantic hagfish

## Slime formation mechanism

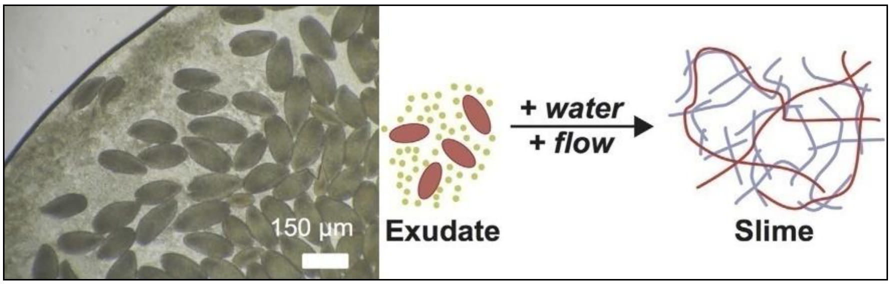
The slime serves as an instant defense mechanism against probable predators by clogging their mouth and gills. The slime forms when a glandular secretion, named exudate, is released into the nearby seawater from ventrolateral pores (Figure 2). The exudate is created by approximately 150 slime glands that line the whole length of the body in two rows [5].

The glands are enveloped in connective tissue and a striated muscle layer, which can contract and eject the gland contents. The whitish exudate composed of two major functional components Coiledup threads (named skeins) and Mucin vesicles that are secreted together with a ‘residual fluid’ [10].

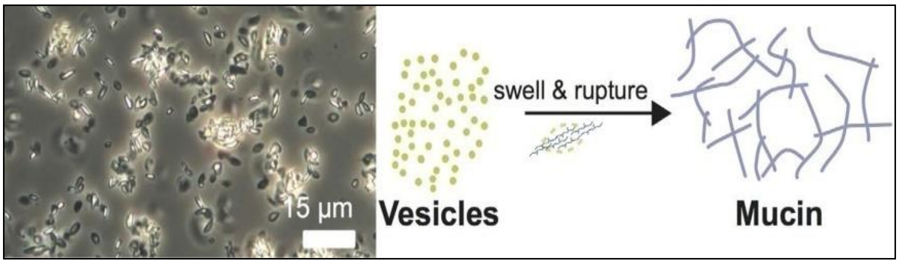
When the skeins are expelled from the slime gland via holocrine secretion into the seawater they unravel and liberate their long fiber, creating a network. The mucin vesicles contain sulfonated mucin like glycoproteins. Upon ejection, the vesicles enlarge, burst and release their mucus. Swelling vesicles are considered to stick on the uncoiling thread and together with agitation of the nearby water aid skein unraveling. The hydrated mucus and the net of unraveled threads together shape hagfish slime [17]. Revealed that hagfish slime holds considerable levels of alkaline phosphatase, lysozyme, and cathepsin B, which are concerned in natural immunity in various aquatic chordates.



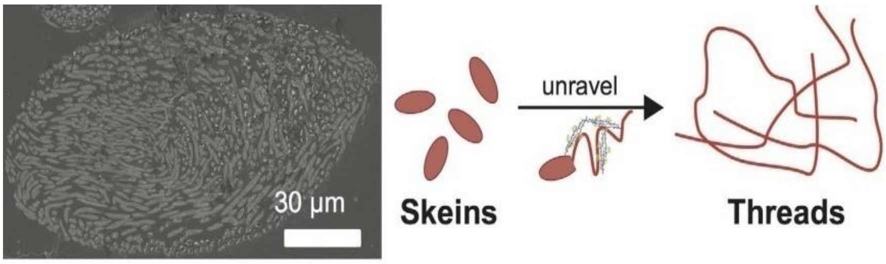

Exudate is liberated from pores after electrical stimulation. Exudate in water forming Hagfish slime.




Microscopy image of hagfish exudate exhibiting both skeins and vesicles with mucin.




When in water, the vesicles swell, burst, and form mucin strands under the pressure of flow.




When the skeins are expelled from the slime gland into the seawater they unravel and liberate their long fiber, creating a network.

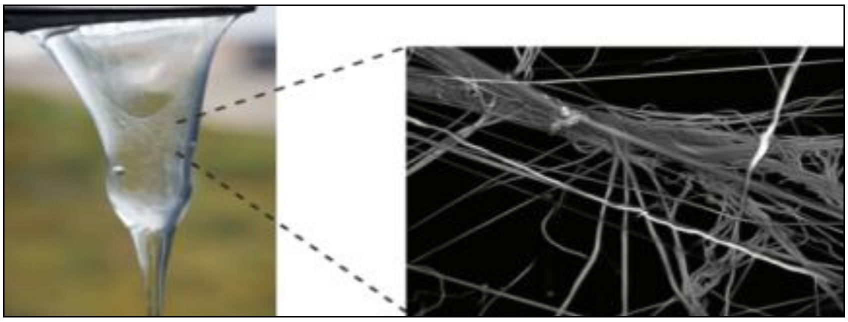
**Fig 2:** Mechanism of Slime formation [8].

Only the occurrence of naturally occurring $Ca^2$+ or $Mg^2$+-ions permitted for an stretched network and full water retention possibly due to $Ca^2$+- mediated vesicle burst and cross-linking of the mucin found by [4].

Hagfish slime glands (diameter 2-3 mm) was composed of two kinds of secretory cells, Gland mucous cells (GMCs) and Gland thread cells (GTCs), which turn out into the mucous and fibrous components of the slime, respectively. The chemical composition of mucus from the slime glands was investigated and found that it composed of 77% protein, 12% carbohydrate, 5% lipid, and 6% sulfate by dry weight [15]. The records recommended that the mucus was consisting of glycoproteins in which the leading carbohydrates are sulfated mucopolysaccharides. [19], observed that mucin vesicles combined into seawater that swell and extend into high-aspect ratio mucin strands. Mucins append to the thread skeins, transmit hydrodynamic forces to them and effect their unraveling by loading them in tension. The emptying and refilling of slime glands in Atlantic (*Myxine glutinosa*) and Pacific (Eptatretus stoutii) hagfishes were calculated and found that individual Pacific hagfish slime glands can liberate multiple boluses of exudate. In Pacific hagfish glands, thread skein morphometrics were preserved from the first bolus of exudates manifested to the last, although the mucous vesicle to thread skein ratio declined as more exudate was showed [16].

**Hagfish Slime Fibers**

Slime can be pulled out either in the occurrence of water or by electrical stimulation in the deficiency of water. Hagfish is moved in sea water by local pressure. The slime contain a loosely tangled mass of that is numerous centimetres long (Figure 3). This mass contracts spontaneously, and the resulting compact mat of fibres contains stands that can be drawn out several feet in length with viable thickness. The strands are soft & elastics when wet, strong & bendable when dry. The yield of fibers is around 0.25 g/l from slime [12].



Hagfish slime Hagfish slime fiber

**Fig 3:** Hagfish Slime Fibers [3]

**Structure of Hagfish slime fibers**

The slime threads have α-keratin like intermediate filament (IF) structure and thread bundles are aligned 1–3 µm in diameter and are a number of centimeters long.

The formation of these bundles of fibers is inimitable and comprise of following steps:

(A) Individual α-helices form coiled-coil dimers that self-assemble into subfilaments,
(B) The subfilaments resultant in complete IF (10 nm diameter),
(C) It aligned to form of one continuous macroscopic fiber. This process occurs completely within a single gland thread cell (GTC) and does not stop until the whole cell is fully filled with this newly formed fiber.

(D&E) Upon liberation of the glands, individual GTC lose the thin membrane that covered them showed in Figure 4.

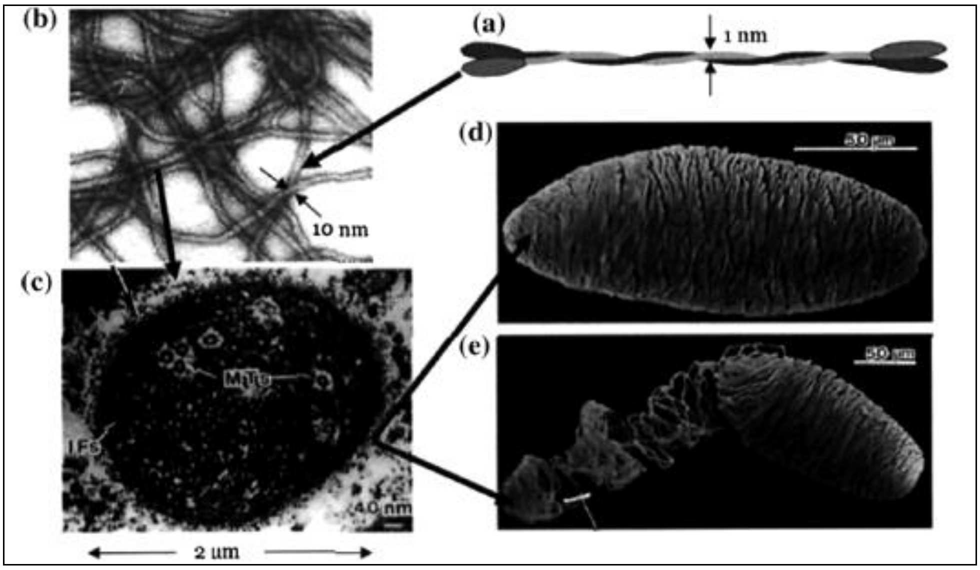



**Fig 4:** Helical structure of slime threads [9].

**Method for manufacturing fiber**

Gathering of slime from the hagfish is done. Then dissolve purified slime thread proteins in an acidic solution and allowed the proteins to coagulate into a film on the surface of an electrolyte solution. After that fibers pulled from these films. Fiber mechanics depends on casting conditions and postspinning processing. Protein concentrations lower than five percent yield films that are too fragile to make fibres. Postsecondary drawing resulted in fibers with superior material properties alike to those of regenerated silk fibers.

**Spinning of hagfish slime fiber**

Hagfish fibers are spun by means of a wet spinning technique. The hagfish slime, dissolved it in liquid, and then reassembles its construction by spinning it like silk. This protein based fibers have excellent mechanical properties. Hagfish fiber could provide a greener substitute to polymers for instance rayon, nylon or polyester-all which had been made from petroleum [11].

**Physical properties of hagfish fibers**

The hagfish threads possess intriguing properties such as-

- Hagfish slime fibers are remain soft and stretchy even after elongating at 33% longer than their original length.
- It possesses high breaking strain of 220%.
- Once this transition begins, the thread can be lengthened farther, to more than triple its original length.
- According to Fudge's measurements, it breaks at a stress of approximately 700 megaPascals.
- The tensile properties of the hagfish threads, a low initial stiffness of 6.4 MPa (0.06 g/den) but significantly high strength (180 MPa) (1.6 g/den) and low elongation of 2.2 % [14].

[18] showed that the slime thread on a weight basis was 5 times stronger than steel and at 800 MPa, it is basically as strong as spider silk (1 GPa), which is made mainly from a alike IF protein.

**Uses**

The strong, flexible fabrics made from hagfish slime, it is environmentally-friendly could be used in, the auto industry, medical applications, sports clothing, apparels, safety helmets, bulletproof vests and may more [1]. The U.S. Navy is presently working with hagfish slime for creating a substance to protect divers from underwater attacks, fight fires, and even stop missiles [2]. An antibacterial bandage fabricated from the Hagfish mucus. It was observed that the bandage would be able to stop maceration-permanent damage to nearby tissues due to extreme moisture [13].

**Conclusion**

Hagfish slime is a protein-based, jelly-like substance released by hagfish as defense against potential predators. Hagfish slime glands produce two main cell types: gland thread cells (GTCs) and gland mucous cells (GMCs). Both GTCs and GMCs lose their plasma membranes as they go by through the narrow gland duct, releasing bare thread skeins and countless mucin vesicles. A wet spinning technique is used to spin Hagfish fibers. The strong, flexible fabrics made from hagfish slime could be used in protective clothing, sports clothing, medical clothing, automobile, industrial proposes and many more. The slime is prepared by strands that are stronger than nylon, thinner than human hair, and very stretchy. Hagfish slime could present an eco-friendly substitute, but only if they were able to be farmed successfully [7]. Hagfish slime threads will be a candidate of high performance eco-friendly clothing and will be fashion for future.

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