Reproduction

Dr. S. Selvaraju, M.V.Sc., Ph.D, Scientist (SS), Animal Reproduction Animal Physiology Division, NIANP, Banagalore-560030
Overall functions of the male

Produce and maintain supply of sperm
   Termed - Spermatogenesis

Detect females in estrus
   Using - Pheromones, Visual Cues

Inseminate females and fertilize the female gamete
Reproductive Organs in the Male

- Cowpers Gland
- Crura (pl)
- Rectum
- Prostate
- Seminal Vesicles
- Ampulla
- Bladder
- Sigmoid Flexure
- Retractor Penis Muscle
- Vas Deferens
- Caput Epididymis
- Cauda Epididymis
- Glans Penis
- Scrotum
- Testis
**Testis**

- Factory
  - 1-25 X 10^9 sperm/day
  - "Plant" must be air conditioned

- Penis
  - Delivery System
    - Erection
    - Protrusion
    - Ejaculation

**Epididymis**

- Finishing School
  - Fluid Absorption
  - 8-25 X 10^9 sperm
    - membrane changes
    - nuclear & flagellar stabilization
    - motility, fertility
    - cytoplasmic droplet translocation

- Tail of Epididymis

- Warehouse and Delivery
  - Storage 10-50 X 10^9 sperm
  - Sperm for 5-10 ejaculates
  - Smooth muscle contractions upon sexual stimulation

**Accessory Sex Glands**

- Alterations & Packaging
  - Metabolic substrates
  - Surface coatings
  - Transport for sperm
Structure of the Testis

**Tunica Albuginea**
- Connective tissue which holds testis together

**Spermatocord**
- Contains vas deferens, pampiniform plexus, external cremaster muscle nerves

**Vas Deferens**
- Transport of sperm during ejaculation

**Seminiferous Tubule**
- Sperm producing cells - true germinal epithelium

**Corpus Epididymis**
- Maturation of spermatozoa

**Rete Testis**
- Function in sperm transport from seminiferous tubules - 100 tubules

**Caput Epididymis**
- Function - maturation of spermatozoa, fluid absorption

**Efferent ductules**
- 6-12 tubules - absorb fluids

**Cauda Epididymis**
- Final maturation and storage. Only sperm capable of fertilization
Blood supply to testis

1. **Pampiniform Plexus**
   - Counter-current heat exchange causes a cooling of arterial blood supply
   - Single artery surrounded by a network of veins (Increased surface area)

2. **Convoluted testicular artery on the surface of the testis**
   - In Ram temperature decrease 4°C before entering testis

Scrotum, testis and spermatic cord are all involved in thermoregulation
Cryptorchidism - Lack of testis descent into scrotum and thus thermoregulation is absent

Bilateral - sterile
   No spermatogenesis
   Testosterone is produced

Unilateral - fertile
   Reduce sperm producing capacity

Common in boars and stallions
   Testis descent occurs late

<table>
<thead>
<tr>
<th>Time of Testicular Descent</th>
<th>Gestation Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull</td>
<td>100-105 Days</td>
</tr>
<tr>
<td>Boar</td>
<td>100-110 Days</td>
</tr>
<tr>
<td>Stallion</td>
<td>300 Days</td>
</tr>
</tbody>
</table>

Stallion testes should be down within 16 months. Some may take two years. Testes are below the inguinal ring after birth however.
Sertoli cells and Leydig cells

**Sertoli cells**
- Sustentacular or nurse cells
- Tight junctions between adjacent cells - forms part of blood testis barrier
- Hormones
  - androgen binding protein (ABP)
  - inhibin

**Leydig cells - interstitial cells**
- Lie between seminiferous tubules
- Secrete testosterone in response to LH

**Basement membrane** - forms part of blood testis barrier

**Myoid cells** - forms part of blood testis barrier

**BTB:** Protect the seminiferous cells from autoimmune reaction
- Resistant to most harmful factors (radiation, body temperature, infection)
Seminiferous tubule
- Caput (head)
- Corpus (body)
- Cauda (tail)
Functions of epididymis

1. Transport of sperm - 9-11 days in bull

**Mechanisms**

Pressure of new sperm

Regular contraction of smooth muscle

Peristaltic-like contractions (every 6 sec) in caput and corpus are independent of sexual activity

Stimulated contractions of cauda

Increased contractions stimulated by sexual activity may reduce transport time in cauda itself
2. Concentration of sperm

Mechanism
- Fluid absorbed by efferent ductules. Concentration doesn’t change much after proximal caput

Fluid absorbed in Caput
- Contains tall columnar epithelium with Sterocilia
  Sterocilia absorb fluid to concentrate sperm

Rete contains $1 \times 10^8$ sperm/ml - cauda $7 \times 10^9$ sperm/ml
Ram - 40 ml of fluid/day comes from testis and reduced to 1ml
3. Maturation of sperm in Caput to Corpus region

Covered by forward motility factor

1. Sperm gain ability to be motile and fertilize the oocyte

2. Involves biochemical and physical changes to sperm

3. Controlled by rate of transport through epididymis and epididymal secretions

   Allows time for maturation to occur

4. Epididymal fluid changes

   Secretions are different in the various segments of epididymis. Utilized to stimulate maturation and motility
Examples of changes sperm undergo:

1. **Increase in specific gravity**
   Sperm lose H₂O - become more dense

2. **Nucleus more condensed and stable**
   DNA in nucleus is inactive and held together by disulfide bonding

3. **Increase (-) charge on plasma membrane**
   Aid in fertilization? Covered with a carbohydrate to bind to ovum

4. **Sperm become less resistant to cold shock**
   Rapid change in temperature damages sperm. Membrane is fragile.

5. **Migration of cytoplasmic droplet**
4. Storage of sperm - Cauda

Only approximately 1/2 sperm produced reach cauda

1. ~70% of sperm in cauda
   Major site of sperm numbers in excurrent (outside testis) ducts.
   2% in vas deferens

2. Can be stored for several weeks
   Stored without loss of function -
   Arrests sperm metabolism - sperm don’t burnout
   Allows for repetitive ejaculations of a short period
   Sperm are indefinitely viable as prolonged sexual
   rest results in the first couple of collections
   showing poor sperm quality
Factors conducive to storage in Cauda

1. Reduced pH
   pH in cauda is approximately 5.8

2. Low $O_2$ High $CO_2$
   Slows oxidative metabolism

3. High K:Na ratio
   Opposite of extracellular fluid surrounding normal cells of body

4. Low concentrations of energy substrates
   Slow metabolism
Other factors related to epididymal function

1. Temperature
   Cooler (3-5°C) than body temperature
   High temperature interferes with spermatogenesis not storage

2. Testicular androgens
   Vital to epididymal function by maintaining secretory activity
   ABP produced by sertoli cells keeps levels of testosterone high in epididymis

3. Ejaculation frequency
   Bull studs collect 2X / collection and usually collect 2X / week
   or 3X / week depending on bull
Functions of vas deferens

1. Low level steady-state contractions of vas deferens
   Thick muscular wall. This occurs in non-excited state

2. Increased contractions caused by sexual excitement
   Strong peristaltic contractions of smooth muscle stimulated by nerves during sexual arousal

Sperm stored in ampulla age rapidly

   Increased temperature and Poorer environment for sperm

   No secretions produced like the cauda, therefore increase in metabolic activity

   Male not used for a period of time may have poor quality sperm the first few ejaculates collected
Fate of unejaculated sperm

Half of the produced sperm not available for ejaculation
Epididymis, vas deferens and ampulla

1. Resorbed by excurrent duct system
   Some selective removal of abnormal sperm in epididymis (macrophages)

2. Sperm lost in urine
   87% of daily sperm from epididymis of inactive ram are found in urine

3. Masturbation loss of sperm
   Management problem in Boars and sometimes Stallions
Sperm Numbers in Region of the Male Tract ($\times 10^9$)

<table>
<thead>
<tr>
<th></th>
<th>Sexually Rested Bull</th>
<th>Depleted 20 ejaculates in 5 hours</th>
<th>Bull 6 collections/ per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caput</td>
<td>19.4</td>
<td>16.2</td>
<td>22.6</td>
</tr>
<tr>
<td>Corpus</td>
<td>4.7</td>
<td>3.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Cauda</td>
<td>37.6</td>
<td>13.7</td>
<td>26.2</td>
</tr>
<tr>
<td>Vas deferens &amp; Ampulla</td>
<td>7.9</td>
<td>2.1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

High ejaculation frequency the % of immature sperm in ejaculate do not increase significantly. However the number decreases.
Semen, secretions from

- Seminal vesicles, ~ 60% by volume
  - NaCO$_3$, fructose, coagulating proteins
- Prostate gland, ~ 35%
  - Citrate, proteins
- Bulbourethral glands, ~ 4%
  - Alkaline mucus
- Sperm, ~ 1%
Sources of seminal plasma

- Testis: Minor Contribution
- Epididymis
- Vas deferens
- Ampulla: Secretory Glands
- Seminal Vesicles
- Prostate: Major Contribution
- Cowpers (Bulbourethral)
Functions of seminal plasma

1. Transport media
   Gives fluid volume to sperm, helps move sperm through the urethra.
   In sow volume is very important for fertility

2. Culture media
   Proper environment for sperm viability and motility in the female reproductive tract.
   Cow the vagina is a hostile environment

3. Stimulates sperm motility
   Biochemical stimulation - cauda sperm were quiescent.
   Seminal plasma activates metabolic activity

4. Retards sperm capacitation
   Prevents sperm from events for immediate fertilization.
   Secretions in cervix, uterus and oviduct remove coating on sperm so they can fertilize

5. Stimulates sperm transport in female -
   Uterine muscle contractions
   Oxytocin and Prostaglandin F2α are in seminal plasma
**Nutrients**  
**Energy Source**

1. **Fructose**  
- Major secretion in bull seminal vesicles  
- (10X glucose in blood) Not much in other species

2. **Sorbitol**  
- Alcohol Sugar

3. **Glycerol Phosphorylcholine**  
- Origin epididymis  
- May function in survival of sperm in epididymis

4. **Lactic Acid**  
- Anerobic - metabolic product

5. **Fatty Acids**  
- Energy

6. **Amino Acids**  
- Energy

7. **Buffers**  
- Control pH from rapid changes  
- Cauda pH 5.8 to seminal plasma pH 6.8

**Chemical composition of seminal plasma**
Spermatozoa Structure and Functions

- **Head**
  - Acrosome:
  - Nucleus:
- **Midpiece**
  - Centrioles:
  - Mitochondria:
- **Tail: flagellum**
  - Microtubules:
Spermatogenesis
Seminiferous tubules, sertoli cells spermatogenic wave (time) and spermatogenic cycle (space)
Hormonal control of spermatogenesis
Facts about accessory sex glands

- **Accessory glands**
  - Contributions not needed for fertility
  - Coating of gland secretion removed during capacitation

- **Ampulla**
  - thickened glandular portion of ductus deferens as it connects with urethra
  - Large in stallion, bull
  - Present in dog but not always grossly visible
  - Absent in boar, tom

- **Vesicular glands (seminal vesicles)** - sac like organs with lobulated surface
  - Provide volume, protein, sugars, salts
  - Generally fill before copulation and empty during ejaculation
  - Boar - store large volume of fluid
  - Bull - more a solid mass of tissue, produces only small volume of fluid
  - Absent in tom, dog
  - Stallion - fills during sexual stimulation

- **Prostate** - solid tissue mass which secretes during copulation
  - Animals with extended copulation times (boar and dog) have high volume contribution from prostate
  - Secretion mainly ionic compounds (NaCl, Na citrate, and variety of enzymes)
  - Present in all domestic species
  - Bull and boar - anterior mass is body of prostate, disseminated portion is pars disseminata

- **Bulbourethral (Cowper's)** - small, except in boar; muscular gland associated with caudal pelvic urethra
  - Boar - large gland containing large volume of stored gel (sialic acid) which is emitted during ejaculation
  - Can differentiate castrated from cryptorchid pig on basis of rectal palpation. In ruminant and boar, ducts open into urethral recess, situated dorsally, which may prevent passage of catheter
<table>
<thead>
<tr>
<th>Male reproductive features of the domestic species</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Testis orientation</th>
<th>Bull</th>
<th>Stallion</th>
<th>Boar</th>
<th>Dog</th>
<th>Cat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cauda</td>
<td>horizontal</td>
<td>perineal, cauda up</td>
<td>horizontal</td>
<td>perineal, cauda up</td>
</tr>
<tr>
<td></td>
<td>down</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Ampullae           | +        | +        | _        | +?       | _        |

| Seminal vesicle    | +        | +        | +        | _        | _        |

| Prostate           | +        | +        | +        | +        | +        |

| Bulbourethral gland| +        | +        | ++       | _        | +        |

<table>
<thead>
<tr>
<th>Penis type</th>
<th>fibroelastic</th>
<th>vascular</th>
<th>fibroelastic</th>
<th>vascular, os</th>
<th>vascular, os</th>
</tr>
</thead>
</table>

| Copulation duration| 1 second     | 20 sec   | 6 min       | 20 min      | seconds      |

| Volume (typical)   | 5 cc         | 60 cc    | 200 cc      | 20 cc       | 0.04 cc      |

| Sperm conc. (Million/ml) | 1.2 | .10 | .15 | NA | 1.7 |

| Total cells in ejaculate (Million/ml) | 6 | 6 | 30 | .5 | 0.057 |

| Site of semen deposition in female | vagina | cervix / uterus | cervix | vagina | vagina |

---

Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings
Thanks