ISSN 0015-5497, e-ISSN 1734-9168

Folia Biologica (Kraków), vol. 65 (2017), No 2
https://doi.org/10.3409/fb65_2.133

Short Communication

Adhesive Movement Characteristics of the Snail *Achatina fulica*

Piotr KACZOROWSKI, Elżbieta PISKORSKA, Dorota OLSZEWSKA-SŁONINA, and Grzegorz GRZEŚK

Accepted July 24, 2017 *Published online September 07, 2017* *Published September 20, 2017*

KACZOROWSKI P., PISKORSKA E., OLSZEWSKA-SŁONINA D., GRZEŚK G. 2017. Adhesive movement characteristics of the snail *Achatina fulica*. Folia Biologica (Kraków) **65**: 133-135.

The present study contains observations and recording images of the snail foot during spontaneous rectilinear motion on a horizontal glass sheet. Most of the analyzed parameters of snail movement and the folding of the foot epithelium showed linear correlations and varied according to strength. Snail velocity is strongly associated with the foot wave frequency and with the shift of the animal per one wave. This confirms the efficiency of the epithelium folding effect in the foot wave.

Key words: Adhesive movement, *Achatina fulica*, locomotion, snail, mollusca.

Piotr KACZOROWSKI, Elżbieta PISKORSKA, Dorota OLSZEWSKA-SŁONINA, Department of Pathobiochemistry and Clinical Chemistry, Nicolaus Copernicus University Collegium Medicum, M. Skłodowskiej-Curie 9, 85-094 Bydgoszcz, Poland.
E-mail: kaczorowski@cm.umk.pl
piskorska_e@cm.umk.pl
dorolsze@cm.umk.pl
Grzegorz GRZEŚK, Department of Pharmacology and Therapeutics; Nicolaus Copernicus University Collegium Medicum, M. Skłodowskiej-Curie 9, 85-094 Bydgoszcz, Poland.
E-mail: farmakologia@cm.umk.pl

Adhesive (sticky) movement of land snails is one type of snail movement realized through a series of muscle contraction waves extending along a substrate adjacent to the surface of the foot. A functional unit, that is the foot wave, consists of muscle and nerve cells. The wave also causes simultaneous folding of the integument (epithelium). Through the functions of contraction and relaxation, the foot of a snail is divided into zones of moving and unmoving units. The animal adheres and moves at the same time (BARKER 2001; LAI *et al.* 2010; TYRAKOWSKI *et al.* 2012; YAMAGUCHI *et al.* 2000). Analysis of the mucus present on the foot during movement showed that the viscosity of mucus during the foot wave is lower than between waves, which significantly contributes to the effectiveness of this movement (DENNY 1981; DENNY & GOSLINE 1980; IWAMOTO *et al.* 2014).

The aim of this study was to characterize the adhesive, rectilinear movement of a snail, including phenomena occurring on the foot.

Material and Methods

The study was performed on a group of 359 African land snails, *Achatina fulica* (weight 8-68 g, shell length 35-80 mm), obtained from a breeding group in the Department of Pathobiochemistry and Clinical Chemistry, Nicolaus Copernicus University Collegium Medicum in Bydgoszcz.

Each experiment consisted of observations and recording images of the snail foot during spontaneous rectilinear motion on a horizontal glass sheet using a CCD camera equipped with zoom lens (5-50 mm F/1.8) (Fig. 1A). Program IC Capture.AS 2.0 for computer image recording was used. Short movies were recorded (10-20 seconds). Subsequently, using VirtualDub 1.9.11 and Gimp 2.8.4 programs, the following parameters of snail movement and the folding of foot epithelium were investigated: snail velocity (vs), foot length (ls), foot width (ws), number of foot waves (nw), foot wave length (lw), length of space between

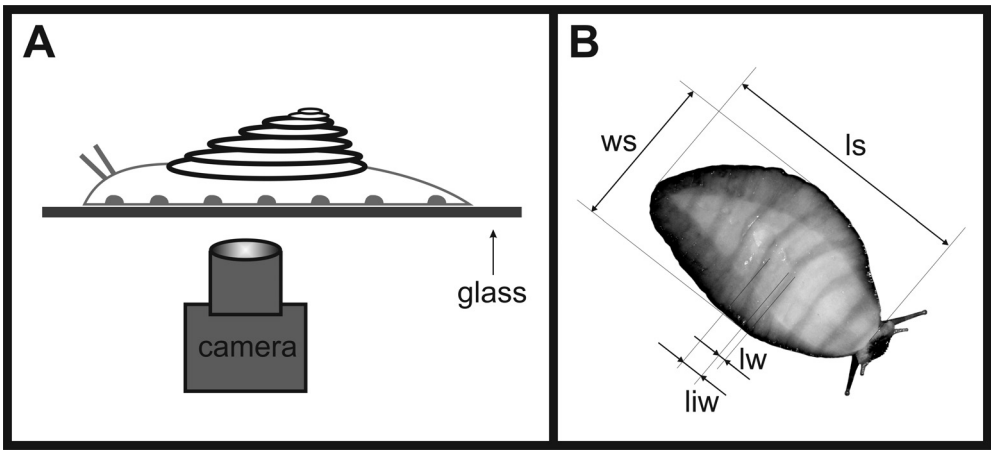

Fig. 1. Scheme of experimental setup (A) and photo of foot waves during movement of the animal on the glass sheet (B). ls – foot length, ws – foot width, lw – foot wave length, liw – length of space between waves,

waves (liw), percentage of the foot occupied by all simultaneously occurring waves ($cw=lw \cdot nw \cdot ls^{-1} \cdot 100$), foot wave frequency (fw), shift of a snail per one wave (mw) (Fig. 1B). Statistical analysis was performed using Statistica 12.

Results and Discussion

After normality tests: the Lilliefors test (max. $D=0.074354$, $P<0.01$) and the Shapiro-Wilk test ($W=0.978288$, $P<0.000031$) for results of snail velocity, a non-normal distribution for the parameter was observed. The consequence of this was a presentation of the analyzed values of the parameters by the median and the interquartile range (IQR) (Table 1) and application of the R-Spearman test ($P<0.05$) to determine the correlation between the measured parameters (Table 2).

Most of the analyzed parameters showed linear correlations and varied according to strength. The snail velocity is strongly associated with the foot wave frequency, which was previously observed by LAI *et al*. (2010) for garden slugs (*Deroceras reticulatum*). Interestingly, the level of correlation for snails ($r=0.47$) seems to be lower than in slugs ($r=0.77$). Similarly, a lower correlation was also observed between the snail velocity and the foot wave length (snails $r=0.26$; slugs $r=0.74$).

Moreover, the snail velocity is highly correlated with the shift of the animal per one wave ($r=0.85$). This confirms the efficiency of the epithelium folding in the foot wave. As a result, after the wave reaches the anterior region of the foot, the snail moves forward for a longer distance through stronger folding of foot epithelium (TYRAKOWSKI *et al.* 2012). The increased frequency of foot waves amplifies the effect. Other correlations are presented in Table 2.

Studies have suggested that there are minor differences in the movement of snails, which are probably species-specific. Variation in snail velocity, in the case of *Deroceras reticulatum*, depends primarily on the foot wave frequency (LAI *et al.* 2010), whereas in the case of *Achatina fulica* it depends on efficiency of the epithelium folding in the foot wave. These results can be a starting point for further investigations aiming at the analysis of e.g., the pharmacological modulation of snail locomotion.

Table 1

The values of the movement parameters of a snail and the folding of foot epithelium

n=359	vs (mm/s)	ls (mm)	ws (mm)	nw	lw (mm)	liw (mm)	cw (%)	fw (Hz)	mw (mm)
median	0.35	73.09	31.08	8	1.95	6.92	20.11	0.45	0.80
IQR	0.17	18.04	5.52	1	0.47	1.84	5.16	0.10	0.33

vs – snail velocity, ls – foot length, ws – foot width, nw – number of foot waves, lw – foot wave length, liw – length of space between waves, cw – percentage of the foot occupied by all simultaneously occurring waves, fw – foot wave frequency, mw – shift of a snail per one wave.

Table 2

The presence of Spearman's correlation between the parameters of movement of a snail and the folding of foot epithelium (n=359)

	The correlation coefficient (r) and the significance level (P)							
	mw	fw	cw	liw	lw	nw	ws	ls
vs	r= 0.850 P<0.001	r= 0.467 P<0.001	NC	r= 0.188 P<0.001	r= 0.255 P<0.001	r = -0.193 P<0.001	r= 0.226 P<0.001	r= 0.106 P=0.044
ls	r= 0.196 P<0.001	NC	r= -0.395 P<0.001	r= 0.792 P<0.001	r= 0.338 P<0.001	r= 0.424 P<0.001	r= 0.250 P<0.001	
ws	r= 0.207 P<0.001	NC	NC	r= 0.112 P=0.049	r= 0.126 P=0.027	NC		
nw	NC	r= -0.275 P<0.001	NC	NC	NC			
lw	r= 0.173 P=0.001	r= 0.229 P<0.001	r= 0.597 P<0.001	r= 0.408 P<0.001				
liw	r= 0.223 P<0.001	NC	r= -0.308 P<0.001					
cw	NC	r= 0.133 P=0.012						
fw	NC							

vs – snail velocity, ls – foot length, ws – foot width, nw – number of foot waves, lw – foot wave length, liw – length of space between waves, cw – percentage of the foot occupied by all simultaneously occurring waves, fw – foot wave frequency, mw – shift of a snail per one wave, NC – no correlation

References

BARKER G.M. 2001. The Biology of Terrestrial Molluscs. CABI Publishing, Landcare Research, Hamilton, New Zealand.

DENNY M.W. 1981. A quantitative model for the adhesive locomotion of the terrestrial slug, *Ariolimax columbianus*. J. Exp. Biol. **91**: 195-217.

DENNY M.W., GOSLINE J.M. 1980. The physical properties of the pedal mucus of the terrestrial slug, *Ariolimax columbianus*. J. Exp. Biol. **88**: 375-393.

IWAMOTO M., UEYAMA D., KOBAYASHI R. 2014. The advantage of mucus for adhesive locomotion in gastropods. J. Theoret. Biol. **353**: 133-141.

LAI J.H., ALAMO DEL J.C., RODRIGUEZ-RODRIGUEZ J. 2010. The mechanics of the adhesive locomotion of terrestrial gastropods. J. Exp. Biol. **213**: 3929-3933.

TYRAKOWSKI T., KACZOROWSKI P., PAWŁOWICZ W., ZIÓŁKOWSKI M., SMUSZKIEWICZ P., TROJANOWSKA I., MARSZAŁEK A., ŻEBROWSKA M., LUTOWSKA M., KOPCZYŃSKA E., LAMPKA M., HOŁYŃSKA-IWAN I., PISKORSKA E. 2012. Discrete movements of foot epithelium during adhesive locomotion of land snail. Folia Biol. (Kraków) **60**: 99-106.

YAMAGUCHI K., SEO N., FURUTA E. 2000. Histochemical and ultrastructural analysis of the epithelial cells of the body surface skin from terrestrial slug, *Incilaria frustorferi*. Zool. Sci. **17**: 1137-1146.