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 FACTORS FACILITATING THE MOVEMENT OF SPERM IN THE FEMALE REPRODUCTIVE SYSTEM

The mammalian female reproductive tract interacts with sperm in various ways in order to facilitate sperm migration to the egg while impeding migrations of pathogens into the tract, to keep sperm alive during the time between mating and ovulation, and to select the fittest sperm for fertilization. The two main types of interactions are physical and molecular. Physical interactions include the swimming responses of sperm to the microarchitecture of walls, to fluid flows, and to fluid viscoelasticity. When sperm encounter walls, they have a strong tendency to remain swimming along them. Sperm will also orient their swimming into gentle fluid flows.

 The female tract seems to use these tendencies of sperm to guide them to the site of fertilization. When sperm hyperactive, they are better able to penetrate highly viscoelastic media, such as the cumulus matrix surrounding eggs.

Molecular interactions include communications of sperm surface molecules with receptors on the epithelial lining of the tract. There is evidence that specific sperm surface molecules are required to enable sperm to pass through the uterotubal junction into the oviduct. When sperm reach the oviduct, most bind to the oviductal epithelium. This interaction holds sperm in a storage reservoir until ovulation and serves to maintain fertilization competence of stored sperm. When sperm are released from the reservoir, they detach from and re-attach to the epithelium repeatedly while ascending to the site of fertilization. We are only beginning to understand the communications that may pass between sperm and epithelium during these interactions.

 Given all of these factors that operate on the process of reproduction, it should not be surprising that the female reproductive tract interacts in various ways with sperm in order to facilitate migration to the egg, store sperm until needed, and select sperm of the best quality to fertilize.

 There are two main categories of interactions of sperm with the female reproductive tract, namely, physical and molecular. The physical category includes the swimming responses of sperm to the microarchitecture of the walls of the tract, to fluid flows, and to fluid viscoelasticity. Molecular interactions include communications of sperm surface molecules with receptors in the epithelial linings of the tract. Indirect molecular interactions, such as effects of tract secretions on sperm, effects of seminal plasma on the tract, or interactions of sperm with immune cells that enter the lumen of the tract

Physical Interactions

Surfaces

The architecture of cell surfaces can affect the direction of sperm movement. It has long been observed that sperm tend to accumulate at surfaces, particularly the surfaces of slides and coverslips. When sperm that are swimming along a flat horizontal surface reach a side wall, they tend to continue swimming along the corner where the two walls meet. The surfaces of the walls of the female reproductive tract are, of course, far more complex in design than the surfaces of microscope slides. They observed that when human sperm that were swimming along a surface encountered a sharp outward turn, the sperm would leave the surface until they encountered another surface. Using this information, they constructed a “one-way running track” for sperm. When human sperm were loaded into this circular channel with scalloped walls, they tended to swim in a counterclockwise direction around the circle It is very interesting that a scanning electron micrograph of the inner surface of the bovine uterotubal junction reveals shapes that resemble the architecture of the running track. This resemblance indicates that the micro architectural of the junctional walls could guide sperm to swim toward the oviduct.

Fluid flows

The fluid in the lumen of the female reproductive tract is rarely static: ciliary beating, contractions of smooth muscle in its walls, and secretion of fluids into the lumen create fluid flows.

At a certain low range of fluid flow velocity, sperm orient into a flow and swim against it below this range, the direction of swimming is unaffected by the flow; above this range, sperm are swept downstream. There is little information about the velocity of flows that exist within the female reproductive tract.

Viscoelasticity

Sperm encounter viscous fluids in the female tract, some of which contain significant elastic properties. These include estrous cervical mucus, oviduct fluid in some species, which is considered to be a viscoelastic network immersed in a viscous fluid. Viscoelastic fluids can reduce the swimming velocity of sperm, but can also modify the bending pattern and subsequent swimming trajectories of sperm.

Molecular Interactions

The primary sites of known, direct molecular interactions of sperm with the tract that bear most directly on fertilization are interactions with the epithelia lining the uterotubal junction and the oviduct.