What Multicellularity Has Brought to Organisms

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Introduction

The evolution of cells to multicellular organisms can be recognized as an important step in diversifying life. This major evolutionary event introduced both animals and plants to Earth, both of which evolved from unicellular ancestors. Animals come from unicellular ancestors such as capsaspora or choanoflagellates. Similarly, plants have also evolved from a single-celled organism, Cyanobacteria. With this change to multicellularity, comes benefits and consequences. A major benefit is the improved immune system of these organisms, which has evolved to better meet new intricate needs. However, a potential consequence can be a greater chance of cancer. This new immune system plays an interesting role in several diseases such as cancer.

How organisms have changed from one-cell to multi-cellular and the benefits and consequences of this change

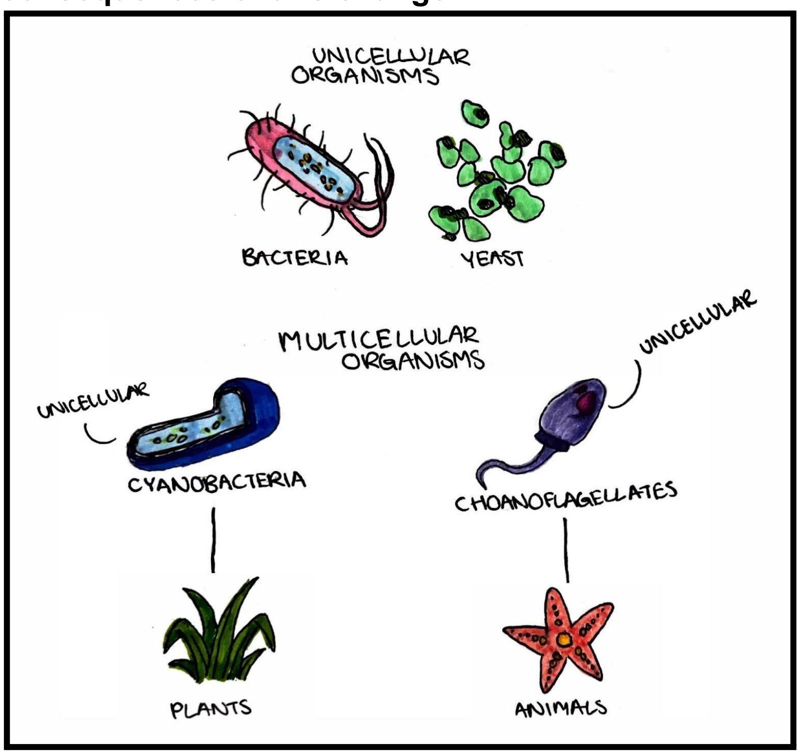

Figure 1: Examples of both unicellular and multicellular organisms. Both plants and animals evolved from their unicellular ancestors.

Over time, organisms have evolved from being unicellular, having only one cell, to multicellular, containing multiple cells. The traditional theory on how this change occurred is that natural selection created multicellular organisms because of their better fit for the environment today. To achieve the complexity of multicellularity, a change in fitness, the measure of how successfully organisms survive and reproduce, had to occur.

Multicellular organisms tend to form groups of cells in order to increase overall size, gain further cell functions, establish homeostasis, or avoid predators. The improved fitness in multicellular organisms connects with their increased stress resistance. With unicellularity, stress resistance is weakened. However in multicellular organisms, the repair of damaged cells is much faster as they can employ specific cells to focus on stress. Instead of one cell managing all the stress like in unicellular organisms, the work is distributed with multicellularity.

The complexity of multicellular organisms, its differing cells, also allows them to adapt to surroundings more effectively than in unicellular organisms. But, with the use of many and different types of cells, there is a great amount of coordination needed to ensure organization. Consequently, the access cells have to nutrients is affected as well the function of all cells. As multicellular systems increase in size, diffusion is no longer enough to support oxygen and nutrient needs. More energy is used to maintain normal functions in these multicellular systems. The distribution of nutrients to cells is then done through vascularization, the development of blood vessels, which takes more energy. Another instance where multicellular organisms use more energy is during proliferation. Control is necessary to keep larger systems organized. More energy is used to keep the activity of cells coordinated. In unicellular organisms, proliferation, the rapid reproduction of cells, is considered the “default state.” But, in multicellular organisms, not every cell can proliferate at the same time or at all. This causes organisms to divide only certain cells at times. But, this can be vulnerable to mistakes. For example, mistakes in multicellular divisions can lead to cancer-causing cells.

How the immune system has evolved to meet the needs of multi-cellular organisms.

Organisms have always had a way of defending themselves from pathogens, which cause disease. Organisms need to be able to protect themselves in order to survive. At the same time, pathogens are constantly evolving to be effective in the organisms they infect.

While unicellular organisms have basic methods of protecting themselves, multicellular organisms have evolved their immune cells. Just as the immune system evolves through the life cycle of humans, it has evolved on a larger scale for initial multicellular organisms. As it is exposed to challenges on the way, the system evolves. Defense mechanisms are picked up and added to the immune system.

Antibiotics are produced by unicellular organisms such as bacteria and fungi. These antibiotics inhibit the growth of other potentially harmful bacteria. Today, antibiotics serve an important role in humans, fighting off infection after being formed by specific cells. Uni-cellular organisms also employ programmed cell death to stop the spread of disease. Other methods of immunity in these organisms include RNA interference and stress response. RNA interference is when RNA mediates the organism’s resistance to viruses. Stress response in unicellular organisms detects the presence of pathogens non-specifically. It increases the expression of genes encoding stress proteins which can bring a cell back to homeostasis, optimal conditions.

The transition from one cell to multiple cells made it clear that a more complex immune system would be necessary. Pattern recognition has evolved in multicellular organisms. Using cell receptors, organisms can identify cells that have certain features that characterize them as pathogens. Unicellular organisms also use this method of pattern recognition but it is more advanced in multicellular organisms. After multicellular organisms recognize pathogens, they use phagocytosis to get rid of the infected cells. Phagocytosis was developed in unicellular organisms for feeding. But, multicellular organisms have developed it as a defense mechanism, phagocytes engulf the pathogens and break them down. Just as uni-cellular organisms use stress response, multi-cellular organisms tend to use systemic response which can also send signals about an infection. An example of this would be inflammation in mammals alerting an organism about a localized infection.

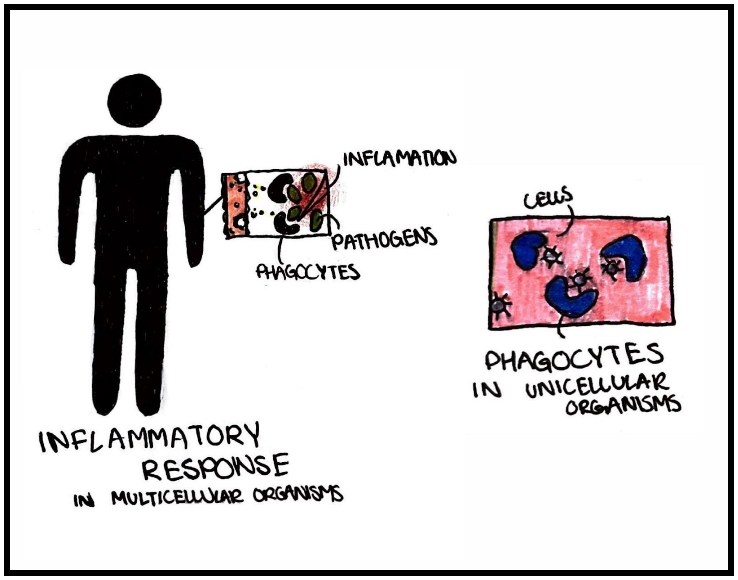

Figure 2: A closer look at inflammatory response at a local site of infection, an example of a systemic response signal. As pathogens infiltrate the skin, inflammation arises to alert the body and serve as defense. The phagocytes shown are used as a defense mechanism, that eats the pathogens, in multicellular organisms. However, in unicellular organisms, the same phagocytes are used to simply feed.

Unicellular organisms have only innate immunity, which is what has been encoded in organisms' genes. This immunity has been passed down through generations with little change. With only short-term memory, defense mechanisms have to restart to fight any infection as information about past fights doesn't get stored. As multicellular organisms are more complex, restarting defense mechanisms is not efficient enough. Adaptive immunity is introduced, made up of mechanisms that have been acquired. This immunity includes immunological memory, allowing organisms to remember how to fight past infections and become immune to them. These two systems are linked and communicate with each other in multicellular organisms. Using the innate system as the first line of defense, the adaptive system regulates the innate cells. The innate cells detect intruders and alert the immune system to then activate its second line of defense.

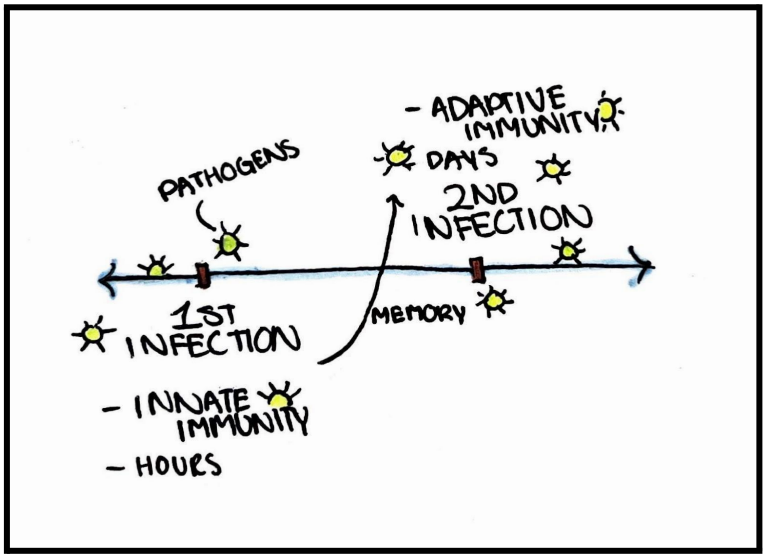

Figure 3: A depiction of how the first line of defense, innate immunity, and the second, adaptive immunity are initiated. With no memory of previous attacks, innate immunity kicks in during the first emergence of these pathogens taking hours. However, when the second infection begins, adaptive immunity stores information from the first attack and fights the infection for days.

The multicellular immune system's role in disease such as cancer

The transition from unicellularity to multicellularity was a major evolutionary advance in network structure and has contributed to cancer. The new shaping of gene regulatory networks includes vulnerability to disruption which can allow the development of cancer. There are many phenotypic, observable, similarities between cancer cells and unicellular organisms. Both have the competitive growth of cells instead of cooperative growth. They also both depend on fermentation. The multicellular state of cells is taken down during the development of cancer, taking organisms back to unicellular genes which help sustain the cancer phenotype. By taking in the evolutionary correlation of multicellularity and cancer, studies can focus on the vulnerabilities regarding cancer. This view on gene regulatory networks can help contribute to potential cancer treatment options and strategies.

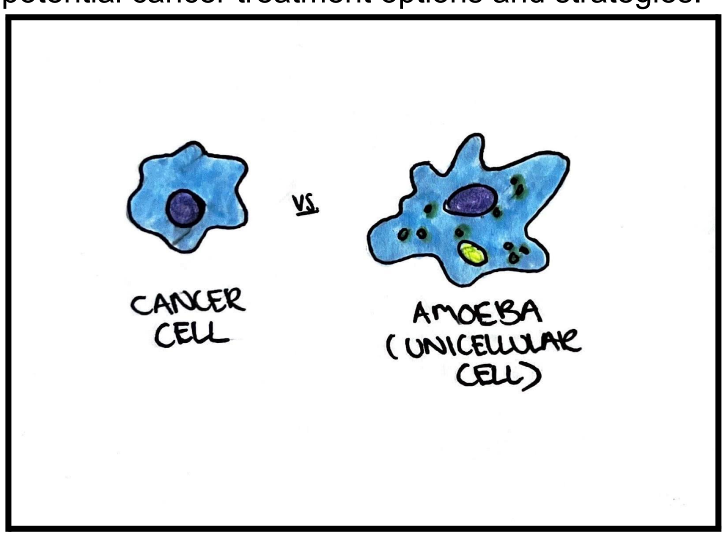

Figure 4: A representation of the shared traits by cancer cells and unicellular organisms. There are distinct similarities between the two.

Conclusion

The achievement of multicellularity marks crucial evolution. Without the transformation of unicellularity to multicellularity, Earth would not be the same. Multicellularity allows great growth. While there are some consequences and challenges that follow this change, there are benefits as well. The complexity of multicellular organisms allows for more functions, including a well-developed immune system. The improved immune system, which has evolved along with multicellularity, brings in new methods of defense. Multicellularity has however contributed to cancer. But, an understanding of just how multicellularity leaves organisms vulnerable can potentially contribute to cancer studies.

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