A.A.S.E.R.T. PROGRESS REPORT

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SPECIFIC AIMS:
The specific aims of the parent proposal have not been modified, but the aims of the student projects supported by this AASERT have evolved since the original proposal was submitted.

Mauricio Schabes proposed to investigate the hydrodynamic consequences of deploying particle-capturing devices on flexible support structures by studying filter-feeding ectoprocts living on macroalgal blades. The ectoprocts were not sufficiently abundant to provide a reliable study system, so Mauricio has used compound ascidians living on large solitary ascidians instead.

Marlene Martinez was a beginning student who thought that she wanted to study filter feeding when the proposal was submitted. As I stated in the proposal, "I do not assign pieces of my research to my students, but rather help them to formulate their own dissertation topics because I feel that a very important part of graduate training is to learn to recognize important questions and to develop systems to address them." Therefore, when Marlene switched her interests to the biomechanics of walking underwater versus in air, I encouraged her to pursue that project instead. Although gravity is the most significant force for animals or robots running in air, fluid dynamic forces are likely to be more important for creatures or machines running underwater. The specific aims of Marlene's research are to use crabs as a system to identify how body shape and leg kinematics affect walking and running performance and stability in air versus in water.

M. Schabes completed his project sooner than anticipated. When I asked the Scientific Officer for this AASERT at O.N.R. (R. S. Alberte) what I should do about the funds that had been earmarked for Schabes in the proposal, he instructed me to use those funds to support other graduate students. Therefore, two student projects have been added:

Suzanne Worcester has been studying the hydrodynamics of seagrass canopies, which are important features of many harbors and estuaries. The specific aim of her work supported by the AASERT is to quantify how the mixing and transport of water-borne materials (such as dissolved substances and larvae) are affected by seagrass beds.

Lance Davidson has been studying the mechanics of how microscopic sheets can be deformed by the swelling of gel layers on their surfaces. The specific aim of his work supported by the AASERT is to develop a large-deformation finite-element model of an elastic plate with a layer of swelling gel attached to it, and to use this to explore the consequences of various geometries and boundary conditions to the shape changes the plate undergoes.

RESULTS: (I will only mention results of the student research supported by the AASERT. Results of the parent grant will be reported in the annual progress report for that grant.)

The general goal of the AASERT award is to increase the number of high-quality scientists and engineers resulting from Defense-sponsored research via augmenting support of research training for graduate students. Proposers are encouraged to recruit students from groups underrepresented among U.S. citizens in science and engineering. I have used this award to help support the research training of four graduate students, two of which are minority (Hispanic) students, and two of which are women.

M. Schabes completed an investigation of the hydrodynamic consequences of epibionts (*Didemnum* sp.) growing on benthic hosts (*Styella clava*) subjected to the oscillatory water motion of ocean waves. In a series of wave-tank experiments, he quantified the hydrodynamic forces on the hosts when bearing epibionts in differnt spatial arrangements, and he used these results to predict the probability of dislogement of hosts in a variety of marine habitats. Schabes' results will not only permit us to address the basic biological question of the circumstances under which epibionts mechanically harm their hosts, but also provide useful guidelines about the deployment of sensors on "host" support structures.

M. Martinez has begun a comparative study of the ambulation of various species of subtidal and intertidal crabs in air versus water. She did a cladistic analysis of potential species to study so that she could restrict her comparisons within one lineage, and she began quantifying their distributions and behaviors in the field. She constructed a filming arena and worked out a video technique for 3-D measurement of crab kinematics, and has started to use this to determine how they navigate over different types of substrata. She also has been designing and testing her force transducers for lift and drag measurements, and her underwater treadmill for physiological measurements (see plans below).

S. Worcester used a dye-tracking technique to quantify how seagrass beds slow the advection and increase the dispersion of water-borne materials in estuaries, and she further quantified the hydrodynamic transport of larvae and rafting adults of benthic ascidians in such habitats. Her results not only enhance our understanding of the physical mechanisms by which larvae are dispersed, but point out the importance of rafting by adults in the colonizaton of new substrata by fouling organisms. Her data on the effects of grass beds on turbulent dispersion of dissolved materials in estuaries also has the potential practical application of permitting us to assess the effects of removal or planting (i.e. mitigation) of grass beds on the transport in estuaries of substances such as olfactory signals used by organisms, or as pollutants.

Lance Davidson has been studying the mechanics of how microscopic sheets can be deformed by the swelling of gel layers on their surfaces. The biological process he is investigating is gastrulation (the inpocketing of an epithelial sheet to initiate the formation of the gut in the early development of many animal embryos), but the insights he gains from his mechanical analysis should provide background for the design of biomimetic composite materials that can change their own shapes in response to charge or osmotic signals. He has been using a large-deformation finite-element model of an elastic plate with a layer of swelling gel attached to it to explore the effects of the relative thickness and stiffness of the plate (e.g. epithelial sheet) and the gel (e.g. extracellualr matrix) and the manner in which the edge of the plate is constrained by surrounding tissues. Quite different shapes can be produced by the gel swelling, depending on the design of the plate-gel composite.

<u>PLANS FOR THE COMING YEAR</u>: (students only)
M. Schabes and S. Worcester have completed their research projects and are writing their results for publication.

M. Martinez has three research objectives for the coming year: 1) to compare the hydrodynamic design of semi-terrestrial, intertidal, and subtidal crabs; 2) to compare the locomotor performance of individual crabs of various body designs when they ambulate in water versus in air; and 3) to measure water flow and substratum roughness in crab habitats so that future lab experiments to evaluate the hydrodynamic stability of different crab morphologies can be designed. She will measure the lift and drag forces on a variety of species of crabs to test the hypotheses that subtidal and intertidal species are more streamlined than semiterrestrial species, and that negative lift may help keep the aquatic crabs on the substratum. She will also video the animals running in water and in air, and will conduct a kinematic analysis to quantify the locomotory adjustments made by the animals as they make the transition between water and air. She also plans to measure the oxygen consumption of the crabs running at defined speeds on a treadmill in water versus in air. Her work not only addresses the basic biological question of the evolution from aquatic to terrestrial locomotion, but also will provide information critical to the design of robots that can walk efficiently underwater without washing away or overturning.

L. Davidson will modify his finite-element model to deal with visco-elastic plates and will use the model to explore the time-dependent aspects of deforming such sturctures via gel swelling. He also plans to measure the necessary morphological and material parameters of sea urchin embryos (an important model system for the study of gastrulation) to use in his model, and to test the predictions of the model by comparing them with the kinematics of urchin gastrulation.

PUBLICATIONS AND THESES: (I will only list the student work that was supported by the AASERT. The publications resulting from work on the parent grant will be presented in the annual progress report for that grant, which is due in the autumn.)

Martinez, M. M. (1992) Crab running mechanics: Air vs.water (abstract). Am. Zool. 32: 117A.

Schabes, M. (1992) Mechanical Consequences of the Association Between the Solitary Ascidian, *Styela clava* Herdman, 1881, and its Epibiota. M.A. Thesis, Department of Integrative Bioology, University of California, Berkeley.

Worcester, S. A. (1992) Adult rafting and larval swimming: Does dispersal mode affect the recruitment of a colonial ascidian into new habitats? (abstract). Am. Zool. 32: 122A.