The anatomical features and kinematics of undulatory burrowing in the polychaete *Armandia brevis*

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Abstract
Recent work has shown that diverse polychaetes extend burrows through muddy sediments by fracture. Radial body expansions near the anterior, achieved both by peristalsis and eversion of pharynges and proboscis, apply forces that are amplified at the tip of the curved-shape burrow, resulting in fracture. The opheliid annelid, *Armandia brevis* (Moore 1906), lacks an expandable anterior consistent with burrowing by fracture. Instead, *A. brevis* burrows with a lateral undulatory motion in homogeneous sediments. We hypothesized that radial sediments on the scale of this small burrower are granular aggregators rather than a cohesive elastic solid. Kinematic analysis of worms burrowing in clear granular analog materials (cryolite and gelatin grains) showed a wave efficiency during burrowing close to one, indicating minimal slipping and that the grains are not fluidized. In addition, histological 3D reconstruction (Figure 5.4) of the internal anatomy shows transverse muscles extending from the ventral groove that act antagonistically to the longitudinal muscles along the interior of the body wall. Circular muscles—used to contract the body radially during peristaltic locomotion—are lacking in this sinusoidal burrower.

Background

Recent work has shown that many polychaetes burrow by dorsal-ventral body expansions of the anterior, resulting in fracture.

Observation and preliminary data showed that *A. brevis* burrows in a non-slipping wave locomotion, indicating that the granular material acts as a solid in which forces displace grains locally rather than as a fluid in which bulk grain displacement occurs.

What are the anatomical features that allow *A. brevis* to burrow in an undulatory motion?

Anatomical 3D reconstruction revealed oblique muscles extending from the ventral groove act antagonistically to the longitudinal muscles along the interior of the body wall.

What are the kinematics that allow *A. brevis* to burrow in an undulatory motion?

Preliminary data shows that *A. brevis* burrows with a slip factor ~1, indicating that the animal’s forward velocity = wave velocity and thus no slipping occurs:

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\text{slip factor} = \frac{\text{animal’s forward velocity}}{\text{wave velocity}}
\]

The non-slipping wave locomotion indicates that the sand is not fluidizing.

Methods

Anatomical 3D reconstruction
- Specimen were embedded in medium-viscosity epoxy resin (Spurr, 1969)
- Serial sectioning with a Diatome Diamond Knife
- 3D reconstruction preformed using AMIRA 5.4

Kinematic analysis
- Gelatin grains and cryolite were used as analogs for granular sediment aggregates and sand grains
- Video data quantified using ImageJ and MATLAB

Future Studies

Relate anatomy to kinematics
- Reconstruct a fixed undulated specimen for comparison with a specimen in its relaxed state
- Determine the functionality of the oblique muscles and their role in burrowing

Comparison with related species (Opheliidae)
- Compare kinematics and anatomy to *Ophelina acuminata*, a larger but morphologically similar undulatory burrower
- Compare anatomy to *Thoracophelia mucronata*, an opheliid that burrows by peristalsis

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References


