Developmental biology

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TOPIC

- Gametogenesis; spermatogenesis, composition of semen, in vitro and in vivo capacitation of mammalian sperm, Oogenesis, totipotency; fertilization, morphogenesis and morphogen, blastogenesis,establishment of body axes formation, fate map, gastrulation in frog and chick; genes in development inchick, homeotic genes, development of eye and heart, placenta in mammals

PYQ

- WRITE IN DETAILS THREE PHASES OF OOGENESIS IN FEMALE (2023)
- DESCRIBE THE STRUCTURE AND FUNCTION OF MAMMALIAN PLACENTA (2022)
- EXPLAIN THE MECHANISM OF SPERMATOGENESIS IN MAMMALS WITH THE HELP OF SUITABLE DIAGRAM (2022)
- EXPLAIN MORPHOGENETICS MOVEMENTS IN GASTRULATION OF FROG (2021)
- WHAT IS INVASIVE PLACENTA .DISCUSS IT'S TYPES ,CAUSES AND RISK FACTOR(2021)
- GIVE A SCHEMATIC REPRESENTATION OF DIFFERENTIATION OF SEXUAL PHENOTYPES DURING EARLY EMBRYONIC DEVELOPMENT IN MAMMALS (2020)
- ILLUSTRATE THE PROCESS OF DEVELOPMENT DURING GASTRULATION IN A CHICK EMBRYO (2019)

Spermatogenesis

- It is the process of formation of male gametes i.e. SPERMS
- It begins during puberty and continues till death
- With advancing age, the number of sperms, produced as well as well as, quality of sperms reduces
- In humans the process takes 65-75 days
- It can be divided into two stages :-

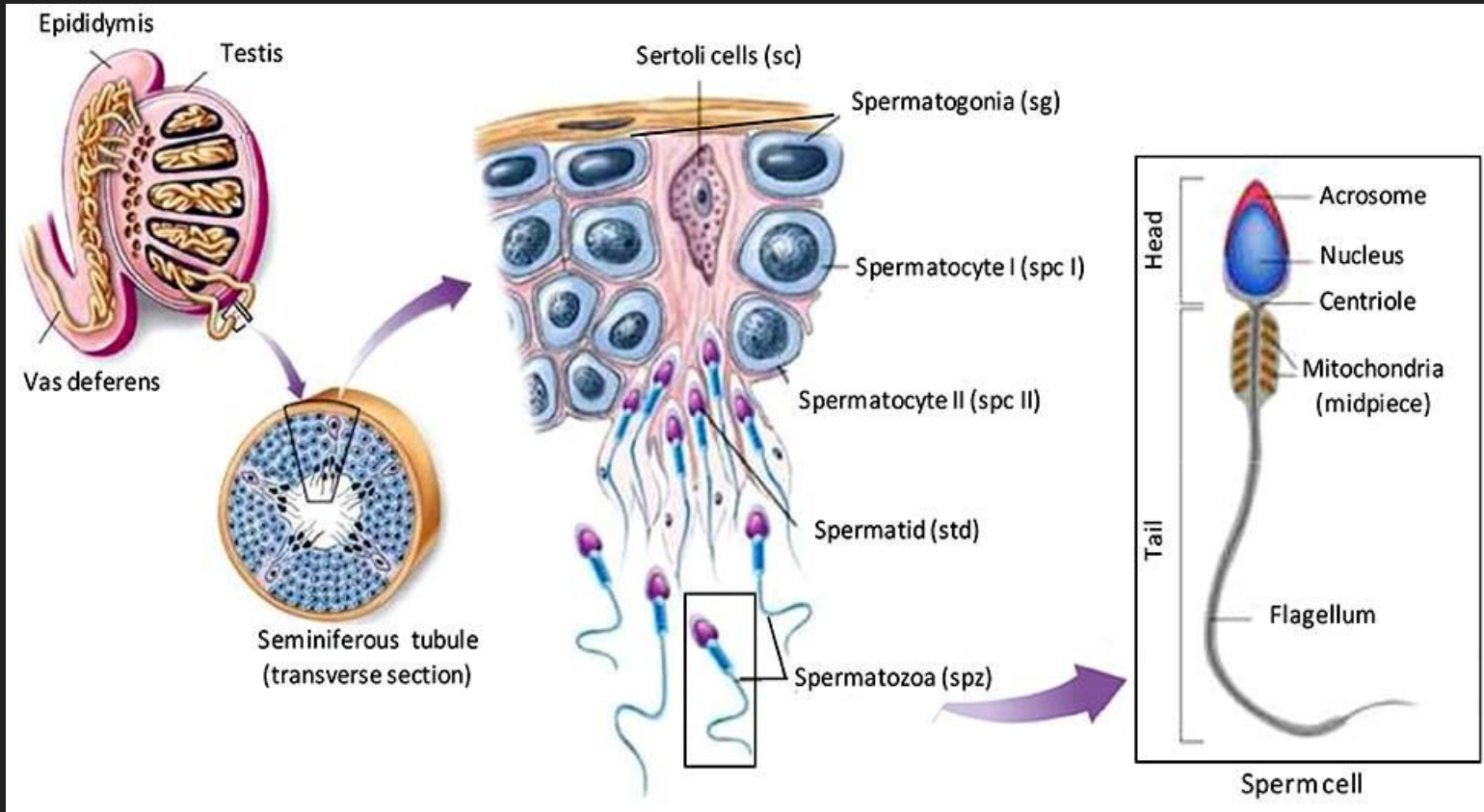
Spermatocytogenesis

Formation of spermatid from spermatogonia

Spermiogenesis

differentiation of spermatids into sperms

SPERMATOGENESIS



Primordial germ cell

- Derived from epiblast cells
- Formed during 2nd week of IUL
- TWO LAYER OF CELLS
- Migrate to the wall of yolk sac
- Further, migrate to gonadal / genital ridge (5th week)
- Dormant until puberty
- Forms sex chords along with sertoli cells

SEX CHORDS

- Doesn't have any lumen
- At puberty : lumenisation of seminiferous tubule occurs
- Stimulate spermatogonial cells

- Process of production of spermatozoa from spermatogonial stem cell
- Maturation of sperm begins at puberty
- Sequence of events by which spermatogonia are transformed into mature sperms
- **Spermatogonia** - dormant in seminiferous tubules of testes during foetal & potential period
- They increase in number during puberty
- At birth , germ cells in male infant can be recognized as sex cords of testis as large pale cells surrounds by supporting cells which form sertoli cells

- Shortly before puberty sex cords acquire a lumen & become seminiferous tubules

Steps

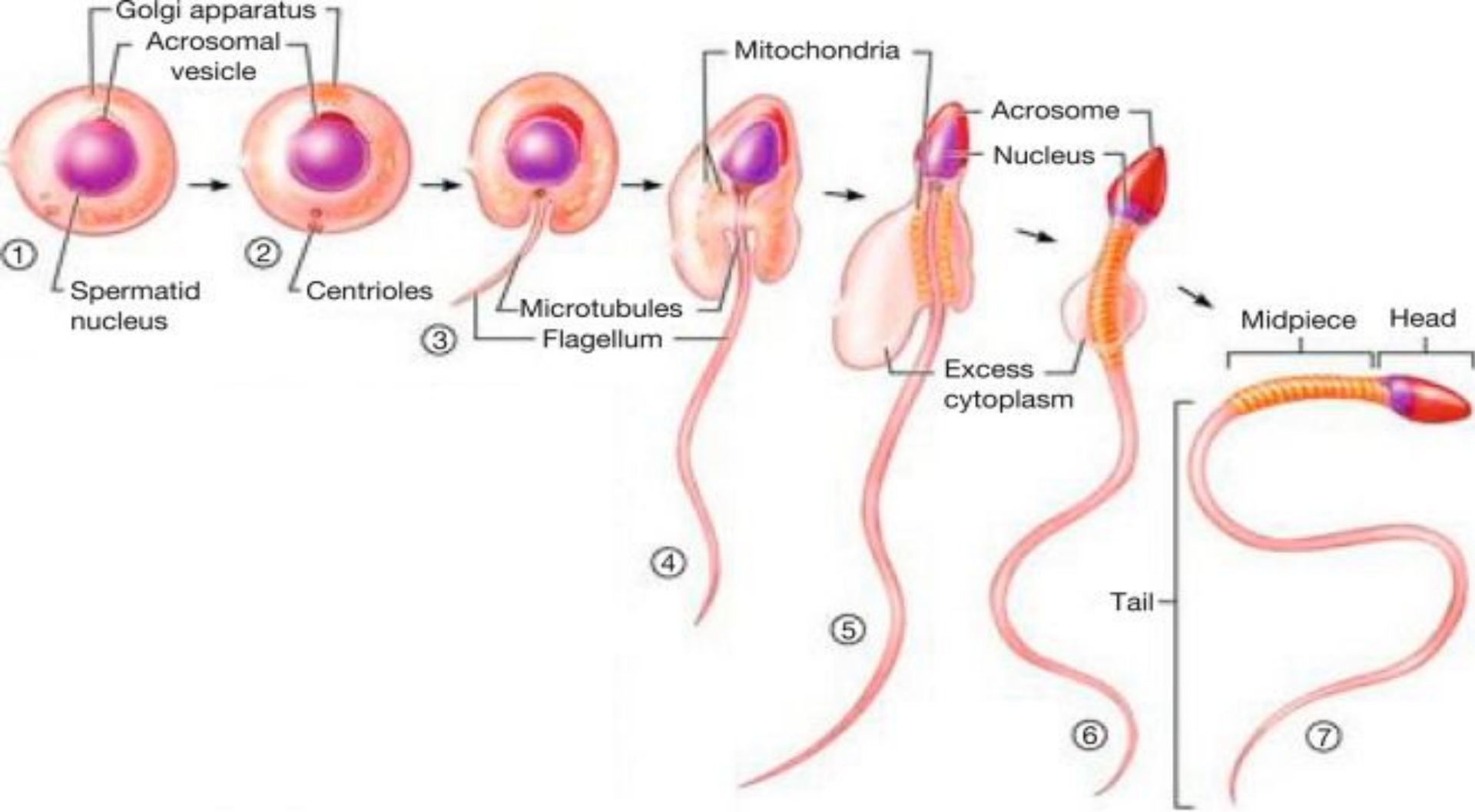
- PGCs divide by mitosis to form - type A spermatogonia (dark & light cells)
- Type A spermatogonia light cells undergo limited mitotic division to form type B spermatogonia
- Type B spermatogonia further divide by mitosis to form primary spermatocytes
- Primary spermatocytes - enters prolonged prophase of 22 days followed by meiosis I & results secondary spermatocytes (haploid chromosomes)
- During second meiotic division - secondary spermatocyte form spermatids

- Spermatids undergo series of changes resulting spermatozoa
- Sertoli cell provide support & nutrition for development of germ cells to form mature sperms
- Final stage where spermatid eventually forms spermatozoa
- Spermiation :- release of sperm into lumen of seminiferous tubule

-SPERMIOGENESIS

- CHANGES

- Formation of ACROSOME - cap like covering proximal 2/3rd of nucleus (head)
- Contains enzymes which assists sperm during penetration of ovum & its surrounding layers during fertilization
- Condensation of nucleus
- Formation of neck, middle piece & tail
- Shedding of cytoplasm (absorbed by the sertoli cell)
- Last stages of maturation occurs in epididymis
- Total time taken - 74 days


Golgi apparatus
Acrosomal vesicle
Mitochondria
Acrosome
Nucleus
1
Spermatid nucleus
2
Centrioles
3
Microtubules
Flagellum
4
5
Excess cytoplasm
6
Midpiece
Head
Tail
7

Hormones regulation this process

- Regulated by LH (produced by pituitary gland)
- LH binds to receptors on leydig cell & stimulate testosterone production
- Testosterone in turn binds to sertoli cells to promote spermatogenesis
- FSH (follicle stimulating hormone) is also essential due to its binding to sertoli cell stimulating testosterone production

Semen

- Fluid contains sperms cells, which is emitted from the male reproductive tract and capable of fertilizing by female's egg
- Made up of secretions from male reproductive organs
- pH:- 7.2 -7.8 , pH < 7.2 —— low sperm count or malformations in reproductive tract , pH > 7.8 ——urinary tract infection

Composition

- 70 % produced by seminal vesicle , contains amino acids , fructose , citrate , flavins , enzymes , prostaglandins , phosphorylcholine , proteins and vitamin C
- Main energy source of sperm cells , suppress immune response which is generated by female

30 % produced by prostate gland, contains citric acid , phosphate, fibrinolysin, proteolytic enzymes , zinc and lipids

- Zinc stabilizes the sperm DNA

5 % produced by testes and epididymis , contains sperms

- 1-2 % produced by bulbourethral and urethral glands, contains mucus and sialic acid
- Mucus contributes to the jelly texture of semen , increase the mobility of sperm

Sperm concentration in semen :- 20 million /ml

- Smell and flavour :- basic amines like spermine , spermidine , putrescine and cadaverine

Semen analysis parameters

VOLUME

REACTION &PH

LIQUEFACTION

MORPHOLOGY OF SPERM

- FRUCTOSE LEVEL
- RBC
-PUS CELL

MOTILITY OF SPERM

SPERM COUNT

Capacitation

- Changes happens in sperms
- Only capacitated sperms can penetrate through corona radiata.
- Happens in isthmus of female genital tract

outside the female body (in the lab)

IN VITRO CAPACITATION OF MAMMALIAN SPERM

- In an artificial fertilization technique , such as intrauterine insemination (IUI) sperm do not go through the female reproductive system as they would in natural fertilization
- Sperm are directly placed inside the uterine fundus
- Hence, molecular events that occur in vivo must be initiated to give the sperm the ability to fertilize with egg
- Same is true for IN VITRO FERTILIZATION - the sperm must go through the capacitation process outside the female body , as the egg- sperm fusion occurs in laboratory

IUI IVF

- Both procedures required pre- treatment of the ejaculated sperm in the lab, that is known as the IN VITRO CAPACITATION

TECHNIQUES OF IN VITRO CAPACITATION

Density gradient centrifugation
- Sperm washing by swim up

INDUCTION

Sperm cell are harvested through ejaculation or from the epididymis

↓

Allow to liquefy at room temp

Media is added to mimic the composition of fallopian tube

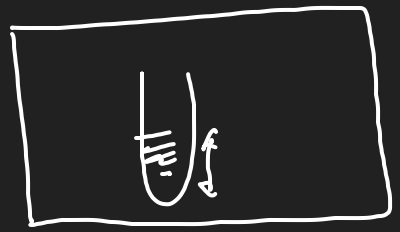
Media components :- Glucose , lactose , pyruvate , albumin

- A cholesterol acceptor (albumin) is required to facilitate the removal of cholesterol from the sperm cell membrane
- Calcium chloride is added to facilitate the influx of calcium ions

Density gradient centrifugation

- Media are placed in a test tube from higher to lower density, followed by the semen sample

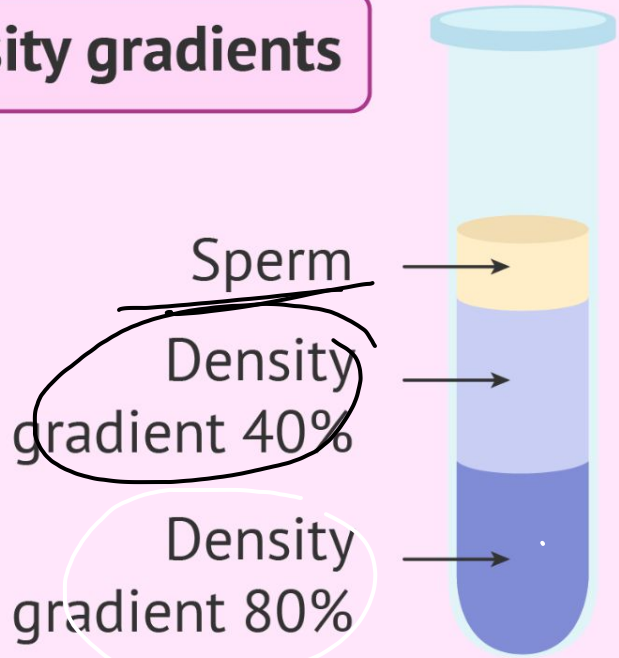
Centrifugation



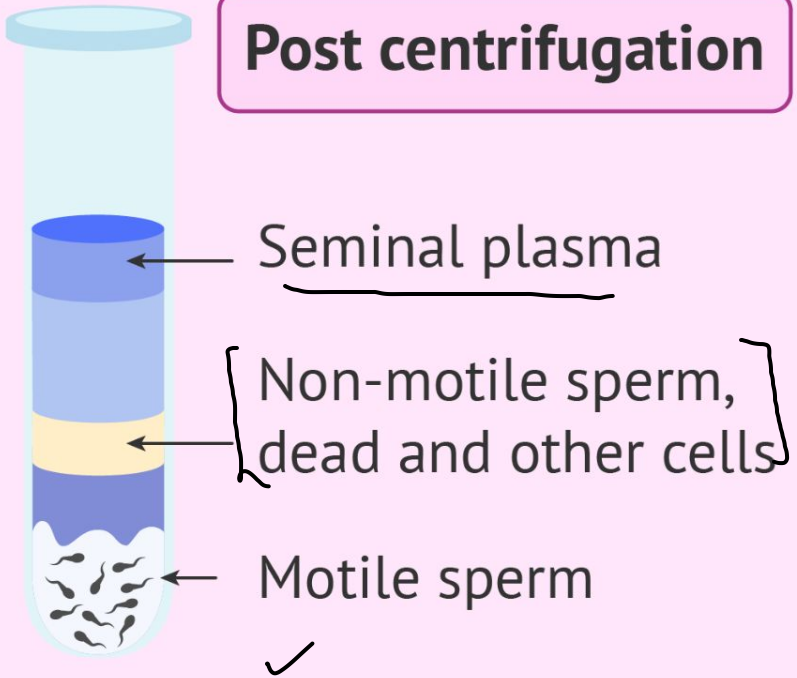
Sperm with the best quality will be able to overcome all the gradient and reaches the bottom of the tube

These sperm will be extracted as they have progressive motility

Density gradients



Post centrifugation



Sperm washing by swim up

- Media are placed in a tube, where semen sample is added

↓

Centrifugation

↓

All the sperm cells are gathered at the bottom of the tube

↓

Seminal plasma will be separated from top

↓

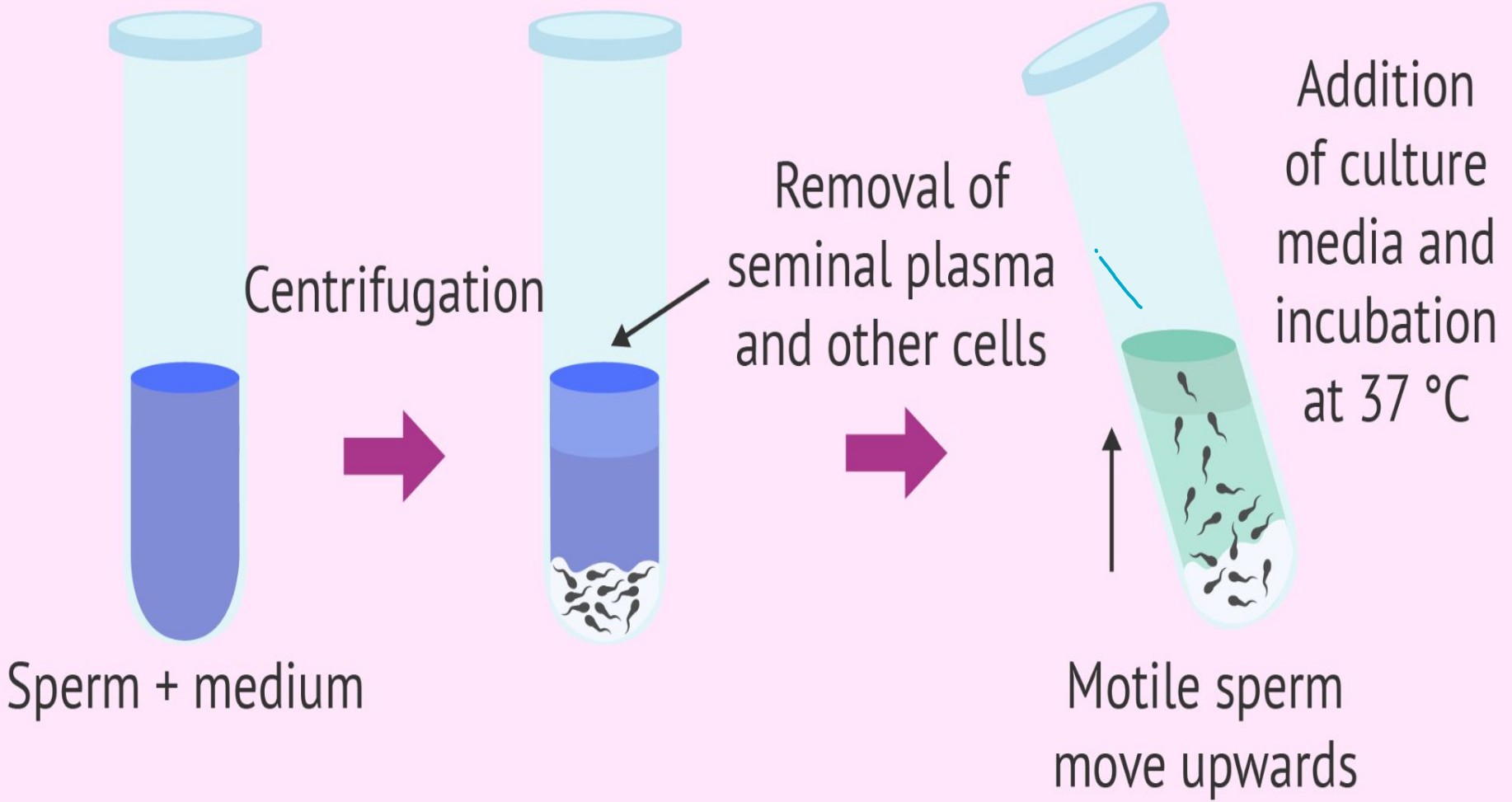
A specific culture media is added

↓

Tube is left in an inclined position , so that the best quality sperm can swim upwards until they reach the edge

Wait for 45 minutes

Upper part of the culture media is separated , which contains sperm with progressive motility


Centrifugation
Removal of seminal plasma and other cells
Addition of culture media and incubation at 37 °C
Sperm + medium
Motile sperm move upwards

Oogenesis

(Starts in the Intra-uterine life)

46 XX Oogonia |oogonium| female germ cell

↓ Mitosis

2n 1° oocyte

↓ Meiosis - I

(Arrested in the Diplotene stage of prophase -I)

prophase- I

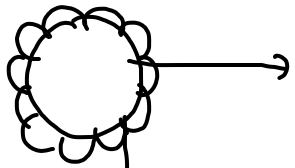
- Leptotene
- Zygotene
- Pachytene
- Diplotene

Meiosis - I

Diakinesis

This arrested stage "Dictyate stage"

In the Intrauterine life



→ get surrounded by follicular cells of the ovary

1° oocyte → primodial follicle

↳ when a new born girl child is born

→ ovary has million No. of primodial follicle.

↳ During Menopause – No follicle in ovary.

(Test for ovarian Reserve) → done to see whether follicle are tht in the ovary or Not.

[At the age of puberty] – (60,-70,000) No. of follicles

- 1st polar body is released at the time of
- 2nd polar body is released at the time of
- Size of ova
- Fertilisation span of ova
- Time between lh surge and ovulation
- Maximum no. of follicles seen at

1st week development - fertilisation & implantation

BLASTOCYST

- Day of implantation
- Implantation completes by
- Type
- Site
- In fallopian tube there are three types of cells

Placenta

- Placenta is developing organ in the uterus , during pregnancy
- It is a mechanical and physiological connection between mother and foetus
- Placenta has 2 parts :-
- Foetal part - chorionic part
- Maternal part - desidua basalis
- Decidua capsularis it covers the blastocyst
- Rest of the part of endometrium called - decidua parietalis

Types of the placenta on the involvement of foetal membrane

- Chorionic placenta - placenta is formed from chorion layer (eg- human)
- Chorioallantoic placenta - placenta is derived from allantoic and chorion layer (eg- eutherian mammal)
- Yolk Sac placenta - placenta form from yolk sac (eg - kangaroo)

Classification of placenta according to fate of uterine wall

- Non decidual placenta - no part of uterine placenta is shed in the after birth (eg- horse, zebra)
- Decidual placenta - some part of uterine tissue is passed out as decidua , after birth (eg- human)
- Contra decidual - uterine part not comes , rather than foetal placenta get absorbed

Types of placenta according to histology

- Placenta can be divided on the nature of extra embryonic membrane
- And histological point of degree of involvement of foetal and maternal tissue
- 1. Epitheliochorial placenta
- Syndesmochorial placenta
- Endotheliochorial placenta
- Haemochorial placenta
- Haemoendothelial placenta

Types of placenta according to the distribution of villi on chorion

- Diffuse placenta - the villi remains scattered all over the surface of the chorion , eg- pig, horse
- Cotyledonary placenta - the villi are arranged in patches , eg- goat , sheep
- Intermediate placenta/discoidal placenta - villi occurs on small disc shape area , eg- rat, rabbit
- Metadiscoidal placenta - villi first form all over but , later it resistant to one area , eg- human

Functions of placenta

- Placenta produces foetus umbilical cord
- It is the physiological connection between mother and foetus
- It provides nutrients
- It secrete hormone - estrogen , progesterone , human placental lactogen, thyroxin
- It secrete antibody
- It removes nitrogenous waste , it allows selective diffusion , it prevent harmful material from maternal blood to foetal
- Help in gas exchange

Embryology of frog

- Copulation : rainy season
- Frog shows - hibernation (winter sleep) & aestivation (summer sleep)
- Male frog : vocal sacs —– (croaking A kind of sexual call for female)
- Male frog have amplexary or copulatory pad

- Frog —— forelimbs have 4 digits
- Hindlimbs have 5 digits (webbing of toes found in hindlimbs only not in forelimbs)
- Male frog have two digits contain copulatory pads in forelimbs
- Pseudocopulation :- female lays eggs (in form of secondary oocyte)

Egg membrane

Development of frog

Egg of frog amount of yolk - mesolecithal egg

Distribution - telolecithal

Cleavage - unequal holoblastic

- Fertilization in frog - external (outside body)
- Development in frog - indirect

(larval stage - tadpole larva)

Metamorphosis —— progressive

Metamorphosis

Progressive metamorphosis

Simple feature — complex feature

Advance character in adults

Eg- frog tadpole — adult frog

retrogressive metamorphosis

complex feature— simple feature

advance character in larva

ascidian tadpole – adult ascidian

Fertilization in frog

Grey crescent or crescentic surface area

Before fertilization

after fertilization

Cleavage or segmentation or cellulation

Cleavage in frog

Development of chick

Gastrulation· in highly telolecithal eggs (birds, reptiles and fishes) is greatly modified due to exceptionally large amount of yolk. The excessive yolk. prevents the cleavage in the vegetal pole region.

- The yolk eggs of birds undergo discoidal meroblastic cleavage. Cleavage occurs only in the blastodisc, a small disc of cytoplasm 2-3 mm in diameter at the animal pole of the egg cell. The first cleavage furrow appears centrally in the blastodisc, and other
- cleavages follow to create a single-layered blastoderm (Figure 6). As in the fish embryo,
- these cleavages do n<?
- t extend into th(;! yolky c<?
- toplas<?n, so the early-cleavage cells are
- <?ontiriuous with.each other'and with the yolk at their bases
-