Spermatogenesis and sperm transport;

sub-title; the life of a sperm

Dr K Lindsay

Leaning 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

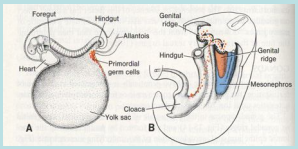
Autosomes	Sex Chrom.	Gonad	Syndrome
44	XO	Ovary	Turner's
44	XX	Ovary	Norm.Female
44	XXX	Ovary	Super Female
44	XY	Testis	Norm.Male
44	XXY	Testis	Kleinfelter's
44	XYY	Testis	Super Male
66	XXX	Ovary	Non viable trip.
66	XXY	Testis	Non viable trip.
44	XX ^{SXT}	Testis	Sex reversal

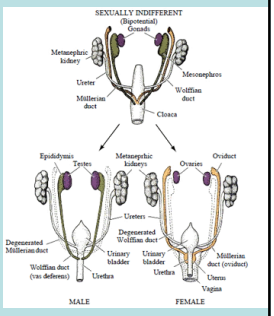
The Y chromosome

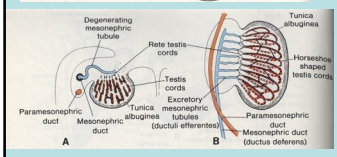
Stained with quinacrine below has ~78 genes with ~ 600 base repairs with 'mirror' image repeats tending to conserve and not crossover

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

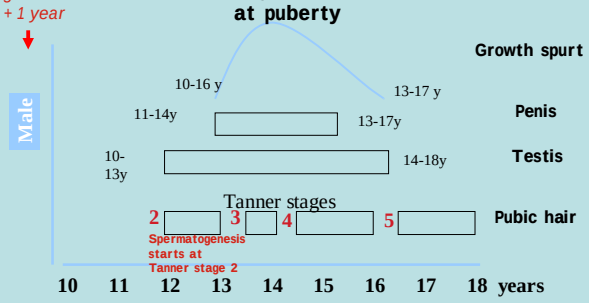




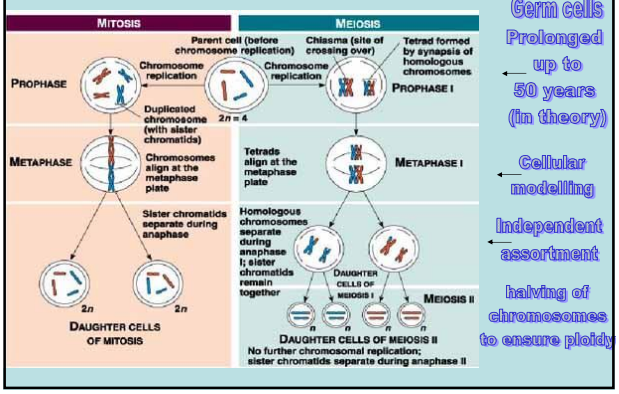


Reproductive Development in the human male requires growth and cell differentiation stimulated by FSH and testosterone at puberty

Fetal & early growth + 1 year



Making germs cells requires cell divisions



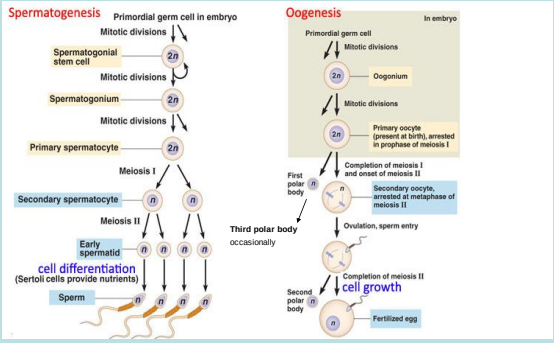
Germ cells Prolonged up to 50 years (in theory)

Cellular modelling

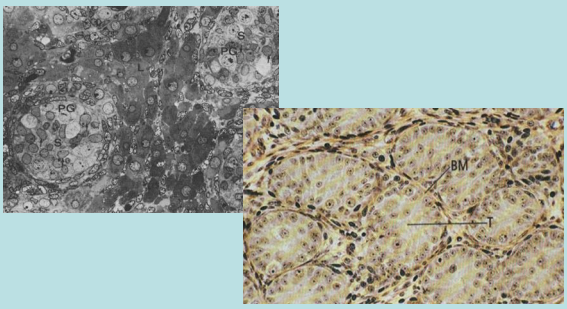
Independent assortment

halving of chromosomes to ensure ploidy

Nuclear divisions in gameto-genesis

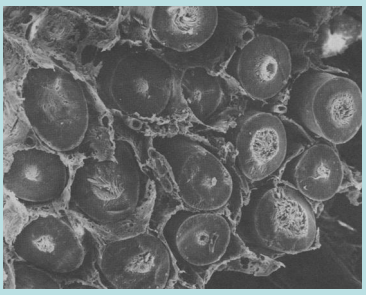


Fetal testes have the beginnings of seminiferous tubular structure.



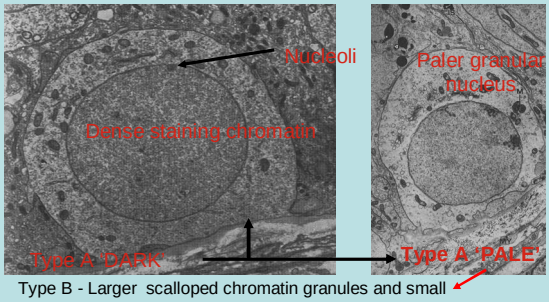
The adult testis is tubular

(Rat - Cut section SEM & human)



Basal cell Spermatogonia: mitotic division

Division renews Type A 'Dark' when producing Type A 'Pale" which produce type B



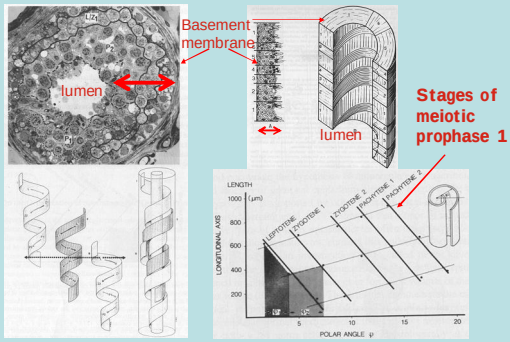
Type B - Larger scalloped chromatin granules and small clumps attached to nuclear envelope with nucleoli in interior of nucleus.

Spatial changes along the tube
The spermatogenic wave.

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

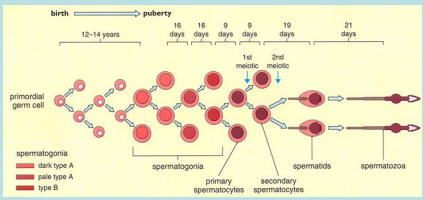
The sequence in humans appears to be chaotic, but on closer examination shares the same fundamental feature of successive cell associations.

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

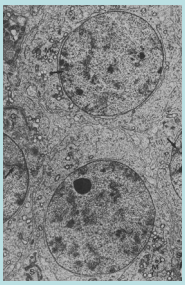


Time/Temporal changes
The spermatogenic cycle

There is a standard mitotic interval or quiescence for stem cells to enter spermatogenesis so that a single area of the seminiferous tubule is a 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.

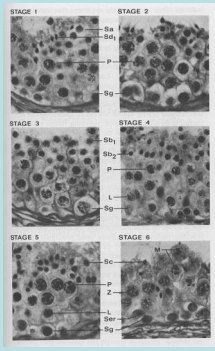


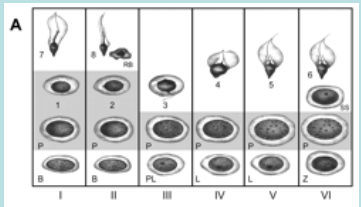
Intermediate cell type Spermatocytes meiotic division



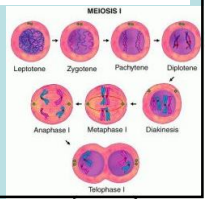
- Primary or “resting” spermatocytes produce two daughter cells.
- Secondary spermatocytes contain a single set of chromosomes and are very short lived.

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

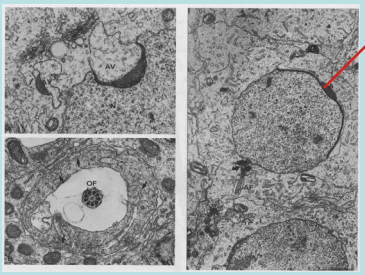




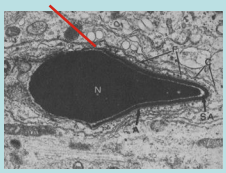
The initials describe cell type
SG/ B-spermatogonia,
S (a,b,c,d) -spermatid
Pl-preleptotene,
L/l-lepotene,
Z/z-zygotine
P/p-pachytene



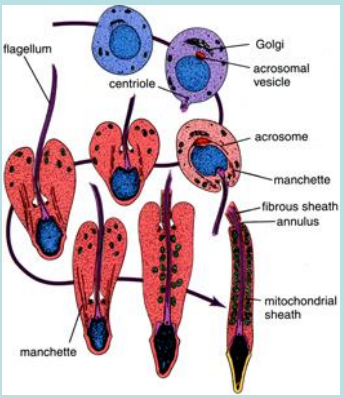
Luminal cell type spermatids
cytoplasmic modelling or spermiogenesis



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



Spermiogenesis; summary



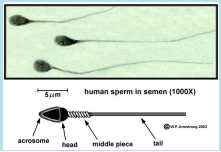
Acrosome; an organelle derived From Golgi, with enzymes assisting mechanical forces from tail in the penetration of the zona pellucida at fertilisation

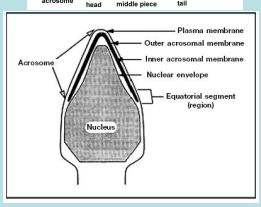
Manchette; conically shaped array of microtubules that covers the nucleus a spermatid; probably used to change the shape during maturation.

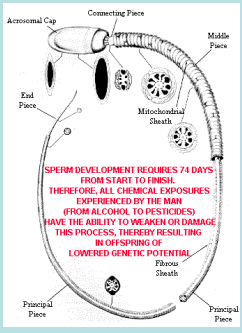
Mitochondria congregate and align in a mid-piece

The tail (flagellum) is derived from the distal centriole with retained proximal centriole in primates contributing as a male component to microtubular-organising centre in zygote.

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

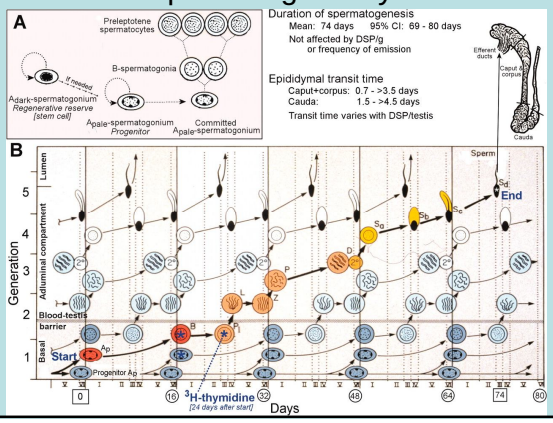






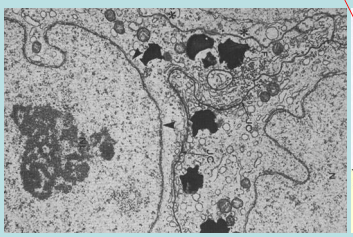
SPERM DEVELOPMENT REQUIRES 74 DAYS FROM START TO FINISH. THEREFORE, ALL CHEMICAL EXPOSURES EXPERIENCED BY THE MAN (FROM ALCOHOL TO PESTICIDES) HAVE THE ABILITY TO WEAKEN OR DAMAGE THIS PROCESS, THEREBY RESULTING IN OFFSPRING OF LOWERED GENETIC POTENTIAL

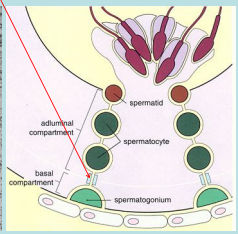
The spermatogenic cycle



The Sertoli cell- (Enrico Sertoli 1865)

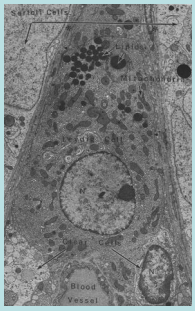
Tall irregular cells with large basal nuclei lining the seminiferous tubules supporting germ cell development across compartments of testis.
Special tight junctions producing a blood-testis barrier which creates local environments and separates mitotic , meiotic from post-meiotic germ cells



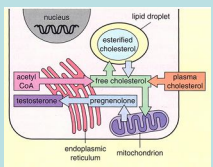


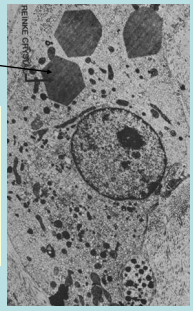
The Leydig cell- (Franz Leydig 1850)

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



Fredrech Reinke 1896 associated with age & possibly degenerative part protein

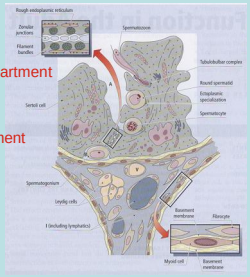




The Testis in section illustrating the relationship between cell types forming compartments

•The Endocrine matrix
1- The intravascular compartment
-communication to body.

2-The interstitial compartment containing Leydig cells and lymphatics



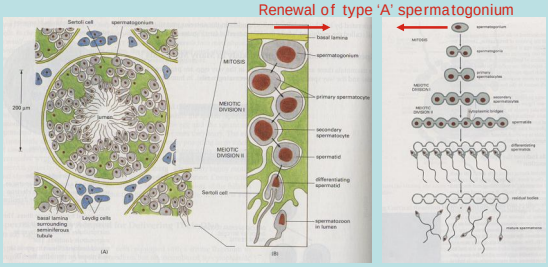
•The gamete producing tubules
1-Basal intratubular compartment with
Sertoli cells
Spermatogonia

2-The adluminal compartment containing
Sertoli cells;
Spermatocytes
Spermatids
Spermatozoa

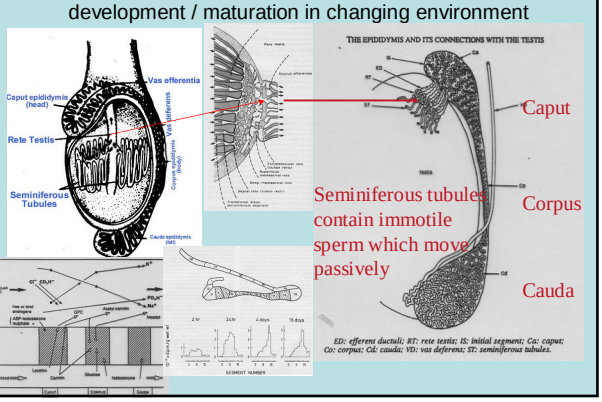
From Essential Reproduction.

Summary of spermatogenesis

Renewal of type 'A' spermatogonium



Sperm transport
The epididymis & connections with the Testis and post-testicular development / maturation in changing environment



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

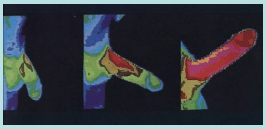
Sperm Transit.

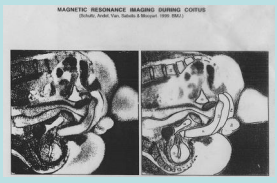
- Sperm transit times can be effected by sexual activity and impact on the quality of sperm found in the ejaculate.

- Days in human epididymis

Caput~ 1-2.5
Corpus ~0.5
Cauda ~ 5
Total ~ 1-12

Penile erection, leading to coitus and ejaculation



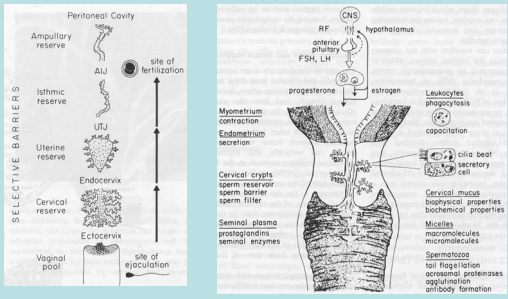


•**Orgasm requires** ' build-up of excitation in specific centres in the central nervous system.
•May be divided into :-
Seminal emission;
oozing of semen associated with alpha adrenergic neurons.
Pulsatile Ejaculatory spurts;
Prostatic fluid
Sperm rich epididymal fluid
Seminal vesicular fluid
Usually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

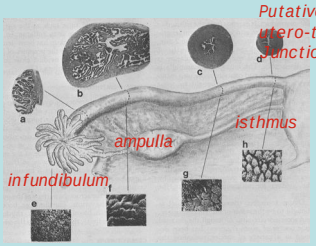
The female tract barrier & assistant

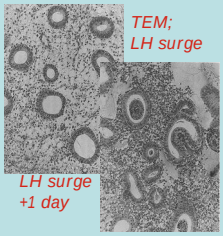


Sperm transport through the cervix.

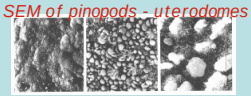
- Coitus on the day of max. mucus hydration is correlated with pregnancy and micro-architecture may provide channels.
- Generally considered semen does not usually enter uterus in human.
- Only motile sperm penetrate cervical mucus
- Sperm colonise extensive crypts in cervix and some species deep channels may provide route to uterus.
- Whether sperm are able to leave crypts where considerable leukocytosis occurs in 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 of ovulatory side

Uterine pinopods – uterodomes
(secretory epithelium)
and the fallopian tube





SEM of pinopods - uterodomes



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 (30th 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.