VERTEBRATE REPRODUCTION AND DEVELOPMENT

Most of the higher plants and animals have separate sexes and thus reproduce sexually. Sexual reproduction was one of the most important biological advances to occur when life was evolving millions of years ago. Essentially, it has allowed evolution to proceed more rapidly than it has in those organisms which reproduce asexually. This is apparent because it allows for continual recombination of chromosomes and genes when the gametes (egg and sperm) of two individuals join together (fertilization), and initiate the development of a new individual.

In today's lab session we want you to become familiar with the anatomy of vertebrates, and for this we will use the human reproductive system as an example. Most of you are probably aware of the intricacies of your own sex but we would hope that you learn more of the opposite sex as well. You will discover that although the two sexes are rather different, close examination will reveal that they also have some similarities that you are probably not aware of. In addition, you should also gain an understanding of the early developmental stages beginning with the fertilized egg (zygote) through the very early embryonic stages.

1. The Human Reproductive Systems

Sexually reproducing animals have what is referred to as primary reproductive organ or gonads. These gonads, ovaries in females and testes in males, produce the sex cells, eggs and sperm. In some animals the reproductive system is fairly simple and eggs and sperm are expelled from the body of each sex and fertilization is accomplished externally. In many organisms, including humans, the male transfers his sperm to the female during a sexual union (coitus, copulation, intercourse, etc.) and fertilization is achieved internally within the body of the female. We want you to become familiar with the human male and female reproductive systems by examining the models of each sex provided. Refer to the description of each system within this text and become familiar with the location of each underlined structure, first on the models, and then label each of these structures in Figures 1 and 2. When using the models, refer to the number on the model if in doubt to the location of a particular structure, as well will give the number of that part in parentheses in the text.

A. Male Reproductive System

As stated earlier, the primary reproductive organs in males are the testes (singular – testis) (3) which are housed externally in a pouch of skin, the scrotum (2). The testes descend from the inguinal canal within the body cavity before or shortly after birth. If they don't descend, the individual will be sterile because sperm production must take place at a few degrees lower than body temperature. An operation is usually performed on those males which have undescended testes to correct this situation. Each testis contains hundreds of seminiferous tubules where the sperm are produced. These connect with a larger tube, the coiled epididymis (4) which is located on the dorsal side of the testis. Here the sperm are held until maturation occurs after which they enter the vas deferens (12 and 16) or sperm duct. The vas deferens loops up and over the urinary bladder (14) (see Figure 1). Before the vas deferens enters the urethra (9), two accessory glands add seminal fluid to the sperm which helps to maintain the sperm in a viable state. The first pair of accessory glands are the seminal vesicles (15), the second is the single, large, globular, prostate gland (13).

After leaving the prostate, another small accessory gland, the Bulbourethral (Cowper's) gland (11), adds additional seminal fluid. Most of the seminal fluid is supplied by the prostate, but the total mixture of

sperm and seminal fluid is referred to as semen, which is expelled from the urethra during the male orgasm. Rhythmic contractions of the reproductive organs forcibly expel the semen, a process known as ejaculation. Soon after the urethra leaves prostate, it enters the male copulatory organ, the penis (1). Most of the penis is made up of spongy erectile tissues (7 & 8), which upon sexual arousal become engorged with blood, thus maintaining the erection. The tip of the penis is the soft, sensitive glans (6), which is covered by the thin membranous prepuce, which is removed from those individuals that have undergone circumcision.

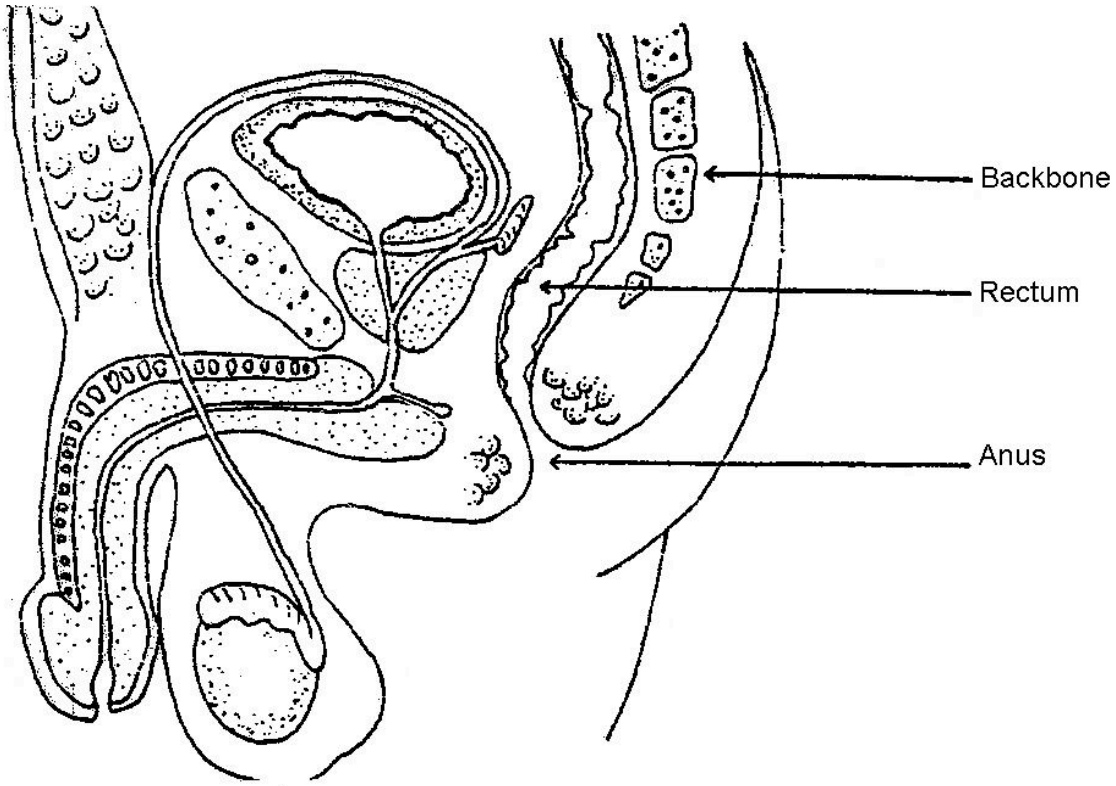

Figure 1. Human Male Reproductive Organ

Please note that in the human male, the reproductive system (vas deferens) joins with part of the excretory system (urethra). However, during intercourse and ejaculation it is practically impossible for urine from the urinary bladder to mix with the semen. This is prevented by sphincter muscles at the base of the urinary bladder which close off the urethra, thus preventing mixture of the two fluids.

B. Female Reproductive System

The primary reproductive organs of females are the ovaries (9), which unlike the male testes, remain within the body cavity of the female. The ovaries contain primordial eggs, some of which will eventually develop and mature into the ova or eggs after puberty is reached. An average female is born with about 500,000 primordial eggs but only about 500 of these will mature into ova during her childbearing years. Compare this with the 200-300 million sperm a man releases each time he ejaculates! During each monthly menstrual cycle, an alternating ovary will produce an ovum which is forcibly expelled from the ovary. The ovum is usually captured by the fingerlike fimbriae on the ends of the oviducts or fallopian tubes (11). There, cilia sweep the ova into the fallopian tubes en route to the uterus (7). It is interesting to note that fertilization usually occurs in the upper third of the fallopian tube but may occur within the ovary itself.

If fertilized, the resulting zygote implants in the lining of the uterus or endometrium (8). Here it will remain and develop into the 9-month old infant. During menstruation, the outer layers of the endometrium are shed, which comprises most of the menstrual flow. However, if pregnancy occurs, the endometrium remains intact until after birth. The uterus (7), or womb, is an extremely muscular organ that stretches to fit the size of the developing fetus. During birth, it begins contractions known as labor, to forcibly expel the infant. As the uterus contracts, the tip of that structure, the cervix (5), begins to thin and pull back over the opening of the uterus in a process known as dilation. When the opening is dilated about 4", the infant is delivered down the birth canal or vagina (3-4). The vagina not only serves as the birth canal but it has a dual function in that it receives the penis during intercourse. The vagina is an extremely elastic structure averaging 3-4" in length and lying at right angles to the uterus. In young girls and some virgins, the opening to the vagina is covered by a thin membrane, the hymen. This structure may become ruptured before or during intercourse and its absence does not necessarily imply that the individual is not a virgin.

The external genitalia of the female are collectively known as the vulva and include several distinct structures. The mons vereris (which is gray in the models) is a mound of fatty tissue that overlies the pubic bone. It and the labia majora (1) become covered with pubic hair during the onset of puberty. The labia majora (singular – labium majus) develop from the same embryonic tissues that develop into the scrotum in males. The labia majora enclose and protect another inner pair of lips, the labia minora (2) (singular – labium minus). The labia minora are thin, sensitive, and covered with mucous membranes to keep them moist. Located where the labia minora meet at their anterior end is a small bulbous structure, the clitoris (17). This organ is homologous to the male penis and is composed largely of erectile tissue which becomes engorged with blood during sexual arousal, similar to the erection maintained by males. The clitoris is the center for the female orgasm not the vagina. Stimulation of the clitoris, either directly or during intercourse by stretching of tissues surrounding it, initiates orgasm in the female. However, there is no ejaculation in the female and orgasm is not necessary for conception to occur. Note that in the female, the urethra (16) is not connected to the reproductive tract and opens separately within the labia minora.

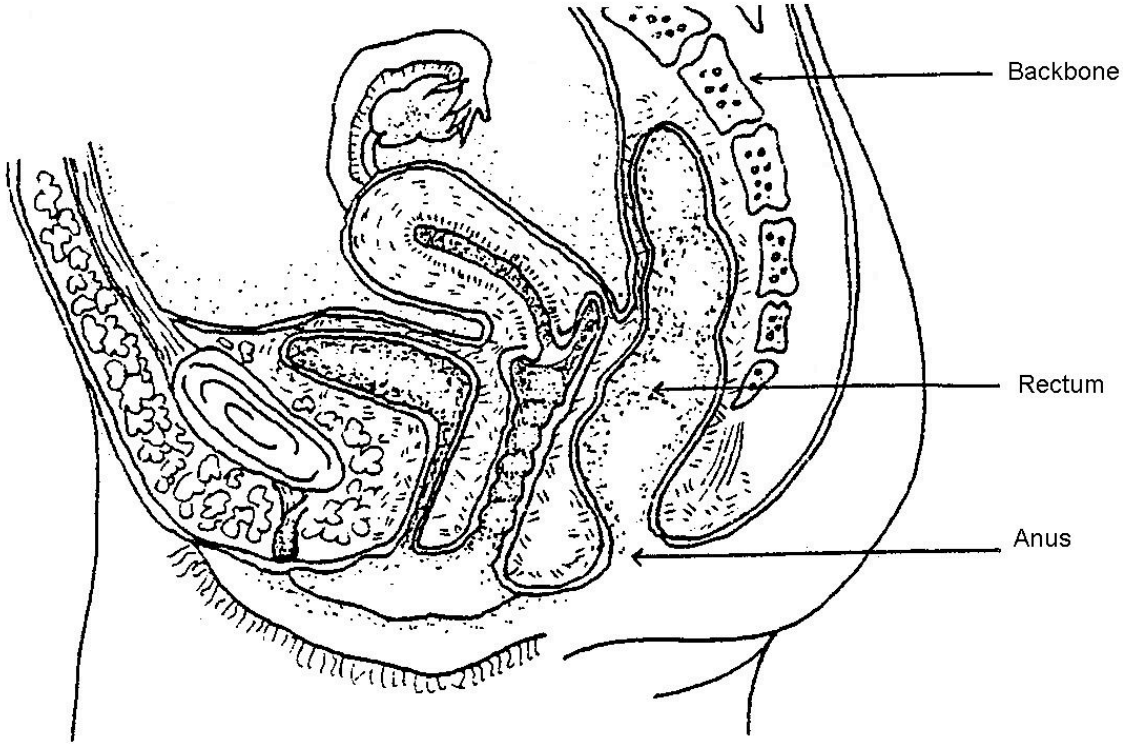

Figure 2. Human Female Reproductive Organs

1. View a slide of human sperm at 450X, sketching a single sperm and indicating the function of each part.

2. Give the **functions** of the following Male Structures:

Scrotum	_____	Prostate Gland	_____
Testes	_____	Bulbourethral Gland	_____
Epidiymis	_____	Urethra	_____
Vas Deferens	_____	Prepuce	_____
Seminal Vesicles	_____	Glans Penis	_____

3. Give the **functions** of the following Female Structures:

Ovary	_____	Cervix	_____
Oviduct	_____	Vagina	_____
Uterus	_____	Clitoris	_____
(section of uterus) Endometrium	_____	Labia Minora	_____
(section of uterus) Myometrium	_____	Labia Majora	_____

4. **Spermatogenesis – Cross-section of testes**
   View a cross-section of testes at 100X and note the following: seminiferous tubules, spermatocytes (sperm forming cells) and sperm cells (with flagella).

5. **Oogenesis – Cross-section of ovary**
   View a cross-section of an ovary at 100X and note the eggs and ovarian follicles (the blister-like structure surrounding the egg).

II. Development

Soon after the egg and sperm have united to form the zygote, this single cell begins to divide and will eventually result in the new individual. The study of the development of the fertilized egg (zygote) into the complex, interdependent system of tissues and organs that make up the adult animal is called embryology or developmental biology. It is difficult to study the embryological stage3s of humans for obvious reasons. We can however, study an organism that has early developmental stages similar to us, the starfish. You are probably asking, why the starfish, they're not even a vertebrate animal? The starfish is an echinoderm, but because these organisms exhibit similar developmental patterns to vertebrates, (deuterostomes) scientists believe that the two groups evolved from a common ancestor over 500 million years ago. Another reason to study the starfish is because its eggs and thus its zygotes are relatively large, which facilitate study. In addition, we would like you to observe the development of the frog to compare a slightly different developmental pattern.

Eggs that possess a small amount of yolk that is evenly distributed throughout the egg are termed isolecithal, an example being starfish and human eggs. Those eggs which have yolk concentrated at one end are termed telolecithal, an example being frog eggs. Obtain a slide of starfish development and observe at 100X.

A. **Unfertilized Egg** – Try and locate a single cell with a definite nucleus and nucleolus, the unfertilized egg. Observe a model of an unfertilized frog egg or preserved frog eggs. What are the similarities or differences you see between the eggs of these two organisms? Make a drawing of an unfertilized egg in Figure 3.

B. **One-cell stage** – Now locate a single cell on your starfish slide which lacks a nucleus. This is the zygote or one-cell stage. Examine it and note that it is surrounded by a thin fertilization membrane. What is the function of this structure? Make a drawing of a zygote in Figure 3.

C. **Two-cell stage** – The process of cell division by which the zygote develops into a multicellular organism is referred to as cleavage. Locate and observe a two-cell embryo and note the fertilization membrane present. Make a drawing of this stage in Figure 3.

D. **Four-cell stage** – Locate and observe under low and high power a four-cell stage and make a drawing of it in Figure 3.

E. **Eight-cell stage** – Find and observe an eight-cell stage. Note that the fertilization membrane is still barely visible. Make a drawing of this stage in Figure 3. Has the size of the embryo increased up to this point?

F. **Morula** – The 16 and 32 cell states are usually referred to as morulas. Try and locate one of these and note that the fertilization membrane is no longer present. Has the size of the embryo increased since the 8 cell stage?

G. **Blastula** – As the cells of the embryo undergo additional cleavage, a spherical ball of cells called the blastula develops. It can be recognized in its early stages as a circular mass of large cells that are rather dark around the edge and lighter in color in the center. The blastula is hollow and the fluid filled center is called the blastocoel. Locate and observe an early blastula and make a drawing of it in Figure 3.

H. **Gastrula** – As the blastula develops, its cells continue to divide into smaller cells. This spherical single layer of cells then undergoes an important development called gastrulation. This occurs when the cells on one side of the blastula invaginate or push into the blastocoel. They continue to invaginate until a blind tube develops called the archenteron. This will eventually develop into the primitive gut or digestive tract, and the cells lining the archenteron are now referred to as the endoderm. The outer layer of cells is termed the ectoderm, which will give rise to the skin and nervous system. At the interior end of the archenteron, a pouch will develop that will give rise to the third tissue layer, the mesoderm. The cells of the mesoderm will eventually develop into muscles, bones, and the circulatory system. Locate and observe a gastrula and make a drawing of it in Figure 3.

Figure 3 – Early Embryonic Stages of the Starfish

A. Unfertilized Egg	B. 1 Cell Stage (Zygote)	C. 2 Cell Stage	D. 4 Cell Stage
E. 8 Cell Stage	F. Morula	G. Blastula	H. Gastrula