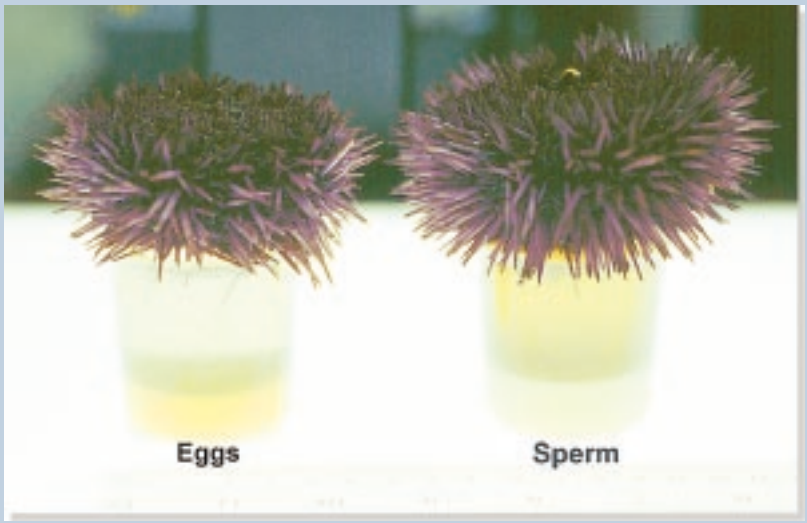
Gravity Shown to Affect Sperm Function and Fertilization

Joseph Tash, a professor at the University of Kansas Medical Center and a NASA researcher, has investigated the effects of gravity on sperm and how they function during fertilization. Tash has found that both microgravity and hypergravity environments have an effect on sperm activity, which suggests that sperm are sensitive to changes in gravitational forces. He has also found that this sensitivity appears to affect the ability of sperm to fertilize eggs.

As we look to the future of space exploration, long-term presence at gravity levels different from those on Earth will be common. The effects of altered gravity on the reproductive process is an area we have only begun to explore but is one that will become increasingly relevant. Can animals be bred successfully for food away from Earth's surface? Would conception be altered in humans living in a colony on a reduced-gravity planet? Can we expand our basic understanding of sperm function and fertilization by learning what role gravity plays in these processes?

Joseph Tash, a specialist in the male reproductive system, is beginning to answer some of these questions. Along with his colleagues, he flew two experiments on the Space Shuttle to investigate the effects of microgravity on sperm activity and fertilization. Sea urchins were selected for the studies since the process of fertilization is so widely studied in this species. Tash also examined these phenomena in hypergravity—a gravity environment greater than Earth's that is typically achieved through centrifugation. Tash has discovered that sperm activation is altered—albeit in different ways—in both microgravity and hypergravity, and has concluded that sperm are sensitive to changes in gravitational forces. This gravitational sensitivity appears to affect both sperm activation and the process of fertilization.



Female and male sea urchins (Strongylocentrotus purpuratus) and their collected gametes. This species flew on space shuttle missions STS-81 and STS-84.

Microgravity Speeds Up Sperm Activation

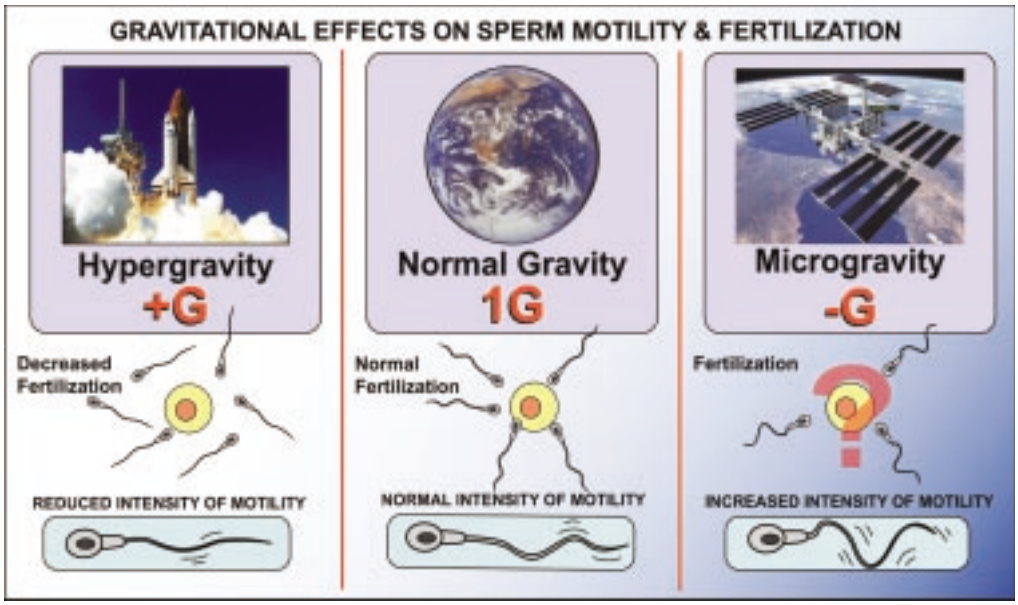
The space flight studies were carried out on the STS-81 and STS-84 Shuttle/Mir missions in a facility called Biorack, which was developed by the European Space Agency. Since a microscope was not available to physically observe the sperm, indirect observing methods had to be devised.

Sperm are activated to swim after they emerge from the testes. The proteins that initiate movement in the "tail" of the sperm undergo a chemical process called phosphorylation, making them active and activating the sperm's tail. The tail begins to move and the sperm swims toward the egg. In the Shuttle experiments, phosphorylation of proteins was measured in the sperm that flew in space and controls maintained on the ground.

Tash found that the phosphorylation process occurred three to four times faster in microgravity than in the Earth's gravitational environment. This means that the sperm are activated for movement much more quickly in microgravity than on Earth.

Hypergravity Slows Sperm and Diminishes Fertilization

Tash then examined sperm activation in a hypergravity environment. Hypergravity was achieved with the use of a centrifuging microscope, which exposed the sperm to a gravitational force greater than Earth's 1 g while allowing the sperm to be directly observed. The result was opposite to that obtained in space: the phosphorylation process and the rate of sperm motility significantly



declined in hypergravity. A decline was observed at a gravity level as low as 1.3 times that of Earth's gravity.

The fact that both microgravity and hypergravity were shown to have an effect on sperm leads to the broader conclusion that sperm are sensitive to changes in the level of gravity. Put another way, gravity does indeed appear to affect sperm physiology and function.

Tash also discovered that hypergravity caused approximately 50 percent decreases in both the rate of binding of sperm to eggs and in fertilization. These results, coupled with the activation and motility findings, show that sperm are not only sensitive to small changes in gravitational forces but also that gravity affects the ability of the sperm to fertilize eggs.

Another implication from Tash's hypergravity experiments is that gravity affects sperm more than eggs. In these experiments, he found that both sperm-egg binding and fertilization were inhibited by about 50%, which suggests that sperm are more sensitive to changes in gravity than eggs. He states: "The fact that the sperm-egg binding and the egg's response were cut by the same amount suggests to us that the primary effect of the hypergravity is on the sperm and not the egg." In other words, if hypergravity affected the egg to a similar degree as the sperm, Tash would have expected a much greater inhibition of the egg response relative to the proportion of the drop in sperm-egg binding. Tash is looking forward to further experiments to investigate this hypothesis.

Next Research Steps

Tash's findings that gravity affects sperm function and fertilization provide intriguing new information about some of the basic biological processes underlying the process of reproduction. The new information will inevitably lead to further investigations addressing both fundamental and practical questions.

Additional studies of sperm function in altered gravity environments are needed to answer what Tash calls the "$64,000 question": Why is sperm activation enhanced in microgravity and impeded in hypergravity? Tash has isolated flagellar proteins—proteins that reside in the tail of the sperm cell and contribute to its motility—that may help answer this question. Since it is these proteins that are altered in microgravity and hypergravity, they may therefore be the key to understanding sperm tail activation on the molecular level and exactly what role gravity plays in this system.

Further research will help answer questions about the role of gravity in the biology of reproduction and may lead to a better understanding of reproduction in all gravity environments.

References

1. Tash JS; Kim S; Schuber M; Seibt D; Kinsey WH. Fertilization of sea urchin eggs and sperm motility are negatively impacted under low hypergravitational forces significant to space flight. *Biology of Reproduction* 65(4):1224-31, 2001.
2. Tash JS; Bracho GE. Microgravity alters protein phosphorylation changes during initiation of sea urchin sperm motility. *FASEB Journal* 13 Suppl:S43-54, 1999.
3. Bracho GE; Fritch JJ; Tash JS. Identification of flagellar proteins that initiate the activation of sperm motility in vivo. *Biochemical and Biophysical Research Communications* 242(1):231-7, 1998.

Technology Spinoff

In the process of preparing sea urchin sperm for the Shuttle experiments, Tash developed a new way of storing immotile sperm. Recently patented, this new technology allows for the storage and transport of non-frozen sperm by employing chemical simulation of the sperm's environment both inside and outside of the testes. This method, which permits the sperm to be stored for longer periods of time at non-frozen temperatures without damage, could have widespread applications in commercial animal reproduction and human infertility.