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P3_9 Scooby and Shaggy: Metabolic Miracles

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Abstract

In the cartoon 'What's New Scooby-Doo?' the characters Shaggy and Scooby are seen to eat large volumes of food without gaining any weight. Their effective temperatures in order to radiate away the excess energy were calculated to be $T_{Sh} \sim 97.0 \pm 33\,^{\circ}$C for Shaggy, and $T_{Sc} \sim 140 \pm 43\,^{\circ}$C for Scooby. It was concluded that under normal circumstances, the subjects would perish of extreme hyperthermia. It was also noted that Shaggy could survive if he was able to sweat continuously at the maximum rate for a human.

Introduction

'Shaggy' and 'Scooby' are characters from the cartoon 'What's New Scooby-Doo?'. In the program they are seen to eat large amounts of food [1]. We consider the implications of having a metabolism that would allow Shaggy (a teenage boy) and Scooby (a Great Dane) to remain at a normal weight. We ignore sweating as it is complex to model, though we shall discuss it later.

Gluttony

During the show, the duo are seen to eat around 1 and 30 standard plates of food, three times a day (not including snacks) [1]. A conservative estimate of their average food intake is taken as $\sim$ 10.0 $\pm$ 5 times that of an average American adult male [1], equating to approximately 0.110 $\pm$ 0.06 GJ worth of food per day [2].

The average daily amount of calories burnt by our subjects arises from their BMRs (Basal Metabolic Rates), the rate at which the body uses energy while at rest to remain alive [3].

$$BMR \sim 4M^{\frac{2}{3}} \quad (1)$$

BMR can be calculated for a mammal by Eq. (1) [4], where M is the mass of the organism in kg. Shaggy and Scooby have masses of 72.6 kg and 31.8 kg respectively [5]. A BMR modifier must be applied depending on their level of activity. Our subjects are mostly very lazy [1], hence a modification factor of 1.2 [6]. Thus BMRs of 83.5 W and 48.1 W are found respectively. Over a day, this equates to an energy expenditure of 7.20 MJ and 4.20 MJ respectively.

Exercising During Exorcising

Most episodes of the show have an iconic chase scene in which Shaggy and Scooby run at an equal velocity [1]: the top speed of a Great Dane (an impressive feat, given that the top speed of a Great Dane ranges from 15.5 - 17.8 ms^{-1} [7]). We can approximate the resulting energy expenditure by modifying the BMR values of our subjects with a factor of 2 for extreme activity.

$$BMR_A = \frac{6BMR_L + 2BMR}{7} \quad (2)$$

Assuming one chase per week, we can obtain an average BMR for Shaggy and Scooby on a typical day, BMR_A. This is summarised in Eq. (2) where BMR_L is the 'lazy day' BMR from earlier, and BMR is the unmodified BMR. Hence, we find BMR_A values of 92.0 W and 52.3 W for Shaggy and Scooby respectively.

Feeling the Heat

From the BMR_A values we find the total energy Shaggy and Scooby burn to be 7.90 MJday^{-1} and 4.50 MJday^{-1} respectively. Subtracting these from their average daily energy intakes from food gives the total excess energy that they must expel (we are only considering radiative heat loss as normally this is the dominant method [8]). Thus, their total excess energies are found to be 0.102 ± 0.06 GJday^{-1} and 0.106 ± 0.06 GJday^{-1} respectively. Converting into Watts gives the rates at which Shaggy and Scooby must radiate energy: $P_{Sh} = 1.18 \pm 0.7$ kW and $P_{Sc} = 1.23 \pm 0.7$ kW respectively.

$$P = \varepsilon\sigma A\left(T^4 - {T_c}^4\right) \rightarrow T = \sqrt[4]{\frac{P}{\varepsilon\sigma A} + {T_c}^4} \quad (3)$$

Using the Stefan-Boltzmann law, Eq. (3) [9], we can find the surface temperatures of Shaggy and Scooby that would allow them to radiate away this excess energy. Where: P is the rate at which energy is radiated, $\varepsilon = 0.98$ [10] is the emissivity of human skin, A is the surface area of the radiating body, T_c is the temperature of the environment taken to be 294 K for room temperature and T is the temperature of the radiating body. It is assumed that ε is roughly the same for a dog. For area, values of $A_{Sh} = 1.9$ m^2 [11] for Shaggy and $A_{Sc} = 1.02$ m^2 [12] for Scooby were taken. Substituting in the relevant values obtains $T_{Sh} = 370 \pm 33$ K and $T_{Sc} = 413 \pm 43$ K.

Conclusion

The final values of $T_{Sh} \sim 97.0 \pm 33\,^\circ$C and $T_{Sc} \sim 140 \pm 43\,^\circ$C, suggest that Shaggy and Scooby would, under normal conditions, perish. This is due to their core body temperatures vastly exceeding the $\sim$ 37 °C homeostatic temperature required for normal function of a mammalian body (even at the extremums), i.e. terminal hyperthermia. If conduction/convection were included, these temperatures would be even higher, as heat loss by these processes is less efficient than via radiation, due to the power radiated varying by $P \propto T$ rather than $P \propto T^4$ [13]. If sweating were included; the maximum rate of heat loss by sweating ($\sim$ 1.2 kJs^{-1} [14]) would just allow for the excess energy to be evaporated away. However, this could only be applied to Shaggy, as Scooby cannot sweat to a significant degree. Shaggy would then have to continuously regain the water and salt lost to sweating, as well as go through life wet and smelly. It is suggested that these are the factors behind why it is more advantageous to store excess energy as fat.

References

[1] What's New, Scooby-Doo?: Complete Series One to Three, written by Ruby J and Spears K, Warner Brothers (2002).

[2] http://tinyurl.com/m3ug4ol (25/10/2016).

[3] http://tinyurl.com/pow4ja9 (08/11/2016).

[4] White, C.R. and Seymour, R.S., Proceedings of the National Academy of Sciences, 100(7), pp.4046-4049 (2003).

[5] http://tinyurl.com/z9ery3j (25/10/16).

[6] http://tinyurl.com/87epf67 (25/10/16).

[7] http://tinyurl.com/j4dstux (25/10/16).

[8] http://tinyurl.com/gvfypgv (23/11/16).

[9] http://tinyurl.com/daaem (23/11/16).

[10] http://tinyurl.com/jc45ysm (25/10/16).

[11] http://tinyurl.com/zpsdvbt (25/10/16).

[12] http://tinyurl.com/h5le38n (25/10/16).

[13] http://tinyurl.com/zcdjh6z (23/11/16).

[14] http://tinyurl.com/zraor3q (23/11/16).