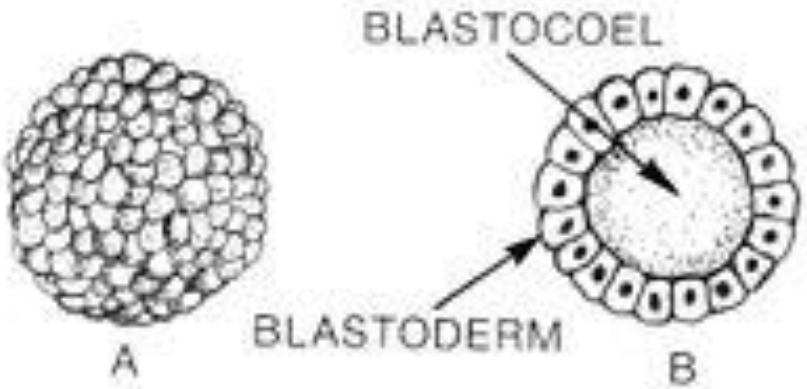
CLEAVAGE PATTERNS

Zoology Department

What is cleavage?

- A Cleavage is a process of **series of mitotic divisions** where the fertilized egg divide into numerous **smaller nucleated cells called blastomeres** and ultimately resulting into a hollow spherical body called **blastula**.

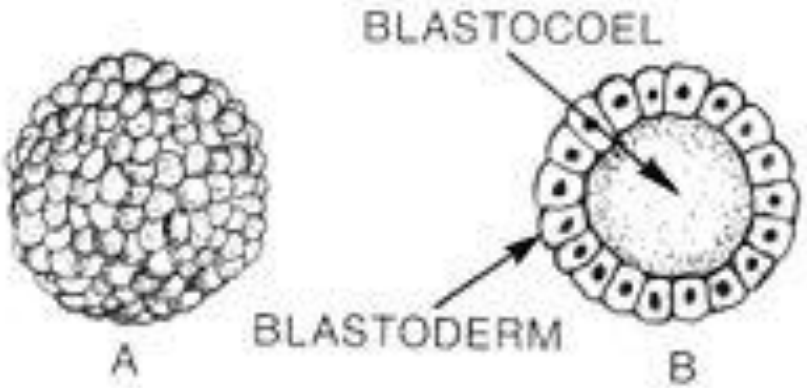


Blastula of frog

- The process of cleavage remains one of the earliest mechanical activity in the conversion of a single celled egg into a **multi-cellular embryo**.
- 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.

- 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

- 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.
- 2. **Vertical plane**: The cleavage furrows may lie on either side of the meridional plane. The furrows pass from animal to vegital 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**.

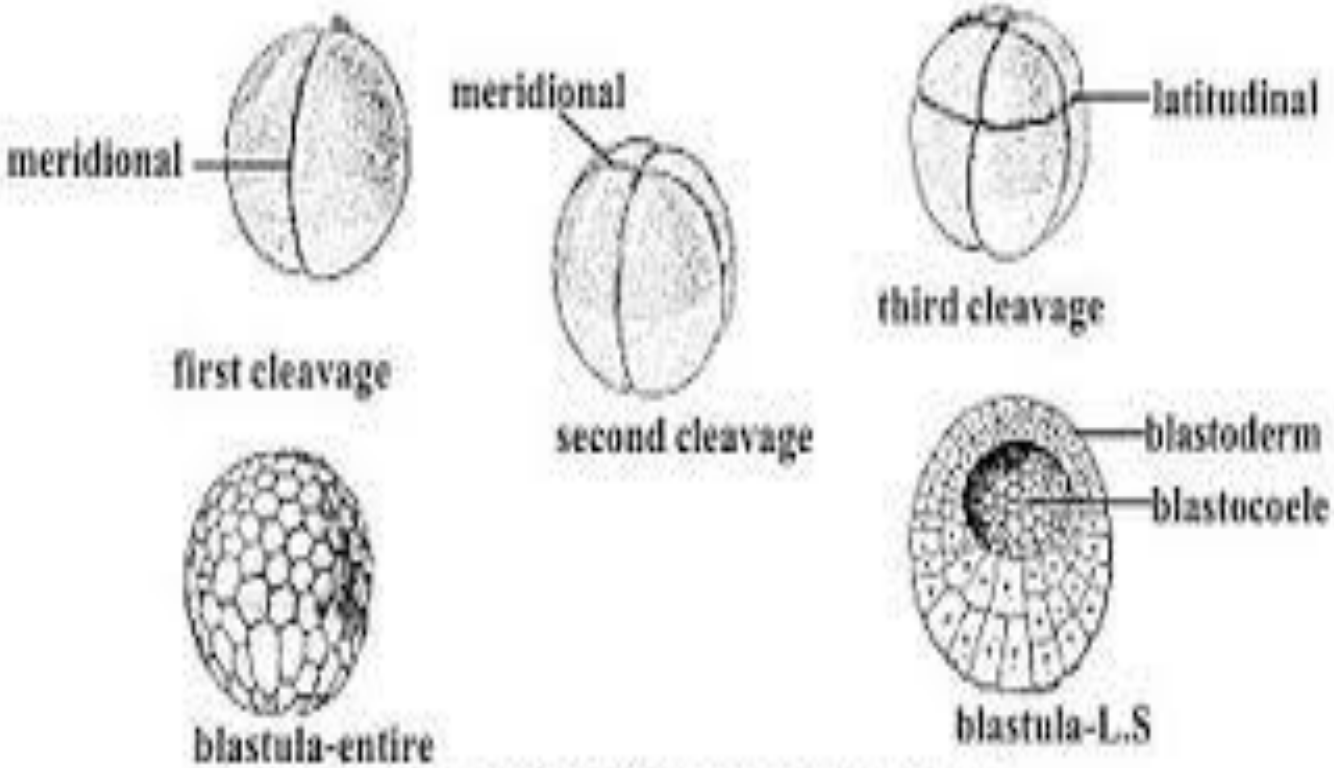


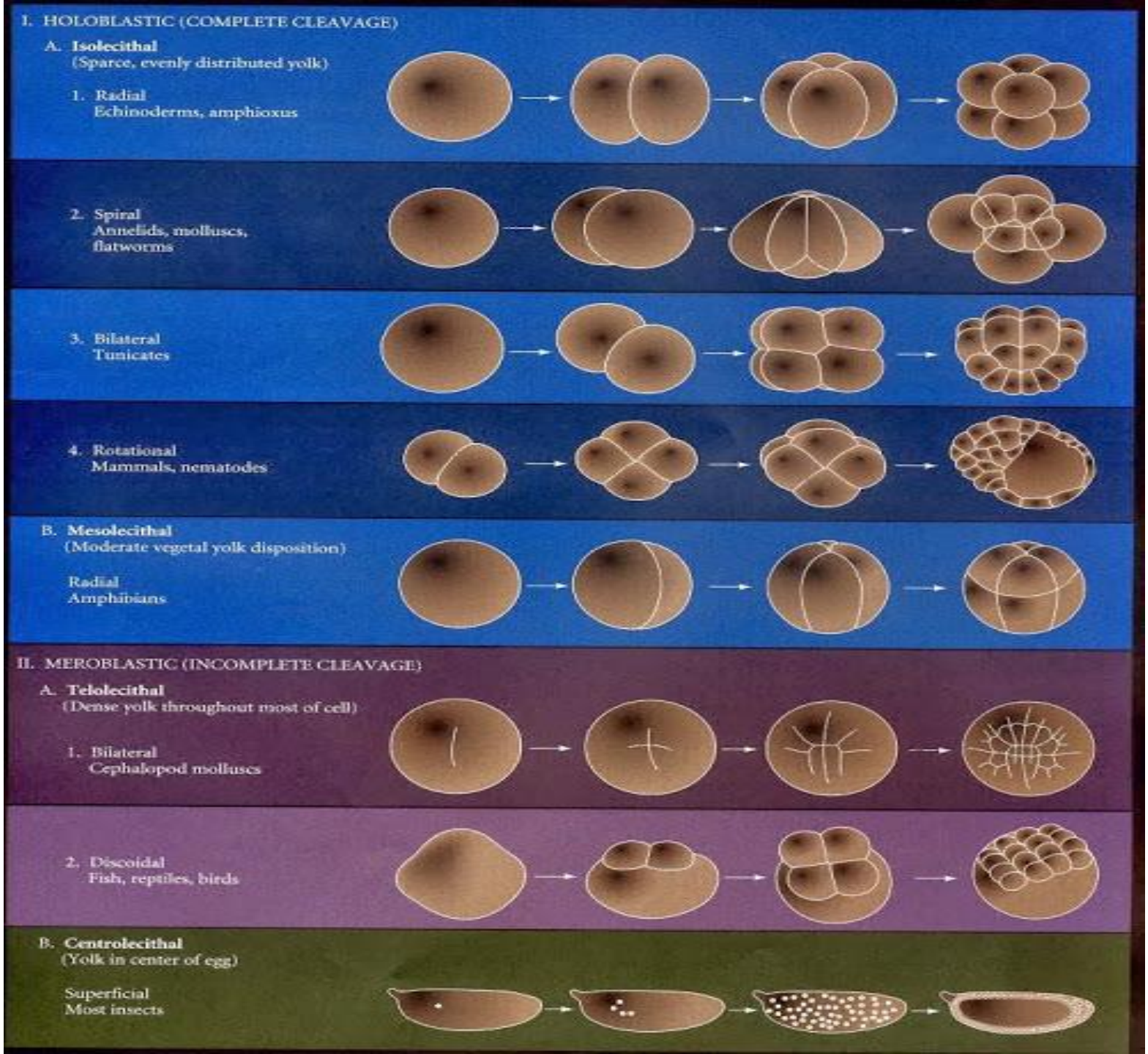
Fig.5.2.1. Cleavage in frog's egg

Influence of yolk on cleavage

On the basis of amount and distribution of yolk, cleavage patterns may be of following types:

- 1. **Total** or **holoblastic cleavage** - In this type the cleavage furrow bisects the entire egg. Such a cleavage may be either equal or unequal. (Micro/Homolecithal egg)
- (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 telolocithal 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. E.g. Amphibian egg.

- 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.


I. HOLOBLASTIC (COMPLETE CLEAVAGE)
A. Isolecithal
(Sparce, evenly distributed yolk)
1. Radial
Echinoderms, amphioxus
2. Spiral
Annelids, molluscs, flatworms
3. Bilateral
Tunicates
4. Rotational
Mammals, nematodes
B. Mesolecithal
(Moderate vegetal yolk disposition)
Radial
Amphibians
II. MEROBLASTIC (INCOMPLETE CLEAVAGE)
A. Telolecithal
(Dense yolk throughout most of cell)
1. Bilateral
Cephalopod molluscs
2. Discoidal
Fish, reptiles, birds
B. Centrolecithal
(Yolk in center of egg)
Superficial
Most insects

On the basis of arrangement of blastomeres, cleavage is of four types-

(1) **Radial cleavage** - In this, regular cleavage divisions are at right angle to the earlier. So the cells are placed just one above the other. So the upper four blastomeres are arranged just above the lower four blastomeres. e.g. Echinodermata, Chordata.

(2) **Spiral cleavage** - In this cleavage planes are oblique. Four blastomeres of lower plane rotate clock wise or anti-clock wise. If the blastomeres **rotate clock-wise** then the cleavage is called as **Dextral spiral cleavage** e.g. Mollusca. And if the blastomere **rotates anti-clock-**wise, then such cleavage is called as **Sinistral Spiral cleavage.**

e.g. Helminthes (Aschelminthes and platyhelminthes), Annelids.

(3) **Bilateral cleavage-** Due to unequal holoblastic cleavage, bilateral symmetry is established. Blastomere of one lateral side are small in size and another four lateral blasotmeres are large in size. e.g. Amphibia, Tunicata (Urochordata), Cephalochordata.

(4) **Biradial cleavage** - First two cleavages are meridional and third cleavage is vertical so eight blastomeres are formed in which four central blastomere are large and four blastomeres are small e.g. Ctenophora.

Classification of cleavage on the basis of fate of blastomeres .It is of 2 types-

(a) **Determinate cleavage - (Mosaic development**)

The fate of the blastomere is fixed. In this cleavage a specific blastomere forms a specific part of embryo. In this cleavage if any blastomere of embryo is removed or destroyed then the related part of embryo becomes deformed. e.g. Annelida, Mollosca, Platyhelminthes, Nematoda.

b)Indeterminate cleavage - (Regulative development)

The fate of blastomeres is not fixed. Each blastomere has capacity o form the complete embryo. There will be no effect on embryo formation if any blastomere or part is removed from embryo e.g. Echinoderms, Chordates. Due to totipotent nature of blastomere they can form identical twins, when these cells are separated.

Laws of cleavage (Principles)

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

- **Sach's law** - Cleavage divisions occurs repeatedly. Each successive division is at right angle to the earlier.
- **Hertwig law** -At the time of cleavage the formation of spindle fibres occurs in longest axis of the egg.
- **Pflugger's law** - During cleavage formation of spindle fibres takes place in the region of lesser resistance or less yolk.
- **Balfour's law** - The rate of cleavage is inversely proportional to the amount of yolk.

Special characteristic features of cleavage.

- All cleavages are **mitotic with very short interphase** in between. It begins immediately after the nuclear fusion of two gametes.
- Cleavage **results in smaller cells**, the blastomeres. Therefore the **volume as a whole does not change**.
- By each cleavage the number of blastomeres **multiplies in geometric progression** in a typical doubling sequence- 2, 4, 8, 16, 32..
- Only a few early cleavage are regular (**Synchronous),** the later division become entirely irregular **(Asynchronous).**

Products of cleavage

- **Morula**: When the developing embryo appears mulberry-like during slightly later stages of cleavage, it is called morula. It appears so because the free outer and inner side of the blastomers still remain rounded except the surfaces which remain in contact with each other.
- **Blastula:** The hollow spherical embryo having a single layer of blastomeres called blasdoderm, surrounding a cavity known as blastocoel.

Mechanism of blasulation

- The blastomeres produced tend to assume spherical shape due to few reasons such as:
- They have viscous surface and tend to adhere to any adjacent surface that has similar physical and chemical properties.
- Any fluid or semifluid mass tends to assume spherical shape to reduce the free surface energy to a minimum.
- When surface tension is high, a more or less spherical form is maintained. If it becomes low, the surface becomes flattened.

Different types of blastulae

- **Coeloblasula**: It is in the form of hollow sphere. Its blastocoel is filled with mucopolysaccharides. The blastoderm is a single layer of blastomere. E.g. Echinoderms and Amphioxus.
- **Periblastula or Superficial blastula**: It is similar to coeloblastula, but the blastocoel is filled with yolk. E.g. insects

Different types of blastulae

- **Discoblastula**: in such blastula, the floor of blastocoel is formed of yolk sac while the roof is formed of epiblast. E.g. Reptiles, Birds, fish.
- **Amphiblastula**: Formed of two types of structurally different blastomeres. E.g.Amphibians have upper micromeres and lower macromeres.
- **Blastocysts**: In such blastula, the cells of the outer peripheral layer of morula are arranged more like an epithelium and form the trophoblast. The cells inside are irregularly shaped and form the inner cell mass. E.g. Mammals.
- **Stereoblastula**: No cavity appears in blastula. The smallers micromeres accumulate as cluster of cells over the vegetally placed macromeres. This results in a solid blastula. E.g.some annelids, Molluscs, Planarians.

Significance of blasulation

- Regardless of the shape of the blastulae, major presumptive organ forming areas of future embryonic body are segregated into definite parts of the blastoderm.
- The exact pattern of arrangement of presumptive organ forming areas varies from species to species.
- Blastocoel permits the migration and rearrangement of the major presumptive organ forming areas during gastrulation.