Actin in plant cells book review examples

Environment, Animals

Actin in Plant Cells

Actin, one of the most abundant proteins, occurs in all eukaryotic cells constituting almost five percent of cellular protein. Actin is the predominant component of the cytoskeleton. It is worth noting that the all-important cytoskeleton of a plant has three principal components; actin filament, microtubules and intermediate filaments (Jeon, 2003). As a component of the cytoskeleton of plant and animal cells, actin is of crucial importance in a plethora of cell processes that act in concert to govern cell growth and morphology. The cell processes influenced by the actin cytoskeleton include; cell division, organelle movement, vesicle trafficking, organelle motility, and cell signaling, among other processes just to mention a few. The role of the actin cytoskeleton in the processes highlighted above can be instituted by depolymerizing the actin cytoskeleton and observing the consequences. As Hussey, Ketelaar & Deeks (2006) suggest, latrunculins and the cytochalasins are among the classes of depolymerizers that can be used to depolymerize the actin cytoskeleton while studying its role in most fundamental plant processes.

Discovery of Actin

The discovery of actin is closely related to the discovery of actomyosin. In this light, it is inevitable to discuss how actomyosin was discovered for one to clearly give an account for the discovery of actin. Theodor Engelmann (1879) is known to have been the first individual to study motion in plants and protozoa (Wayne, 2009). Engelmann insightfully stated that the movement exhibited by plants and protozoa is almost similar to the type of

movement exhibited by animals as a result of muscle movement. Engelmann’s assertions were later echoed by Albert Szent-Györgyi (1949) who aptly stated that the similarity in basic principles by which plant an animal organs operate indicate that both plants and animals are made up of the same living matter (Wayne, 2009). Later, after reading about myosin, which was discovered by Vladimir Engelhardt and Militza Ljubimowa, anecdotally a husband and wife, Szent-Györgyi’s interest in studying muscular movement was further boosted. Literature shows that Szent-Györgyi went to the extent of using Engelhardt and Ljubimowa method of isolating myosin (using KCl) to help in his studies. His research entailed the addition of ATP to a thread of myosin on a slide and watching under a microscope.

One day, an aid in Szent-Györgyi’s lab (Szent-Gy ö rgyi and Banga, 1941 as cited in Wayne, 2009) unintentionally left a minced muscle in KCl while he went home for the night only to find the sample strangely thicker than usual the following day. The reaction of this sample on addition of ATP was also strangely vigorous. On studying the two samples, which they labeled myosin A and myosin B (sample left overnight in KCl), Szent-Györgyi and his team (including Ferenc Brunó Straub) discovered that myosin B was enriched with a protein that was a contaminant in myosin A. Such a protein had earlier been isolated by Halliburton (1887) in an impure form. To institute the action of this protein on myosin, Straub added a solution of the protein to myosin A causing myosin B to go into action hence prompting Straub to name this protein Actin (as it had activated myosin A) while myosin B was named

Actomyosin. Proteins similar to actin were later to be discovered in non-muscle cells, like plant cells.

Forms of Actin and Assembly/Disassembly of the Forms

As one of the most preserved proteins on the planet, actin exists mainly in two radical forms; Globular actin (G-actin) and Fibrous actin (F-actin). These names were proposed by Szent-Györgyi and Straub as they continued to carry out experiments on actin. Initially, their experimental results lacked reliability hence were not reproducible (Wayne, 2009). The two embarked on a mission to raise the reliability of their findings. This involved varying the concentration of KCl and observing the accompanying effect on the viscosity of the extract. On varying the concentration of KCl, Straub noticed that the viscosity of the extract was also at variance. The viscosity of the extract increased with the increase in concentration up to a concentration of 0. 1 M KCl. Further increase in the concentration resulted in to a decrease in viscosity of the extract. This was a clear indication that salts have optimal concentration at which they promote polymerization. It was at this point, based on the varying viscosity of the extract, that Straub and Szent-Györgyi asseverated that actin exists in globular and fibrous subunits hence the names F-actin and G-actin (Wayne, 2009).

According to Koolman & Röhm (2005), G-actin exists as a monomer with an approximate mass of 42 kDa. This form of actin carries an ATP or ADP molecule. ATP bound G-actin exhibits more polymerization activity than ADP bound F-actin. The high polymerization activity of ATP bound G-actin enables it to polymerize outside the cell of an organism (in vitro). For example, in a test tube an ATP-bound G-actin can undergo an immediate polymerization in

the presence of Mg2+. However, most plants cells have the ATP-G-actin. F-actin is a polymer form of actin that, unlike G-actin, has polarity. F-actin has two ends, a barbed (+) end and a pointed (-) end (Hussey, Ketelaar & Deeks, 2006; Kamkin, & Kiseleva, 2011), names that are derived, not from the structure of both ends, but from a manner in which the polarity of the two ends can be visualized (Gallo, 2011). As Hussey, Ketelaar & Deeks (2006) attest, the (+) end has a high affinity to monomers than the (-) end hence grows faster.

The ATPase activity of actin enables the transformation of G-actin to F-actin through polymerization. Formation of filaments from the monomers occurs in two key steps; nucleation and elongation. Nucleation involves the combination of two monomers to form a dimer. With subsequent addition of monomers to the product of nucleation, the filament gradually increases in length (elongation). Likewise, F-actin can be reversed to G-actin through de-polymerization. These two processes are generally termed “ treadmilling”. Due to G-actin’s propensity polymerize, the polymerization of G-actin to F-actin is a regulated process that is controlled by a number of mechanism (Jeon, 2003). One of such mechanisms involves the bonding of G-actin with other more than fifty types of actin-sequestering proteins. For instance, a G-actin bound to profilin hence hindering its conversion F-actin. On the same note, Cytochalasins can serve to inhibit the addition of monomers to the (+) end hence impeding further polymerization leading to a process called net-depolymerization (Hussey, Ketelaar & Deeks, 2006). It is also pertinent to note that the two ends have critical concentration at which the addition of a monomer rather than a loss of a monomer is more preferred (Gallo, 2011).

Both end have different critical concentrations of about 0. 6 µM for the pointed end and 0. 08 µM for the barbed end; perhaps the reason why the barbed end has a high affinity for monomers than the pointed end. Again, addition of monomers to both ends continues until a steady state is attained (Gallo, 2011). At this state, the actin filament (F-actin) is maintained at constant length through the losing a monomer at one end while the other end gains a monomer (Gallo, 2011).

During polymerization, the bound ATP is hydrolyzed accompanied with a gradual release of Pi (ADP-phosphate) as an intermediate product (Kamkin, & Kiseleva, 2011; Jeon, 2003). This process has a half time of about 2 s and as can be seen from Jeon's (2003) assertion, the inorganic phosphate remains attached to the ADP. The release of this phosphate can be accelerated with the addition of a regulatory protein like Cofilin, one of the cell proteins that is found in eukaryotic cells just like profilin.

The whole process involving the dynamics of actin is summarized in the diagram below.

Source: http://www. utm. utoronto. ca

Localization of Actin in Plant Cells

Actin can be temporally or spatially localized in plant cells. As mentioned earlier, actin in plants is exist as one of the major components of the cytoskeleton. In an experiment, actin in plant cells can be visualized through labeling with phalloidin, a fluorescent fungal toxin that attaches to F-actin. Wayne (2009) averts that the method was later improved by Peter Hepler and a group of other scientists who pioneered a method of visualizing actin in living plant cells through the injection of plant with fluorescently labeled

phalloidin in an attempt to observe actin filament. According to Benedikt et al. (1998), actin can also be visualized with the help of a green fluorescent type of protein genetically coded to fuse with the actin-binding proteins (as cited in Wayne, 2009).

Functions of Actin in Plant Cells

Cytoplasmic Streaming

Cytoplasmic streaming is a phenomenon that takes place in virtually all plants. Verchot-Lubicz & Goldstein (2009) maintain that the role of cytoplasmic streaming is still not somewhat clear and has received remarkably little coverage in literature. Nonetheless, cyclosis (as cytoplasmic streaming is also known) plays a pertinent role enabling molecule exchange and protein exchange across plant organelles. Furthermore, this phenomenon is directly associated with the mobility of cell organelles in the sense that endoplasmic reticulum and mitochondria, among others, can move within the cell (Verchot-Lubicz & Goldstein, 2009). The movement of such large components of the cytoplasm serves to create a convection, which is faster than diffusion (Wayne, 2009). Experiments have shown that there is an involvement of the actin/myosin system in cytoplasmic streaming. Streaming compounds have been observed to slide along the actin filament (the product of G-actin polymerization); an observation that has validated the decisive role that actin plays in cytoplasmic streaming. Further, research has shown that actin and myosin provide the motive force that promotes cytoplasmic streaming with the plant myosin being identified to offer over twenty times more force than animal myosin (Wayne, 2009).

Root Hair Morphogenesis

During root hair formation, the specialized epithelial cells, canonically called the trichoblast bulge and elongate at the cell membrane at distinct places (Baluska et al., 2000; Miller, De Ruijter, Bisseling & Emons, 1999). Through an experiment, scientist have shown that F-actin has a role to play during the growth and development of root hairs. During one such experiment, microtubules were removed from the trichoblasts of one plant while latrunculin B was introduced to the trichoblast of another plant (Baluska et al., 2000). After some time, it was observed that the plant in which microtubules were removed developed root hairs while the plant in which latrunculin B was injected into the trichoblasts stopped root hair formation after the bulging stage (Baluska et al., 2000). It was postulated that plants get rid of microtubules as soon as root hairs start bulging hence do not have a direct influence on root hair formation. Liu (2011) affirms that microtubules only serve to maintain the direction of the root growth. F-actin is to a considerable extent associated to the developing root hair throughout the growth period (Baluska et al., 2000).

Conclusion

Actin is one of the most preserved and dominant protein making up the cytoskeleton of eukaryotic cells. Actin is tremendously crucial for several processes that are indispensable for plant growth and morphology. For instance actin/myosin system play and all-encompassing role in cytoplasmic streaming, a process responsible for organelle exchange and organelle mobility. In the same light, actin plays a crucial role in during the growth of root hairs. Actin was first isolated by Halliburton (1887) in an impure form,

but later Albert Szent-Györgyi (1949) and his team isolated a relatively pure form of actin with the help of a method proposed by Vladimir Engelhardt and Militza Ljubimowa. Actin received its name based on its effect on myosin. Actin exists in two forms, Globular actin (G-actin)and Filamentaous actin (F-actin). G-actin is a monomer with a capability of binding to ATP or ADP. F-actin, however, is a polymer that has two end, a barbed end (+) and a pointed end (-). The two forms actin can be interconverted through polymerization and depolymerization. The distribution and localization of actin in plants takes a spatial or a temporal form.

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