Cleavage

Fertilization results into the formation of zygote. The process of segmentation (cleavage) immediately follows fertiliza-tion or any other process which activates the egg. Cleavage consists of division of the zygote into a large number of cel-lular entities. The cells which are produc-ed during segmentation are called blastomeres.

At first, the cells remain closely asso-ciated, but later on they form the lining of a hollow sphere called blastula. The blastula contains a cavity named blastocoel and its outer covering is designated as blastoderm. The formation of blastula culminates the cleavage period.

The process of segmenta-tion prepares the groundwork for the future design of the embryo by producing ade-quate number of cells. The cleavage also establishes the fundamental conditions for the initiation of next developmental stage —Gastrulation.

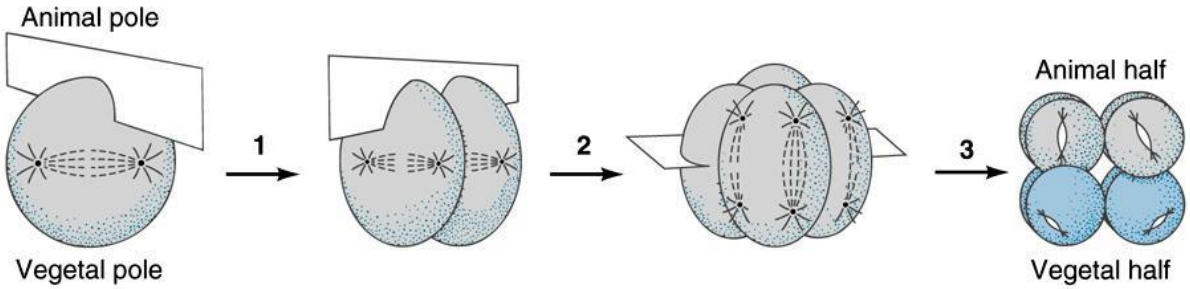
2. Planes of Cleavage:

During early cleavage, distinct geome-trical relationships exist between the blastomeres, i.e., each plane of cell-division bears a definite relationship with each other.

The planes of division are:

a. Meridional plane of cleavage:

When a furrow bisect both the poles of the egg passing through the median axis or centre of egg it is called meridional plane of cleavage. The median axis runs between the centre of animal pole and vegetal pole.



b. Vertical plane of cleavage:

When a furrow passes in any direction (does not pass through the median axis) from the animal pole towards the opposite pole.

c. Equatorial plane of cleavage:
This type of cleavage plane divides the egg halfway between the animal and vegetal poles and the line of division runs at right angle to the median axis.

d. Latitudinal plane of cleavage:
This is almost similar to the equatorial plane of cleavage, but the furrow runs through the cytoplasm on either side of the equatorial plane.

3. Types of Cleavage:

Considerable amount of reorganisation occurs during the period of cleavage and the types of cleavage depend largely upon the cytoplasmic contents.

Different types of cleavage encountered in different eggs are catalogued below:

a. Holoblastic op total cleavage:
When the cleavage furrows divide the entire egg.

It may be:

Equal:
When the cleavage furrow cuts the egg into two equal cells. It may be radially symmetrical, bilaterally, symmetrical, spirally symmetrical or irregular.

Unequal:
When the resultant blastomeres become unequal ir size.

b. Meroblastic cleavage:
When segmentation takes place only in a small portion of the egg resulting in the formation of blastoderm, it is called meroblastic cleavage. Usually the blastoderm is present in the animal pole and the vegetal pole becomes laden with yolk which remains in an tihcleaved state, i.e., the plane of division does not reach the periphery of blastoderm or blastodisc.

c. Transitional cleavage:
In many eggs, the cleavage is atypical which is neither typically holoblastic nor meroblastic, but assumes a transitional stage between the two.

4. Effects of Yolk in Cleavage:

The fertilized egg in most cases contains yolk, which are inert bodies. During division these bodies exert mechanical influences. In the egg of Amphioxus, the yolk is thin and remains uniformly distributed. Therefore the division is complete and early divisions occur at a very quicker rate.

The amphibian egg contains yolk which is localised at the vegetal pole. Here division initiates from the animal pole and extends towards the vegetal pole, where the progress of cleavage slows down considerably.

Consequently, the animal pole divides faster than the vegetal pole. The eggs of reptiles and birds are fully laden with large masses of yolk, thus restricting the cytoplasm and nucleus on the periphery as a circular disc on the animal pole. Here the lines of cleavage divide only the small animal pole region. Such effects of yolk on cleavage pattern influence the pattern of further development.

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5. Mechanism of Cleavage:

The incidence of cleavage provides unique opportunity to study the mechanism of cell division and specially the role of different cell organelles during division.

Opinions differ regarding the accumulation of force for the initiation of cleavage and following factors are believed to be responsible for controlling the cleavages:

(a) Localised expansion of cortex.

(b) Increased stiffness of the cortical cytoplasm.

(c) Increase of tangential force activity in the cortex.

(d) Contractile nature of the regions near the cortex and

(e) Formation of new cell membrane from the subcortical cytoplasm.

Though the abovementioned factors are not clearly understood, it is evident that three structures present within the cell: Cortical layer, Spindle structures and Chromosomes play the important part.

The energy which is required during the process is supplied by the metabolic activity of the developing egg. Besides the factors involved in segmentation, there are cleavage laws which govern the behaviour of the cells during cleavage.

Sach's rules:
The blastomeres tend to divide into identical daughter cells and a cleavage furrow tends to cut the previous cell at right angles.

Hart wig's laws:
The position of nucleus is vital and it tends to lie at the centre of the protoplasmic content of the cell. The nucleus exerts influence on cleavage. The long axis of mitotic spindle usually coincides with the long axis of the protoplasmic content. During cleavage the long axis of the protoplasm has the tendency to cut transversely.

Balfour's law:
The rate of cleavage is inversely proportional to the amount of yolk material present in the egg.

6. Chemical Changes during Cleavage:
Significant chemical changes go on in the fertilized egg during cleavage.

They are:
Increase of nuclear material:
During cleavage a steady increase in nuclear material (predominantly DNA) is observed. Cytoplasm of the egg is the source of such nuclear material. Cytoplasmic DNA contained in mitochondria and yolk platelets are available.

RNA synthesis:
During cleavage messenger RNA (mRNA) and transfer RNA (tRNA) are synthesised during cleavage, especially in late stages.

Synthesis of proteins:
Throughout the period of cleavage there is steady and spectacular increase in protein synthesis.

Cleavage Patterns

Early cleavage patterns vary widely between different groups of animals, based largely on the orientation of the division planes. The simplest pattern is radial cleavage, in which successful division planes are at 90 degree angles relative to each other. This result in the blastomeres aligned directly over or to the side of one another. In spiral cleavage, the division planes are not at 90 degree angles, resulting in blastomeres that are not aligned directly over or beside one another.

Radial Cleavage: occurs such that the resulting daughter cells are located exactly on top of one another. Radial cleavage is a characteristic of Deutrostomes, and results in indeterminant cells (Cells that can individually give rise to a complete embryo, and they don't have a determined embryological fate early on during the development of the embryo).

Radial Cleavage

Spiral Cleavage: occurs such that the resulting daughter cells are not located exactly on top of one another; instead, they are located at a slight angle. Spiral cleavage is a characteristic of Protostomes, and results in determinant cells (Cell that have a determined embryological fate early on during the development of the embryo). In other words, determinant cells areprogrammed to become a specific type of cell, early on during the process.

Spiral Cleavage

Determinate and Indeterminate Cleavage Cleavages may be classified into determinate and indeterminate types based on the potentiality of the blastomeres for the future development.

Determinate: the developmental fate of each embryonic cell is established very early. If a cell is isolated from the 4-cell stage the embryo will not fully develop. This is because the fate of each blastomere is predetermined in the early embryonic stage itself. Annelids, mollusks and ascidians which produce mosaic type of eggs exhibit determinate cleavage.

Indeterminate: early embryonic cells retain capacity to develop into a complete embryo if isolated from other cells. Cleavage produces blastomeres which are qualitatively equipotential or totipotent. When they are isolated, they develop into complete embryos. This is because the fatesof blastomeres are not predetermined in the early embryonic period. Vertebrates and certain invertebrates such as echinoderms which produce regulative type of eggs exhibit indeterminate cleavage.

Classification of Eggs

(1) ON THE BASIS OF AMOUNT OF YOLK

(a) Alecithal eggs - Yolk is present in very less amount almost negligible. e.g. Eutheria mammals.

(b) Microlecithal or oligolecithal or Melolecithal egg- Yolk is present in less amount e.g. Metatheria, Protachordata, Echinodermata

(c) Mesolecithal Yolk is present in moderate amount. e.g. Amphibia, Petromyzon, Dipnoi-[lung fishes]

(d) Megalecithal or Polylecithal - Yolk is present in large amount. e.g. Insects, Reptiles, Birds, Prototheria (Monotremata) Egg laying mammals.

(2) ON THE BASIS OF DISTRIBUTION OF YOLK

(a) Isolecithal or Homolecithal - Yolk is distributed uniformally in eggs. e.g. Alecithal and microlecithal eggs.

(b) Moderately telolecithal - Yolk is concentrated in lower part of egg and cytoplasm in upper part e.g. Frog and other amphibia.

(c) Discoidal egg or Highly telolecithal- Yolk found in large amount and cytoplasm is found in the form of disc. e.g. Polylecithal eggs of reptilia, Birds, Prototheria.

(d) Centrolecithal - Yolk is concentrated in centre of egg and cytoplasm is found in the form of a thin layer surrounding yolk. (Peripheral cytoplasm) e.g. Insect.

Telolecithal and centrolecithal eggs are heterolecithal or anisolecithal eggs.

(3) ON THE BASIS OF SHELL

Two of types (a) Cleidoic eggs (b) Non-cleidoic egg

(a) Cleidoic egg - These eggs contain a thick and hard outermost shell. This hard shell is permeable for gases. Yolk, Salts and Water is present in large amount in cleidoic eggs. Cleidoic egg is a terrestrial adaptation. e.g. Birds & Reptiles, Prtotheria mammal and insects. (b) Non cleidoic egg - Egg membranes are soft in these eggs e.g. All viviparous animals and in oviparous animals which lays eggs in water.