

# Spermatogenesis and sperm transport;

sub-title; the life of a sperm

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## Learning objectives

### Spermatogenesis;

- To understand basic testicular anatomy and relationship between the compartments
- To understand the cell types (key players) and their architectural relationships within the testis
- To understand the development of the human sperm
- To understand the temporal & spatial characteristics needed found in the testis

### Sperm transport

- To understand the post-testicular developments in sperm.
- To understand the interaction between sperm and the female reproductive tract.

## Chromosomes & gonadal development

Autosomes	Sex Chrom.	Gonad	Syndrome
44	XO	Ovary	Turner's
44	XX	Ovary	Norm.Female
44	XXX	Ovary	Super Female
44	XY	Testis	Norm.Male
44	XXY	Testis	Klinefelter's
44	XYY	Testis	Super Male
66	XXX	Ovary	Non viable trip.
66	XXY	Testis	Non viable trip.
44	XX <sup>SXT</sup>	Testis	Sex reversal

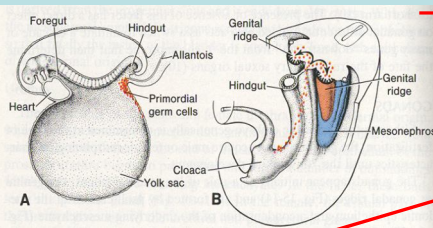
## The Y chromosome

Stained with quinacrine below has ~78 genes with ~ 600 base repeats with 'mirror' image repeats tending to conserve and not crossover



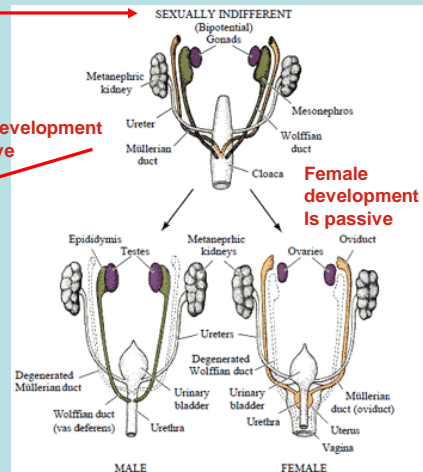
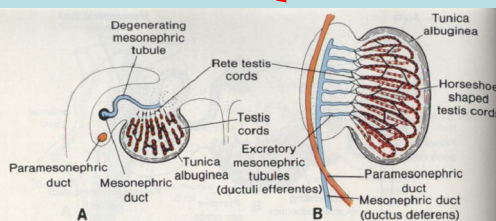
**The Sex determining Region (SRY)**  
 ; when translocated to X produces male phenotype;  
 ; has critical deletions in intersex cases  
 ; when injected in XX mouse embryo produces male phenotype

Sexual dimorphism is caused by the early embryo developing male gonads induced by combining germ and somatic cell lines activated by the SRY gene

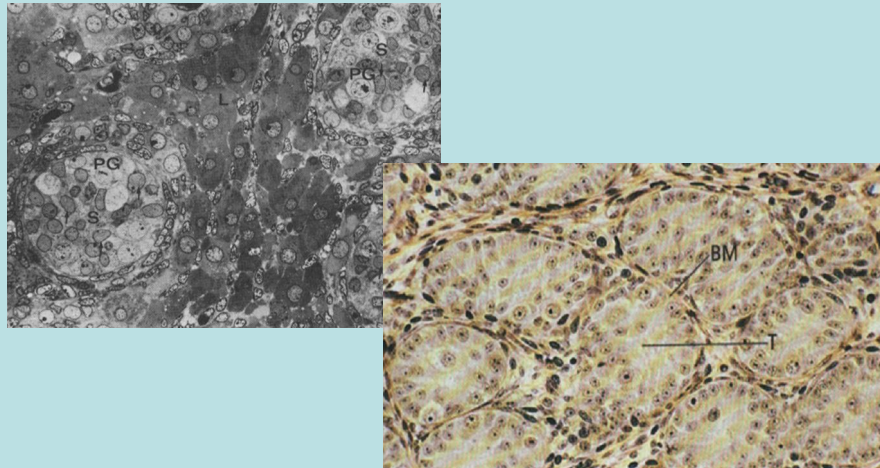


Male development is active

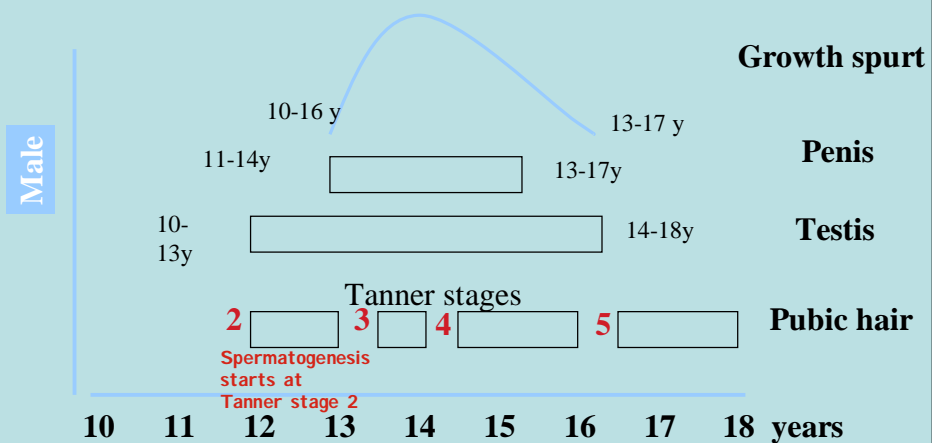
Female development is passive



The fetal testis has the beginnings of a tubular structure

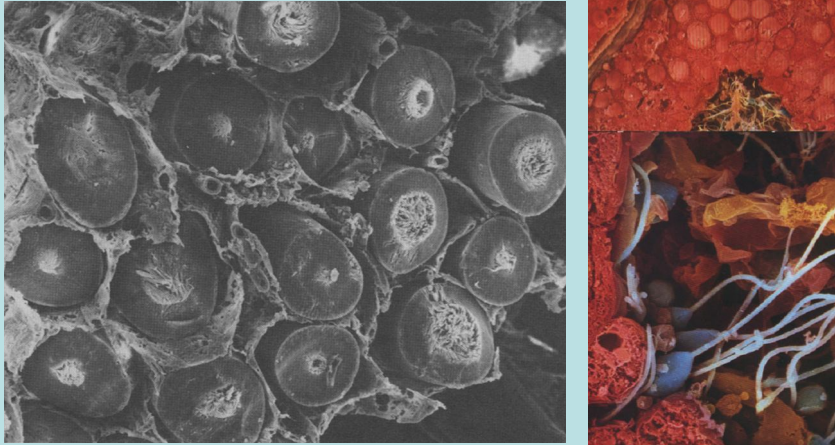


### Reproductive Development in the human male



## The adult testis is tubular

(Rat - Cut section SEM & human )

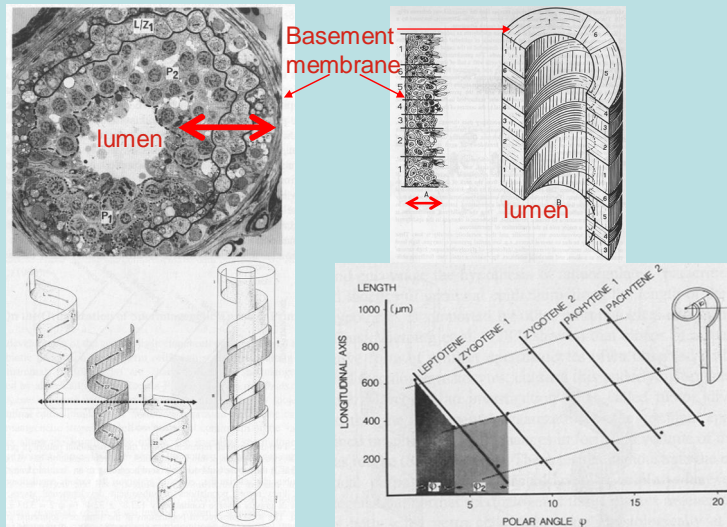


### Spatial changes along the tube The spermatogenic wave.

An orderly sequence of successive cell associations is observed along the length of the seminiferous tubule of rodents.

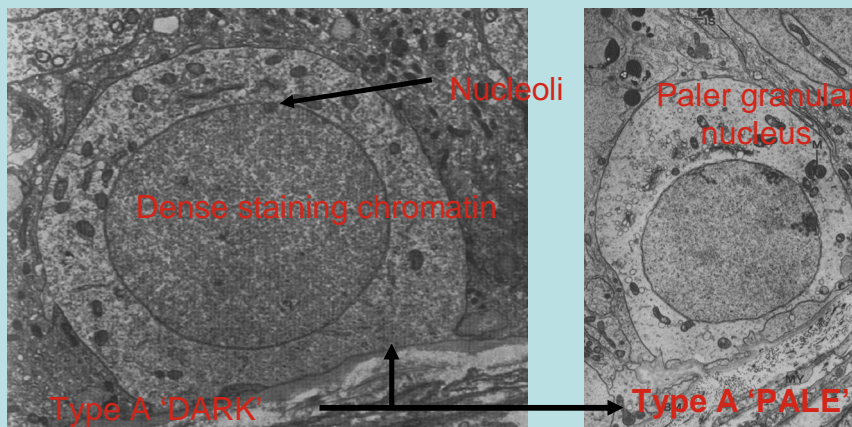
The sequence in humans appears to be chaotic, but on closer examination shares the same fundamental feature.

The apparent chaotic appearance is due to the angular / polar cell-cell relationship



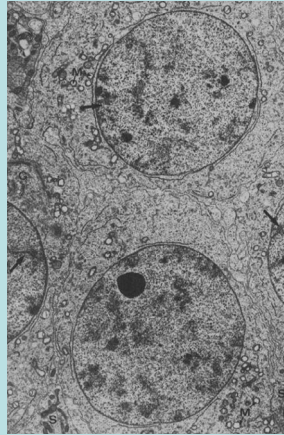
A basal stem cell 'nest' supply of Spermat-ogonia exhibiting renewal followed by committed mitosis.

Division renews Type A 'Dark' when producing Type A 'Pale'



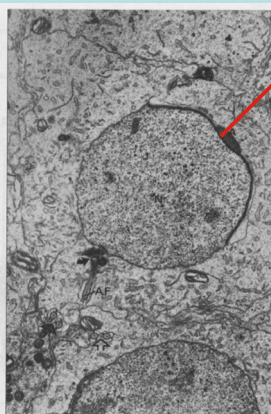
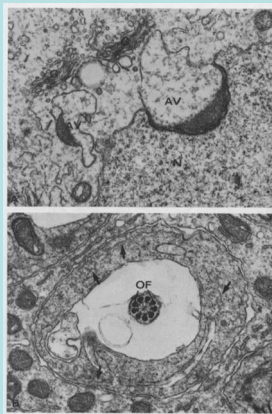
Type B - Larger scalloped chromatin granules and small clumps attached to nuclear envelope with nucleoli in interior of nucleus.

Intermediate cell type Spermato-cytes exhibiting meiotic division and moving away from the basement membrane

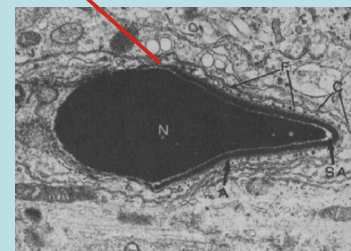


- Primary or "resting" spermatocytes produce two daughter cells.
- Secondary spermatocytes contain a single set of chromosomes and are very short lived.

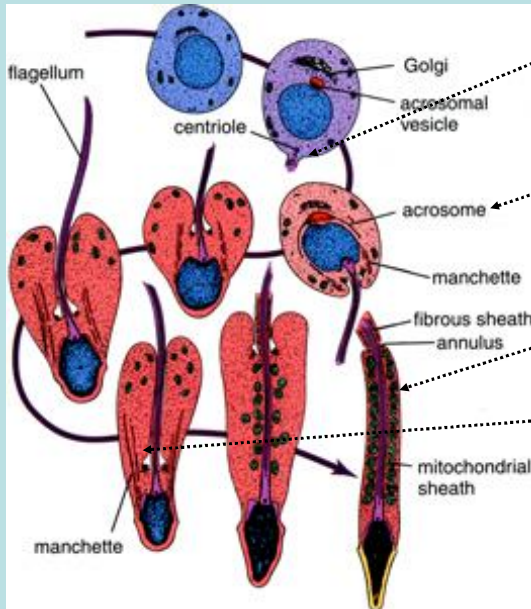
Luminal cell type spermatids exhibit cytoplasmic modelling or spermiogenesis producing cells recognised as spermatozoa.



The Acrosome eventually 30-60% of the head attenuated at the equatorial segment



# Spermiogenesis; summary



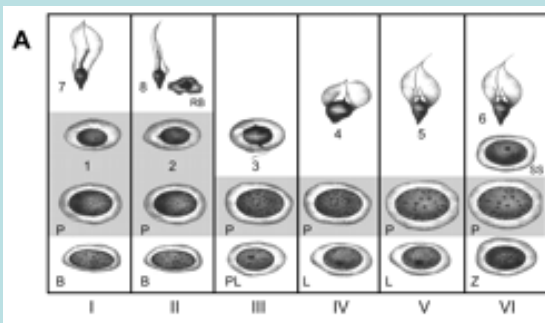
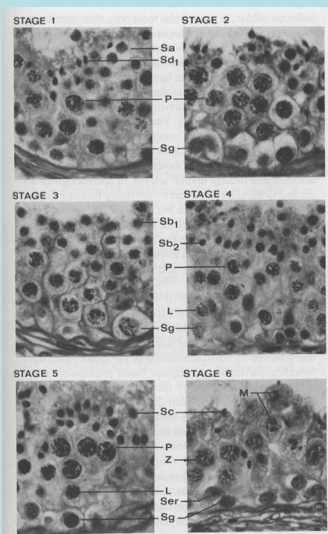
The centriole is also known as the microtubular organising centre and is an important paternal contributor to the zygote (in some species) and critical for 'tail' development.

Acrosome; an organelle derived From Golgi, with enzymes assisting mechanical forces from tail in the penetration of the zona pellucida at fertilisation

Mitochondria form gyres within the mid-piece

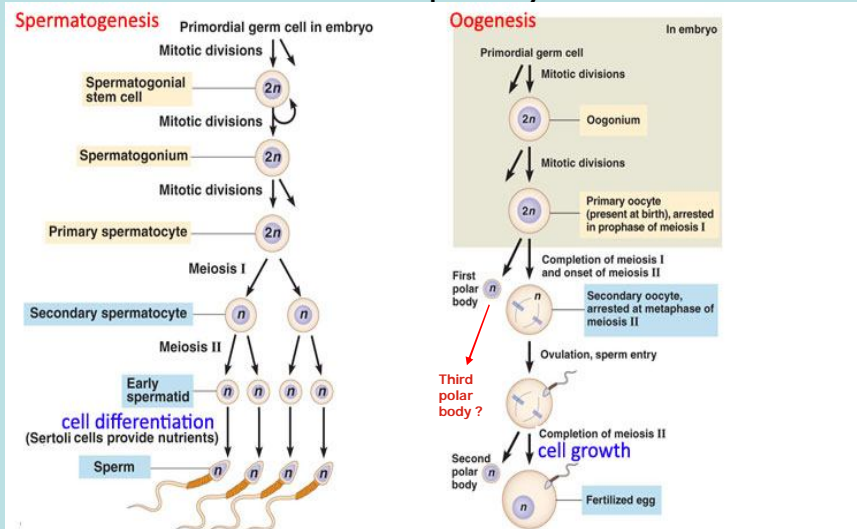
Manchette; conically shaped array of microtubules that covers the nucleus of a spermatid; an ephemeral structure probably used to change the cell shape during maturation and provides transient storage for structural and signaling proteins.

## Stages of Human Spermatogenesis in the Human seminiferous tubes; Clermont 1963

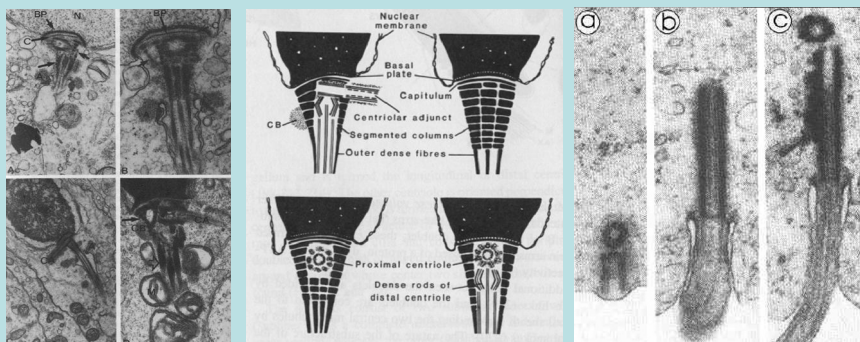


The initials describe to cell type  
 SG/ B-spermatogonia,  
 S (a,b,c,d) -spermatid  
 PI-preleptotene,  
 L/I-leptotene,  
 Z/z-zygotine  
 P/p-pachytene

## Nuclear divisions in gametogenesis to ensure ploidy



'Round' spermatids elongate and develop a tail from the distal centriole (a-c)





## Centrosome degeneration in spermatogenesis (Manandhar et al 2004 Biolreprod)

Intact centrosomes until round spermatid (A) as distal centriole extends as axoneme (B).

**Degeneration  
Species specific**

C; complete;  
rodents,  
snails,

D; retained proximal &  
partial distal in primates

E; fully retained  
Xenopus &  
Drosophila)

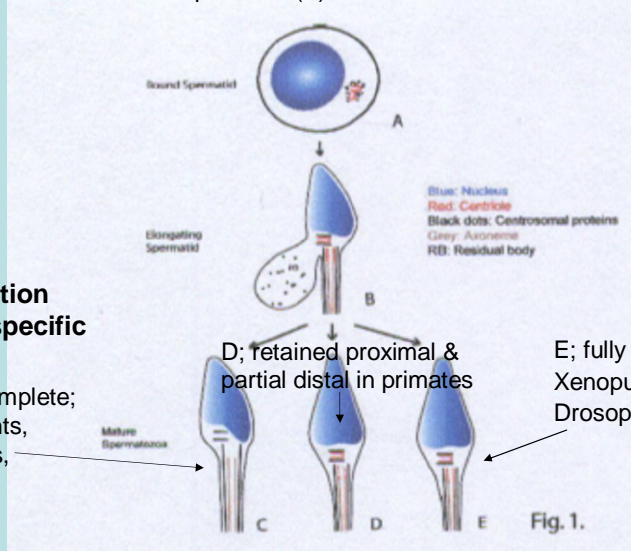
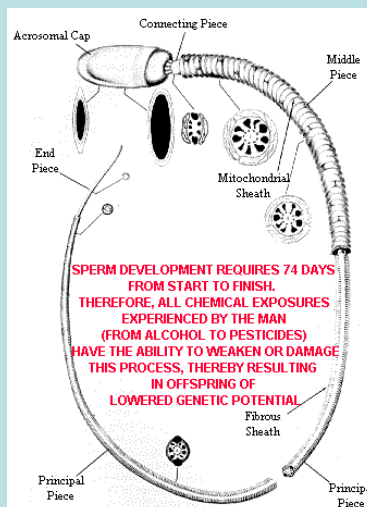
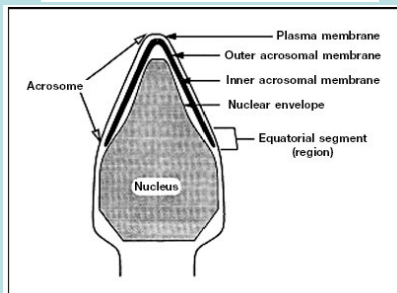
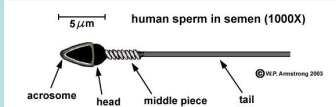
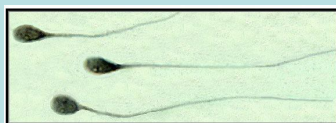


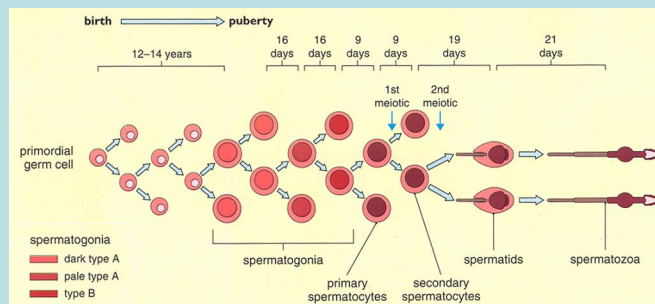
Fig. 1.

The human spermatozoon; has a condensed chromatin head of ~ 3 x 5  $\mu\text{m}$  flattened rostrally (beak like) with mitochondrial gyres in a mid-piece of 7 - $\mu\text{m}$  and a flagella type tail of 50-55 $\mu\text{m}$ .

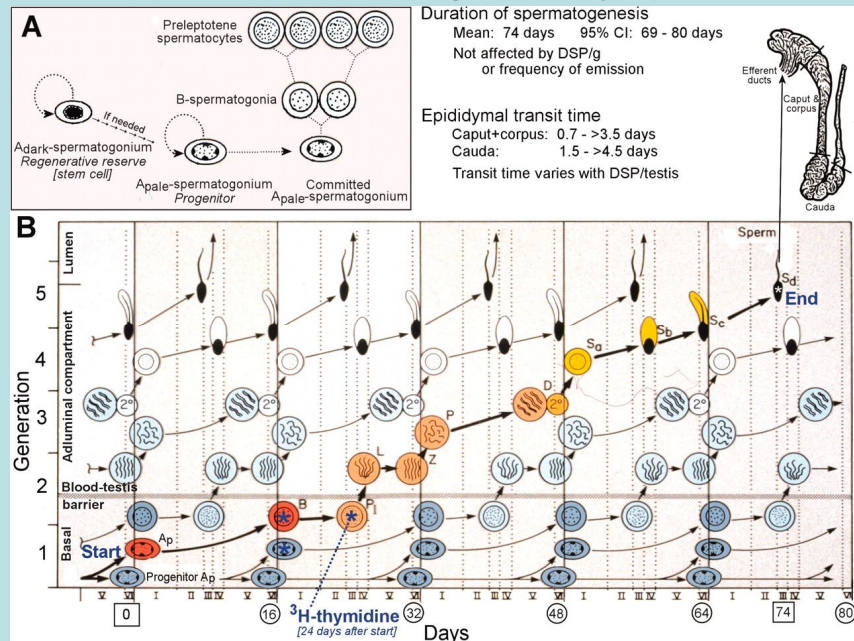


# Time/Temporal changes The spermatogenic cycle

There is a standard mitotic interval or quiescence for stem cells to enter spermatogenesis so that a single area of the seminiferous tubule is at the same stage of development. Generations of daughter cells are linked due to incomplete divisions producing associations over time in a sequence known as the spermatogenic cycle.

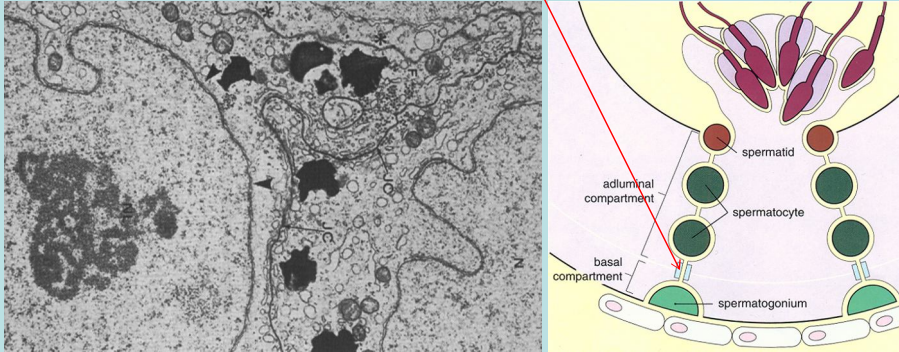


# The spermatogenic cycle



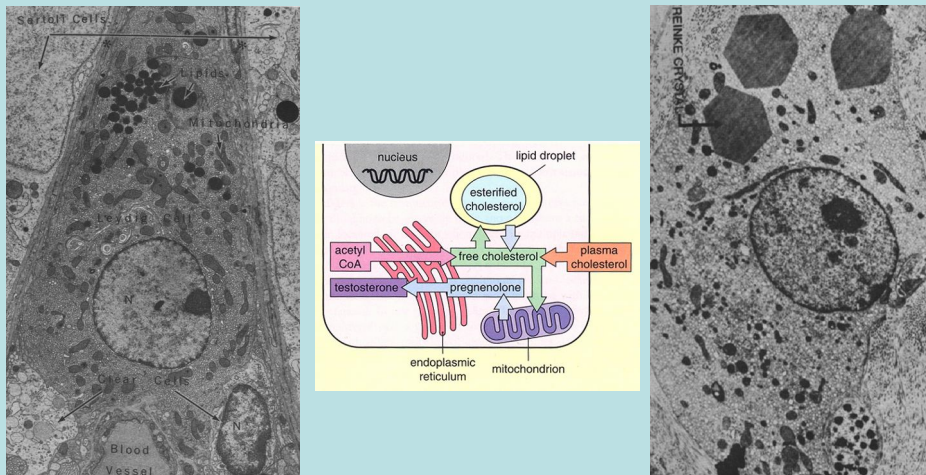
## The Sertoli cell

Tall irregular cells with large basal nuclei lining the seminiferous tubules supporting germ cell development across compartments of testis. Special tight junctions producing a blood-testis barrier which creates local environments and separates mitotic, meiotic from post-meiotic germ cells



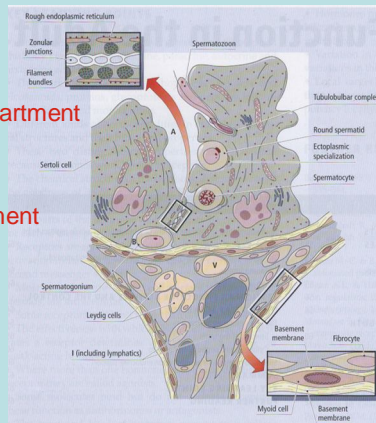
## The Leydig cell

Found in the interstitial compartment of the testis they contain large quantities of smooth endoplasmic reticulum and lipid. Source of Testosterone and may contain Reinke crystals.



## The Testis in section illustrating the relationship between cell types forming compartments

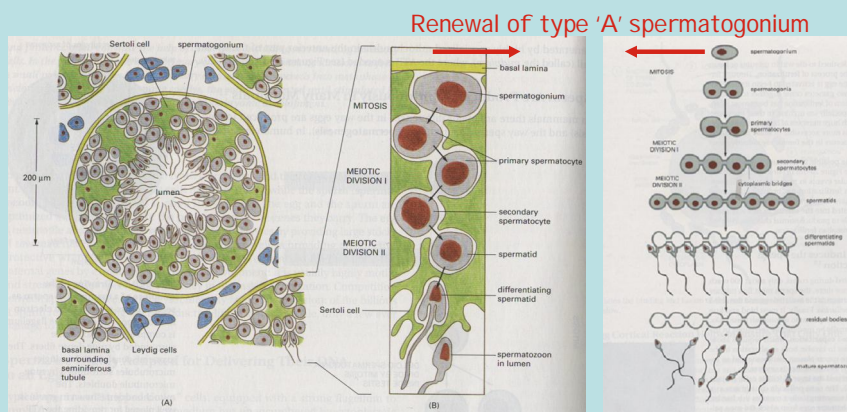
- The Endocrine matrix
- 1- The intravascular compartment -communication to body.
- 2-The interstitial compartment containing Leydig cells and lymphatics



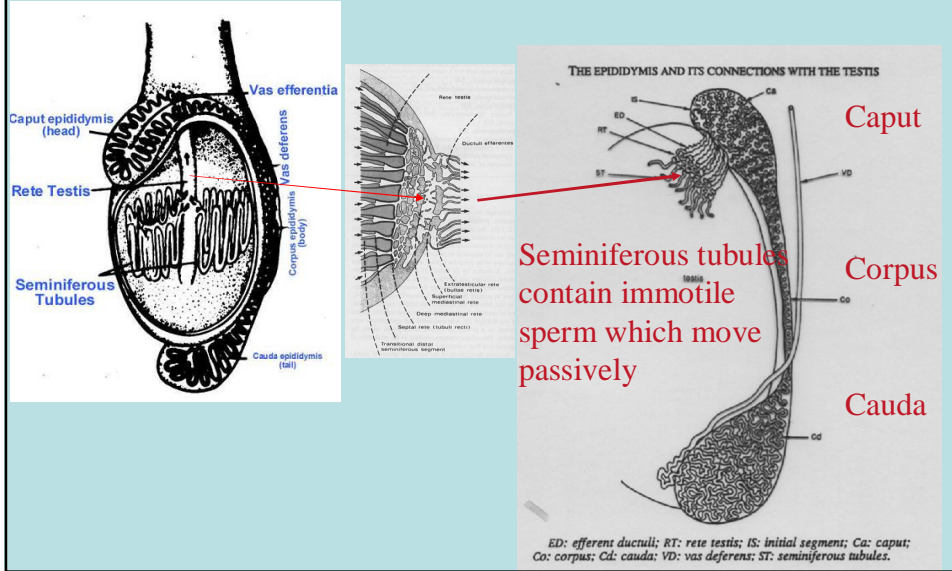
- The gamete producing tubules
- 1-Basal intratubular compartment with Sertoli cells Spermatogonia
- 2-The adluminal compartment containing Sertoli cells; Spermocytes Spermatids Spermatozoa

From Essential Reproduction.

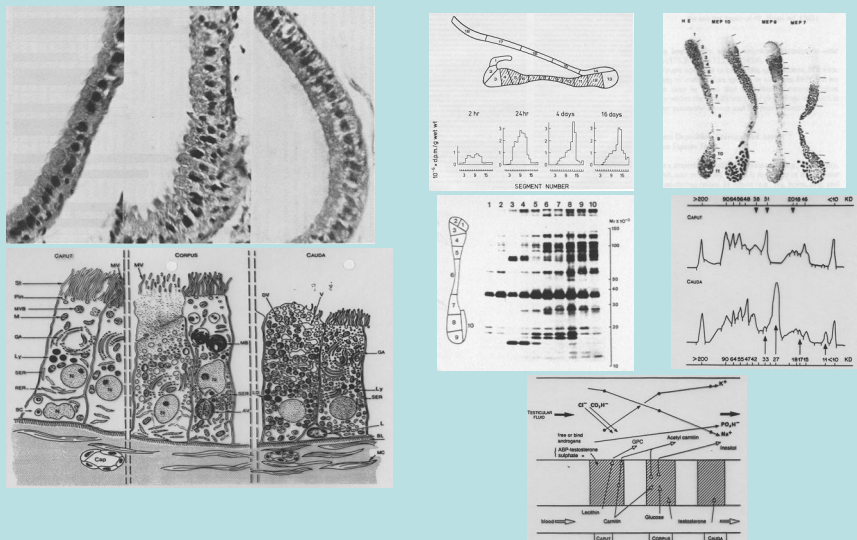
## Summary of spermatogenesis



## Sperm transport The epididymis & connections with the Testis.



The epithelial cells of the epididymis change along the length demonstrated by uptake of radioactive methionine, proteins & immunostaining, electrolyte changes in the epididymis of rodents; & Proteins in Chimps



## Epididymis

A convoluted tube dorso-laterally on the testis

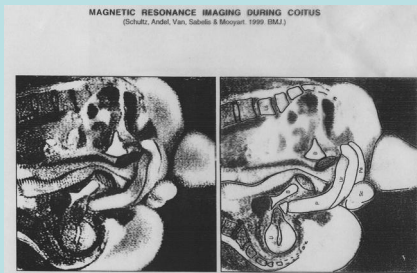
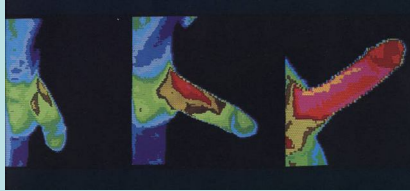
- Allows concentration of sperm numbers (10-100x)
- Storage (70% of sperm)
- Sperm passage by peristaltic muscle contraction in duct wall - ~ 12 days.
- Passage time is influenced by ejaculatory frequency.
- Non ejaculated sperm degenerate and are reabsorbed or expelled by retrograde leakage into bladder.
- Provides environment to mature capability for motility
- Provides environment for mature capacity to fertilise

## Sperm Transit.



- Sperm transit times can be effected by sexual activity and impact on the quality of sperm found in the ejaculate.
- Days in human epididymis
  - Caput ~ 1-2.5
  - Corpus ~ 0.5
  - Cauda ~ 5
  - Total ~ 1-12

## Penile erection, leading to coitus and ejaculation



- **Orgasm requires** a build-up of excitation in specific centres in the central nervous system.
- May be divided into :-
  - **Seminal emission;** oozing of semen associated with alpha adrenergic neurons.
  - **Pulsatile Ejaculatory spurts;** Prostatic fluid  
Sperm rich epididymal fluid  
Seminal vesicular fluid  
Usually in tandem with orgasm

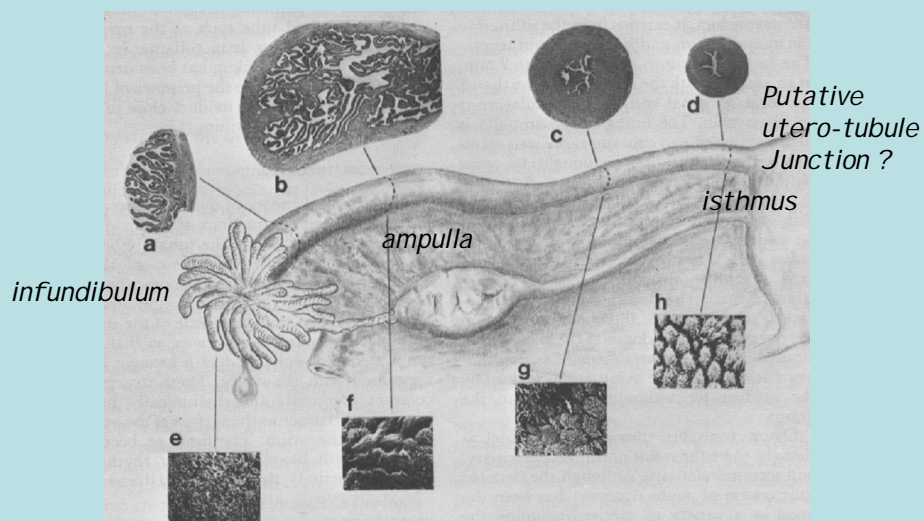
## Semen deposition into vagina

- Semen is deposited close to external os in human.
- Vaginal pH <5, hostile to sperm and alkaline semen provides a better milieu.
- Seminal plasma coagulates and then is broken down over 20-30 min. by which time most sperm that are able are thought to have penetrated cervical mucus.
- In some species a negative vaginal pressure may occur during intromission sucking sperm into the vaginal canal.
- Some species develop a vaginal plug.

## Sperm transport through the cervix.

- Coitus on the day of max. mucus hydration is correlated with pregnancy and micro-architecture may provide channels.
- Generally considered semen does not usually enter uterus in human.
- Only motile sperm penetrate cervical mucus
- Sperm colonise extensive crypts in cervix and some species deep channels may provide route to uterus.
- Whether sperm are able to leave crypts where considerable leukocytosis occurs is unclear.
- The central cervical column may be the limit of the cervical reservoir.
- Carbon particles placed in vagina may be found in oviduct within minutes - too fast for sperm motility alone.
- Radio-labelled particles concentrate on ovulatory side

## The fallopian tube





## Sperm transport through oviduct

- Sperm may be recovered from peritoneal fluid.
- Selection in female tract based on sperm morphology
- Sperm may survive for 4 -7 day but often only as little as a day.
- It has been suggested that the first sperm to arrive at the site of fertilisation act as 'pathfinders' – not compelling
- Various compartments have been postulated as a reservoir
- The ability of sperm to interact with cells of the female tract may be influenced by acquired molecules from seminal plasma, removal of such molecules could effect hyperactive motion.
- The initial failure of IVF was overcome by sperm exposure to oviductal fluid leading to the concept of 'capacitation'.

## Capacitation

- A species and time dependent preparation for fertilisation -
- Not all sperm undergo a 'physiological' capacitation despite the population of sperm gaining functional competence.
- Early signs of sperm senescence may be similar to capacitation
- Whether some changes associated with capacitation are essential or facilitate fertilisation remains unclear.

### Taxis

- Thermo-taxis; 2C differences have been seen between the cooler isthmus and warmer ampulla in the rabbit.
- Chemo-taxis; perhaps by switching between symmetrical flagella beats and asymmetrical hyperactivity controlled via odorant receptors. Likely in species that fertilise in vitro, identification of factors remains elusive and is compounded by general stimulants.

## Sperm competition

- Male competition and female promiscuity are features of sexual selection.
- Reproductive traits evolve rapidly when females are promiscuous producing exaggerated phenotypes.
- In some species females exhibit discrimination between the sperm of different males.
- In some species sperm quality is influenced by female novelty.

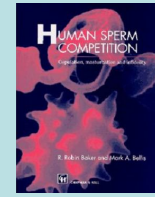
John Calvin (30<sup>th</sup> US President 1923-19) and wife Grace visited a chicken farm 'The Coolidge Effect'



Ethologist Frank Beach in 1955 is attributed with the name based on the story;

Result; a name for the impact of novelty on the male sexual response.

## The kamikaze sperm hypothesis- sperm wars !



- A theory of post-copulatory reproductive competition in mammals
- The human connection is based on survey from 'life-style' magazines indicating significant extra-pair copulation through female choice and selected volunteer study groups.
- Includes both intra-pair and extra-pair post-copulatory semen collection for comparison, results have been interpreted as the production of 'killer sperm' in response to a reproductive competition.
- But there is no in vitro evidence of 'killer sperm' or other selective interactions between sperm from different males.
- Comparison of testis/body weight ratios are inconsistent with sexual selection pressures based on promiscuity in human females.