

CLEAVAGE AND TYPES

The process of cleavage remains one of the earliest mechanical activity in the conversion of a single celled egg into a multicellular embryo. It is initiated by the sperm during fertilization. However in parthenogenetic eggs cleavage can commence without the influence of fertilization.

The process of cleavage or **cellulation** happens through repeated mitotic divisions. These divisions result in cells called **blastomeres**. In later stages of development the blastomeres occupy different regions and differentiate into several types of body cells.

The first cleavage of frog's egg was observed by **Swammerdam** in 1738. The entire process of cleavage in frog's egg was studied by **Prevost** and **Dumas** in 1824. With the development of microscopes cleavages and further stages were observed in the eggs of sea urchin, star fishes, amphioxus and hen's eggs.

From all these studies it has become clear that all divisions in cleavage are **mitotic**. The mitotic process is very rapid. In the eggs of sea urchin division of the blastomeres can be observed every 30 minutes.

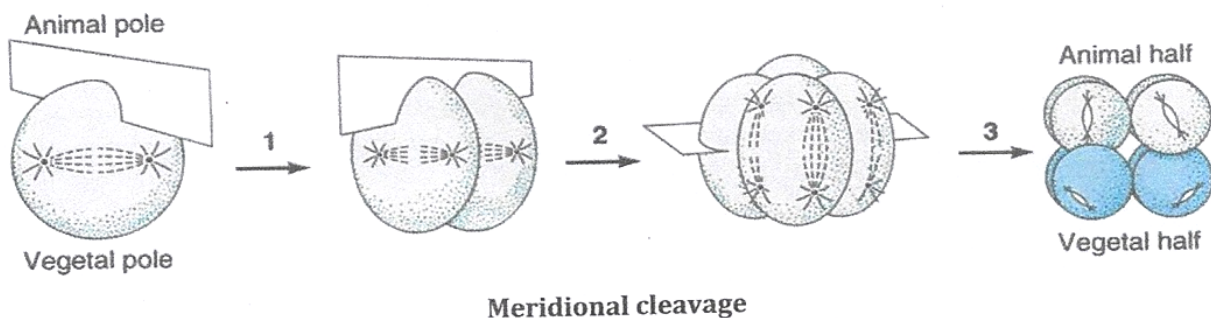
As the cleavage progresses the resultant daughter cells, namely the blastomeres get reduced in size. During cleavage there is no growth in the blastomeres. The total size and volume of the embryo remains the same.

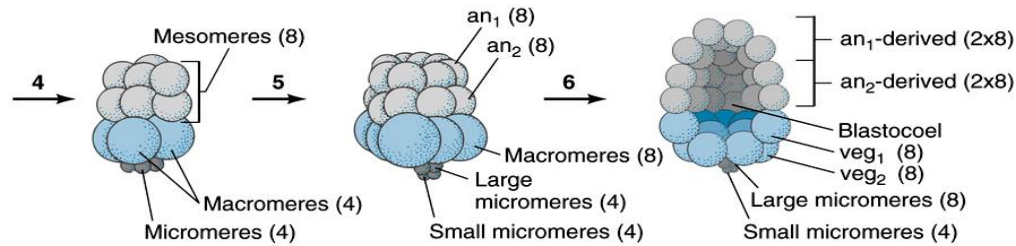
The cleavages result in a compact mass of blastomeres called **morula**. It gets transformed into **blastula**. While the wall of the blastula is called the **blastoderm**, the central cavity is called the **blastocoel**.

The planes of cleavage

An egg can be divided from different planes during cleavage. Depending on the position of the cleavage furrow the planes of cleavage are named.

1. **Meridional plane:** The plane of cleavage lies on the animal vegetal axis. It bisects both the poles of the egg. Thus the egg is divided into two equal halves.





Blastocoel formation

2. **Vertical plane:** The cleavage furrows may lie on either side of the meridional plane. The furrows pass from animal to vegetal pole. The cleaved cells may be unequal in size.

3. **Equatorial plane:** This cleavage plane bisects the egg at right angles to the main axis. It lies on the equatorial plane. It divides the egg into two halves.

4. **Latitudinal plane:** It is similar to the equatorial plane, but it lies on either side of the equator. It is also called as **transverse** or **horizontal cleavage**.

Influence of yolk on cleavage

Yolk is needed for embryonic development. However the fertilized egg has to undergo all stages of development and result in a suitable 'young form' initiating next generation. Somehow with all the influences of yolk the developmental procedures are so adapted and modified that a well formed embryo will result. The initial influence of yolk is felt during the process of cleavage. The amount of the yolk and its distribution affect the process of cleavage.

Accordingly several cleavage patterns have been recognized.

1. **Total or holoblastic cleavage** - In this type the cleavage furrow bisects the entire egg. Such a cleavage may be either equal or unequal.

(a) **Equal holoblastic cleavage** - In microlecithal and isolecithal eggs, cleavage leads to the formation of blastomeres of equal size. Eg: Amphioxus and placental mammals.

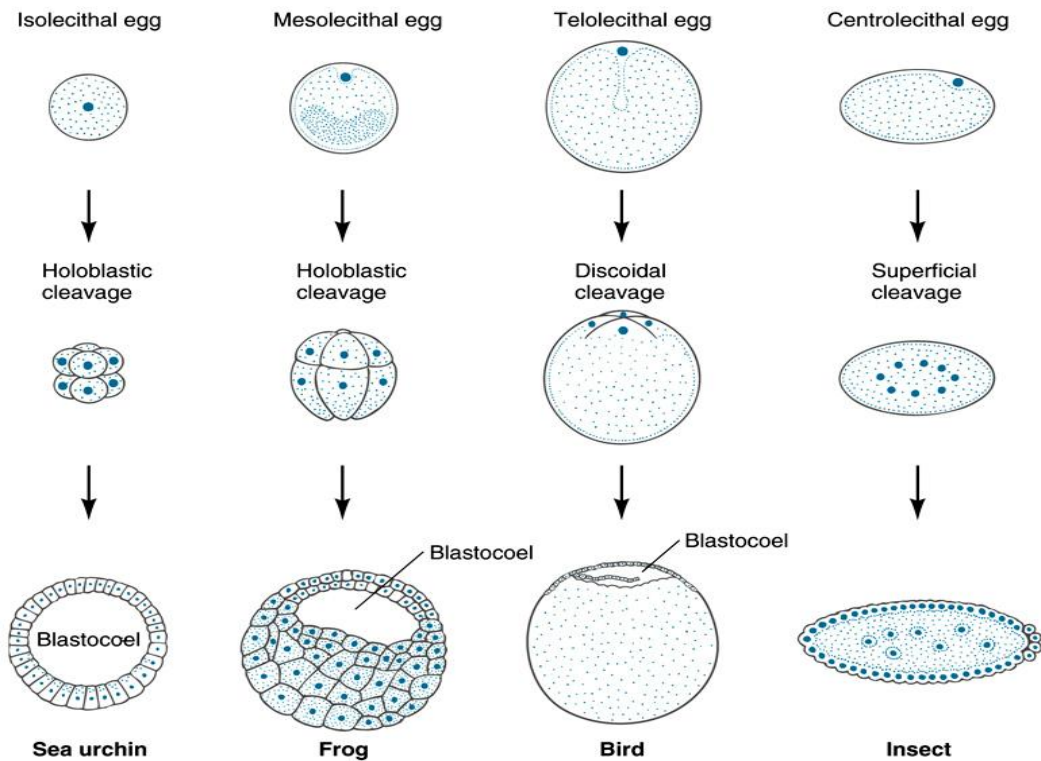
(b) **Unequal holoblastic cleavage** - In mesolecithal and telolecithal eggs, cleavage leads to the formation of blastomeres of unequal size. Among the blastomeres there are many small sized micromeres and a few large sized macromeres.

2. **Meroblastic cleavage** - In this type the cleavage furrows are restricted to the active cytoplasm found either in the animal pole (macrolecithal egg) or superficially surrounding the egg (centrolecithal egg). Meroblastic cleavage may be of two types.

(a) **Discoidal cleavage** - Since the macrolecithal eggs contain plenty of yolk, the cytoplasm is restricted to the narrow region in the animal pole. Hence cleavage furrows can be formed only in

the disc-like animal pole region. Such a cleavage is called **discoidal meroblastic cleavage**. Eg: birds and reptiles.

(b) **Superficial cleavage** - In centrolecithal eggs, the cleavage is restricted to the peripheral cytoplasm of the egg. Eg: insects.



Typical cleavage patterns of isolecithal, mesolecithal, telolecithal and centrolecithal eggs

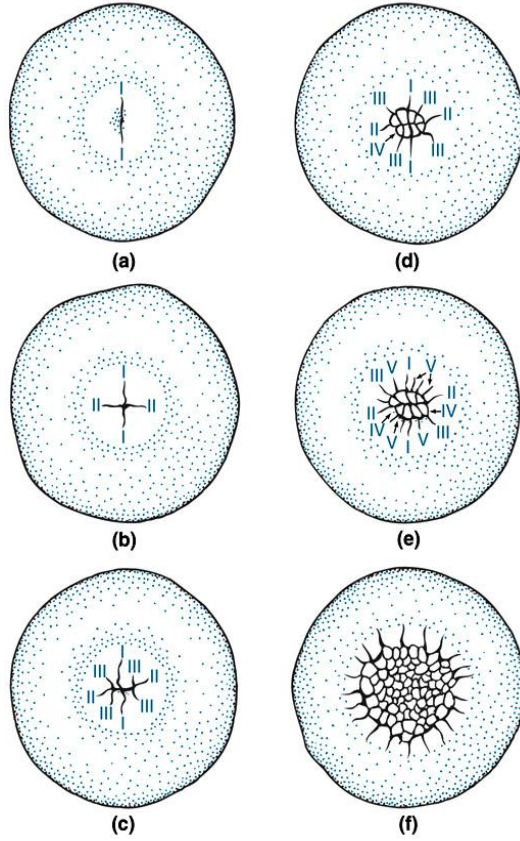
Laws of cleavage

Apparently there are several cleavage patterns. However, all cleavages follow a common procedure. The cleavages are governed by certain basic principles or laws.

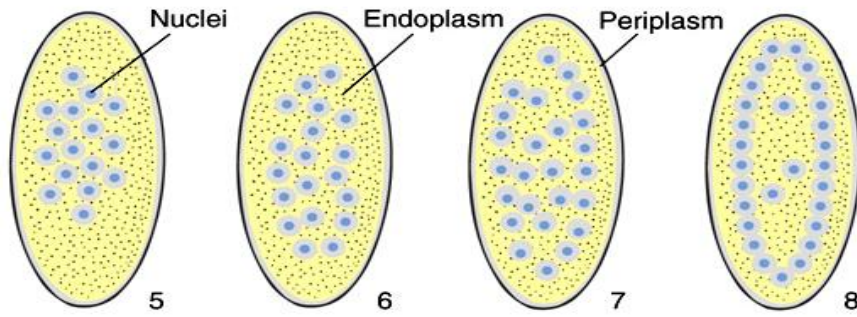
1. **Sach's laws** - These laws were proposed by Sach in 1877.

- i) Cells tend to divide into equal daughter cells
- ii) Each new division plane tends to intersect the preceding plane at right angles.

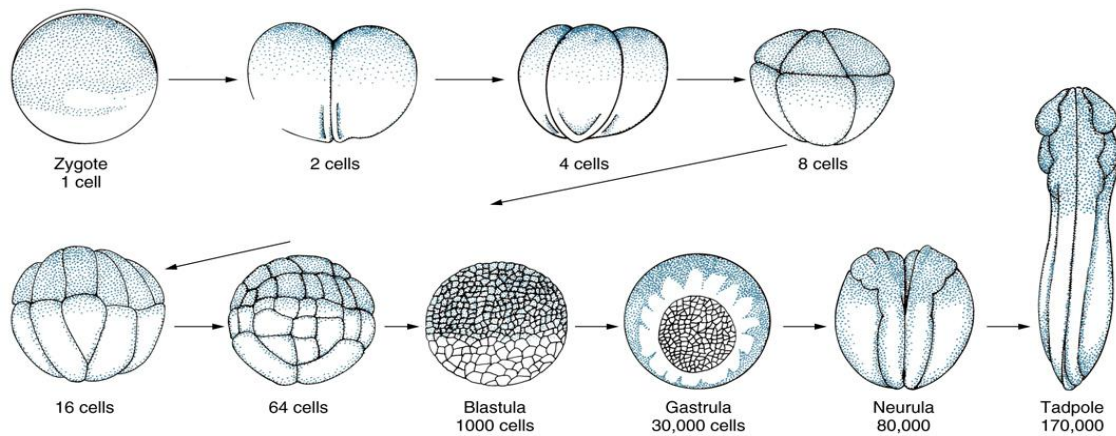
2. **Balfour's law** (Balfour 1885) - "The speed or rate of cleavage in any region of egg is inversely proportional to the amount of yolk it contains".



Meroblastic discoidal cleavage



Meroblastic superficial cleavage



Cleavage in amphibians

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 results 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 Deuterostomes, and results in indeterminate 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). In other words, you can take a single cell from a developing embryo, and given the right condition, that single cell can give rise to a whole embryo (If you've taken embryology classes you've definitely heard of experiments like this done with frog embryo).

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 are programmed to become a specific type of cell, early on during the process.



Radial cleavage



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 fates of 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.