

Survival Time of Princess Kaguya in an Air-Tight Bamboo Chamber

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Princess Kaguya is a heroine of a famous folk tale, as every Japanese knows. She was assumed to be confined in a bamboo cavity with cylindrical shape, and then fortuitously discovered by an elderly man in the forest. Here, we pose a question as to how long she could have survived in an enclosed space such as the bamboo chamber, which had no external oxygen supply at all. We demonstrate that the survival time should be determined by three geometric attributes regarding her body and the bamboo chamber. We also emphasize that this geometric problem shed light on an interesting scaling relation between biological quantities for living organisms.

Key words: Metabolic Rate, Respiration, Allometry, Biophysics

1. Introduction

Imagine being trapped in a closed room with no window, chimney, or hole in the wall to allow the flow of air. Would you survive for long or remain safe in that situation?

The most serious and imminent danger associated with entrapment in a sealed room is the inevitable development of oxygen deficiency disease. Oxygen is one of the key elements required for the sustenance of life, as experimentally confirmed in the 1770's by Joseph Priestley [1]. The author demonstrated that mice could survive in closed containers as long as they contained plants that emit oxygen through photosynthesis; otherwise, the mice could not survive without the plants. This may be true for all mammals including humans [2]. By incorporating oxygen into the body, humans create approximately 30 molecules of the energy source adenosine triphosphate (ATP) from one molecule of glucose [3]. Therefore, once all the oxygen in a sealed room is consumed by an entrapped individual, the body can no longer produce energy without which it would be difficult to survive. Here is the question: How long can a human being survive in a sealed room with no external oxygen supply?

This article provides a viable solution to the question posed. Our argument is based on a fictional mysterious girl “Princess Kaguya”, who is the heroine of the most famous folk tale in Japan [4]. In the tale, an old man working as bamboo cutter discovered a miniature girl inside a glowing bamboo shoot; see Fig. 1. Believing her to be a divine presence, he and his wife decided to raise her as their own child. When the girl came of age, she was conferred with the formal name “Princess Kaguya”, which incorporates the Japanese term Kaguya derived from the light and life she radiated. The legendary story of Princess Kaguya has been handed down through generations [5]; it was animated in 2013, released worldwide, and was finally nominated for a



Fig. 1. Cartoon of the situation where a girl was discovered by an old man. The folk tale states that the old man found a small girl sitting inside a bamboo chamber that shined like gold. He then took her home, named her Princess Kaguya, and nurtured her.

2015 Academy Award for a feature length animation film [6].

As mentioned above, Princess Kaguya was assumed to have been discovered inside the stalk of a bamboo plant (see Fig. 2), which was completely air-tight. This poses the question of how long Princess Kaguya had survived in the bamboo chamber. We will see below that solving this problem may facilitate understanding of the interplay between metabolism and respiration [8, 9]. In addition, this problem can be easily extended to situations on different scales, and is not limited to a “miniature girl situation”; it thus provides an intellectual exercise for considering the allometric relationship of living matter with respect to oxygen.