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Gillyweed – Drowning with Gills?

Rowan Reynolds & Chris Ringrose
The Centre for Interdisciplinary Science, University of Leicester
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Abstract
In David Yates' film adaptation of J. K. Rowling's *Harry Potter and the Goblet of Fire*, Harry Potter passes the second Triwizard task by consuming Gillyweed. This Mediterranean plant allows him to breathe underwater by growing gills on his neck. The gills were approximated to be 60 cm^2 in surface area, and using standard measurements for a boy of his age, Harry was estimated to need to process 443 litres of water per minute. This came to mean the water would have to flow at 2.46 m s^{-1} across his gills, far faster than he could inhale and exhale.

Introduction

In David Yates' film adaptation of J. K. Rowling's *Harry Potter and the Goblet of Fire* [1], Harry Potter is seen consuming Gillyweed: a Mediterranean plant which leads to temporary growth of gills, and webbed fingers and toes. But are the gills large enough to provide sufficient oxygen for Harry to swim?

Oxygen Requirements

The Oxygen content of the Black Lake (which is presumed to be 10°C) would be around 11.29 mg L^{-1} [2]. While swimming, the maximum oxygen use is approximately 60.3 mL kg^{-1} min^{-1} [3]. Assuming a normal BMI, and that Harry is the average height for a 14 year old boy, he would weigh around 58 kg [4]. This means that he would use 3.50 litres of oxygen every minute while swimming. 11.29 mg of oxygen per litre of water can be converted to 0.00790 litres of oxygen per litre of water. This means Harry's gills must process 443 litres of water at 100% efficiency every minute while swimming in order to survive.

Gill Size

The Gillyweed causes gills to form on either side of Harry's neck, with three gill slits on each side. The formation of the gills causes Harry's neck to appear swollen. Each slit appears to be approximately 10 cm long, and 1 cm wide. This gives an area of 10 cm^2 per slit, and therefore a total area of 60 cm^2 where water can flow out.

Figure 1) A close-up shot of Harry's gills in the film [1].

Assuming the water takes as long to flush into the gills as out, with no time taken to swap between the two, the required efficiency can be calculated as follows.

443 litres of water must pass through 60 cm^2 of area every minute. This is the same as 0.00738 m^3 s^{-1} passing through 0.0060 m^2 which can be converted to a velocity of 1.23 m s^{-1}. However, the water must pass in and out in that time, giving 2.46 m s^{-1}. This is extremely fast if Harry is to bring water into his gills through respiratory power alone. The velocity of normal breathing has been recorded as 1.30 m s^{-1} [5]. 2.46 m s^{-1} is almost twice the velocity of normal airflow, which makes Harry's gills unfeasible.

In the film, Harry is frequently seen swimming with his mouth closed, which is not how fish use their gills. If Harry were to open his mouth to allow water

into his throat and out through the gills, it may be plausible that he could breathe underwater. However, without doing this, it is simply not plausible that he could extract sufficient oxygen for survival.

Conclusions

If Harry were to swim – as he does in the film – with his mouth closed, he would not be able to extract oxygen from the water fast enough to survive while swimming. This is because he would need to force the water past his gills at 2.46 m s^{-1} through simply breathing in and out. However, if he were to open his mouth, and allow the water in and then out through his gills, he only needs to travel at half this velocity. It could also flow continuously, without the need to breathe in and out which would reduce the force required by his respiratory system.

References

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