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Matric number: 18/mhs07/020

Department: Pharmacology

Course code: PHS 212

Question: Discuss the factors facilitating the movement of sperms in the female reproductive tract.

1. **Female reproductive tract environment:** The female reproductive tract, composed of the ovaries, oviducts, uterus, cervix, and vagina, is immature at birth and develops into a fully functional reproductive unit by PND 42. The ovary is considered mature once the rat has experienced at least two ovulatory cycles, and this typically occurs by PND 42. Not all segments of the reproductive tract mature at the same rate as the ovary. The epithelium of the oviduct has all its components by PND 21 and the epithelium of the vagina is hormonally responsive by PND 30. The aim of this chapter is to describe the postnatal histological development of the female reproductive tract tissues and highlight important developmental landmarks in each tissue at the various postnatal ages. Female reproductive tract development is a complex process intricately tied to the patterning of the male reproductive tract and renal anlage. Development starts from undifferentiated mesoderm known as the genital ridge, with germ cells migrating to this location from the yolk sac. The müllerian duct begins as an invagination of the coelomic epithelium at the top of the genital ridge and elongates by active cell proliferation using the Wolffian duct as a guide. Many genes have

been linked to female reproductive tract development, but only a few have been directly implicated by animal knockout models; this is because the simplex female reproductive tract pattern (i.e., one with a single cervix and uterus, with two separate fallopian tubes) is limited to humans and other primates. Most recently, genomic sequencing has identified more genes, mostly transcription factors and extracellular signaling molecules, and mutations in those genes, associated with malformations of the female reproductive tract. The most common congenital abnormality of the human female genital tract occurs when the paired müllerian ducts fail to fuse or the subsequent septum fails to resorb, yielding a spectrum of uterine anomalies, including uterus didelphys and bicornuate uterus. External female genital tract development requires both the absence of a key male determining factor (SRY) and presence of its antagonist. Virilization of genetically female fetuses is due to excessive androgens from congenital adrenal hyperplasia or maternal blood.

2. **Cell- cell interactions:** Cell–cell interaction refers to the direct interactions between cell surfaces that play a crucial role in the development and function of multicellular organisms. These interactions allow cells to communicate with each other in response to changes in their microenvironment. This ability to send and receive signals is essential for the survival of the cell. Interactions between cells can be stable such as those made through cell junctions. These junctions are involved in the communication and organization of cells within a particular tissue. Others are transient or temporary such as those between cells of the immune system or the interactions

involved in tissue inflammation. These types of intercellular interactions are distinguished from other types such as those between cells and the extracellular matrix. The loss of communication between cells can result in uncontrollable cell growth and cancer. Cell–cell interactions drive numerous physiological processes and help enable coordinated functioning in multicellular organisms. Many cell–cell interactions have not been well characterized, partially because, until recently, much work was devoted to examining cell matrix interactions, and partially because studying cell–cell associations comes with a long list of challenges. There are three key challenges to the latter. First, such associations are generally more geometrically complex. This is not to say that cell–cell adhesion plaques are necessarily smaller, but cell–substrate interactions can be examined over the area of some spread, adhered cell, whereas cell–cell junctions are limited to a slightly thickened perimeter of the cell, with 3D orientation even when cells are plated on flat surfaces. Second, various extracellular matrices are readily isolated or purchased, while cell–cell junctions rely more on specific receptor–receptor interactions, which in turn rely on expensive antibodies or purified receptors. Finally, effects of cell–cell interactions are very difficult to isolate from cell–substrate interactions in adherent cells. The reverse is a bit simpler—some cell models can work with sparsely plated cells. But generating consistent cell culture conditions where cell–cell interactions dominate is not always a simple matter.

3. **Gene expression:** Gene expression is the process by which

information from a gene is used in the synthesis of a functional gene product. These products are often proteins, but in non-protein-coding genes such as transfer RNA (tRNA) or small nuclear RNA (snRNA) genes, the product is a functional RNA. Gene expression is expanded by the subsequent discoveries of reverse transcription and RNA replication. The process of gene expression is used by all known life eukaryotes (including multicellular organisms), prokaryotes (bacteria and archaea), and utilized by viruses—to generate the macromolecular machinery for life.

In genetics, gene expression is the most fundamental level at which the genotype gives rise to the phenotype, i.e. observable trait. The genetic information stored in DNA represents the genotype, whereas the phenotype results from the "interpretation" of that information. Such phenotypes are often expressed by the synthesis of proteins that control the organism's structure and development, or that act as enzymes catalyzing specific metabolic pathways.

All steps in the gene expression process may be modulated (regulated), including the transcription, RNA splicing, translation, and post-translational modification of a protein. Regulation of gene expression gives control over the timing, location, and amount of a given gene product (protein or ncRNAs) present in a cell and can have a profound effect on the cellular structure and function. Regulation of gene expression is the basis for cellular differentiation, development, morphogenesis and the versatility and adaptability of any organism. Gene regulation may also serve as a substrate for evolutionary change.

Gene expression is an important process to develop various biological functions and drive the phenotypes. Following the molecular central dogma, a gene a piece of DNA on the chromosome is first transcribed to RNA (transcription). Gene expression is influenced by numerous factors, including molecules within the cell, mutations causing dominant negative effects and haploinsufficiency, signaling molecules from surrounding cells and the environment, and epistasis. Various molecules within the cell modulate gene expression.

4. **Phenotypic sperm traits:** Sperm competition is the competition between the ejaculates of different males for the fertilization of a given set of ova. Charles Darwin (1871) proposed sexual selection as a process that operates on variation in male ability to compete with other males for access to reproductive opportunities, and which promotes traits that confer an advantage in reproductive competition. In most taxa individual females may copulate (or spawn) with multiple males (i.e., are polyandrous). As a consequence, the ejaculates of different males may co-occur around a set of ova at the time of fertilization, resulting in sperm competition. Sperm competition introduces variation in male reproductive success determined by the relative competitive fertilizing efficiency of the ejaculates of different males, and generates postcopulatory, intrasexual selection, which promotes traits that increase the fertilization success of an ejaculate under competitive conditions. A second consequence of polyandry is the potential for intersexual selection to continue after copulation through mechanisms that enable females (or ova) to bias the outcome of sperm competition in

favor of the sperm of certain males, a process known as sperm selection or cryptic female choice. The past three decades have seen an explosion of interest in postcopulatory sexual selection that has highlighted the importance of sperm competition and cryptic female choice as engines of evolutionary change. This chapter reviews recent empirical and theoretical advances to discuss various ways in which sperm competition may shape the evolution of sperm and ejaculate traits.