Inorganic Phosphate, Metabolism, Phospholipids, and Multilamellar Organelles

All living things have cells that go through a series of chemical processes to ensure the body works efficiently. This series of processes is known as cellular metabolism, and one of the most important players of cellular metabolism is inorganic phosphate. Inorganic phosphate (Pi) is one of the few forms of phosphorus present in the human body. The phosphorus in our body is responsible for skeletal development and metabolism.[1] Inorganic phosphate is unique in the sense that it has two major roles in cellular metabolism. The first is the production of vital biological material such as adenosine triphosphate (ATP), nucleic acids, phospholipids, and proteins.[2] The second major role inorganic phosphate has is involved in metabolic pathways. Some examples of metabolic pathways inorganic phosphate has a role in include energy transfer and protein activation.[2]

As previously mentioned, inorganic phosphate is vital to the production of biological material, but phospholipids are particularly important. Phospholipids are vital due to their ability to protect cells and help the cell perform specific functions.[3] In relation to phospholipid structure, inorganic phosphate is required to change from its inorganic form to the active organic material that makes up the phospholipid structure we see in cells.[4] In consideration to metabolism, inorganic phosphate is important to the efficiency of metabolism by providing cellular metabolites, products of metabolism to fuel the body's ability to perform biological functions, to organisms. Without the presence of inorganic phosphate, organisms will be at risk of severe medical disorders such as kidney stone formation and osteoporosis.[5]

Remaining on the focus of phospholipids, they have a key role in the formation of multilamellar organelles. Multilamellar organelles are membrane bound organelles that specialize in lipid secretion and storage.[6] These organelles, with a relative size of about 0.1 to 2 micrometers, are created by many cell types found in mammals and provide lipid materials needed for tissue function and protection.[7] However, multilamellar organelles are not only found in eukaryotes as they have been observed in types of protozoa.[7] With phospholipids making up multilamellar organelles, they tend to form an onion-like shape,[8] with several layers stacked upon each other.

Basically, life on Earth will not be able to function without phosphorus, but more specifically inorganic phosphate. Pi is central to the survival of cells and cellular processes. One such process is metabolism, since cellular metabolism requires the right concentration of inorganic phosphate.[2] Further, with the importance of inorganic phosphate in metabolism comes its presence in phospholipids. With the nature of phospholipids and their purpose in multilamellar organelles, Pi plays a part here too. Given the fact that such organelles are composed of phospholipids, Pi has a role in the contribution of necessities to extracellular areas through lipid layers.[9]

The research article “A phosphate-sensing organelle regulates phosphate and tissue homeostasis,” contains various figures that support and display the researchers findings regarding the newly discovered PXo bodies. The first figure to be analyzed, figure 2, consists of fluorescent and immunogold labeled images. The fluorescent images reveal PXo bodies’ unique characteristics by using dyes, proteins, stains, and tags to indicate the presence of certain components. In the fluorescent imaging, the green fluorescent protein (GFP) and HA tag, which appears red, were placed on opposite ends of the organelle. The overlapping of the green and red fluorescence creates a yellow stain, meaning that a specific component is present. Based on this, we are able to see that PXo bodies have acidic components, lipids, phospholipids, and experience the glycosylation process. However, PXo bodies appear to lack lysosomes, a golgi, and the endocytosis process based on no yellow stain commemorating the presence of such components. In addition, the DAPI fluorescent stain, which appears blue, represents the nucleus. As such, images in figure 2 showed PXo bodies to be an oval-shaped organelle with consistently appearing blue stains.

Figure 3 uses fluorescence resonance energy transfer (FRET) to show how PXo regulates cytosolic inorganic phosphate (Pi) levels.[10] FRET uses a yellow fluorescent dye and cyan fluorescent protein to display the FRET ratio, ranging from a deep blue to a dark red, which indicates how much inorganic phosphate is present in the cytoplasm. The blue fluorescence shows a high level of Pi, whereas red means low levels of Pi. Based on this information, figure 3 images reveal Pi levels increasing as PXo is inhibited. This conclusion is also supported by the graph present in figure 3.f.[10] This graph shows the average FRET ratio of Pi levels between inhibited or uninhibited PXo’s and normal cells. Furthermore, figure 3 suggests that PXo bodies transport Pi out of the cytoplasm, as PXo bodies restrict Pi levels within the cytoplasm.

Figure 4 contains images and graphs that displays the quantity and size of PXo bodies with accordance to Pi availability.[10] In order to identify how Pi levels affect PXo bodies, the researchers put PXo bodies in a normal situation, phosphonoformic acid (PFA) to inhibit Pi, and then PXo-i to inhibit PXo bodies. Figure 4.a-c displayed a decrease in PXo body size and quantity when PFA and PXo-i was applied. In addition, figure 4.e-l uses fluorescence imaging to show PXo bodies when exposed to or concealed from PFA. The images also displayed the lack of PXo body expression when Pi is inhibited. This conclusion is further supported by figure 4.d.[1] Therefore, this data suggests that PXo bodies depend on Pi for biological processes as without it, PXo bodies would be unable to complete normal functions.[10]

Lastly, figure 5 displays charts that contain information on the types of lipids found within PXo bodies. More specifically, figures 5.d and e show that phospholipids take up 90.6% and 84.2% respectively of PXo bodies, with phosphatidylcholine (PC) and phosphatidylethanolamine (PE) holding the majority. Unsurprisingly, with PC and PE being the most important phospholipids in mammals[11], their composition in PXo bodies should remain as the most abundant. However, the difference between the charts is that the chart in panel D displays the PXo body control and panel E shows PXo bodies with the PFA inhibitor.[10] Notably, when Pi was inhibited, the phospholipids change in proportion with PC decreasing. This data suggests that vital phospholipids, such as PC, will decrease in quantity when Pi is inhibited within the PXo bodies.

Based on the data analyzed, it can be concluded that PXo bodies form a distinct organelle with unique biochemical capabilities. PXo bodies are clearly important to the biological processes in eukaryotic cells as this paper displayed evidence that PXo bodies are vital to the transport of Pi. In the case of a deficiency of Pi, there are negative impacts to cell growth and division.[10] Furthermore, the uniqueness of PXo bodies is displayed by the lack of cellular components most commonly taught to be in eukaryotic cells. As an example, we are taught that eukaryotic cells have a golgi body, but the PXo is different in the fact that is lacks markers of a golgi body.[12] This in addition to the information provided in the analyzed paper support the claim that PXo bodies are a distinct organelle that requires further study.

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