gametogenesis

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Objectives

- Definition of gamatogenesis
- Terminology
- The process of gametes formation
- Identify the different stages (phases) of gametogenesis in males testis and females ovary
- Name the stages at which the first and second meiotic divisions take place
- Outline the stages of spermiogenesis
- Define the stages of oocytes development
Human genetic material

• DNA contains the genetic information which controls cell processes.

• DNA, is a large molecule which coils up into a structure called **chromosome** when the cell is about to divide.
  – When the cell is not dividing it is loose in the nucleus in the form of **chromatin**.
The process of gametes formation
It occurs in the gonads (ovary or testis)

- It is Defined as:
  A process by which a diploid or haploid cells undergo cell division and differentiation to form mature haploid gametes.

Gametogenesis, the production of sperm (spermatogenesis) and eggs (oogenesis), takes place through the process of meiosis.

Spermatogenesis and oogenesis are both forms of gametogenesis, in which a diploid gamete cell produces haploid sperm and egg cells.
Terminology

- **Diploid**: Having the full chromosome number (46 in humans).
- **Haploid**: Having half the full of chromosome number (23 in humans).
- **Somatic Cells (All body cells)**: Diploid cells that form the body.
- **Germline Cells**: Cells that give rise to gametes (eggs and sperm).
- **Gametes**: Haploid cells that donate genetic material to offspring (newly formed babies).
- **Meiosis**: Cell division producing haploid cells from diploid cells.
- **Ploidy**: The number of sets of chromosomes in a biological cell.
Once the *haploid* gametes are formed, they lose the ability to divide again.

Within *haploid*-dominant life cycles, the multicellular *haploid* stage is the most obvious life stage.

At some point in each type of life cycle, **MEIOSIS** produces *haploid* cells that will fuse with the *haploid* cell of another organism.

The *haploid* multi-cellular stage produces specialized *haploid* cells by **MITOSIS** that fuse to form a diploid zygote.
Diploid Cells

- Is a cell, having a pair of each type of chromosome, one of the pair derived from the ovum and the other from the spermatozoon.
- In the diploid-dominant life cycle, the multi-cellular diploid stage is the most obvious life stage.
- It occurs with most animals, including humans.
- In animals, sexually-reproducing adults form haploid gametes from diploid germ cells (Sperms and ova).
- The gametes of two individuals will fuse to form a diploid zygote that becomes the sporophyte.
So, Meiosis is the first step in gametogenesis: In which separation of homologous chromosomes into haploid daughter cells occur.
Meiosis (Meiotic division)

- Meiosis is the fundamental process underlying sexual reproduction.
- It involves two essential outcomes:
  1. **Reduction Division**: The process in which each gamete receives a haploid set (n) of chromosomes and genes. (The diploid number (2n) is restored after fusion of the two gametes.).
  2. **Rearrangement of genes** on the maternal and paternal chromosomes. This ensures that the offspring are genetically different from one another.
Human cell division

2 types of cell division:

A special somatic cell (2n) divides to form 4 cells with half the genetic material (n) through Meiosis.

Somatic cells (2n) divide to form two identical cells (2n) of the same kind through Mitosis.
Meiotic (Meitotic) division

1st meiotic division

2nd meiotic division

Comparing Meiosis and Mitosis

- In Meiosis, diploid cells are partitioned into four new haploid cells.
- In meiosis, the daughter cells have half the number of chromosomes as the parent.
- whereas the daughter cells produced by meiosis are different because crossing over has occurred.
- The events that occur in meiosis but not mitosis include homologous chromosomes pairing up, crossing over, and lining up along the metaphase plate in tetrads.
- When the homologous chromosomes separate and move to opposite poles during meiosis I, the ploidy level is reduced from two to one, which is referred to as a reduction division.
- In mitosis, diploid cells are partitioned into two new diploid cells.
- In mitosis, the daughter cells have the same number of chromosomes as the parent cell.
- The daughter cells produced by mitosis are identical,
- Meiosis II and mitosis are not reduction division like meiosis I because the number of chromosomes remains the same; therefore, meiosis II is referred to as equatorial division.
Gametogenesis divided into 4 phases

1. Extra-gonadal origin of primordial germ cells
2. Proliferation of germ cells by mitosis
3. Meiosis
4. Structural and functional maturation of the ova and spermatozoa
Primordial Germ Cells

- Are the earliest precursors of all germ cells
- Are formed in the early stages of embryonic development
- Are first recognizable close to the hindgut as large cells with high alkaline phosphatase
- Proliferate and migrate into the gonad (testis or ovary)
- Differentiate into male or female germ cells (determined by sex chromosomes)
Spermato genesis is the process of producing sperm with half the number of chromosomes (haploid) as somatic cells.

The germ cells progress first from the diploid to haploid state and then change shape to become spermatozoa.

Spermato genesis occurs in the seminiferous tubules.

Seminiferous tubules are part of the male gonad or testes.
Spermatogenesis occurs from puberty to old age, producing immense numbers of spermatozoa at an average rate of 1.5 million spermatozoa per minute.

- The sperm will mature in the epididymis, nourished by sertoli cells for up to 10 weeks.
- Humans aged 13-90 can make 1 billion sperm a day.
Spermatogenesis can be divided into three parts:

I. Spermatocytogenesis—proliferative phase
II. Meiosis—production of the haploid gamete
III. Spermiogenesis
   - Spermatids mature into spermatozoa (sperm)
The process: Spermatogonia (gonium)

- Located near outer surface of seminiferous tubule
- Originate at puberty
- One or two mitotic divisions of spermatogonia occur to maintain their population in a stem cell pool
- Spermatogonia proliferate several times and undergo 1 to 5 stages of division and differentiation
- After the last division, the resulting cells are termed PRIMARY SPERMATOCYTES (diploid in number: 44 autosomes and 2 sex cells)
  - Increases in size
  - Undergoing G2.
Stem cell spermatogonia remain dormant for a time and then join a new proliferation of spermatogonia

- This new wave of spermatogonial divisions does not wait for the previous generation of cells to complete spermatogenesis.
- The purpose of this phenomenon is to ensure a residual population of spermatogonia.
- The time required for one spermatogonium to divide and form spermatozoa requires about 4.5 to 5 times that time span between divisions of the stem cell spermatogonia.
The primary spermatocytes then undergo the first of the two divisions that constitute **MEIOSIS**

- The first meiotic division produces 2 **SECONDARY SPERMATOCYTES**
- Division of the **SECONDARY SPERMATOCYTES** completes meiosis and produces the **SPERMATIDS**

- The **SPERMATIDS**
  - Is Haploid in number: **22 autosomes (double stranded)** and **1 sex cell** each
  - Can see the cleavage furrow
  - Undergoing Meiosis I (**Reduction Division**)
  - Chromosomes are reduced into half number.
Leydig cell
Blood capillary
Basement membrane
Sertoli cell nucleus
Blood-testis barrier (tight junction)
Cytoplasmic bridge

SPERMATOCYTIC CELLS:

- Spermatogonium (2n) (stem cell)
- Primary spermatocyte (2n)
- Secondary spermatocyte (n)
- Early spermatid (n)
- Late spermatid (n)
- Sperm cell or spermatozoon (n)
Spermatid

- Haploid in number: 
  22 *(single stranded)* autosomes and 
  1 sex cell.

- Undergoing Meiosis II 
  *(Equational Division)*
The maturation process (spermatid....spermatozoa)

- **Spermatocytogenesis:** spermatogonia differentiate into primary spermatocytes
- **Meiosis:** reduction division whereby diploid primary spermatocytes reduce their chromosome complement, forming haploid spermatids
- **Spermiogenesis:** transformation of spermatids into spermatozoa (sperm)
Spermatozoa

- It is the motile sperm cell, or the moving form of the haploid cell that is THE MALE GAMETE.

- It joins an ovum to form a zygote.

- Matured Sperm Cell are ready to fertilized the egg.
Cells involved in spermatogenesis

Sertoli cell

Sertoli cells are supporting cells that have several functions.

- They form the blood-testes barrier: nutrients, and circulating substances do not directly reach the germ cells
- Determine which substances reach the germ cells
  Environment for germ cells to develop and mature
  Substances initiating meiosis or the reduction from diploid to haploid cells

Leydig cells: Produce testosterone Located adjacent to seminiferous tubules.
Oogenesis
Oogenesisis the process of producing ovum with half the number of chromosomes (haploid) as somatic cells.

In mammals, oogenesis occurs in the ovarian follicle of the ovary.
Oogenesis begins in early foetal life.

- All oocytes formed in females are produced during foetal life. They degenerate with time and at birth the ovaries contain about 2 million oocytes.

- All the oocytes go into meiotic arrest when they reach the first meiotic division during foetal life.

- The primary oocytes remain in the prophase of the first meiotic division until the time of puberty, when they are gradually released to complete meiosis at regular intervals known as the ovarian cycle.

- On the average only one oocyte matures during each cycle, which occurs at monthly intervals, so that the total amount of oocytes to be ovulated is about 500 oocytes in a lifetime.
Primordial germ cell

- Mitotic divisions
  - Oogonium

- Primary oocyte (present at birth), arrested in prophase of meiosis I

First polar body

- Completion of meiosis I and onset of meiosis II
  - Secondary oocyte, arrested at metaphase of meiosis II

- Ovulation, sperm entry

Second polar body

- Completion of meiosis II
  - Fertilized egg

In embryo

Primary oocyte within follicle

Growing follicle

Mature follicle

Ruptured follicle

Ovulated secondary oocyte

Corpus luteum

Degenerating corpus luteum
The Process:

- Oogonia (2n) divide by mitosis to form primary oocytes (2n) surrounded by follicular cells.
- The primary oocytes begin to undergo meiosis but the process stops and does not resume until puberty.
- After puberty, a primary oocyte give rise to a large, secondary oocytes (2n) and a first polar body.
- A secondary follicle that contains secondary oocyte is pushed to one-side of fluid-filled cavity.
- A process called ovulation releases the secondary oocyte from the surface of the ovary.
- If the oocyte is not fertilized shortly after its release, it will degenerate.
Before birth:
- Oogonium
- Mitosis
- Primary oocyte (arrests in prophase I)

After puberty:
- Meiosis continues
- Secondary oocyte (arrests in metaphase II)
- Ovulation, sperm entry
- Meiosis, fertilization
- Polar body
- Fertilized Egg
Oogonium/Oogonia

➢ Diploid in number: 44 autosomes and 2 sex cells

➢ It is very small and under the process of development.

➢ Undergoing G₁-S.
1. During prophase of meiosis I at the **dictyotene stage**, lasting from foetal life to the after puberty.

2. At metaphase in the 2° Oocyte prior to ovulation.
Primary Oocytes

- It is a cell whose primary function is to divide by the process of meiosis.

- It is also diploid in number: 44 autosomes and 2 sex cells

- Increases in size

- Undergoing G2.
Oogenesis

Primary oocyte arrested in diplotene of prophase I → Completion of meiosis I → entry into meiosis II → Completion of meiosis II → Activation or Fertilization → Mature egg

Secondary oocyte arrested in metaphase II → 1st polar body → 2nd polar body
Secondary Oocytes

➢ Undergoing Meiosis I (Reduction Division).

➢ Chromosomes are reduced into its half number.

➢ Begins during embryonic development, but halts in the *diplotene stage* of prophase I until puberty.

➢ *Primary oocytes* that continue to develop in each menstrual cycle, however, *synapsis* occurs and tetrads form, enabling chromosomal crossover to occur.

➢ Result of meiosis I, the primary oocyte has now developed into the secondary oocyte and the first polar body.
**Meliotic Events**

**Before birth**
- Mitosis
- Growth

**Oogonium (stem cell)**

**Primary oocyte**

**Primordial follicle**

**Follicle Development in Ovary**

**Childhood**
- Each month from puberty to menopause

**Primordial follicle**

**Growing follicle**

**Vesicular (Graafian) follicle**

**Secondary oocyte**

**Meiosis II completed**

**Ovulation**

**Ovulated secondary oocyte**

**Spindle**

**Meiosis I (completed by one primary oocyte each month)**

**First polar body**

**Polar bodies (all polar bodies degenerate)**

**Meiosis II of polar body**

**Second polar body**

**Sperm**

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If a secondary oocyte is fertilized, it enters the second meiotic division.

Meanwhile, the empty follicle is developing into corpus luteum; if pregnancy does not occur, the corpus luteum begins to degenerate in about 10 days.

A second MEIOTIC division will give rise to an ootid and second polar bodies.

THE OOTID develops into a functional ovum, while the non-functional polar bodies will be disintegrate.

The mature ovum has haploid (n) number of chromosomes.
Secondary oocyte formed after Meiosis I is completed

A zona pellucida surrounds the oocyte

Cumulus oophorus surrounds the oocyte

A fluid-filled antrum forms between the follicular cells

Two layers formed from the ovarian stoma:
  Theca interna - vascular
  Theca externa - connective tissue capsule
Immediately after meiosis I, the haploid secondary oocyte initiates meiosis II (Equational Division).
This process is also halted at the metaphase II stage until fertilization, if such should ever occur.
When meiosis II has completed, an ootid and another polar body have now been created.
Both polar bodies disintegrate at the end of Meiosis II, leaving only the ootid, which then eventually undergoes maturation into a mature ovum.
The function of forming polar bodies is to discard the extra haploid sets of chromosomes that have resulted as a consequence of meiosis.
Oogenesisis

Supportive videos
https://www.youtube.com/watch?v=vsiZOHernd0
https://www.youtube.com/watch?v=Zu1a0h3JWXw