The following points highlight the top ten theories to explain the locomotion in amoeba.

1. Adhesion Theory:

According to this theory, locomotion in Amoeba is performed by adhesion similar to drop of water which spreads irregularly on uneven glass plate. The protoplasm flows, like the fluid of the drop, in the path of greater adhesion. Due to adhesive properties pseudopodia generally grow in the paths of adhesion.

However, this explanation is not satisfactory and does not hold good as the pseudopodia are sometimes given out independently even without any contact with any surface.

2. Surface Tension Theory:

This theory was first of all advocated by Berthold (1886) and later supported by Butschli (1894) and Rhumbler (1898). According to this theory, protoplasm is a fluid, there must exist at the surface of the protoplasmic mass a tension (surface tension) acting to make the mass spherical.

Wherever on such a sphere the surface tension is locally lowered by external or internal changes, the protoplasm flows out in the form of a projection, the pseudopodium. In such a projection, the protoplasm will flow forward in the centre and back along the sides. In other words, there is a fountain streaming of protoplasm in the pseudopodium.

This theory is supported by the facts that drops of certain chemical mixtures will move in amoeboid fashion because of local decreases in the surface tension and that in some amoeboid forms fountain streaming can be observed in active pseudopodia. However, majority of Amoebae do not exhibit fountain streaming in their pseudopodia.

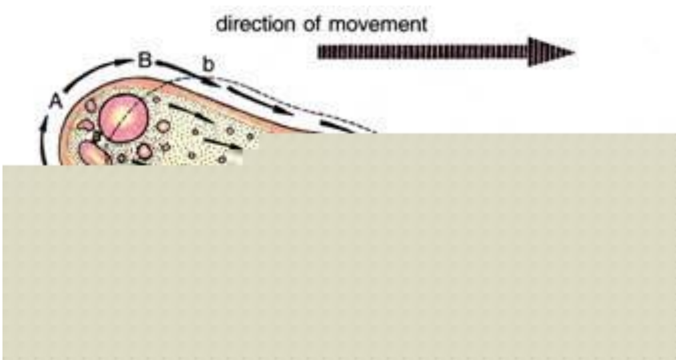
Furthermore, most of the amoeboid forms have gelated surface instead of fluid as assumed by this theory. Therefore, surface tension theory may apply only to a few very fluid amoebae. This view is no longer supported now-a-days. It is believed that surface tension difference may cause change in the shape, but this does not account satisfactorily for the formation of pseudopodia.

3. Rolling Movement Theory:

Jennings (1904) worked on Amoeba verrucosa which has almost no pseudopodia.

If a particle of carmine is placed on the upper surface of a moving A. verrucosa, it is seen that the particle flows forward, rolls over the anterior edge, then it stops on the substratum until the entire direction of movement animal has passed over it, then the particle moves upwards at the posterior end and comes on the upper surface and moves forward.

This is due to streaming movements of protoplasm of the animal accompanied by rolling action of the body and these two processes bring about locomotion.



Jennings' observations may be correct for A. verrucosa, which is devoid of pseudopodia, but it cannot be applied to Amoeba proteus which moves with the pseudopodia.

4. Contraction Theory:

Dellinger (1906) examined an Amoeba proteus not from the top, but from side view, exactly in front of the observer and came to the conclusion that a contractile substance present in the endoplasm is mainly responsible for the formation of pseudopodia.

According to him, the Amoeba extends the anterior end to form a pseudopodium, then it lifts it and places it on the substratum, then it contracts this pseudopodium which causes the body to move forward. This process is repeated.

Thus, the animal is pulled from in front and pushed from behind due to contractions of a contractile substance located in the endoplasm as a coarse reticulum. In this way the Amoeba actually walks putting one foot out, then another. According to Dellinger, pseudopodia are formed by an exchange of water between the ectoplasm and endoplasm which causes alternate contractions and expansions.

Dellinger proposed it as a walking locomotion because, in a profile, Amoeba appears to walk on the tips of its leg-like pseudopodia. The contraction theory is now discarded.

5. Gel-Sol Theory:

Pantin (1923) studied the marine Amoeba Umax, it forms a pseudopodium by swelling of protoplasm due to secretion of acid and absorption of water at that place. As the pseudopodium forms and extends in front, a gelatinous ectoplasmic tube is formed. At the posterior end, this ectoplasmic tube changes into endoplasm.

The ectoplasmic tube contracts and forces the endoplasm to stream to the front, this brings about locomotion

6. Sol-Gel Theory or Change of Viscosity Theory:

This theory was strongly advocated by Hyman (1917) and also adopted by Pantin (1923—1926) and Mast (1925). It is supposed to be the best to explain the locomotion in Amoeba. This theory is based on the reversible change of protoplasm from sol to gel state.

According to Mast, amoeboid movement is brought about by four processes:
(i) Attachment of Amoeba to the substratum,

(ii) Gelation of plasmasol at the anterior advancing pseudopodia,

(iii) Solation of plasmagel at the posterior end and receding pseudopodia,

(iv) Contraction of plasmagel tube at the posterior end to drive the plasmasol forwards.

As the plasmasol changes into plasmagel at the anterior end, the plasmagel tube extends forwards and is converted into plasmasol at the posterior end, the plasmagel tube drives the plasmasol forwards to form a pseudopodium.

A thin plasmagel sheet persists intact at the anterior end and prevents the plasmasol from reaching the plasma lemma, but this sheet may break at times so that the plasmasol streams through filling the hyaline cap, but soon the plasmasol gelates to form a new plasmagel sheet.

Pseudopodia are formed because plasmagel is elastic and under tension, it is pushed out where the elastic strength is the lowest. During locomotion of Amoeba, the elastic strength of plasmagel is the highest at the sides, intermediate at the posterior end, and lowest at the anterior end; this results in an elongated shape of the animal and a forward extension of the anterior end to bring about locomotion.

7. Molecular Folding-Unfolding Theory:

Recently, Goldacre and Lorch (1950) have explained the phenomena of solation and gelation on the molecular basis. According to Goldacre and Lorch, the contraction of the plasmagel tube cannot supply enough force for moving the animal.

They state that all proteins gelate when their molecules unfold and they solate when their molecules fold. In the fluid endoplasm the protein molecules lie folded compactly, these molecules unfold at the tip of the advancing pseudopodia to form a layer of straightened and attached molecules.

Posteriorly the protein molecules begin to fold again and they impart a contraction force. In Amoeba, the contraction is confined towards the posterior side which forces the contracted proteins towards the anterior end.

As the animal moves, the plasmagel contracts at the posterior end, it changes into plasmasol which flows in front, and then by gelation, it forms the advancing pseudopod anteriorly. With further folding, these posterior molecules solute and pass forward in the endoplasm.

Such molecules attract substances from the sides of the Amoeba and release them on folding again to accumulate them at the posterior side of the animal to produce further contraction force. The rear part of the cell is squeezed like a tube of toothpaste, this drives the plasmasol to the front end where it forces out a pseudopod.

Attachment of the animal to the substratum is necessary for locomotion. It is supposed that the energy for the movement of Amoeba, folding and unfolding of protein molecules is provided by adenosine triphosphate (ATP), a substance which has stored chemical energy and which is-known to provide energy for contraction of muscles in Metazoa.

This explanation of locomotion appears satisfactory since it shows that the mechanism of pseudopod formation and muscle contraction is similar.

8. Fountain-Zone Contraction Theory:

This theory was proposed by Allen (1962) that amoeboid movement is a slow contraction of molecules is based on the observation that endoplasmic molecules near the front end start moving before those at the posterior end. This shows that locomotion cannot be due to squeezing from behind forwards as claimed in some other theories.

The endoplasm contains long protein chains which undergo contraction at the anterior end and here the plasmasol is converted into plasmagel.

In this plasmagel, the protein chains are folded by which the gel state results. It is believed that at the region near the tip of the forming pseudopodium the everting plasmasol changes into plasmagel to form a wall or fountain zone, and this anterior region develops tension which is transmitted to the hinder end of the endoplasm.

At the posterior end, the protein chains unfold by which the plasmagel is converted into plasmasol. Thus, the animal is pulled forward by the contraction or tension at the anterior end. It is essential for the surface of the Amoeba to temporarily adhere to the substratum because internal streaming alone cannot cause locomotion.

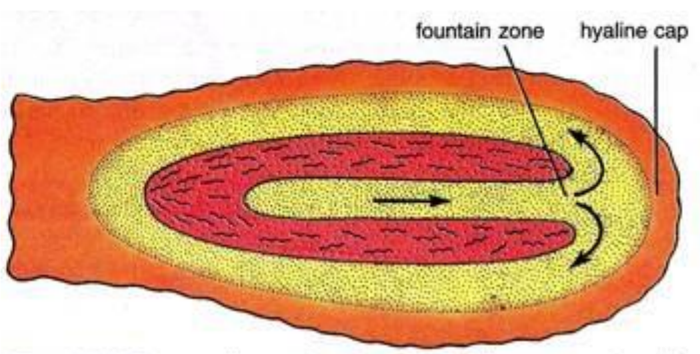


Fig. 14.9. Diagram illustrating the amoeboid movement on the basis of fountain zone theory (After **Allen**).

9. Views of Rinaldi and Jahn (1963):

Rinaldi and Jahn (1963) have analysed motion pictures of granule movements in advancing pseudopodia and observations given in support of theories of Mast (1925) and Allen (1962). They have strongly criticised the fountain-zone theory of Allen and supported the concept as proposed by Pantin and Mast.

They have advocated that during movement when plasmagel is converted into plasmasol at the posterior end, then due to contraction in the plasmagel a hydraulic pressure is exerted on the plasmasol.

This pressure remains very less in the anterior end, moderate in the middle and very high in the posterior end of Amoeba. Due to this pressure the plasmagel in the anterior end breaks resulting into a forward flow of plasmasol which forms pseudopodium.

Since, there occurs constant conversion of plasmagel into plasmasol at the posterior end and the pressure remains less at the anterior end, the plasmasol flows forward and forms pseudopodium which brings about locomotion (Fig. 14.10).

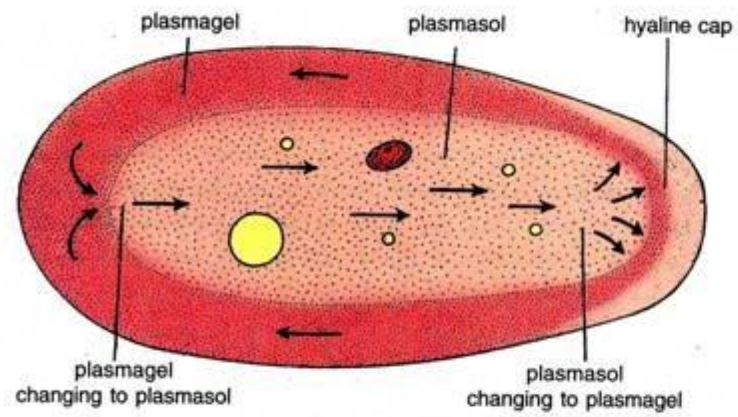


Fig. 14.10. Diagram illustrating the amoeboid movement on the basis of hydraulic pressure theory of **Rinaldi** and **Jahn** (1963).

10. Views of Wolpert, Gingley and Garrod (1968):

Wolpert, Gingley and Garrod (1968) have again confirmed the theory of Mast with the comment that the concept of amoeboid movement as suggested by Pantin and Mast is essentially correct. However, they have said that the plasmalemma of Amoeba is very elastic in nature which helps in the formation of pseudopodia to affect locomotion.

Barrington (1967) has concluded that the biochemical principles involving in Amoeba's activity have something in common with those involved in other types of movements. The energy needed for it comes form ATPs.