Osmotic Investigations: Studies on Cell Mechanics (1877), by Wilhelm Pfeffer [1]

By: Parker, Sara Keywords: Pfeffer cell [2]

Wilhelm Pfeffer [3] published his book *Osmotische Untersuchungen: Studien Zur Zellmechanik* (Osmotic Investigations: Studies on Cell Mechanics) in 1877 during his time as a professor of botany at the University of Basel [4] in Basel, Switzerland. Gordon R. Kepner and Eduard J. Stadelmann translated the book into English in 1985. Verlag von Wilhelm Engelmann in Leipzig [5], Germany, published the original book in German in 1877 and Van Nostrand Reinhold Company in New York, New York, published the English version in 1985. The book focuses on the cell mechanics of osmotic processes to explain why high pressure exists in plant cells. The book also provides one of the earliest detailed descriptions of the Pfeffer Cell, a devise Pfeffer had created to model and study osmosis in plant cells. The model helped Pfeffer propose theories for how osmosis affected metabolism, growth, and development of plant cells.

Osmotic Investigations explores the functions of osmosis and osmotic pressures in plants. Pfeffer had worked and studied at several universities including the University of Basel [4], where he wrote this book, the University of Bonn [6] in Bonn, Germany, and the University of Leipzig [7] in Leipzig [5], Germany. One scientist that influenced Pfeffer was Carl Wilhelm von Nägeli, who studied plant physiology at the University of Zurich [8] in Zurich, Switzerland, in the mid nineteenth century. Pfeffer noted in his 1858 book *Pflanzenphysiologische Untersuchungen* (Physiology Investigations of Plants), that Nägeli had showed how the cell wall grows in surface area and thickness. Nägeli had argued that the pressure against the plasma membrane, or turgor pressure, had little influence on the surface growth of the cell wall, but Pfeffer had argued that turgor pressure caused growth, and he'd described it as the result of two corresponding pressures.

The first kind of pressure occurs when a substance cannot pass through the plant membrane, and osmotic pressure occurs against the cell membrane, which then causes the protoplasm, or liquid part, in the cell to push against the cell wall. The second pressure is when the cell wall reacts correspondingly with an equal and internally directed pressure. These two pressures create turgor pressure.

Unlike Nägeli, Julius von Sachs, who studied plants at the University of Würzburg [9] in Würzburg, Germany, in the 1860s and 1870s, argued that turgor was significant in the growth of the cell wall, and he encouraged Pfeffer to pursue plant physiology. Pfeffer did so with his studies on the effects of light, carbon dioxide, temperature, and osmotic pressure on plant growth. Moritz Traube, who studied membrane chemistry in Berlin, Germany, influenced Pfeffer's work on osmotic pressure because he was perhaps the first person to prepare artificial membranes, which he'd made from cupric ferrocyanide, a compound of carbon, copper, nitrogen, and iron. In 1864, Traube had demonstrated the capability of membranes to react differently to water molecules than they did to small, dissolved solute molecules. Traube used these membranes to search for the causes of high osmotic pressure in plants. In *Osmotic Investigations*, Pfeffer discussed building on the work of Nägeli, von Sachs, and Traube with his work on osmosis.

The book has two parts and twenty-six chapters: Part I titled "Physical Part" and Part II titled "Physiological Part." Part I focuses on Pheffer's experiments with osmosis and is broken into parts A and B. Part A covers chapters one through six and discusses the apparatus and methods of the experiments. The first chapter describes the preparation of the cells, and chapter two discusses the measurement of osmotic water flow. Chapters three through five discuss the filtration, measurement, and calculation of pressure. Finally, chapter six is about the preparation and check of experimental solutions. Part B covers the experiments and conclusions in chapters seven through seventeen. The topics in these chapters cover different aspects of osmosis and osmotic pressure, including diosmosis of solutes, osmotic water flow, and osmotic pressure.

Pfeffer spends most of Part A describing the preparation of the technical apparatus and its measurements. He devised a new apparatus called the *Pfeffer Zelle* or Pfeffer Cell, a device used as a model for the plant cell and plant membrane in order to measure the amount of pressure within a plant cell. It contains a manometer used for measuring the pressure, a porcelain cell, and connecting and closing pieces. Pfeffer describes the process of preparing the Pfeffer Cell because he said it improved upon the devise and experiments of Traube, whose membranes often broke due to high pressures. Pfeffer discusses the treatment of the porcelain cells, which are necessary for the strength of the membranes, as well as copper ferrocyanide as a model for the plant membrane. He says that the amount of time needed to create the Pfeffer Cell helps to create a stronger device and helps prevent the membrane from tearing.

Part B covers many aspects of osmosis in plants. Pfeffer defines osmotic pressure as the equilibrium state between the inward flow of a fluid through a membrane toward a fluid of higher concentration, called endosmosis, and the removal of particles or molecules form a fluid as filtration. Endosmosis occurs when a fluid, which in plants is water, does not pass through a membrane and thus a force causes the flow of water through the membrane to reach equilibrium. Pfeffer explains that the experimental results may not give a definite account of the molecular structure of precipitation membranes, but they would enable scientists to follow the path of a solute through the membrane, which is the process of osmosis.

Pfeffer defines osmotic pressure as the point when equal quantities of fluid flow in and out of a membrane, or diosmosis. Osmotic pressure draws water particles into the interior of the cell along the same paths as those on which they filter outward under pressure. However, if a solute cannot pass through the membrane, then there is a unilateral water flow in which pressure pushes the fluid outward through the capillary space. Pfeffer states that his experiments proved the connection between osmotic pressure and diosmosis, but values of the pressure did not give a relative measure of the width of the pores in the membranes because the nature of the membrane material plays a role in the osmotic effect.

The "Physiological Part" or Part II of the book spans chapters eighteen to twenty-six. Some of the topics of Part II include the plasma membrane, the molecular structure, diosmosis through the plasma membrane, pressure relations in the cell, cell mechanics of movements, and some growth and formation processes. Chapter twenty-four is about plant development, titled &Some Growth and Formation Processes." This chapter relates the experiment with the Pfeffer Cell to the growth of the cell. Pfeffer explains that osmotic pressure seeks to expand the surface area of the cell wall and transversely compresses the cell wall to support layers of the cell. He describes this process as like a mass (or a sponge) that can swell and is then wrapped in a cloth and put in a press. The mass extrudes water until the external pressure is no longer capable of pressing out the stored water, which a greater force retains. The pressure within the cell expands the cell walls from within the cell and the pressure from outside of the cell, such as from surrounding cell walls, creates corresponding turgor pressures.

The cell wall increases in volume by swelling, and it retains absorbed liquids only after the pressure ends. With osmotic pressures come other processes, such as the material needed to form the cell wall. These materials must come through the plasma membrane in both dissolved and insoluble forms. Pfeffer says that the materials needed to form the cell wall must be in contact with an aqueous medium, with air, or another medium, but could not be isolated. He says that there are no facts available about the mechanical cause of the cell wall formation, so he stops the discussion with his conjecture that materials for the cell wall relate to osmosis.

Pfeffer next discusses the formation and distribution of the substances that mediate growth and locomotion of the cell, which are the accumulation of protoplasm in specific locations. Pfeffer says that researchers do not know how external influences affect formation of these substances, but he states that influences such as light, temperature, chemical reagents, gravity, and electricity influence movements in the protoplasm. He spends the rest of chapter twenty-four on chemical reactions that may affect the growth and morphology [10] of the plant. For example, he explains that pressure on the plasma membrane due to a chemical reaction and hydrostatic pressure, which is the pressure equal to the force that the cell wall exerts when it forces water to leave the cell, may affect the plants growth. Even if the pressure is minimal, the pressure could gradually produce important morphological changes in the protoplasm, which would affect the plant cells overall.

Pfeffer's translators, Gordon R. Kepner and Eduard J. Stadelmann, discuss the impact of *Osmotic Investigations* in the introduction to their 1985 book. Kepner and Stadelmann note that Charles Overton, who studied cell membranes in Germany in the early 1900s, described the book three decades after publication as epoch-making, and that Pfeffer had received less than his due of credit. The translators state that they translated the book to disseminate Pfeffer's contributions and make available his authoritative and historically interesting commentaries on the mid-nineteenth century theories of the cell membrane and osmotic phenomena. *Osmotic Investigations* received some recognition after Jacobus van't Hoff, a 1901 Nobel Prize in Chemistry laureate, used Pfeffer's measurements to support his theory of osmotic pressure. The translators explain that Pfeffer's work was neglected because his writing was speculative and abstract.

Sources

1. Collander, Runar. "Overton, Charles Ernest." *Dictionary of Scientific Biography* 10 (2008): 256–7.
2. Nägeli, Carl Wilhelm von, and Karl Eduard Cramer. *Pflanzenphysiologische Untersuchungen* [Physiology Investigations of Plants]. Zurich, Switzerland: Schulthess, 1858. https://books.google.com/books/about/Pflanzenphysiologische_Untersuchungen.html?id=wc1AAAAAcAAJ [11] (Accessed

November 11, 2015).
3. Overton, Charles E. "Über den Mechanismus der Resorption und Sekretion [On the Mechanism of Absorption and Secretion]," in Eds. Nagel, Wilibald A., *Handbuch der Physiologie des Menschen* [Manual of Human Physiology], II (Brunswick, 1907):744–898. https://books.google.com/books/about/Handbuch_der_Physiologie_des_Menschen.html?id=ij4UAAAAQAAJ [12] (Accessed November 11, 2015).
4. Pfeffer, Wilhelm. *Osmotische Untersuchungen: Studien Zur Zellmechanik*. Leipzig [5], Germany: Verlag Von Wilhelm Engelmann, 1877. Translated by Gordon R. Kepner and Eduard J. Stadelmann as *Osmotic Investigations: Studies on Cell Mechanics*. New York, N.Y.: Van Nostrand Reinhold Company, 1985. https://archive.org/details/osmotischeunter01pfefgoog [13] (Accessed November 11, 2015).
5. Robinson, Gloria. "Pfeffer, Wilhelm Friedrich Phillip." *Dictionary of Scientific Biography* 10: (2008) 57–8.
6. Rudolph, G."Traube, Moritz." *Dictionary of Scientific Biography* 13 (2008): 451–3.
7. Sach, Julius von. *Lehrbuch der Botanik* [14] [Textbook of Botany]. Leipzig [5]: Engelmann, 1874. https://archive.org/details/lehrbuchderbotan00sach [15] (Accessed May 9, 2017).
8. Traube, Moritz. *Gesammelte Abhandlungen* [Collected Essays]. Eds. Herman und Wilhelm Traube. Berlin: Mayer und Müller, 1899. https://archive.org/stream/gesammelteabhan00traugoog#page/n11/mode/2up [16] (Accessed May 9, 2017).
9. Van't Hoff, Jacobus Henricus. "Die Rolle des Osmotixchen Druckes in der Analogie Zwischen Lösungen und Gassen." *Zeitschrift für Physikalische Chemie* 1 (1887): 481–508. https://babel.hathitrust.org/cgi/pt?id=uva.x030529698;view=1up;seq=497 [17] (Accessed May 9, 2017). Translated as "The Role of Osmotic Pressure in the Analogy between Solutions and Gases." *Journal of Membrane Science* 100 (1995): 39–44.

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