OPEN ACCESS Freely available online

Journal of Geography and Natural Disasters

Editorial

The functional ecology and mechanical properties of biological hooks in nature

George Lazarovits

A&L Biologicals, Canada

Editorial

The selection of biological hooks in nature is wide so how do we endeavor to narrow the field into a manageable set that can be analyzed and commercialized such that they all have a natural product that is reproducible and of value to the human population? We turn to the ancient evolutionary theory of cladistics which makes use of a simple measure to differentiate between organisms, the visual structures that differentiate and also consolidate them into sets. Nachtigal supplies us with a textbook of classes of attachment mechanisms which yield a number on instances where the connectors resemble those of man-made devices, from ratchets to hinges, but always in two structures and never with an intervening third which is separate from the two such as the rod of a hinge on a door. It is important to consider the use of available technology, to look at these examples with new eyes as are made available by new microscopy techniques, computer integration and new layered manufacture techniques such as SEM (Scanning electrodeposition Electron Microscopy) and bio-printing. The end result has been the simplest of all attachment devices seen to be possible and inevitably the first option when looking at commercial applications. Advances in biomaterials too mean that we can look at more options with greater versatility from fusing bone with attachment devices treated with hydroxyapatite to anchorage devices for the sensitive walls of the gut and/or the abdomen as well as brain implants for sensing magnetic fields. It is hoped that the reader will enjoy this work as much as I have with the great promise that it will hold forth the right of way for the advance of technology and the sustenance of the age which is about to come.

The hook as a shape occurs very early on the evolutionary scale. Cellulose appears as a biological building block in the Cambrian age from fossil records, and hooks have been found in chitinous organisms as mandibles, maxillae as well as tarsi. Hook separation forces associated with plant seed and fruit dispersal have been studied in four species by SN Gorb. A fifth, Arctium minus is purported to have been the source of engineering design inspiration for George de Mestral. There are marked differences in the shape and functionality of natural A. minus hooks, and the probabilistic fastener that he designed and developed, namely the needle-like profile for insertion of the A. minus hooks, their lack of reusability and their physical size. In functionality, Velcro resembles that of Circaea lutetiana, not A. minus. From the study of SN Gorb's data, it is concluded that there are additional indicators for structural behaviour as well as the morphological variables indicated by Gorb, and these are flexible versus fixed bases to the shafts and degrees of resilience of the component material. The natural substrate properties are presented as being indicative of the receptiveness of the hooks to a range of substrates. Field testing consisted of tensile testing mounted A. minus hooks in an Instron tensile tester in a laboratory to note the fracture strength and mode of failure which was characteristic of a composite biomaterial. The study indicates that contrary to Gorb, the reduction in the size rendered the bending moment due to the hook span to be negligible and of little effect. Note that an early original botanical paper on A. minus is missing presumed lost from the British Library and that finite element analysis follows in paper III, and an experiment into the use of confocal microscopy in paper II. Results indicate that the contact separation force is independent of bending moment and the "span" of the hook, a scaling effect that is important for the design for manufacture of micron range-sized hooks. igher plants use a variety of dispersal agents such as wind, water, animals and people [1]. Dispersal by animals is known as zoochory. The dispersal of seeds or fruit (known as diaspores, more often fruit than seeds) by attachment to animal fur or feathers is known as epizoochory. Diaspores of this kind do not provide valuable nutrition to the animal to which they attach themselves nor do they actively attract animals to parent plants. Instead, they have special structures such as hooks, barbs, burrs and spines or sticky secretions, and they detach easily from the parent plant. A. minus is commonly known as burdock, and it is found throughout the UK and is a member of the thistle family. It is common knowledge that it is an annual noxious weed commonly found by the side of pathways and riverbanks. It grows approximately to 2 m in height and generally features single or multiple primary stems off which arise secondary and tertiary branches. In fur and feathers, the diaspores may remain attached for a long period of time until animals groom them off or until the animal dies. A. minus has natural symbiotic partners in seed dispersal that are wild animals and birds indigenous to the UK, such as rabbits, badgers, foxes, sheep and deer. The diaspores of A. minus are adapted for dispersal by mechanical interlocking.

In terms of the plant's life cycle, the hooks become operational early in the year, acting as a defense mechanism while the immature seeds develop. From observation, at this stage, the tensile force required to remove the fruit from its supporting stem is at its highest. The corolla or flowers are in evidence at the apex of the fruit, protruding from the basal cup comprising of the ovary and surrounding bracts. This fruit is green and the hooks are developed. As the fruit matures, the corolla withers and then disappears. The seeds are present in the ovary, and these are freed by the total disintegration of the fruit which begins immediately when the fruit is separated from its host plant with the use of the now brown and dry bract hooks. Each of the bracts is flattened at the base where it originates, becoming narrower to form the shaft of the hook. Therefore, each hook has a single degree of freedom which, Gorb says, decreases the contact separation force and increases the propensity of the fruit to attach because the ability to bend implies weaker and flexible cell structures yet a greater ability to become attached in a probabilistic manner.