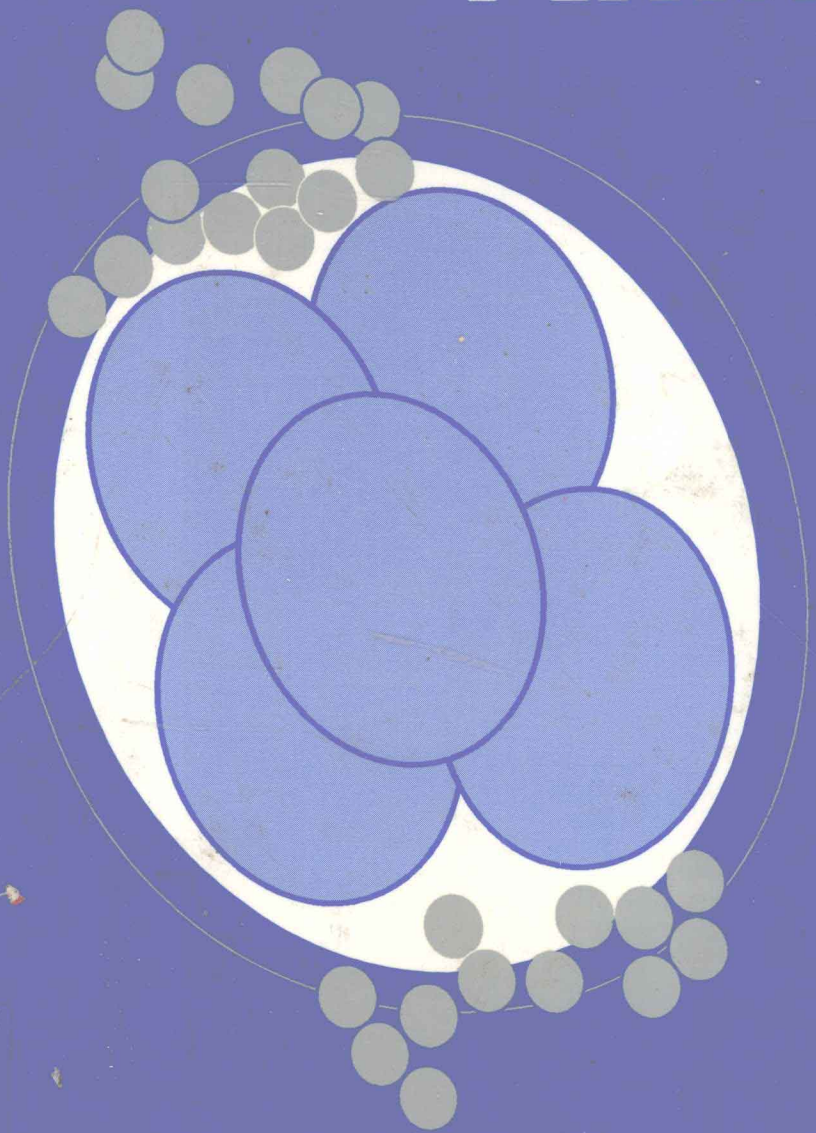
Reproduction in Farm Animals

6th Edition



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6th Edition

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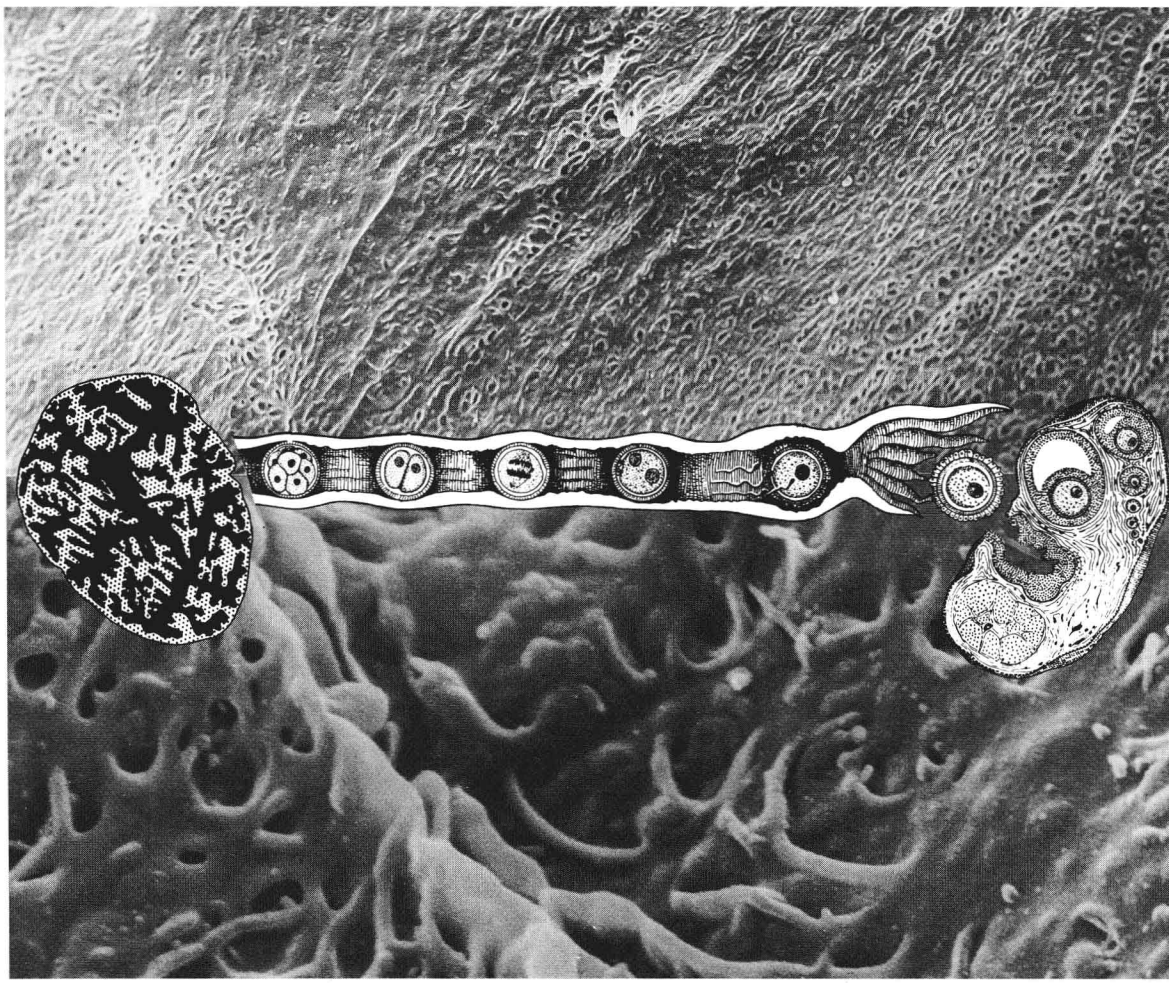

Frontispiece: The beginning of life. The oviduct: spermatozoa and eggs are transported, simultaneously, in opposite direction; sperm hyperactivation and final maturation of eggs are completed before sperm binding to the zona pellucida and fertilization.

Dedicated to M.C. Chang

(The Worcester Foundation of Experimental Biology, Shrewsbury, Massachusetts, USA)

preface

The first edition, published in 1962, covered the basic and comparative aspects of reproductive physiology in a simplified manner to meet the needs of students in reproductive biology, veterinary medicine, and animal sciences. This objective is maintained in the sixth edition, which represents a condense, concise treatise on the physiology and biochemistry of reproduction of farm animals. The book is divided into major sections and these, in turn, are loosely arrayed into two domains: the components of the reproductive system and the regulation of the reproductive process, from the control of ovulation to the initiation of parturition. The reader will note the profound differences among the various animal species. To address this issue we provided separate coverage of the major species, where this seemed appropriate so that the student of reproduction could ascertain the similarities and differences among them.

During the past decade there were significant advances in the main concepts of animal reproduction as a result of modern biotechnology such as the use of immunology and radioimmunoassay; andrology; biochemistry; cryobiology; tissue, organ, and cell culture; and gonadotropin releasing hormones and their analogs. Modern techniques of bioengineering of farm animals involves microinsemination, recombination of DNA, and in vitro manipulation, transfer and expression of genes. These techniques were greatly improved with the use of computers, microcomputers, and commercially available diagnostic and analytical kits. A wide variety of techniques have been employed for the evaluation of semen, such as evaluation of sperm fertilizability using zona-free hamster egg (fresh or frozen); motility pattern as viewed by videotape microscopy; in vitro penetrability of sperm in bovine cervical mucus; and cryopreservation of embryos and semen using computerized freezers. Most of the investigations reviewed in this edition are based more on holistic research than on research at the submicroscopic or molecular level. However, the excitement generated by recent advances in molecular biology and development tend to downgrade the value of whole-animal research. No attempt was made to provide a detailed bibliography, but a selected number of classic papers and review articles are listed at the end of each chapter.

This edition could not have been revised without the cooperation of the contributing authors and their willingness to follow the editorial guidelines. The chapters have been concisely edited, and the major concepts have been summarized in tables supplemented by line drawings and scanning electron micrographs. All chapters have been completely revised and condensed. There have been numerous deletions from the fifth edition, as well as integration of new and modern concepts such as "growth factors," molecular biology and genetics, and in vitro and micromanipulation of gametes and embryos.

Some tabulated appendices include: chromosome numbers and reproductive ability of bovine, caprinae and equinae species and some of their hybrids; reproductive disease of viral, protozoan, or bacterial origin; and preparation of physiologic solutions, sperm stains, tissue culture media, and cryoprotectants. These appendices proved to be helpful for staging demonstrations, laboratory exercises, and training workshops for teachers, laboratory technicians, and students. It is hoped that the sixth edition will be of some help to serious students in animal sciences and veterinary medicine, as well as researchers and teachers.

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acknowledgments

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I. functional anatomy of reproduction

1
Anatomy of Male Reproduction

R.R. ASHDOWN and E.S.E. HAFEZ

The male gonads, the testes, lie outside the abdomen within the scrotum, which is a purselike structure derived from the skin and fascia of the abdominal wall. Each testis lies within the vaginal process, a separate extension of the peritoneum, which passes through the abdominal wall at the inguinal canal. The deep and superficial inguinal rings are the deep and superficial openings of the inguinal canal. Blood vessels and nerves reach the testis in the spermatic cord, which lies within the vaginal process; the *ductus deferens* accompanies the vessels but leaves them at the orifice of the vaginal process to join the urethra. Besides permitting the passage of the vaginal process and its contents, the inguinal canal also gives passage to vessels and nerves supplying the external genitalia.

The spermatozoa leave the testis by efferent ductules that lead into the coiled duct of the epididymis, which continues as the straight ductus deferens. Accessory glands discharge their contents into the ductus deferens or into the pelvic portion of the urethra.

The urethra originates at the neck of the bladder. Throughout its length it is surrounded by cavernous vascular tissue. Its pelvic portion, which is enclosed by striated urethral muscle and receives secretions from various glands, leads into a second penile portion at the pelvic outlet. Here it is joined by two more cavernous bodies to make up the body of the penis, which lies beneath the skin of the body wall. A number of muscles grouped around the pelvic outlet contribute to the root of the penis. The apex or free part of the penis is covered by modified skin—the penile integument; in the resting condition it is enclosed within the prepuce. The topographic features of the organs of the important farm species are shown in Figure 1–1. Detailed descriptions of the organs are given by Nickel et al. (1973).

The testis and epididymis are supplied with blood from the testicular artery, which originates from the dorsal aorta near the embryonic site of the testes. The internal pudendal artery supplies the pelvic genitalia and its branches leave the pelvis at the ischial arch to supply the penis. The external pudendal artery leaves the abdominal cavity via the inguinal canal to supply the penis, scrotum, and prepuce. Lymph from the testis and epididymis passes to the lumbar aortic lymph nodes. Lymph from the accessory glands, urethra, and penis passes to the sacral and medial iliac nodes. Lymph from the scrotum, prepuce, and peripenile tissues drains to the superficial inguinal lymph nodes.

Afferent and efferent (sympathetic) nerves accompany the testicular artery to the testis. The pelvic plexus supplies autonomic (sympathetic and parasympathetic) fibers to the pelvic genitalia and to the smooth muscles of the penis. Sacral nerves supply motor fibers to the striated muscles of the penis and sensory fibers to the free part of the penis. Afferent fibers from the scrotum and prepuce travel mainly in the genitofemoral nerve.

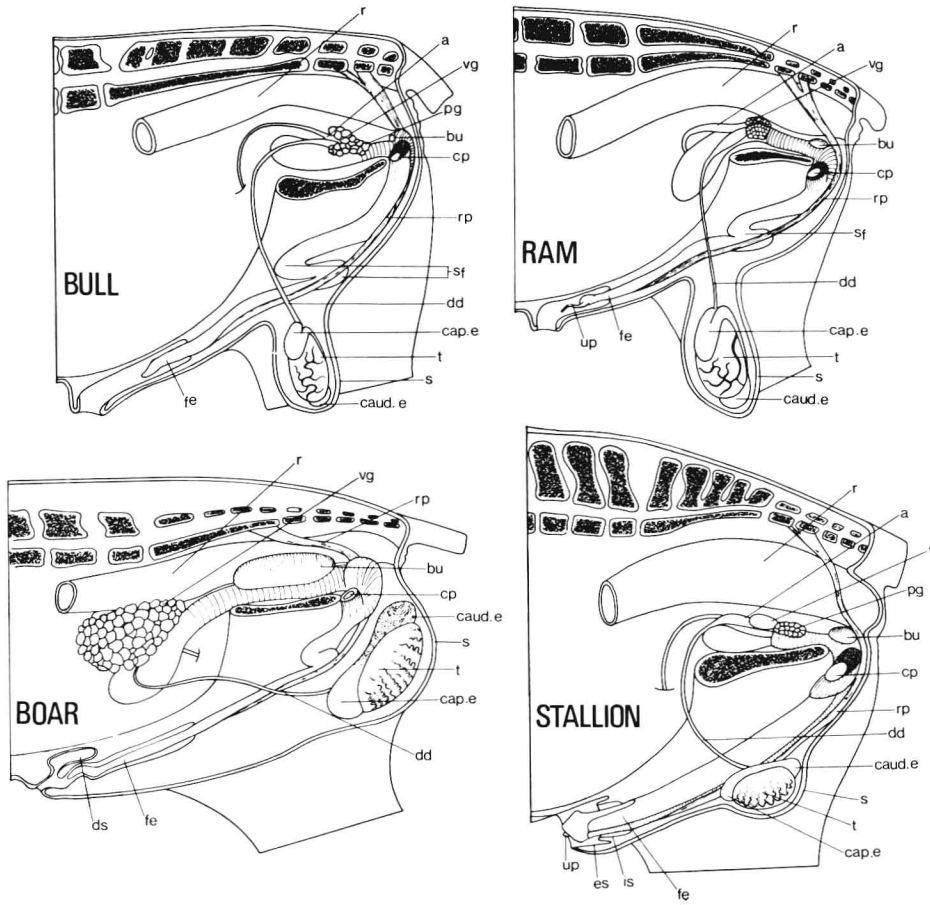

FIG. 1–1. Diagram of the male reproductive tracts as seen in left lateral dissections. *a,* Ampulla; *bu,* bulbourethral gland; *cap. e,* caput epididymidis; *caud. e,* cauda epididymidis; *cp,* left crus of penis, severed from the left ischium; *dd,* ductus deferens; *ds,* dorsal diverticulum of prepuce; *es,* prepenile prepuce; *fe,* free part of penis; *is,* preputial fold; *pg,* prostate gland; *r,* rectum; *rp,* retractor penis muscle; *s,* scrotum; *sf,* sigmoid flexure; *t,* testis; *up,* urethral process; *vg,* vesicular gland. (Adapted from Popesko (1968). Atlas der topographischen Anatomie der Haustiere. Vol. 3, Jena, Fischer.)

DEVELOPMENT

Prenatal Development

The testes develop in the abdomen, medial to the embryonic kidney (mesonephros). The plexus of ducts within the testis becomes connected to mesonephric tubules and so to the mesonephric duct, to form the epididymis, ductus deferens, and vesicular gland. The prostate and bulbourethral glands form from the embryonic urogenital sinus and the penis forms by tubulation and elongation of a tubercle that develops at the orifice of the urogenital sinus.

Two agents produced by the fetal testis are responsible for this differentiation and development (Gondos, 1980). Fetal androgen causes development of the male reproductive tract. "Müllerian inhibiting substance," a glycoprotein, is responsible for suppression of the paramesonephric (Müllerian) ducts from which the uterus

and vagina develop (Vigier et al., 1983). Abnormalities in differentiation and development of gonads and ducts can result in varying degrees of intersexuality (Hare and Singh, 1979).

Descent of the Testis

During testicular descent (Wensing, 1986), the gonad migrates caudally within the abdomen to the deep inguinal ring. It then traverses the abdominal wall to emerge at the superficial inguinal ring, which is, in fact, the much-enlarged foramen of the genitofemoral nerve (L3, L4). The testis completes its migration by passing fully into the scrotum. Descent is preceded by the formation of the vaginal process, a peritoneal sac extending through the abdominal wall and enclosing the inguinal ligament of the testis. The inguinal ligament of the gonad is often called the *gubernaculum testis,* and it terminates in the region of the scrotal rudiments. Descent follows the line of the *gubernaculum testis.* The time of descent varies (Table 1–1). In the horse, the epididymis commonly enters the inguinal canal before the testis, and that part of the inguinal ligament connecting testis and epididymis (proper ligament of testis) remains extensive until after birth.

Sometimes the testis fails to enter the scrotum. In this condition (cryptorchidism), the special thermal needs of testis and epididymis are not met, although the endocrine function of the testis is unimpaired. Bilaterally cryptorchid males therefore show more or less normal sexual desire but are sterile. Occasionally some of the abdominal viscera pass through the orifice of the vaginal process and enter the scrotum; scrotal hernia is particularly common in pigs.

Postnatal Development

Each component of the reproductive tracts of all farm animals grows in size relative to overall body size and undergoes histologic differentiation, but functional competence is not achieved simultaneously in all components of the reproductive system. Thus, in the bull, the capacity

TABLE 1–1. Chronology of Development of the Male Reproductive Tract in Farm Animals

	Bull	Ram	Boar	Stallion
Testicular descent	Enters scrotum half-way through fetal life	Enters scrotum half-way through fetal life	Enters scrotum in last quarter of fetal life	Enters scrotum just before or just after birth
Primary spermatocytes in seminiferous tubules	24 weeks	12 weeks	10 weeks	Variable throughout seminiferous tubules of each testis
Spermatozoa in seminiferous tubules	32 weeks	16 weeks	20 weeks	56 weeks (variable)
Spermatozoa in cauda epididymidis	40 weeks	16 weeks	20 weeks	60 weeks (variable)
Spermatozoa in the ejaculate	42 weeks	18 weeks	22 weeks	64–96 weeks
Completion of separation between penis and penile part of prepuce	32 weeks	> 10 weeks	20 weeks	4 weeks
Age at which animal can be considered sexually "nature"	150 weeks	> 24 weeks	30 weeks	90–150 weeks (variable)