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First year Licence -SNV /2023-2024

Animal Biology subject

General embryology course summary

Gametes

Fertilisation

Segmentation

Gastrulation

Collective of Biology teachers L1-SNV-FSB-USTHB

Gametes

I - Notion of soma and germen

Sexual reproduction is made possible by cells specialised in reproduction, or gametes.
Gametes are haploid cells, with n chromosomes; they carry half of the paternal or maternal genetic message.
These gametes are produced in specialised organs, the gonads, the male gonad or testis (poly p.9, fig.1); the female gonad or ovary (poly p.17, fig.1A) from a particular category of cells, the gonocytes or primordial germ cells. These primordial germ cells separate very early from the three embryonic layers.
The three embryonic layers are at the origin of the **SOMA** or set of body cells known as somatic cells.

The gonocytes are the origin of the germ cells that evolve to form haploid gametes. All the gonocytes and their descendants constitute the **GERMEN**.

II - The male gamete (spermatozoon)

1-The stages in its formation or spermatogenesis (see OPU book, 2017, p.13, fig.6).

1.1 Multiplication: This occurs continuously from puberty (passage to adulthood with the ability to reproduce). The cells that undergo these mitoses (maintenance of the 2n number of chromosomes) are spermatogonia. Strain spermatogonia (with a dark dusty nucleus) always give a strain spermatogonia and a pale dusty spermatogonia which divides by successive mitoses into crusty spermatogonia. The exact number of mitoses varies from species to species.

1.2 Growth: cytoplasmic growth is observed in crusty spermatogonia which become auxocytes called spermatocytes I. The 2n number of chromosomes is therefore retained.

1.3 Meiotic maturation : Each spermatocyte I undergoes the first reductional division of meiosis and gives two spermatocytes II (with n fissured chromosomes and 2q DNA) which undergo the second equational division of meiosis, each giving two round spermatids with n chromosomes and q DNA.

1.4 Cytoplasmic differentiation into spermatozoa or spermiogenesis : the spermatid transforms into a spermatozoon **(see OPU book, 2017, p.14, fig.7).**

2-Ultrastructure of the spermatozoon (see OPU book, 2017, p.15, fig.8)

The spermatozoon is constitueted by 3 parts:
-Head: it contains the nucleus and the acrosome.
-Neck: it contains the proximal centriol, distal centriol and segmented columns.
-Flagellum: formed by parts, the intermediate part, the main part (the tail) and the terminal part.

3 -Characteristics of the male gamete

-It is a small cell with no cytoplasm.
-It is produced in large numbers and continuously.

- It carries the paternal genetic message in n-chromosome nucleus.
-It is mobile (after remaining in the epididymis) and therefore able to move towards the female intervention of microtubules and mitochondria of the flagellum.
-It is capable of lysing the envelopes of the female gamete by the enzymes contained in acrosome.

4 -The somatic cells of the testis (see OPU book, 2017, p.11, fig.5)
In the testis, inside the seminiferous tubules, alongside the germ cells, somatic cells can be seen, the Sertoli cells which play a nourishing and hormonal role. The interstitial tissue contains Leydig cells, which produced hormones, mainly testosterone.

<u>III. The female gamete</u>

1-The stages of its formation or oogenesis (see OPU book, 2017, p.21, fig.3).

1.1. Multiplication: oogonia multiply during embryonic life.

1.2. Oocyte growth: takes place in several stages: it begins during embryonic life: the ovary at birth does not contain oogonia but primary oocytes (oocytes I). It continues during childhood.
This oocyte growth will resume at each cycle for some primary oocytes.
For eggs that contain reserves, it is during this period that these reserves are accumulated. For all eggs this will be the time when maternal ribosomes are accumulated.

1.3. Nuclear or meiotic maturation (meiosis) takes place over several stages.
During fetal life, prophase of the first division of meiosis is initiated and then stopped.
In vertebrates, during the hours preceding ovulation, this first division is completed and produces an oocyte II. The second division of meiosis will only take place if fertilization is achieved.
On the contrary, in the sea urchin, the two divisions of meiosis are completed before fertilization.
Cytoplasmic division is unequal and the cytoplasm is retained in a single ovotid or ovule with formation of polar globules.

2-Different types of eggs (see OPU book, 2017, p.24, fig.5; p.27, Table 1).
The presence or absence of yolk makes it possible to distinguish:
- Eggs completely devoid of yolk: **aleciths** example: Mammals
- Eggs with little yolk: **oligolecith**s example: Sea urchins
- Eggs with an average quantity of yolk: **mesolecith**s. This yolk is arranged heterogeneously in a yolk gradient**: heterolecith**s example: Amphibians
- Eggs with very abundant yolk: **megalecith**s where the yolk occupies a central place: **centrolecith**s example: Insects or almost total: **telolecith**s example: Birds.

3- The egg envelopes and accompanying cells

Around the plasma membrane, a vitelline membrane (in yolk eggs) **(see OPU book, 2017, p.25, 26, fig.6a-c)** or a pellucida zone (in alecith eggs) of a glycoprotein nature develops **(see OPU book, 2017, p.26, fig.6 bis d)**. It contains the specific sites of the spermatozoon. A mucus gangue often envelops the vitelline membrane and swells on contact with water (sea urchins, amphibians) **(see OPU book, 2017, p.25, fig.6a)**.

In birds, the albumen or egg bank is deposited around the yolk (representing the female gamete itself). A shell membrane and a shell envelope the whole **(see OPU book, 2017, p.25, fig.6b)**.

In mammals, the follicular cells accompanying oocyte I will evolve and take part in the formation of follicles **(see OPU book, 2017, p.26, fig.6 bis d)**. Some of these will accompany oocyte II at the time of egg laying or release of the gamete into the oviduct.

4-Characteristics of the female gamete

Large cell.

Large cytoplasm rich in ribosomes, will be the cytoplasm of the fertilized egg.

Produced cyclically and in limited numbers (atresia phenomenon).

Nucleus with n chromosome (maternal genome).

Immobile cell, leads a slowed life.

Fertilisation

I-Definition

This is the starting point of embryonic development, the union of the male gamete and the female gamete. A zygote or fertilised egg is formed by the return to diploidy.

II-Methods of fertilisation

1-External fertilisation: the gametes are released outside the genital tract and are found in the water (sea urchins, amphibians).
2-Internal fertilisation: the gametes meet in the female genital tract (birds, mammals).

III-Gamete encounters

1- Gamete pathway: in species with external fertilisation (sea urchins), the spermatozoa are attracted to ovules and agglutinate (action of the fertilisins released by the ova - LILLIE experiment, 1912); Spermatozoa are recognised by eggs of the same species.
In species with internal fertilisation (birds, mammals), the meeting takes place in the female genital tract.

2- Capacitation: before fertilising the female gamete, the spermatozoa undergo the phenomenon of capacitation, which corresponds to the removal of inhibition of the acrosome enzymes. This takes place in the gangue (sea urchin, amphibian) or the cumulus oophorus (human). Capacitation consists of various modifications (membrane constituents, metabolism, sperm motility).

IV- Main stages of fertilisation in mammals

1-Recognition, adhesion/fixation
1-1- Adhesion of the spermatozoon to the zona pellucida (OPU book, 2017, p.34, fig. 5)
1-2- Acrosomal reaction (OPU book, 2017, p.34, fig. 6)
1-3- Penetration through the zona pellucida (OPU book, 2017, p.35, fig.7)
2-Fusion of gametes (OPU book, 2017, p.36, fig.9A, B, C): plasmogamy

V- Consequences of fertilization

1-Activation of the egg
1-1-Blocking of polyspermy
In all vertebrates, polyspermia is blocked (except in birds).
1-1-1- Early blockage: change in membrane potential (Na^+ input).
1-1-2-Late blockage: Cortical reaction (OPU book, 2017, p.38, fig.10A, B), this is the release by exocytosis of the contents of the cortical granules which leads to:
a- Modification of sperm receptor sites by enzymes (supernumerary spermatozoa detach).
b- Detachment of the vitelline membrane from the plasma membrane (rupture of the binding proteins by enzymes contained in the cortical granules).
c- The penetration of water between the two membranes (osmosis) and the formation of a **perivitelline space** (action of proteoglycans).

d- The deposition of structural proteins against the plasma membrane forms the **hyaline layer** which, by thickening, helps to maintain the blastomeres during segmentation.
e- The deposition of structural proteins at the vitelline membrane forms the **fertilisation membrane** which is impermeable to spermatozoa.

1-2-Completion of meiosis
1-3-Amphimixis (OPU book, 2017, p.39, fig.11)
-Spermaster or monoaster stage
-Amphiaster stage
-Diaster stage
-Amphimixis stage

2-Structural changes in amphibians

2-1-Orientation (or equilibration) rotation (OPU book, 2017, p.40, fig.13)
This is due to the detachment of the two plasma and vitelline membranes; the free egg in the perivitelline space tilts and is oriented with the animal pole upwards and the vegetative (heavier) pole downwards. This equilibrium position is determined by gravity.

2-2- Symmetrisation rotation (OPU book, 2017, p.41, fig.14)
In the region opposite the point of penetration of the spermatozoon, a light zone appears due to the sliding of the superficial cortical layer which marks the future dorsal surface: this is the **grey crescent**. The plane passing through the PA-PV axis and the point of penetration of the spermatozoon cuts the grey crescent into two equal halves: this is the **plane of bilateral symmetry**.

Segmentation

I. General Overview

Segmentation allows the formation of a multi cellular organism from a single cell (zygote). It corresponds to successive mitoses of the zygote into daughter cells or blastomeres without an increase in total volume or modification of the external shape of the germ, which passes through a morula stage (resembling a small blackberry), and then develops an internal cavity, the blastocoel (or blastocystic cavity in humans). This segmentation cavity is formed either by cellular spacing (amphibians, mammals) or by yolk lysis (birds). The germ obtained at the end of the segmentation is called blastula or blastocyst (human).

II. Different Modes of Segmentation

There are several modes of segmentation depending on the richness of eggs in yolk and its distribution. The presence of yolk (yolk plates) prevents division or cleavage planes. Two main types of segmentation are distinguished:

1-Total or Holoblastic Segmentation

Cleavage planes affect the entire fertilized egg. This type of segmentation is observed in oligolecithal, heterolecithal, and alecithal eggs. Segmentation can be equal (identical blastomeres), subequal (almost equal blastomeres), or unequal (blastomeres of different sizes), which leads to the formation of macromeres, micromeres, and sometimes mesomeres. Segmentation can be synchronous, where cell divisions occur at the same rate, or asynchronous, where blastomeres divide at different rates (e.g.,micromeres divide more rapidly than macromeres).

2-Partial or Meroblastic Segmentation

Only a portion of the egg cytoplasm, characterized by its low yolk content, undergoes division. This occurs in megalecithal telolecithal and centrolecithal eggs. Two different modalities are observed:

- Partial discoidal segmentation: e.g.,birds (only the germinal disc divides).
- Partial superficial or peripheral segmentation: e.g.,insects (only the egg's periphery divides).

III. Comparison of Segmentation in Certain Vertebrates

- **Amphibians**: Holoblastic or total, unequal, and asynchronous segmentation **(see OPU book, p.48, fig.2).**
- **Birds**: Meroblastic or discoidal partial, unequal, and asynchronous.

Mammals (Humans): Holoblastic or total, subequal, and somewhat synchronous **(see OPU book, p.51, fig.5).**

Gastrulation in Amphibians

I-Definitions and methods of study

1-Definitions

Gastrulation ensures the establishment of the three embryonic layers: ectoderm, mesoderm and endoderm thanks to **Morphogenetic movements**.
The internal penetration movement is **Embolia**.
The movement of extension on the surface is **Epibolia.**
The winding movement on a treadmill is the movement of **Involution**.
When the territory spreads out, there is **Divergence.**
When the territory is grouped into a smaller volume, there is **Convergence.**

2-Methods of study

It is the tattooing of the germ with vital colorings which made it possible to follow the fate of every zone **(see OPU book, 2017, p.54, fig.1)** and made it possible to establish the map of the **presumptious territories** of the blastula **(see OPU book, 2017, p.55, fig.2)**.

II-Morphological phenomena

1- Dorsal external views

Below the gray crescent, invagination first forms the dorsal lip of the blastopore **(see OPU book, 2017, p.56, fig.3A)**.
By acquiring lateral lips, this blastopore forms an arc or horseshoe **(see OPU book, 2017, p.56, fig.3B)**; it then becomes circular by the formation of a ventral lip **(see OPU book, 2017, p.56, fig.3C, D)**.
At the end of gastrulation which lasts 24 hours, the diameter of the blastopore gradually reduces **(see OPU book, 2017, p.56, fig.3E)**.

This blastopore is continually crowded with macromeres rich in yolk or yolk cells of the endoblast.

III- Analysis of movements of presumptive territories

1- Outer layer

It gradually spreads over the surface and compensates for the penetration of other territories. It undergoes an epiboly movement **(see OPU book, 2017, p.59, fig.7A-E)**. At the end of gastrulation, the germ shows us a dorsal neurectoblast and a ventral epiblast, constituting the outer envelope of the gastrula **(see OPU book, 2017, p.59, fig.7E)**.

2- Inner layer

It penetrates en masse like a plug that is pushed into the blastopore: it undergoes an embolism movement. It constitutes the floor of the new cavity which is called **Archenteron** (ancestor of the digestive tract). It pushes back the old blastocoel which gradually decreases in volume and disappears at the end of gastrulation **(see OPU book, 2017, p.57, fig.5A-E)**. Finally, formed of cells rich in yolk, it causes the rocking movement of the germ which places its heavy belly (rich in yolk) downwards.

3- Pharyngeal endoblast located above the dorsal lip

This small territory enters first, as soon as the notch is formed, by wrapping around the dorsal lip and internally lining the territory remaining outside **(see OPU book, 2017, p.57, fig.5A-E)**.

4- Precordal and cordal territories

They undergo the treadmill winding movement (involution) around the dorsal lip of the blastopore, following the pharyngeal endoblast. These territories converge and are placed in a mid-dorsal position against the internal face of the dorsal neurectoblast remaining outside and form the roof of the new cavity or archenteron **(see OPU book, 2017, p.57, fig.5A-E)**.

5- Mesoblast

It converges towards the lateral then ventral and finally dorsal lips of the blastopore, rolls up by involution and spreads inside the germ to the left and right of the cordal territory to which it remains attached.

It is in cross section that the establishment of this mesoblast can be observed. we note that initially attached to the endoblast, the mesoblast subsequently separates from it and then becomes a true middle layer or mesoderm. It then progresses towards the ventral side **(see OPU book, 2017, p.60, fig.8A-C)**.

Conclusion

In approximately 24 hours, the germ became a gastrula made up of **three layers**; **ectoderm (outer layer), mesoderm (middle layer), and endoderm (inner layer).**

Bilateral symmetry, established by the formation of the gray crescent, is morphologically visible at the end of gastrulation because the germ tends to stretch in the antero-posterior direction.

For more information:

COLLECTIF D'ENSEIGNANTS DE BIOLOGIE L1-SNV de L'USTHB, 2017- Cours illustré de Biologie Animale, Tome 1 Embryologie générale, Edition OPU, Alger, 99p.

Translation of French/English figures legends	
French	**English**
1^{er} globule polaire	1st polar globule
1^{er} globule polaire (n) GP1	1st polar cell (n) GP1
$2^{ème}$ globule polaire (n) GP2	2nd polar cell (n) GP2
Acrosine	Acrosine
Acrosome	Acrosome
Albumen	Albumen
Annulus	Annulus
Appareil de Golgi	Golgi apparatus
Axonème	Axoneme
Blastocœle	Blastocoel
Bouton embryonnaire	Embryounicbutton
Cavite Blastocystique	Blastocysticcavity
Cellule de Leydig	Leydigcell
Cellule de Sertoli	Sertolicell
Cellule souche:ovogonie (2n)	Stem cell: ovogony (2n)
Centriole distal	Distal centriole
Centriole proximal	Proximal centriole
Centrosome	Centrosome
Chalaze	Chalaza
Chambre à air	Air chamber
Coiffe post-acrosomienne	Post-acrosomal cap
Colonne segmentée	Segmented column
Condensation de la chromatine (C)	Chromatin condensation (C)
Coquille	Shell
Corona radiata	Corona radiata
Couche enveloppante ou trophoblaste	Wrap-around layer
Couche hyaline	Hyaline layer
Coupes transversales	Cross-sections
Crêtes neurales	Neural crests
Croissant gris	Grey crescent
Cytoplasme	Cytoplasm
Cytoplasme résiduel	Residualcytoplasm
Disque germinatif (cytoplasme+noyau)	Germ disc (cytoplasm + nucleus)
Division équationnelle	Equational division
Division réductionnelle	Reduction division
Doublet de microtubules	Microtubule doublet
Endoblaste non pharyngien	Non-pharyngeal endoblast
Endoblaste pharyngien	Pharyngeal endoblast
Enzymes	Enzymes
Epiblaste	Epiblast
Espace périvitellin	Perivitellin space
Face dorsale	Dorsal face
Face ventrale	Ventral face
Fibres longitudinales	Longitudinal fibers
Formation de l'axonème du flagelle (D)	Formation of flagellar axoneme (D)
Formation des vésicules proacrosomiques (B)	Formation of proacrosomalvesicles (B)
Gaine fibreuse	Fibrous sheath

Gangue gélatineuse ou muqueuse	Gelatinous or mucous gangue
Globules polaires	Polar globules
Gradient vitellin	Vitelline gradient
Granule cortical	Cortical granule
Granules pro-acrosomiques	Pro-acrosomal granules
Lumière du tube séminifère	Lumen of the seminiferous tubule
Manchon mitochondrial	Mitochondrial sheath
Matériel cordal	Cordal material
Matériel préchordal	Prechordal material
Membrane basale	Basement membrane
Membrane coquillère	Shell membrane
Membrane de fécondation	Fertilization membrane
Membrane ovulaire	Ovular membrane
Membrane plasmique ou membrane ovulaire	Plasma membrane or ovular membrane
Membrane vitelline	Vitelline membrane
Mésoblaste	Mesoblast
Mésoblaste dorsal	Dorsal mesoblast
Mésoblaste ventral	Ventral mesoblast
Microvillosités	Microvilli
Microvillosités ovocytaires	Oocyte microvilli
Mitochondrie	Mitochondrion
Neurectoblaste	Neurectoblast
Noyau	Nucleus
Noyau	Nucleus
Noyau de fécondation	Fertilization nucleus
Noyau de l’ovule	Nucleus of the ovum
Noyau en cours de condensation	Condensing nucleus
Œuf alécithe	Alecite egg
Œuf mégalécithe et centrolécithe	Megalocith and centrolocith egg
Œuf mégalécithe et télolécithe	Megalocith and telolecith egg
Œuf mésolécithe	Mesolecith egg
Œuf oligolécithe	Oligolecite egg
Ovocyte I (2n)	Oocyte I (2n)
Ovocyte II (n)	Oocyte II (n)
Ovocyte II en métaphase II	Oocyte II in metaphase II
Ovotide ou ovule (n)	Ovoid or ovule (n)
Phase d’accroissement	Growth phase
Phase de différenciation (spermiogénèse)	Differentiation phase (=spermiogenesis)
Phase de maturation (méiose)	Maturation phase (meiosis)
Phase de multiplication (mitoses)	Multiplication phase (mitoses)
Pièce intermédiaire	Middle piece
Pièce terminale	End piece
Plaque basale	Basal lamina
Plaquette vitelline	Vitelline plate
Pôle animal	Animal pole
Pôle végétatif	Vegetative pole
Pore de l’acrosome	Acrosome pore
Protéines de structure	Structural proteins
Queue	Tail
Spermatide	Spermatid
Spermatocyte I	Spermatocyte I
Spermatocyte II	Spermatocyte II
Spermatogonie	Spermatogonia

Spermatogonie croûtelleuse	Crusty spermatogonia
Spermatogonie poussiéreuse pâle	Pale dusty spermatogonia
Spermatogonie poussiéreuse sombre	Dark dusty spermatogonia
Spermatogonie souche	Sperùatogonia
Spermatozoïdes	Spermatozoon
Tête	Head
Tête spermatique	Spermatic head
Traînée spermatique	Sperm trail
Vaisseau sanguin	Blood vessel
Vésicule acrosomique	acrosomal vesicle
Vésicule golgienne	Golgi vesicle
Vitellus	Vitellus
Zone pellucide	Zona pellucida