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Golden Fleece: An Ancient Sheep

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Abstract
Of the many infeasible creatures and relics of ancient Greek mythos, the Golden Fleece from Jason and the Argonauts has drawn much attention from historians as to what it represented in terms of politics, technology and religion. However, we will instead explore the scientific basis to the possibilities of the existence of a gold fleeced ram. This article specifically addresses the biological and geochemical aspects to this multidisciplinary problem, and follows previous research carried out by this group regarding the physical and biophysical aspects.

Introduction
Written in the 3rd century BC, *Argonautica*, by Apollonius Rhodius, is one of the oldest and most complete accounts of Jason and the Argonauts, a tale that is one of the most famous and foundational in Greek classical history. The agonist of *Argonautica*, one Jason of Iolcos, quests across uncharted seas and overcomes impossible obstacles in order to obtain a legendary relic, with promise of his rightful crown. This relic, the fleece of a ram with wool of gold, can almost be described as unassuming among the many fanciful creatures and relics in the tales of ancient Greece. It is the fleece's representation of power, rather than any monetary value, which is at the heart of Jason's quest. However, a fleece of gold must have once belonged to a creature capable of creating its fleece as a product of gold rather than the usual keratin.

In slightly more recent history, in 1953, the Russian chemist Vinogradov published an extensive work concluding that the accumulation of gold by organisms was entirely random and that there was no evidence of auriferous animals in any part of the world [1]. However, if such a creature were to exist, it would raise a number of interesting issues regarding physical, geochemical, biochemical, and evolutionary feasibility.

Old Sheep
Work previously done by this group showed that assuming a fleece with the same proportions as that of a normal sheep's wool fleece, the Golden Fleece would weigh approximately 50kg, almost the weight of another entire ram on its back. Vinogradov's statement is seen to be correct on the most part; the maximum gold content in marine invertebrates is found to range from orders of 0.001 to 0.1 nanograms per gram (ng/g) of dry biomass, while the largest measurements range from 2 to 50 ng/g for migratory birds collected in an auriferous area [2].

Assuming the body water content of the ordinary 66kg ram is roughly 60% of its full bodyweight, the dry biomass of a 116kg golden fleeced ram will be constituted of over 65% gold. This is 130 million times that seen in the most aurous of known terrestrial vertebrates [2]. No creature has so far seen to have such large proportions of any metal. There are, however, examples of bacteria that utilise metal nanoparticles, and a recently discovered deep-sea vent-dwelling snail with iron plated foot scales. This suggests the bio-capability of producing metal constituent body parts in simple organisms, yet it would be a significant extrapolation to extend this to the vertebrates. Much less likely is the specific case of gold. This partly due to being among the least reactive metals, and therefore, gold is difficult to implement into biological systems. More notably, gold is such a rare metal that a species is unlikely to have a reliable enough source in order to evolve a use for it, and an organism that can is unlikely to stumble upon enough to make any use of it.

For example, the gold content of water sources ranges widely, with sea and river water from non-auriferous regions having gold content per litre measuring below the nanograms [2], while river and ground water from auriferous regions has been found to reach respective gold concentrations of 15.44 and 67.82 ng/L.

If we give the ram the benefit of the doubt, and we assume it obtained its gold from groundwater equivalent sources in auriferous regions, it would still have to consume at least 750 billion litres of water to grow its 50kg coat. Using data from the Ministry of Environment [3], a ram consuming the recommended 11 litres per day would take 180 million years to do so with the anatomical capabilities of an ordinary sheep. This assumes all gold is used for fleece growth and not subsequently damaged, lost or eroded; an unlikely prospect due to available weathering time and the natural malting of the primitive breeds on which the ram is modelled.

Cold Sheep

Another constraint relates to the large difference in the thermal properties of wool and gold. The thermal conductivities of bulk steel and keratin are known, as are those of steel wool and sheep's wool. The thermal conductivity of gold is 5 to 10 times more than that of steel [4, 5], and 500 times that of bulk horn keratin [6]. Using the properties of both sheep's wool [5] and steel wool [7] to model the aurous wool of the ram, the fleece is likely to have thermal conductivity of 10 to 40 $Wm^{-1}K^{-1}$. This is 250 to 1000 times more conductive than ordinary sheep's wool. Therefore, as a warm blooded vertebrate, the sheep would overheat easily in the sun, and require a far thicker coat than the model rams in order to maintain body heat in the harsh Caucasian mountains. This causes a long cascade of further issues due to increased weight and the subsequent gold requirement of the ram. Although the evolution of such the creature is already infeasible, these further issues point clearly and evidently towards the likelihood that a ram with golden wool could not exist outside of the ancient Greek mythos.

References

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