RESEARCH PAPER

How possible was Prometheus' punishment?

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ABSTRACT

We discuss the feasibility of the regeneration of Prometheus' liver: would cells be able to regrow fast enough to allow Prometheus' liver to be eaten every day by an eagle? A simple model is constructed that incorporates the eating habits of eagles – how much food they eat in a day – as well as the natural regeneration time of a human liver. Our calculations have shown that if Prometheus' liver was the only food source of the eagle (300g consumed per day), it would take approximately 2 days for complete regeneration.

Background

The myth of Prometheus comes from the ancient Greeks. In the myth, the titan Prometheus fought alongside the gods against the rest of the titans (Gillespie, 2017). Zeus, king of the gods, repaid the titan by allowing him to create humans. Prometheus created the first humans in the image of the gods, but he and Zeus disagreed on how important the humans should be. Zeus denied fire to the creatures of the Earth, and so Prometheus climbed up Mount Olympus and stole fire from the gods to give to people. When Zeus realized what Prometheus had done, he chained him to a cliff, where every day his liver would be eaten by an eagle, and subsequently regrow overnight to be eaten again the next day. In order to verify the feasibility of this myth, the eating habits of eagles, and the regeneration time of the human liver are considered.

Eagles

Golden eagles are still to be found in modern Greece and it is possible to use this species as a model when investigating the myth (National Geographic, 2018). Golden eagles are large birds of prey that tend to feed on smaller mammals, birds, reptiles, and sometimes larger carrion. They typically require between 250g and 450g of food daily in order to sustain themselves. However, they can eat up to 900g in a day, storing this food in a crop in their oesophagus for later (National Eagle Center, 2017). We have assumed that the eagle would not try to remove Prometheus' liver, and would instead treat him as carrion and take bites. After all, the eagle is consuming Prometheus' liver in order to punish Prometheus rather than as a reward.

The liver

In this paper, Prometheus' liver is assumed to be human-sized. In a typical human male, the liver weighs roughly 1.5kg (Molina and DiMaio, 2012) and has an approximate volume of $4m^3$ (Obradović, Aleksić and Mijatov-Ukropina, 1991). One remarkable feature of the liver is that it contains many hepatocyte cells, enabling the organ to regenerate after injury (Furchtgott, Chow and

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ACCEPTING EDITOR: Stuart Macdonald

Periwal, 2009; Duncan, Dorrell and Grompe, 2011). This involves restoring both the mass of the liver, and any lost bodily functions.

The liver is able to regenerate so well because of the presence of numerous signal chemicals, such as hepatocyte growth factor, interleukin-6, and tumour necrosis factor, which are sensed by the remaining hepatocyte cells. These stimulate rapid cell growth and mitosis to restore the initial mass of the liver (Hay, 2016). Generally, other cell types within the liver do not divide in order to restore their original numbers until the majority of the mass is reformed.

The maximum amount of the liver that can be removed and yet still result in full mass and functional regeneration is 75% of the initial mass. Studies have shown that full regeneration of the mass takes one week in mammals, provided that any remaining lobes of the liver are intact (Duncan, Dorrell and Grompe, 2011). In our model, only the mass regeneration time of the liver is considered, as the ability of the liver to function normally is not a requirement for the eagle to eat it daily.

Calculations

In artistic interpretations of the myth, Prometheus is depicted as the same size as a human, and so a human-sized liver can be used in the model. Assuming that the eagle eats only 300g of a liver per day, this is about 20% of the total mass of the liver. We know that it takes one week, or 168 hours, for 75% of the mass of the liver to regenerate. Assuming a constant rate of regeneration, the time taken for 20% of the liver to regenerate can be calculated as 44.8 hours. This is longer than the regeneration time stated in the myth, which should be, at most, 24 hours. However, if we consider that the eagle may not be eating Prometheus' liver purely to survive, we can calculate how much of a liver could be eaten and regenerated in a single day (24 hours). From these calculations, 10.7% of the liver could be consumed by the eagle per day and still allow regeneration of the total liver mass for the next day. This is equivalent to 160.5g of a 1.5kg liver.

Problems

There are various problems that arise when considering this myth: for the regeneration of the liver, at least two of the lobes must remain intact, which is unlikely to happen without careful dissection (Duncan, Dorrell and Grompe, 2011). When carrion is present, it is generally not a single eagle that feeds from the carcass, but many (Hay, 2016). This would be detrimental to Prometheus' ability to regenerate his liver, as a higher percentage of the liver would be eaten, and so it would be unable to regenerate fast enough. As Prometheus was chained to a cliff (Gillespie, 2017), he was unlikely to be able to eat much. The regeneration of so many cells would probably require lots of energy, and so the lack of sustenance of Prometheus would likely affect the rate of regeneration.

Conclusion

This myth is not feasible because the eagle's dietary requirements would outpace the regeneration of Prometheus' liver by a factor of two. Prometheus would be able to regenerate 300g of liver in 44.8 hours, but by that time the eagle would have returned to eat more. If the eagle is eating Prometheus' liver only to torment him for 30,000 years, then it could consume 10.7% (160.5g) daily before allowing it to regrow by the next day.

Acknowledgements

This paper first appeared in the *Journal of Interdisciplinary Science Topics* in April 2018. It is reproduced by kind permission of the authors and the journal's editor.

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