Biology

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Biology

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Module 1				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.1 Compare and contrast existing models, identify patterns, and use structural and functional evidence to analyze the characteristics of life. Engage in argument about the designation of viruses as non-living based on these characteristics.	● Evaluate evidence to argue the classification of viruses as living or non-living, including: ● characteristics shared by living things - made up of cells, reproduction, contain DNA, growth and development, ability to metabolize, response to stimuli, maintaining homeostasis, and evolution. ● patterns and models of viral structure and replication.	sexual/asexual Reproduction, DNA, metabolism, Stimulus, homeostasis, Evolve, Virus, nucleic acid, viral cycle	* Text: Introduction to Viruses * Video companion: Viruses * Article: Welcome to the Virosphere * Activity: HHMI Virus Explorer * Review: Module 1	Amoeba Sisters: Characteristics of Life Amoeba Sisters: Viruses HHMI Virus Explorer
BIO1.LS1.2 Evaluate comparative models of various cell types with a focus on organic molecules that make up cellular structures.	● Infer the function of cellular components based on the structure of its organic macromolecules ○ carbohydrates ○ lipids ○ proteins ○ nucleic acids ● Evaluate models to distinguish between major cell types (prokaryotes and eukaryotes). ● Compare model cells of a complex organism depending upon the abundance or absence of organelles and their function (suggestions: red blood cell, neuron, muscle fiber, skin cell, etc.)	organic molecules Carbohydrates Lipids, proteins, Nucleic acids, organelles, centriole, nucleus, cell wall, chloroplast, Ribosome, Endoplasmic reticulum, golgi apparatus, Vacuole, vesicle, lysosome , cytoskeleton, Mitochondria, cell membrane, prokaryote, eukaryote	* Video companion: Biomolecules * Video companion: Enzymes * Video companion: Cells * Article: Bacteria are All Around Us And That's Okay - Questions: Bacteria are All Around Us -- And That's Okay * Review: Module 1	Amoeba Sisters: Biomolecules Amoeba Sisters: Protein Structure and Folding Amoeba Sisters: Enzymes Amoeba Sisters Videos:Introduction to Cells Learn.Utah Interactives

Module 1				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.5 Research examples that demonstrate the functional variety of proteins and construct an argument based on evidence for the importance of the molecular structure to its function. Plan and carry out a controlled investigation to test predictions about factors, which should cause an effect on the structure and function of a protein.	● Explain how the function of proteins is dependent on structure. ● Analyze the various functions of proteins in cells. ○ controlling rates of chemical reactions ○ regulating cell processes ○ forming cellular structures as in the cell membrane where they help transport molecules into or out of the cell or help with cell communication throughout an organism ● Plan and carry out an investigation to demonstrate enzyme function including the factors which may inhibit the action of a given protein/enzyme. ● Develop and/or analyze a model to explain how the enzyme-substrate complex impacts chemical reactions in an organism's cells and how changing the shape of a protein can inhibit its function.	peptide bonds amino acids Polypeptide structure-primary, secondary, tertiary, quaternary activation energy Enzyme, catalyst Enzyme-substrate, complex, denature	* Activity: Exploring Enzymes * Review: Module 1	Amoeba Sisters: Protein Structure and Folding

Module 2				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.7 Utilize a model of a cell plasma membrane to compare the various types of cellular transport and test predictions about the movement of molecules into or out of a cell based on the homeostasis of energy and matter in cells.	● Create a model of the plasma membrane. Using the model, explain how cell transport occurs across the cell membrane. ● Evaluate the model and determine the role of the plasma membrane in maintaining homeostasis. ● Predict how molecules will move (passive or active transport) across the plasma membrane. ● Predict which types of molecules are able to cross the plasma membrane and its impact on the cell.	Cell, (plasma)membrane fluid mosaic model Concentration, Passive transport, active transport, diffusion Osmosis, exocytosis Endocytosis, isotonic Hypotonic, hypertonic Homeostasis, equilibrium, transport Proteins, Phospholipid bilayer, carrier proteins	* Video companion: Cell transport * Activity: Cellular Soap Opera	Amoeba Sisters: Inside the Cell Membrane Amoeba Sisters: Cell Transport HHMI Cystic Fibrosis
BIO1.LS1.8. Create a model of photosynthesis demonstrating the net flow of matter and energy into a cell. Use the model to explain energy transfer from light energy into stored chemical energy in the product.	● Create a model to explain how light and matter are transformed through the cell during photosynthesis. ● Demonstrate how elements and molecules are rearranged in photosynthesis - carbon, hydrogen, oxygen, and carbohydrates. ● Understand how light energy is first transformed, stored as chemical energy in photosynthetic organisms, and transferred between systems across all levels of organization.	photosynthesis Chlorophyll, pigment Thylakoid, stroma ATP, Light-dependent reactions, Light-independent reactions, energy chemical energy Hydrogen, oxygen, carbon, glucose	* Video companion: compare photosynthesis and cellular respiration * Article: Scientists Look to Hack Photosynthesis for a 'Greener' Planet * Questions: Scientists Look to Hack Photosynthesis for a 'Greener' Planet * Interactive companion: HHMI Photosynthesis * Review: Module 2	HHMI Photosynthesis Interactive Amoeba Sisters: Photosynthesis

Module 2				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.9 Create a model of aerobic respiration demonstrating flow of matter and energy out of a cell. Use the model to explain energy transfer mechanisms. Compare aerobic respiration to alternative processes of glucose metabolism.	• Analyze a model of energy flow in a cell to show the redistribution of energy from glucose to ATP. • Construct an explanation of how the absence of oxygen necessitates a cell to perform anaerobic respiration. • Analyze and interpret data to explain variation in glucose metabolism by organisms in aerobic and anaerobic environments.	ADP, ATP phosphorylation Aerobic respiration Anaerobic respiration glucose metabolism Cellular respiration fermentation carbohydrates	* Video companion: compare photosynthesis and cellular respiration * Review: Module 2	Amoeba Sisters: Cellular Respiration

Module 3				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.6 Create a model for the major events of the eukaryotic cell cycle, including mitosis. Compare and contrast the rates of cell division in various eukaryotic cell types in multicellular organisms.	● Create a model of the complete cell cycle, including G1, S phase, G2, mitosis, and cytokinesis. ● Use a model showing the movement of chromosomes to explain the function of mitosis. ● Examine and construct an explanation for the different rates of mitosis of various types of eukaryotic cells in multicellular organisms.	cell cycle, G1, S phase G2, mitosis (M phase) Cytokinesis, chromatin Chromosomes, centrioles, spindle fibers, centromere Sister chromatids daughter cells, interphase, prophase Metaphase, anaphase Telophase, cell furrow cell plate	* Video companion: Mitosis * Review: Module 3	Amoeba Sisters: Cell Cycle Amoeba Sisters: Mitosis Learn.Utah Interactives
BIO1.LS1.3 Integrate evidence to develop a structural model of a DNA molecule. Using the model, develop and communicate an explanation for how DNA serves as a template for self replication and encodes biological information.	● Explain how DNA is organized into genes and chromosomes which ultimately carry biological information. ● Evaluate evidence of DNA structure to create a model of DNA. ● Use a DNA model to explain how its pattern and structure allows for replication. ● Explain the importance of DNA replication to produce identical DNA prior to cell division. ● Investigate how errors during DNA replication may produce mutations. ● Understand that not all segments of DNA are transcribed for proteins and that portions of DNA are involved in regulating gene expression.	DNA deoxyribonucleic acid Adenine, cytosine, guanine, thymine phosphate nucleotide hydrogen bonds Gene, gene expression DNA replication DNA polymerase	* Video companion: DNA from HHMI * Video companion: DNA Replication * Activity: Strawberry Extraction * Article: What We Can and Can't Learn from our Pets' DNA * Questions: What We Can and Can't Learn from our Pets' DNA * Review: Module 3	The DNA Double Helix Discovery Video Amoeba Sisters: DNA Replication Learn.Utah Interactives

Module 3				
Standard	**Learning Targets**	**Vocabulary to Review**	**Included in this Document**	**Additional Online**
BIO1.LS1.4 Demonstrate how DNA sequence information is decoded through transcriptional and translational processes within the cell in order to synthesize proteins. Examine the relationship of structure and function of various types of RNA and the importance of this relationship in these processes.	● Use a DNA model to explain how its pattern and structure allows for a single gene to become a template for the synthesis of a single protein. ● Use the model to explain the role of mRNA in the processes of transcription and translation, focusing on how the structure of mRNA is related to its function. ● Use the model to explain the role of tRNA in the process of translation, focusing on how its structure is related to its function. ● Integrate information about transcription and translation to explain the connection between genotype and phenotype. ● Understand that cell types differentiate due to the expression of specific genes during mitosis	genotype phenotype Protein synthesis DNA mRNA tRNA rRNA codon anticodon transcription translation polypeptide amino acid RNA polymerase	* Review: Module 3	Animation for Protein Synthesis - PBS Learning Media Learn.Utah Interactives
BIO1.ETS2.3 Analyze scientific and ethical arguments to support the pros and cons of application of a specific biotechnology technique such as stem cell usage, in vitro fertilization, or genetically modified organisms.	● Research and evaluate the ethical arguments for and against a biotechnological technique.	stem cells in vitro fertilization Genetically modified organisms	* Article & Questions: Is It Ethical to Genetically Engineer Animals * Review: Module 3	
Answer Keys for Articles and Module Reviews				

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Virus – The Biological Brain Twister

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A B S T R A C T

Viruses are intracellular pathogens that bind to specific receptor molecules on the surface of the target cells for their entry to initiate infection. They exist as lifeless independent particles prior to their invasion of host cells which were subsequently infected due to virus. These parasitic particles find significant importance in the field of genetics, molecular and cell biology as they paved way for major advancement in human health aspects. In numerous researches and discussions were underway on these entities as of whether they belong to the realm of living organisms or not. Researchers of different period have shown evidences about virus as both living and non-living. Though the debaters on the non-living aspect gained more information recent studies have gradually made the researchers to relook at the existence of the parasite as a living entity in the domain of the tree of life. This paper reviews the views of different authors at different periods with their research views about virus. The author of this paper involves in each of the discussion points including recent researches on protein folding studies and there upon concludes that virus belongs to a living entity just like bacteria and eukaryotes.

Introduction

Virus is a small infectious agent that typically consists of nuclei acid molecule in a protein coat. Ever since its time of discovery in the year 1892 by Dmitri Ivanosky, where he described a non-bacterial pathogen infecting the tobacco plants (Fig. 1) till the isolation of this pathogen by Martinus Beijernick and naming of this pathogen called VIRUS (Lecoq *et al.*, 2001), stood out as milestone of Virology history. Though they have made milestones they exhibit the characteristics of both living and non-living (as biochemicals) considered as a microbiological mystery. This entity has constantly sparked debates in the world of science, is it biology or chemistry? Is it alive or dead? Let us analyse about this peculiar question in detail.

Virus – The contradiction

To declare virus as a living thing, let us see whether virus check all or at least some boxes of lining things.

Life is scientifically defined as organism that,

Maintain Homeostasis
Are composed of cells

Undergo metabolism
Can grow
Adapt to their environment
Respond to stimuli
Reproduce

So only if virus satisfies these 7 aspects, they can be considered as a living entity. As we are dealing with a very unique organism that are at the verge of life, we surely need to take a closer look or even a different approach in order to give a fair verdict. Hence I am considering certain other factors such as

Evolution
Giant viruses
Protein folding

Along with the already considered seven criteria, let us clear up the point one at a time.

Living organisms maintain homeostasis

Homeostasis is any self-regulating process by which biological systems tend to maintain stability, while adjusting to conditions that are optimal for survival. Considering viruses are very small even smaller than bacteria (Ventakaraman Prasad *et al.,* 2012). They are just complicated assemblies of biomolecules like protein nuclei acid, lipids and carbohydrates. First of all, a biological system must be made up of cells or at least a cell. Whereas viruses are simply boxes of chemicals (Jake Port, 2017). They neither have the organelles nor have an internal environment for maintaining homeostasis.

Thus virus falls flat when it comes to maintaining Homeostasis conditions.

Living things are composed of cells

As said earlier living organism must possess cells or a cell. And viruses do not. But they do exhibit complexity in their structure and they do come in different sizes (Ventakaraman Prasad *et al.,* 2012) (ranging from 20 nm to 1000 nm) and exhibit a variety of shapes and symmetry (icosahedral, helical, complex, prolate, spherical) enveloped or non-enveloped virus; classified scientifically as 7 different classes called the BALTIMORE CLASSIFICATION (Fig. 2) depending on the type of genome 1) ds DNA 2) ss DNA 3) ds RNA 4) (+) ss RNA 5) (-) ss RNA 6) ss RNA-RT 7) ds DNA-RT. Though it contains multiform and elaborate and intricate morphology, it is ultimately not a cellule.

Thus viruses nearly miss this criterion.

Living things undergo metabolism

Anabolism and catabolism together gives metabolism. Thus metabolism is a set of life sustaining chemical transformations within the cells of organism. This is an essential operation to maintain the living state of cells. Viruses are nano particles and agents of infections. They are devoid of ATP and they neither undergo respiration, excretion nor feed on anything.

Hence they fail to hit the mark.

Living things can grow

Growth and development is a vital quality for any living organism. Viruses are simple entities without any metabolic activity. But they do grow. They aren't capable of independent growth, Eclipse phase in a virus is considered as a phase of growth. Eclipse phase is defined as the time between infection by a bacteriophage or other virus to the time of appearance of mature progeny (Adam *et al.,* 1959). Virus cell therefore is a clear indication of growth and maturation of a viral particle. Virion is usually described as a fully formed entire virus. The growth curve drawn during lytic and lysogenic cycles also imply that

viruses do grow. However they use and derive energy for their growth from the host.

Thus virus checks this box.

Living things adapt to their environment

Most viruses are persistent innocuous and non-pathogenic. They remain passive for a long period outside the cell or they take advantage of their host replication machinery to replicate (Villarreal, 2004). As said, their actions exclusively rely upon the environment. They remain as a crystallized inanimate particle, outside and are activated only inside a living host cell for which they are defined as obligate intracellular parasites.

Thus viruses fulfill this necessity.

Living things respond to stimuli

Viruses are mostly and widely accepted as molecular entities rather than cellular entities. They are organisms that are constantly changing between biology and biochemistry (Villarreal, 2004). As explained earlier viruses do not have any metabolism to provide energy. And they do not contain any energy to respond to any stimuli. Their protective protein coat safeguards them from the harsh temperatures, pH, light or any other cabes that usually stimulates any living organism.

Thus virus fails to satisfy the fact.

Living things reproduce

Viruses reproduce, to say more accurately they surely do replicate. But they aren't capable of autonomous replication. They do not grow or multiply outside the host instead they hijack the host cells apparatus to carry out their transcriptional and translational processes. Unlike other obligate intracellular parasites such as Chlamydia and Rickettsia that behave as a non-living entity outside the host and use their own replication methods instead of depending on the host's machinery, viruses use host cells DNA or RNA to produce viral proteins. Thus they are self-assembling organic molecules (Patrick Fortterre, 2010). Stuck between the puzzle of replication or reproduction, Claudiu Bandea in 1983 stated that, "In this phase (eclipse phase) the virus shows major physiological properties such as growth, metabolism and reproduction. Therefore life is an effective presence". So whether it is simply an assembly of molecules or the reproduction of daughter cells at the end of lytic and lysogenic cycle, new outputs are surely obtained.

And by this point of view, the reproduction norm is a definite "Yes".

Evolutionary aspect

Evolutionary and phylogenetic studies have cracked even the most challenging cases in biology. But again, we are met with a dead end as viruses do not fossilize (Viviane Ritcher, 2015). Thus scientists have come up with some possible theories; one theory suggests that both bacteria and virus are descended from a common ancestor. And viruses do share certain macromolecules present in Archae, Bacteria and Eukarya as indicated in Figure 3 (Patrick Fortterre, 2010). All three domains are descended from the Last Universal Common Ancestor (LUCA).

It is also believed that DNA polymerases enzyme present in Eukaryotes have viral origin.

Bacteria evolved to be a more complex form and whereas viruses gradually shed their genes which they found unimportant until they can't even reproduce on their own (Viviane Ritcher, 2015).

Fig.1 TMV virus

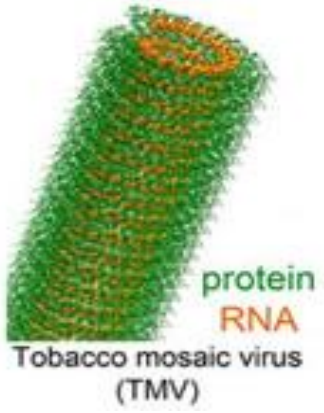


Fig.2 Baltimore classification

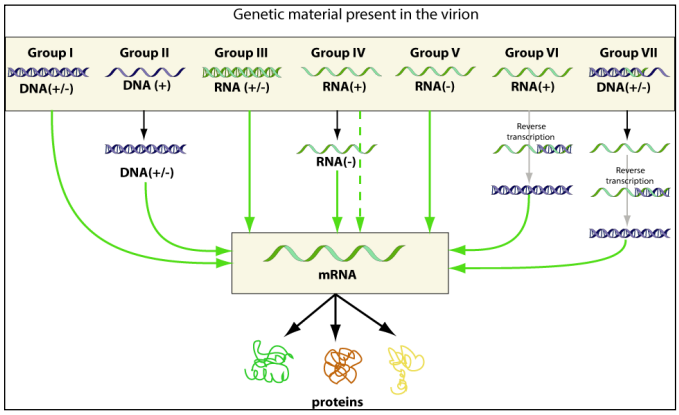


Fig.3 LUCA domain

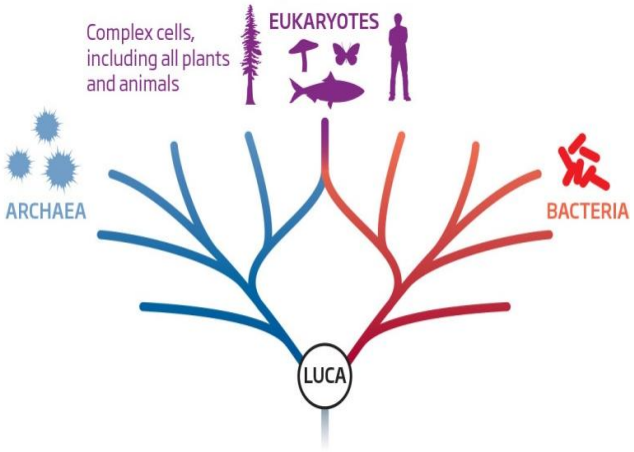


Fig.4 Mimivirus

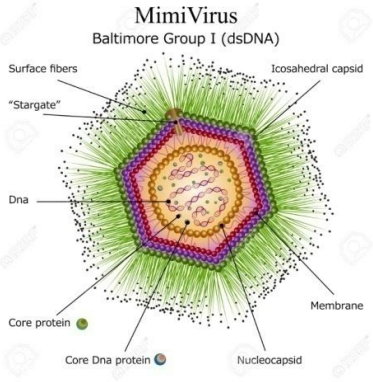


Fig.5 Sputnik Virion

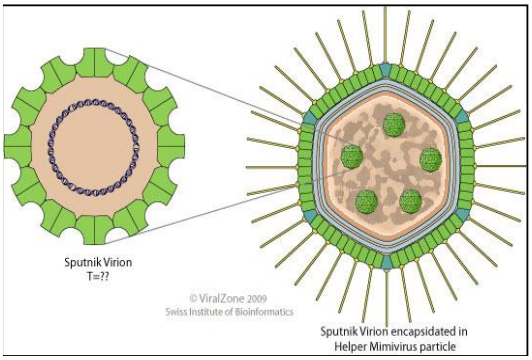


Fig.6 Mamavirus

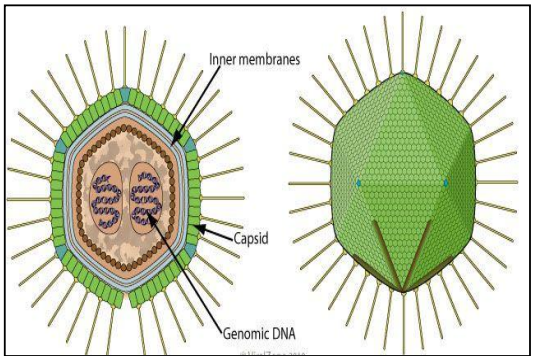


Fig.7 Protein folding

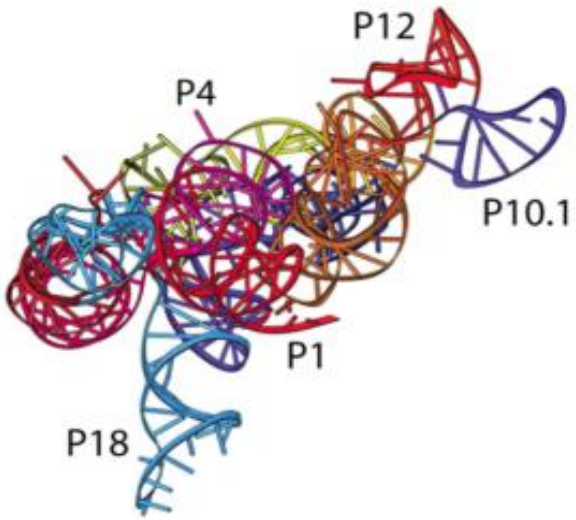
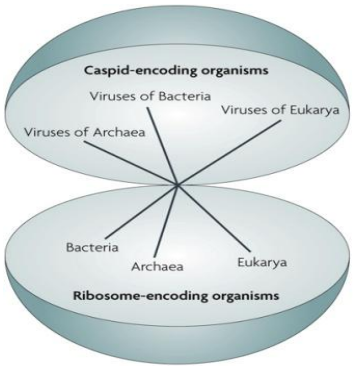


Fig.8 Ribosome – Capsid organisms



But the hallmark genes of viruses have no obvious ancestors in cellular forms (Eugene V Koonin *et al.,* 2015). Another theory suggests that viruses may be evolved from bits of DNA/RNA that escaped from large genes (Transposons).

As the widely accepted theory suggests both virus and modern bacteria had a common ancestors. Viruses can be considered as a living organism but of a different fourth domain.

Viruses get sick?

Considering virus whether alive or dead remained dormant for few years until the recent discovery of GIANT VIRUS called the MIMIVIRUS (Fig. 4) (Mimicking Microbe) in 2003 by Didier Raoult *et al.,* Mimivirus also contained certain eukaryotic genes. Later another giant virus called Mamavirus which was discovered in a cooling tower of Bradford, UK. As reported by La scola *et al.,* in 2008, this giant virus contained 900 protein coding genes which is higher than the previously known *Acanthamoeba polyphaga* Mimivirus.

This virus was nearly the size of a bacterial cell and it is known to attack its host, the Amoeba.

But the real root cause of the debate is that another small sub-viral agent called SPUTNIK (Sputnik-3) invades the Mimivirus and thereby disrupting the replication cycle of Mimivirus ultimately making it *Sick*. Sputnik is the first known virophage (Fig. 5).

Thus Jean Michel Claverie concludes that "There's no doubt, this is a living organism, the fact that it can get sick makes it more alive" (Pearson H, 2008). Sputnik discovery also suggests the fact that these viruses could be having major effects on the ocean's nutrient cycle.

After Mimi and Mama virus (Fig. 6) even larger viruses have been discovered. In 2011, largest known then virus called the Megavirus Chilensis was found and in the year 2013, the largest virus (Genomewise) known upto date called the Pandora virus was discovered by Prof Jean Michel Claverie and Dr Chantal Abergel *et al.,* 2013. The genome of Pandora virus was twice as large as Mimi and Mama viruses.

Is protein folding the answer?

A new study uses protein folds as evidences to declare that viruses are living. These protein folds do serve as a marker for evolutionary studies. The researchers Gustavo

Caetano Anolles *et al.,* (Fig. 7) analyzed all of the known folds in 5080 organisms representing all branches of the tree of life, including 3460 viruses. They identified 442 protein folds were shared proves that virus do exhibit properties that cells have. Thus Caetano-Anolles concludes that "Viruses now merit a place in by Gustavo the tree of life. Obviously, there is much more to viruses than once thought".

The tiny particle that remained as an enigma for more than a century and still exists as an enigma continuously baffling minds of mankind by its contradictory characters, is surely a biological puzzle. But various scientists, virologists have stated their views and endlessly debating whether viruses are alive or dead. John Mattik's views on this particle are "People say viruses aren't free living but that's a philosophical question- Are we free living? Life is an interconnected system". What was once considered as a mere box of biochemicals till the giant virus discovery? This historic encounter has rekindled the debate and it has also led to the fact that "It suggests there are other representatives of this viral family out there in the environment", Koonin says, Viruses are ultimately polyphyletic.

In contrary, if a particle containing nucleic acid, protein, lipid and carbohydrates are considered as a living entity, then scientists put forth the point that DNA/RNA must also be considered as a living thing.

Thereby considering all the above traits, first of all our current views and definitions of life is very constricted. Thus the root is faulty. Our view must be a bit more elaborate, as virologist Didier Raoult suggests to define, life into 2 major forms/groups:

Ribosome encoding organisms (Archae, Bacteria, Eukarya) (Fig. 8).

Capsid encoding organism (Virus).

Or, we can accept viruses to be the fourth domain of life. Though they are at the edge of life, drawing a fine line between natural and synthetic, viruses surely exhibit some key characteristics of living. Although they are still regarded as particles, agents and non-living they indeed occupy a major aspect in the web of life.

Thus I surmise by claiming that these viral entities clearly reside as an element in this realm of life.

Acknowledgement

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Amoeba Sisters | Video Recap

NAME: _____

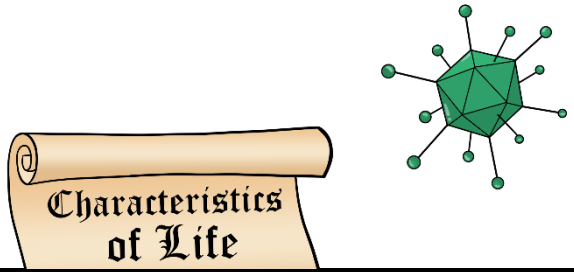
Amoeba Sisters Video Recap: *Viruses*

1. Are viruses considered to be living organisms? Why or why not?

_____

_____

_____



2. Are viruses considered to be cells? Would they be included in these cell theory statements?

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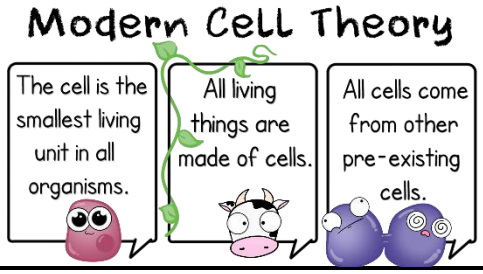
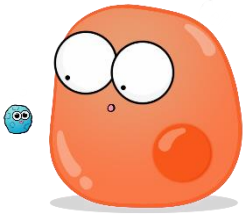


3. Compare and contrast a **virus** to a **cell**. What would be some differences? What are some similarities?



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_____

_____

Determine whether the following statements are TRUE or FALSE by applying what you have learned. If false, you will be asked to explain why.

4. _____ Viruses can be treated with **antibiotics**.

If false, why? *[If true, leave blank]* _____

_____

5. _____ Viruses are smaller than the **hosts** they infect.

If false, why? *[If true, leave blank]* _____

_____

6. _____ Viruses are **prokaryotes**.

If false, why? *[If true, leave blank]* _____

_____

Determine whether the following statements are TRUE or FALSE by applying what you have learned. If false, you will be asked to explain why.

7. _____ Virus structure includes **biomolecules** such as **proteins** and **nucleic acids**.

If false, why? *[If true, leave blank]* _____

_____

8. _____ Viruses require a **host** to **reproduce**.

If false, why? *[If true, leave blank]* _____

_____

9. _____ Viruses *only* target **animals** (including humans).

If false, why? *[If true, leave blank]* _____

_____

Amoeba Sisters | Video Recap

NAME: _____

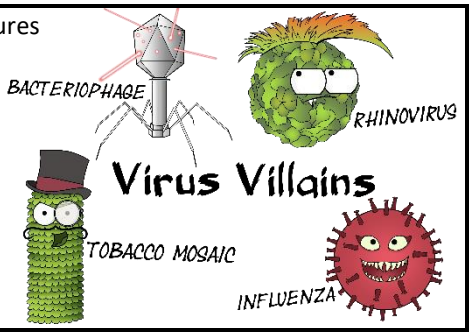
Amoeba Sisters Video Recap: *Viruses*

10. Viruses come in many different **structures**. What would these different virus structures likely have in common? What might be different?

_____

_____

_____



The Lytic Cycle

*It is time to focus on how viruses reproduce by exploring the **lytic cycle**! For the following question numbers, illustrate the scenario described to show the virus and host cell.*

The virus <u>attaches</u> to the host cell.	11.	**The virus <u>inserts</u> its genetic material into the host cell (or the virus itself may be taken inside the cell where its genetic material will be used by the host).**	12.
Based on the viral genetic instructions, the host <u>manufactures</u> and <u>assembles</u> copies of the virus.	13.	**The newly formed viruses can <u>lyse</u> the host cell and now infect new host cells.**	14.

The Lysogenic Cycle

*15. Can you relate this illustration to how the **lysogenic** cycle would be different from the **lytic** cycle?*

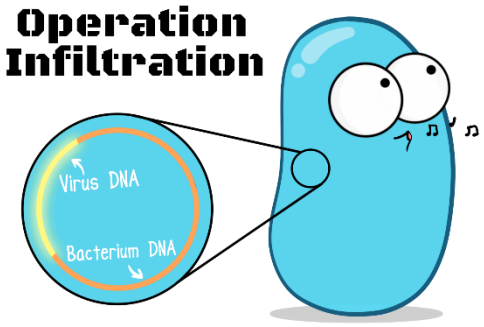
_____

_____

_____

_____

_____

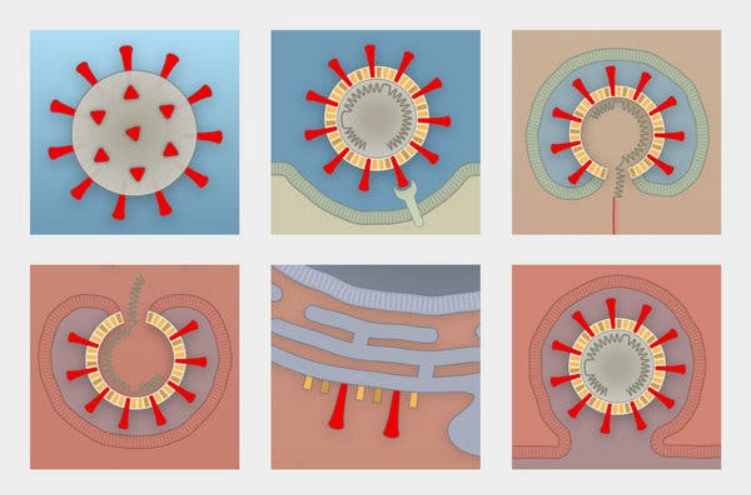


Welcome to the Virosphere Name: _____
https://www.nytimes.com/2020/03/25/learning/lesson-of-the-day-welcome-to-the-virosphere.html

What do you know about the structure and transmission of the coronavirus?

Look at the images below from left to right. The first image shows the coronavirus and the second image illustrates what happens as the virus enters a vulnerable cell.

Can you label the rest of the images? Here are some key words you will need to use: viral RNA, viral protein and viral copies.



Read the article below. Link is also provided here: https://www.nytimes.com/2020/03/24/science/viruses-coranavirus-biology.html

Welcome to the Virosphere

SARS-CoV-2, the cause of the pandemic, belongs to one of 6,828 named species of virus. Hundreds of thousands more species are known, with perhaps trillions waiting to be found.

In January, Chinese virologists isolated the virus that causes Covid-19. Earlier this month, a team of virologists gave this new virus a new name: SARS-CoV-2.

To do so, they had to move the virus to the head of a very, very long line.

In recent years, scientists have discovered that the world of virus diversity — what they sometimes call the virosphere — is unimaginably vast. They have uncovered hundreds of thousands of new species that have yet to be named. And they suspect that there are millions, perhaps even trillions, of species waiting to be found.

“Suffice to say that we have only sampled a minuscule fraction of the virosphere,” said Edward Holmes of the University of Sydney in Australia.

With the discovery of viruses in the late 1800s, scientists soon recognized that different species caused different diseases — rabies and influenza, for example. Later, virologists learned how to recognize new kinds of viruses by growing them in labs, where subtler biological features emerged.

After decades of this painstaking work, virologists have officially named 6,828 species of viruses; the figure includes 1,000 or so that will be formally accepted in the next few weeks by the International Committee on the Taxonomy of Viruses. That’s a paltry count when you consider that entomologists have named 380,000 species of beetles alone.

But in recent years, virologists have changed the way they hunt. Now they look for bits of genetic material in samples — water, mud, blood — and use sophisticated computer programs to recognize viral genes.

Matthew Sullivan, a virologist at Ohio State University, has used this method to search for viruses that infect life in the ocean. He and his colleagues analyzed genetic material in seawater collected on a scientific voyage around the world. Some genes belonged to species already known to science. But many were new. In 2016, Dr. Sullivan and his colleagues reported over 15,000 viruses, each representing a new species.

That was more than twice as many species as all the previously identified viruses. And with that, Dr. Sullivan thought he and his colleagues had pretty much finished off the diversity of viruses in the sea. But they went on collecting more water, and invented new ways to search it for the genetic material of viruses. In 2019, they reported finding a total of 200,000 species.

“I’ve stopped saying, ‘We’re done,’” Dr. Sullivan said.

Other researchers are discovering thousands of new viruses as well. “Right now, we are in the exponential phase,” said Dr. Jens H. Kuhn, the lead virologist at the Integrated Research Facility at Fort Detrick in Maryland. “If someone gives me a million dollars and I go out and sample sea cucumbers, I will present you with 10,000 new viruses.”

Formally describing a new virus remains a time-consuming task. When Chinese researchers isolated the Covid-19-causing virus earlier this year, they found that it had a distinctive crown of proteins. This hallmark told them that the virus belonged to the coronavirus family, which contains 39 known species. The World Health Organization used this finding to give the disease its name — Coronavirus Disease 2019, or Covid-19 for short.

To determine just what kind of coronavirus they were dealing with, virologists sequenced its genes. The virus was genetically similar to the one that caused the SARS outbreak in 2002. In March, the International Committee on Taxonomy of Viruses declared that the two viruses belonged to the same species. The virus that caused SARS is known as SARS-CoV. So they called the Covid-19-causing virus SARS-CoV-2.

The viruses that infect humans are the best understood of all. But only about 250 species of viruses choose us as their host — “an insignificant fraction of the virosphere infect humans,” Dr. Holmes said.

While hundreds of thousands of new species still await their own names, virologists believe that far more await discovery. Dr. Holmes estimates that the viruses infecting animals, plants, fungi and protozoans (a group called eukaryotes) number 100 million species.

Bacteria and other single-celled microbes belong to a group called prokaryotes. In a paper published on March 4 in Microbiology and Molecular Biology Reviews, Dr. Kuhn and his colleagues argued that there are, at minimum, 100 million species of viruses that infect prokaryotes.

But some researchers suspect there are many more species of prokaryotes in the world — which would mean many more species of viruses. The true figure might be as high as 10 trillion.

For each of those species, scientists will have to figure out how it is related to other viruses. That is far harder to determine for viruses than for familiar life-forms like animals and plants.

Scientists who study animals and plants can rely on the tried and true classification system first established by Carl Linnaeus in the 1700s. Our species belongs to the class Mammalia, for instance, and, above that, the animal kingdom. Virologists have struggled to figure out the classes and kingdoms of the virosphere. Part of the problem is that viruses have a penchant for trading genes with other species, making it hard to draw bright lines between groups of them.

And very often, a new virus simply makes no sense. An extreme example came to light in February when scientists searching for viruses in a lake found a new one they named Yaravirus. Of Yaravirus's 74 genes, 68 are unlike any ever found in any virus.

In recent years, Dr. Kuhn and his colleagues have sought to tame this chaos. They have developed what they call a "megataxonomy" to classify viruses that seems to work. The team sorted viruses based on whether they carried one or more of a few "hallmark genes." They also looked for groups of species that trade genes among each other, and less so with other groups.

"A coherent account of the global organization of the virus world is now within reach," they wrote in their new paper. Dr. Kuhn, in an interview, said, "We were all a bit surprised this system is so logical in the end."

Dr. Kuhn and his colleagues submitted their system to the taxonomy committee, and he said it would likely be accepted soon. Still, the megataxonomy is far from complete. Yaravirus, for instance, still floats on its own, lonely and unclassifiable.

Some researchers are skeptical about the megataxonomy. Dr. Holmes thinks it is too soon to attempt one, given that researchers have found so few viruses. "Why build something so rigid when it may just fall as we sample more?" he asked. Dr. Kuhn argues that it's worth starting to build a system, even if it needs to be adjusted later.

Making sense of the virosphere is not just an intellectually challenging puzzle, Dr. Kuhn said. At Fort Dietrick, he runs experiments on some of the world's most dangerous viruses, such as Ebola and SARS-CoV-2. A better understanding of the virosphere could help him and his colleagues come up with ways to combat these threats and others we don't even know about yet.

"We have to understand what is out there," he said.

Questions

1. How do virologists search for new viruses? How do today's approaches differ from earlier methods of researching viruses?

2. What does the research of Matthew Sullivan, a virologist at Ohio State University, demonstrate about the diversity of viruses in the sea?

3. How did Chinese researchers and virologists isolate and identify the virus that causes Covid-19 earlier this year? How did the International Committee on Taxonomy of Viruses name the virus?

4. How do viruses infect and affect humans compared to other species?

5. Why is it so hard for virologists to classify viruses?

6. Why did Jens H. Kuhn, the lead virologist at the Integrated Research Facility at Fort Detrick in Maryland, and his colleagues create the "megataxonomy"? How have other researchers responded to his creation?

INTRODUCTION

This handout complements the Click and Learn "Virus Explorer" developed in conjunction with the 2016 documentary, *Spillover: Zika, Ebola & Beyond* (http://www.hhmi.org/biointeractive/virus-explorer).

PROCEDURE

Follow the instructions as you proceed through the Click and Learn, and answer the questions in the spaces provided.

1. Let's review. Click on the "About" tab at the bottom. Read the information and list four (4) ways in which viruses can differ from each other.

2. This interactive uses several abbreviations. Fill in what each abbreviation stands for in the table below.

Abbreviation	Description
nm	
bp	
ss	
ds	

3. Close the "About" window, and locate the **i** next to each viral characteristic tab across the top. Click on these icons and answer the questions below associated with each viral characteristic.

a. **Envelope:** Not all viruses have an envelope. If a virus has this outer layer, explain how it forms.

b. **Structure:** What determines the shape of the capsid, or core?

c. **Host(s):** From the virus' perspective, why is the host important?

d. **Genome Type:** Viral genomes may vary by four characteristics of their genetic information. What are they?

e. **Transmission:** Define the terms "vector" and "zoonotic."

f. **Vaccine:** What is one advantage of being vaccinated against a particular virus?

4. Virus Scavenger Hunt: Use the home page of the Virus Explorer and the various viral characteristic tabs across the top to answer the questions below.

a. What is one difference between the rabies virus and the influenza virus?

b. Of the nine viruses shown, which is the only one that infects plants?

c. What are three characteristics that adenoviruses, T7 virus, and papillomaviruses have in common?

d. Recently, Zika virus has been in the news. Treatment of it is of particular concern. Why?

e. Which two viruses infect all the vertebrates included in the interactive?

f. Of the nine viruses shown, which is the only one that infects bacteria?

g. List four characteristics that human immunodeficiency virus (HIV) and Ebola virus have in common. (Be specific.)

h. List four characteristics that HIV and Ebola virus do not share. (Be specific.)

5. Locate the **+** next to each virus name. Click on these icons and answer the questions below associated with selected viruses.

a. Rabies virus: People often associate rabies virus with dogs. Why is this incomplete?

b. Influenza virus: Influenza virus has a segmented genome. Why is this an advantage for the virus?

c. HIV: HIV infects immune cells. Why is this a disadvantage to the infected person?

d. HIV: Where in the world is HIV most prevalent?

e. Adenovirus: Adenoviruses can cause many mild clinical conditions in humans. What are three?

f. Papillomavirus: What is the common name for papillomas?

g. Papillomavirus: What kind of symptoms do some human papillomaviruses cause?

h. Zika virus: Why is Zika virus of great concern to pregnant women?

i. Tobacco mosaic virus (TMV): Name one unique characteristic of the tobacco mosaic virus.

j. Ebola virus: What animal is associated with Ebola virus outbreaks?

EXTENSION ACTIVITY: SIZE, SCALE, AND PROPORTION: HOW BIG IS A VIRUS ANYWAY?

Instructions: Click on the "Show Relative Sizes of the Viruses" tab at the bottom of the interactive home page. Answer the questions below in the spaces provided. (You will need a calculator for some items.)

1. Using the white scale bar provided, approximately how long (tall) is TMV?

2. What is the approximate diameter of HIV?

3. What is the approximate diameter of Zika virus?

4. So, how big is a nanometer? Study the sample problem provided and then answer Questions 5–10, showing your work in the space provided for each.

Sample Problem
An average small paperclip measures 3.0 cm in length.

Calculate the length of the paperclip in millimeters, micrometers, and nanometers.

a. Millimeters (mm)? 30 mm

Since there are 10 mm in a centimeter, the calculation is completed in the following way:

3.0 cm x 10 mm/1 cm = 30/1 = 30 mm

b. Micrometers (µm)? 30,000 µm

Since there are 1000 µm in a millimeter, the calculation is completed in the following way:

30 mm x 1000 µm/1 mm = 30,000 µm

c. Nanometers (nm)? 30,000,000 nm

Since there are 1000 nm in a micrometer (µm), the calculation is completed in the following way: 30,000 µm x 1000 nm/1 µm = 30,000,000 nm

So, a small paperclip measures 3.0 cm in length, or you can say it measures 30,000,000 nm in length!

5. A single grain of salt measures 0.5 mm in width.

a. What is the width in micrometers (µm)? (Show your work.)

b. In nanometers (nm)? (Show your work.)

6. The average human skin cell measures 30 µm in diameter.

a. What is the diameter in millimeters (mm)? (Show your work.)

b. In nanometers (nm)? (Show your work.)

7. If you lined up human skin cells side-by-side, how many would fit along the length of the paperclip in the sample problem above? Justify your answer with math.

8. Using your response to item 1 above, if you lined up TMV particles end to end, how many would fit along the length of the same paperclip? Justify your answer with math.

9. Using your responses to item 6, if you lined up TMV particles end to end, how many would fit across the diameter of the average human skin cell? Justify your answer with math.

10. *Claim*: An individual virus docks on the surface of a cell, infects it, hijacks the cellular machinery inside, and replicates itself, sometimes thousands of times.

Justification: Based on what you learned about size, scale, and the component parts of a virus, justify with scientific reasoning how a virus is able to accomplish this.

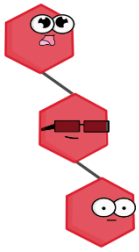
Amoeba Sisters Video Recap: *Biomolecules*

Directions: *For each statement, write a "C" if it best applies to the carbohydrates, "L" if it best applies to lipids, "P" if it best applies to proteins, or "N" if it best applies to nucleic acids.*

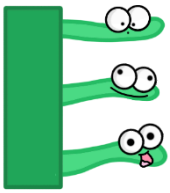
1. ____ I am useful for a fast source of energy.

2. ____ I have involvement in the immune system (ex: antibodies).

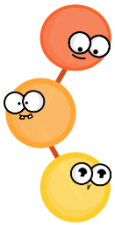
3. ____ I am helpful for long term energy storage.



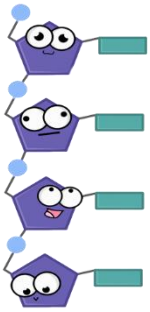
4. ____ I have a large role in muscle development.



5. ____ If athletes "pasta load," they consume a lot of me.



6. ____ A mutation in DNA would initially start with me.



7. ____ I make up cell membranes.

8. ____ Enzymes, which can speed up reactions, belong in my category.

9. ____ I am important for insulation.

11. ____ My category includes genetic material.

10. ____ I contain elements C, H, and O and have a ring-like structure.

12. ____ I can contain long fatty acid chains.

Directions: The following table is designed to help you organize your knowledge about biomolecules. Some of the information has been filled in for you.

Biomolecule:	Makes Me Think of… (this can be original for you)	Monomer:	Elements:	Example(s):
Carbohydrate	*13.*	*14.*	*C, H, O*	*15.*
Lipid	*16.*	*Glycerol + Fatty Acid* *Note: Many do not consider lipids to have true monomers. Read why in the video description!	*17.*	*18.*
Protein	*19.*	*20.*	*21.*	*22.*
Nucleic Acid	*23.*	*24.*	*25.*	*DNA, RNA*

Amoeba Sisters Video Recap: *Enzymes*

1. In the box below, please illustrate an enzyme and substrate. Label the following key words in your illustration: **enzyme**, **substrate**, and **active site**.

2. Enzymes are typically which type of **biomolecule**?

_____

3. Describe the effects that enzymes can have on **substrates**.

_____

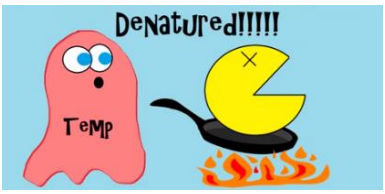
_____

_____

_____

_____

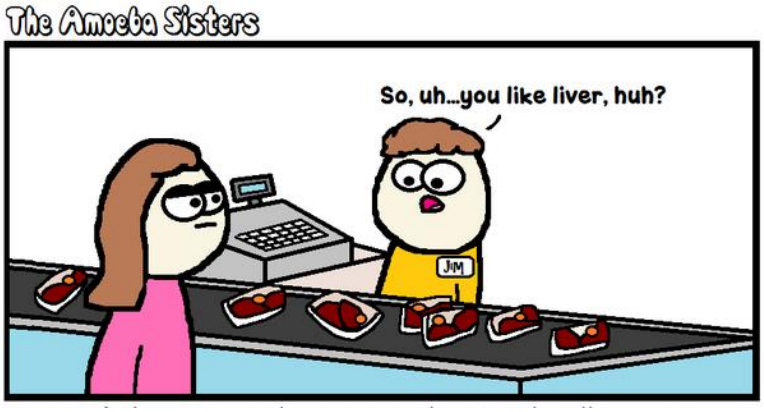
In order to function efficiently, enzymes need to be at an ideal **pH** and **temperature**. Different enzymes have different ideal pH and temperature conditions. If the pH or temperature is extreme for a particular enzyme, it can even **denature** an enzyme, which can prevent it from binding and acting on its substrate. For the following two scenarios, name the variable (temperature or pH) that is affecting the function of the enzyme.



A) ATP is produced by cellular respiration in your human body cells. There are a variety of enzymes that work to produce ATP, but one of those enzymes is called phosphofructokinase-1. This enzyme is sensitive to blood acidity. Blood can become more acidic if a patient is in respiratory distress.

4. **Variable affecting enzyme function:** _____

B) A popular lab that can be performed by students is to test the reaction rate of catalase enzyme when it acts on the substrate hydrogen peroxide. Catalase has the ability to break down hydrogen peroxide. Catalase can be found in beef liver from the grocery store! However, if the beef liver is boiled first, the catalase will not be able to break down hydrogen peroxide.



5. **Variable affecting enzyme function:** _____

Real Life Enzyme Scenarios

Please fill in the chart for every real life scenario listed below. Some boxes have been filled in for you!

Scenario	 **Identify Enzyme:**	 **Identify Substrate:**	**Illustrate the Scenario (label <u>enzyme</u> and <u>substrate</u> in illustration):**	**Describe the relationship between the substrate and enzyme in the scenario.**
Lactase is an enzyme that breaks down a sugar found in dairy products known as lactose. Some people are lactose intolerant, and this can be due to not having enough lactase production. People who are lactose intolerant may not feel well after eating foods containing lactose.	6.	lactose	7.	8.
An enzyme called glucocerebrosidase breaks down a glycolipid in the body known as glucocerebroside. However, in a genetic disease known as Gaucher's disease, the body does not produce enough glucocerebrosidase. Therefore glucocerebroside can build up in the body and this can cause serious side effects such as anemia and swelling of the liver and spleen.	9.	10.	11.	12.
Pancreatitis is an inflammation of the pancreas which can damage pancreatic tissue. The pancreas produces digestive enzymes such as amylase and lipase. These enzymes assist in breaking down certain food biomolecules. In this disorder, enzyme production from pancreatic tissue may be stopped.	13.	14.	15.	Since the pancreatic tissue can be damaged in this disorder, the production of the enzymes in this tissue (amylase and lipase) may be disrupted as well. This would affect the ability to break down certain types of food biomolecules (substrate).

Amoeba Sisters Video Recap: *Introduction to Cells*

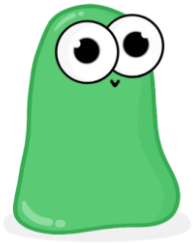
Directions: *For each statement, write a "P" if it best applies to* ***prokaryotes only****, "E" if it best applies to* ***eukaryotes only****, and "both" if it applies to* ***both prokaryotes and eukaryotes****.*

1. _____ I have a **cell membrane** (**plasma membrane**).

2. _____ I have a **nucleus**.

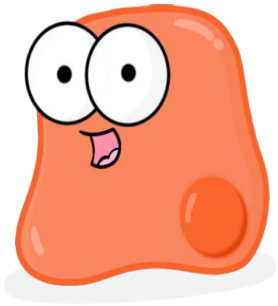
3. _____ **Bacteria** are an example of me.

4. _____ **Fungi** are an example of me.



5. _____ **Animals** are an example of me.

6. _____ I contain **ribosomes**.



7. _____ I contain **membrane-bound organelles**.

8. _____ I contain **cytoplasm**.

9. _____ **Your body cells** are made of this type of cell.

10. _____ **Protists** are an example of me.

11. _____ **Plants** are an example of me.

12. _____ I contain **genetic material** such as **DNA**.

13. The **cell theory** makes several fascinating statements about cells! What are three statements mentioned in the video that are included in the cell theory?

A Tour Inside the Cell!

Let's do a recap of the structures discovered inside the cell after the video tour! Fill in the below chart to help you organize what was visited! Remember there are more functions and structures that you can discover online.

Structure or Organelle on the Tour:	***Makes Me Think of…*** *(provide an illustration or analogy!)*	***Function(s):***	****Type of Cell?*** **Is it in both prokaryotes and eukaryotes? Or just eukaryotes?*
Cell Membrane	14.	15.	16.
Cytoplasm	17.	18.	19.
Ribosome	20.	21.	22.
Nucleus	23.	24.	25.
Endoplasmic Reticulum (Rough and Smooth)	26.	27.	28.
Golgi apparatus	29.	30.	31.
Mitochondria (Singular: Mitochondrion)	32.	33.	*Eukaryote Cells (in both animal and plant cells)*
Cell Wall	34.	35.	36.
Chloroplast	37.	38.	39.
Vacuole	40.	41.	42.

ScienceNews for Students

MICROBES

Bacteria are all around us — and that's okay

Although these microbes remain poorly understood, they could prove key to protecting life across the planet

From the great outdoors to our internal organs, the world is awash in unseen bacteria (some seen growing on plate here). Most people assume (unfairly) that these germs are all dangerous. Biologists know better. Studying these poorly understood microbes could better reveal how they function as the "invisible backbone of life."

JARUN011/ISTOCKPHOTO

By **Lindsey Konkel**

October 4, 2018 at 5:45 am

Victoria Orphan has loved the ocean for as long as she can remember. She used to snorkel in the Pacific Ocean near her family's home in San Diego, Calif. She'd grab her mask and snorkel tube to visit the hidden world of plants and animals beneath the ocean's surface. Orphan went to college at the University of

California, Santa Barbara in the early 1990s. There she discovered something that changed the way she thought about the oceans — and life on Earth.

Another student showed her a small vial of seawater. Orphan didn't think it looked all that interesting. It was just plain old water. Then the other student added a fluorescent chemical to the water and shined ultraviolet light on it. The tube lit up as millions of tiny bacteria began to glow. Just moments earlier, the microbes had been invisible. "These tiny organisms were all over the place," says Orphan, "and yet we couldn't see them. We knew almost nothing about them."

She now spends her days exploring this hidden single-celled world. As a geobiologist at Caltech in Pasadena, Calif., she studies how bacteria and other microscopic life shape the deep sea.

On a research vessel, Victoria Orphan holds a tube of sediment retrieved from the seafloor. The orange material is a large mat of bacteria. Researchers collected the bugs from a crack in the ocean floor near California. It's a site where methane gas seeps out.

VICTORIA ORPHAN

Bacteria play central roles in many ecosystems. These include the oceans, soil and atmosphere. They're also a big part of the global food web. Bacteria make it possible for all other life on Earth to exist. That's why scientists say these single-celled organisms are the invisible backbone of all life — at least on Earth.

Yet there's plenty we don't know about them. Scientists think they've identified fewer than one percent of all bacterial species. That's been driving Orphan and others to explore the mysteries of their one-celled world. They suspect bacteria will prove key to understanding — and protecting — Earth's most important natural resources.

The methane eaters

Some bacteria eat really weird things. Scientists have found bacteria that eat rocks, sewage — even nuclear waste. Orphan studies a type of bacteria that live on the sea floor and gobble up methane.

Explainer: CO_2 and other greenhouse gases

Methane is a greenhouse gas. Like carbon dioxide and some other greenhouse gases, it enters the air when people burn oil, gas and coal. There are also natural sources of methane, such as natural gas, rice production and cow manure. Greenhouse gases trap heat in the atmosphere. An excess of these gases in Earth's atmosphere has been warming the global climate.

Methane can seep out of the Earth on the sea floor. Some scientists say that even more methane would escape into the atmosphere if it wasn't for marine bacteria. Certain of those bacteria dine on methane. That allows the oceans to trap a huge amount of the gas. "These microorganisms are the gatekeepers.

They prevent ocean methane from getting into the atmosphere where it can change greenhouse-gas levels," Orphan explains.

Finding single-celled organisms on the vast sea floor can be a challenge. Through the window of a submarine, she looks for clusters of clams and giant tube worms. These organisms signal that invisible marine bacteria live there, too. Wherever those methane-eaters live, they create new molecules as they dine. Other organisms use those new molecules as food. An entire food web springs up on the ocean floor.

Orphan and her team have found methane-eating bacteria along cracks on the sea floor, where this gas is seeping out. These cracks often happen where two *tectonic plates* bump into each other.

Some bacteria, they learned, can eat methane only by partnering with other single-celled organisms called archaea (Ar-KEE-uh). That important detail could help scientists better predict how much methane is escaping into the air, says Orphan.

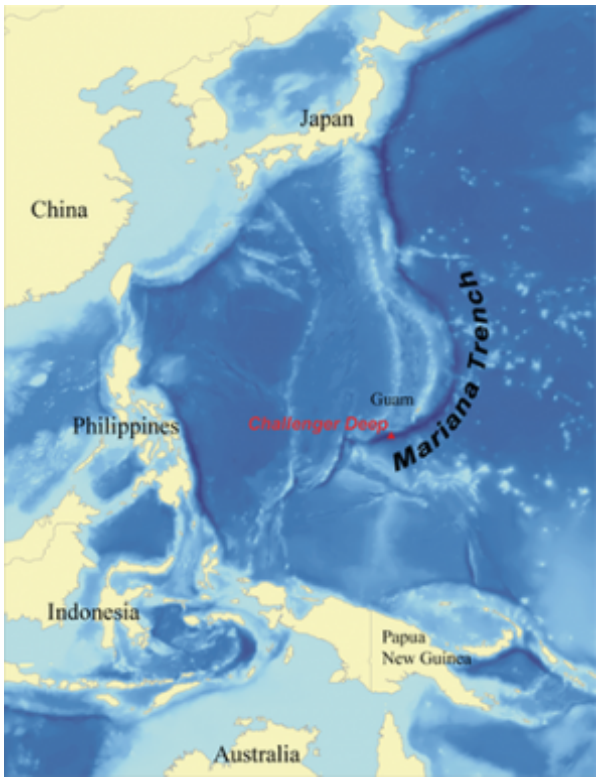
In the trenches

Methane eaters aren't the only deep-sea bacteria to interest scientists. "The deep sea is home to some pretty cool microbes," says Jennifer Biddle. She's a marine microbiologist at the University of Delaware in Newark. Biddle studies bacteria that live in deep ocean trenches.

These underwater canyons are some of the least-studied places on Earth. They are incredibly hard to reach. Challenger Deep wins the record for the deepest-known spot on the planet. At the bottom of the Mariana Trench, in the western Pacific, Challenger Deep sits some 11 kilometers (more than 7 miles) below the ocean surface. If Mount Everest, the world's tallest mountain, sat in the Mariana

Trench, its peak would still be more than a mile beneath the waves.

The Mariana Trench is one of the toughest places for life to survive. Zero sunlight reaches it. Its temperatures are frigid. Large animals, such as whales or fish, can't visit because the intense pressures there would crush them. Little surprise, then, that most of the locals are microscopic. They have adapted its extreme conditions.



The Mariana Trench is the deepest place on the planet. Jennifer Biddle and colleagues discovered new clues about the bacteria that survive here.

KMUSSER/WIKIMEDIA COMMONS (CC-BY-SA-3.0)

Biddle and other scientists teamed up with deep-ocean explorers to send a submarine to Challenger Deep. James Cameron piloted the vessel. (He's the movie director famous for *Avatar* and *Titanic*.) Cameron visited the bottom of Challenger Deep in March 2012 while making a documentary called *Deepsea Challenge 3D*. But the sub's trek wasn't just to get mesmerizing video for the Big Screen. The vessel also brought back sediment from the bottom of the trench.

Biddle and the other scientists screened that sediment for DNA. They were scouting for genes of familiar bacteria. They turned up evidence of some known as Parcubacteria.

Scientists didn't even know this big group of bacteria existed until 2011. Back then, they found some in groundwater and dirt from a few places on land. But

Biddle's group now showed it also survives in one of the most inaccessible depths of the ocean.

Explainer: DNA hunters

Here, on the trench floor, the microbes were breathing nitrogen, not oxygen (as they did on land). And that makes sense. They had adapted to nitrogen since their home had little access to oxygen.

The more places we find such little-known bacteria, says Biddle, the more we can learn about what they do for their ecosystems.

Story continues below video.

In 2012, film director James Cameron traveled to the deepest place in the ocean: Challenger Deep. There he collected water and sediment samples for scientists to study.

WORLD SCIENCE FESTIVAL

From bread to biofuels

Even the bacteria in our kitchens and compost heaps interest scientists.

Sourdough bread gets its unique tart flavor when a mix of bacteria munches on the sugars in bread flour. Those bacteria make carbon dioxide, acids and other flavorful compounds. But to function, sourdough bacteria need their friends. Isolate just one bacterial species from the mix and the chemical reaction won't happen. No sourdough.

Microbiologist Steve Singer lives near San Francisco, a California city famous for sourdough bread. He works for the Department of Energy at Lawrence Berkeley National Laboratory. And he suspected he could use the lessons of sourdough to make better biofuels. These plant-based fuels can power cars or trucks. They are considered "green," meaning more Earth-friendly, than fossil fuels.

To make biofuels, scientists must break down plants into sugars. These sugars can then be turned into fuels such as ethanol (a type of alcohol). The chemical reactions that break down the plants require help from enzymes. These are molecules that jump-start or speed up chemical reactions.

The enzymes currently used to make biofuels are expensive. They also don't work well, Singer says. That's why researchers all over the world are searching for enzymes that might lower the cost and speed the production of biofuels.

He turned his search for them to the compost pile. There, bacterial communities were hard at work breaking down rotting fruits and veggies.

Singer took a small sample of the compost back to his lab. There, he let bacteria from the compost grow in a beaker. Later, he collected enzymes that these bacteria made and tested them on other plant bits. It worked: The enzymes broke down the plants into sugars.

For ideas about how to make Earth-friendly fuels, microbiologist Steve Singer studies bacteria living on garbage.

STEVE SINGER

Just as the sourdough bacteria need their friends to function, Singer discovered that these microbes produced the useful enzymes only when they were part of robust communities of different compost bacteria. Singer is now scaling up his project. His team is growing bacteria in huge vats called bioreactors. After he makes lots of the new enzymes, he can test whether they work better than existing ones for converting plant wastes into fuels.

"Taking something from the environment and trying to figure out how it works is one of the best parts of being a microbiologist," Singer says.

Meta microbes

Singer is studying his new enzymes without knowing which bacteria are making them. This isn't all that unusual. Bacteria are invisible to the unaided eye. Even with a microscope, telling two species apart can be hard. They don't look as different as might two species of birds or flowers.

Scientists needed a different way to tell bacteria apart and know when they've stumbled upon new ones. Key to this sleuthing: DNA.

All organisms shed a little DNA throughout their environment. "It's like a fingerprint. Each is unique," explains Kelly Ramirez. She studies bacteria at the Netherlands Institute of Ecology in Wageningen.

Swab your kitchen counter and you might find human DNA (from you and your parents). There might be some plant DNA (from the veggies you just cut up) and from a fungus or two. There might even be some dog or cat DNA if you have a pet. You'll also get a bunch of bacterial DNA because, well, bacteria a everywhere!

All of the cast-off genetic bits are known as environmental DNA, or eDNA.

Scientists can use these genetic fingerprints to discover new bacteria, notes Ramirez. They just need to bring any little bit of dirt or seawater or compost to a lab and check out what's in it.

The sum of all the genetic material in an environment is called the *metagenome* (MET-uh-GEE-noam). Think of it as a DNA soup. All the molecules used to build the genes of different organisms are jumbled together.

Scientists use computers to untangle the mess.

More than 1,000 scientists are working together to catalogue all the bacteria on the planet. Their project is called the Earth Microbiome Project. So far they've collected more than 100,000 bacterial samples. Here are some of the places they've looked.

EARTH MICROBIOME PROJECT

Like a sieve, computer programs filter the soup. They look for familiar patterns known as *genetic sequences*. They form an organism's DNA fingerprint. If scientists find a fingerprint they don't recognize, it may be because it's from some new species.

Scientists can compare these patterns to the fingerprints of familiar bacteria to see where the new bacteria fall within the tree of life. "We can now discover new microbes without ever seeing them," explains Biddle at the University of Delaware.

The bacterial limb of the tree of life is sprouting new shoots and branches faster than at any time in history. Thirty years ago, all known single-celled organisms on the planet fit into a dozen major groups. Now there are about 120 known groups, or phyla (FY-lah). And the number of named bacteria in each group grows daily.

Little life, big data

What do you get when you add up the DNA sequences of millions of new bacteria? Lots and lots of data.

You can think about the planet as a machine, and all the ecosystems on Earth as the machine's parts, says Jack Gilbert. All these data on bacterial DNA are key to "understanding the parts that make up the machine and how they all work together," he says. Gilbert is a microbiologist at Argonne National Laboratory near Chicago, Ill.

His team is trying to organize those data into a virtual catalog of all the bacteria on Earth. It's called the Earth Microbiome Project. More than 1,000 scientists around the world are helping collect samples. They're looking in a host of different environments, then testing them for bacterial DNA.

So far the researchers have collected 100,000 samples. They've catalogued bacteria from the deepest ocean. They've found bacteria on the International Space Station, some 350 kilometers (220 miles) above Earth. They've discovered bacteria in exotic locations like the Amazon rainforest and ordinary places like public toilets.

Classroom questions

Discovering which bacteria lurk there — and why — is the first step to understanding how different ecosystems drive the vast machine we think of as life on Earth. Learning about bacteria may help us answer questions about how our planet works, Gilbert says. Bacteria may explain why coral reefs in the ocean teem with life. Or they could explain why the soils of the North American prairie are so good for planting crops.

That's why this search is so important, he says: "This is knowledge that can help us take better care of the planet."

CITATIONS

Journal: S.E. McGlynn et al. Subgroup characteristics of marine methane-oxidizing ANME-2 archaea and their syntrophic partners revealed by integrated multimodal analytical microscopy. *Applied and Environmental Microbiology*. Apr. 6, 2018. doi: 10.1128/AEM.00399-18.

Journal: K.S. Ramirez et al. Detecting macroecological patterns in bacterial communities across independent studies of global soils. *Nature Microbiology*. Vol. 3, Nov. 20, 2017, p. 189. doi: 10.1038/s41564-017-0062-x.

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Journal: R. Leon-Zayas et al. The metabolic potential of the single cell genomes obtained from the Challenger Deep, Mariana Trench within the candidate superphylum Parcubacteria (OD1). *Environmental Microbiology*. Vol. 19, Jul. 2017, p. 2769. doi: 10.1111/1462-2920.13789.

Wordfind

ScienceNews for Students

CLASSROOM QUESTIONS

Questions for ‘Bacteria are all around us — and that’s okay’

From the great outdoors to our internal organs, the world is awash in unseen bacteria (some seen growing on plate here). Most people assume (unfairly) that these germs are all dangerous. Biologists know better. Studying these poorly understood microbes could better reveal how they function as the "invisible backbone of life."

JARUN011/ISTOCKPHOTO

By **Science News for Students**

October 4, 2018 at 5:30 am

To accompany feature ‘Bacteria are all around us — and that’s okay’

SCIENCE

Before Reading:

1. You can’t see bacteria with the unaided eye, but they’re all around us, no matter where we are. How does this make you feel?

2. What sorts of jobs do you think bacteria perform in the environment? Why do bacteria matter?

During Reading:

1. Scientists estimate that what percentage of the world’s bacteria species are still undiscovered?

2. What is a greenhouse gas?

3. Based on this story, how do some scientists identify where to look for bacteria that interest them on the ocean floor?

4. What’s the deepest place on Earth? How far below the ocean’s surface is it?

5. How do microbes affect the flavor of sourdough bread?

6. What are biofuels?

7. What are enzymes?

8. Where did Steve Singer find bacteria that are good at breaking down plants?

9. What is a metagenome?

10. What is the Earth Microbiome Project? How many scientists are participating in it?

After Reading:

1. Why do scientists care about bacteria eating methane on the ocean floor? How might these bugs help our planet?

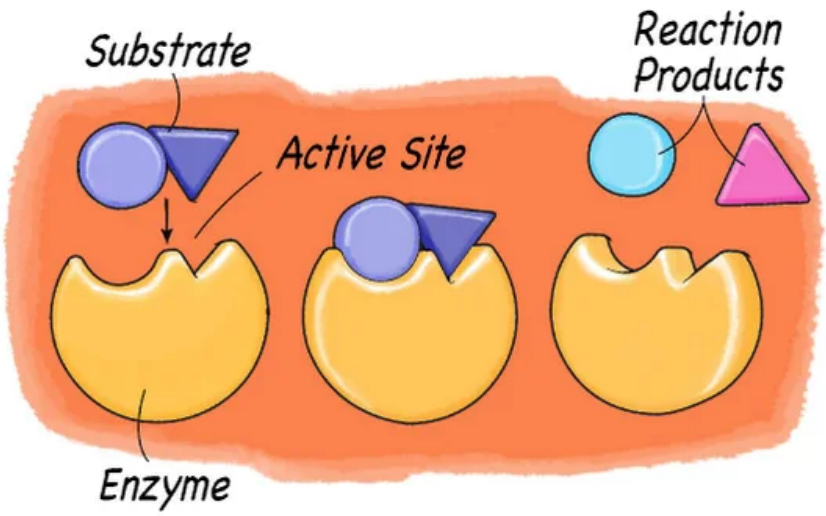
2. How can researchers discover new species of bacteria without ever seeing them under a microscope?

Bring Science Home

Exploring Enzymes

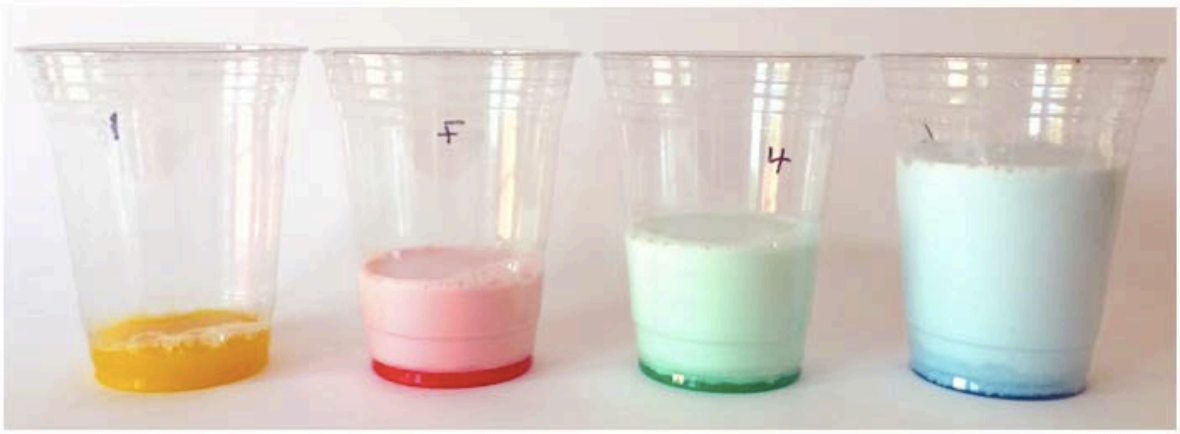
A catalyzing science project

By Science Buddies, Svenja Lohner on November 10, 2016



Ready, set, react! Learn how enzymes power everything from our digestion to protecting our cells from damage--and watch them in action in this activity! Credit: George Retseck

A hands-on science activity helps students observe the role of the catalase enzyme in breaking down hydrogen peroxide in the body.



Introduction

Have you ever wondered how all the food that you eat gets digested? It is not only the acid in your stomach that breaks down your food—many little molecules in your body, called enzymes, help with that too. Enzymes are special types of proteins that speed up chemical reactions, such as the digestion of food in your stomach. In fact, there are thousands of different enzymes in your body that work around-the-clock to keep you healthy and active. In this science activity you will investigate one of these enzymes, called catalase, to find out how it helps to protect your body from damage.

Background

Enzymes are essential for our survival. These proteins, made by our cells, help transform chemicals in our body, functioning as a catalyst. A catalyst gets reactions started and makes them happen faster, by increasing the rate of a reaction that otherwise might not happen at all, or would take too long to sustain life. However, a catalyst does not take part in the reaction itself—so how does this work? Each chemical reaction needs a minimum amount of energy to make it happen. This energy is called the activation energy. The lower the activation energy of a reaction, the faster it takes place. If the activation energy is too high, the reaction does not occur.

Enzymes have the ability to lower the activation energy of a chemical reaction by interacting with its reactants (the chemicals doing the reacting). Each enzyme has an active site, which is where the reaction takes place. These sites are like special pockets that are able to bind a chemical molecule. The compounds or molecules the enzyme reacts with are called their substrates. The enzyme pocket has a special shape so that only one specific substrate is able to bind to it, just like only one key fits into a specific lock. Once the molecule is bound to the enzyme, the chemical reaction takes place. Then, the reaction products are released from the pocket, and the enzyme is ready to start all over again with another substrate molecule.

Catalase is a very common enzyme that is present in almost all organisms that are exposed to oxygen. The purpose of catalase in living cells is to protect them from oxidative damage, which can occur when cells or other molecules in the body come into contact with oxidative compounds. This damage is a natural result of reactions happening inside your cells. The reactions can include by-products such as hydrogen peroxide, which can be harmful to the body, just as how a by-product of a nice bonfire can be unwanted smoke that makes you cough or stings your eyes. To prevent such damage, the catalase enzyme helps getting rid of these compounds by breaking up hydrogen peroxide (H_2O_2) into harmless water and oxygen. Do you want to see the catalyze enzyme in action? In this activity you will disarm hydrogen peroxide with the help of catalase from yeast.

Materials

- Safety goggles or protective glasses
- Five teaspoons of dish soap
- One package of dry yeast
- Hydrogen peroxide, 3 percent (at least 100 mL)
- Three tablespoons
- One teaspoon
- Five 16-ounce disposable plastic cups
- Tap water
- Measuring cup
- Permanent marker
- Paper towel
- Workspace that can get wet (and won't be damaged by any spilled hydrogen peroxide or food-colored water)
- Food coloring (optional)

Preparation

Take one cup and dissolve the dry yeast in about one-half cup of warm tap water. The water shouldn't be too hot but close to body temperature (37 Celsius). Let the dissolved yeast rest for at least five minutes.

Use the permanent marker to label the remaining four cups from one to four.

To all the labeled cups, add one teaspoon of dish soap.

To cup one no further additions are made at this point.

Before using the hydrogen peroxide, put on your safety goggles to protect your eyes. In case you spill hydrogen peroxide, clean it up with a wet paper towel. If you get it on your skin, make sure to rinse the affected area with plenty of water.

To cup two, add one tablespoon of 3 percent hydrogen peroxide solution. Use a fresh spoon for the hydrogen peroxide.

To cup three, add two tablespoons of the hydrogen peroxide.

To cup four, add three tablespoons of the hydrogen peroxide.

Optionally, you can add a drop of food color to each of the labeled cups. (You can choose a different color for each one for easy identification)

Procedure

Take cup number one and place it in front of you on the work area. With a fresh tablespoon, add one tablespoon of the dissolved yeast solution to the cup and swirl it slightly. What happens after you add the yeast? Do you see a reaction happening?

Place cup number two in front of you and again add one tablespoon of yeast solution to the cup. Once you add the enzyme, does the catalase react with the hydrogen peroxide? Can you see the reaction products being formed?

Add one tablespoon of yeast solution to cup number three. Do you see the same reaction taking place? Is the result different or the same compared to cup number two?

Finally, add one tablespoon of yeast solution to cup number four. Do you see more or less reaction products compared to your previous results? Can you explain the difference?

Place all four cups next to each other in front of you and observe your results. Did the enzymatic reaction take place in all of the cups or was there an exception? How do the results in each cup look different? Why do you think this is the case?

Now, take cup number one and add one additional tablespoon of 3 percent hydrogen peroxide to the cup. Swirl the cup slightly to mix the solution. What happens now? Looking at all your results, what do you think is the limiting factor for the catalase reaction in your cups?

Extra: Repeat this activity, but this time do not add dish soap to all of the reactions. What is different once you remove the dish soap? Do you still see foam formation?

Extra: So far you have observed the effect of substrate (H_2O_2) concentration on the catalase reaction. What happens if you keep the substrate concentration constant but change the concentration of the enzyme? Try adding different amounts of yeast solution to three tablespoons of hydrogen peroxide, starting with one teaspoon. Do you observe any differences, or does the concentration of catalase not matter in your reaction?

Extra: What happens if the environmental conditions for the enzyme are changed? Repeat the catalase reaction but this time vary conditions such as the pH by adding vinegar (an acid) or baking soda (a base), or change the reaction temperature by heating the solution in the microwave. Can you identify which conditions are optimal for the catalase reaction? Are there any conditions that eliminate the catalase activity?

Extra: Can you find other sources of catalase enzyme that you could use in this activity? Research what other organisms, plants or cells contain catalase and try using these for your reaction. Do they work as well as yeast?

Observations and results

You probably saw lots of bubbles and foam in this activity. What made the foam appear? When the enzyme catalase comes into contact with its substrate, hydrogen peroxide, it starts breaking it down into water and oxygen. Oxygen is a gas and therefore wants to escape the liquid. However, the dish soap that you added to all your solutions is able to

trap the gas bubbles, which results in the formation of a stable foam. As long as there is enzyme and hydrogen peroxide present in the solution, the reaction continues and foam is produced. Once one of both compounds is depleted, the product formation stops. If you do not add dish soap to the reaction, you will see bubbles generated but no stable foam formation.

If there is no hydrogen peroxide present, the catalase cannot function, which is why in cup one you shouldn't have seen any bubble or foam production. Only when hydrogen peroxide is available, the catalase reaction can take place as you probably observed in the other cups. In fact, the catalase reaction is dependent on the substrate concentration. If you have an excess of enzyme but not enough substrate, the reaction will be limited by the substrate availability. Once you add more hydrogen peroxide to the solution, the reaction rate will increase as more substrate molecules can collide with the enzyme, forming more product. The result is an increasing amount of foam produced in your cup as you increase the amount of H_2O_2 in your reaction. You should have seen more foam being produced once you added another tablespoon of hydrogen peroxide to cup one, which should have resulted in a similar amount of foam as in cup two. However, at some point you will reach a substrate concentration at which the enzyme gets saturated and becomes the limiting factor. In this case you have to add more enzyme to speed up the reaction again.

Many other factors affect the activity of enzymes as well. Most enzymes only function under optimal environmental conditions. If the pH or temperature deviates from these conditions too much, the enzyme reaction slows down significantly or does not work at all. You might have noticed that when doing the extra steps in the procedure.

Cleanup

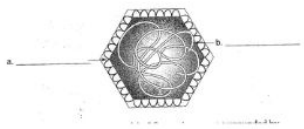
Pour all the solutions into the sink and clean all the spoons with warm water and dish soap. Wipe your work area with a wet paper towel and wash your hands with water and soap.

Review Module 1 **Name:** _____

1. Explain each characteristic of life.

Made of cells	
Reproduction	
Contains DNA	
Growth and development	
Ability to metabolize	
Response to stimuli	
Maintain homeostasis	
Evolution	

2. Viruses are made of two components: _____ and _____.
3. The _____ involves the virus making new viruses rapidly and breaking open the cell.
4. The _____ involves the virus incorporating itself into the host genome and making copies of the viral genome.
5. Vaccines can help to **destroy / prevent** a virus.
6. As more individuals in a population are inoculated, the viral infection rate **increases / decreases.**
7. Label the parts of the virus:



8. Which type of virus changes more frequently – RNA or DNA? _____
9. Label the lytic and lysogenic cycle in the diagram below:

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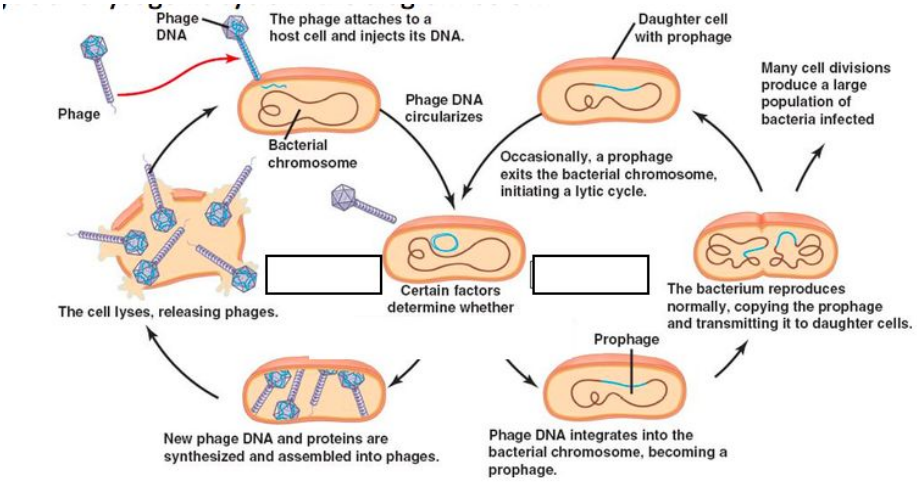

10. Define homeostasis

    _____

11. How many parents are involved in asexual reproduction? _____ Are the offspring the same or different from the parents? _____
12. How many parents are involved in sexual reproduction? _____ Are the offspring the same or different from the parents? _____
13. Name the 6 kingdoms: _____, _____, _____, _____, _____, _____
14. Complete the chart to compare the kingdoms – you may check multiple boxes if kingdoms have more variety and you may not check off all the boxes for each kingdom.

	Archaebacteria	**Eubacteria**	**Protist**	**Fungi**	**Plant**	**Animal**
Prokaryotic?						
Eukaryotic?						
Autotrophic?						
Heterotrophic?						
Unicellular?						
Multicellular?						
Phototrophism?						
Internal Digestion?						

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External Digestion?						
May have features of fungus-like, animal-like, or plant-like?						

For questions 15 and 16, refer to the following paragraph and the table.

Robert is studying the characteristics of life. He constructs the table shown below to compare examples of living things and nonliving things.

	Penguin	Earthworm	Oak Tree	Elevator
Made of cells	yes	yes	yes	no
Grow and develop	yes	yes	yes	no
Respond to the environment	yes	yes	yes	yes
Move from place to place	yes	yes	no	yes
Use energy	yes	yes	yes	yes

15. Based on the examples shown in the table, which is not a characteristic of all living things?
    a. being made of cells
    b. growth and development
    c. moving from place to place
    d. using energy
16. The data in the table most strongly support which of these conclusions?
    a. Any of the characteristics of life can distinguish living things from nonliving things.
    b. Nonliving things may have some, but not all, of the characteristics of life.
    c. Nonliving things may have some or all of the characteristics of life.
    d. No set of characteristics can distinguish living things from nonliving things.

For question 17, refer to the following paragraph.

Valerie conducted a controlled experiment on pothos plants, which are common houseplants. Her hypothesis is that the direction of light will affect the growth pattern of a plant. In one test group, she allowed the plants to receive light from one direction only. Valerie observed that the plants in this group bent their stems and leaves toward the light.

17. Valerie's observations most strongly demonstrate which of these characteristics of life?
    a. response to stimuli from the environment
    b. obtaining and using materials and energy
    c. evolution, or change over time
    d. maintaining a stable internal environment
18. Julian claims that viruses are alive. His supporting evidence is that viruses use the universal genetic code, are able to reproduce, and can evolve. Which statement would be most useful in an argument against Julian's claim?
    a. Viruses are too small to be classified as living things.
    b. Viruses evolve only after many generations.
    c. Viruses satisfy only some characteristics of life, not all of them.
    d. Viruses reproduce only under the proper conditions.

19. A student builds a model of the circulatory system that also compares blood chemistry at different points in the system. This study most strongly focuses on which characteristic of living organisms?
    a. responding to stimuli
    b. growing and developing
    c. changing over time
    d. homeostasis
20. Living things have certain qualities. For something to be considered alive, it must have those characteristics. Which is <u>NOT</u> one of these characteristics?
    a. made of cells
    b. responds to the environment
    c. is visible with the unaided eye
    d. obtains and uses energy
21. Which of the following occurs during a lytic, but not a lysogenic, viral replication cycle?
    a. The phage uses the host cell's "machinery" to replicate its own DNA
    b. A prophase is replicated each time the bacterium divides.
    c. A phage injects DNA into the host
    d. Whole viruses leave the host cell and infect other cells.
22. Which of the following is an <u>INCORRECT</u> statement about viruses that reproduce using <u>lysogenic cycles</u>?
    a. Prophage genes can direct harmless bacteria host cells to make toxins that cause serious illness.
    b. They can switch to a lytic cycle if triggered by an environmental signal.
    c. They kill their host cells by lysing them.
    d. They can remain in bacterial cells indefinitely.

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23. Which of the following is a characteristic that is shared by prokaryotes AND eukaryotes?
    a. Both contain DNA
    b. Both give us essential vitamins.
    c. Both are between 10 and 100 micrometers in diameter.
    d. Both have membrane-bound organelles.
24. Which feature is common to the domains Archaea and Eukarya?
    a. RNA polymerase is present.
    b. Histones are absent.
    c. Cell walls contain peptidoglycan.
    d. Cells lack nuclei and membrane-bound organelles.
25. The _____end of the water molecule has a more negative charge and the hydrogens have a more positive charge. This is called _____.
26. Name four properties that water has due to its polarity. _____, _____, _____, and _____
27. Functional groups determine the _____ of a molecule.

28. Identify each functional group in the table:

Structural Formula	Name of Group
$-CH_3$	
-COOH	
-OH	
$-NH_2$	
-CO	
$-OPO_3^{2-}$	

29. Dehydration synthesis removes a molecule of _____ to join monomers into polymers.
30. Hydrolysis adds a molecule of water to break a polymer into _____
31. All carbohydrates have the same ratio of C:H:O which is _____.
32. Proteins contain 4 elements – C, H, O, and ____
33. How many different amino acids are there? _____
34. Nucleic acids contain the elements C, H, O, _____ and _____.

35. Complete the chart to compare the macromolecules.

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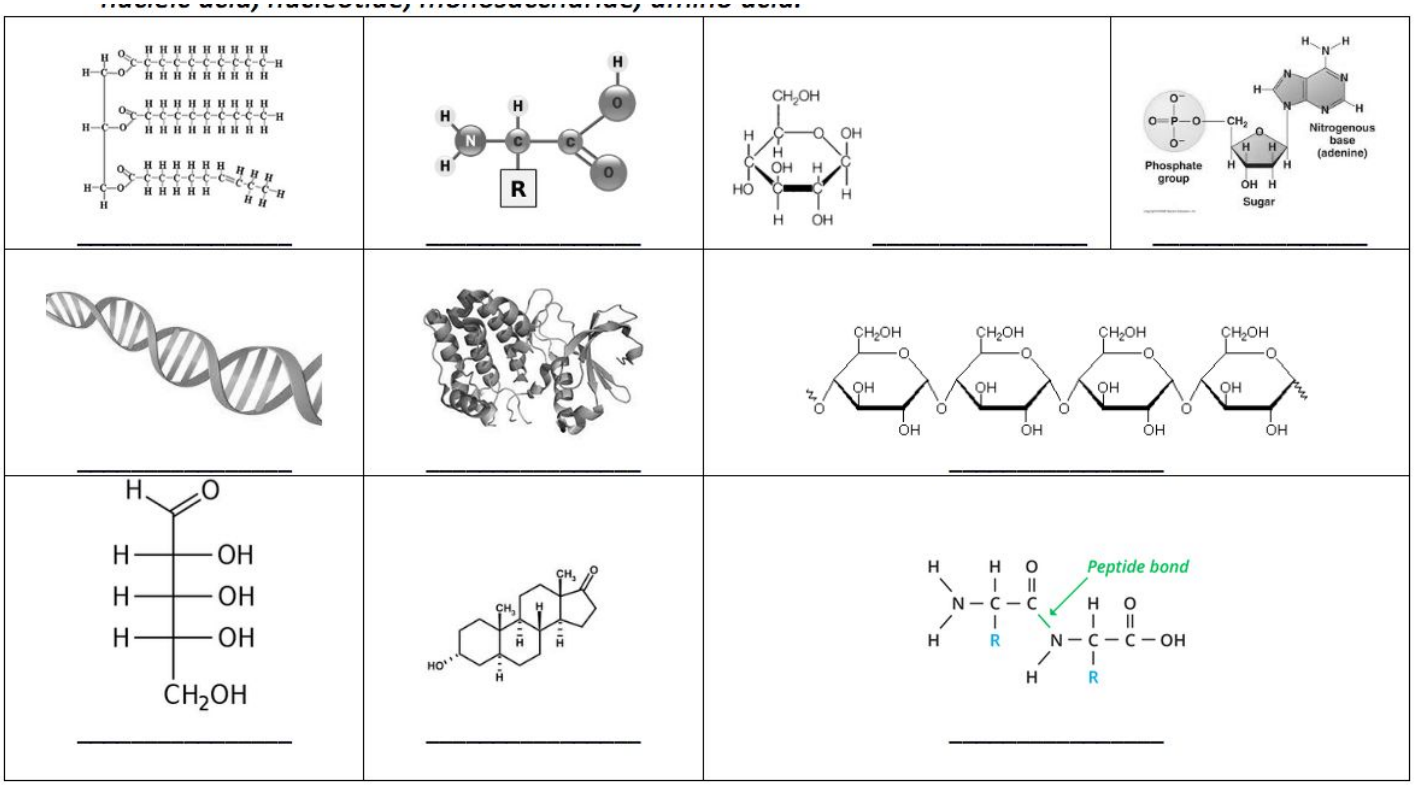
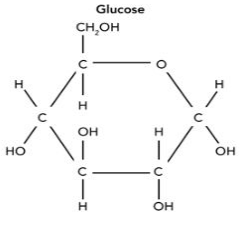
	Carbohydrates	Lipids	Proteins	Nucleic Acids
Examples of monomers?				
Example of polymers?				
Functions?				

36. On the table below, label the pictures with the following words: *carbohydrate, lipid, protein, nucleic acid, nucleotide, monosaccharide, amino acid.*



37. Cells use glucose as a monomer to make a variety of polymers.
    Which of the following correctly describes a type of glucose polymer?
    a. cellulose, which forms a tough fiber in plants



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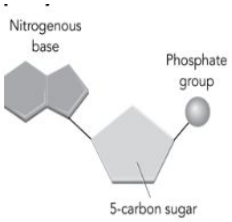
b. DNA, which contains genetic information
c. catalase, which is a component of cell membranes
d. thyroxine, which binds to cell receptors

Most enzymes are proteins. Many cells make and use an enzyme called catalase to facilitate the decomposition of hydrogen peroxide (H_2O_2). The products of the decomposition are hydrogen (H_2) and oxygen (O_2). Stephanie is investigating the structure and function of catalase, and she is comparing catalase to other proteins.

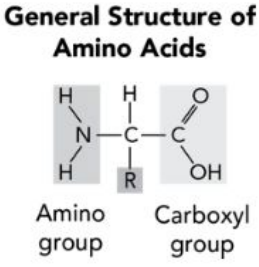
38. What can Stephanie predict will distinguish the structure of catalase from the structures of the other proteins she is studying?
    a. many regions made entirely of hydrogen and oxygen
    b. the chemical properties of the peptide bonds
    c. the types of amino acids it contains
    d. the sequence of amino acids it contains
39. Stephanie increases the pH of catalase beyond its normal range. She observes a decrease in the rate of decomposition of hydrogen peroxide. What is the most likely explanation for this result?
    a. a change in the chemical properties of the reactants
    b. a change in the chemical properties of the products
    c. a change in the shape of the catalase molecule
    d. a change in the amino acid sequence of the catalase molecule

40. Cells within organisms often need to communicate and work together to carry out life's processes. Which of the following enables cells to communicate?
    a. Proteins on cell surfaces act as receptors to certain compounds.
    b. The double helix of DNA acts as a tunnel for messenger molecules.
    c. Carbohydrates store and release information.
    d. Starches store excess information until it's needed by cells.
41. The diagram shows the chemical structure of a nucleotide. Nucleotides can form polymers called nucleic acids. In these polymers, how do the nucleotide monomers compare with one another?



    a. The nitrogenous base may differ among the monomers.
    b. The 5-carbon sugar may differ among the monomers.
    c. The number of phosphate groups may differ among the monomers.
    d. The monomers are identical, but may bond together in various ways.
42. Amino acids are the monomers that form proteins. The diagram shows the general structure of an amino acid. Which property of amino acids allows for a wide variety of proteins?

    a. the variety of bonds that may form between two amino acids
    b. the variability of the R group



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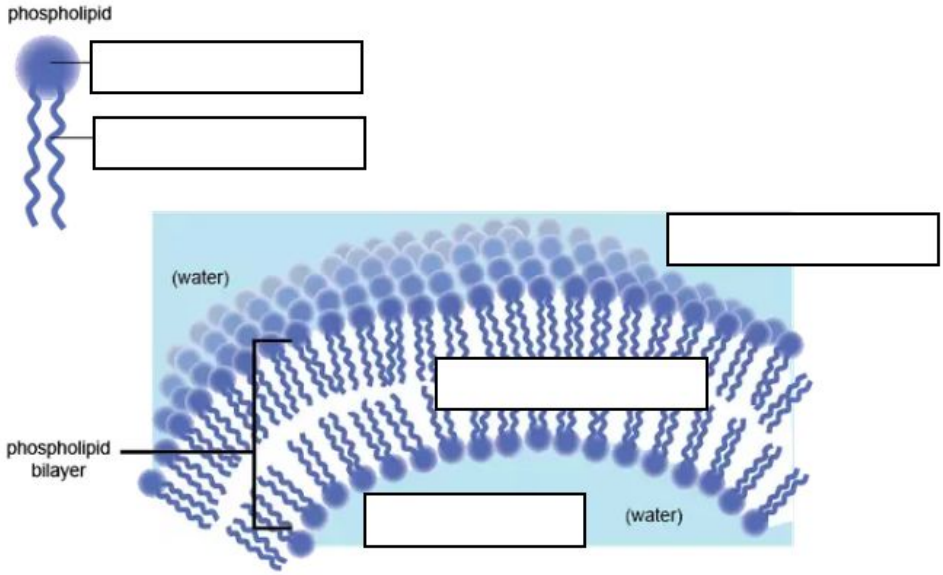
c. the number of amino groups ($-NH_2$) that may attach to the central carbon atom

d. the number of carboxyl groups (-COOH) that may attach to the central carbon atom

43. Jamal is comparing glycogen and starch. He learns that both compounds are complex carbohydrates. Many animals store glycogen in liver and muscle cells, and plants store starch in seeds, tubers, and other parts. Based on this information, which is the most likely function of both glycogen and starch?
    a. transporting nitrogen-containing wastes
    b. providing glucose when cells need energy
    c. coding for genetic information
    d. catalyzing chemical reactions
44. The _____ forms a flexible barrier with its surroundings.

45. Label each box of the phospholipid and the cell membrane illustration as hydrophobic or hydrophilic.



46. The _____region of a prokaryote contains DNA.
47. _____and cilia help prokaryotes to move in their environment.
48. You find a cell that has DNA, cytoplasm, a cell wall, golgi bodies, ER, and ribosomes. What type of cell have you most likely found? _____
49. The cellular metabolism are the collective cell _____.

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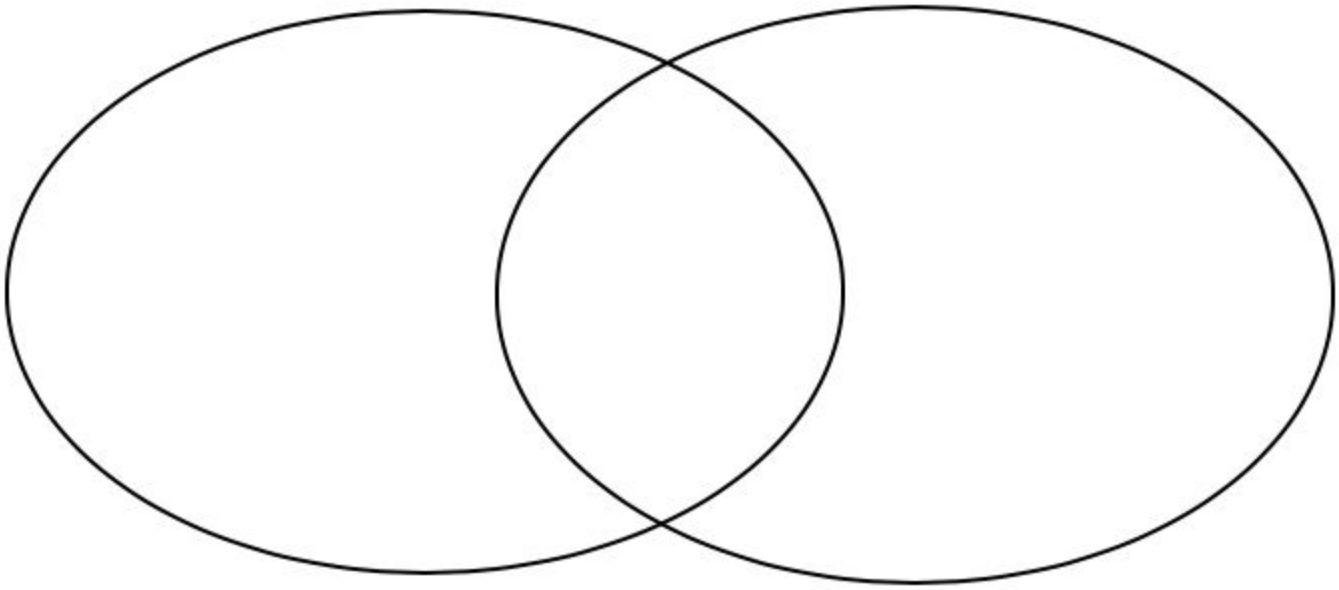
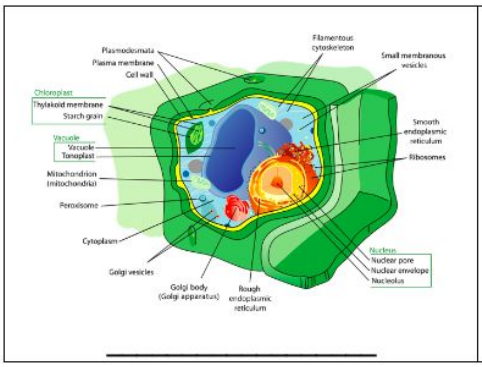
50. Lysosomes and centrioles are not found in plant cells; they are only found in _____ cells.
51. Complete the Venn diagram to compare eukaryotic and prokaryotic cells. Use the following words:

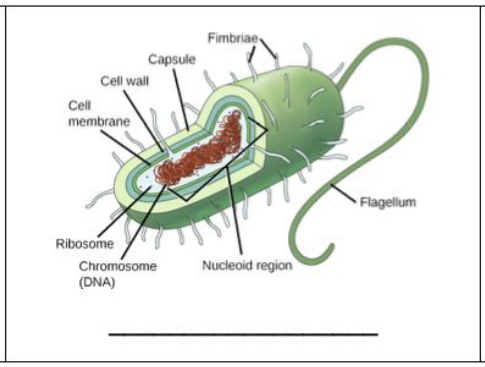
No nucleus Nucleus Cytoplasm Ribosomes Capsule Nucleoid Cell wall
Maybe cell wall Plasma membrane DNA

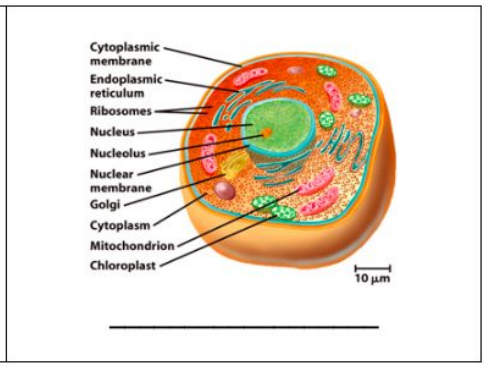
Prokaryote Eukaryote



52. Identify each picture as a prokaryotic cell or a eukaryotic cell.







53. _____ is the form of DNA when it is uncoiled. It is formed as chromosomes when it is coiled.
54. The plasma membrane is made of a _____ bilayer.

Match each function with the organelle that performs that overall category job in eukaryotic cells:

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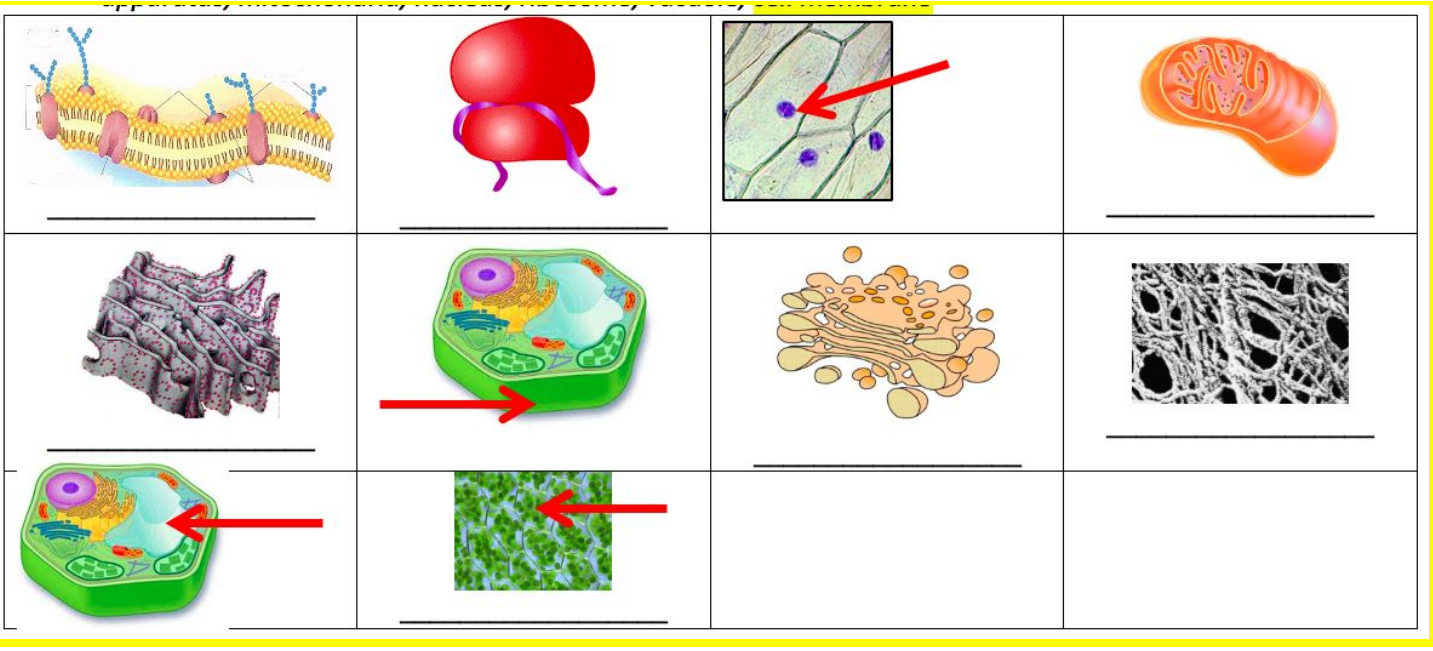
55. genetic control of the cell _____ 56. uses carbon dioxide to make glucose ____ 57. breaks down hydrogen peroxide ____ 58. phospholipid bilayer ___ 59. stores water and other materials ____ 60. makes ATP energy using glucose ____ 61. transports materials within the cell ____ 62. packages and transports materials out of the cell ____ 63. supports the cell, made of cellulose in plants and chitin in fungi ____ 64. recycles waste and old organelles ____ 65. makes proteins ____	A. cell wall B. chloroplast C. endoplasmic reticulum D. golgi apparatus E. lysosome F. mitochondria G. nucleus H. peroxisome I. plasma membrane J. ribosomes K. vacuole

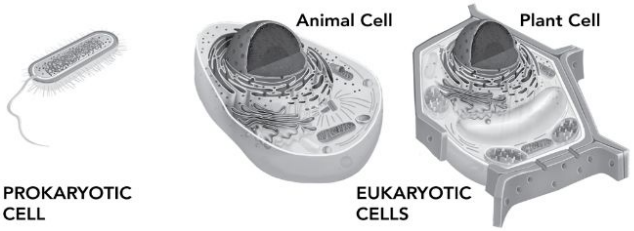
66. The molecule, _____, makes up the ribosomes.
67. **Smooth ER** is important in synthesizing _____ , oils, phospholipids, and steroids. What organ has an abundant of smooth ER? _____ Calcium ions stored by the smooth ER are important for _____ contraction.
68. **Rough ER** secretes proteins such as insulin that regulates _____ in the bloodstream. There are four steps to protein secretion: _____ is threaded into the cavity of the rough ER and the protein folds into a 3D shape. Short carbohydrate chains are linked to the protein, making it a glygoprotein. When it is ready for _____ ,the protein is packaged into a transport vesicle. The vesicle then buds from the ER _____.

69. Identify each organelle based on the picture. *Use the words: cell wall, chloroplast, cytoskeleton, ER, golgi apparatus, mitochondria, nucleus, ribosome, vacuole, cell membrane*



70. The organelle, _____ , is very abundant in muscle cells.
71. The organelle, _____, is very abundant in fat cells
72. The organelle, _____ , is very abundant in liver cells.
73. Which organelle would you expect to be very abundant in pancreas cells to make insulin? _____ to export the insulin? _____
74. Which organelle would you expect to be very abundant in stomach cells to make the enzyme, pepsin? _____ to export the pepsin? _____
75. Red blood cells are enucleated. This means it doesn't have a _____.
76. Plants have a lot of _____ in their leaves but none in their roots.

A cell can be identified based on the structures present in the cell. The illustration below shows three different types of cells.



77. Which type of cell structure is included in all three cells?
    a. a cell membrane made of a lipid bilayer
    b. a nucleus that contains DNA
    c. mitochondria that contain DNA
    D. a cell wall made of cellulose
78. Which two types of structures are present in a plant cell, but not an animal cell?
    a. chloroplasts and nucleus
    b. cell membrane and cell wall
    c. chloroplasts and mitochondria
    D. chloroplasts and cell wall

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79. The table compares the structures and characteristics of two cells.

Structure	Cell 1	Cell 2
DNA	Located in cytoplasm	Located in nucleus
Cell membrane	Present	Present
Cell wall	Present	Absent
Mitochondria	Absent	Present
Ribosomes	Present	Present

What conclusion about the cells does the data in the table support?

a. Cell 1 is from a plant; Cell 2 is from an animal.
b. Cell 1 is prokaryotic; Cell 2 is from a plant.
c. Cell 1 is prokaryotic; Cell 2 is from an animal.
d. Cell 1 is eukaryotic; Cell 2 is prokaryotic.

80. Which of the following structures occurs in cells of all types, including prokaryotic cells and eukaryotic cells?

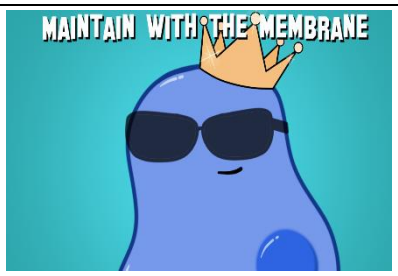
a. a cell membrane made of a lipid bilayer
b. a large central vacuole that stores water
c. mitochondria that provide energy for cell processes
d. chloroplasts that capture and transform the energy of sunlight

81. Stewart is investigating the responses of plants to their environment. As part of the investigation, he studies a plant that receives sufficient water and has straight, upright stems and firm leaves. He also studies another plant that was grown in dry soil, and that has wilted stems and leaves. When Stewart examines the cells of the plants under a microscope, which organelle will display the greatest difference between the two plants?

a. the nucleus, because chromosomes thicken in water
b. the cell membrane, because water diffuses across it
c. chloroplasts, because photosynthesis depends on water volume
d. the central vacuole, because it stores water and provides support

Amoeba Sisters Video Recap: *Cell Transport*

The cell membrane is important for maintaining **homeostasis**, because it controls what enters and leaves a cell.



1. Sketch the **phospholipid bilayer** of a cell membrane below and label the **polar heads** and **nonpolar tails**.

2. What is **simple diffusion**?

_____

_____

_____

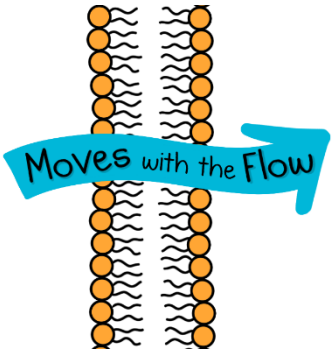
_____

3. Circle the statements below that would be TRUE about **simple diffusion**. HINT: There is more than one!

A) It is a form of passive transport.
B) Molecules travel with the concentration gradient.
C) It is how glucose travels across the cell membrane.
D) It is how oxygen and carbon dioxide travel across the membrane.
E) This transport is typical for large molecules.

Moving with the Concentration Gradient

4. "Moving with the flow" (i.e. going with the concentration gradient) is the direction of flow in passive transport. Show this in the diagram on right by **drawing in 10 total circles (to represent molecules)**. You must decide a certain amount to place on the left vs. the right side after viewing the arrow indicating the direction of movement. **Label the high concentration side and low concentration side**.



Endocytosis and Exocytosis

5. Are **endocytosis** and **exocytosis** forms of passive or active transport? _____

6. Give a scenario where a cell may need to perform a form of **endocytosis**. _____

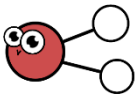
_____

_____

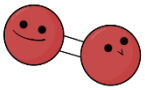
7. Give a scenario where a cell may need to perform a form of **exocytosis**. _____

_____

_____



Traveling Molecules



For the following scenarios, determine whether the molecules in the scenario are moving by (S) simple diffusion, (F) facilitated diffusion, or (A) active transport.

8. _____ For water to travel across the cell membrane at a substantial rate, the water molecules travel through protein channels known as **aquaporins**.

9. _____ While water molecules are polar, they are also very small. One fact not mentioned in the video is that some water molecules are able to squeeze directly through the phospholipid bilayer due to their small size.

10. ____ Charged ions are traveling through a cell membrane with the concentration gradient.

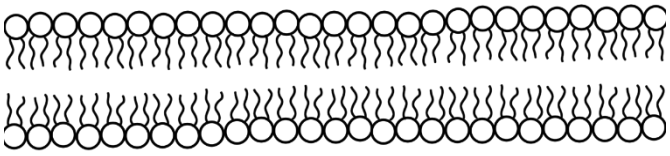
11. ____Cells lining the gut need to take in glucose, but at a certain time, the concentration of extracellular glucose is lower than the concentration already stored in the cells.

12. ____At a certain time, glucose is in a high concentration outside of a cell and needs to travel through the membrane into the cell.

Facilitated Diffusion via a Protein Channel

For the below image, label the **13. polar area** and **14. non-polar area** on the diagram.

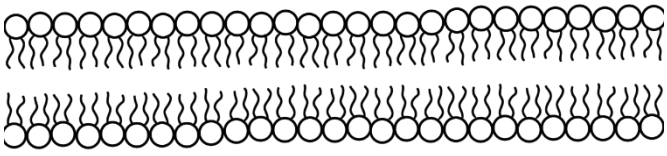
Draw in **15. protein channel** and **16. molecules that would represent a potential concentration gradient in facilitated diffusion** via a protein channel on the diagram.

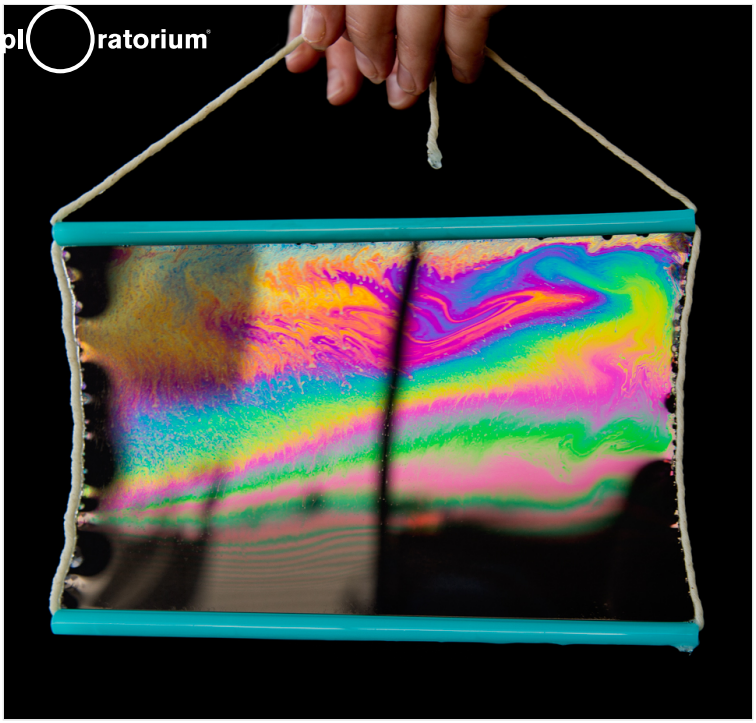


Active Transport via a Protein Channel

For the below image, label the **17. polar area**, and **18. non-polar area**.

Draw in **19. protein channel** and **20. molecules that would represent a potential concentration gradient in active transport** via a protein channel on the diagram.





Cellular Soap Opera

Soap films can behave like membranes.

Every cell in your body needs to take in nutrients, oxygen, and raw materials and export wastes and other substances—but it's not just a random traffic jam! A cell membrane (also called a plasma membrane) regulates what comes in and what goes out. Explore the properties of soap films and relate them to the properties of plasma membranes and the mechanics of transport across membranes.

COVID-19 Learning Note: Some viruses, including the novel coronavirus, are surrounded by the same type of membrane that surrounds human cells. This Snack uses a soap film to model how membranes behave. Because soap has similar properties to the components of a virus's membrane, it can disrupt the viral membrane on contact, inactivating the virus.

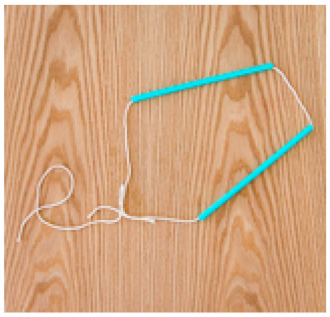
Tools and Materials

- Dish soap, Dawn™ brand recommended
- Water
- Glycerin *(can be found at walgreens or walmart in beauty supplies or can substitute corn syrup)*
- Cotton string
- Two drinking straws
- Scissors
- Aluminum roasting pan or similar container that is wider than the straws

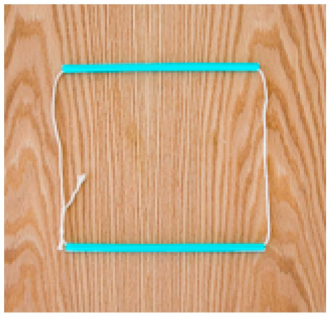
- Sheet of black construction paper or other black material

Assembly

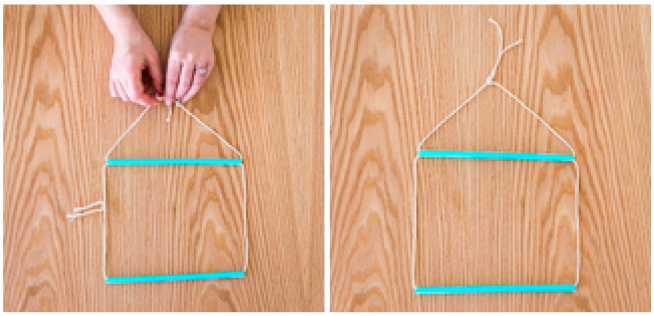
1. To make your bubble solution, mix dish soap and water in a 1:10 ratio, adding one tablespoon of glycerin to each gallon of solution. Let the solution age at least overnight for the longest-lasting bubbles.
2. Tie a separate small loop of string about 3cm in diameter-set aside.
3. Fill the roasting pan with the soap solution to a depth of at least 1 inch (2.5 cm).
4. Cut a piece of string that's approximately four times the length of the straw. Thread it through the two straws and tie the ends together to make a loop (see photo below).



5. Move the straws and string into the shape of a rectangle. This is your bubble frame (see photo below). Cut the excess string from the ends of the knot. Move the string through the straws so that the knot is hidden inside one of the straws.



6. To create a handle for the frame, cut another piece of string that's approximately three times the length of the straw. Thread the string through one of the straws and tie the ends together (see photos below).



To Do and Notice

This activity is easiest to do with at least two people. One person can make the soap film and hold the handle while the other person explores how the film behaves.

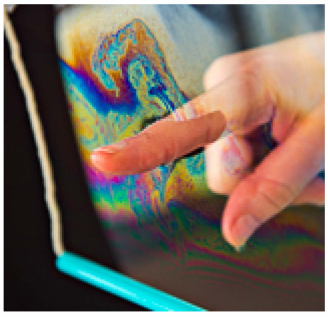
Shape the bubble frame into a rectangle. Holding the frame by the handle, immerse the entire frame into the bubble solution.

Lift the frame up by the handle until the bottom of the frame is slightly out of the bubble solution and the straws are parallel to the tabletop. You should have a rectangular soap film between the two straws. If there isn't any soap there try immersing and lifting the frame again.

Hold the soap film in front of the black construction paper or other black material. Carefully observe the surface of the film. Blow gently on the film and watch what happens.

Repeat the first two steps if the bubble pops while you are completing the steps below.

Wet your finger in the bubble solution. Gently poke through the soap film with your finger. What happens? Can you move your finger around in the film? Now wet a non-soapy finger in plain water and poke it into the film. What happens?



Try gently poking a dry finger through the soap film. What happens now?

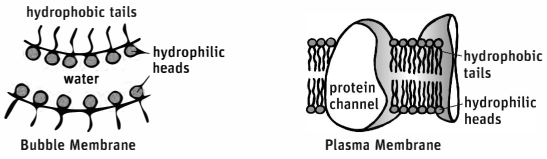
Make a new film on the frame. Roll the small loop of string in the bubble solution to coat its surfaces. Hold the bubble film flat and lay the loop on the film teasing the loop into an open circle.

Leave the loop in this position and pass an object (such as a pen) through the loop and move the loop around the soap film.

Based on your observations, what conditions allow objects to pass through the soap film without popping it? What conditions cause the film to pop? Do you think the flexibility of the film influences its ability to resist popping? Why or why not?

What's Going On?

Both the bubble membrane and plasma membrane create a somewhat fluid barrier between two distinct sides. While the bubble membrane only separates arbitrary right and left sides of the bubble, the cell's plasma membrane separates the interior and exterior of a cell. In both cases, the membranes are semipermeable, meaning that they allow certain substances to pass through while others can't. The soap film is a "water sandwich," a layer of water positioned between two layers of soap molecules. The *hydrophilic* (water-loving) heads of the soap molecules point inward toward the water layer, and the *hydrophobic* (water-hating) tails of the soap molecule point to the outside of the film, in contact with the air (see diagram below). Like the bubble, the plasma membrane also has a bilayered structure. In a cell, though, the membranes are made of molecules called *phospholipids*, which have hydrophilic heads on the outer layer of the membrane and hydrophobic tails on the inner layer of the membrane.



When a finger, string, or other object is coated in water or bubble solution and inserted through the soap film, the film remains in contact with a "like" solution and doesn't burst. In contrast, a dry object or an object with a different chemical make-up shears the film. Like the bubble membrane, a cell's plasma membrane will also allow molecules that have a similar chemical makeup to the interior of the membrane to pass through. For cells, this includes molecules that are hydrophobic, like the bulk of the membrane. Some polar molecules that are partially charged are also able to pass through the membrane, but it is their small size that enables them to do so as they pass through the spaces between the phospholipids.

Large polar molecules, such as glucose, and fully charged ions, such as H^+, Na^+, and K^+, require special transport processes to cross the membrane. The loop of string "channel" in the bubble membrane models this type of movement, allowing materials that are unlike the membrane to cross it. In cells, the channels are made up of proteins that are embedded in the membrane. Protein channels in the plasma membrane are not simple tunnels. They undergo complex shape changes and often require energy to move molecules across the membrane. Like the loop of string, the protein channels are not fixed and are able to move within the membrane. This bi-layered, flexible membrane with mobile channels is known as the *Fluid Mosaic Model*.

Going Further

Coat a finger with a different type of material (vegetable oil or rubbing alcohol, for example) and see if you can penetrate the film without popping it. Try it several times with different fluids. What do the fluids that work seem to have in common?

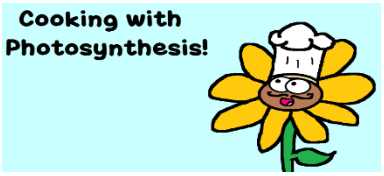
Tips

Try other Exploratorium activities including the Naked Egg Snack at

https://www.exploratorium.edu/snacks

Amoeba Sisters Video Recap: "Photosynthesis and Cellular Respiration"

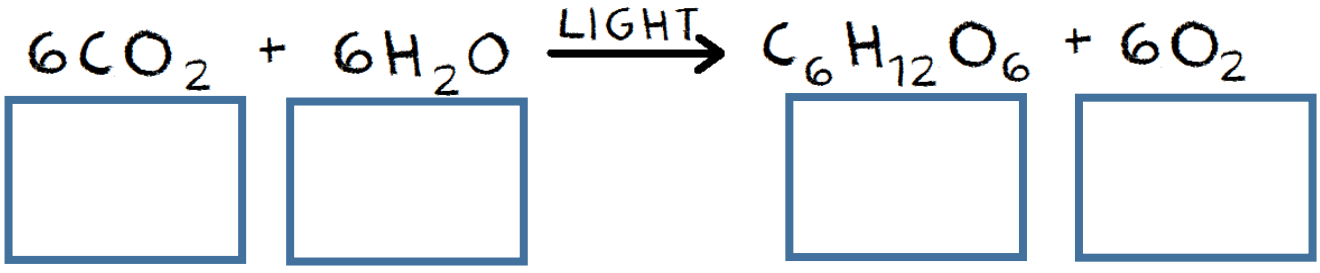
NOTE: This recap compares two Amoeba Sisters videos: photosynthesis and cellular respiration.

1. In photosynthesis, what are the two major reactions that take place? _____ _____ 	2. Where do each of these reactions take place? -_____ - _____ 
3. In aerobic cellular respiration, what three major steps are involved? _____ _____ _____	4. Where do each of these three major steps take place (for eukaryotes)?  - _____ - _____ - _____

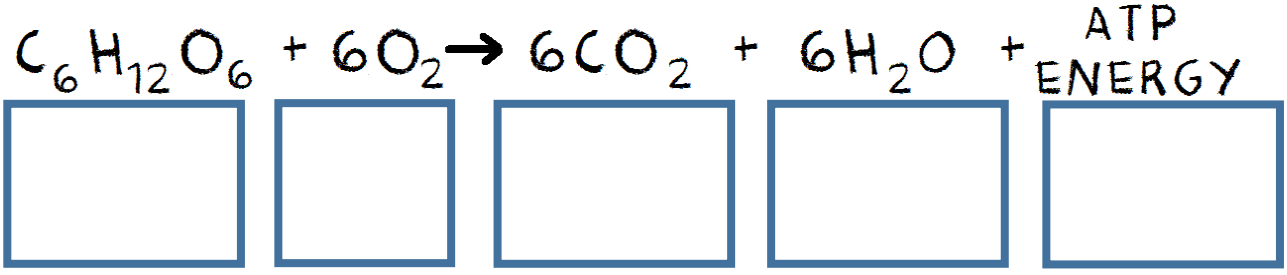
Formula Illustrations

For the following formulas, (1) determine whether the formula is photosynthesis or cellular respiration, (2) circle the products, and (3) creatively illustrate each reactant or product in the box underneath.

5. Formula is for: _____



6. Formula is for: _____



If Chloroplasts and Mitochondria Could Speak

*If chloroplasts and mitochondria could only speak! Decide whether each quote could be stated by a chloroplast (label "C"), mitochondria (label "M"), or **both** organelles (label "C, M").*

7. _____ My main goal is to produce a lot of ATP energy.

8. _____ I contain pigments to help capture light energy.

9. _____ Oxygen gas production will happen within me.

10. _____ I can be found in plant cells.

11. _____ I can be found in animal cells.

12. _____ Carbon dioxide gas production will happen within me.

13. _____ Muscle cells would contain a lot of me.

14. _____Water production will happen within me.

15. _____ Glucose production will happen within me.

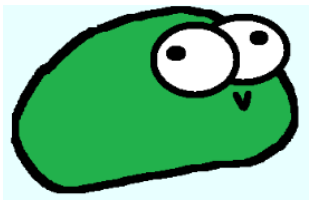
16. _____ I would be found within a photosynthetic protist.

17. _____ I am the site of aerobic cellular respiration.

18. _____ Krebs and the Electron Transport Chain both happen within me.

19. _____ I contain chlorophyll.

20. _____ The Calvin Cycle happens within me.



ScienceNews for Students

PLANTS

Scientists look to hack photosynthesis for a ‘greener’ planet

Plants serve as the inspiration for new energy technologies — and more efficient agriculture

Scientists are looking at how plants turn sunlight into sugars — a process known as photosynthesis — as a model for cleaner ways to produce energy for people and industry. Their research even suggests ways people can help plants photosynthesize more efficiently.

XURZON/ISTOCK /GETTY IMAGES PLUS

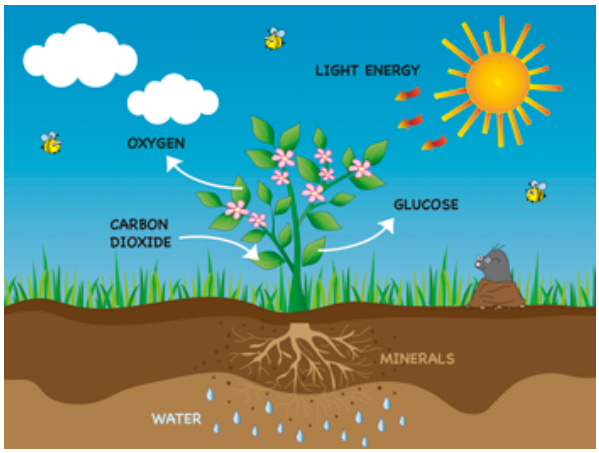
By **Lindsay Patterson**

December 5, 2019 at 6:45 am

Photosynthesis comes as naturally to plants as breathing does to people. This process converts the simple ingredients of carbon dioxide, water and sunlight into energy. Photosynthesis allows plants to grow. In turn, we rely on photosynthesis as the foundation for our life on Earth.

Carina Baskett recalls the first time she learned about photosynthesis. She says, “I remember feeling like, this seems so magical.”

She’s now a plant biologist at the Institute of Science and Technology Austria in Klosterneuburg. “It’s just so amazing that plants are taking air, water and light — things we walk around in, all the time — and they’re turning that into energy and food for the whole world.”



MILENA MOIOLA/ISTOCK /GETTY IMAGES PLUS

Sunlight can trigger a reaction in green plants. Its energy splits the water molecules in leaves into hydrogen and oxygen atoms. The plant then uses that hydrogen to react with carbon dioxide, to form sugars — a type of food and fuel.

The sun’s energy makes us feel warm when it hits our bare skin. But when sunlight touches the leaves of a plant it does more. It powers a chemical reaction that converts one type of energy into another. Those plant leaves contain plenty of water. That water is made of oxygen atoms bonded to hydrogen atoms. The sun’s energy can excite electrons inside the water molecule enough that the bonds split.

This triggers a reaction “that takes the oxygen away from the water. And that becomes the oxygen in the air that we all breathe,” explains Baskett. Meanwhile, she notes, “Hydrogen from the water gets smushed together with the carbon dioxide [in air], and that makes sugar.”

People and all other animals use this sugar — glucose — as an energy source from food. Plants become the food that our bodies can convert into energy. Essentially, photosynthesis is the reason we can exist, Baskett explains.

It's no mystery why photosynthesis fascinates her and other scientists. Many of them now want to know more about it, imitate it — even improve upon it.

Blinking plants

The basics of photosynthesis are well-known. Chlorophyll, the green pigments in plants, use sunlight to make sugars. But there's still a lot to learn about how plants control the process and its efficiency. Enter Avihai Danon. He's a plant biologist at the Weizmann Institute of Science in Rehovot, Israel. He studies how plants regulate, or control, photosynthesis. In a paper published last year in *iScience*, *his team* described one such process. He describes it as plants "blinking."

"Too much light can actually burn the plant's cells," says Danon. He compares a plant exposed to too much light to a person playing with electricity. "If suddenly there is a rise in light level, how do they handle it? Do they get burned?"

Any gardener knows plant species are adapted to live in particular amounts of sunlight. But light conditions naturally change. Clouds travel across the sky, wind ruffles leaves and the sun's position moves throughout the day. To study how photosynthesis adjusts to these changes, Danon studied mustard plants in his lab under low light.

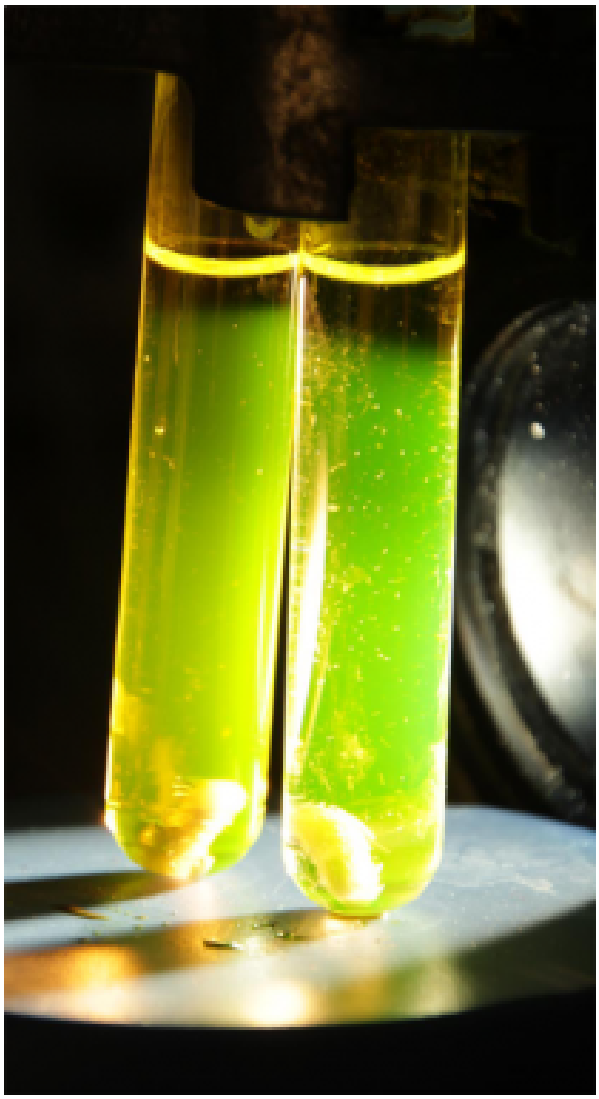
In one test, he increased the light's intensity every 10 minutes. This was to mimic the rising sun. As the light changed, Danon measured the plant's fluorescence (Fluor-ESS-ents). This is a form of light energy released by photosynthesis. Measuring the fluorescence helped Danon see how much photosynthesis occurred under different levels of light.

As the day brightened, Danon expected to see a steady increase in photosynthesis. Instead, the pattern resembled more of a flicker.

Photosynthesis would slow way down, and then bump back up a little. Down, and then up. Again and again, little by little, it adjusted to the strengthening light.

“It’s taking a better-be-safe-than-sorry approach,” Danon explains. The plant was anticipating the worst conditions, he says, before adjusting to the actual changes.

Danon couldn’t help but draw a comparison to how human eyes respond to sudden, bright sunlight. When we step outside on a sunny day, our pupils constrict. That response protects our eyes from damage while making sure we still can see important things around us.



REISNER LAB

Scientists at the University of Cambridge are working to create a type of solar fuel that’s made from natural, rather than synthetic, chemicals. The catalyst they use comes from a plant.

Plants can’t move, so their “blinking” helps protect them from burning or bleaching when they are in bright sun. A plant’s light gauges — you can think of them as antennae — register when light levels change. These antennae shrink, and in the process reduce photosynthesis. This shrinking also protects them from sudden changes that might damage the entire plant.

Danon is inspired by what plants can do. "If plants have developed this type of very *sophisticated* response, and they are successful for hundreds of millions of years, maybe it can help us in our own engineering," he says.

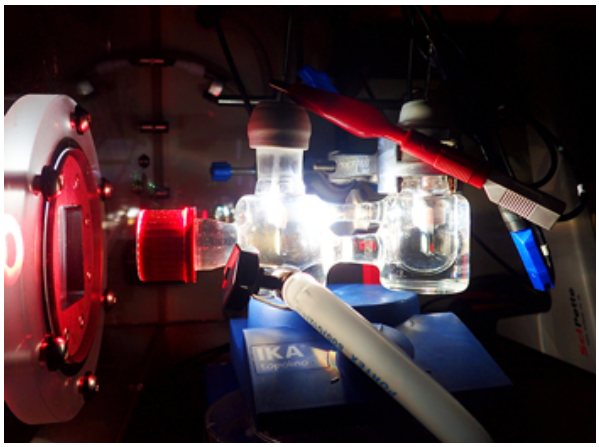
Artificial photosynthesis

Scientists have already begun copying, or mimicking, photosynthesis. Their artificial processes also use light to split oxygen and hydrogen — for energy. The dream is to eventually replace fossil fuels. If people could make energy from sun, air and water — as plants do — it would cut down on planet-warming releases of carbon dioxide. It also could create a huge new source of renewable energy.

Many researchers look to solar fuels — fuels made from sunlight — as "green" replacements for today's carbon-based fossil fuels. These include oil, gas and coal.

Solar fuels can take many forms. They might look like traditional carbon-based fuels, using carbon dioxide to "recycle" emissions from fossil fuels. Hydrogen and oxygen, the chemical products of photosynthesis, can power fuel cells that allow cars to run on electricity. Also, solar energy can convert sunlight into electricity that could be stored in batteries. No matter what form solar fuels take, the first step is splitting water into its elemental building blocks.

"Nature has this power," explains Julien Warnan. He's a chemist working with Erwin Reisner on solar fuels at the University of Cambridge in England. Nature has had a lot of time to figure out how to do this efficiently, he notes. When it comes to splitting up water's building blocks, engineers are "a bit more limited," he says. "Everyone is trying to develop different tools to do it."



KATARZYNA SOKÓŁ/ST. JOHN'S COLLEGE, UNIV. OF CAMBRIDGE

Researchers at the University of Cambridge in England engineered a semi-artificial form of photosynthesis in the lab. One of their setups, shown here, used light to split water into oxygen and hydrogen. That hydrogen can be used as a fuel to run vehicles, as a feedstock for industrial processes and more.

Last year in the journal *Nature Energy*, Warnan's team described a new way to use sunlight to split water. The idea, Warnan explains, "is to take water and air and put that together in a box." Then you add a *catalyst*. This is some material that can trigger chemicals to react. Later, he says, "You shine light on this box. And what comes out is fuel — like what you put in your car or a plane."

Scientists around the world are experimenting with devices — think of them as artificial leaves. Like the processes in leaves, they split water into hydrogen and oxygen. Warnan's team wasn't the first to do it. But they did it with a different type of catalyst. It's the same one that a plant uses to jump-start a chemical reaction.

They extract that catalyst from a plant, rather than creating it from chemicals in a lab. That means fewer harsh chemicals would go into making their solar fuel. But more work is needed before people can produce a solar fuel from water as easily as plants can.

"The great power of the plant is that it can always regenerate and replenish [the catalyst] if it breaks down," says Warnan. "We cannot." This type of solar fuel, therefore, "is still very expensive," he points out.

Explainer: What is a catalyst?

So don't expect to gas up with solar fuels in the near future. The current devices cannot harvest enough sunlight affordably. That's why plants are such good teachers. Having done photosynthesis for millions of years, they've already figured out how to do it efficiently.

Energy analysts predict that people will use twice as much energy by 2050 as they do now. Artificial leaves could be one way to wean humanity off its dependence on fossil fuels.

Hacking plants

Nearly 8 billion people share our planet today. The United Nations estimates that there will be 9.7 billion people living on this warming world by 2050. They will stretch the demand for food and energy to its limits.

Photosynthesis has evolved to work as well as it needs to — for plants. One group of scientists is now looking to improve upon photosynthesis — this time, for people. RIPE, which stands for Realizing Increased Photosynthetic Efficiency, is a global research effort. It aims to "hack" photosynthesis in ways that could yield more crops.

Amanda Cavanaugh is a plant biochemist at the University of Illinois in Urbana. She works with RIPE. Her research focuses on one tiny enzyme that has a big impact on photosynthesis. It's known as Rubisco (Rew-BIS-koh).

"It doesn't get a lot of credit, but it has arguably the most important job in the world," she says.

RIPE, UNIVERSITY OF ILLINOIS

Don Ort (left), Paul South (center) and Amanda Cavanaugh study plants modified to be better recyclers of chemicals mistakenly made by a Rubisco error. At least one-fifth of the time, Rubisco selects oxygen, not carbon dioxide, in trying to perform photosynthesis. "Rubisco has even more trouble picking out carbon dioxide from oxygen as it gets hotter," says Cavanagh. "Our goal is to build better plants that can take the heat today and in the future."

Rubisco grabs carbon dioxide out of the air and helps convert it to sugar, or glucose. That's the process that makes plants into an energy-conversion system that fuels the growth of animals.

All photosynthetic life relies on the Rubisco enzyme, Cavanaugh says. And while "it's critically important," she adds, "it's not particularly good at its job."

She's talking about a common mistake that plants make during photosynthesis. About one in every five times, a plant will "grab" an oxygen molecule from the air instead of carbon dioxide. That's like accidentally putting salt in coffee rather than sugar. So instead of making energy for the day, the plant produces toxic compounds.

Plants have come up with a way to recycle the unwanted compounds. But doing this uses energy that the plant might otherwise put into growth. If science could figure out a way to correct Rubisco's mistake, Cavanaugh estimates, agriculture could feed another 200 million people a year.

"For years, people have been fascinated by the possibility of engineering a better Rubisco," she says. Doing so might allow farmers to "grow more food on less land." And that, she argues, is "the ultimate goal for a plant biologist."

When Rubisco makes those mistaken compounds, a plant gets rid of them. It does that by transporting these unwanted chemicals to three different structures within the plant cell. Cavanaugh and her colleagues saw this “recycling” process as wasting a plant’s precious energy and time. “We wondered if there was a way to speed that up,” she says.

RIPE scientists at the University of Illinois are working with researchers at the Agriculture Department to make plant photosynthesis more efficient. They have begun focusing on the role of an enzyme known as Rubisco.

IGBILLINOIS/YOUTUBE

To find out, she and her colleagues worked with tobacco plants in a greenhouse. (Tobacco is not a food crop, but they used it because it’s quick to grow.) The researchers tested plants having somewhat different genetic traits. Then they “starved” these plants of the carbon dioxide they needed to grow. The plants’ Rubisco responded by making lots of mistakes.

The plants that thrived under these conditions proved to be the best recyclers of the toxic compounds.

Then the scientists grew the super recyclers in farm fields. These tobacco plants grew 40 percent larger than normal. The researchers described their engineering feat last Jan. 4 in *Science*.

The next step is to apply the lessons learned in tobacco to crops, such as potatoes, cow peas and soybeans. Cavanaugh is excited about the likely success of moving this photosynthetic hack into food plants.

"Photosynthesis is one of the best understood biological processes in life," says Cavanaugh. "But there's so much we don't know about it. It's now starting to open up in a really neat way."

NGSS: Earth and Human Activity, HS-ETS1-1, HS-ETS1-2, HS-LS1-5, HS-LS1-6, HS-LS1-7, HS-LS2-5, MS-ETS1-2, MS-LS1-6, MS-LS1-7

CITATIONS

Journal: K.E. Dalle et al. Electro- and solar-driven fuel synthesis with first row transition metal complexes. *Chemical Reviews*. Vol. 119, Feb. 15, 2019, p. 2752. doi: 10.1021/acs.chemrev.8b00392.

Journal: P.F. South et al. Synthetic glycolate metabolism pathways stimulate crop growth and productivity in the field. *Science*. Vol. 363, Jan 4, 2019, p. eaat9077. doi: 10.1126/science.aat9077.

Journal: A. Tendler et al. Fold-change response of photosynthesis to step increases of light level. *iScience*, Vol. 8, Sept. 25, 2018; p. 126. doi: 10.1016/j.isci.2018.09.019.

Journal: K.P. Sokol et al. Bias-free photoelectrochemical water splitting with photosystem II on a dye-sensitized photoanode wired to hydrogenase. *Nature Energy*. Vol. 3, Sept. 3, 2018, p. 944. doi: 10.1038/s41560-018-0232-y.

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ScienceNewsforStudents

CLASSROOM QUESTIONS

Questions for ‘Scientists look to hack photosynthesis for a ‘greener’ planet’

Scientists are looking at how plants turn sunlight into sugars — a process known as photosynthesis — as a model for cleaner ways to produce energy for people and industry. Their research even suggests ways people can help plants photosynthesize more efficiently.

XURZON/ISTOCK /GETTY IMAGES PLUS

By **Science News for Students**

December 5, 2019 at 6:40 am

To accompany feature “Scientists look to hack photosynthesis for a ‘greener’ planet”

SCIENCE

Before Reading:

1. What do you know about photosynthesis?

2. How might photosynthesis be important to life on Earth?

During Reading:

1. What is the basic chemistry that happens in photosynthesis?

2. What two things are produced by photosynthesis? Why are they important to people and other living organisms?

3. Does a plant get burned if it gets too much sunlight? How does a plant handle sudden bright sunlight?

4. Why are scientists trying to imitate photosynthesis?

5. What are “solar fuels”? Name any examples you can think of.

6. What is a catalyst? How are scientists trying to use a plant catalyst to create solar fuels?

7. Scientists are also trying to “hack” photosynthesis to improve crop production. Why?

8. What enzyme are crop scientists trying to engineer? When this enzyme makes a mistake, what is the result?

9. How might correcting that enzyme’s mistakes improve crop yields?

10. Why are scientists using tobacco plants to study this enzyme? What will they do next with the lessons they learn from their tobacco studies?

After Reading:

1. In what ways are plants critical to sustaining life on our planet?

2. How are humans contributing to the warming of our planet? What impact does this warming have on us and other people around the world? In what ways might growing more plants help?

INTRODUCTION

This worksheet complements the animation series *Photosynthesis*.

PROCEDURE

1. This animation series contains seven parts. Read the questions below for each part before watching it.
2. After watching each part, answer the questions in the spaces provided.
3. After completing all seven parts of the animation, answer the summary questions in Part 8.

QUESTIONS

PART 1: OVERVIEW

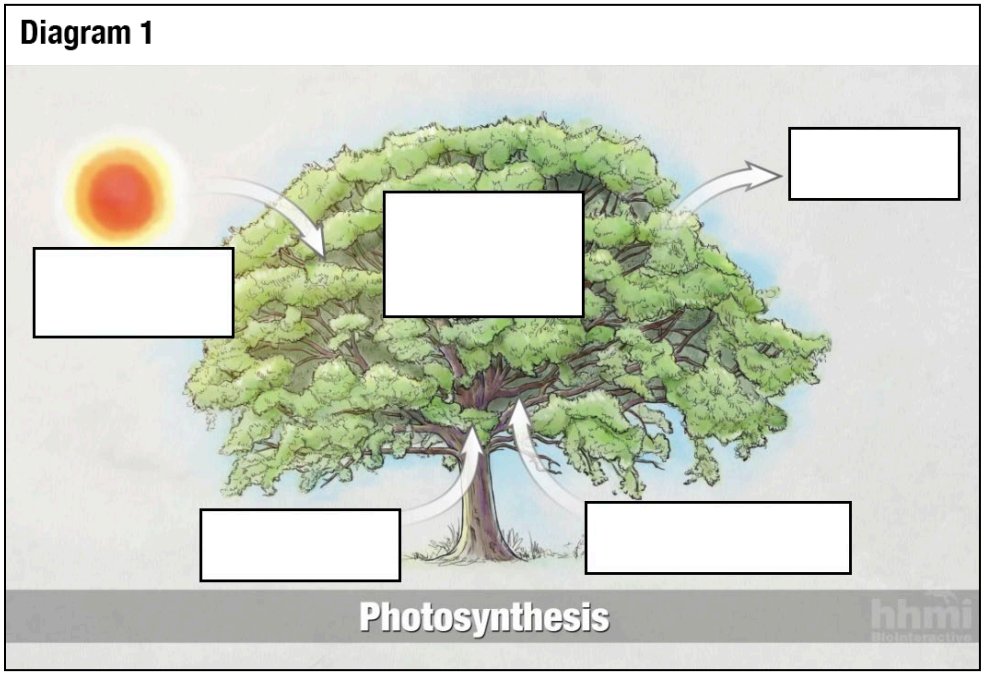
1. Which of the following kinds of organisms do photosynthesis? Select all that apply.

☐ plants ☐ fungi ☐ animals ☐ algae ☐ all bacteria ☐ some bacteria

2. What is the overall purpose of photosynthesis?

3. On Diagram 1, fill in the labels with photosynthesis's main inputs and outputs of matter and energy.

Diagram 1



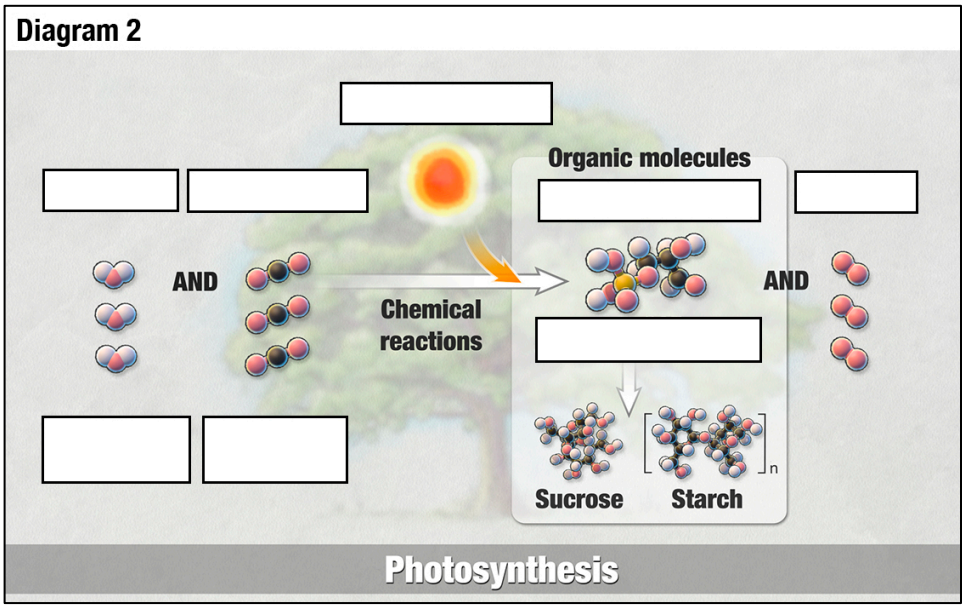
PART 2: CHEMICAL PROCESS

1. Complete the following sentence.

Photosynthesis is a set of _____ in which _____energy is converted to _____energy.

2. On Diagram 2, fill in the labels with the following descriptions. Some of the objects have multiple labels.

- water (H_2O)
- carbon dioxide (CO_2)
- oxygen (O_2)
- G3P (sugar)
- electron acceptor
- electron donor
- carbohydrates
- energy input

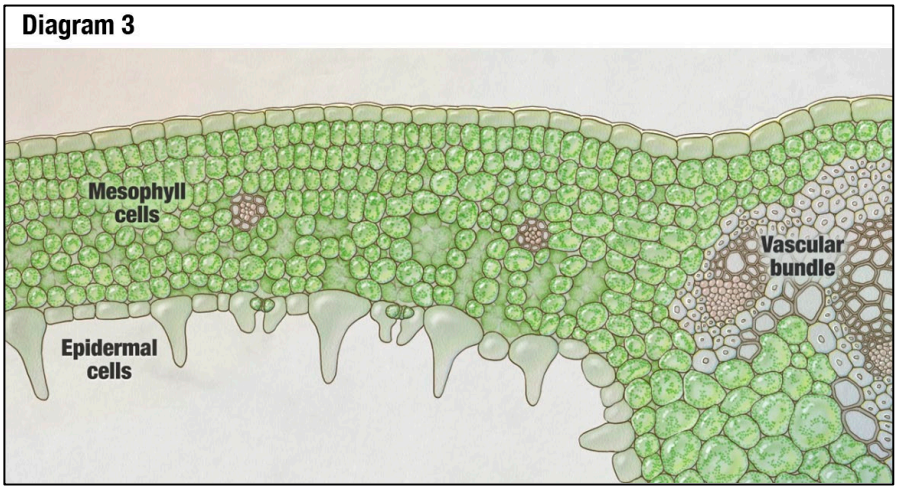


PART 3: LEAF STRUCTURE

1. In what plant structures does photosynthesis occur? Make your description as specific as you can.

2. On Diagram 3, complete the following tasks.

a) Draw how CO_2 gets into the leaf.
b) Draw how O_2 gets out of the leaf.
c) Label the name of the structure through which these gases pass.



3. What structure is used to transport organic molecules from the leaf to other parts of the plant?

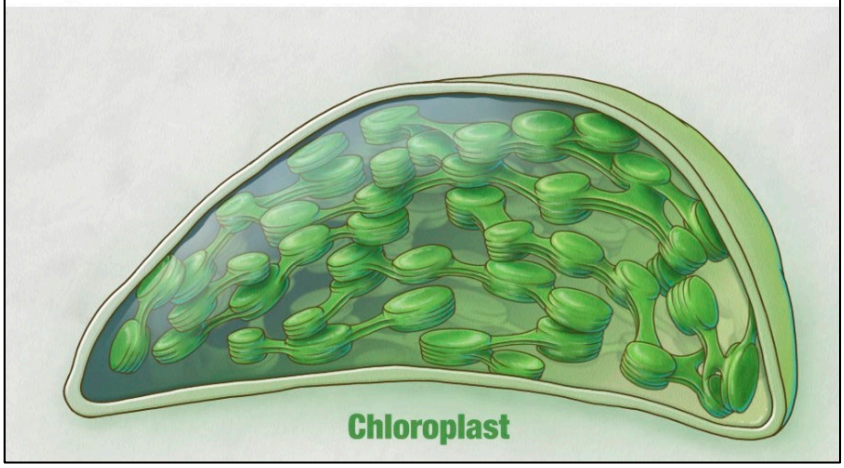
4. Why are leaves green?

PART 4: CHLOROPLASTS

1. On Diagram 4, label the following items. Multiple labels may apply to the same part of the diagram.

- location of the light reactions
- location of the Calvin cycle
- thylakoid
- stroma

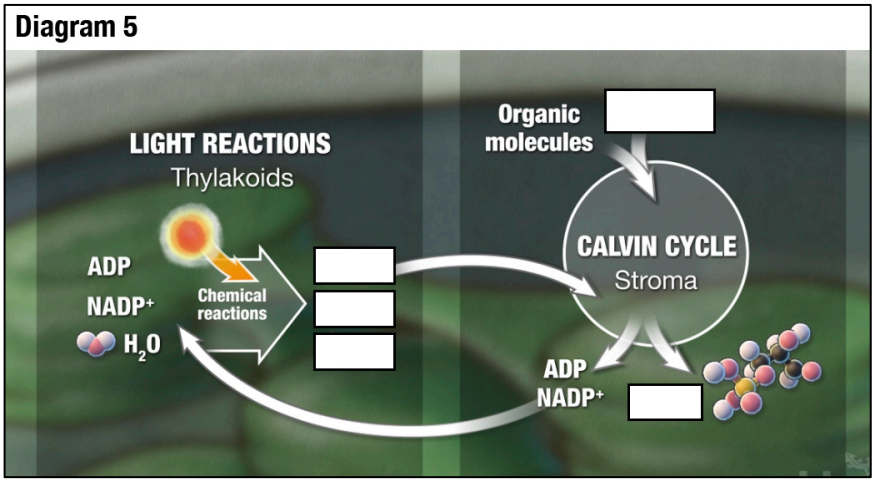
Diagram 4



2. On Diagram 5, fill in the labels with the following descriptions to show the connections between the light reactions and the Calvin cycle.

- carbon dioxide (CO_2)
- oxygen (O_2)
- G3P (sugar)
- ATP
- NADPH

Diagram 5



3. How does a plant increase its biomass?

PART 5: LIGHT REACTIONS

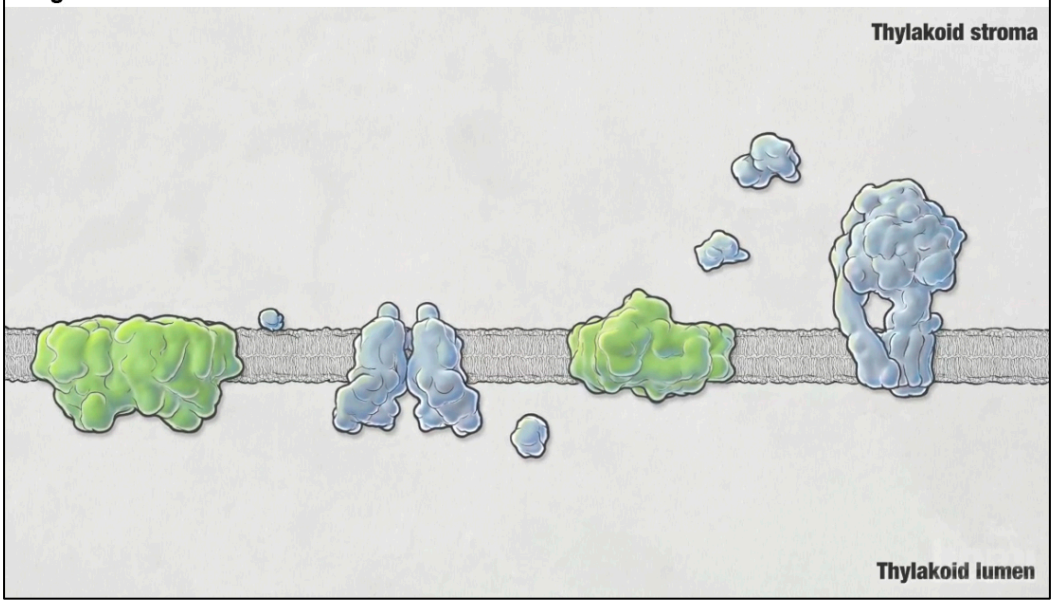
Photosystems I and II (PSI and PSII)

1. What is the function of the photosystems?

2. On Diagram 6, complete the following tasks.

a) Label PSI and PSII.
b) Draw the path of the electron transport chain.

Diagram 6



The Events of the Light Reactions

3. For **PSII**, the **cytochrome complex**, and **PSI**, draw and label what happens at that structure on Diagram 6. Then describe the events in a bulleted list in Table 1.

Table 1: Descriptions of the steps in the light reactions.

Structure	What is happening with matter?	What is happening with energy?
PSII		
cytochrome complex		
PSI		

4. At the end of the electron transport chain, where is the light energy that was absorbed and converted by chlorophyll stored? List **two** answers.

Chemiosmosis and ATP Synthase

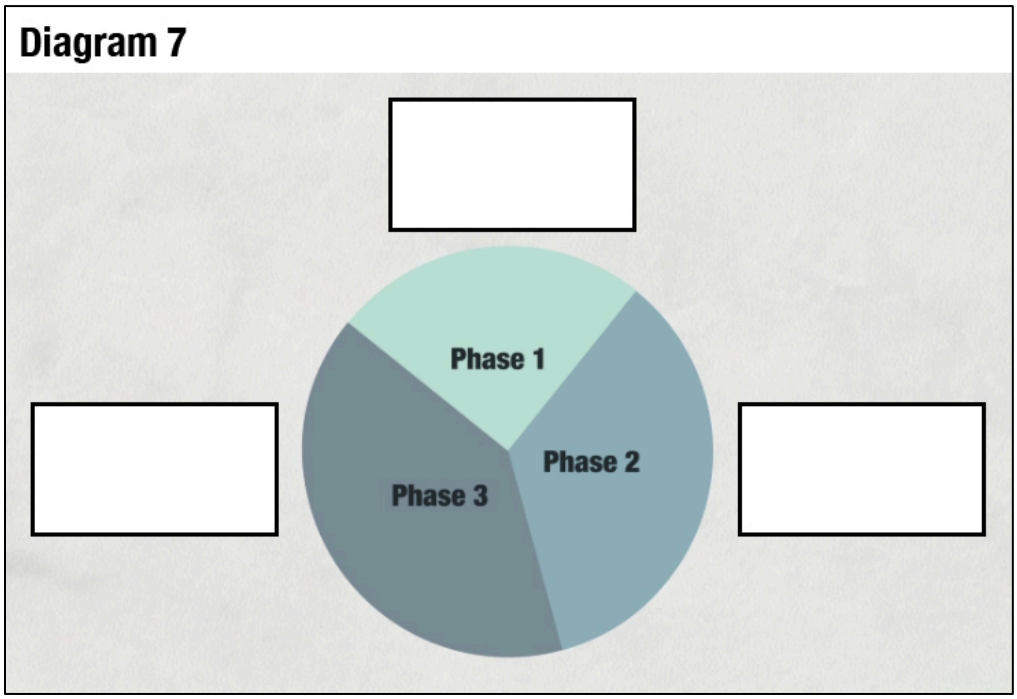
5. Label the ATP synthase on Diagram 6.

6. Describe how the proton (H^+) gradient is used to make ATP.

7. What two molecules bring chemical energy from the light reactions to the next stage of photosynthesis, the Calvin cycle?

PART 6: CALVIN CYCLE

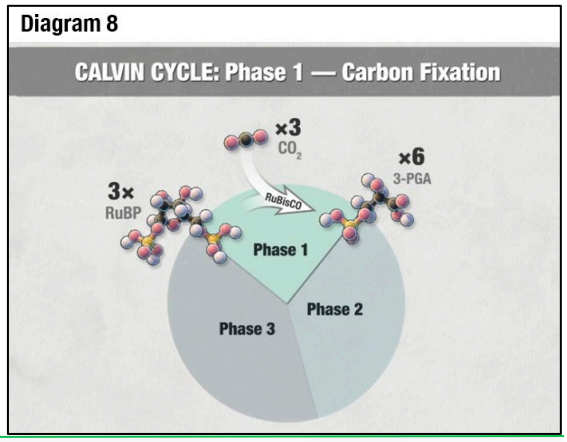
1. Label Diagram 7 with the three phases of the Calvin cycle.



Briefly describe what is going on in each phase and answer the questions shown.

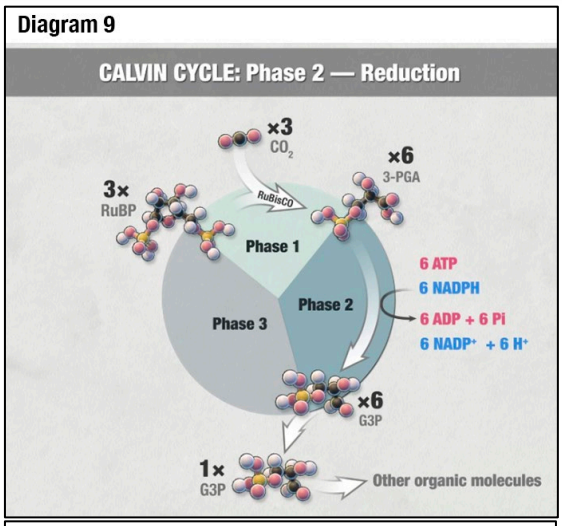
Phase 1 (Diagram 8)
Description:

What enzyme catalyzes the reaction in this phase?



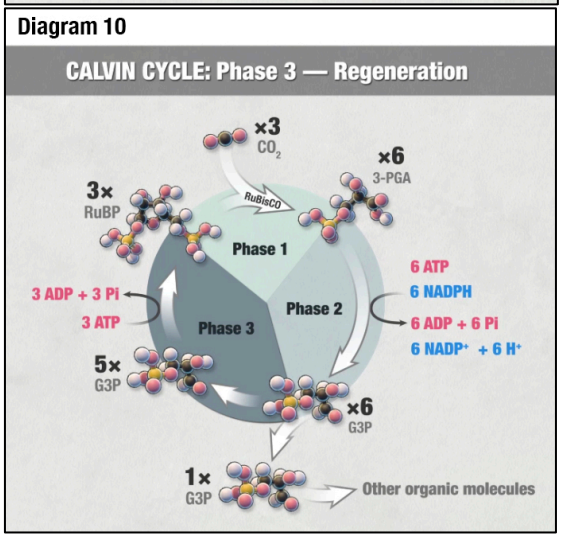
Phase 2 (Diagram 9)
Description:

Diagram 9



Phase 3 (Diagram 10)
Description:

Diagram 10



Why is the series of reactions in the Calvin cycle called a "cycle"?

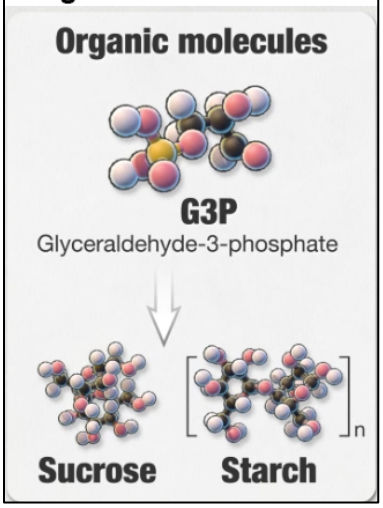
2. At the end of the Calvin cycle, what molecules have the energy that originally came from light?

PART 7: BIOSYNTHESIS

1. Complete the following sentence based on Diagram 11.
   Glyceraldehyde-3-phosphate (G3P) can be used by plant cells to make _____ and _____.
2. Which molecule in Diagram 11 is used to transport energy to other parts of the plant?

3. Which molecule in Diagram 11 is stored in the plant for later use as an energy source?

Diagram 11



PART 8: TEST YOUR KNOWLEDGE

1. Based on everything you've learned from the animations, what is the overall purpose of photosynthesis?

2. Describe how oxygen gas (O_2) is produced during photosynthesis. Include the specific structures in the plant where the reaction occurs.

3. Describe the path of an electron from a molecule of water to the sugar G3P.

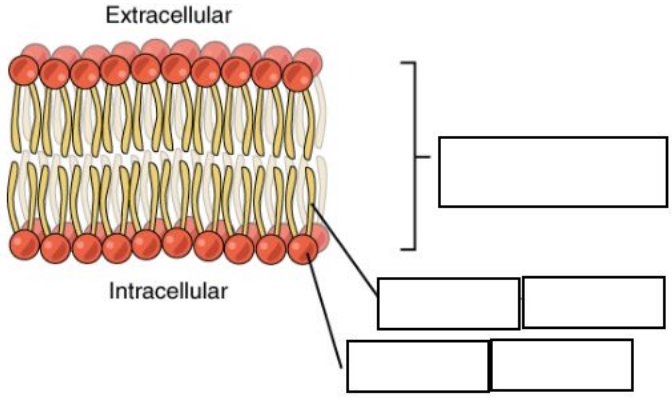
4. Describe how ATP is produced in the light reactions.

5. Which of the following statements best explains how the energy in a photon of light is stored in a molecule of the sugar G3P? _____
   a. Light energy directly provides energy to RuBP and CO_2, which produce G3P in the Calvin cycle.
   b. Light energy directly provides energy to ATP synthase, which produces ATP during the light reactions.
   c. Light energy energizes electrons to make ATP and NADPH, which provide energy to produce G3P in the Calvin cycle.

6. When three molecules of carbon dioxide (CO_2) react with three molecules of RuBP during the Calvin cycle, six molecules of the sugar G3P are produced. One G3P molecule exits the Calvin cycle during Phase 2. What happens to the other five G3P molecules?

Module 2 Review **Name:** _____

1. Match each protein with its function.
   a. Transport ____ A. Carry out sequential reactions
   b. Enzyme ____ B. recognizes neighboring cell
   c. Junction ____ C. attach the extracellular matrix to cytoskeleton
   d. Glycoprotein ____ D. allow specific ions to enter/exit cell
   e. Receptor ____ E. form intercellular junctions
   f. Attachment ____ F. bind signaling molecules to relay messages through signal transduction
2. The _____ and _____ can move freely in the membrane. This is called the fluid mosaic model. In animal cells, _____ helps keep the phospholipids moving freely.
3. Label the cell membrane – phospholipid bilayer, head, tail, nonpolar, polar.



4. Nonpolar molecules _____ move freely through the cell membrane.

5. _____ moves molecules from high to low concentration, or **up / down** their concentration gradient. Diffusion _____ require energy Some larger molecules require transport proteins to diffuse through the membrane, and this is called **passive / active** transport.

6. _____ is the diffusion of water from high to low concentration across a selectively _____ membrane.

7. A cell containing 25% carbon dioxide is placed in a solution containing 75% carbon dioxide. What will happen in this system?
   a. Carbon dioxide will diffuse out of the cell
   B. Carbon dioxide will diffuse into the cell
   b. The cell will use active transport to remove the carbon dioxide
   c. The cell is in a hypertonic environment

8. A freshwater plant is placed in salt water. What do you expect will happen to the cell – select all that apply.

Supported and adapted from Pearson Materials

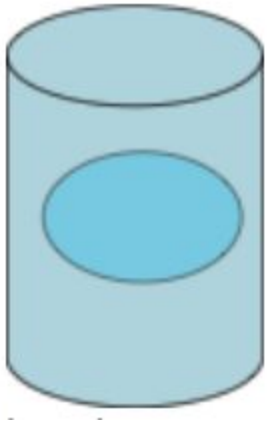
a. The cell vacuole will empty c. The cell will shrink
b. The cell will swell d. The cell will use active transport to remove salt

9. If a cell lyses / shrinks, it has been placed in a hypertonic solution. But, if a cell lyses, shrinks, it has been placed in a hypotonic solution. If a cell doesn't swell or shrink, it has been placed in a(n) _____ solution.

10. A carrot is placed in distilled water. Will the carrot swell or shrink? _____What kind of environment is the distilled water compared to the carrot? _____

11. A carrot is placed in salt water. Will the carrot swell or shrink? _____. What kind of environment is the salt water compared to the carrot?
_____

12. A cell is placed into a beaker containing a 10% sucrose solution. The cell contains a 50% sucrose solution. Use an arrow to illustrate the direction in which **water** will diffuse in the figure below. Assume that the cell's membrane is **not** permeable to the sucrose.



13. A cell lyses. The cell has a salt concentration of 50%. Which of the following could be a possible salt concentration of the outside environment?
a. 10% salt b. 50% salt c. 70% salt

14. _____ transport uses energy ATP to move molecules against their concentration gradient.

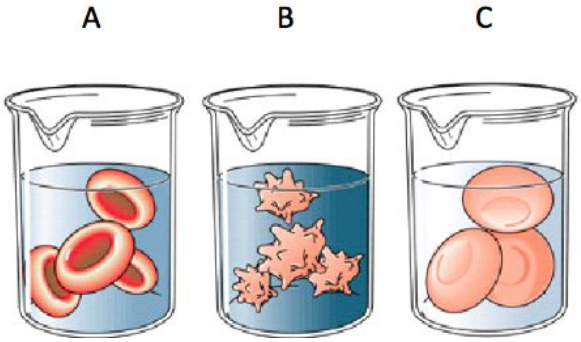
15. Exocytosis and endocytosis move _____ and/or _____ molecules in/out of a cell.

16. Enzymes belong to the _____ group of macromolecules. They lower the _____ energy of a reaction. They are **unchanged/changed** in a reaction.

17. Enzymes may lose function or have decreased function if there is a change in temperature or pH. This means the enzyme has been _____.

18. Which of the following are most likely enzymes?
a. Fructose c. Catalase
b. Guanine d. Galactose

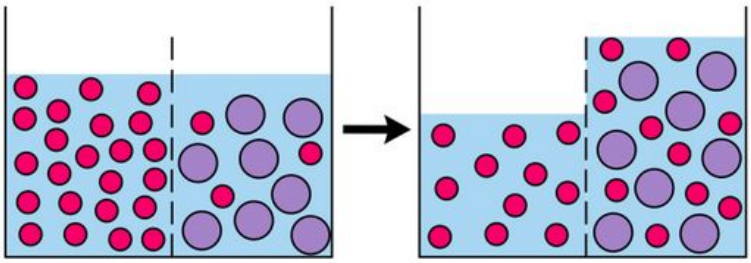
19. Look at the three beakers below and fill in the table. The dialysis bag is impermeable to sugar.



	Solution compared to cells (hypotonic, hypertonic, isotonic)	How did water move?
Beaker A		
Beaker B		
Beaker C		

20. Cells lining kidney tubules function in the reabsorption of water from urine. This retains water in the bloodstream so that less is lost in the urine. Thus, dehydration is prevented. In response to chemical signals, they reversibly insert additional aquaporins into their plasma membranes. After a long run on a hot day, would you find more or less aquaporins? _____ After sitting on a park bench on a mild day? _____

21. Using **all** the words - diffusion, concentration gradient, high concentration and low concentration - explain what happened the diagram below. The small circles are representing water molecules.



22. Alexis is using models of the cell membrane to compare the types of cellular transport. One model shows a molecule entering through a protein pump down the concentration gradient. Which type of cell transport is being modeled?

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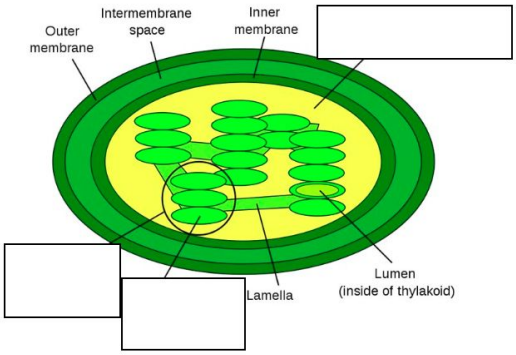
a. diffusion, because protein pumps are needed to move substances from a higher concentration to a lower concentration
b. endocytosis, because protein pumps transport substances that are too large to pass through the cell membrane
c. active transport, because protein pumps are needed to move substances against a concentration difference
d. osmosis, because protein pumps allow water to cross the cell membrane

23. Nayla is planning an investigation on the role of osmosis in maintaining homeostasis. She plans to study red blood cells in a liquid suspension, similar to blood plasma. For Nayla to observe the greatest variety of osmotic activity in the red blood cells, she should test the effect of which of these independent variables?

a. temperature of the liquid suspension
b. oxygen concentration of the red blood cells
c. the number of red blood cells per liter of the liquid suspension
d. salt concentration of the liquid that surrounds the red blood cells

24. In the chloroplast below, label the thylakoids, stroma, and grana.



25. Write the overall summary reaction of photosynthesis.

26. Write the light reaction.

27. Write the Calvin cycle reaction.

28. Sunlight is the source of energy that boosts _____ in photosynthesis.

29. During the light reactions, _____ gas is produced. During the Calvin Cycle or dark reactions, _____ is used.

Supported and adapted from Pearson Materials

30. Chlorophyll is the _____ that reflects mostly green light and and is most responsible for photosynthesis.

31. Water is used in photosystem II to be split to form _____ gas and _____ ions.

32. ATP synthase uses a hydrogen _____ gradient to power the formation of _____. ATP synthase is an example of a _____ within the four categories of macromolecules.

33. The scientific word that means to add phosphate groups to ADP to form ATP is _____.

34. Two energy carriers, _____ and _____, are used to power sugar synthesis during the Calvin cycle.

36. Write the chemical formula for cellular respiration.

37. Aerobic respiration means that the cells do use _____. Anaerobic respiration means that the cells do not use _____.

38. The three stages of aerobic respiration are _____, _____, and _____.

39. In glycolysis, _____ is broken down into pyruvate and 2 NADH molecules are created. This occurs in the _____ of the cell.

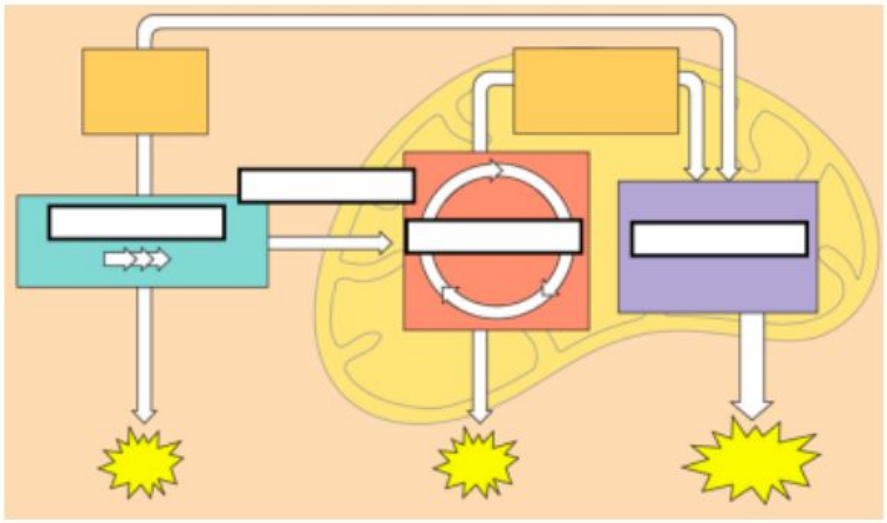
40. In the citric acid or Krebs cycle, pyruvate is reduced to two energy carriers _____ and _____. This occurs in the _____ of the mitochondria. There are ____ ATP molecules made per glucose molecule entered in the reaction. A by-product of _____ is released from the cell.

41. In oxidative _____, the two energy carriers, $FADH_2$ and NADH are used to create a concentration gradient of _____ ions. The inner mitochondrial _____ is the site of this process. The _____ ATP synthase moves hydrogen ions down their _____ gradient to form 28 ATP molecules.

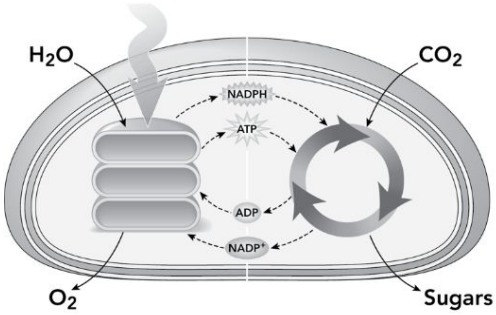
42. Both aerobic and anaerobic respiration use the process of _____ to start the reaction.

43. _____ continues to break down pyruvate to make ATP and either lactic acid or alcohol as a by-product.

44. Label the parts of cellular respiration and use the word bank **aerobic respiration, NADH, glycolysis, ATP, FADH2, oxidative phosphorylation, citric acid (Krebs) cycle.**



45. During photosynthesis, how is the light energy that strikes the cell transformed into the chemical energy stored in sugars?



a. Energy is transferred directly to sugars, with no intermediates.

b. Energy is transferred to sugars through intermediates such as H_2O, O_2, and CO_2.

c. Energy is transferred to sugars through intermediates, such as chloroplasts.

d. Energy is transferred to sugars through light-dependent reactions.

46. Which statement accurately describes the role of the light-independent reactions?

a. transforming light energy into chemical energy

b. transferring chemical energy to high-energy sugars

c. returning chemical energy to light energy

d. transferring light energy among different compounds

47. . What is the relationship between the light-dependent reactions and light-independent reactions?

a. The light-dependent reactions depend on the light-independent reactions for energy that is transferred by ATP and NADPH.
b. The light-dependent reactions and light-independent reactions both convert energy from the sun to chemical energy.
c. High-energy electrons are transferred from the light-independent reactions to the light-dependent reactions.
d. Energy in the form of ATP and NADPH is transferred from the light-dependent reactions to carbohydrates in the light-independent reactions.

48. During photosynthesis, the light-dependent reactions supply ATP to the light-independent reactions. How is ATP used in the light-independent reactions?

a. ATP provides the hydrogen atoms that are incorporated into sugars.
b. ATP provides the carbon and oxygen atoms that are incorporated into sugars.
c. ATP provides the chemical energy for the reactions to occur.
d. ATP receives the chemical energy that the reactions release.

49. Which statement best describes an event that occurs in glycolysis that contributes to the production of ATP?

a. Pyruvic acid is broken down to form carbon dioxide.
b. Oxygen molecules are broken down and converted into pyruvic acid.
c. High-energy electrons are passed to NAD^+ forming NADH.
d. Carbon atoms in glucose are transformed into energy in the form of ATP.

50. Most organisms obtain energy from food by the process of cellular respiration. Which is the **most likely** explanation for the reason that Earth does not run out of oxygen?

a. The overall reactions of photosynthesis and cellular respiration are the opposite of one another, therefore the products of one are the reactants of the other, creating a cycle.
b. The energy—and thus oxygen—flows for cellular respiration and photosynthesis take place in the same direction, and therefore build upon one another.
c. Cellular respiration is a process that deposits energy and oxygen, and photosynthesis withdraws energy and uses oxygen, therefore balancing each other.
d. Oxygen readily accepts electrons, so cellular respiration uses a negligible amount of oxygen.

51. Cells rely on compounds that readily store and release energy. Which statement describes how energy storage and release occurs in cells?

a. A The Krebs cycle serves to store energy and make it readily available for cell function.
b. ATP attracts an additional phosphate group and stores energy in the form of ADP.
c. ATP stores energy and releases it as it reverts back to ADP.

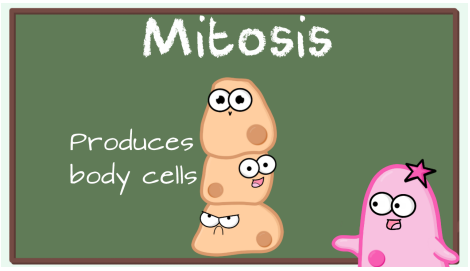
d. The electron transport chain stores energy in the bonds of NAD^+ and releases it as NAD^+ reverts back to NADH.

52. Enzo is developing a model of the electron transport chain. What is the role of ATP and NADH in the model?

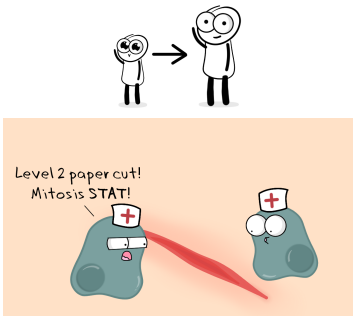
a. ATP and NADH provide the energy for electron transport to occur.
b. ATP and NADH are synthesized as electrons are transported along the chain.
c. ATP is used to synthesize NADH in one step of the chain.
d. NADH is used to synthesize ATP in one step of the chain.

Amoeba Sisters Video Recap of *Mitosis: The Amazing Cell Process That Uses Division to Multiply*

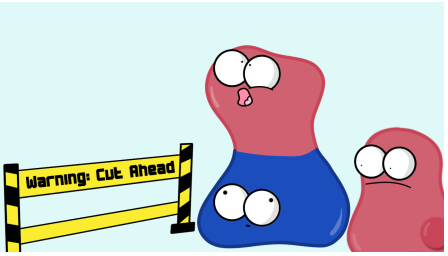
1. Mitosis is done by your body cells. What types of cells do **not** undergo mitosis?



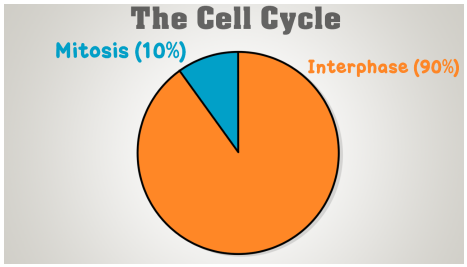
2. Describe 2 ways that mitosis is important for your body.



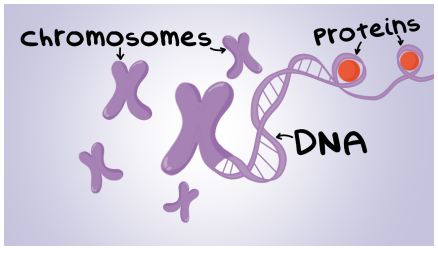
3. This illustration is trying to demonstrate something that mitosis is not. In mitosis, the cells that are created are



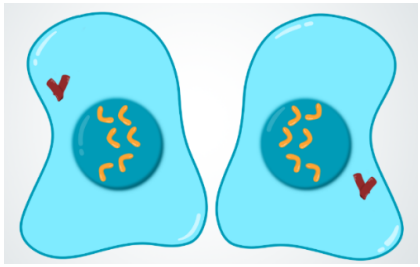
4. Mitosis is just one small part of the cell cycle! Describe what would occur if cells were in mitosis more than they were in interphase.



5. When cells are dividing, it is important to understand that they have to move **chromosomes** equally to both cells. Based on this illustration, describe what a **chromosome** is made of.

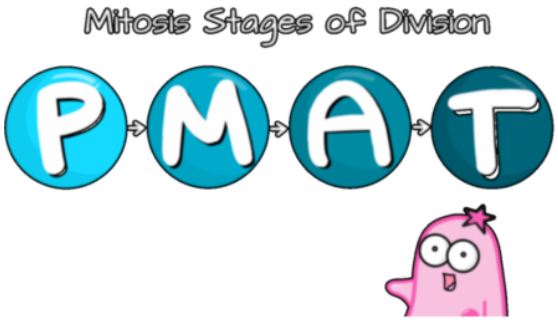


6. Mitosis starts and ends with **diploid** cells. That means they have two sets of chromosomes (both parents each contribute a set). In humans, how many chromosomes should be in each of these **diploid** cells after mitosis?

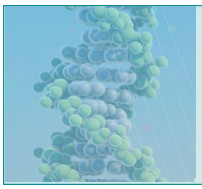


Sketch the Mitotic Stages

Directions: We encourage you to be creative with a cartoon illustration of your own for each phase. Label the **chromosomes**, **spindles**, and **nucleus** (if applicable).



Prophase	Metaphase
Anaphase	**Telophase**



The Double Helix

hhmi | BioInteractive

Film Activity
Student Handout

INTRODUCTION

This activity explores the research shown in the short film *The Double Helix*, which tells the story of how DNA's structure was discovered.

PROCEDURE

Use the information in the film to answer the following questions in the spaces provided. You may want to use the film's transcript as a reference.

1. In the 1950s, many scientists thought that proteins, not DNA, carried genetic information.
   a. Why did proteins seem better suited for storing genetic information?

   b. Oswald Avery's experiments with bacteria led him and other scientists to propose the following claim: **DNA, not proteins, carries genetic information**. Complete the table below to explain how Avery's experiments supported this claim.

Claim: DNA, not proteins, carries genetic information.
Evidence: *(List three pieces of evidence for the claim from Avery's experiments.)*
Reasoning: *(In full sentences, explain how each piece of evidence supports the claim.)*

2. What are the chemical components of a DNA nucleotide? _____
   a. a phosphate, a sugar, and a nitrogenous base
   b. a phosphate, a nitrogenous base, and an amino acid
   c. a nitrogenous base, a sugar, and an amino acid
   d. a nitrogenous base, ATP, and a sugar
3. The two strands of a DNA molecule are held together by hydrogen bonds between the: _____
   a. phosphate groups on each strand
   b. nitrogenous bases on each strand
   c. bases and the phosphate-sugar backbone
   d. carbon atoms in the sugars

4. In the diagram below, Strands I and II represent complementary sections of DNA. The sequence of Strand I is shown. What is the sequence of Strand II? _____

   Strand I ----------CTAC----------

   Strand II ----------????----------

   a. AGCA
   b. CTAC
   c. TCGT
   d. GATG

5. The instructions for the traits of an organism are determined by: _____
   a. the proportions of A, T, C, and G in DNA molecules
   b. the order of nucleotides in DNA molecules
   c. the length of DNA molecules
   d. the way nucleotides are paired in the two strands of a DNA molecule

6. Watson and Crick first built a triple-helix model of DNA. In this model, the nitrogenous bases were on the outside of the DNA molecule, and the phosphate groups were on the inside.
   a. At that time, why did it seem reasonable for the bases to be on the *outside* of the DNA molecule?

   b. What evidence caused Watson and Crick to revise this model? Give specific examples from the film.

7. Table 1 contains data that Erwin Chargaff published about the composition of DNA.

Table 1. Proportions of nitrogenous bases in the DNA of different organisms. Data from Chargaff and Davidson (1955).

Organism	Tissue	% Adenine	% Guanine	% Cytosine	% Thymine
Yeast		31.3	18.7	17.1	32.9
Sea urchin	Sperm	32.8	17.7	18.4	32.1
Rat	Bone marrow	28.6	21.4	21.5	28.4
Human	Thymus	30.9	19.9	19.8	29.4
Human	Sperm	30.3	19.5	19.9	30.3

   a. Compare the composition of the DNA in the different organisms. Describe any similarities or differences you observe.

   b. Based on the data in Table 1, mark the following statements as true (T) or false (F). Justify each answer in one or two sentences.

      ____ In each organism, there is approximately one adenine for every thymine.

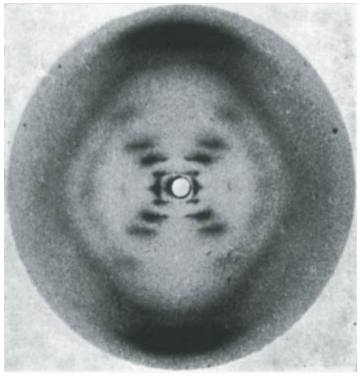
____ In each organism, the proportions of adenine plus thymine equal those of cytosine plus guanine.

____ In each organism, there is approximately one guanine for every thymine.

____ In each organism, there is approximately one guanine for every cytosine.

c. Why are the proportions of nitrogenous bases in the DNA of the two different human tissues (thymus and sperm) about the same?

8. The image on the right is of *Photo 51*, which was taken in 1952 by Rosalind Franklin and her student Raymond Gosling. It shows the x-ray diffraction pattern of a DNA molecule, which provides information about the positions of atoms in DNA.



a. Describe the patterns you see in the image.

b. What conclusions did Watson and Crick reach after seeing this image and reading Franklin's report discussing the symmetry of DNA?

9. Watson and Crick used scientific reasoning, their knowledge of biochemistry, and the research of other scientists to make one of the most important scientific claims of their time: **DNA is a double helix with strands running in opposite directions. Between these strands, A pairs with T, and C pairs with G**.

Complete the table on the following page to explain the evidence that Watson and Crick used to support this claim:

DNA is a double helix with strands running in opposite directions. Between these strands, A pairs with T, and C pairs with G.

Evidence: *(List three pieces of evidence for the claim. Name the scientists who were responsible for each piece.)*
Reasoning: *(In full sentences, explain how each piece of evidence supports the claim.)*

10. Even before the structure of DNA was known, studies indicated that the genetic material must have the following properties:

    - be able to store information
    - be consistently replicated between generations
    - be able to allow for changes, and thus evolution, to occur

    Explain how the structure of DNA gives it these three properties. Write one or two sentences per property.

Amoeba Sisters | Video Recap

NAME:_____

Amoeba Sisters Video Recap: *DNA Replication*

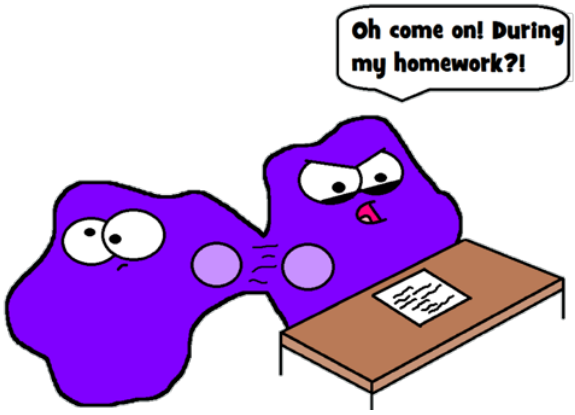
1. To understand DNA replication, we need to understand the "why." **Why** does DNA need to replicate before cells divide?

_____

_____

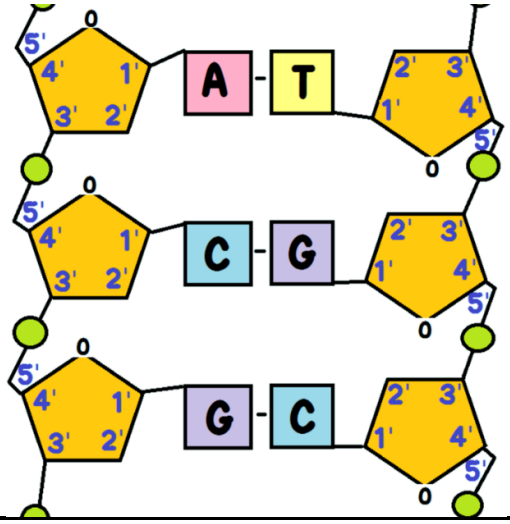
_____

_____



In the below DNA diagram, label ONE of each bolded term:

2. **Deoxyribose (sugar)**. Total number in image? _____
3. **Nitrogenous base**. Total number in image? _____
4. **Hydrogen bond**. Total number in image? _____
5. **Phosphate**.
6. Label **5' to 3' strand** and **3' to 5' strand**.



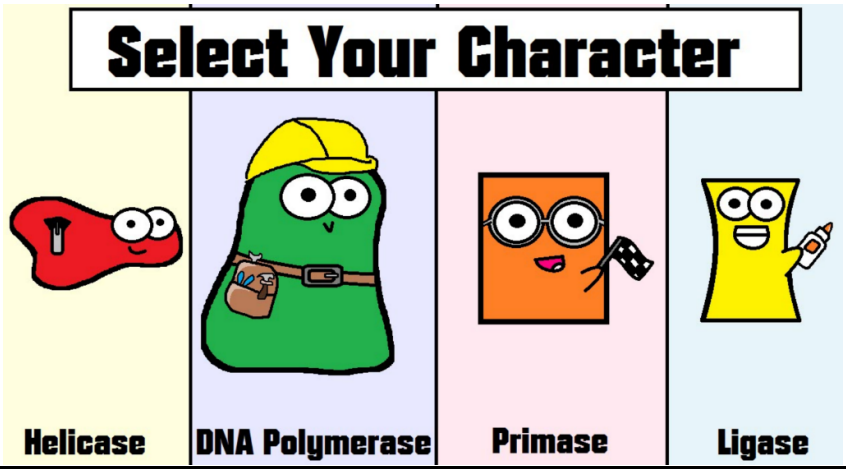
3. DNA Replication has many key players! These are just a few of the major key player **enzymes.** In your own words, describe each of their functions in DNA replication.

Helicase:_____

DNA Polymerase:_____

Primase:_____

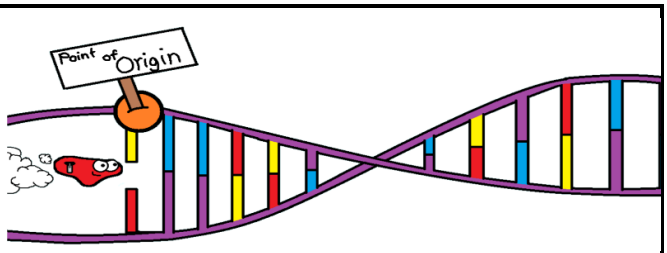
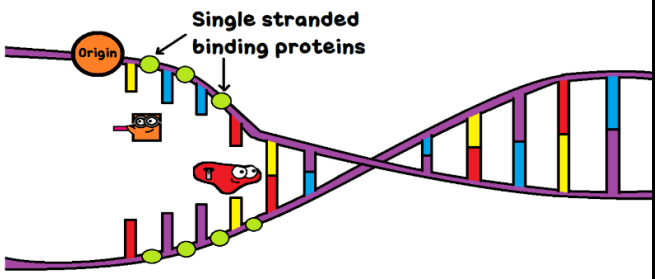
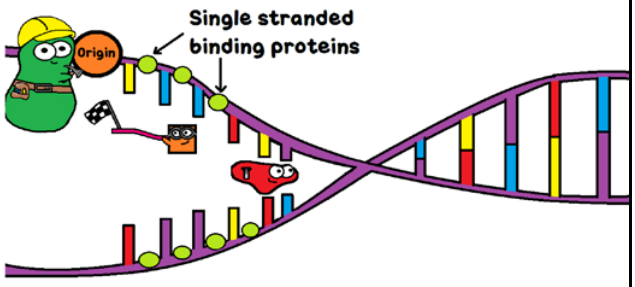
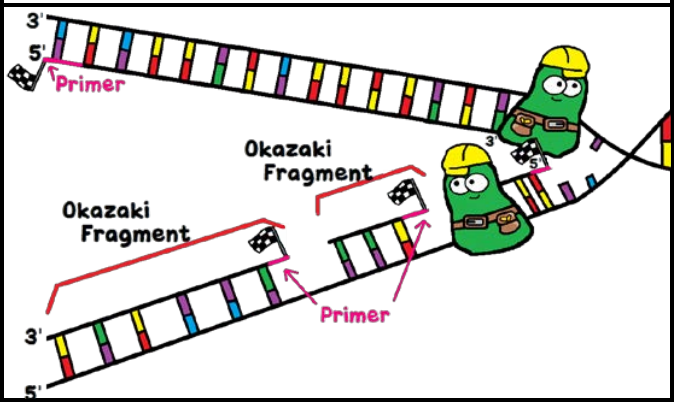
Ligase:_____



Amoeba Sisters | Video Recap

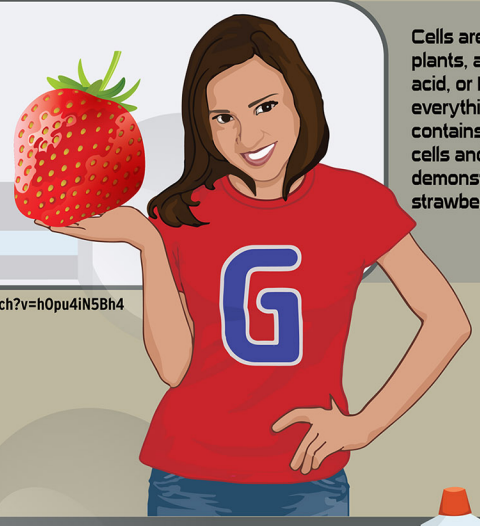
NAME: _____

Your turn to narrate! Narrate the illustrations below to explain the sequence of events occurring in DNA replication.

4.	
5.	
6.	
7.	

8. Label the leading and lagging strands in the last picture. Explain what is meant by the "lagging" strand and why this occurs.

How to Extract DNA from a Strawberry



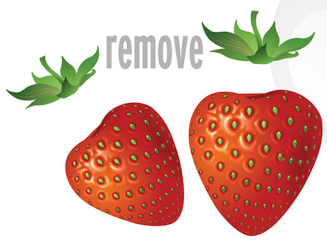
Cells are the basic unit of life and make up all plants, animals and bacteria. Deoxyribonucleic acid, or DNA, is the molecule that controls everything that happens in the cell. DNA contains instructions that direct the activities of cells and, ultimately, the body. This activity will demonstrate how DNA can be isolated from a strawberry using common household materials.

https://www.youtube.com/watch?v=hOpu4iN5Bh4

What you will need:

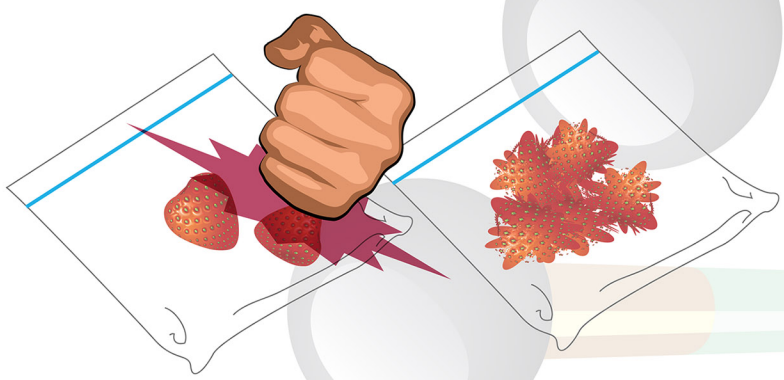
1	2	2 tsp	1/2 cup	2	1	1	1/2 cup	1
re-sealable plastic bag	Strawberries (fresh or frozen)	Dish detergent	Water	Plastic cups	Coffee filter	Scientist	COLD Rubbing Alcohol	Coffee Stirrer

1



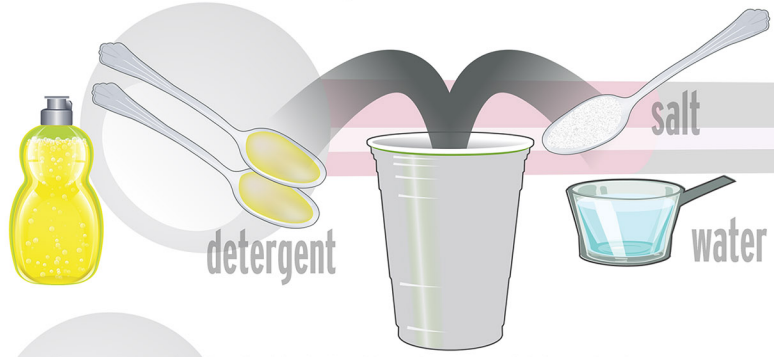
Pull off any green leaves on the strawberry that have not been removed yet.

2



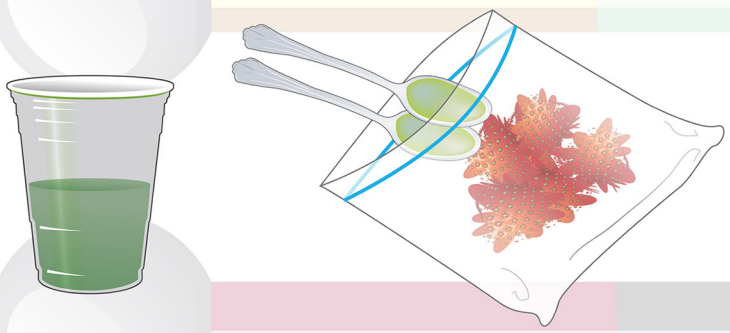
Put the strawberries into the plastic bag, seal it and gently smash it for about two minutes. Completely crush the strawberries. This starts to break open the cells and release the DNA.

3



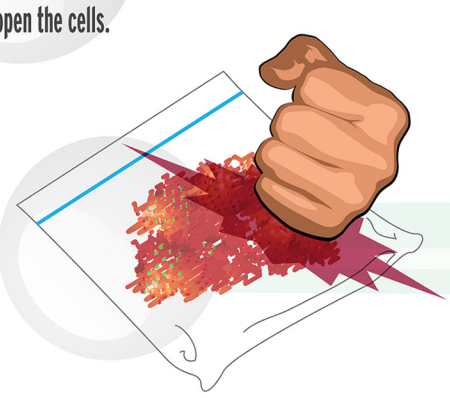
In a plastic cup, make your DNA extraction liquid: mix together 2 teaspoons of detergent, 1 teaspoon of salt and 1/2 cup of water.

4



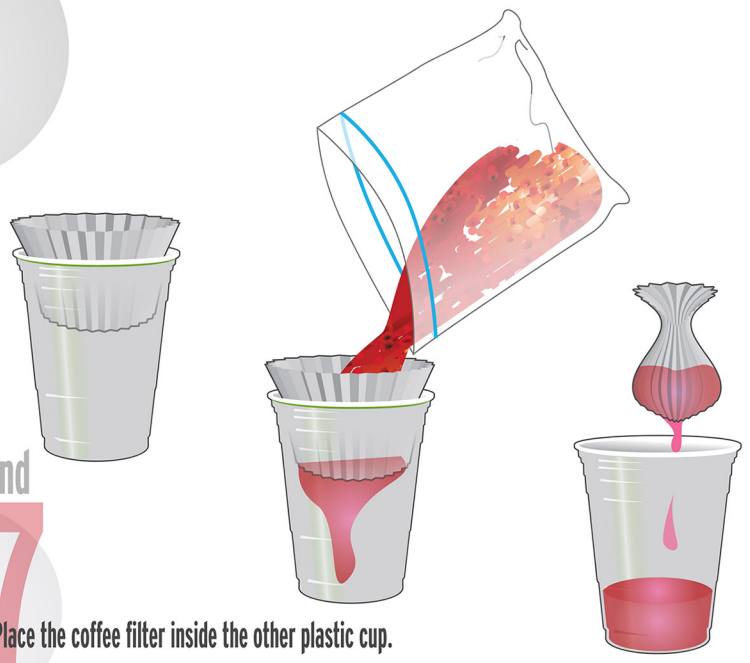
Add 2 teaspoons of the DNA extraction liquid into the bag with the strawberries. This will further break open the cells.

5



Reseal the bag and gently smash for another minute (avoid making too many soap bubbles).

6 and 7



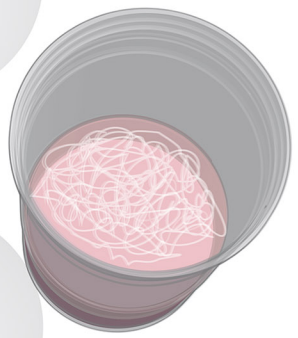
Place the coffee filter inside the other plastic cup.

Open the bag and pour the strawberry liquid into the filter. You can twist the filter just above the liquid and gently squeeze the remaining liquid into the cup.

8

Next, pour down the side of the cup an equal amount of cold rubbing alcohol as there is strawberry liquid. Do not mix or stir. You have just isolated the DNA from the rest of the material contained in the cells of the strawberry.

9



Within a few seconds, watch for the development of a white cloudy substance (DNA) in the top layer above the strawberry extract layer.

10

Tilt the cup and pick up the DNA using a plastic coffee stirrer or wooden stick.

National Human Genome Research Institute
GENOME UNLOCKING LIFE'S CODE

ScienceNews for Students

GENETICS

What we can — and can't — learn from our pets' DNA

People are turning to DNA tests to learn more about the breed, behavior and health of their dogs and cats

This is Sweetie when she was a young dog. Is she part greyhound? Part Labrador? Her owner gave her a DNA test to find out. (A doggie friend digs in the background.)

L. GUNTER; ADAPTED BY L. STEENBLIK HWANG

By **Bethany Brookshire**

October 24, 2019 at 5:45 am

Sweetie, now 12, looks kind of like a greyhound. Or maybe a Labrador. She's long and lean, with straight, silky fur, a happy-go-lucky face and floppy ears. Mostly, Sweetie looks like, well, a sweetie. She is a dog, after all.

"When I first got her, I was convinced she was a labradoodle reject," says Lisa Gunter. Gunter is a psychologist — someone who studies the mind — at

L. GUNTER

Sweetie is 12 years old now. More than 95 percent of dogs in shelters in Arizona and California are like her, a mix of two or more different dog breeds.

Arizona State University in Tempe. Her research focuses on how people perceive dog breeds. She couldn't help bringing her research home to Sweetie.

Labradoodles are a mix of Labrador and poodle. When someone breeds a Labrador and poodle together, the puppies sometimes get a poodle's curly coat — but not always. DNA is the long string of instructions that tells an organism's cells what molecules to make. Maybe Sweetie just got the DNA for smooth hair instead of poodle curls.

Gunter adopted her dog from a shelter in San Francisco, Calif. She didn't know what breeds Sweetie's parents might have been. And Sweetie wasn't telling. To find out, Gunter had her dog's DNA tested with a kit from Wisdom Panel. This company provides the tests Gunter uses for her own research. She swabbed Sweetie's mouth and mailed the sample to the company.

A few weeks later, Sweetie's results were ready. To Gunter's surprise, Sweetie didn't have any poodle or Labrador — or greyhound. "She's half Chesapeake Bay retriever, which is rare for central valley California," Gunter says. Her dog also is part Staffordshire terrier, part German shepherd and part rottweiler.

Doggie looks can be deceiving.

DNA testing for people is very popular. But now we can also check out what genetic traits a fluffy feline or pettable pooch carries in its DNA. We can learn what breeds a pet descends from, or in what region of the world its ancestors evolved. We can even try to predict how a pet might behave or what diseases it might face some genetic risk of developing.

Explainer: How DNA testing works

But for all that these tests might provide some interesting results, they need to be taken with caution. Pet DNA tests aren't necessarily as accurate as the human variety. And DNA itself isn't destiny. Scientists and veterinarians are concerned that as DNA testing becomes more popular, people might confuse a DNA-based risk with illness — whether or not the pet is actually sick.

Playful pup or fraidy-cat?

The DNA in a dog or cat (or human!) comes in long, coiled strands called chromosomes. A dog has 39 pairs of chromosomes, and a cat has 19 pairs (humans have 23 pairs). These chromosomes are long chains of four smaller molecules called nucleotides (NU-klee-oh-tydz). The nucleotides occur over and over again — billions of times — forming long sequences. The sequence of those different nucleotides encodes instructions for cells.

Determining the sequence — or sequencing — those nucleotides was once a long, expensive process. So scientists came up with other ways to look at genetic differences between one individual and another. One of these depends on the fact that much of the strings of nucleotides, called *sequences*, are the same from one dog or cat to

DNA testing looks into dog breeds and cat ancestry

another dog or cat. (One cat may have stripes and the other spots, but both need the same basic DNA that tells cells how to, say, build a strand of fur. That sequence will be the same.) But every now and then, one of the four nucleotide building blocks has randomly been substituted for another.

It's like misspelling one word in a long sentence or paragraph. These spelling mistakes are known as SNPs (pronounced snips). That's short for single nucleotide polymorphisms (Pah-lee-MOR-fizms). Sometimes, a "spelling" glitch doesn't change much. But in other cases, one alteration could change the whole meaning of the passage. In genetics, that one SNP may change at least part of the function of some cells or tissues. It could change a cat's coat from striped to solid. Another SNP might make a pet more or less likely to get a disease.

Many genetic tests for dogs and cats search for patterns of SNPs. Different groups of SNPs can determine a dog's breed or a cat's ancestry, and some are linked to certain diseases. But these tests only look at SNPs that scientists already know about. There are many other potential SNPs waiting to be found. DNA also contains large regions that can be copied over and over, or that can end up deleted entirely.

That's why Elinor Karlsson didn't want to stop with SNPs. She wanted to sequence the whole doggie genome — meaning every single gene — letter by letter. Karlsson is a geneticist at the University of Massachusetts Medical School in Worchester. She's got a special interest in mutts like Sweetie. "Mutts are just cool. Nobody knows anything about them," she says. "As a scientist one of the things most fun to do is … seeing how much [of what] people think about dogs holds up."

L. GUNTER

Sweetie (left) has a "sister" Sonya (right). Gunter and her wife did not get Sonya's DNA tested because Sonya is a border collie they obtained from a breeder — so they know all about her family tree.

Karlsson is especially interested in behaviors. Dog breeders and scientists don't know very much about what genes make a dog anxious or sad.

"Dogs and humans aren't that different," she says. "We study genetics to try and understand what makes people suffer from certain diseases, like psychiatric [Sy-kee-AT-rik] diseases." These are disorders of the mind. "Dogs get psychiatric disorders," she notes, much like people. They're called behavioral disorders in pets. Dogs can suffer from anxiety, or become obsessive about chewing, retrieving or herding. Her laboratory has already identified a few candidate genes for *obsessive-compulsive* behavior in dogs. Her team published those findings back in 2014.

But getting enough DNA to determine dog behavior is a tough task. A curly coat or pointy ears might be controlled by one or a few genes. Behavior is much more difficult to pin down. One behavior could be controlled by many, many genes. To find them all, a researcher would have to study the DNA of thousands or tens of thousands of dogs, Karlsson says. "We couldn't have a lab with thousands of dogs. It'd be extremely loud."

To get the DNA from so many dogs, Karlsson founded Darwin's Ark. Like Wisdom Panel, Darwin's Ark offers genetic testing for your pet. Karlsson's test sequences every gene, not just SNPs. But it's not quite as thorough as some human tests.

Sequencing every letter of the genome is a tricky process, like typing out a book as you read it. You're bound to make a few spelling mistakes or miss some words. To address this problem, human DNA tests tend to run an analysis 30 times to fill in all the gaps. Write out the same book 30 times over and compare all the versions together, and you'll end up much closer to the original.

L. GUNTER

Sweetie and Sonya have a cat in the house, too! This is Henry. Cats can get their DNA tested, but most cats are not mixes of specific breeds, so they don't have family trees that are as diverse as dogs.

Karlsson's test on dogs tends to run through the genes just once. So there might be tiny regions that get missed. To make up for that, Karlsson adds more dogs. They will all have very similar DNA — they're all dogs. And by sequencing enough of them, Karlsson hopes to fill in the DNA details that might get missed in only one sequence.

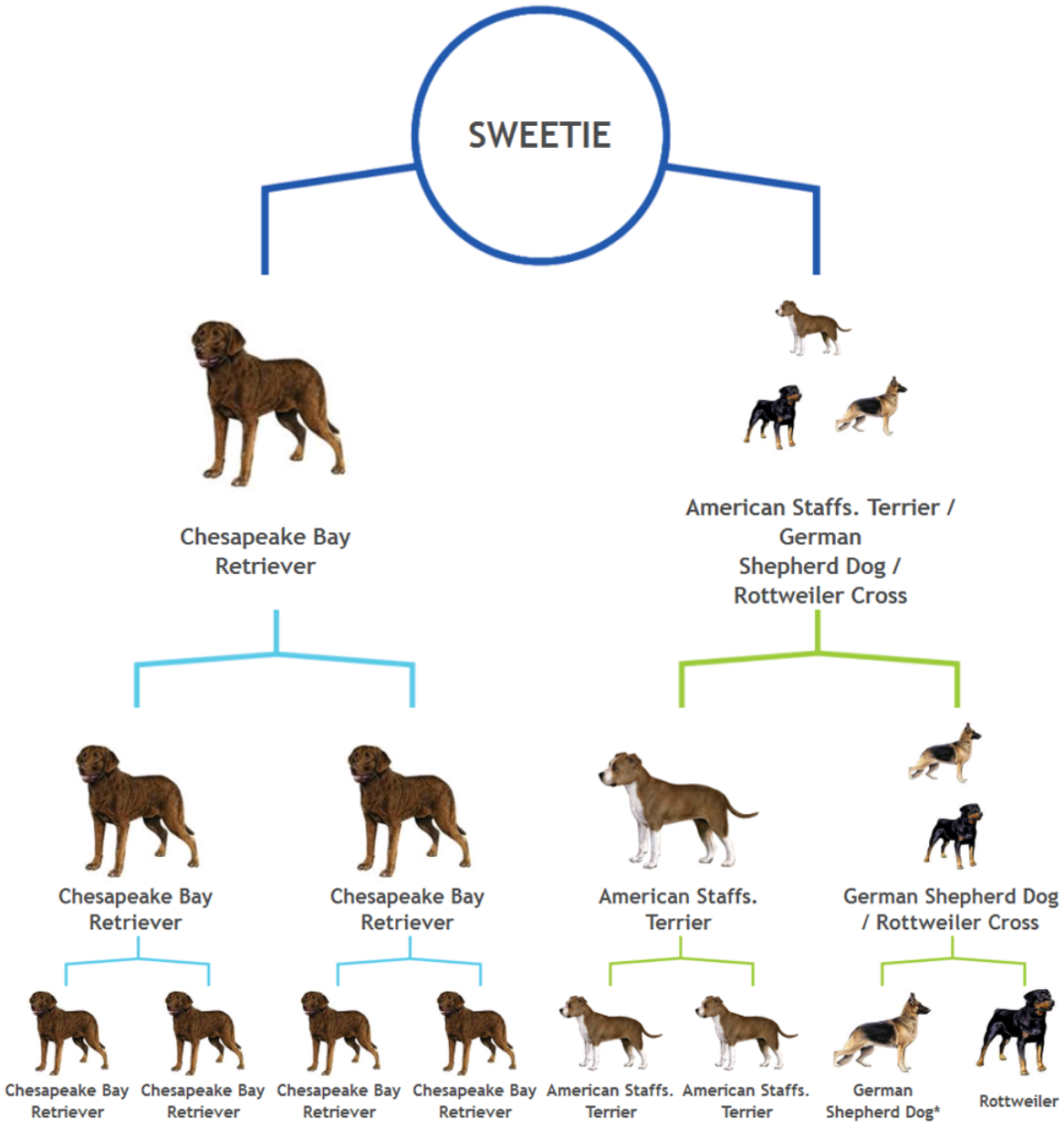
Looking for clues to attitudes

To learn about how a dog behaves, researchers need to survey its owners. Darwin's Ark does this through *citizen science* — research in which non-scientists

can take part. Pet owners fill out several long surveys giving details about their dogs' personality. What do they like? What are they afraid of? By pulling such details from the surveys, Karlsson is hoping to match genes to a dog's behavior.

That's important, because people assume a lot about a dog's behavior when they look at its breed. But maybe they shouldn't, especially if it's a mutt.

Sweetie, for example, has good doggie friends — but she's not very good at making new ones. "It could be attributed to her American Staffordshire terrier or German shepherd ancestry," Gunter says. When Sweetie loves someone, though, she is a real cuddle bug. Gunter thinks that could be due to those first two breeds. Or maybe it's due to her Chesapeake Bay retriever or rottweiler traits. "You could tell a pretty compelling story with any of the breeds in her heritage," she notes.



These are the breed results that Gunter got for Sweetie. There's no greyhound or lab to be seen. Instead, Sweetie has one parent who was a Chesapeake Bay retriever, and another that was part German shepherd, part rottweiler and part Staffordshire terrier. See larger version.

L. GUNTER

Scientists don't yet know precisely how the behaviors of different breeds combine in a dog, Gunter points out. "Genetic influences of multiple breeds do not combine like dabs of differently colored paints or dashes of our favorite

attributes," she says. "I'm uncertain how informative it is to know the breed heritage of your mixed breed dog if we don't know how multiple breeds affect behavior." Maybe it's better, she says, to just take your dog's behaviors and work with them.

Adam Boyko is a geneticist at Cornell University in Ithaca, N.Y. He's also the scientist behind EmBark, another dog-genetics test. He says some people learn the breed of the mutt and see a totally new dog. "We see a ton of owners that are so thankful to [learn] the breed mix because now they realize they have a better understanding of a dog's behavior and things they can do to keep their dog happy," he says. "They might find out their dog is part border collie and teach it to herd." That might help it release some of its pent-up energy. Knowing what breeds are in their dog's ancestry didn't change the way the dog behaved. But it did change how people reacted to that behavior.

From DNA to disease

The DNA test that Gunter gave Sweetie didn't tell her anything about Sweetie's health. But some tests, such as EmBark, can do that. "What we can tell the owner is whether or not the dog has specific known genetic variants that are associated with certain diseases," Boyko says. EmBark offers a test for more than 170 health conditions. These include ones where a DNA tweak may underlie some disease. An updated version of Wisdom Panel (not the one Sweetie got) offers a health test for more than 150 dog diseases as well.

Boyko's lab has identified DNA tweaks that are associated with risks of seizures, heart disease and more. These data are of interest to dog owners. But they can be very important for dog breeders, Boyko says. These people want to know if a dog they want to breed carries genes that might boost a risk of certain diseases in its offspring. If so, maybe they would want to breed it with some other dog, or not breed it at all.

NIMIS69/ISTOCK/GETTY IMAGES PLUS

People love the squished-looking faces of pugs. But too much inbreeding means these animals can have difficulty breathing. DNA tests can help breeders know which animals should be mated together to make more pugs.

Cat breeders also want to know if their chosen breed carries the risk of some genetic disease. Basepaws is a genetic test that can investigate that. Wisdom Panel and a company called Optimal Selection also offer tests targeted to cat breeders.

Breeders and veterinarians can also send samples from their cats to a veterinary genetics lab at the University of California, Davis or to the one in which Leslie Lyons works. (Yes, that's pronounced "lions," and yes, she says, it's very ironic.) She's at the University of Missouri in Columbia. Lyons' lab specializes in finding genetic links to diseases in cats. "The end goal for me is to improve the health of domestic cats. And one way to do that is to eradicate genetic disease," she says.

But her hopes go far beyond felines. "Ultimately, we'd like to say this cat disease models that human disease or dog disease," she says. If certain treatments for that disease work in other species, she notes, "we can apply them to cats." And

her findings might work the other way around, too. A treatment that works in a cat might later be tried in dogs or people.

Unfortunately, people sometimes take these genetic tests as doggie dogma — that they determine a pet's future health. In fact, they don't. Even veterinarians don't always know how to interpret the results of genetic tests for pets.

S. ZIELINSKI

Oscar is an orange tabby cat, classified as a domestic short hair. He doesn't belong to any specific breed.

"[DNA tests] aren't like other kinds of blood tests a vet does," notes Lisa Moses. She's a veterinarian at the MSPCA Angell Animal Medical Center in Boston, Mass. She's also a bioethicist — someone who studies codes of conduct in medicine — at Harvard University in Cambridge, Mass.

Moses first heard about the DNA tests that people can get, such as 23andMe. The tests work just like Wisdom Panel and other dog-genetics tests. And people often misinterpret their results, she's found. In fact, Moses didn't know how to interpret them at first. "I just assumed if you had a positive [genetic] test, you had the disease," Moses says. "And I think that's what most people think."

But that's not true. Certain SNPs, deleted DNA sections or extra copies of some sequences are common in large populations. And some people who have them

do indeed develop the illness they're associated with. Yet most people who have them never get sick because of those genes, she notes. The same goes for dogs and cats.

Decode DNA with caution

Worries about genetic misconceptions keep bioethicists like Moses and scientists like Karlsson up at night.

After Karlsson had published papers on dog genetics, she began talking to people from companies that test dog DNA. She suddenly realized that "people could just start offering tests [based on] my papers." This horrified Karlsson because she knew a single research paper is only the beginning of understanding what a gene variant might do. Many more studies would need to be done before she could firmly link a gene variant with some disease.

How reliable are different dog DNA tests? C&EN Speaking of Chemistry tested their resident pup, Ultraviolet, to find out.

C&EN/ACS PRODUCTIONS

"I knew those results weren't good enough for a genetic test," she says. "But there was no regulation that would stop that from happening." There is no government group to decide or rule whether a dog- or cat-DNA test is a good one or not.

Horrified, Moses and Karlsson got together with their colleague Steve Niemi. He's a veterinarian and director of the Office of Animal Resources at Harvard. They published an article in *Nature* on July 26, 2018. It pointed out that many of the genes that companies interpret as a test for diseases in dogs might not stand up to follow-up studies. The report also noted that tests of human and pet DNA can make mistakes.

The paper begged companies that test a pet's DNA to set strong standards for which genetic sequences and diseases they attempt to link, and how they

interpret the findings for breeders and pet owners.

Boyko also says people should be careful when making decisions about vet care based on a DNA test. A DNA test can only offer warnings of risks. A dog that has a gene associated with blindness is at risk for blindness, he notes. But it's not necessarily blind. "What we're telling the owner is what you need to look out for," he says. The next stop should be a vet who can monitor and test your animal now and in the future. The DNA results will be helpful there, Boyko says, because the vet will have a better idea of what tests to run.

And then a person would have to decide whether or not to run those tests. A human can know their dog has a DNA-based risk for a disease. But the dog doesn't know the difference. Regular vet visits can be stressful for some dogs, notes Moses. Pets have different needs than people do. And in some cases, it might be easier on a dog or cat to not run the tests. In other cases, the test might be just fine.

Classroom questions

In the end, your cat or dog is still your pet. "We want explanations; those are satisfying," Gunter says. "We want to understand what makes our dogs who they are. But in a lot of ways we know that, we know who our dogs are." Our pets are more than their DNA and breed and background. They are our companions and friends. We don't need to know their DNA to know who they are. We just need to pay attention.

Sweetie didn't become more terrier-like when Gunter read her DNA results. Her personality didn't change when Gunter learned about her background. Those DNA results added to what Gunter knew about her life story. But the DNA test didn't change the dog. Sweetie, in the end, is still Sweetie.

NGSS: HS-LS3-1, HS-LS3-3, HS-LS4-4, MS-LS3-2, MS-LS4-4, MS-LS4-5

CITATIONS

Journal: L.M. Gunter, R.T. Barber and C.D.L. Wynne. A canine identity crisis: Genetic breed heritage testing of shelter dogs. *PLOS ONE*. Vol. 13, August 23, 2018. doi: 10.1371/journal.pone.0202633.

Journal: L. Moses, S. Niemi and E. Karlsson. Pet genomics medicine runs wild. *Nature*. Vol. 559, July 25, 2018, p. 470. doi: 10.1038/d41586-018-05771-0.

Journal: J. Donner et al. Frequency and distribution of 152 genetic disease variants in over 100,000 mixed breed and purebred dogs. *PLOS Genetics*. April 30, 2018. doi: 10.1371/journal.pgen.1007361.

Journal: L.M. Gunter, R.T. Barber and C.D.L. Wynne. What's in a Name? Effect of Breed Perceptions & Labeling on Attractiveness, Adoptions & Length of Stay for Pit-Bull-Type Dogs. *PLOS ONE*. March 23, 2016. doi: 10.1371/journal.pone.0146857.

Journal: R. Tang et al. Candidate genes and functional noncoding variants identified in a canine model of obsessive-compulsive disorder. *Genome Biology*. Vol. 15, March 14, 2014. doi: 10.1186/gb-2014-15-3-r25.

Journal: O. Goldstein et al. *IQCB1* and *PDE6B* mutations cause similar early onset retinal degenerations in two closely related terrier dog breeds. *Investigative Opthalmology & Visual Science.* Vol. 54, October 25, 2013, p. 7005. doi: 10.1167/iovs.13-12915.

ScienceNews for Students

CLASSROOM QUESTIONS

Questions for ‘What we can — and can’t — learn from our pets’ DNA’

This is Sweetie when she was a young dog. Is she part greyhound? Part Labrador? Her owner gave her a DNA test to find out. (A doggie friend digs in the background.)

L. GUNTER; ADAPTED BY L. STEENBLIK HWANG

By **Science News for Students**

October 24, 2019 at 5:30 am

To accompany feature “What we can — and can’t — learn from our pets’ DNA”

SCIENCE

Before Reading:

1. Do you or does someone you know have a pet? Describe this pet.

2. Has anyone in your family taken an at-home genetic test? What did they learn?

During Reading:

1. What is DNA?

2. What sorts of information can we learn about our pets from their DNA?

3. What do many genetic tests for pets search for? What is one drawback of such tests?

4. What is a genome?

5. Why does geneticist Elinor Karlsson study dog genomes?

6. How are researchers like Karlsson tying pet behavior with genetics?

7. What is disease risk? What is the difference between this risk and the actual disease?

8. Why are scientists interested in using DNA tests to study animals’ disease risk?

9. What *can’t* pet DNA tests tell us about our pets?

10. After testing a pet’s DNA for disease risks, what should be an owner’s next step?

After Reading:

1. Would you test your pet’s DNA? What would you want to learn and why?

2. The story explains that genetic tests for pets are not currently regulated by the government. Should that change? Explain your answer using evidence from the story.

Student Question | Is It Ethical to Genetically Engineer Animals?

BY MICHAEL GONCHAR APRIL 21, 2016 5:00 AM

April 21, 2016 5:00 am

Photo

A genetically engineered salmon from AquaBounty Technologies, rear, with a conventionally raised sibling roughly the same age. Related Article

Credit

Paul Darrow for The New York Times

Student Opinion

New technologies have made genetically engineering animals relatively easy to accomplish. Salmon can be modified to grow faster. Mosquito genes can be edited to combat diseases like malaria and the Zika virus. Pigs can be altered so their organs might some day be transplanted to humans.

But are the risks inherent in tinkering with animal DNA worth the potential rewards? Is it ethical to genetically engineer animals?

In "Open Season Is Seen in Gene Editing of Animals," Amy Harmon writes:

SIOUX CENTER, Iowa — Other than the few small luxuries afforded them, like private access to a large patch of grass, there was nothing to mark the two hornless dairy calves born last spring at a breeding facility here as early specimens in a new era of humanity's dominion over nature.

But unlike a vast majority of their dairy brethren, these calves, both bulls, will never sprout horns. That means they will not need to undergo dehorning, routinely performed by farmers to prevent injuries and a procedure that the American Veterinary Medical Association says is "considered to be quite painful."

Instead, when the calves were both just a single cell in a petri dish, scientists at a start-up company called Recombinetics used the headline-grabbing new tools of gene editing to swap out the smidgen of genetic code that makes dairy cattle have horns for the one that makes Angus beef cattle have none. And the tweak, copied into all of their cells through the normal machinery of DNA replication, will also be passed on to subsequent generations.

"It's pretty cool," said Micah Schouten, the calves' caretaker, looking at his charges.

The uproar over the new ease and precision with which scientists can manipulate the DNA of living things has centered largely on the complicated prospect of editing human embryos. But with the federal government's approval last week of a fast-growing salmon as the first genetically altered animal Americans can eat, a menagerie of gene-edited animals is already being raised on farms and in laboratories around the world — some designed for food, some to fight disease, some, perhaps, as pets.

Just this week, researchers reported having edited mosquitoes so that they will no longer carry the parasite that causes malaria. And the power to reshape other species, scientists and bioethicists say, raises questions that are both unique to animals and may bear on the looming prospect of fiddling with our own.

“We’re going to see a stream of edited animals coming through because it’s so easy,” said Bruce Whitelaw, a professor of animal biotechnology at the Roslin Institute at the University of Edinburgh. “It’s going to change the societal question from, ‘If we could do it, would we want it?’ to, ‘Next year we will have it; will we allow it?’ ”

Students: Read the entire article, then tell us:

1. Is it ethical to genetically engineer animals? Why?

2. What are the risks in changing animal DNA? What are the possible rewards?

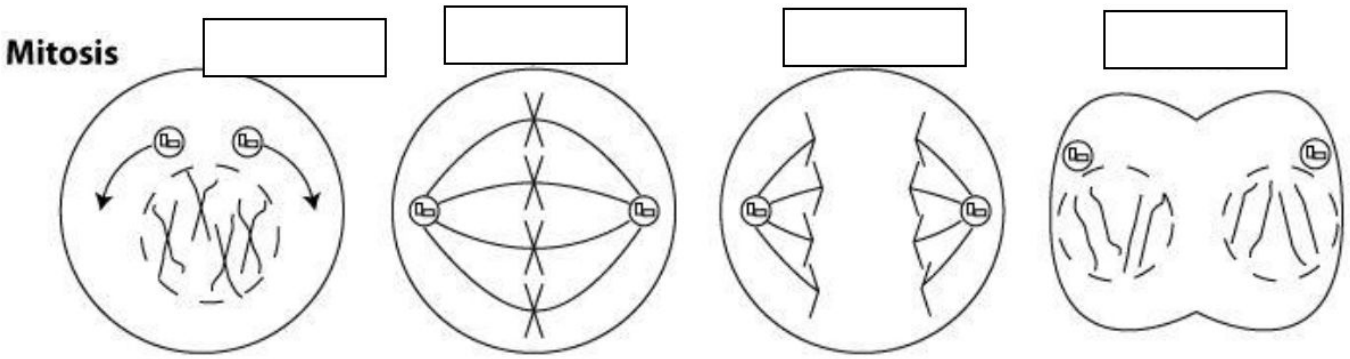
3. Do the rewards outweigh the risks, or vice versa? Why?

4. What rules, if any, should the government put in place to regulate genetically engineering animals?

5. The technology of editing animal genes is the same process that could some day be used to edit human genes. How do you feel about gene editing of humans, whether to eliminate genetic diseases or to select for desired traits? Why?

Module 3 Review **Name: _____**

1. The sister chromatids are moving apart during _____.
2. Chromatin condenses into _____during prophase.
3. A new nuclear membrane is forming around the chromosomes during _____.
4. The cytoplasm of the cell is being divided in _____.
5. The chromosomes are located at the middle of the cell in _____.
6. The division called the cleavage furrow appears during telophase in _____cells.
7. The chromosomes are moving towards the poles of the cell in _____.
8. Chromosomes are not _____during interphase
9. Chromosomes are _____during S phase of interphase
10. The cell prepares to _____in G2 phase of interphase.
11. The cell _____during G1 phase of interphase.

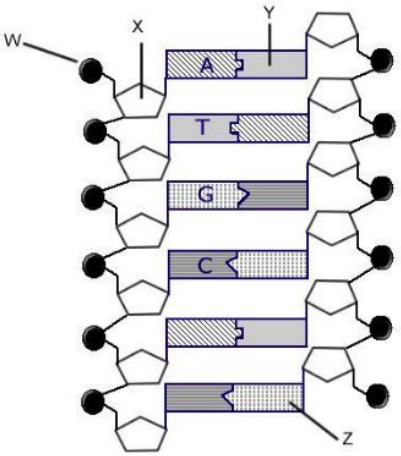


12. _____ reproduction produces genetically different offspring, and _____ reproduction produces genetically identical offpsring. There are two parent(s) in _____ reproduction and one parent in _____ reproduction.

13. Prokaryotes, such as bacteria, reproduce by _____ which means splitting in two.
14. The monomer of _____ is a nucleotide, and the _____ is polynucleotide.
15. DNA has a set of alternating structures along the sides of the "_____". This is called the sugar-phosphate backbone.
16. The four _____ _____ are adenine, thymine, cytosine, guanine.
17. The bases pair together according to _____ rules. A pairs with ___ and C pairs with ___.
18. According to Chargaff's rules, if DNA consists of 30% cytosine, approximately what percentage is thymine?
    a. 30% b. 40% c. 20% d. 60%

19. RNA is different from DNA because it contains the sugar _____ and the nitrogenous base _____ instead of thymine.

20. Label the phosphate group, deoxyribose sugar, nitrogenous bases, and hydrogen bonds on the DNA model below.



21. When replicating, each parent strand becomes a _____ for the assembly of a new strand.

22. Watson and Crick proposed that _____ of the replicated DNA is parent strand and _____ is new strand. This called the semi-conservative model.

23. Since the two strands of DNA are arranged opposite to each other, we say that they are _____.

24. DNA _____ unzips the DNA and breaks the hydrogen bonds between bases.

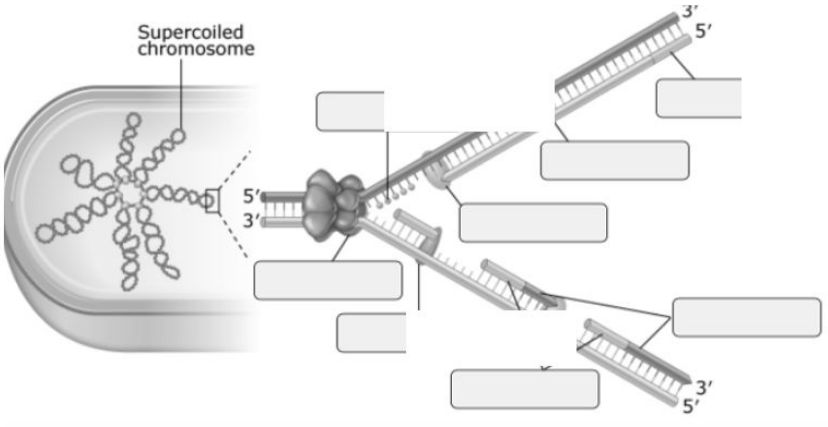
25. DNA _____ brings bases from the cytoplasm to the new DNA strand.

26. _____ fragments are made on the lagging strand as it grows _____ from the replication fork.

27. DNA _____ links the Okazaki fragments together.

28. DNA polymerase also checks for _____ in replication (ex. C instead of T, etc.)

29. Label the diagram below, using the words – *leading strand, lagging strand, Okazaki fragments, DNA polymerase, DNA helicase. Only label the boxes provided.*



30. The information within the actual _____ is the genotype. The physical _____ of the organism is its phenotype.

31. _____ is the creation of mRNA from DNA. _____ is the synthesis of protein from the mRNA code.

32. **Transcription/translation** occurs in the nucleus of the cell.

33. _____ stands for messenger RNA because it takes the DNA code into the cytoplasm of the cell.

34. Adenine always pairs with _____ and cytosine always pairs with _____.

35. _____ _____ are coded by the specific base sequence of the DNA and mRNA.

36. The nucleotides are arranged in sets of three to code for a specific amino acid, called a _____.

37. If you found a protein that was made of 27 amino acids, what is the minimum number of nucleotides that it must have? _____ How about 90 amino acids?

38. Look up the genetic code in your book or online. What amino acid is coded by the codon AAA? _____ CUA? _____

39. The codon _____ codes for methionine, or _____.

40. The codon _____, _____, UGA codes for stop.

41. What amino acid sequence is coded from the mRNA strand? GCC UAU CUU CCC ACA

42. There is an error in transcription so the new mRNA strand reads GCC UAU CUA ACA. What change is there to the amino acid sequence?

43. During mRNA processing, _____ are removed before the mRNA leaves the nucleus. The parts that are allowed to stay within the nucleus and move to the ribosome are called _____.

44. tRNA carries the correct _____ _____ to the ribosome. The part of tRNA that matches the mRNA codon is called the _____.

45. As the amino acids form, a _____ bond forms between the amino acids.

46. Which type of mutation is usually the most destructive and why – silent, missense, or frameshift?

47. Copies of the enzyme DNA polymerase work together to synthesize DNA. Why are two copies of the enzyme necessary at each replication fork?

a. One copy breaks apart the original DNA molecule, and the other copy synthesizes two complementary strands.
b. One copy synthesizes two complementary strands, and the second copy edits or corrects the new strands if necessary.
c. Each copy attaches to one strand, and each synthesizes a complementary strand.
d. Both copies attach to the same strand, where they work together to synthesize the complementary strand.

48. A scientist used a radioactive isotope of nitrogen to label the nitrogenous bases of the DNA in bacterial cells. The labeled cells were then allowed to grow and divide for one generation in a medium of non-radioactive nitrogen. Where is the radioactive nitrogen in the DNA of the bacterial cells?

a. distributed evenly among all of the DNA
b. in both strands of the DNA of half of the cells
c. in one strand of the DNA of half of the cells
d. in one strand of the DNA of all of the cells

49. Human nerve cells and muscle cells have many structural and functional differences. What role does DNA play in these differences?

a. Nerve cells and muscle cells contain different DNA.
b. DNA in muscle cells is condensed into chromatids.
c. Muscle cells are more likely to have DNA mutations than nerve cells.
d. Transcription factors and gene expression is different in nerve cells and muscle cells.

50. As a result of a point mutation, the base cytosine (C) was replaced by adenine (A) in a sequence of mRNA. Under which circumstance does this mutation cause the protein to be significantly shorter?

a. The mutation introduced a stop codon into the middle of the mRNA molecule.
b. The mutation changed the genetic code used during translation
c. The mutation occurred in a region of mRNA that is not translated
d. The mutation introduced a start codon in the middle of the mRNA molecule.

51. Proteins are assembled at ribosomes using mRNA as a template. Which property of tRNA allows it to assist in this process?

a. Each of many tRNA molecules contains an anticodon, and it may bind to any amino acid.
b. Each of many tRNA molecules contains an anticodon, and it binds to a specific amino acid.
c. One tRNA molecule contains all of the anticodons and binds to all of the amino acids that are specific for the protein.
d. One tRNA molecule contains all of the codons and binds to all of the nucleotides that are specific for the protein.

52. Several differences between DNA and RNA allow the cell to differentiate between the two molecules, ensuring that transcription and translation occur appropriately. Which is one of the properties of RNA that differentiates it from DNA?

a. RNA includes phosphate groups instead of nitrogenous groups.
b. RNA is double stranded instead of single stranded.
c. RNA contains uracil (U) instead of thymine (T).
d. RNA contains cytosine (C) instead of guanine (G).

Questions

1. How do virologists search for new viruses? How do today's approaches differ from earlier methods of researching viruses?

They look for bits of genetic material in samples — water, mud, blood — and use sophisticated computer programs to recognize viral genes.

2. What does the research of Matthew Sullivan, a virologist at Ohio State University, demonstrate about the diversity of viruses in the sea?

There is tremendous diversity. They reported over 15,000 viruses in 2016 but in 2019 they found over 200,000. There are far more viruses than they realized.

3. How did Chinese researchers and virologists isolate and identify the virus that causes Covid-19 earlier this year? How did the International Committee on Taxonomy of Viruses name the virus?

They found that it had a distinctive crown of proteins and virologists sequenced its genes.

4. How do viruses infect and affect humans compared to other species?

Only 250 species of viruses infect humans. Most viruses do not infect humans.

5. Why is it so hard for virologists to classify viruses?

Scientists have to figure out how they relate to other viruses. That is harder to do for viruses than for living things like animals and plants.

6. Why did Jens H. Kuhn, the lead virologist at the Integrated Research Facility at Fort Detrick in Maryland, and his colleagues create the "megataxonomy"? How have other researchers responded to his creation?

They developed it to classify viruses. The sorting is done by looking for hallmark genes. They also look for groups of species that trade genes with each other. They think that other researchers will accept it soon.

KEY

Questions for ‘Bacteria are all around us — and that’s okay’

By Science News for Students
October 4, 2018

Before Reading:
1. You can’t see bacteria with the unaided eye, but they’re all around us, no matter where we are. How does this make you feel? ***Answers vary***
2. What sorts of jobs do you think bacteria perform in the environment? Why do bacteria matter? ***Answers vary***

During Reading:
1. Scientists estimate that what percentage of the world’s bacteria species are still undiscovered? ***Approximately 99% are undiscovered***
2. What is a greenhouse gas? ***Greenhouse gas is a gas that enters the air when people burn oil, gas, and coal or by natural processes. Greenhouse gases trap heat in the atmosphere.***
3. Based on this story, how do some scientists identify where to look for bacteria that interest them on the ocean floor? ***Scientists look for clusters of clams and giant tube worms since they feed on the molecules created by the bacteria.***
4. What’s the deepest place on Earth? How far below the ocean’s surface is it? ***Challenger Deep in the Mariana Trench - 11 kilometers below the ocean surface***
5. How do microbes affect the flavor of sourdough bread? ***Bacteria break down sugars in the flour, releasing carbon dioxide, acids, and other flavorful compounds***
6. What are biofuels? ***Biofuels are plant-based fuels.***
7. What are enzymes? ***Enzymes are molecules that speed up chemical reactions.***
8. Where did Steve Singer find bacteria that are good at breaking down plants? ***A compost pile.***
9. What is a metagenome? ***The sum of all genetic material in an environment.***
10. What is the Earth Microbiome Project? ***How many scientists are participating*** in it? ***The project is a catalog of all the bacteria on Earth. One thousand scientists are working on the project.***

After Reading:
1. Why do scientists care about bacteria eating methane on the ocean floor? How might these bugs help our planet? ***A better understanding could help us control methane as a greenhouse gas.***
2. How can researchers discover new species of bacteria without ever seeing them under a microscope? ***Scientists use eDNA to create genetic fingerprints of new bacteria.***

Review Module 1 **Name: _____**

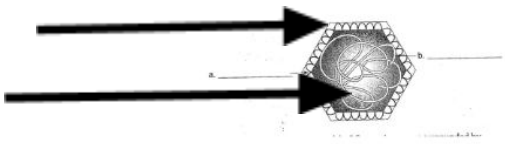
1. Explain each characteristic of life.

Made of cells	Life is characterized by highly ordered structures made of cells
Reproduction	Organisms reproduce their own kind.
Contains DNA	DNA is used to carry genetic material.
Growth and development	Inherited information encoded in DNA controls the pattern of growth and development of all organisms.
Ability to metabolize	Organisms take in energy and use it to power all of their activities
Response to stimuli	All organisms respond to environmental stimuli.
Maintain homeostasis	Organisms have regulatory mechanisms that maintain a beneficial internal environment.
Evolution	Adaptations evolve over countless generations as individuals with heritable traits that are best suited to their environments have greater reproductive success.

2. Viruses are made of two components: genetic material and protein capsid.
3. The lytic cycle involves the virus making new viruses rapidly and breaking open the cell.
4. The lysogenic cycle involves the virus incorporating itself into the host genome and making copies of the viral genome.
5. Vaccines can help to **destroy / prevent** a virus.
6. As more individuals in a population are inoculated, the viral infection rate **increases / decreases.**
7. Label the parts of the virus:

Protein capsid

genetic Material



8. Which type of virus changes more frequently – RNA or DNA? RNA

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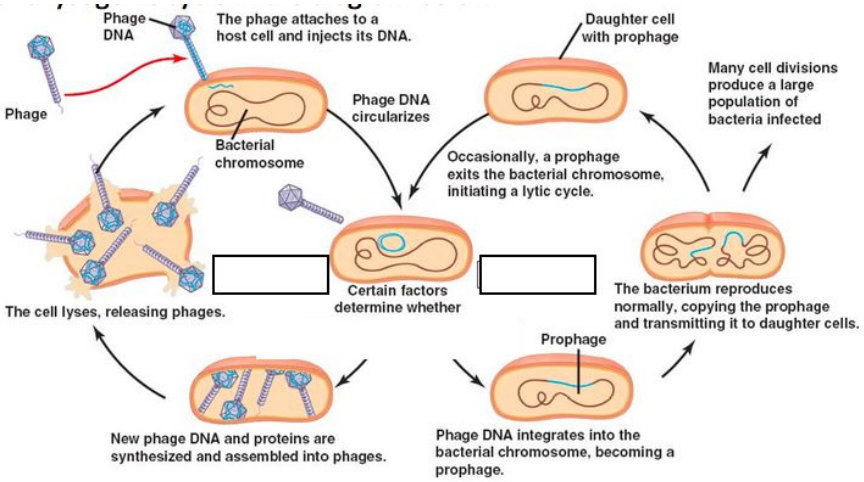
9. Label the lytic and lysogenic cycle in the diagram below:
   Lytic is the diagram on the left. Lysogenic is the diagram on the right.



10. Define homeostasis maintaining stable internal conditions.
11. How many parents are involved in asexual reproduction? one Are the offspring the same or different from the parents? same
12. How many parents are involved in sexual reproduction? two Are the offspring the same or different from the parents? different
13. Name the 6 kingdoms: Archaea, Eubacteria, Protist, Fungi, Plant, Animal
14. Complete the chart to compare the kingdoms – you may check multiple boxes if kingdoms have more variety and you may not check off all the boxes for each kingdom.

	Archaebacteria	**Eubacteria**	**Protist**	**Fungi**	**Plant**	**Animal**
Prokaryotic?	x	x				
Eukaryotic?			x	x	x	x
Autotrophic?	x	x	x		x	
Heterotrophic?	x	x	x	x		x
Unicellular?	x	x	x	A few		
Multicellular?			x	x	x	x
Phototrophism?					x	
Internal Digestion?						x

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External Digestion?				x		
May have features of fungus-like, animal-like, or plant-like?			x			

For questions 15 and 16, refer to the following paragraph and the table.

Robert is studying the characteristics of life. He constructs the table shown below to compare examples of living things and nonliving things.

	Penguin	Earthworm	Oak Tree	Elevator
Made of cells	yes	yes	yes	no
Grow and develop	yes	yes	yes	no
Respond to the environment	yes	yes	yes	yes
Move from place to place	yes	yes	no	yes
Use energy	yes	yes	yes	yes

15. Based on the examples shown in the table, which is not a characteristic of all living things?
    a. being made of cells
    b. growth and development
    c. moving from place to place
    d. using energy
16. The data in the table most strongly support which of these conclusions?
    a. Any of the characteristics of life can distinguish living things from nonliving things.
    b. Nonliving things may have some, but not all, of the characteristics of life.
    c. Nonliving things may have some or all of the characteristics of life.
    d. No set of characteristics can distinguish living things from nonliving things.

For question 17, refer to the following paragraph.

Valerie conducted a controlled experiment on pothos plants, which are common houseplants. Her hypothesis is that the direction of light will affect the growth pattern of a plant. In one test group, she allowed the plants to receive light from one direction only. Valerie observed that the plants in this group bent their stems and leaves toward the light.

17. Valerie's observations most strongly demonstrate which of these characteristics of life?
    a. response to stimuli from the environment
    b. obtaining and using materials and energy
    c. evolution, or change over time
    d. maintaining a stable internal environment

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18. Julian claims that viruses are alive. His supporting evidence is that viruses use the universal genetic code, are able to reproduce, and can evolve. Which statement would be most useful in an argument against Julian's claim?
    a. Viruses are too small to be classified as living things.
    b. Viruses evolve only after many generations.
    c. Viruses satisfy only some characteristics of life, not all of them.
    d. Viruses reproduce only under the proper conditions.

19. A student builds a model of the circulatory system that also compares blood chemistry at different points in the system. This study most strongly focuses on which characteristic of living organisms?
    a. responding to stimuli
    b. growing and developing
    c. changing over time
    d. homeostasis

20. Living things have certain qualities. For something to be considered alive, it must have those characteristics. Which is NOT one of these characteristics?
    a. made of cells
    b. responds to the environment
    c. is visible with the unaided eye
    d. obtains and uses energy

21. Which of the following occurs during a lytic, but not a lysogenic, viral replication cycle?
    a. The phage uses the host cell's "machinery" to replicate its own DNA
    b. A prophase is replicated each time the bacterium divides.
    c. A phage injects DNA into the host
    d. Whole viruses leave the host cell and infect other cells.

22. Which of the following is an INCORRECT statement about viruses that reproduce using lysogenic cycles?
    a. Prophage genes can direct harmless bacteria host cells to make toxins that cause serious illness.
    b. They can switch to a lytic cycle if triggered by an environmental signal.
    c. They kill their host cells by lysing them.
    d. They can remain in bacterial cells indefinitely.

23. Which of the following is a characteristic that is shared by prokaryotes AND eukaryotes?
    a. Both contain DNA
    b. Both give us essential vitamins.
    c. Both are between 10 and 100 micrometers in diameter.
    d. Both have membrane-bound organelles.

24. Which feature is common to the domains Archaea and Eukarya?
    a. RNA polymerase is present.
    b. Histones are absent.
    c. Cell walls contain peptidoglycan.
    d. Cells lack nuclei and membrane-bound organelles.

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25. The oxygen end of the water molecule has a more negative charge and the hydrogens have a more positive charge. This is called polarity.
26. Name four properties that water has due to its polarity. Adhesion, cohesion, surface tension, high boiling point
27. Functional groups determine the reactivity of a molecule

28. Identify each functional group in the table:

Structural Formula	Name of Group
$-CH_3$	methyl
-COOH	carboxyl
-OH	hydroxyl
$-NH_2$	amino
-CO	carbonyl
$-OPO_3^{2-}$	phosphate

29. Dehydration synthesis removes a molecule of water to join monomers into polymers.
30. Hydrolysis adds a molecule of water to break a polymer into monomers
31. All carbohydrates have the same ratio of C:H:O which is 1:2:1.
32. Proteins contain 4 elements – C, H, O, and N
33. How many different amino acids are there? 20
34. Nucleic acids contain the elements C, H, O, N and P.

35. Complete the chart to compare the macromolecules.

	Carbohydrates	Lipids	Proteins	Nucleic Acids
Examples of monomers?	glucose	Fatty acids, glycerol	Amino acids	nucleotides
Example of polymers?	Starch, cellulose, chitin, glycogen, peptidoglycan	Steroids, phospholipid, cholesterol	Protein enzyme	DNA RNA
Functions?	Store short term energy Structure and support	Store long term energy Form steroids insulation	Form enzymes, antibodies, transport	Store genetic information

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36. On the table below, label the pictures with the following words: *carbohydrate, lipid, protein, nucleic acid, nucleotide, monosaccharide, amino acid.*

Answers in order, right to left, row by row: lipid, amino acid, monosaccharide, nucleotide, nucleic acid, protein, carbohydrate, monosaccharide, lipid, protein

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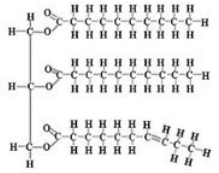
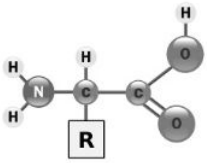
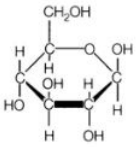
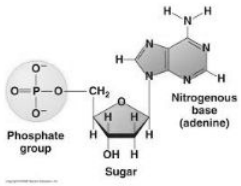
<td>  </td>
<td>  </td>
<td>  </td>
<td>  </td>
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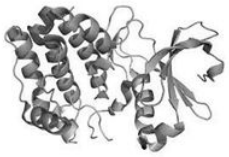
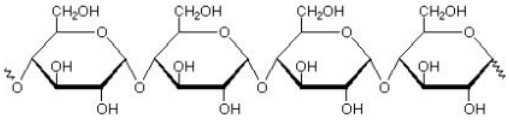
<td>  </td>
<td colspan="2">  </td>
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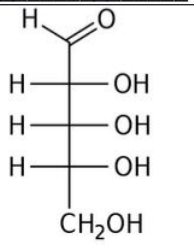
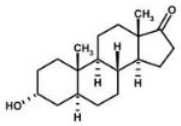
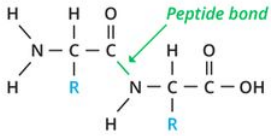
<td>  </td>
<td>  </td>
<td colspan="2">  </td>
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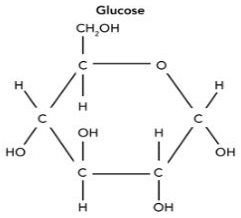
37. Cells use glucose as a monomer to make a variety of polymers. Which of the following correctly describes a type of glucose polymer?



a. cellulose, which forms a tough fiber in plants
b. DNA, which contains genetic information
c. catalase, which is a component of cell membranes
d. thyroxine, which binds to cell receptors

Most enzymes are proteins. Many cells make and use an enzyme called catalase to facilitate the decomposition of hydrogen peroxide (H_2O_2). The products of the decomposition are hydrogen (H_2) and oxygen (O_2). Stephanie is investigating the structure and function of catalase, and she is comparing catalase to other proteins.

38. What can Stephanie predict will distinguish the structure of catalase from the structures of the other proteins she is studying?

a. many regions made entirely of hydrogen and oxygen
b. the chemical properties of the peptide bonds
c. the types of amino acids it contains
d. the sequence of amino acids it contains

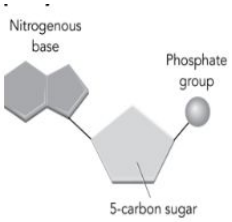
39. Stephanie increases the pH of catalase beyond its normal range. She observes a decrease in the rate of decomposition of hydrogen peroxide. What is the most likely explanation for this result?

a. a change in the chemical properties of the reactants
b. a change in the chemical properties of the products
c. a change in the shape of the catalase molecule
d. a change in the amino acid sequence of the catalase molecule

40. Cells within organisms often need to communicate and work together to carry out life's processes. Which of the following enables cells to communicate?

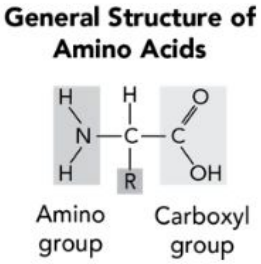
a. Proteins on cell surfaces act as receptors to certain compounds.
b. The double helix of DNA acts as a tunnel for messenger molecules.
c. Carbohydrates store and release information.
d. Starches store excess information until it's needed by cells.

41. The diagram shows the chemical structure of a nucleotide. Nucleotides can form polymers called nucleic acids. In these polymers, how do the nucleotide monomers compare with one another?



a. The nitrogenous base may differ among the monomers.
b. The 5-carbon sugar may differ among the monomers.
c. The number of phosphate groups may differ among the monomers.
d. The monomers are identical, but may bond together in various ways.

42. Amino acids are the monomers that form proteins. The diagram shows the general structure of an amino acid. Which property of amino acids allows for a wide variety of proteins?



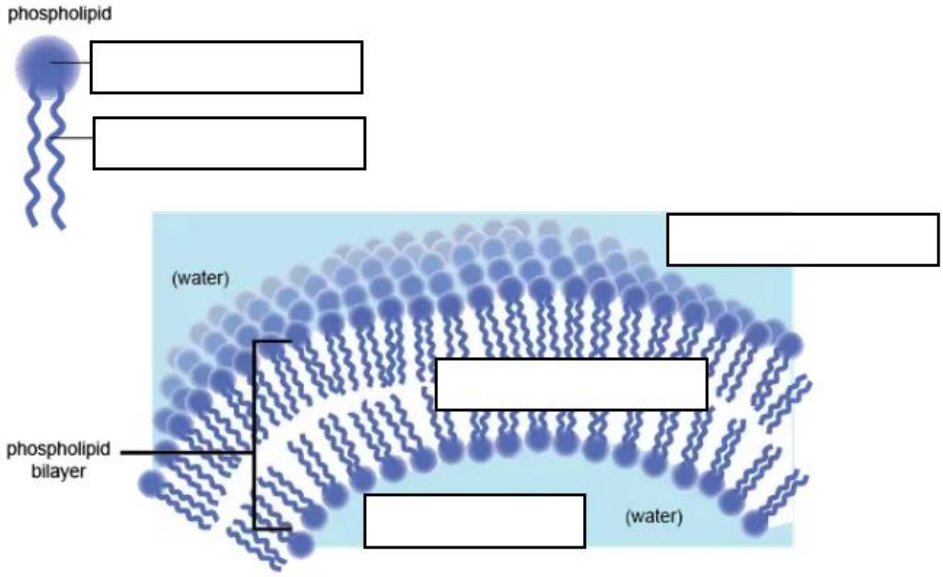
a. the variety of bonds that may form between two amino acids
b. the variability of the R group
c. the number of amino groups ($-NH_2$) that may attach to the central carbon atom
d. the number of carboxyl groups (-COOH) that may attach to the central carbon atom

43. Jamal is comparing glycogen and starch. He learns that both compounds are complex carbohydrates. Many animals store glycogen in liver and muscle cells, and plants store starch in seeds, tubers, and other parts. Based on this information, which is the most likely function of both glycogen and starch?

a. transporting nitrogen-containing wastes
b. providing glucose when cells need energy
c. coding for genetic information
d. catalyzing chemical reactions

44. The cell membrane forms a flexible barrier with its surroundings.

45. Label each box of the phospholipid and the cell membrane illustration as hydrophobic or hydrophilic. Answers listed from top down in order: hydrophilic, hydrophobic, hydrophilic, hydrophobic, hydrophilic.



46. The nucleoid of a prokaryote contains DNA.
47. Flagella and cilia help prokaryotes to move in their environment.
48. You find a cell that has DNA, cytoplasm, a cell wall, golgi bodies, ER, and ribosomes. What type of cell have you most likely found? Eukaryote since there are membrane-bound organelles.
49. The cellular metabolism are the collective cell reactions or processes.
50. Lysosomes and centrioles are not found in plant cells; they are only found in animal cells.
51. Complete the Venn diagram to compare eukaryotic and prokaryotic cells. Use the following words:

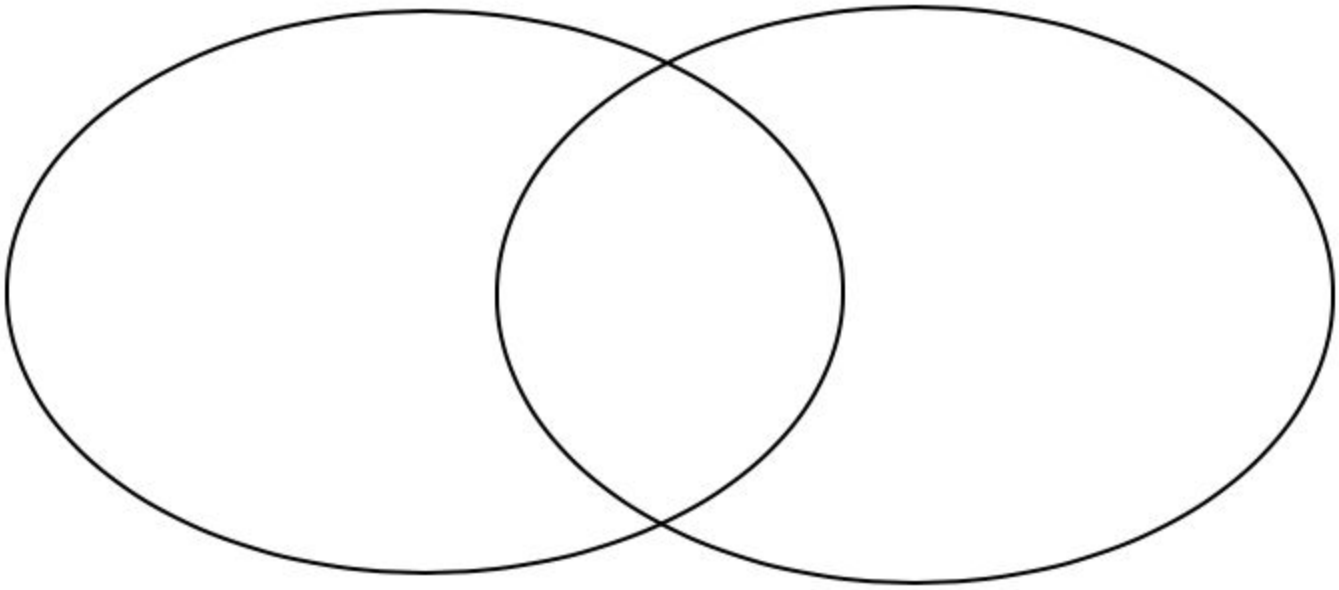
No nucleus Nucleus Cytoplasm Ribosomes Capsule Nucleoid Cell wall Maybe cell wall Plasma membrane DNA

Prokaryote - no nucleus, cell wall, capsule, nucleoid

Eukaryote - nucleus, maybe cell wall

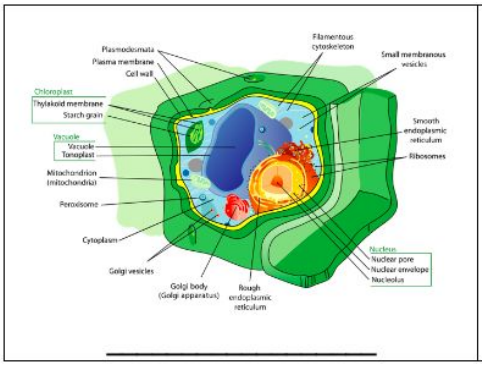
Both - cytoplasm, ribosomes, plasma membrane, DNA

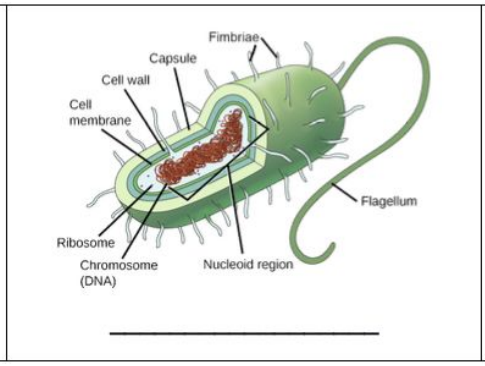
Prokaryote Eukaryote

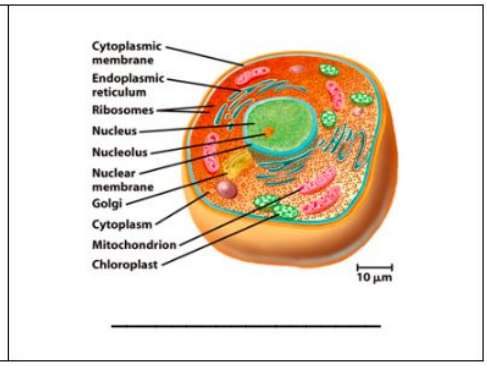


52. Identify each picture as a prokaryotic cell or a eukaryotic cell.

Left to right - eukaryote, prokaryote, eukaryote







53. Chromatin is the form of DNA when it is uncoiled. It is formed as chromosomes when it is coiled.

54. The plasma membrane is made of a phospholipid bilayer.

Match each function with the organelle that performs that overall category job in eukaryotic cells:

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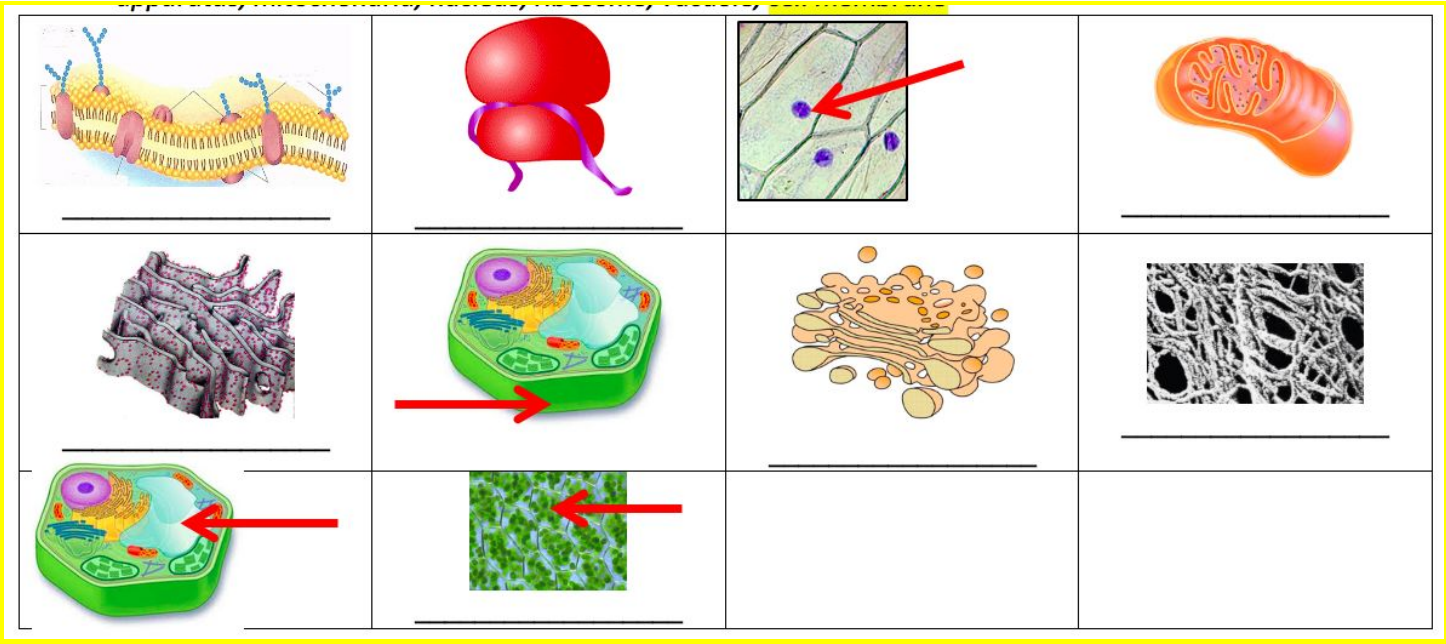
55. genetic control of the cell G 56. uses carbon dioxide to make glucose B 57. breaks down hydrogen peroxide H 58. phospholipid bilayer I 59. stores water and other materials K 60. makes ATP energy using glucose F 61. transports materials within the cell C 62. packages and transports materials out of the cell D 63. supports the cell, made of cellulose in plants and chitin in fungi A 64. recycles waste and old organelles E 65. makes proteins J	A. cell wall B. chloroplast C. endoplasmic reticulum D. golgi apparatus E. lysosome F. mitochondria G. nucleus H. peroxisome I. plasma membrane J. ribosomes K. vacuole

66. The molecule, rRNA, makes up the ribosomes.
67. **Smooth ER** is important in synthesizing lipids , oils, phospholipids, and steroids. What organ has an abundant of smooth ER? liver Calcium ions stored by the smooth ER are important for muscle contraction.
68. **Rough ER** secretes proteins such as insulin that regulates glucose in the bloodstream. There are four steps to protein secretion: mRNA is threaded into the cavity of the rough ER and the protein folds into a 3D shape. Short carbohydrate chains are linked to the protein, making it a glygoprotein. When it is ready for export ,the protein is packaged into a transport vesicle. The vesicle then buds from the ER membrane.

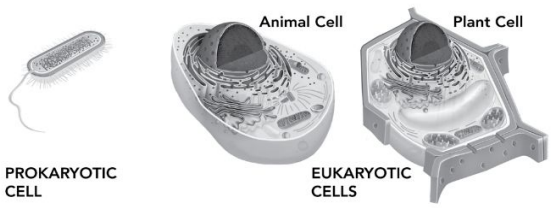
69. Identify each organelle based on the picture. *Use the words: cell wall, chloroplast, cytoskeleton, ER, golgi apparatus, mitochondria, nucleus, ribosome, vacuole, cell membrane*

Answers left to right by row: cell membrane, ribosome, nucleus, mitochondria, ER, cell wall, golgi apparatus, cytoskeleton, vacuole, chloroplast



70. The organelle, mitochondria , is very abundant in muscle cells.
71. The organelle, vacuoles, is very abundant in fat cells
72. The organelle, smooth ER , is very abundant in liver cells.
73. Which organelle would you expect to be very abundant in pancreas cells to make insulin? Rough ER to export the insulin? Golgi apparatus
74. Which organelle would you expect to be very abundant in stomach cells to make the enzyme, pepsin? ribosomes to export the pepsin? Golgi apparatus
75. Red blood cells are enucleated. This means it doesn't have a nucleus.
76. Plants have a lot of chloroplasts in their leaves but none in their roots.

A cell can be identified based on the structures present in the cell. The illustration below shows three different types of cells.



77. Which type of cell structure is included in all three cells?
    a. a cell membrane made of a lipid bilayer
    b. a nucleus that contains DNA
    c. mitochondria that contain DNA
    D. a cell wall made of cellulose
78. Which two types of structures are present in a plant cell, but not an animal cell?
    a. chloroplasts and nucleus
    b. cell membrane and cell wall
    c. chloroplasts and mitochondria
    D. chloroplasts and cell wall

79. The table compares the structures and characteristics of two cells.

Structure	Cell 1	Cell 2

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DNA	Located in cytoplasm	Located in nucleus
Cell membrane	Present	Present
Cell wall	Present	Absent
Mitochondria	Absent	Present
Ribosomes	Present	Present

What conclusion about the cells does the data in the table support?

a. Cell 1 is from a plant; Cell 2 is from an animal.
b. Cell 1 is prokaryotic; Cell 2 is from a plant.
c. Cell 1 is prokaryotic; Cell 2 is from an animal.
d. Cell 1 is eukaryotic; Cell 2 is prokaryotic.

80. Which of the following structures occurs in cells of all types, including prokaryotic cells and eukaryotic cells?

a. a cell membrane made of a lipid bilayer
b. a large central vacuole that stores water
c. mitochondria that provide energy for cell processes
d. chloroplasts that capture and transform the energy of sunlight

81. Stewart is investigating the responses of plants to their environment. As part of the investigation, he studies a plant that receives sufficient water and has straight, upright stems and firm leaves. He also studies another plant that was grown in dry soil, and that has wilted stems and leaves. When Stewart examines the cells of the plants under a microscope, which organelle will display the greatest difference between the two plants?

a. the nucleus, because chromosomes thicken in water
b. the cell membrane, because water diffuses across it
c. chloroplasts, because photosynthesis depends on water volume
d. the central vacuole, because it stores water and provides support

By Science News for Students
December 5, 2019

To accompany feature “Scientists look to hack photosynthesis for a ‘greener’ planet”

Before Reading:
1. What do you know about photosynthesis? ***Answers vary***
2. How might photosynthesis be important to life on Earth? ***Answers vary***

During Reading:
1. What is the basic chemistry that happens in photosynthesis? ***Carbon dioxide, water, and sunlight are converted into energy***
2. What two things are produced by photosynthesis? Why are they important to people and other living organisms? ***Sugar (glucose) is an energy source for people and animals. Oxygen is made available for us to breathe.***
3. Does a plant get burned if it gets too much sunlight? How does a plant handle sudden bright sunlight? ***Too much sun can damage a plant’s cells. Plants are able to respond to intense light by reducing photosynthesis.***
4. Why are scientists trying to imitate photosynthesis? ***Scientists would like to replace fossil fuels with a more renewable energy and also reduce carbon dioxide emissions.***
5. What are “solar fuels”? Name any examples you can think of. ***Carbon-based fuels that recycle emissions from fossil fuels, hydrogen, oxygen, solar energy***
6. What is a catalyst? How are scientists trying to use a plant catalyst to create solar fuels? ***A catalyst is a material that can trigger chemicals to react. Scientists are experimenting with artifical leaves, using a catalyst to split water into hydrogen and oxygen.***
7. Scientists are also trying to “hack” photosynthesis to improve crop production. Why? ***To yield more food for a growing human population***
8. What enzyme are crop scientists trying to engineer? When this enzyme makes a mistake, what is the result? ***Rubisco - One in every five times a plant will “grab” an oxygen molecule from the air instead of a carbon dioxide. Instead of making energy, the plant produces toxic compounds.***
9. How might correcting that enzyme’s mistakes improve crop yields? ***The plant could put more energy into growth, rather than recycling the unwanted compounds.***
10. Why are scientists using tobacco plants to study this enzyme? What will they do next with the lessons they learn from their tobacco studies? ***Tobacco plants are quick to crow for the studies. The scientists will apply what they learn to food crops.***

After Reading:
1. In what ways are plants critical to sustaining life on our planet? ***Plants produce energy and release oxygen. In addition, they take in carbon dioxide.***

2. How are humans contributing to the warming of our planet? What impact does this warming have on us and other people around the world? In what ways might growing more plants help? ***Humans convert fossil fuels to energy for our homes, businesses, and vehicles. Fossil fuel burning releases carbon dioxide into the atmosphere. Global warming is caused by an increase in greenhouse gases such as carbon dioxide. Plants take in carbon dioxide. More plants = more carbon dioxide removed from the atmosophere.***

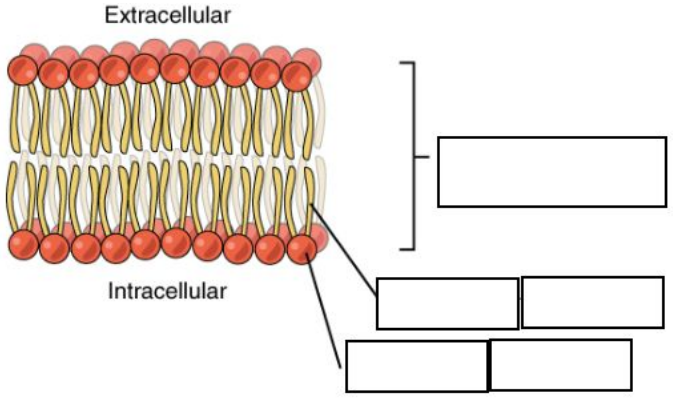
Module 2 Review **Name: _____**

1. Match each protein with its function.

a. Transport D	A. Carry out sequential reactions
b. Enzyme A	B. recognizes neighboring cell
c. Junction C	C. attach the extracellular matrix to cytoskeleton
d. Glycoprotein B	D. allow specific ions to enter/exit cell
e. Receptor F	E. form intercellular junctions
f. Attachment E	F. bind signaling molecules to relay messages through signal transduction

2. The phospholipids and proteins can move freely in the membrane. This is called the fluid mosaic model. In animal cells, cholesterol helps keep the phospholipids moving freely.
3. Label the cell membrane – phospholipid bilayer, head, tail, nonpolar, polar.

Answers top to bottom, left to right: phospholipid bilayer, non polar tail, polar head



4. Nonpolar molecules can move freely through the cell membrane.

5. Diffusion moves molecules from high to low concentration, or **up / down** their concentration gradient. Diffusion does not require energy Some larger molecules require transport proteins to diffuse through the membrane, and this is called **passive / active** transport.

6. Osmosis is the diffusion of water from high to low concentration across a selectively permeable membrane.

7. A cell containing 25% carbon dioxide is placed in a solution containing 75% carbon dioxide. What will happen in this system?
   a. Carbon dioxide will diffuse out of the cell
   B. Carbon dioxide will diffuse into the cell
   b. The cell will use active transport to remove the carbon dioxide
   c. The cell is in a hypertonic environment
8. A freshwater plant is placed in salt water. What do you expect will happen to the cell – select all that apply.

a. The cell vacuole will empty	c. The cell will shrink
b. The cell will swell	d. The cell will use active transport to remove salt

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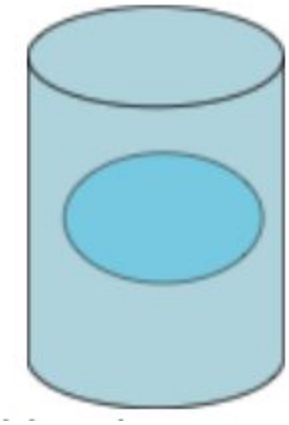
9. If a cell lyses / shrinks, it has been placed in a hypertonic solution. But, if a cell lyses, shrinks, it has been placed in a hypotonic solution. If a cell doesn't swell or shrink, it has been placed in a(n) isotonic solution.

10. A carrot is placed in distilled water. Will the carrot swell or shrink? Swell What kind of environment is the distilled water compared to the carrot? hypotonic

11. A carrot is placed in salt water. Will the carrot swell or shrink? shrink. What kind of environment is the salt water compared to the carrot? hypertonic

12. A cell is placed into a beaker containing a 10% sucrose solution. The cell contains a 50% sucrose solution. Use an arrow to illustrate the direction in which **water** will diffuse in the figure below. Assume that the cell's membrane is **not** permeable to the sucrose.
The beaker has a higher concentration of water than the cell. Water will diffuse into the cell.



13. A cell lyses. The cell has a salt concentration of 50%. Which of the following could be a possible salt concentration of the outside environment?

a. 10% salt b. 50% salt c. 70% salt

14. Active transport uses energy ATP to move molecules against their concentration gradient.

15. Exocytosis and endocytosis move large and/or polar molecules in/out of a cell.

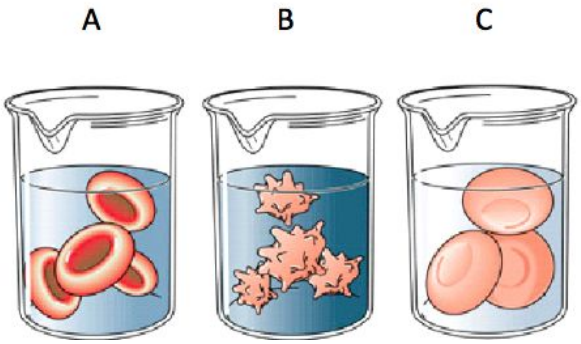
16. Enzymes belong to the protein group of macromolecules. They lower the activation energy of a reaction. They are **unchanged/changed** in a reaction.

17. Enzymes may lose function or have decreased function if there is a change in temperature or pH. This means the enzyme has been denatured.

18. Which of the following are most likely enzymes? (enzymes usually end in -ase)

a. Fructose c. Catalase
b. Guanine d. Galactose

19. Look at the three beakers below and fill in the table. The dialysis bag is impermeable to sugar.

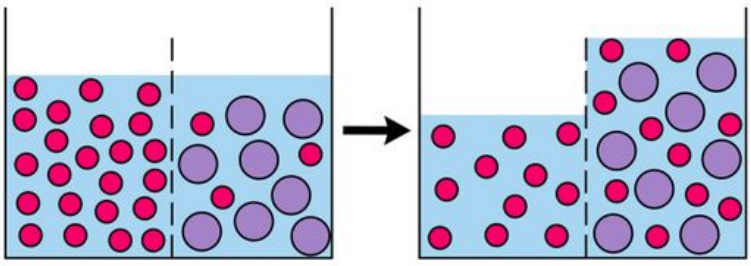


	Solution compared to cells (hypotonic, hypertonic, isotonic)	How did water move?
Beaker A	isotonic	Both directions
Beaker B	hypertonic	Out of the cell
Beaker C	hypotonic	Into the cell

20. Cells lining kidney tubules function in the reabsorption of water from urine. This retains water in the bloodstream so that less is lost in the urine. Thus, dehydration is prevented. In response to chemical signals, they reversibly insert additional aquaporins into their plasma membranes. After a long run on a hot day, would you find more or less aquaporins? more After sitting on a park bench on a mild day? less

21. Using **all** the words - diffusion, concentration gradient, high concentration and low concentration - explain what happened the diagram below

The left side has a high concentration of small circles (representing water) and a low concentration of large circles. The right side has a high concentration of large circles and a low concentration of small circles (representing water). The small circles (Water) moved down their concentration gradient and across the semipermeable membrane from the left to the right. This is an example of osmosis.



22. Alexis is using models of the cell membrane to compare the types of cellular transport. One model shows a molecule entering through a protein pump down the concentration gradient. Which type of cell transport is being modeled?

a. diffusion, because protein pumps are needed to move substances from a higher concentration to a lower concentration

b. endocytosis, because protein pumps transport substances that are too large to pass through the cell membrane

c. active transport, because protein pumps are needed to move substances against a concentration difference

d. osmosis, because protein pumps allow water to cross the cell membrane

23. Nayla is planning an investigation on the role of osmosis in maintaining homeostasis. She plans to study red blood cells in a liquid suspension, similar to blood plasma. For Nayla to observe the greatest variety of osmotic activity in the red blood cells, she should test the effect of which of these independent variables?

a. temperature of the liquid suspension

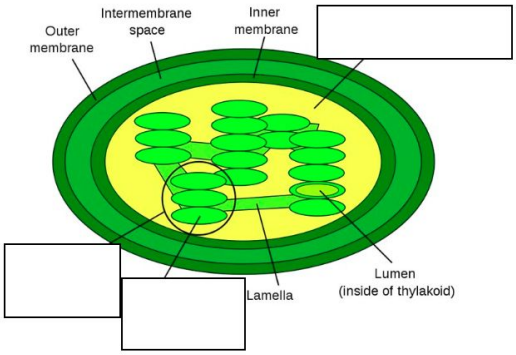
b. oxygen concentration of the red blood cells

c. the number of red blood cells per liter of the liquid suspension

d. salt concentration of the liquid that surrounds the red blood cells

24. In the chloroplast below, label the thylakoids, stroma, and grana.

Answers top to bottom: stroma, grana, thylakoid



25. Write the overall summary reaction of photosynthesis.

the overall summary reaction of photosynthesis:

$6CO_2 + 6H_2O + light \longrightarrow 6O_2 + C_6H_{12}O_6$

26. Write the light reaction.

[not balanced] $H_2O + NADP^+ + ADP + light \longrightarrow O_2 + NADPH + ATP$

27. Write the Calvin cycle reaction.

4. Write the Calvin cycle reaction.

$ATP + NADPH + CO_2 \longrightarrow C_6H_{12}O_6 + NADP^+ + ADP$

28. Sunlight is the source of energy that boosts electrons in photosynthesis.

29. During the light reactions, oxygen gas is produced. During the Calvin Cycle or dark reactions, carbon dioxide is used.

30. Chlorophyll is the pigment that reflects mostly green light and and is most responsible for photosynthesis.

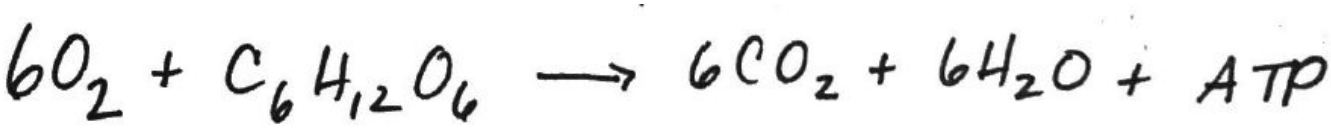
31. Water is used in photosystem II to be split to form oxygen gas and hydrogen ions.

32. ATP synthase uses a hydrogen concentration gradient to power the formation of ATP. ATP synthase is an example of a protein, specifically an enzyme within the four categories of macromolecules.

33. The scientific word that means to add phosphate groups to ADP to form ATP is phosphorylation.

34. Two energy carriers, ATP and NADPH, are used to power sugar synthesis during the Calvin cycle.

36. Write the chemical formula for cellular respiration.



37. Aerobic respiration means that the cells do use oxygen. Anaerobic respiration means that the cells do not use oxygen.

38. The three stages of aerobic respiration are glycolysis, Krebs/citric acid cycle, oxidative phosphorylation.

39. In glycolysis, glucose is broken down into pyruvate and 2 NADH molecules are created. This occurs in the cytoplasm of the cell.

40. In the citric acid or Krebs cycle, pyruvate is reduced to two energy carriers NADH and $FADH_2$. This occurs in the matrix of the mitochondria. There are 2 ATP molecules made per glucose molecule entered in the reaction. A by-product of carbon dioxide is released from the cell.

41. In oxidative phosphorylation, the two energy carriers, $FADH_2$ and NADH are used to create a concentration gradient of hydrogen ions. The inner mitochondrial membrane is the site of this process. The enzyme ATP synthase moves hydrogen ions down their concentration gradient to form 28 ATP molecules.

42. Both aerobic and anaerobic respiration use the process of glycolysis to start the reaction.

43. Fermentation continues to break down pyruvate to make ATP and either lactic acid or alcohol as a by-product.

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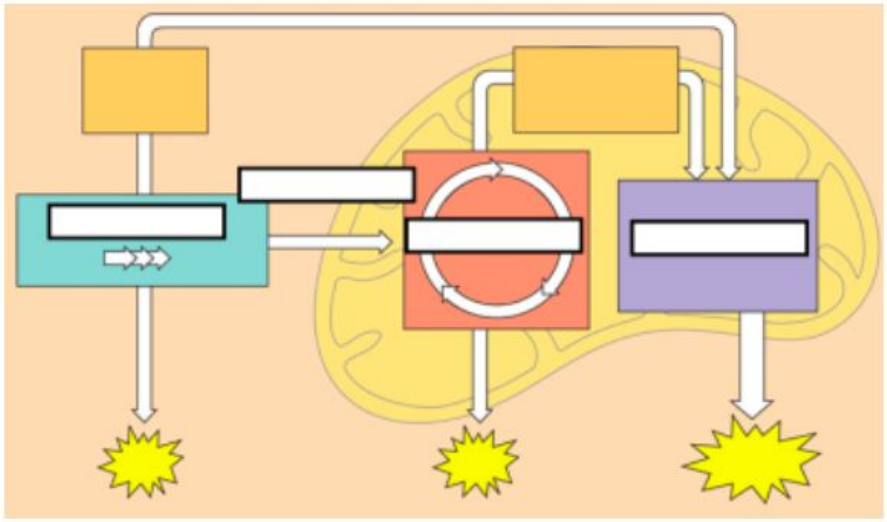
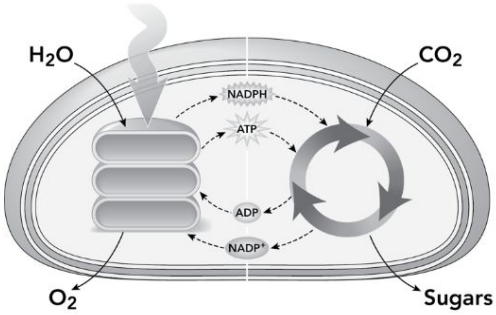
44. Label the parts of cellular respiration and use the word bank **aerobic respiration, NADH, glycolysis, ATP, FADH2, oxidative phosphorylation, citric acid (Krebs) cycle.**

Answers top to bottom, left to right in three rows: NADH, FADH2; glycolysis, aerobic respiration, citric acid cycle, oxidative phosphorylation; ATP, ATP, ATP



45. During photosynthesis, how is the light energy that strikes the cell transformed into the chemical energy stored in sugars?



a. Energy is transferred directly to sugars, with no intermediates.

b. Energy is transferred to sugars through intermediates such as H_2O, O_2, and CO_2.

c. Energy is transferred to sugars through intermediates, such as chloroplasts.

d. Energy is transferred to sugars through light-dependent reactions.

46. Which statement accurately describes the role of the light-independent reactions?

a. transforming light energy into chemical energy

b. transferring chemical energy to high-energy sugars

c. returning chemical energy to light energy

d. transferring light energy among different compounds

47. . What is the relationship between the light-dependent reactions and light-independent reactions?

a. The light-dependent reactions depend on the light-independent reactions for energy that is transferred by ATP and NADPH.

b. The light-dependent reactions and light-independent reactions both convert energy from the sun to chemical energy.

c. High-energy electrons are transferred from the light-independent reactions to the light-dependent reactions.

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d. Energy in the form of ATP and NADPH is transferred from the light-dependent reactions to carbohydrates in the light-independent reactions.

48. During photosynthesis, the light-dependent reactions supply ATP to the light-independent reactions. How is ATP used in the light-independent reactions?

a. ATP provides the hydrogen atoms that are incorporated into sugars.
b. ATP provides the carbon and oxygen atoms that are incorporated into sugars.
c. ATP provides the chemical energy for the reactions to occur.
d. ATP receives the chemical energy that the reactions release.

49. Which statement best describes an event that occurs in glycolysis that contributes to the production of ATP?

a. Pyruvic acid is broken down to form carbon dioxide.
b. Oxygen molecules are broken down and converted into pyruvic acid.
c. High-energy electrons are passed to NAD^+ forming NADH.
d. Carbon atoms in glucose are transformed into energy in the form of ATP.

50. Most organisms obtain energy from food by the process of cellular respiration. Which is the **most likely** explanation for the reason that Earth does not run out of oxygen?

a. The overall reactions of photosynthesis and cellular respiration are the opposite of one another, therefore the products of one are the reactants of the other, creating a cycle.
b. The energy—and thus oxygen—flows for cellular respiration and photosynthesis take place in the same direction, and therefore build upon one another.
c. Cellular respiration is a process that deposits energy and oxygen, and photosynthesis withdraws energy and uses oxygen, therefore balancing each other.
d. Oxygen readily accepts electrons, so cellular respiration uses a negligible amount of oxygen.

51. Cells rely on compounds that readily store and release energy. Which statement describes how energy storage and release occurs in cells?

a. A The Krebs cycle serves to store energy and make it readily available for cell function.
b. ATP attracts an additional phosphate group and stores energy in the form of ADP.
c. ATP stores energy and releases it as it reverts back to ADP.
d. The electron transport chain stores energy in the bonds of NAD^+ and releases it as NAD^+ reverts back to NADH.

52. Enzo is developing a model of the electron transport chain. What is the role of ATP and NADH in the model?

a. ATP and NADH provide the energy for electron transport to occur.
b. ATP and NADH are synthesized as electrons are transported along the chain.
c. ATP is used to synthesize NADH in one step of the chain.
d. NADH is used to synthesize ATP in one step of the chain.

By Science News for Students
October 24, 2019
To accompany feature “What we can — and can’t — learn from our pets’ DNA”

Before Reading:

1. Do you or does someone you know have a pet? Describe this pet. ***Answers vary.***
2. Has anyone in your family taken an at-home genetic test? What did they learn? ***Answers vary.***

During Reading:

1. What is DNA? ***The long string of instructions tht tells an organism’s cells what molecules to make***
2. What sorts of information can we learn about our pets from their DNA? ***What breeds a pet descends from, what region of the world its ancestors evolved, how a pet might behave, what diseases it might have***
3. What do many genetic tests for pets search for? What is one drawback of such tests? ***Patterns of SNPs (Single Nucleotide Polymorphisms) The tests only look at SNPs that scientists already know about.***
4. What is a genome? ***Every single gene in an organism***
5. Why does geneticist Elinor Karlsson study dog genomes? ***She has a special interest in mutts***
6. How are researchers like Karlsson tying pet behavior with genetics? ***One behavior could be controlled by many, many genes. To find them all, a researcher has to study the DNA of tens of thousands of dogs.***
7. What is disease risk? What is the difference between this risk and the actual disease? ***Disease risk is the know genetic variants that are associated with certain diseases. This is different from the animal actually having the disease.***
8. Why are scientists interested in using DNA tests to study animals’ disease risk? ***Scientists want to help improve the health of animals and develop effective treatments for disease.***
9. What can’t pet DNA tests tell us about our pets? ***If an animal is certain to develop a disease. Also, what makes our pets who they are (personality).***
10. After testing a pet’s DNA for disease risks, what should be an owner’s next step? ***Talk with a vet who can monitor and test you animal now and in the future.***

After Reading:

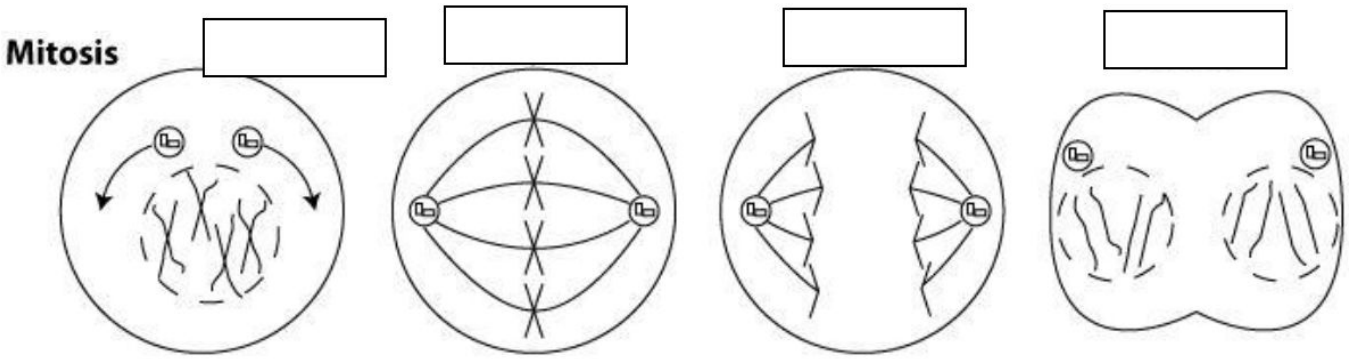
1. Would you test your pet’s DNA? What would you want to learn and why? ***Answers vary.***

2. The story explains that genetic tests for pets are not currently regulated by the government. Should that change? Explain your answer using evidence fromthe story. ***Answers vary.***

Module 3 Review **Name: _____**

1. The sister chromatids are moving apart during anaphase.
2. Chromatin condenses into chromosomes during prophase.
3. A new nuclear membrane is forming around the chromosomes during telophase.
4. The cytoplasm of the cell is being divided in cytokinesis.
5. The chromosomes are located at the middle of the cell in metaphase.
6. The division called the cleavage furrow appears during telophase in animal cells.
7. The chromosomes are moving towards the poles of the cell in anaphase.
8. Chromosomes are not condensed during interphase
9. Chromosomes are copied during S phase of interphase
10. The cell prepares to divide in G2 phase of interphase.
11. The cell grows during G1 phase of interphase.

Prophase metaphase anaphase telophase

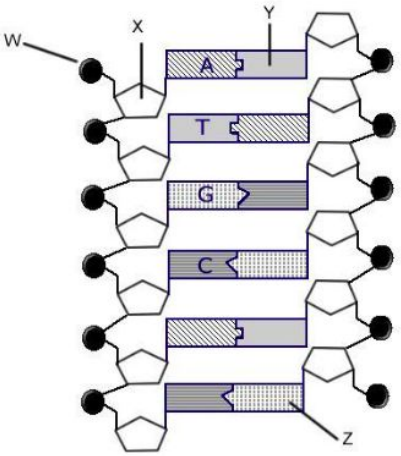


12. Sexual reproduction produces genetically different offspring, and asexual reproduction produces genetically identical offpsring. There are two parent(s) in Sexual reproduction and one parent in asexual reproduction.

13. Prokaryotes, such as bacteria, reproduce by binary fission which means splitting in two.
14. The monomer of nucleic acid is a nucleotide, and the polymer is polynucleotide.
15. DNA has a set of alternating structures along the sides of the "ladder". This is called the sugar-phosphate backbone.
16. The four nitrogenous bases are adenine, thymine, cytosine, guanine.
17. The bases pair together according to Chargaff's rules. A pairs with T and C pairs with G.
18. According to Chargaff's rules, if DNA consists of 30% cytosine, approximately what percentage is thymine?
    a. 30% b. 40% c. 20% d. 60%

19. RNA is different from DNA because it contains the sugar ribose and the nitrogenous base uracil instead of thymine.

20. Label the phosphate group, deoxyribose sugar, nitrogenous bases, and hydrogen bonds on the DNA model below. W - phosphate group; X - deoxyribose sugar; Y - nitrogenous bases; hydrogen bonds are between the nitrogenous bases



21. When replicating, each parent strand becomes a template for the assembly of a new strand.

22. Watson and Crick proposed that half of the replicated DNA is parent strand and half is new strand. This called the semi-conservative model.

23. Since the two strands of DNA are arranged opposite to each other, we say that they are antiparallel.

24. DNA helicase unzips the DNA and breaks the hydrogen bonds between bases.

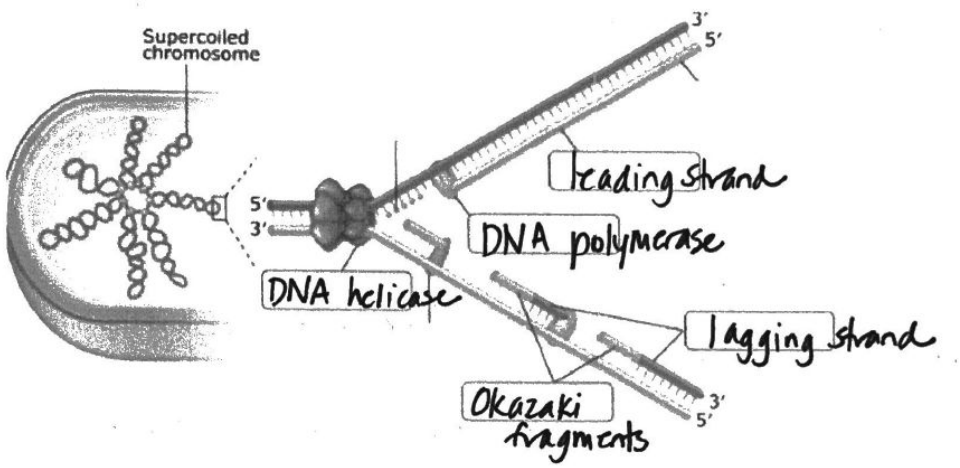
25. DNA polymerase brings bases from the cytoplasm to the new DNA strand.

26. Okazaki fragments are made on the lagging strand as it grows away from the replication fork.

27. DNA ligase links the Okazaki fragments together.

28. DNA polymerase also checks for mistakes in replication (ex. C instead of T, etc.)

29. Label the diagram below, using the words – *leading strand, lagging strand, Okazaki fragments, DNA polymerase, DNA helicase. Only label the boxes provided.*



30. The information within the actual gene is the genotype. The physical appearance of the organism is its phenotype.

31. Transcription is the creation of mRNA from DNA. Translation is the synthesis of protein from the mRNA code.

32. **Transcription/translation** occurs in the nucleus of the cell.

33. mRNA stands for messenger RNA because it takes the DNA code into the cytoplasm of the cell.

34. Adenine always pairs with thymine and cytosine always pairs with guanine.

35. Amino acids are coded by the specific base sequence of the DNA and mRNA.

36. The nucleotides are arranged in sets of three to code for a specific amino acid, called a codon.

37. If you found a protein that was made of 27 amino acids, what is the minimum number of nucleotides that it must have? 81 How about 90 amino acids? 270

38. Look up the genetic code in your book or online. What amino acid is coded by the codon AAA? lysine CUA? leucine

39. The codon AUG codes for methionine, or start.

40. The codon UAA, UAG, UGA codes for stop.

41. What amino acid sequence is coded from the mRNA strand? GCC UAU CUU CCC ACA
Ala - Tyr - Leu - Pro - Thr

42. There is an error in transcription so the new mRNA strand reads GCC UAU CUA ACA. What change is there to the amino acid sequence?
Ala - Tyr - Leu - Thr Proline is deleted

43. During mRNA processing, introns are removed before the mRNA leaves the nucleus. The parts that are allowed to stay within the nucleus and move to the ribosome are called exons.

44. tRNA carries the correct amino acid to the ribosome. The part of tRNA that matches the mRNA codon is called the anticodon.

45. As the amino acids form, a peptide bond forms between the amino acids.

46. Which type of mutation is usually the most destructive and why – silent, missense, or frameshift?
Frameshift - changes the sequence of the amino acids

47. Copies of the enzyme DNA polymerase work together to synthesize DNA. Why are two copies of the enzyme necessary at each replication fork?

a. One copy breaks apart the original DNA molecule, and the other copy synthesizes two complementary strands.

b. One copy synthesizes two complementary strands, and the second copy edits or corrects the new strands if necessary.

c. Each copy attaches to one strand, and each synthesizes a complementary strand.

d. Both copies attach to the same strand, where they work together to synthesize the complementary strand.

48. A scientist used a radioactive isotope of nitrogen to label the nitrogenous bases of the DNA in bacterial cells. The labeled cells were then allowed to grow and divide for one generation in a medium of non-radioactive nitrogen. Where is the radioactive nitrogen in the DNA of the bacterial cells?

a. distributed evenly among all of the DNA

b. in both strands of the DNA of half of the cells

c. in one strand of the DNA of half of the cells

d. in one strand of the DNA of all of the cells

49. Human nerve cells and muscle cells have many structural and functional differences. What role does DNA play in these differences?

a. Nerve cells and muscle cells contain different DNA.

b. DNA in muscle cells is condensed into chromatids.

c. Muscle cells are more likely to have DNA mutations than nerve cells.

d. Transcription factors and gene expression is different in nerve cells and muscle cells.

50. As a result of a point mutation, the base cytosine (C) was replaced by adenine (A) in a sequence of mRNA. Under which circumstance does this mutation cause the protein to be significantly shorter?

a. The mutation introduced a stop codon into the middle of the mRNA molecule.

b. The mutation changed the genetic code used during translation

c. The mutation occurred in a region of mRNA that is not translated

d. The mutation introduced a start codon in the middle of the mRNA molecule.

51. Proteins are assembled at ribosomes using mRNA as a template. Which property of tRNA allows it to assist in this process?

a. Each of many tRNA molecules contains an anticodon, and it may bind to any amino acid.

b. Each of many tRNA molecules contains an anticodon, and it binds to a specific amino acid.

c. One tRNA molecule contains all of the anticodons and binds to all of the amino acids that are specific for the protein.

d. One tRNA molecule contains all of the codons and binds to all of the nucleotides that are specific for the protein.

52. Several differences between DNA and RNA allow the cell to differentiate between the two molecules, ensuring that transcription and translation occur appropriately. Which is one of the properties of RNA that differentiates it from DNA?

a. RNA includes phosphate groups instead of nitrogenous groups.

b. RNA is double stranded instead of single stranded.

c. RNA contains uracil (U) instead of thymine (T).

d. RNA contains cytosine (C) instead of guanine (G).