How does an animal with no heart circulate oxygen?

Heartless beasts

THE phrase “prehistoric monster” might have been coined with sea spiders in mind. Though neither large (the biggest are hand-sized) nor threatening to people, their quintessential creepy-crawliness presses many of the buttons marked “horror” in the human psyche. And prehistoric they certainly are. Fossils show that they date from at least 500m years ago, during the Cambrian period, the dawn of the animals. True spiders, to which sea spiders (some of which have more than eight legs) are but distantly related, are known for certain only from as far back as the Carboniferous period, about 300m years ago.

One of the crucial evolutionary developments that permitted multicellular animals to come into being during, or shortly before, the Cambrian period was a circulatory system. Small creatures, consisting of one or a few cells, can absorb enough oxygen for their respiratory requirements directly from the water they inhabit. It simply diffuses into them. Larger ones, though, need a way of moving the dissolved gas into tissues too far from their body surfaces to be supplied by diffusion alone.

Most solve the problem by having a heart that pushes oxygen-rich blood around the body. However Arthur Woods, a biologist at the University of Montana, reports this week in *Current Biology* that sea spiders employ an alternative tactic. Rather than move oxygen with their hearts, they move it with their guts.

How sea spiders organise their oxygen supply has long been a mystery. Some species have no heart at all, and even in those that do have one, it is usually too puny to seem equal to the task. The consensus, given the animals’ spindly anatomy, which brings all parts of their bodies into proximity with the water they live in, has been that diffusion directly from this water must be enough.

Dr Woods, however, wondered if there was more to it. Sea spiders have no coelum, the body cavity in which most animals keep internal organs such as

their guts. Instead, sea-spider digestive systems extend all the way down inside the animals' legs. As in other animals' digestive systems, food is moved around this eight- (or ten- or 12-) lobed gut by peristalsis, a wavelike motion of the gut walls. Dr Woods suspected that, in an evolutionary two-for-one, this peristaltic action is also moving oxygen.

To test that idea, he collaborated with a team of scuba-diving colleagues to collect 12 species of sea spiders from places as far north as Friday Harbor, off the coast of Washington state, and as far south as McMurdo Station, in Antarctica. Though all of these species had hearts, Dr Woods was able to show that the brunt of the job of oxygen circulation in them was borne by their guts.

He did this by means of three types of experiment. The first mapped fluid movements within an animal, by injecting it with a fluorescent dye and following the dye around. The second used electrodes, inserted through an animal's cuticle, to measure changes in oxygen concentration in various parts of its body. The third looked at how these two things, and also the pattern of peristalsis, altered when the amount of oxygen in the water an animal was kept in was raised or lowered.

The first two types of experiment showed unequivocally that sea spiders' legs also work as gills. They provide a surface through which oxygen can diffuse into the animal, and this oxygen is then carried by peristalsis to other places. These include the abdomen, where the heart can take over the task of moving the oxygen around. The third type of experiment showed that the rate of peristalsis increases when the oxygen concentration in the water around an animal drops. This response, which is independent of the amount of food in the gut, shows that the peristaltic movement of oxygen is an adaptation, rather than just a coincidence.

The complete heartlessness of some species of sea spider is, presumably, a result of gut peristalsis taking over the oxygen-distribution job entirely, rendering that organ redundant. For horror aficionados, the idea of sea spiders lacking hearts merely adds to their ghoulish appeal.

Source: The Economist