A METHOD TO MEASURE SNAIL SHELL VOLUMES

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Abstract: This paper describes a method to determine the volume of a snail shell from the weight of the water displaced by the shell.
Key words: Gastropod, *Helix*, shell size, growth

The volume of a snail shell signifies the amount of housing space the occupant snail needs. This significance holds even if the snail's body fills a portion of the inner space of its shell, leaving aside the rest for other functions (for example, Örstan, 2006). However, shell volume is rarely used in research, probably because one cannot measure it as easily as one can a linear dimension. Also, there is no established method for measuring shell volumes. When used in research, volume is often estimated from linear shell dimensions (for example, Solem & Climo, 1985; McClain & Nekola, 2008), but rarely measured directly (for example, Kemp & Bertness, 1984). Here I present a method to measure the total (shell + inner space) volume of a snail shell.

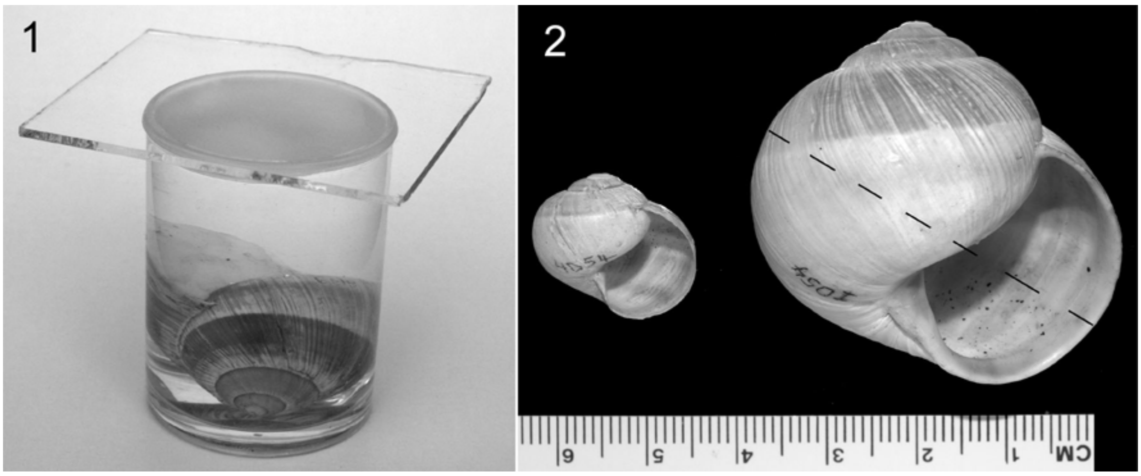
Methods and Materials

The method determines the weight of water equal in volume to that of a shell immersed in water in a vial of known volume. I used a transparent vial with a continuous lip. First, I filled the vial, with or without a snail shell in it, with distilled water almost to the brim and removed any air bubbles. Then, I covered the vial partially with a small glass plate and continued to add water with a dropper while sliding the plate until the vial was sealed completely without an air space. The glass plate ensured that the vial always contained the same total volume. Finally, I weighed the vial and the plate. Before placing an empty shell in water, I weighted it with iron pellets held in its body whorl with a cotton plug and then sealed the aperture against water with moldable silicone (for swimmers' ears). The top of the silicone was flush with the edge of the lip (Fig. 1).

For each volume determination, I obtained 4 weights to the nearest 0.01 g with a digital scale: weight of the empty vial and glass plate (W_1), weight of the vial filled with water and plate (W_2), weight of the vial, shell and plate (W_3), weight of the vial filled with water, shell and plate (W_4). The volume of the shell (V_s) is given by equation 1 where the numerator is the weight of the water equal in volume to that of the shell immersed in it and d_w is the density of water at the measurement temperature.

$$V_s = [(W_2-W_1)-(W_4-W_3)] / d_w \qquad (1)$$

To test the method, I determined the volumes of water added to the vial with calibrated pipets. In 3 trials, the measured volumes were within 0.2% of added volumes.



1. A *Helix cincta* shell sealed with silicone in the water filled vial covered with a glass plate.
2. A juvenile (left) and an adult shell of *Helix cincta*.
The broken line across the adult shell denotes the diameter measured in this study.

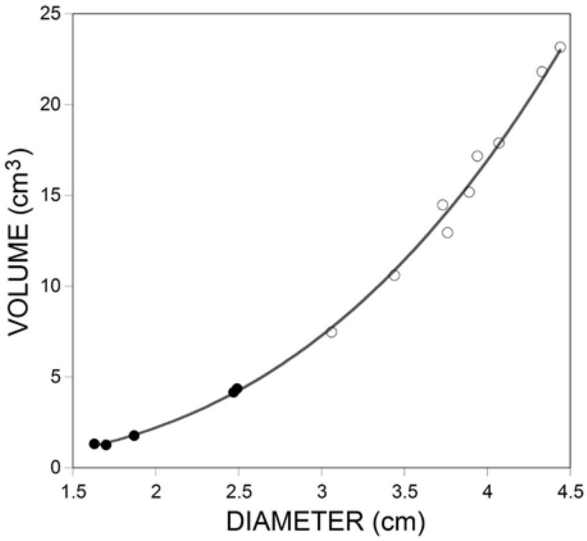
I used the method to determine the shell volumes of the helicid snail *Helix cincta* (Müller 1774). The adult shell of this species has a slightly thickened lip that is not reflected. Therefore, the shell diameter (D; Fig. 2) can be measured unambiguously. Furthermore, the closed umbilicus (present as a narrow slit in some juveniles) simplifies the determination of the shell volume. The specimens were from 4 localities in western Turkey. To determine the precision of the method, I measured the volume of one adult shell 4 times, obtaining a range of 14.36 to 14.59 cm^3 and a mean deviation from the mean of 0.6%.

Results and Discussion

From general geometric considerations, shell volumes are expected to follow the power law $V_s=cL^3$, where c is a constant and L is a linear shell dimension (Schmidt-Nielsen, 1984). The equation that described the relationship between the measured volumes of 14 *H. cincta* shells and their diameters was $V_s=0.290D^{2.93}$ ($r^2=0.996$) (Fig. 3).

Juvenile and adult shells seem to follow the same relationship, probably because the shell shape of *H. cincta* does not change significantly during growth (Fig. 2).

When comparing the volumes of a number of shells, this method can be used even if the water density is unknown, as long as water from the same source is used at the same temperature for all the measurements.



3. The relation of volume (cm^3) to diameter (cm) in 5 juvenile (solid circles) and 9 adult (open circles) shells of *Helix cincta*.

Volumes can then be expressed as weights (numerator of equation 1). The main drawbacks of the method are the time consuming sealing of shell apertures and the difficulty one may have sealing fragile or small shells with silicone.

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