Cell. Mol. Biomed. Rep. (ISSN: 2823-2550) 2022, 2(1): 33-41
https://doi.org/10.55705/cmbr.2022.330941.1021

Review Article

Cellular structure and molecular functions of plants, animals, bacteria, and viruses

Hamid Kheyrodin[1,*], Raheba Jami[2], Fazal UR Rehman[3]

Article info
Received: 22 Oct 2021
Revised: 08 Dec 2021
Accepted: 30 Jan 2022

Use your device to scan and read the article online

Keywords:
Cell wall, Bacterial structure, Fungi, Eukaryotic cells, Prokaryotic cells, DNA

ABSTRACT

Plant cells are the basic unit of life in organisms of the kingdom Plantae. These organisms as eukaryotic cells have a true nucleus along with particular structures called organelles that perform various functions. The plant cell wall can provide a structural framework to support plant growth and defense the cells against various viral and bacterial pathogens. The cell wall can retain flexibility, also when subjected to developmental, biotic, abiotic stimuli, and stresses it can be efficiently remodeled in response. Genes encoding enzymes are able to fabricate or hydrolyze substances of the plant cell wall exhibit differential expression when subjected to different stresses, suggesting they may facilitate stress tolerance such as heavy metals, dust accumulation, and salty medium through changes in cell composition wall. Bacteria are small single-celled organisms that get the nutrients they need from their environment. Sometimes, this environment can be your child or any other living thing. Bacteria are very small and cannot be seen under a microscope. Bacteria help the digestive system and prevent harmful bacteria from entering the human body as well as some other bacteria are also applied to produce drugs and vaccines. A cell wall as the non-living component can cover the outmost layer of a cell. According to the type of organism, the cell envelope has a different composition. The cell envelope separates the interior contents of the cell from the exterior environment. In addition, it provides shape, support, and protection to the cell and its organelles. However, this cellular component is present exclusively in eukaryotic plants, fungi, and a few prokaryotic organisms. Compounds found in plant cells are absent in animal cells, and DNA base sequences reflect this. Moreover, plant DNA is often larger than animal DNA. In this review, we concluded that the differences between plant and animal DNA defendant on the sequence of bases in the helix.

1. Introduction

A diverse array of functions in the plant cell wall can be carried out via different pathways. Also, the cell wall provides flexibility to support cell division, a biochemical scaffold that enables differentiation, and a pathological and environmental barrier that defends against stress [1]. The cell wall forms the cell and provides strength and support to the protoplasm within the cell (Figure 1). Although the wall is an external and inactive

[1]Department of Soil and Plant, Faculty of Agriculture, Assistant professor, Semnan University, Semnan, Iran
[2]Department of Horticulture, Faculty of Agriculture, Herat University, Herat, Afghanistan
[3]Department of Plant Pathology, College of Agriculture, University of Sargodha, Punjab, Pakistan
***Corresponding Author**: Hamid Kheyrodin(hamid.kheyrodin@semnan.ac.ir)

product of protoplasts, it has special functions and plays an important role in absorbing secretion and transmission [2].

2. Mechanical properties of wall layers

All cell walls contain two layers, the middle lamella and the primary cell wall, and many cells produce an additional layer, called the secondary wall. The middle lamella serves as a cementing layer between the primary walls of adjacent cells [3]. The primary wall is the cellulose-containing layer laid down by cells that are dividing and growing. As the main ability, during growth, primary walls are thinner and less rigid than those of cells that have stopped growing [4]. A fully grown plant cell may retain its primary cell wall or it may deposit an additional, rigidifying layer of different compositions; this is the secondary wall. Secondary cell walls are responsible for most of the plant's mechanical support as well as the mechanical properties prized in the wood [5]. In contrast to the permanent stiffness and load-bearing capacity of thick secondary walls, the thin primary walls are capable of serving a structural, supportive role only when the vacuoles within the cell are filled with water to the point that they exert a turgor pressure against the cell wall [6].

3. The chemical composition of the wall

3.1. Cellulose

Celluloses are large polysaccharide molecules formed by combining n molecules of beta-glucose with azide bonds. The joining of two beta-glucose molecules forms a cellobiose molecule [7]. All 5 molecules of cellobiose form crystalline cellulose with a cubic spatial arrangement [8]. Cellulose microfibrils are obtained from the crystal assemblage and cellulose microfibrils are obtained from a total of 20 microfibrils [9].

3.2. Hemicellulose

Hemicelluloses are part of the wall material and chemically formed from the sharing of 5-carbon sugars such as xylans and 6-carbon sugars such as mannose and uronic acids. In most cases, hemicellulose units are made of a spinal axis with a linear structure that is joined at various locations by hydrogen bonds to the cellulose [10].

3.3. Proteins and pectic polysaccharides

These substances are similar to hemicelluloses but have a much higher amount of uronic acids. Most of the middle septum of cells is made of calcium pectate [11]. The proteins in the wall are composed more of the derivatives of the amino acid proline [12].

4. Biotic Stress and the Plant Cell Wall

In the co-evolutionary battleground between plants and microbes over millions of years, plants have evolved a multi-layered defense system in which the cell wall serves multiple purposes. The plant cell wall may serve as a preformed or passive structural barrier as well as an induced or active defense barrier. Microbes have to circumvent the cell wall and other preformed barriers to establish the desired pathogenic relationship with host plants [13]. This requires appropriate host recognition strategies and the development of suitable infection structures and/or chemical weapons. Failure to evolve appropriate strategies to breach the host wall and other preformed structures result in the microbes becoming non-pathogens and non-adapted pathogens [14].

5. Cell membrane

The cell membrane is the outer covering of the cell that protects the internal organs. This membrane, also known as the plasma membrane, has a number of vital functions (Figure 1). Plants, animals, fungi, protozoa, have eukaryotic cells, and prokaryotic cells are found only in bacteria [15]. Eukaryotic cells belong to the main structure, which includes parts such as DNA, ribosome, vesicle (small sac), endoplasmic reticulum (both rough and soft), Golgi apparatus, cytoskeleton, mitochondrial, vacuole, centriole, lysosome, cytoplasm, membrane plasma and cell wall [16]. Plant cells have large vacuoles and limited cell walls, but animal cells do not have cell walls (Figure 1), and some may have very small vacuoles. Therefore, in animal cells, the cell membrane is the outer covering [17].

6. Vacuole

A vacuole is an organ in a cell that is responsible for storing and holding various solutions or substances. Vacuoles are solutions and compounds in which they are created, stored, or excreted. Compounds in vacuoles include a variety of ions, sugars, amino acids, and organic acids. A vacuole is a chamber that is surrounded by a membrane that prevents the cytosol from being exposed to its contents. Because vacuoles are surrounded by semipermeable membranes, only certain molecules can enter and leave through the vacuole membrane [18].

7. Mitochondria

The mitochondrion, in the cell, is an organ that is responsible for cellular respiration and an energy transfer organ that produces chemical energy in food by oxidative phosphorylation in the form of high-energy bonds of ATP phosphate (adenosine). This organelle is present in all aerobic cells except in bacteria whose respiratory enzymes are located in the cytoplasmic membrane. Mitochondria, like chloroplasts, are composed of two inner and outer membranes.

Mitochondria are found in almost all types of human cells that are vital to human survival. In addition to producing energy, mitochondria store calcium for cellular signaling activities, generate heat in the body and mediate cell growth and apoptosis [19]. The number of mitochondria in each cell is very different. In humans, for example, red blood cells contain no mitochondria, while liver cells and muscle cells may contain hundreds or even thousands of mitochondria. Unlike other cellular organs, mitochondria have two distinct membranes and a single genome and are propagated by binary division. These features suggest that mitochondria have a common evolutionary past with prokaryotes [20].

8. Ribosome

Because proteins are synthesized by ribosomes, they are important. Ribosomes are more or less spherical, dense particles than electrons that range in diameter from 40 to about 300 angstroms. The number of ribosomes in a cell reaches about five hundred thousand. This number varies greatly in different cells as well as in different biological and physiological conditions in a cell [21].

9. Endoplasmic reticulum (ER)

ER is an organ found in all eukaryotic cells. The endoplasmic reticulum inside each cell is a membrane structure that exists extensively throughout the cell. This organ acts as a site for the modification of proteins, the production of macromolecules and lipids, and the transport of substances throughout the cell. In addition, the endoplasmic reticulum is the site for protein translation and folding and the formation of functional protein structures. This organelle is also involved in other processes, including the transport of proteins that are supposed to be part of the cell membrane, and the transport of proteins that must be secreted or released from the cell [22].

10. Golgi apparatus

The Golgi apparatus is an organ in eukaryotic organisms that transports molecules from the endoplasmic reticulum to their destination. The Golgi organ also ultimately alters ER products. The Golgi apparatus consists of a set of flat sacs that branch off from the endoplasmic reticulum [23].

11. Chloroplast and photosynthesis

Chloroplast with two membranes has stroma, stromal thylakoids, thylakoids, and granum parts. Chloroplast membranes with chlorophylls *a* and *b* as the main photosynthetic pigments can capture the energy from sunlight and converts it to the energy-storage molecules adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide phosphate (NADPH) in the photosynthesis process. These pigments can have different responses to environmental stress such as dust storms and salinity, and heavy metals [24-30].

12. Bacterial cell

There are two main groups of bacteria including Gram-positive and Gram-negative according to their cellular envelope structure [31, 32]. Gram-negative bacteria, for example, *Staphylococcus aureus* have thick peptidoglycan in the cell wall and cytoplasmic membrane, although Gram-negative bacteria such as *Escherichia coli* have inner and outer membranes with thin peptidoglycan as cell wall (Figures 2a and b) [33, 34]. In addition, there are various biological components related to each type of bacteria in planktonic and biofilm structures, which are illustrated in Figure 2c [35, 36].

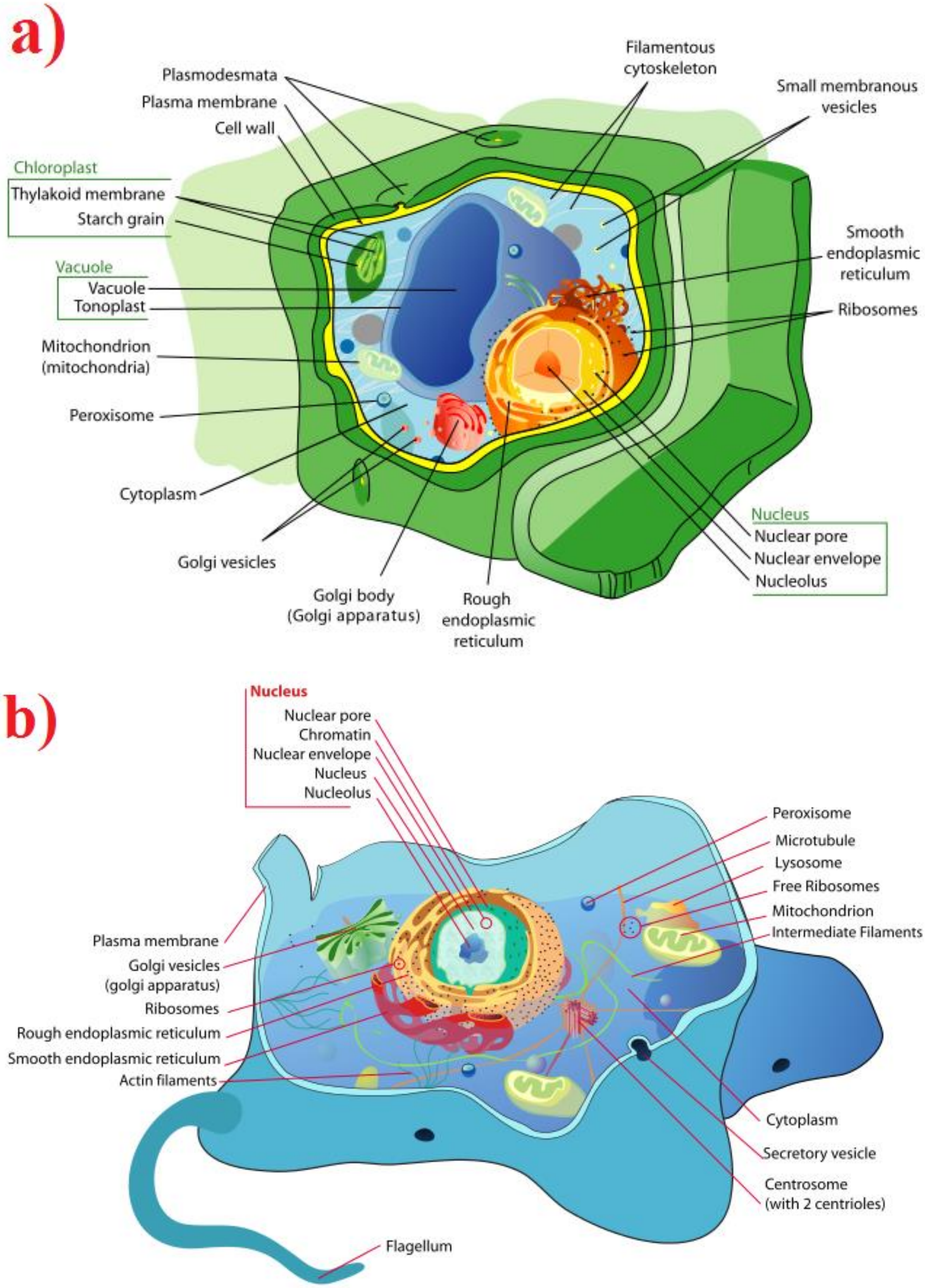

Fig. 1. The main difference of cell structures associated with the plant (a) and animal (b) cells.

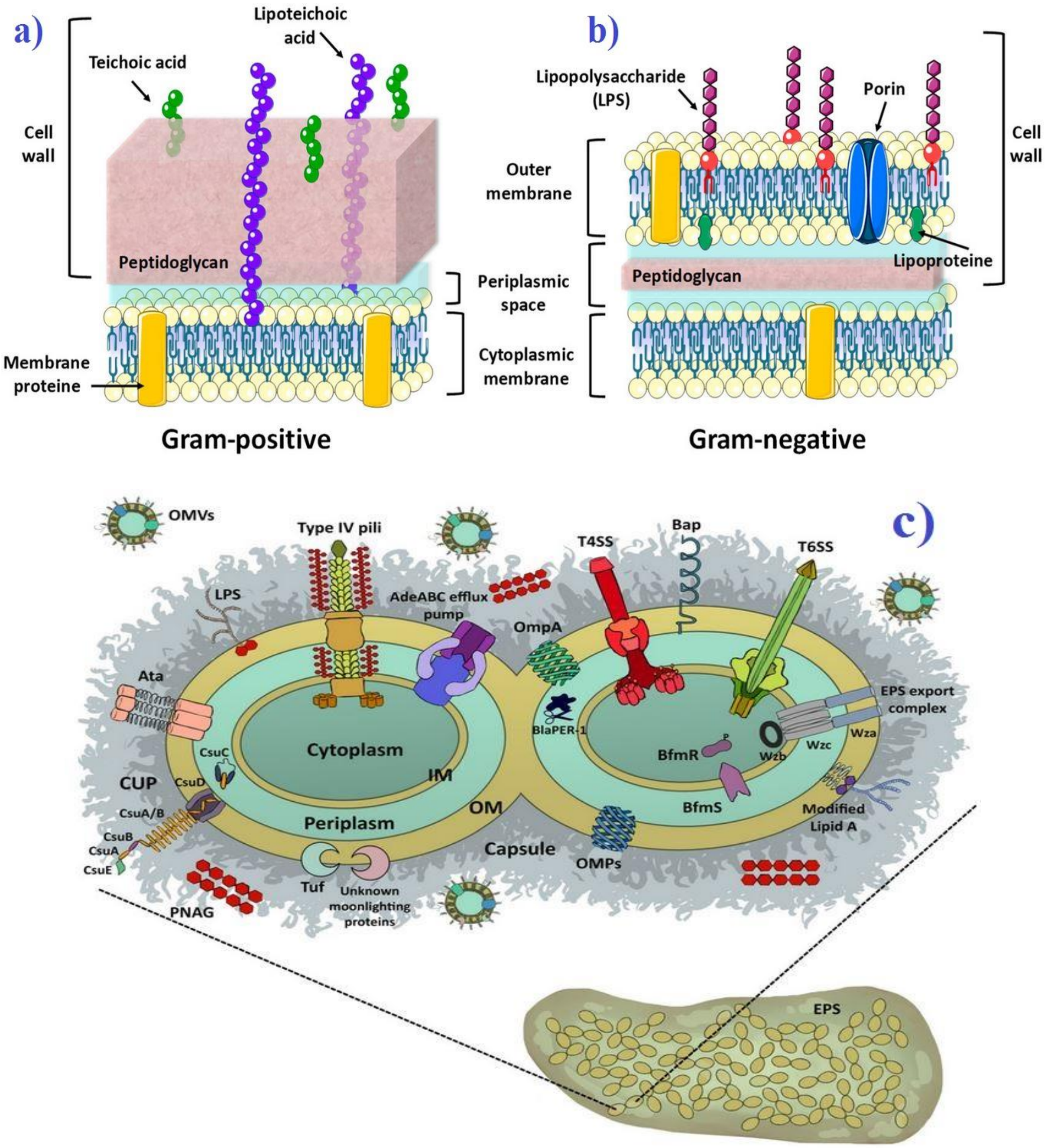

Fig. 2. Different structures of the cellular envelope for Gram-positive (a) and Gram-negative (b) bacteria [33]. Important biological components related to *Acinetobacter baumannii* in biofilm formation (distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/) [35].

13. Viral cells

Viruses are micro-nano infectious agents much smaller compared to bacteria that replicate only inside the living eukaryotic or prokaryotic cells [37]. There are a plethora of viruses, which can infect human, animals, and plants [38]. Usually, viruses have a protective protein coat named capsid structure composed of capsomeres and some viruses such as coronaviruses and influenza A virus also have a lipid envelope derived from the membrane of the host cells (Figure 3) [39, 40].

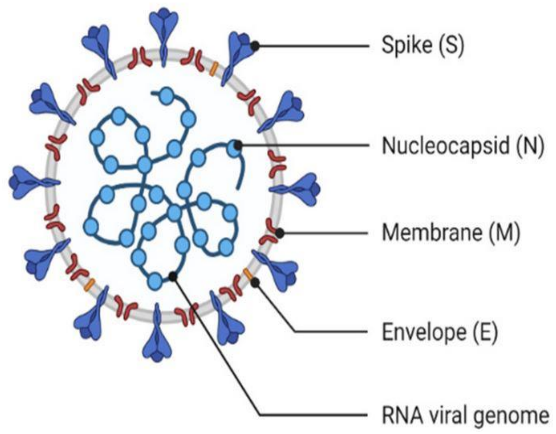

Fig. 3. biological components of coronavirus as an example of viruses with lipid envelope [39].

14. Conclusion

The main functions of the cell wall are to provide structure, support, and protection for the cell. The cell wall in plants is composed mainly of cellulose and contains three layers in many plants. The three layers are the middle lamella, primary cell wall, and secondary cell. Gram-negative bacteria, for example, *S. aureus* have thick peptidoglycan in the cell wall and cytoplasmic membrane, although Gram-negative bacteria such as *E. coli* have inner and outer membranes with thin peptidoglycan as the cell wall. Viruses have a protective protein coat named capsid structure composed of capsomeres and some viruses such as influenza A virus and coronaviruses also have a lipid envelope derived from the membrane of the host cells. One prominent example is known as Cytochrome C. But because the DNA copying process is imperfect, mistakes accumulate over time, making Cytochrome C slightly different in different creatures. The gene regions that specify the amino acid sequence in human Cytochrome C are more similar to those in another mammal like a rabbit, and less similar to a more evolutionarily distant creature. The schematic of classifying animals and plants in kingdoms is facing competition. More recently an alternative system has arisen, based on evolutionary and molecular information. Cytochrome c is perhaps the canonical or paradigmatic molecule in this approach.

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' Contribution

All authors had equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not used any patients in this research.

Funding/Support

This work was supported by Semnan University.

Acknowledgment

The Authors would like to acknowledge funding from Iran Government Research Program.

References

1. Anderson CT, Kieber JJ (2020) Dynamic Construction, Perception, and Remodeling of Plant Cell Walls. Annual Review of Plant Biology 71(1):39-69. doi:10.1146/annurev-arplant-081519-035846
2. Chen H, Fang R, Deng R, Li J (2021) The OsmiRNA166b-OsHox32 pair regulates mechanical strength of rice plants by modulating cell wall biosynthesis. Plant Biotechnology Journal 19(7):1468-1480. doi:https://doi.org/10.1111/pbi.13565
3. Crang R, Lyons-Sobaski S, Wise R (2018) Cell Walls. In: Crang R, Lyons-Sobaski S, Wise R (eds) Plant Anatomy: A Concept-Based Approach to the Structure of Seed Plants. Springer International Publishing, Cham, pp 155-179. doi:10.1007/978-3-319-77315-5_5
4. Zhang T, Tang H, Vavylonis D, Cosgrove DJ (2019) Disentangling loosening from

softening: insights into primary cell wall structure. The Plant Journal 100(6):1101-1117. doi:https://doi.org/10.1111/tpj.14519
5. Zhang B, Gao Y, Zhang L, Zhou Y (2021) The plant cell wall: Biosynthesis, construction, and functions. Journal of Integrative Plant Biology 63(1):251-272. doi:https://doi.org/10.1111/jipb.13055
6. Stępiński D, Kwiatkowska M, Wojtczak A, Polit JT, Domínguez E, Heredia A, Popłońska K (2020) The Role of Cutinsomes in Plant Cuticle Formation. Cells 9(8). doi:10.3390/cells9081778
7. Dadoo N, Zeitler S, McGovern AD, Gramlich WM (2021) Waterborne functionalization of cellulose nanofibrils with norbornenes and subsequent thiol-norbornene gelation to create robust hydrogels. Cellulose 28(3):1339-1353. doi:10.1007/s10570-020-03582-z
8. Alavi M (2019) Modifications of microcrystalline cellulose (MCC), nanofibrillated cellulose (NFC), and nanocrystalline cellulose (NCC) for antimicrobial and wound healing applications. e-Polymers 19(1):103-119. doi:doi:10.1515/epoly-2019-0013
9. Solala I, Driemeier C, Mautner A, Penttilä PA, Seitsonen J, Leppänen M, Mihhels K, Kontturi E (2021) Directed Assembly of Cellulose Nanocrystals in Their Native Solid-State Template of a Processed Fiber Cell Wall. Macromolecular Rapid Communications 42(12):2100092. doi:https://doi.org/10.1002/marc.202100092
10. Dror Y, Rimon E, Vaida R (2020) The Dietary Fiber. In: Dror Y, Rimon E, Vaida R (eds) Whole-Wheat Bread for Human Health. Springer International Publishing, Cham, pp 105-136. doi:10.1007/978-3-030-39823-1_7
11. Parkar SG, Frost JKT, Rosendale D, Stoklosinski HM, Jobsis CMH, Hedderley DI, Gopal P (2021) The sugar composition of the fibre in selected plant foods modulates weaning infants' gut microbiome composition and fermentation metabolites in vitro. Scientific Reports 11(1):9292. doi:10.1038/s41598-021-88445-8
12. Lwalaba JLW, Zvobgo G, Mwamba TM, Louis LT, Fu L, Kirika BA, Tshibangu AK, Adil MF, Sehar S, Mukobo RP, Zhang G (2020) High accumulation of phenolics and amino acids confers tolerance to the combined stress of cobalt and copper in barley (Hordeum vulagare). Plant Physiology and Biochemistry 155:927-937. doi:https://doi.org/10.1016/j.plaphy.2020.08.038
13. Yadav V, Wang Z, Wei C, Amo A, Ahmed B, Yang X, Zhang X (2020) Phenylpropanoid Pathway Engineering: An Emerging Approach towards Plant Defense. Pathogens 9(4):312
14. Schulz S, Stephan A, Hahn S, Bortesi L, Jarczowski F, Bettmann U, Paschke A-K, Tusé D, Stahl Chad H, Giritch A, Gleba Y (2015) Broad and efficient control of major foodborne pathogenic strains of Escherichia coli by mixtures of plant-produced colicins. Proceedings of the National Academy of Sciences 112(40):E5454-E5460. doi:10.1073/pnas.1513311112
15. Eneva R, Engibarov S, Abrashev R, Krumova E, Angelova M (2021) Sialic acids, sialoconjugates and enzymes of their metabolism in fungi. Biotechnology & Biotechnological Equipment 35(1):364-375. doi:10.1080/13102818.2021.1879678
16. Yu H, Guo Y, Zhu W, Havener K, Zheng X (2021) Recent advances in 1,8-naphthalimide-based small-molecule fluorescent probes for organelles imaging and tracking in living cells. Coordination Chemistry Reviews 444:214019. doi:https://doi.org/10.1016/j.ccr.2021.214019
17. Kaiser S, Scheuring D (2020) To Lead or to Follow: Contribution of the Plant Vacuole to Cell Growth. Frontiers in Plant Science 11. doi:10.3389/fpls.2020.00553
18. van Bel AJE (2021) The plant axis as the command centre for (re)distribution of sucrose and amino acids. Journal of Plant Physiology 265:153488. doi:https://doi.org/10.1016/j.jplph.2021.153488
19. Auger C, Vinaik R, Appanna VD, Jeschke MG (2021) Beyond mitochondria: Alternative energy-producing pathways from all strata of life. Metabolism 118:154733. doi:https://doi.org/10.1016/j.metabol.2021.154733

20. Filograna R, Mennuni M, Alsina D, Larsson N-G (2021) Mitochondrial DNA copy number in human disease: the more the better? FEBS Letters 595(8):976-1002. doi:https://doi.org/10.1002/1873-3468.14021
21. Douce R (2012) Mitochondria in higher plants: structure, function, and biogenesis. Elsevier,
22. Lemmer IL, Willemsen N, Hilal N, Bartelt A (2021) A guide to understanding endoplasmic reticulum stress in metabolic disorders. Molecular Metabolism 47:101169. doi:https://doi.org/10.1016/j.molmet.2021.101169
23. Agliarulo I, Parashuraman S (2022) Golgi Apparatus Regulates Plasma Membrane Composition and Function. Cells 11(3). doi:10.3390/cells11030368
24. Alavi M, Karimi N (2015) Effect of the simulated dust storm stress on the chlorophyll a fluorescence, Chlorophyll content, Flavonoids and phenol compounds in medicinal plant Thymus vulgaris L. journal of plant process and function 4(13):17-23
25. Khan I, Awan SA, Rizwan M, Ali S, Hassan MJ, Brestic M, Zhang X, Huang L (2021) Effects of silicon on heavy metal uptake at the soil-plant interphase: A review. Ecotoxicology and Environmental Safety 222:112510. doi:https://doi.org/10.1016/j.ecoenv.2021.112510
26. Alavi M (2017) Evaluation of cement dust effects on soil microbial biomass and chlorophyll content of Triticum aestivum L. and Hordeum vulgare L. International Journal of Human Capital in Urban Management 2(2):113-124. doi:10.22034/ijhcum.2017.02.02.003
27. Alavi M, Sharifi M, Karimi N (2016) Simulated dust storm effect on dry mass, chlorophylls a, b and chlorophyll fluorescence of C 3 (Triticum aestivum L.) and C 4 (Zea mays L.) plants. Biharean Biologist 10(2):113-117
28. Allel D, Ben-Amar A, Abdelly C (2018) Leaf photosynthesis, chlorophyll fluorescence and ion content of barley (Hordeum vulgare) in response to salinity. Journal of Plant Nutrition 41(4):497-508. doi:10.1080/01904167.2017.1385811
29. Alavi M, Sharifi M, Karimi N (2014) Response of chlorophyll a fluorescence, chlorophyll content, and biomass to dust accumulation stress in the medicinal plant, Plantago lanceolata L.'. Iranian Journal of Plant Physiology 4:1055-1060
30. Stirbet A, Lazár D, Kromdijk J, Govindjee (2018) Chlorophyll a fluorescence induction: Can just a one-second measurement be used to quantify abiotic stress responses? Photosynthetica 56(1):86-104. doi:10.1007/s11099-018-0770-3
31. Alavi M, Rai M (2021) Antisense RNA, the modified CRISPR-Cas9, and metal/metal oxide nanoparticles to inactivate pathogenic bacteria. Cellular, Molecular and Biomedical Reports 1(2):52-59
32. Aubais aljelehawy Qh, Hadi Alshaibah LH, Abbas Al- Khafaji ZK (2021) Evaluation of virulence factors among Staphylococcus aureus strains isolated from patients with urinary tract infection in Al-Najaf Al-Ashraf teaching hospital. Cellular, Molecular and Biomedical Reports 1(2):78-87
33. Martínez-Carmona M, Gun'ko YK, Vallet-Regí M (2018) Mesoporous Silica Materials as Drug Delivery: "The Nightmare" of Bacterial Infection. Pharmaceutics 10(4). doi:10.3390/pharmaceutics10040279
34. Abbas-Al-Khafaji ZK, Aubais-aljelehawy Qh (2021) Evaluation of antibiotic resistance and prevalence of multi-antibiotic resistant genes among Acinetobacter baumannii strains isolated from patients admitted to al-yarmouk hospital. Cellular, Molecular and Biomedical Reports 1(2):60-68
35. Pompilio A, Scribano D, Sarshar M, Di Bonaventura G, Palamara AT, Ambrosi C (2021) Gram-Negative Bacteria Holding Together in a Biofilm: The Acinetobacter baumannii Way. Microorganisms 9(7):1353
36. Almasian-Tehrani N, Alebouyeh M, Armin S, Soleimani N, Azimi L, Shaker-Darabad R (2021) Overview of typing techniques as molecular epidemiology tools for bacterial characterization. Cellular, Molecular and Biomedical Reports 1(2):69-77
37. Alavi M, Asare-Addo K, Nokhodchi A (2020) Lectin Protein as a Promising Component to Functionalize Micelles, Liposomes and Lipid NPs against

Coronavirus. Biomedicines 8(12). doi:10.3390/biomedicines8120580
38. Tourang M, Fang L, Zhong Y, Suthar RC (2021) Association between Human Endogenous Retrovirus K gene expression and breast cancer. Cellular, Molecular and Biomedical Reports 1(1):7-13
39. Daemi HB, Kulyar MF, He X, Li C, Karimpour M, Sun X, Zou Z, Jin M (2021) Progression and Trends in Virus from Influenza A to COVID-19: An Overview of Recent Studies. Viruses 13(6). doi:10.3390/v13061145
40. Rahbar-Karbasdehi E, Rahbar-Karbasdehi F (2021) Clinical challenges of stress cardiomyopathy during coronavirus 2019 epidemic. Cellular, Molecular and Biomedical Reports 1(2):88-90

How to Cite This Article:

kheyrodin H, Jami R, Rehman FU (2022) Cellular structure and molecular functions of plants, animals, bacteria, and viruses. Cellular, Molecular and Biomedical Reports 2(1):33-41. doi:10.55705/cmbr.2022.330941.1021