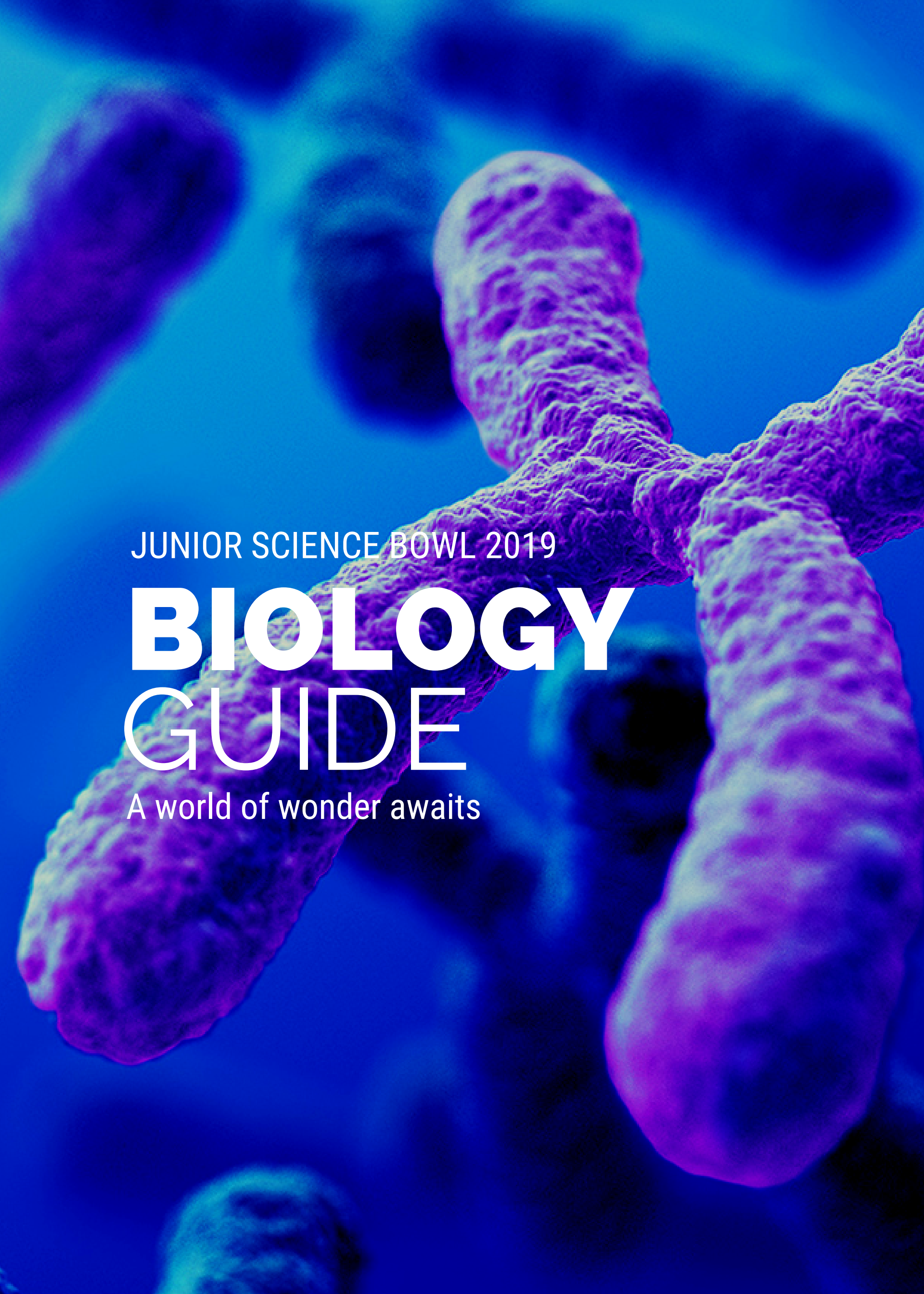


JUNIOR SCIENCE BOWL 2019

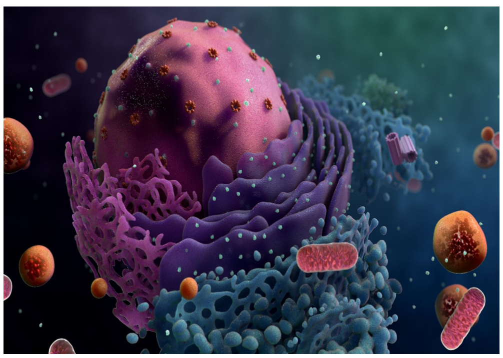
BIOLOGY GUIDE

A world of wonder awaits

Introduction

In the field of Biology, a cellular understanding of living things provides scientists with an unimaginable amount of intelligence when seeing the world. The complexity of the world's many systems are all compressed into the microscopic detail of cells that make up all living organisms. From plants and leaves to humans and animals, all **biotic** entities are compressed into several **specialized** cells that work together to form greater structures and systems, essential for everyday life. In this background guide, the basics of cell biology will be introduced, investigated, and used as a fundamental basis for high school biology.

Aim



This guide aims to highlight topics including the functionality of the cell, cell organelles, cellular respiration, and energy, as well as cellular reproduction. To apply this knowledge to real-life situations, an extension portion has been added to explore how cellular biology is used in modern medicine. This entails the use of cellular knowledge in microscopy, genetics and disease research.

What are Cells?

The definition of a cell is often explained through the laws of the **cell theory**. The cell theory was an ongoing theorem in the early 1800s where scientists such as Rudolf Virchow, Matthias Schleiden, and Theodor Schwann respectively, formulated the first two laws of the theorem.

With the developments of previous scientists in cell biology and the dated observations of the three scientists, the cell theory was born to detail the properties of the cell.

The Three Laws of Cell Theory

1. Cells are the smallest unit of life as they are indivisible.
2. All cells are made up of pre-existing cells through cellular reproduction (Virchow)
3. All living things are made up of cells. (Schwann and Schleiden)

As cells make up all living things, they are also **sub-specialized** to incorporate the essential functions of all biotic organisms. These sub-specialties are categorized based on the function of the cell and are directly associated with the nature of the organism. This relates to the organism being either a **single-celled (unicellular)** or **multicellular** organism, classified by their cells being either **prokaryotic** or **eukaryotic**. A Eukaryotic cell, usually found within multicellular organisms, is a **membrane-bound** cell that contains a nucleus. Eukaryotic cells are found in plants, fungi, bacteria, and animals. The term for "prokaryotic cells" comes from Greek origin meaning "before nucleus" signifying that it does not contain a nucleus or any other membrane-bound **organelles**. Examples of prokaryotic cells include *E.coli* and many other types of bacteria. The table below highlights the three major differences between these two types of cells:

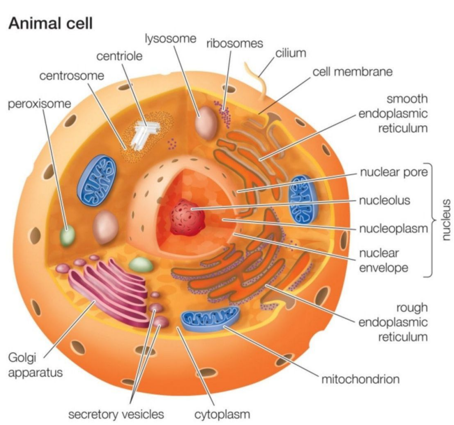
Prokaryotic Cells	**Eukaryotic Cells**
Do not contain a cell membrane: has no regulation of matter exchange	Contain a semipermeable cell membrane that allows the cell to control the amount and types of matter moving in and out of the cell
Do not contain a nucleus	Contains a nucleus
Examples include: most bacteria and archaeans	Examples include: humans, plants and fungi

Animal cell vs. Plant cell

As plants and animals fall under the categorization of living or biotic things, they both also contain cells. Though they are both living things and are made up of cells, the needs of animals and plants on a cellular level are very different. Due to the processes of photosynthesis and cellular respiration (refer to “Mitochondria for Cellular Energy” section), the tiny structures of their cells are different.

For plant cells, the presence of a cell wall surrounding the cell membrane acts as a shield towards foreign cells, usually containing no filtration or **permeability**. In addition to the cell wall, a plant cell also contains a large, central vacuole (which an animal cell does not have) to contain larger amounts of water for distribution around the cell. The most vital differentiation between a plant and animal cell lies in a plant cell’s ability to **procreate** “food” or energy rather than intaking energy from other biotic organisms(animal cell source of energy). This ability is made possible through **chloroplasts** that are sites of photosynthesis where **chlorophyll** is produced as energy. Through these differences, the **cellular productivity** of animal and plant cells are optimized to increase **cellular functionality.**

To further understand the differences between the two types of cells, a labeling requirement with the diagrams below works to promote cellular structure comprehension.



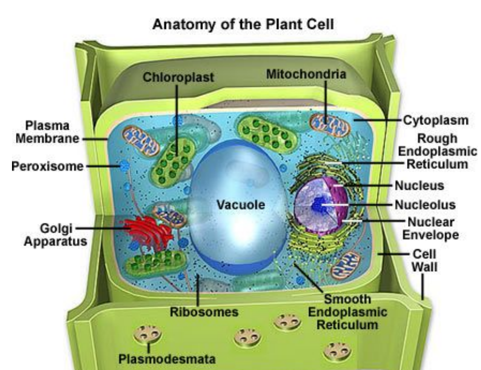


Figure 1

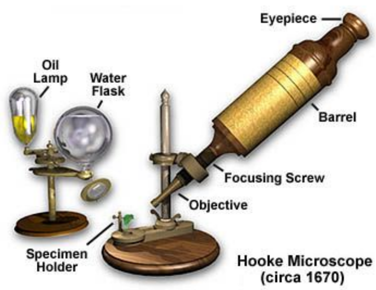
Extension Question:

1. Why does a plant cell require different/additional organelles to maintain cellular productivity?

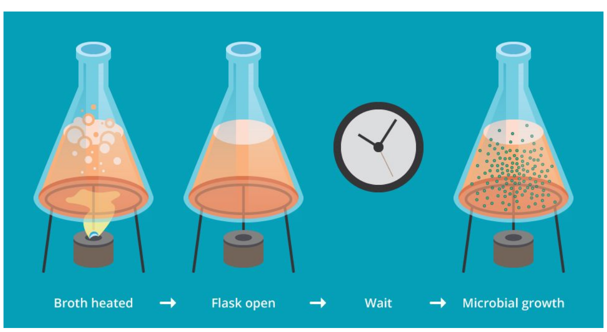
Scientific History

The scientific advancements in cell biology stem from the early contributions of scientists dating back to the first **compound microscope**. This compound microscope was created by Zacharias Janssen in 1595, which motivated the scientific community to start viewing organisms under high magnitudes of magnification..

With the influence of the first compound microscope, Robert Hooke devised his own model of the compound scope, making it the second, yet more advanced model of the microscope. With the new version of the microscope and the research of Robert Hooke, the discovery of the cell emerged in 1665, 70 years after Janssen.



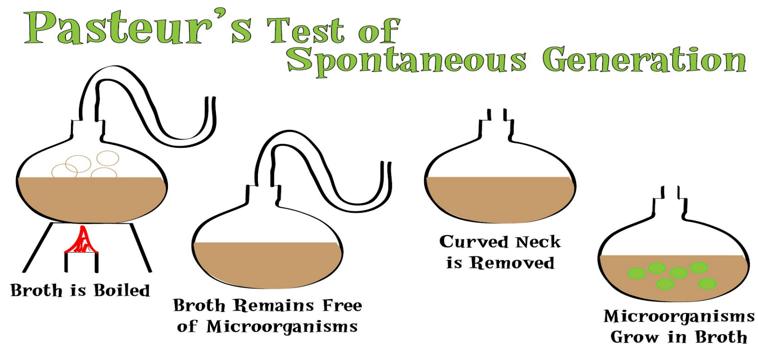
Following this discovery, many other major advancements to the understanding of cells were made. Antonie Van Leeuwenhoek and Robert Brown are staple household names when referring to the discovery of cellular properties. Van Leeuwenhoek, in addition to his other discoveries in the field of science, was accredited for the observations of “free-living cells” or **animalcules** that survive as independent systems. With his observation and the use of a simple single lens, he observed the movement in different single cells. A major result from his research around the late 1600s showed the existence of bacteria and microorganisms present in water. Robert Brown’s contribution involved the discovery and identification of the nucleus in 1831.



Through the trial and error period of cellular understanding, the belief in **Spontaneous Generation** became popular in the cell biology field. **Spontaneous Generation** or **Abiogenesis** is defined as the idea that life can spontaneously/randomly emerge from abiotic/nonliving things.

At the peak of this movement, many scientists brought ideas to the science field that proved/discredited the idea of abiogenesis. Some of which include Francesco Redi and

Louis Pasteur, who discredited and disproved respectively, the theory of spontaneous generation. Through the research and experimentation of Louis Pasteur in 1859, the idea of abiogenesis was disproved with the use of the “S-shaped flask” experiment.



Cellular Functionality

When looking into basic cell functions, it is important to understand the parts within the cell that perform different tasks. The study of this requires an in-depth look into the parts of a cell that work together to create a functioning **open system** where the cell’s productivity is **maximized**. When the productivity of the cell is maximized, the cell’s **potential** is ablefunction at an **optimal** pace. This is how an effective cellular open system is created which promotes the health and functionality of the cell. The specific parts of the cell that influence this open system effect are called **organelles,** where the functions they perform are similar to organs in a human body. These organelles have independent jobs within the cell that contribute to the overall functionality of the cell.

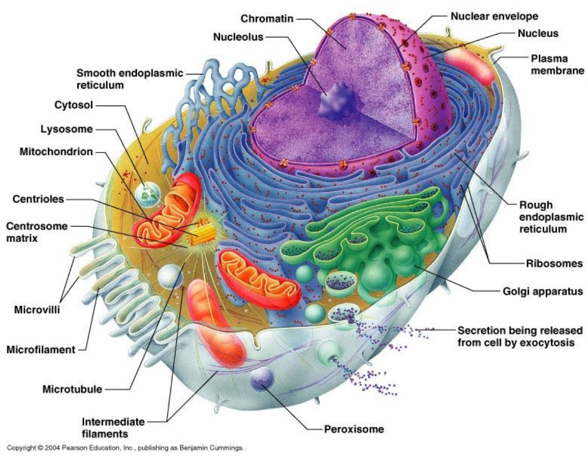
The organelles listed below are fundamentally crucial to cellular function:

Organelle Name	**Organelle Function**
Nucleus	The main control center of the cell, responsible for DNA storage of chromosomes for cell reproduction. This organelle controls the inherited traits of a cell while also directing cell division.

Nucleolus	Smaller structures within the nucleus responsible for RNA and protein production. The nucleolus is also the site of ribosome production.
SER (smooth endoplasmic reticulum)	An interconnected network of flattened sacs that is responsible for the synthesis of lipids/fats.
RER (rough endoplasmic reticulum)	A framework of flattened sacs that is responsible for the synthesis of lipids/fats. Compared to the SER, the RER has ribosomes attached to the surface which aid to create protein. Ribosomes: Tiny organelles that contain RNA, amino acids and other proteins within the cytoplasm.
Mitochondria	Organelle that is the site of energy production as ATP in the cell. This organelle is responsible for cellular respiration and photosynthesis.
Lysosomes	Organelle that acts as the storage of waste products in the cell. Also, infamously dubbed the “suicide sac”.
Cell membrane	Organelle that surrounds the cell, responsible for the exchange of matter and waste. The cell membrane responds to danger within the surroundings of the cell which allows it to control the open system.
Vacuoles	Organelle that is the largest site of storage for the cell. Vacuoles vary in size depending on cellular function and stores nutrients and water.
Cytoplasm	Organelle that fills the mass of the cell which works as a cushion of support for other organelles.
Golgi Apparatus	The organelle that packages and exports proteins and matter from the endoplasmic reticulum

Organelles solely found in plant cells:	
Chloroplast	Organelle solely found in plant cells that is the major site for energy production through photosynthesis.
Cell Wall	Organelle solely found in plant cells that restrict the entrance of matter and surrounds the cell membrane.

The organelles above are labeled below to show a visual representation of cellular structures:



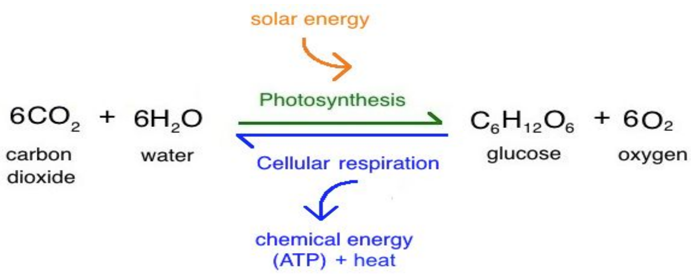
Extension Question:

1. How do these structures work cohesively?

Mitochondria and Cellular Energy

In the production of energy in the cell, the mitochondrion (plural form of "mitochondria") are essential in the formation of **ATP**, the protein responsible for cell function. Due to the use of ATP, a cell is capable of two processes that occur continuously throughout the cell. In any given moment, an animal cell undergoes **cellular respiration** whereas in plant cells, both **photosynthesis** and **cellular respiration** processes occur.

The process of **cellular respiration** occurs as a result of ATP production and works to expel carbon dioxide out of the cell while intaking oxygen. This allows the cell to produce carbon dioxide with the intake of oxygen. Within a plant cell, both cellular respiration and **photosynthesis** work to create an interconnected chain of oxygen production and carbon dioxide intake. The process of photosynthesis is the complete opposite, where carbon dioxide is absorbed into the plant through specialized stomata and guard cells and producing oxygen as a **product.** This process uses a specific set of **reactants** to properly produce oxygen, in which sunlight is a required component.



With the need for sunlight in photosynthesis, the entire process can only be performed during the times where sunlight is available. This requirement isn't evident within cellular respiration and thus, can be performed year-round. With these two processes, energy is produced and circulated with the mitochondrion being vital to their production.

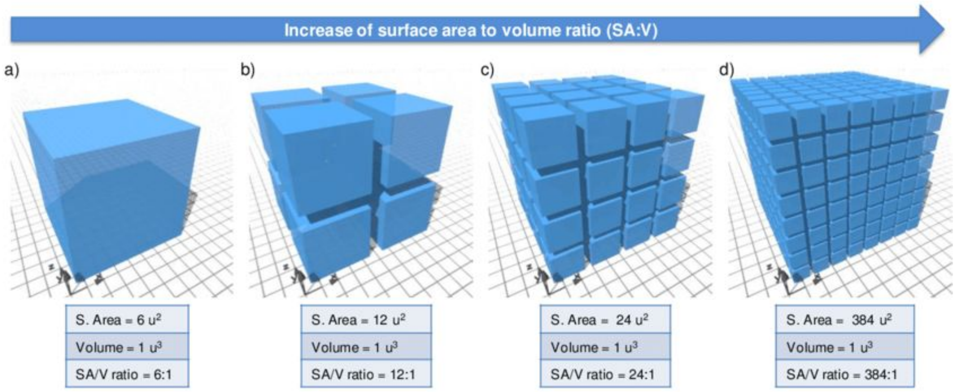
Extension Question:

1. What do the differences between **Cellular Respiration** and **Photosynthesis** suggest about cells and energy?

Cells as Open Systems and Energy

For a cell to be an active and effective **open system**, it would need to have a balanced flow of energy and waste. An open system refers to the balanced exchange of energy and matter with its surroundings. Within an organism, a healthy balance of energy and matter is in the food consumed and waste produced, a healthy input and output balance. The creation of energy in the cell is vital to cellular reproduction and growth, which also improves its **SA:V ratio.**

The SA:V ratio refers to the surface area of the cell compared to its volume. This comparison is used to determine the effectivity of a cell, where when the surface area is high and the volume is low, the cell is working at its greatest productivity potential.The surface area of the cell (cell membrane) controls the amounts of nutrients consumed as well as the amounts of waste excreted. While, the volume relates to the amounts of nutrients stored and waste produced within the cell. To the greatest productivity potential, a cell would need to increase the amounts of energy and nutrients consumed through the surface area of the cell while decreasing the amounts of waste produced. As a result, an optimal SA:V ratio would need **the greatest SA that is directly proportional to the least amount of V.**

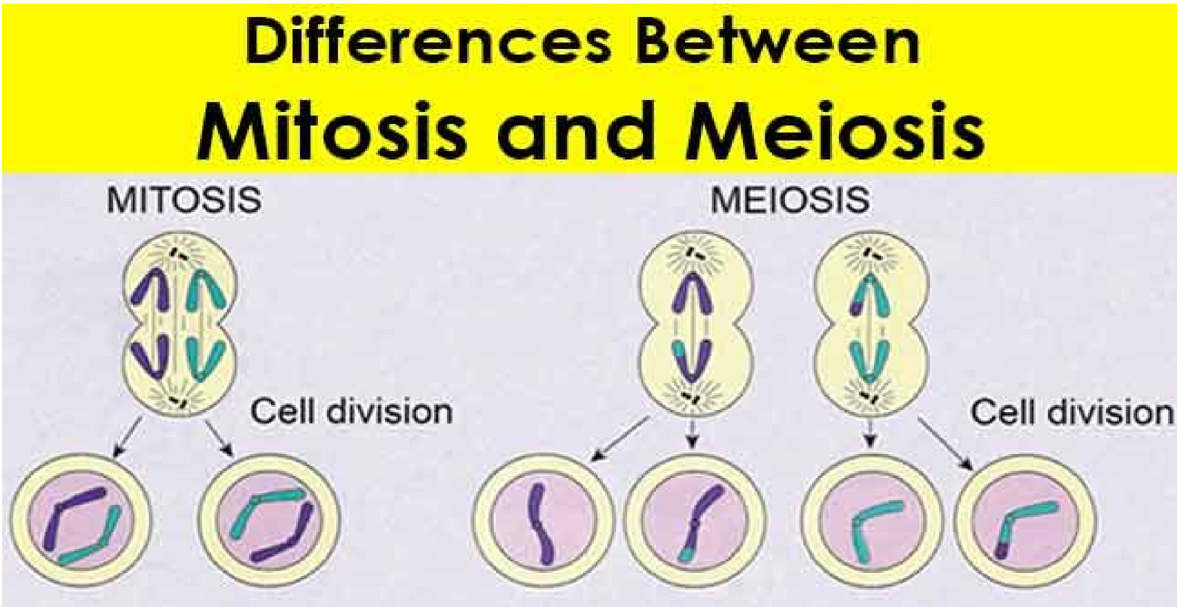


Extension Question:

1. What structures in a cell (plant/animal) help to ensure an effective open system?
2. Between a Eukaryote/Prokaryote cell, which of the two would be an ineffective open system?

Cell Reproduction

Cellular reproduction is the process of procreating cells from pre-existing cells proposed by Virchow in the cell theory. Within procreation, the processes depend on whether the cell is a **gamete** cell or a **somatic** cell. Gamete cells are sexual cells used within animal reproduction which are different within females and males. Somatic cells make up the remaining set of cells from muscles to fingers within animals. With gamete cells, reproduction occurs using a process called **Meiosis** while somatic cells utilise **Mitosis** as its process of reproduction. In meiosis when cells divide, they produce four different sex cells or haploid cells. These haploid or daughter cells are genetically different and involves two successive divisions. Mitosis produces two different somatic cells or diploid cells that are genetically identical and occur in one division. Altogether, a cell's ability to reproduce in both plants and animals works to expand the size of an organism.



Applications in Modern Medicine

As developments in medical treatments progress, new studies constantly rely on cell biology to create hope for people suffering from terminal diseases. Within these studies, concepts like cell communication and gene mapping are applied to HIV and cancer research. Cell communication is a cell's ability to connect with its surroundings through messenger molecules (hormones) that attach themselves to the molecules of another cell. As they bond together on the surface of the secondary cell membrane, a diagnosis of diseases can be reached through carried bacteria. Gene mapping uses microscopes to look at genomes (completed DNA sequence). These specialized microscopes use better techniques to observe genomes and find genetic diseases within patients.

Other technologies that use cell biology to create advancements in modern medicine include the "Green Fluorescent Protein" technology and amazing 3D models of molecules through "X-ray crystallography". The "green fluorescent protein" technology tracks the movement of essential proteins to understand generative disorders like Huntington's disease and Parkinsons. X-ray crystallography use x-rays to analyze x-ray patterns to study molecular structure details and how they function. With the use of these technologies combined, there is potential that leads to future treatments of these deadly diseases.The importance of cellular biology goes beyond its application to medicine and disease research. An understanding of cellular biology allows a greater appreciation for the structures and organisms in everyday life.

Extension Question:

1. What other applications to modern medicine could cellular biology have other than the ones mentioned above?

Glossary words

Biotic: The classification of all living things
Specialize: The adaptation of an organ or organism to a special function or environment
Sub specialize: A deeper analysis into a specialty
Unicellular: Having or consisting of one cell within an organism

Multicellular: Consisting of two or more cells within an organism
Membrane-bound: A structure surrounded by a phospholipid bilayer (membrane)
Organelles: Tiny structures within a cell that each perform different functions
Permeability: The ability to allow or permit the entrance or exit of matter through the cell membrane
Procreate: The ability to reproduce

Chloroplasts: Specialized organelles within plant cells that are responsible for the production of chlorophyll through photosynthesis
Cellular productivity: A cell's ability to perform tasks at an efficient rate
Cellular functionality: A cell's ability to function in a cohesive or collective manner
Compound microscope: An instrument that is used to magnify the view of an object through lens

Animalcules: The microscopic structure of a single celled organism viewed by Leeuwenhoek.
Spontaneous generation or abiogenesis: The idea that life can emerge spontaneously from nonliving or abiotic things
Open systems: An exchange of matter and waste in and out of a structure

Maximized: The ability to gain the most potential

Potential: Having the capacity to become something better
Optimal: A favorable option
ATP: A molecule known as Adenosine triphosphate that transports energy within cells
Product: The result of two reactants added together
Reactant: Substances used in reactions to produce a product

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