Nature's Inspiration: Biomimetic design of seahorse tail muscles

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Background and Motivation

What is Biomimetics?

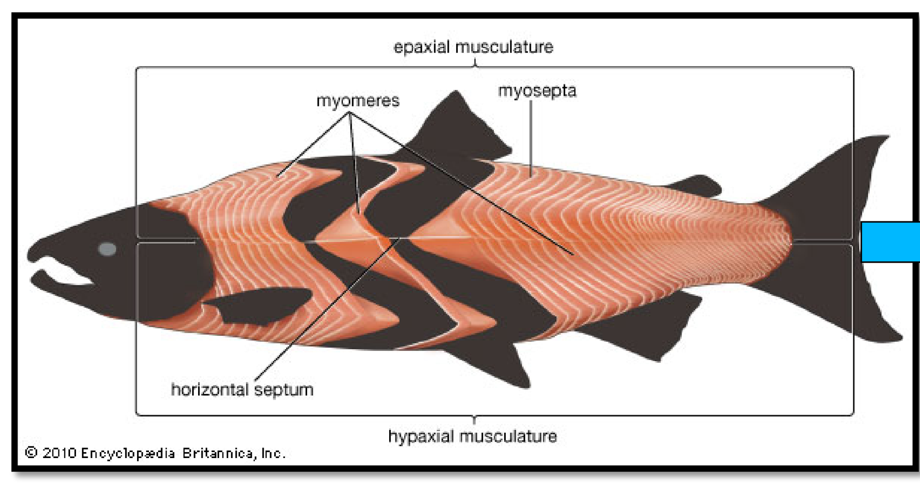
The imitation of models or systems found in nature to solve human problems.

Why the seahorse?

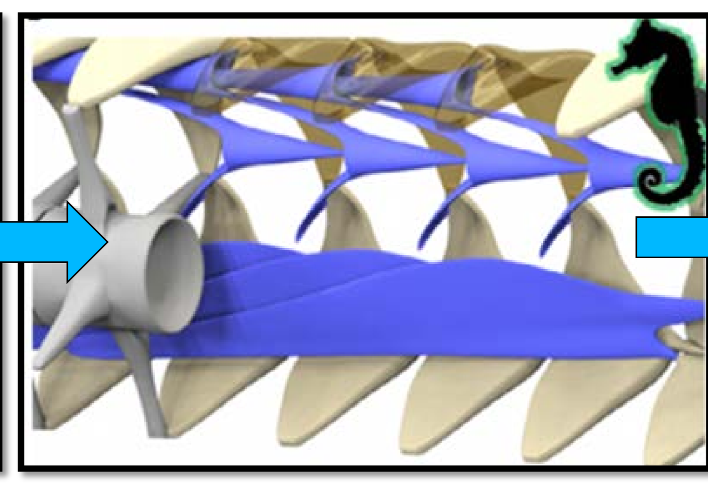
The seahorse tail is a unique appendage among the natural world as it is both prehensile as well as resistant to compression due to its unique skeletal structure and boney plates.

How does the tail function?

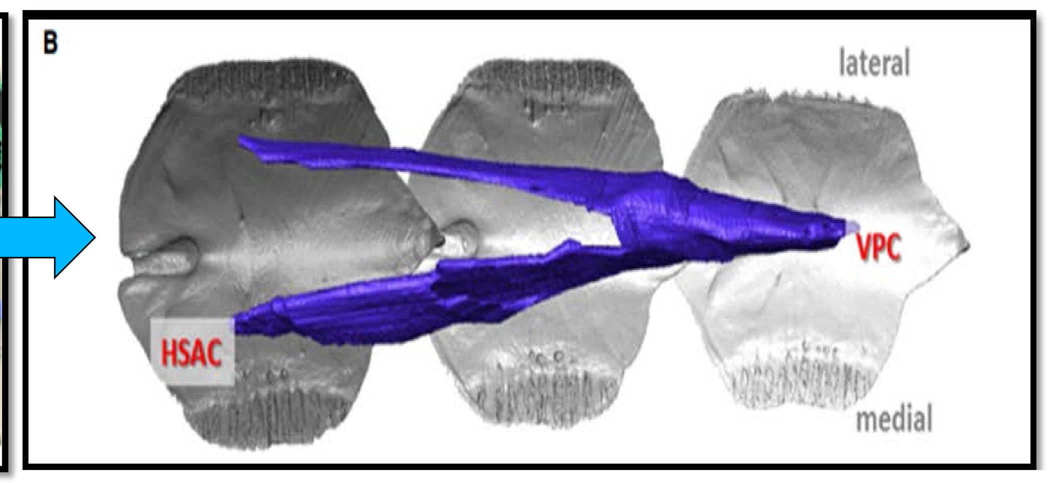
The seahorse tail, like most fish, is comprised of W shaped myomere muscle structures connected to myosepta and cartilage that contract to contort the boney plates.



Myomeres and myosepta [1]



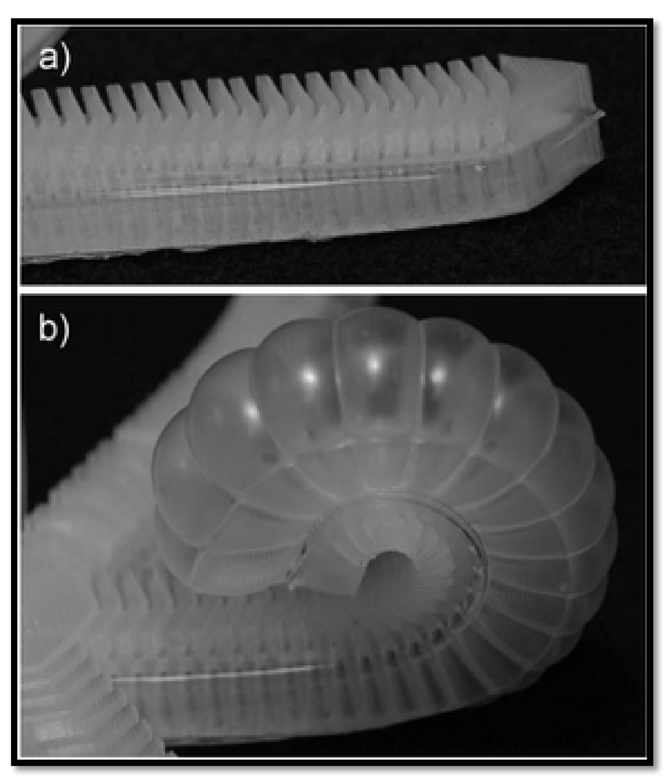
Muscle structure in the seahorse tail [2]



Muscle connection in the boney plates [3]

Artificial Muscles

Parallel chamber tentacle muscle [4]



Series chamber tentacle muscle [4]

McKibben muscle [6]

Servo and motor muscle [7]

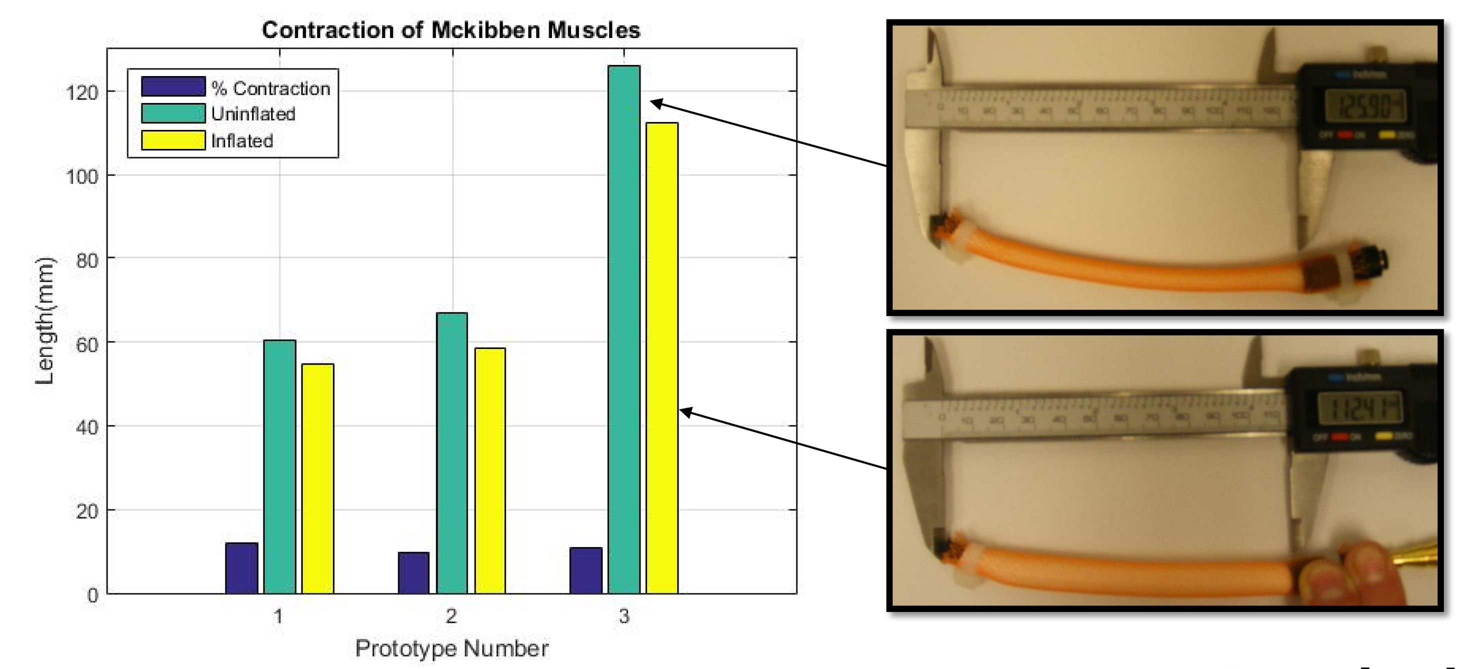
There have been many attempts to make artificial muscles. Notably there are two main types of pneumatically actuated muscles [4-6], in contrast to electric servos and motors [7]; however, these are not the only types just the most well established. Each have their own unique strengths and weaknesses. Parallel chamber pneumatic muscles [4], consist of a soft polymer with three or more parallel chambers that can inflate to cause varying deformations. Series chamber soft muscles [5] are constructed of connected chambers of soft polymer with a stiffer polymer spine. When inflated these chambers deform in a two dimensional plane. McKibbens muscles [6], are an inflatable soft tubing constrained by a meshing that allows it to expand or contract in one dimension depending on the meshing orientation. Electronic servo and motor muscles [7], are powered by either direct motor torque or wires that deform segmented plates due to tension in the wire. This research will compare parallel chamber muscles and McKibben muscles for application as lightweight actuators to control a seahorse-inspired robot. The robot could be used for or applied to the medical field as well as search and rescue in the case of fallen structures or dangerous terrain; the need for resilient yet articulate robotics are needed to perform dangerous or delicate tasks.

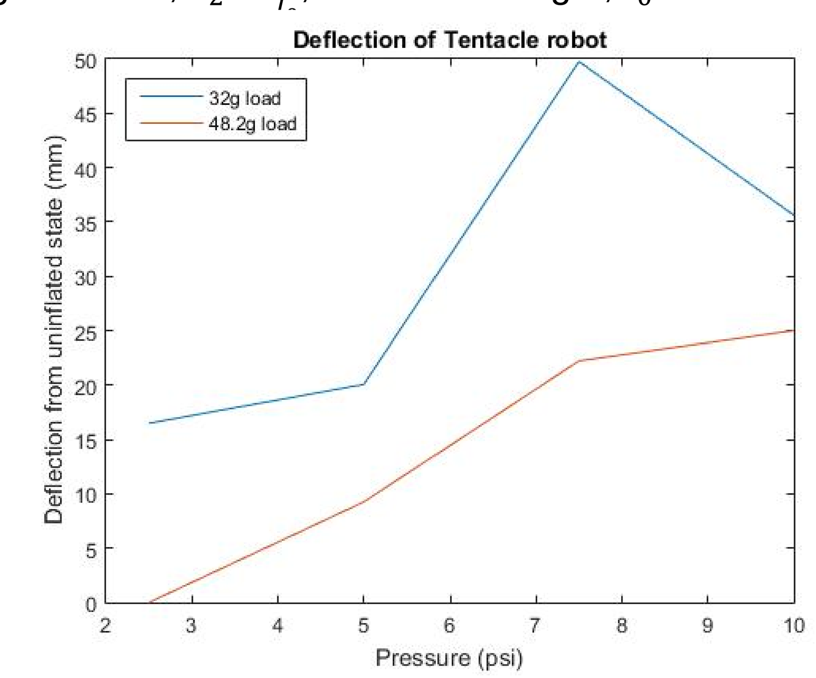
Application and Progress

The parallel chamber muscles were constructed by first creating a 3D printed mold. After which Ecoflex 00-30 polymer was cast to the mold to form the muscle. McKibbens muscles were constructed by inserting a male cap into 3/8" high-temperature silicone rubber tubing. A ¼" expandable polyester meshing was fed over the tubing and secured to the cap. Finally a coupler was fed onto the tubing and the meshing pulled tight and anchored to form a contracting muscle. The McKibbens muscles were measured for their at rest uninflated length then inflated with 60 psi of pressure and measured for their contracted length. Their experimental contraction force was unable to be measured due to a lack of sufficient weight but can be calculated with the equation below [8]. The parallel chamber muscles were inflated at increasing pressures and the deformed center end point was measured to obtain its displacement from its uninflated center end point. It was then subjected to a load of 32.0 grams and 48.2 grams, then observed when inflated at different pressures. Due to the parallel chamber muscle's complex movement most literature is focused on empirical data, rather than analytical and therefore lacks an established governing equation.

$$F(\mu) = \frac{P}{4\pi N^2}\left[3\lambda_2^2 l_0^2 - B^2\right]$$

F= contraction force, P= pressure, N= number of turns in the meshing, B= Length of cord, $\lambda_2 = \frac{l}{l_0}$, l= inflated length, l_0= uninflated length [8]

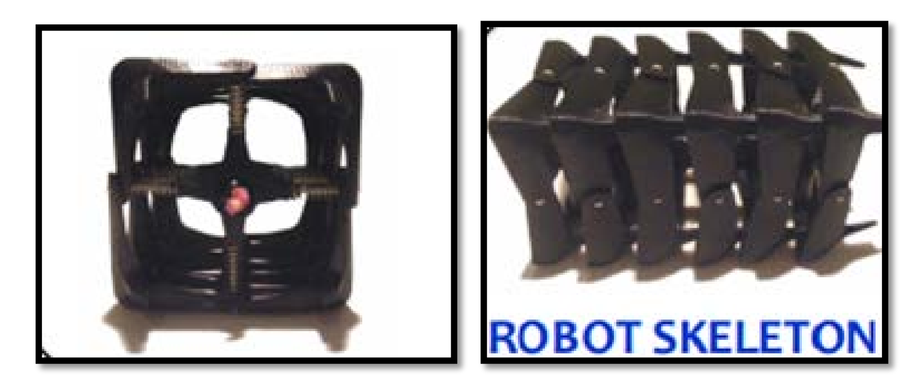




Conclusions

While soft robotic tentacles provide a greater range of motion compared to McKibbens muscles they cannot provide a comparable contractive force. Additionally McKibbens muscles are closer to their biological representation in functionality than soft robotic tentacles.

Tentacles	McKibbens
• High maneuverability • Low pressure needs • Easily replaced	• Higher contraction force • Easier to control • One dimensional motion • Biologically accurate • More durable



3D printed skeletal structure [9]

Future work

Using McKibbens muscles we plan to optimize its design to improve their contraction length and implement them into the seahorse tail skeletal structure seen above [9]. Using these muscles we will actuate the structure to try and obtain the flexibility, dexterity, and compressive resistant performance found in its biological inspiration.

Acknowledgements/References

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