Brachiopods and Bivalves: Clam Metabolism and Really Old Molluscs

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Writer's Comment: The prompt for this assignment was to write an article for a general audience based on published scientific research. I wanted to write about a topic in paleobiology that a lot of people might not know about. I decided on brachiopods, a type of mollusc whose evolutionary history is debated amongst scientists. Although they may not seem as exciting as dinosaurs, these molluscs and the methods used to study them are surely worth reading about. My goal in this article was to inform more people about brachiopods and also to demonstrate how scientific beliefs can change overtime.

Instructor's Comment: The plight of prehistoric molluscs might automatically garner the attention of paleobiologists, but generating lay audience interest in the subject is a much greater challenge–and one that Emma Enssle meets gracefully in this article written for my UWP 102B: Writing in Biology course. Here, Emma weaves together two stories. The first is the story of the brachiopods and bivalves, which she explains using clear terms and comparisons for the benefit of the lay reader. The second story–of equal importance–is that of the recent evolution of scientific understanding on these two types of mollusc. As Emma puts it, the research that she covers in this article is significant because it presents us with a "new way of looking at an old problem." In recounting this challenge to previous research, Emma also offers us a useful example of how scientific thinking changes over time as new knowledge and tools become available.

—Melissa Bender, University Writing Program

You are probably familiar with clams and oysters, but unless you have taken a paleobiology course, chances are that you have never heard of brachiopods. Brachiopods are a type of mollusc with two shells, but they are separate from the bivalve class, which includes clams and oysters. Today brachiopods are very rare, but if you happened to be alive 150 million years ago you would have found that they dominated the ocean floor, being far more numerous and diverse than the bivalves. The reason for the brachiopod and bivalve switch in dominance has been a long standing question for paleobiologists, who have proposed many possible explanations for the bivalve takeover. This has led to decades of studies testing the impacts of predation, competition, and environmental changes on the two groups. However, a 2014 study by Jonathan Payne and colleagues at Stanford University found that brachiopods may never have been dominant over bivalves in the first place, challenging a commonly accepted scientific belief and putting decades of research into question (Payne et al.).

If we expect to benefit from scientific discovery, it is important to understand how and why changes in scientific understanding occur. Learning more about brachiopods and bivalves specifically might not change your life, but it will help you understand why scientists can change their mind about Pluto being a planet or how the infamous DDT was once considered by many to be a blessing of chemical invention. The truth is that scientists can be wrong, like they were about brachiopods and bivalves, and scientific opinions can change if new information is gathered.

But first, what exactly are brachiopods and bivalves? Appearing similar at first, brachiopods and bivalves both have shells made of two parts, which are referred to as valves. In Latin, "valve" translates to "one of the halves of a folding door," an apt description if you picture a clam opening and closing ("Valve"). Despite their apparent similarities, brachiopods and bivalves are quite different. For one, brachiopods are symmetrical when cut down the middle of both valves, like a sandwich. However, bivalves have symmetry on a plane between the two valves, like if you pressed both of your hands together. When cut down the middle, the two sides of a bivalve are not symmetrical.

Brachiopods attach to the substrate on the ocean floor using a stalk-like organ called a pedicle. Once they attach to the substrate, brachiopods tend to stay there, while bivalves can change their position more easily. This is partly because bivalves do not have a pedicle, instead having a muscular foot which they can use for movement. Both brachiopods and bivalves have a burrowing lifestyle. Burrowing allows for protection while still allowing brachiopods and bivalves to feed through the water column (de Fourestier 3).

Another key difference between brachiopods and bivalves is their method of feeding. Brachiopods feed using a special structure called the lophophore, which contains fine tentacles arranged in a rake-like shape. These tentacles are then covered in tiny hairs called cilia, which comb through the water for food molecules and direct these molecules towards the mouth for feeding. Having both tentacles and cilia allows for a greater surface area for more successful water filtration. In contrast, bivalves do not have a lophophore, but instead feed using a siphon to suck water into their body cavity. There, the water is filtered for food particles using gills which are also covered in cilia (de Fourestier 2). Although they have different feeding structures, brachiopods and bivalves are both filter feeders, leading some to consider the possibility of competition for food sources between the two groups.

The main event concerning brachiopods and bivalves is the Permian-Triassic extinction, when the switch in dominance of the two groups appears to have taken place. The Permian-Triassic extinction, which occurred around 252 million years ago based on radiometric dating, was the largest extinction event in earth's history (Burgess et al.). Brachiopod diversity was high prior to the extinction event, with bivalves having lower diversity. After the extinction, a sharp change occurred as brachiopod diversity declined and bivalve diversity increased. This was a major extinction event which led to the loss of most marine species, so a drop in brachiopod diversity is expected. But why did bivalves recover more quickly after the extinction and proceed to dominate over brachiopods? This question has occupied scientists for decades. Many have believed that the extinction event gave bivalves an opportunity to outcompete brachiopods while their numbers were low. Others postulated that predators preferred brachiopods over bivalves, or that environmental changes lead to inhospitable conditions for brachiopods. However, recently a group of researchers decided to ask a new question entirely. What if brachiopods were not actually dominant over bivalves as previously believed?

Payne and fellow researchers challenged the traditional method of using taxonomic diversity and abundance to measure species dominance, the method which put brachiopods on top of bivalves prior to the Permian-Triassic extinction. This method suggested that because there were more species of brachiopods and more brachiopod individuals, they must have been dominant over bivalves. One issue with using taxonomic diversity is the fact that brachiopods and bivalves are of different average sizes and different amounts of tissue, so using the number of individuals to infer dominance may not actually be accurate. Taxonomic diversity is not able to compare the amount of energy transferred between the two groups and their environment, which is a downside because energy transfer better reflects the behavior of organisms in a given environment. For this reason, metabolic data is a more accurate measure of ecological dominance, because it accounts for how much energy is being used and produced by brachiopods and bivalves (Payne et al. 6)

In order to use energy levels to estimate ecological dominance, Payne et al. used information from fossil record databases to calculate the metabolic rate of thousands of brachiopod and bivalve species. These calculations were possible to compute using body size data, even though the actual living organisms were not present. Three different shell measurements were taken of each specimen, and the approximate geologic time period of each specimen was also estimated. Specimens were grouped into their different species, and the feeding mode of each species was taken into account. This is important because there are several different feeding methods of brachiopods and bivalves, and the metabolic rate of species with different feeding modes cannot be easily compared. All of this data together allowed the researchers to calculate the metabolic rate of different species of both brachiopods and bivalves at different times. They also used calculations to account for differences in temperatures over time and for biases caused by large or small species sizes, as temperature and body size both influence metabolic rate (Payne et al. 2,3)

In the end, the researchers found that bivalves were metabolically dominant over brachiopods prior to the Permian-Triassic extinction, which is when scientists have previously believed that brachiopods were dominant. In fact, bivalves were dominant about 100 million years before the extinction event. After the extinction, the difference was even more striking - between brachiopods and bivalves, bivalves conducted 95% of the metabolic activity beginning in the Triassic. This extremely high level of metabolic dominance right after the extinction is different from the previously accepted story of a gradual increase in taxonomic diversity leading to bivalve dominance (Payne et al. 3).

Another crucial aspect of this study is that it debunks a common theory, which is that bivalves gained dominance by outcompetiting brachiopods. This is because bivalve metabolism increased far too rapidly to be explained by the simple outcompetition of brachiopods. Even if brachiopods were driven to complete extinction by bivalves, this would not explain the huge increase in bivalve metabolism. This adds another significance to the use of metabolic data, because it shows that bivalves were not only dominant over brachiopods, but that the evolutionary trajectory of the two groups cannot be explained by direct competition. Instead of stealing resources from brachiopods, bivalves may have gained dominance by tapping into resources that brachiopods were simply unable to use (Payne et al. 5,6).

Surely, the bivalve acquisition of so many new resources must have caused a stir on the seafloor. Payne et al. mention that the amount of primary productivity has not greatly increased over the past 350 million years, suggesting that bivalves may have outcompeted other organisms as they greatly increased their metabolic activity. This adds yet another layer to the story of brachiopods and bivalves, as it means that although brachiopods were not outcompeted by bivalves, there are probably some creatures out there that were (Payne et al. 6).

The results of this study showed that not only were brachiopods not dominant over bivalves as previously believed, but that the evolution of the two groups is not closely related. This paves a way for future studies to investigate how these two groups may have evolved over time, apart from each other. The high metabolic dominance of bivalves is especially interesting, and future researchers may look for species that actually were outcompeted by bivalves in order to understand how they were able to utilize such a high number of resources.

This research by Payne et al. is groundbreaking because it provides scientists a new way to look at an old problem. In biology classrooms, the evolutionary trends of brachiopods and bivalves are commonly used as an example of how complicated ecological relationships can be, and how different explanations can be used to explain an increase or decrease in diversity. However, this study shows how different methods of calculating ecological diversity can tell entirely different stories. Specifically, metabolic data can be a much more useful method of calculating the dominance of different groups, and can give very different results than taxonomic diversity measures. More generally, this way of thinking can be applied to other areas of paleobiology and ecology, serving as a reminder that things are not always as they seem.

Works Cited

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