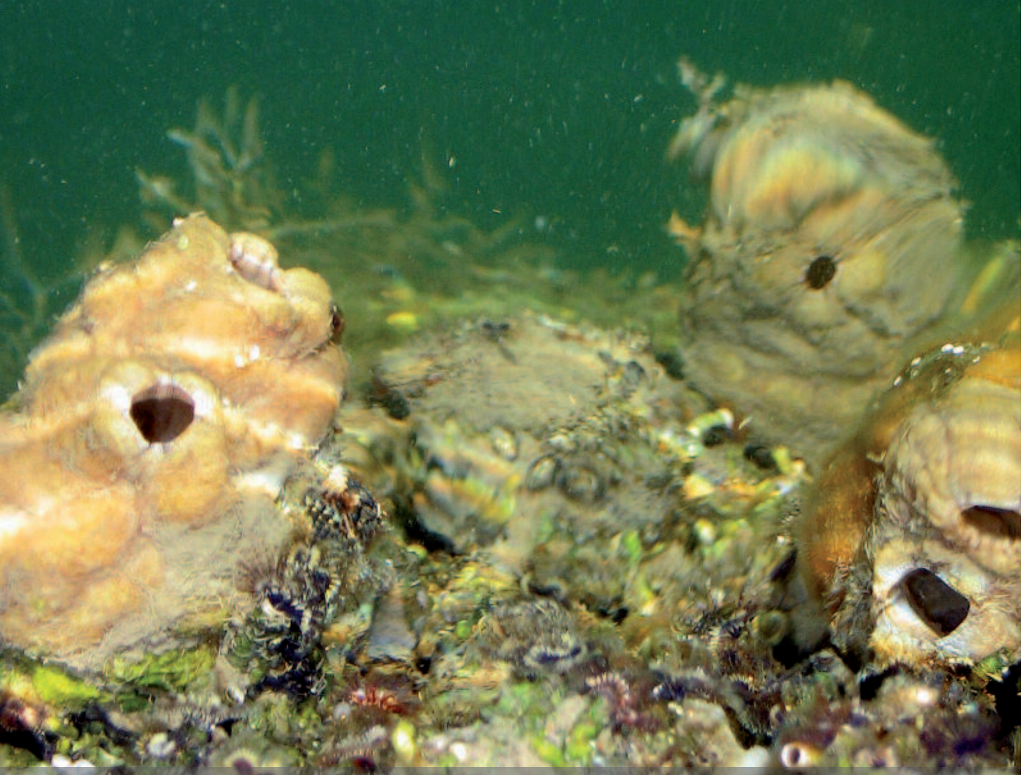

Sea squirts reproduce by broadcast spawning, where eggs and sperm are released into the ocean and the sperm have to swim around to find an egg to fertilise.

What Speed Sperm Should a Sea Squirt Squirt?

ANGELA CREAN

Sea squirt sperm is revealing how a male's environment affects his sperm's quality, with implications for the health of offspring that could also improve the success of human IVF procedures.

A sperm's job is to swim to an egg and deliver the male DNA. So, sperm have essentially been likened to a car – the speed or quality of the sperm can influence its chances of successfully reaching an egg but, once the cargo is dropped off, the sperm's quality is not expected to have any further influence on the development or health of the offspring.

The humble sea squirt suggests this assumption is wrong, and what we've learned from sea squirt fertilisation could be applied to make IVF more efficient.

Sea squirts (ascidians) may not appear to have any similarities with humans, but they are our very ancient ancestors, belonging to the same Phylum (Chordata). Sea squirts get their name from their feeding structures: they have an inhalant and exhalent siphon for filtering food, which 'squirt' water when exposed to air. However, it is not always just water that they squirt!

Sea squirts reproduce by broadcast spawning; both eggs and sperm are released into the ocean, where sperm have to swim around to find an egg to fertilise. This unusual reproductive strategy makes them an ideal species in which to test for links between sperm and offspring quality. We can easily manipulate fertilisation in the laboratory – controlling which sperm have access to eggs while still roughly mimicking the natural process of fertilisation.

To test whether differences in sperm quality have any influence on offspring performance, we first examined whether there are any differences in offspring sired by fast and slow sperm. Sperm have a limited amount of energy. Therefore, sperm may swim quickly to find eggs, and thus burn through their energy reserves quickly, or may swim more slowly to conserve their energy, allowing them to live for longer.

In a single ejaculate, some sperm are fast swimmers and some sperm are relatively slow swimmers. So, to test whether sperm speed can influence offspring performance, we collected the sperm from a sea squirt and used half of it to fertilise a batch of eggs straight away. The other half was left to swim around for an hour (so that only the slower sperm survived), and then we fertilised a second batch of eggs with these longer-lived sperm.

Surprisingly, eggs fertilised by the long-lived sperm were more likely to hatch successfully into larvae. Moreover, when larvae sired by long-lived sperm were settled onto plates and returned to the ocean, they were more likely to survive the first few weeks of life than siblings that were sired by fast sperm. In other words, slow sperm produce better offspring.

This tells us that the quality of the sperm itself, and not just the DNA that a sperm carries, can influence offspring success.

In another experiment we showed that sea squirts change their sperm quality according to the local environment, once again with consequences for offspring performance. Males produced larger, more motile sperm when placed in cages with lots of other sea squirts (high density environments) compared with males kept alone in a cage (low density environments).

When we used these different types of sperm to fertilise eggs, we found that offspring were more likely to survive in high density environments when their father also experienced high density conditions, and more likely to survive in low density environments when their father experienced low density conditions. This tells us that a male's environment can influence his sperm quality, which can in turn influence offspring success.

In addition, our findings raise the possibility that fathers can adaptively influence offspring performance through changes in their sperm quality, priming the offspring so they are more likely to succeed in their predicted environment.

We don't know if the same links between sperm and offspring quality are found in other species with more conventional reproductive modes. But we do know that, even in humans, males change their sperm quality depending on their social environment and perceived risk of sperm competition.

Moreover, there is growing evidence that the paternal environment can influence offspring success across a range of species from flies to humans. How this happens is still largely a mystery.

It is easy to understand how a mother's diet during pregnancy can influence the health of her offspring, because there is a direct link between the mother and child. But can a father's diet prior to conception have any direct influence on his offspring's health? Intuitively we would say no, but correlational studies show that what a father eats during his pre-pubescent years can influence the heath of his children, and even grandchildren!

We don't yet know what is causing these links between the paternal environment and offspring health, but it is suspected they are driven by inherited changes in the epigenome. The epigenome controls gene expression: the epigenome sits on top of the underlying DNA code and switches genes on or off. Epigenetics is the reason why genetically identical cells are able to express a huge variety of different traits.

Think about it: every single cell in your body has the same genetic information, but a skin cell is very different to a neuron. It has been assumed that all of these epigenetic marks are erased when germ cells are produced, as you have to start with a clean slate to rebuild all these different cell types. However, recently scientists have shown that some epigenetic marks survive this erasure, and do get transmitted from parent to child.

Deborah Smith, UNSW

Angela Crean says that links between the paternal environment, sperm quality and offspring success may have practical applications for assisted reproductive technologies.

The reason why epigenetic inheritance is different to genetic inheritance is that the epigenome can be modified by the environment. For example, what you eat can change your epigenome, and this change in the epigenome can be inherited by your children.

Changes in the epigenome can be triggered by all sorts of different environmental conditions like temperature, pollution, hormones, or even behaviour. This means that when we try to understand patterns of inheritance, we now have to consider the effects of the parental environment in addition to genetics.

These recent discoveries of links between the paternal environment, sperm quality and offspring success may also have practical applications for assisted reproductive technologies. As development takes 9 months in humans compared with 12 hours in sea squirts, any differences in offspring performance in humans would most likely be found in the early embryonic stages.

Therefore, the success rate of assisted reproduction procedures could potentially be improved by testing if differences in sperm characteristics influence embryo development. In particular, techniques in which a single sperm is injected directly into an egg could greatly benefit by refining the selection criteria for which sperm to inject.

It might just turn out that the best sperm for the job is the slowest and easiest to catch!

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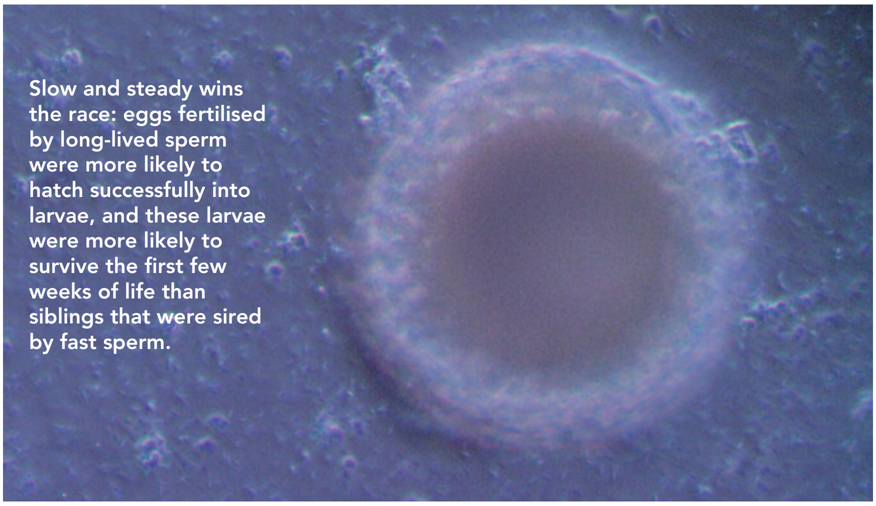

Slow and steady wins the race: eggs fertilised by long-lived sperm were more likely to hatch successfully into larvae, and these larvae were more likely to survive the first few weeks of life than siblings that were sired by fast sperm.