BIOLOGY

Dr. Dennis Englin

THE STUDY OF LIFE FROM A CHRISTIAN WORLDVIEW

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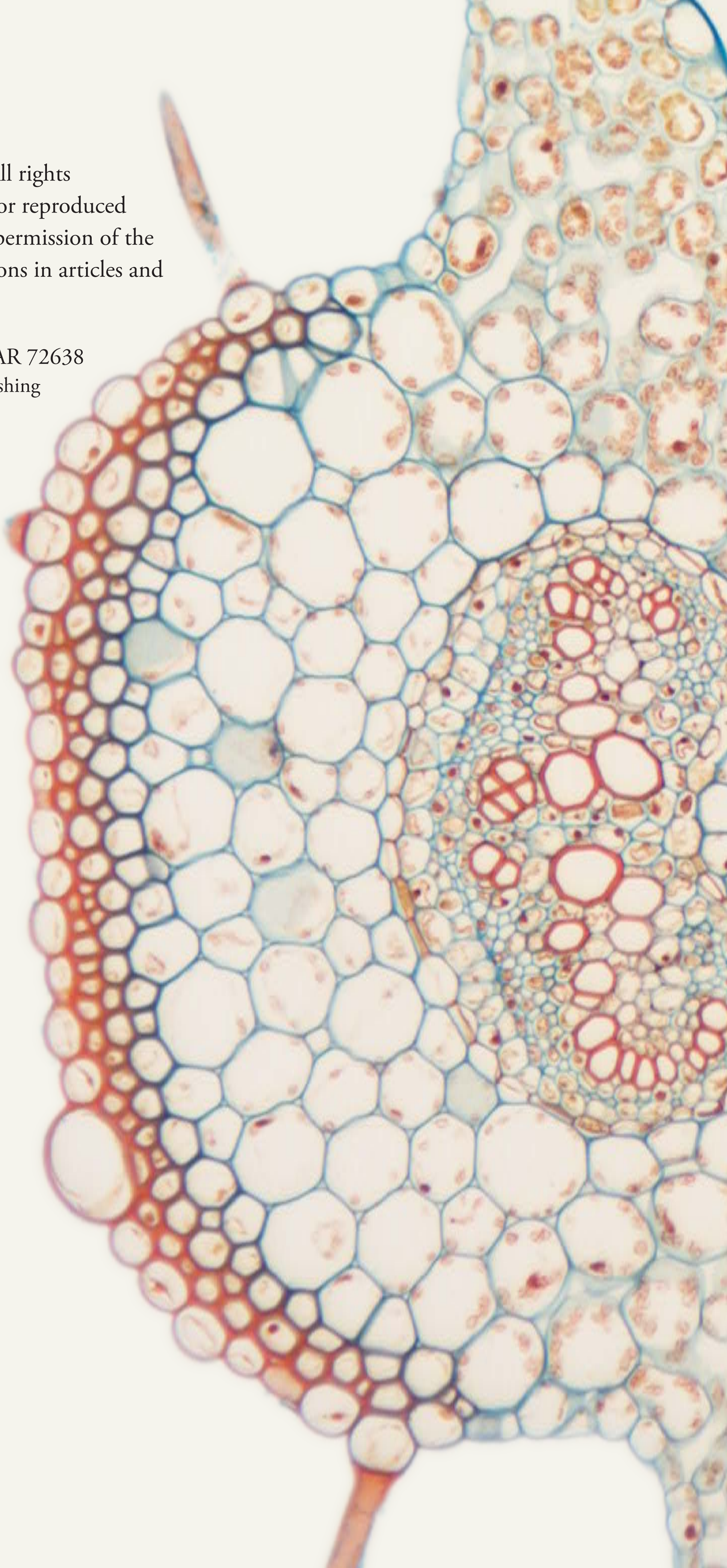

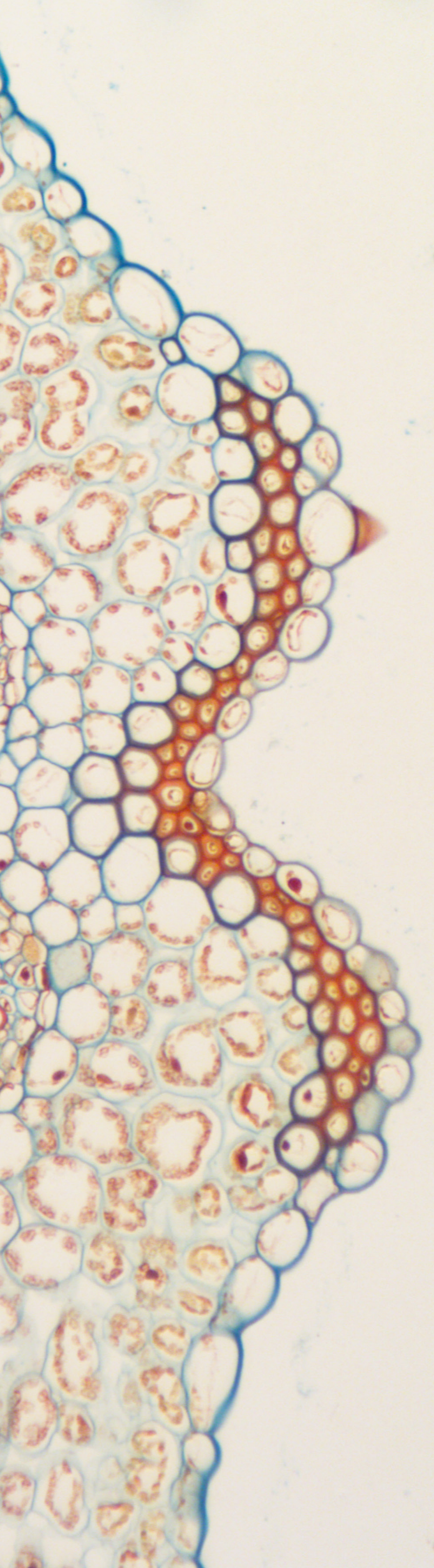

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CHAPTER 1

Chemical Principles in Biology

OBJECTIVES

At the conclusion of this lesson students should have an understanding of...

- Mechanistic and biblical views of life
- Atoms, molecules, isotopes and ions
- Chemical reactions
- Chemical bonds (ionic and covalent)

VARIOUS VIEWS OF LIFE

A little boy once said that he wanted to go to school to learn about dead frogs. Many come away from a biology class thinking that biology is about dead things because they spend all of their time cutting up dead things. To the contrary, biology is the study of living things. We only study dead things to understand living things.

Some have a mechanistic view where they believe that all things are determined simply by physical processes, that life is a matter of all the right molecules being in the right place at the right time. When God created Adam, He . . .

> *formed the man of dust from the ground and breathed into his nostrils the breath of life, and the man became a living creature (Genesis 2:7; ESV).*

Adam was made from the molecules of the earth but the breath of life came from God.

> *Adam became a living being (I Corinthians 15:45; ESV).*

You can have all the right molecules in all of the right places but still have a dead organism. God created living organisms from small single cells all the way to large multicellular organisms with trillions of cells. Life is recognized by the abilities to respond to stimuli (jump when you are pinched), metabolize nutrients (eat and digest a big cheeseburger), adjust to changes in the environment (sweat when it is hot) and reproduce. Cells and bodies and life are from God. Life is housed in the physical but is much more than physical.

Living things are made from the very same raw materials as everything else in creation: **atoms**. Living things are held together in the same way as everything else, by chemical bonds. That is not

WORDS TO UNDERSTAND

- atomic mass number
- atomic number
- atoms
- chemical reaction
- covalent bond
- electrolytes
- electrons
- ionic bond
- ions
- isotopes
- Law of Definite Proportions
- model
- molecule
- neutrons
- nucleus
- protons

to say that there is nothing special about life; there is a lot that is very special.

Biologists have not always been concerned or even aware of the chemical part of life. In the late 1700s, Carolus Linnaeus developed a system for classifying plants and animals. This system, still in use today in a modified form, was based upon Linnaeus's conviction that living organisms were descendants of the first living things created by God in distinct kinds. In 1859, Rudolf Virchow found that cells only came from other cells. This goes along with what was stated by Moses many years earlier in Genesis that God created all life to reproduce after their kind. Chemistry was of little concern to Linnaeus and Virchow. On the other hand, biologists today have come to rely heavily upon mathematics, chemistry, and physics.

In the middle 1800s, Gregor Mendel crossed different varieties of peas and used mathematics to analyze his data. With this work he became the first one to recognize the basic patterns of inheritance that make it possible for organisms to show variety within definite limits. He had no information about events at the cellular and chemical levels of chromosomes to show how traits were inherited and the extent to which variations could occur.

UNIFYING CHEMICAL PRINCIPLES

Life involves a great many changes in both matter and energy and a basic understanding of chemistry leads to a study of biological processes whereby energy from food is acquired, stored, and utilized to allow us to grow and maintain bodily functions.

This study of biology begins with an overview of chemistry. The 1900s brought greater understandings of biology with the development of new tools and techniques for studying DNA and the molecular structures of cells. Chemistry became a powerful tool for understanding cell structures in greater detail.

Atoms that have the same chemical behavior are considered to be the same element. For example, all iron atoms react the same and have the same properties. There are 92 naturally occurring elements and 24 that have been synthetically produced. Human bodies are composed of about 18.5% carbon, 65% oxygen, 9.5% hydrogen, and 3.2% nitrogen by weight. There are many other elements that are vital to life processes that occur in extremely small trace amounts.

Carl Linnaeus (1707–1778)

The basic approach of science is to look for patterns. When patterns are found for the behavior of matter, reasonable predictions can be made. This predictability is one of the most remarkable evidences of design in the universe. Such patterns are seen in the basic building blocks of atoms — the **protons**, **neutrons**, and **electrons**. All iron atoms, for example, have 26 protons. You can be sure that any atom with 26 protons will behave like an iron atom.

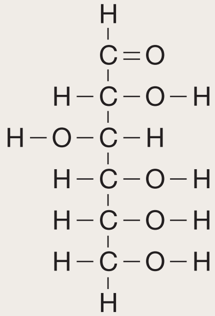
An isolated water source (oasis) with vegetation in a desert.

Each element may be identified by its name, its symbol, and its atomic number. The atomic number is the number of protons possessed by all atoms of each particular element. The chemical symbols may be obvious, as in the case of H for hydrogen, or less so, as in Ag for silver. These less obvious symbols came from older Latin names for the elements. Here are the chemical symbols and atomic numbers for some of the more common elements.

Element	Chemical Symbol	Atomic Number
Hydrogen	H	1
Helium	He	2
Carbon	C	6
Nitrogen	N	7
Oxygen	O	8
Sodium	Na	11
Sulfur	S	16

Element	Chemical Symbol	Atomic Number
Chlorine	Cl	17
Potassium	K	19
Calcium	Ca	20
Zinc	Zn	30
Silver	Ag	47
Gold	Au	79
Mercury	Hg	80

When placed together as in H_2O, the symbols form a chemical formula that represents a **molecule** which is a combination of two or more atoms. The formula H_2O stands for a molecule of water which consists of two hydrogen atoms and one oxygen atom bonded together. $C_6H_{12}O_6$ represents the glucose sugar molecule. It has 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms held together by chemical bonds. The formula indicates how many atoms of each element are in a molecule, but it does not indicate how they are arranged. The arrangement of the atoms in a molecule is given by a structural formula such as the one shown here for glucose.



6 C (carbon atoms)
12 H (hydrogen atoms)
\+ 6 O (oxygen atoms)

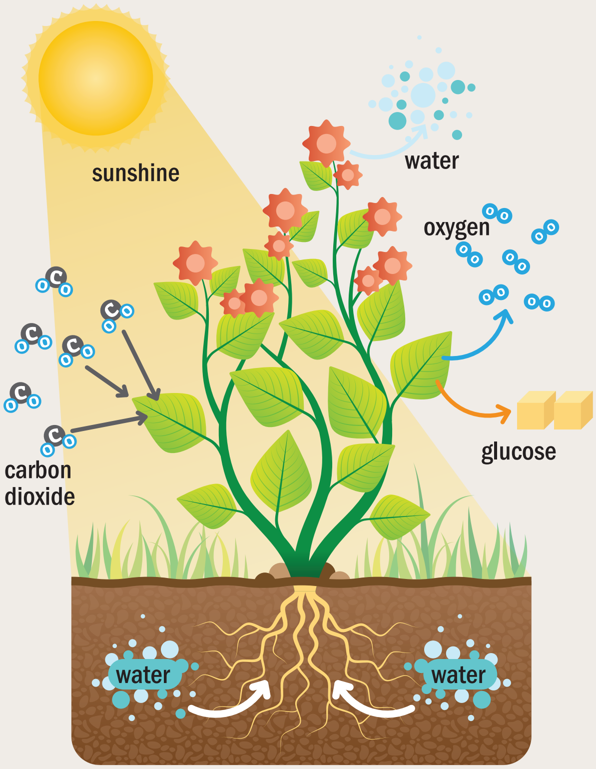
$C_6H_{12}O_6$

A structural formula is a two-dimensional picture of the arrangement of the atoms in a molecule. Add the number of each of the atoms in the structural formula and they will match the number of those atoms in the chemical formula.

CHEMICAL REACTIONS

The shuffling of atoms between molecules in a **chemical reaction** is shown by a chemical equation. Photosynthesis is an example of a series of chemical reactions whereby green plants combine water (H_2O) and carbon dioxide (CO_2) to form the sugar glucose ($C_6H_{12}O_6$) and oxygen (O_2) molecules using energy from the sun. A chemical equation like the one below for photosynthesis shows how the atoms are rearranged to form new molecules.

$$12\ H_2O + 6\ CO_2 \longrightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$$



Photosynthesis

Notice that the number of atoms of each element (not molecules) is the same on both sides of the balanced equation. Twelve molecules of water combine with six molecules of carbon dioxide to yield one molecule of glucose, six molecules of oxygen, and six new molecules of water. Adding up the numbers of atoms of each element on each side of the equation shows that the numbers of atoms of each element are the same on both sides of the equation. The atoms have just been rearranged.

The principle that water molecules always have two hydrogen atoms and one oxygen atom is called the **Law of Definite Proportions**.

A Law describes something that is observed to always happen the same way. An exception is a miracle. An example is the Law of Gravity. It is an observation not an explanation.

The Law of Definite Proportions is that a given molecule will always have the same proportions of atoms of each of its elements.

Protons and neutrons are in the **nucleus** of an atom, whereas electrons are outside of the nucleus. Protons and neutrons have essentially the same mass, but the mass of an electron is almost negligible (almost zero). This is why the mass of an atom is figured by adding the masses of the protons and neutrons but not the electrons. The main difference between a proton and a neutron is their charge.

The Greek philosopher Thales of Miletus found in about 600 B.C. that amber that had been rubbed would attract bits of straw. When you rub a nylon comb through your hair it will attract popcorn and little pieces of paper. Benjamin Franklin observed that a rubber rod rubbed with fur would attract a glass rod rubbed with silk. He said that the rubbed rubber rod (say that fast) had a greater amount of negative charge and that the rubbed glass rod had a greater amount of positive charge. He used the symbols (+) and (-) because they indicated opposites. An important principle came out of these observations. **Opposite charges attract each other and like charges repel each other**.

A mosquito in amber

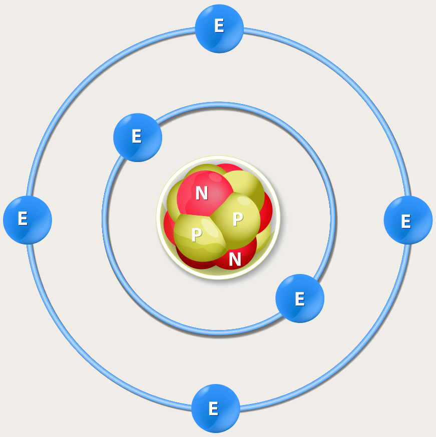
Since Benjamin Franklin's day it has been discovered that the explanation for this behavior of matter lies in the charges of the atom's protons and the electrons. Using Franklin's symbolism, a proton is now known to have a charge of +1 and an electron to have a charge of -1. A neutron has neither +1 nor -1 charge — it is neutral. But even though the neutron has zero net charge, it has a mass essentially the same as that of a proton. Therefore, the mass of an atom is the sum of its protons and neutrons which is called the **atomic mass number**. **Remember, however, that the identity of an atom depends upon its number of protons, not neutrons.** As a side note, weight is the force of gravity upon an object's mass — so mass and weight are not the same thing. The atomic mass number and atomic number can be part of the symbol for an atom. If you were on the International Space Station in orbit around the earth, your weight would be zero, but your mass would be the same as before. The atomic number is indicated by a subscript and the atomic mass by a superscript. The symbol for carbon with 6 protons and 6 neutrons is

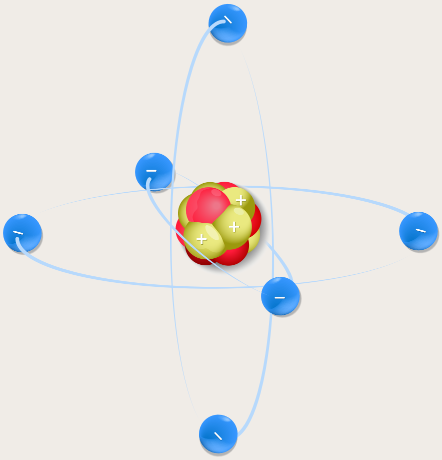
$$^{12}C_6$$

The **atomic number** for the carbon atom is 6 because it has 6 protons and the atomic mass number is 12 because the sum of the protons and neutrons is 12.

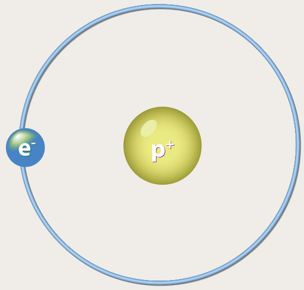
Remember that in $C_6H_{12}O_6$ the subscripts indicated how many atoms of each element are present in the molecule and not the atomic numbers. It means the atomic number if the atomic mass is also given. For example, the symbol O_2 means that there are 2 oxygen atoms in each oxygen molecule and $^{16}O_8$ means that an oxygen atom has 8 protons and 8 neutrons.

Consider $^{14}C_6$ which has 6 protons and 8 (14 – 6 = 8) neutrons. The atoms $^{12}C_6$ and $^{14}C_6$ have different masses but they are still both carbon and behave like carbon except that $^{14}C_6$ is radioactive (gives off

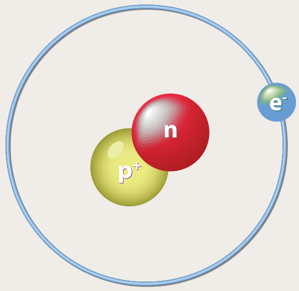




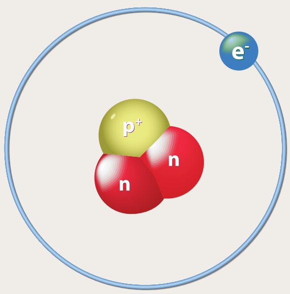
Two models of carbon with protons and neutrons in the nucleus and electrons orbiting



hydrogen



deuterium



tritium

radiation). $^{14}C_6$ has greater mass than $^{12}C_6$ because $^{14}C_6$ has 2 more neutrons than $^{12}C_6$. These atoms are **isotopes** of each other meaning that they have the same number of protons and different numbers of neutrons. An atom cannot be an isotope by itself any more than you can be a brother or sister if you are an only child. You have to be a brother or sister to someone else. Likewise, an atom is an isotope of another atom. Most isotopes are not radioactive even though people usually associate the term with radioactivity.

There are 3 isotopes of hydrogen:

$^{1}H_1$ (1 proton and 0 neutron) called hydrogen

$^{2}H_1$ (1 proton and 1 neutron) called deuterium

$^{3}H_1$ (1 proton and 2 neutrons) called tritium

Tritium is the only radioactive form of hydrogen. When deuterium is in H_2O, the H_2O is called heavy water.

Consider these 3 atoms.

$^{14}N_7$ (7 protons and 7 neutrons) — this is nitrogen

$^{14}C_6$ (6 protons and 8 neutrons) — this is carbon

$^{14}O_8$ (8 protons and 6 neutrons) — this is oxygen

Although each of these atoms has the same atomic mass number (14), they are not isotopes of each other because they have different numbers of protons (atomic numbers).

An important principle that comes out of this is that the living world is filled with order at every level. Our bodies are composed of organ systems with different organs serving different purposes. Each organ consists of various tissues arranged to enable each organ to serve its purpose. Tissues are built up from well-defined patterns of cells, the basic units of life. Individual cells are composed of reproducible systems of membranes, subcellular structures, and molecules. This obvious order is the result of a Designer's conscious planning rather than the lucky result of the collisions between atoms and molecules.

The chemical elements which make up the molecules of living cells are in orderly relationships with each other. Elements can also be divided into natural groups by the types of bonds they form and their reactions. This order is shown in the periodic table. The positions of any two elements on the periodic table can be used to predict the type of chemical bond that will form between them.

In considering chemical bonding, it is necessary to first examine the manner in which electrons are arranged in atoms because chemical bonds are formed by the electrons. In 1913, Niels Bohr presented an idea, or **model** (a description based upon its behavior rather than its appearance). He viewed electrons as being in discreet orbits about the nucleus of an atom like satellites orbiting the earth.

Later, in 1926, Erwin Schrodinger described electrons as occupying more generalized regions about the nucleus where they had a given probability of being present, such as an 80% probability of finding an electron within a given region of the atom. The energy of the electrons was more significant than their locations. He called the possible energies of electrons orbitals rather than orbits. He referred to the energy levels as shells. The innermost shell could have one orbital that could have a maximum of 2 electrons. The next shell could have 4 orbitals with 2 electrons in each, giving a total possible of 8 electrons. He said that atoms were more stable if they had 8 electrons in their outermost shell. They could get 8 electrons by losing, gaining, or sharing them. This explained why different chemical bonds formed between different atoms.

A hydrogen atom ($^{1}H_{1}$) has only one proton and usually one electron at the lowest energy level. An orbital has the greatest stability if it has either zero or two electrons. With only one electron, hydrogen atoms have a half-filled orbital and will therefore join with other atoms in ways that provide each with one more electron.

Oxygen ($^{16}O_{8}$) has eight electrons, two of which are in the lowest energy orbital. At the next energy level (or shell) there are six electrons left for the four orbitals that need eight electrons. Oxygen atoms will normally form chemical bonds in ways that it can essentially gain two more electrons rather than losing the six in its outer orbitals. Nitrogen is very similar in that with seven electrons, it has five in the outer orbitals instead of eight. So it needs to gain three more.

Carbon ($^{12}C_{6}$) has six protons and six electrons. Two fill the lowest energy orbital, leaving four for the outer orbitals that need eight. Carbon gains four electrons by sharing electrons with other atoms. Carbon typically forms four bonds with other atoms. The "shared electrons" constitute chemical bonds.

The need to fill the outer orbitals determines which of three possible chemical bonds can form between atoms.

Climbing ferns on cypress trees in the Florida Everglades

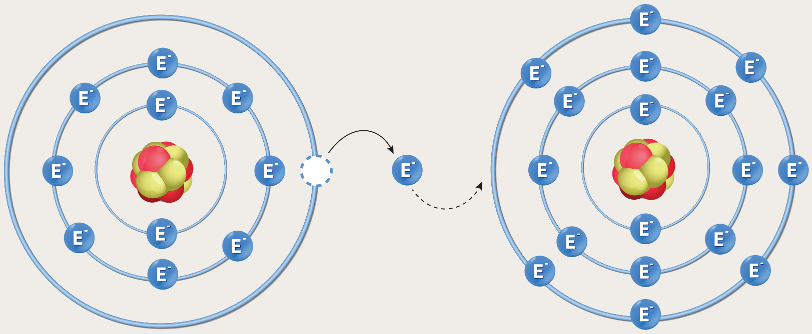
CHEMICAL BONDS

IONIC BONDS

Recall that electrons have a -1 charge and protons have a +1 charge. When an atom has more or fewer electrons than protons, the atom will have an overall charge equal to the differences between the charges. The resulting charged atoms are called **ions**. For example, a calcium atom has 20 protons and usually only 18 electrons. The 2 extra protons give the calcium atom a net +2 charge (Ca^{++}).

Opposite charged objects attract each other. The most abundant ions on earth are Na^+ (sodium) and Cl^- (chloride). In a dry state, they are bonded to each other by their opposite charges, called an **ionic bond**. When sodium and chlorine atoms come in contact with each other, the chlorine atoms take an electron from the sodium atoms. So sodium has a +1 charge with 10 negative electrons and 11 positive protons, and the chloride ion has a -1 charge with 18 electrons and 17 protons. NaCl dissolves readily in water because the positive sodium ions are attracted to the negative side of water molecules and the negative chloride ions are attracted to the positive side of water molecules.

Metal atoms, like sodium and calcium, lose electrons to achieve 8 electrons in the higher energy levels. Non-metals, like chorine, nitrogen, and oxygen, gain electrons to achieve 8 electrons in the higher energy levels.



Sodium
Gives up electron
becomes positive ion

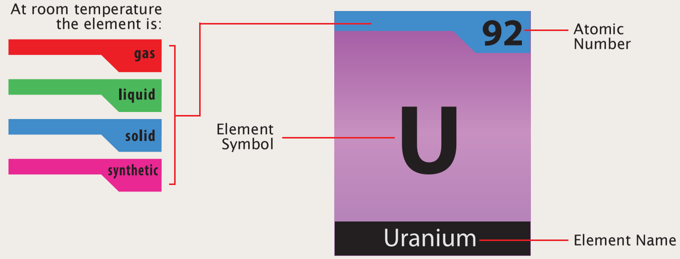
Chlorine
Receives electron
becomes negative ion

A pufferfish

Ionic compounds perform critical roles in the body fluids of living organisms, including generating and propagating nerve impulses, controlling fluid retention by cells, contracting muscle fibers, and initiating heart beats. Ions in solution in body fluids are called **electrolytes**.

Non-metals are on the right side of the periodic table and metals are on the left of the non-metals. Most of the elements are metals.

PERIODIC TABLE OF THE ELEMENTS

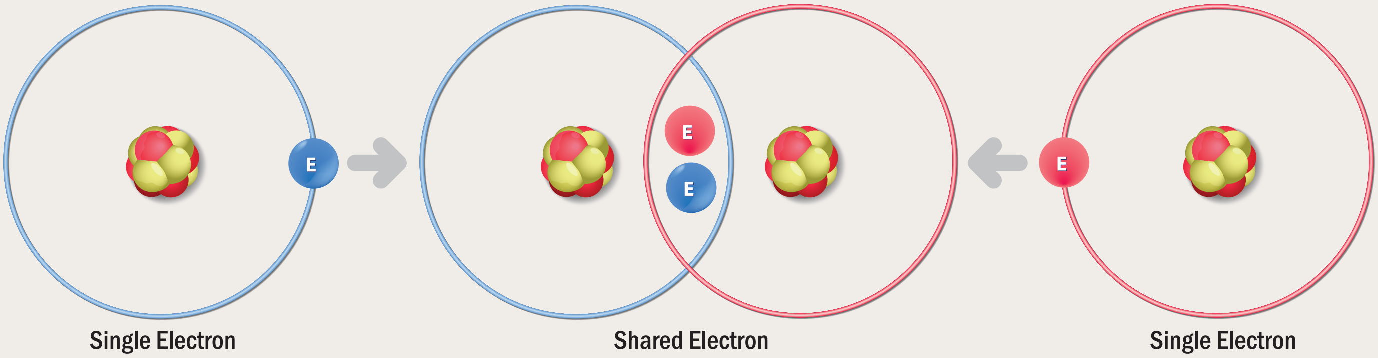


Subcategory in the metal-metalloid-nonmetal trend
(color of background)

- Alkaline Metal
- Lanthanide
- Transition Metal
- Alkaline Earth Metal
- Actinide
- Post-transition Metal
- Metalloid
- Polyatomic Nonmetal
- Diatomic Nonmetal
- Noble Gas
- Unknown Chemical Properties

PERIOD / GROUP ▶	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Caesium	56 Ba Barium	57 - 71 La-Lu	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium	89 - 103 Ac-Lr	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

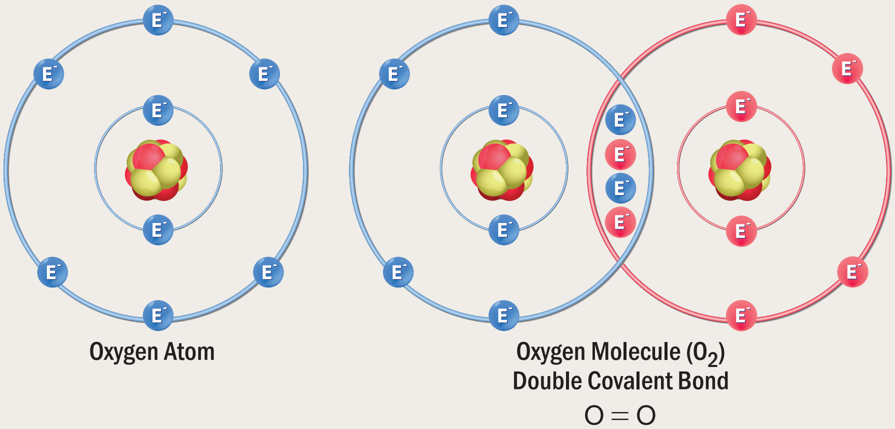


COVALENT BONDS

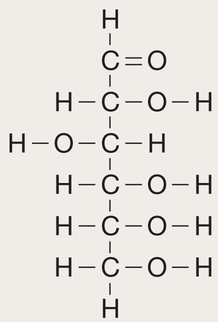
Atoms in molecules of living organisms are mainly held together by stronger **covalent bonds**. Here the bond is not the differences in electrical charges but the sharing of electrons. The electrons being shared spend part of their time around the nucleus of one atom and part of the time around the nucleus of the other atom. In this way, both atoms are able to have stable numbers of electrons in their outer orbitals. An electron from one atom and the electron from another atom form a shared pair of electrons between two atoms. Because the pair of electrons belongs to both atoms they constitute a strong bond between them. Hydrogen gas is the simplest example. Each hydrogen atom has 1 electron so between them they have a pair that gives 2 electrons in the lowest energy orbital of both atoms forming the H_2 molecule.

The most abundant gases in our atmosphere are nitrogen and oxygen, which also form pairs of atoms because they both need more electrons to fill their outer orbitals (N_2 and O_2).

Carbon atoms form the foundation of all molecules of living organisms. We are carbon based. The six electrons of carbon are arranged with two in the inner orbital leaving four for the four outer orbitals. The outer orbitals need four more electrons, which they gain by sharing with other atoms. Because each carbon atom can form 4 covalent bonds with other atoms, they can form many different arrangements of atoms. This gives the basis for carbon being able to form hundreds of thousands of different molecules.

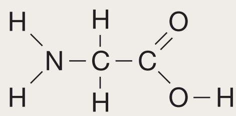


Consider again the structural formula of glucose that we looked at earlier.



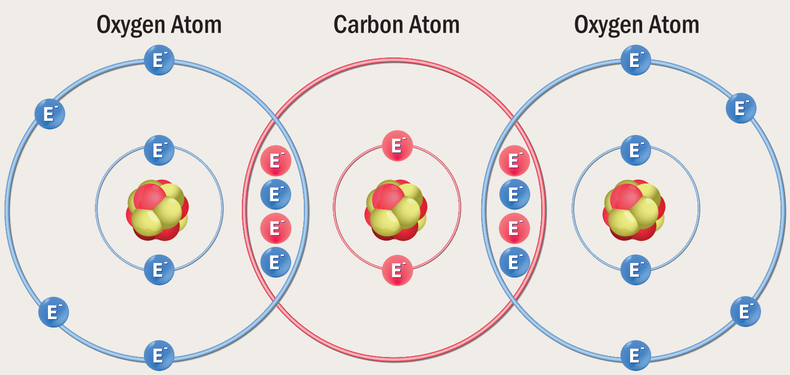
The lines in the structural formula represent covalent bonds. Each carbon atom has four lines (covalent bonds) with other atoms. Oxygen atoms with 8 electrons need two more in their outer orbitals so they form 2 covalent bonds (shared electron pairs) with other atoms. The hydrogen atoms each need one more electron forming one covalent bond with other atoms.

Look at the structural formula for the amino acid (building blocks of proteins) glycine.



Nitrogen atoms have 7 electrons giving them 5 outer electrons, meaning that they need 3 more to fill their outer orbitals. This is why there are three covalent bonds to each nitrogen atom.

Chemistry has become a powerful tool in the study of modern biology. To study biology without chemistry would be like using a sharp stone to cut a piece of wood instead of using a power saw. For those of you who have had chemistry, this chapter is a review but for the rest it lays an important foundation. When someone struggles in the sciences, it is almost always because they do not have the proper background. Carefully study the principles of this chapter until you feel you understand these concepts. Let's get the study of biology off to a great start!

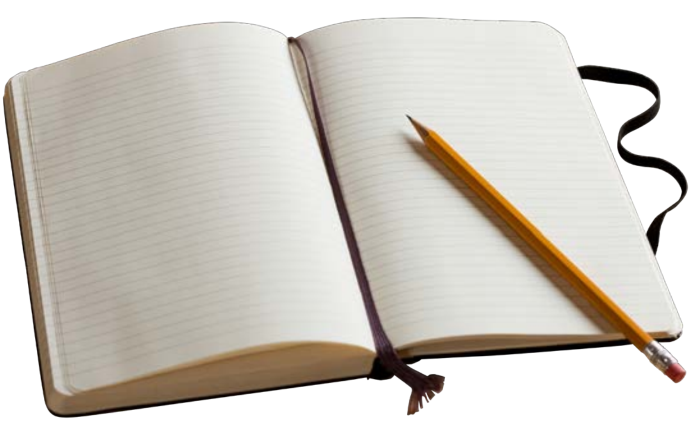


Carbon Dioxide Molecule (CO_2)
2 Double Covalent Bond
O = C = O

Biology – The Study Of Life

REQUIRED MATERIALS

- Pencil and paper



INTRODUCTION

This exercise sets the stage for the rest of this study. Biology is the study of the living. Think back to this laboratory exercise to keep a right perspective while doing the other laboratory exercises. The abundant forms and quantity of life that God has created and their relationships to each other is the focus of this study.

PURPOSE

To gain an overview perspective for the study of biology.

PROCEDURE

Go outside; find a quiet place to observe the life around you. Take a few minutes to just look at everything around you.

Make a list and brief description of most of the living things that you see. Use complete sentences so that it is meaningful to whoever reads this report. Write in such a way that someone else can picture in their mind what you are describing.

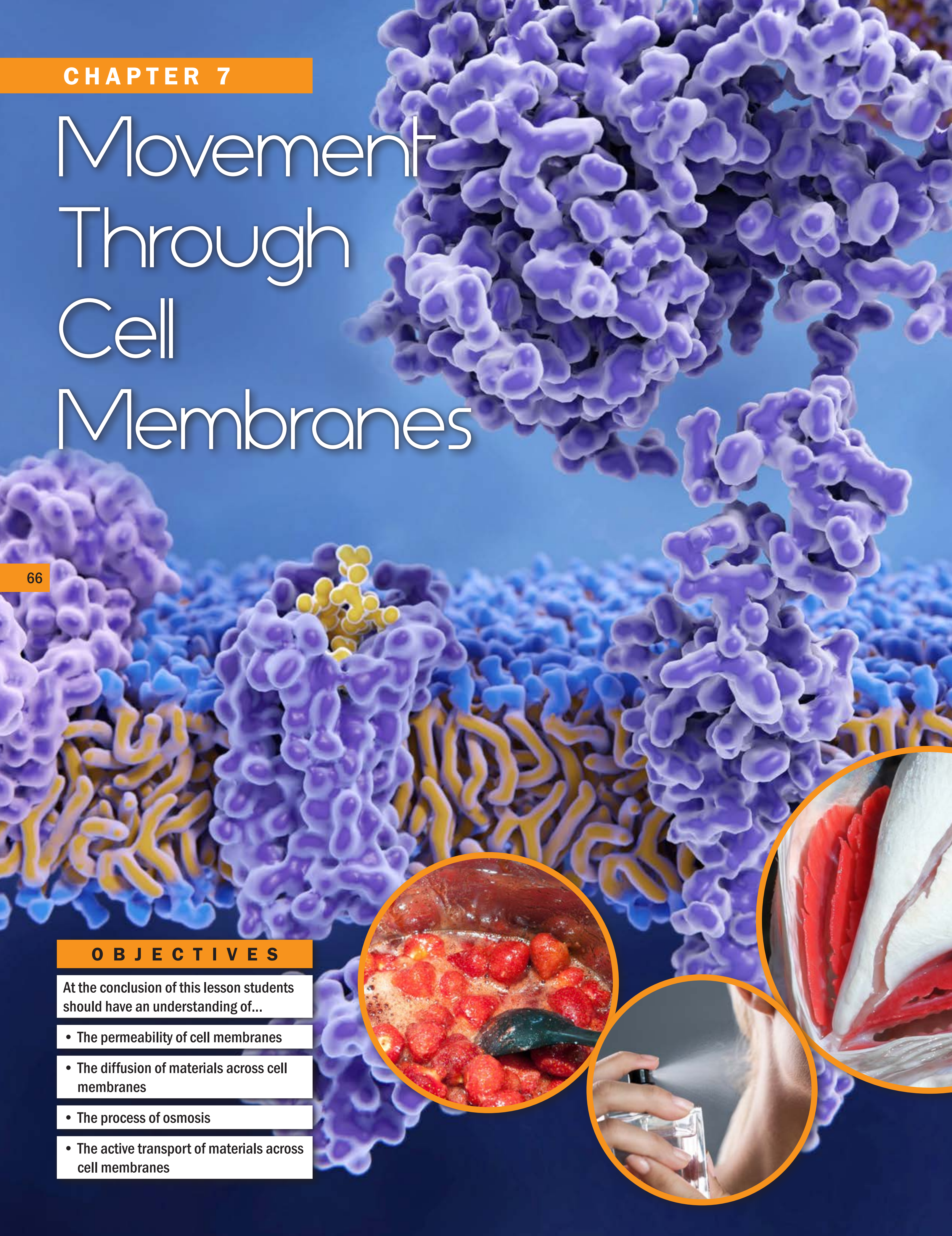
Identify what you could consider to be a keystone species. This is a life form that if removed would have an effect on the other life forms around it. An example would be a pine tree where squirrels get seeds for food from the pinecones. Describe why you consider it a keystone species.

Describe a life form that you see that feeds on another life form.

Describe a life form that you see that is food for another life form.

Dead organisms and waste products have to be broken down so that they can become nutrients for others (such as plants). Describe which life forms you see or know to be there (some are there even though you cannot see them) that carry out this role. These are called decomposers — usually bacteria and fungi.

Sometimes scientific details cause us to lose the wonder of the creation around us. Hopefully, as you look around and see the marvelous life forms and beautiful habitats God created for them, you will keep focus on the wonder of life. The scientific details do help us understand what we are looking at, but we must keep stepping back to see how God created everything to work together so well and be beautiful at the same time.



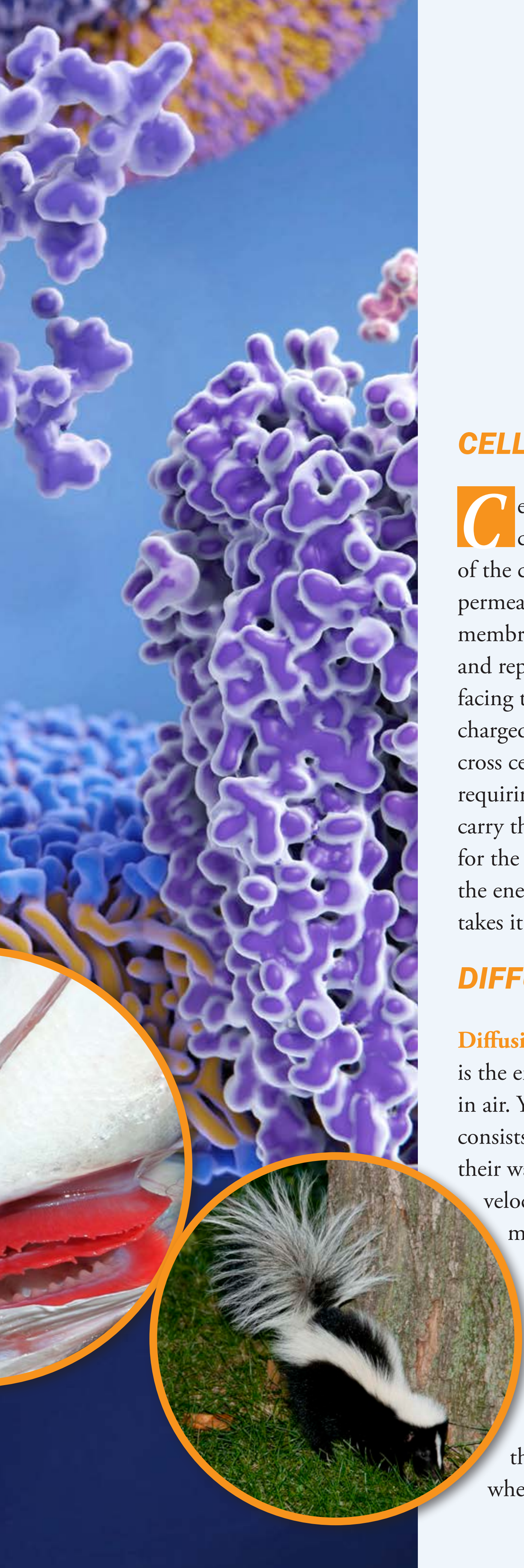
CHAPTER 7

Movement Through Cell Membranes

OBJECTIVES

At the conclusion of this lesson students should have an understanding of...

- The permeability of cell membranes
- The diffusion of materials across cell membranes
- The process of osmosis
- The active transport of materials across cell membranes



CELL MEMBRANES

Cell membranes are selectively **permeable**, meaning that only certain substances are allowed to pass through them, into and out of the cell. It is also sometimes called semipermeable or differentially permeable. The ends of the phospholipids penetrating the middle of cell membranes are non-polar (neutral in charge) so they attract oils and fats and repel water — called hydrophobic. The ends of the phospholipids facing the outer parts of membranes are polar (with negative and positive charged parts) and attract water — called hydrophilic. Molecules can cross cell membranes passively by diffusion or by active transport requiring energy. For some, the movement (kinetic energy) of substances carry them across the membrane and the cell does not have to use energy for the process. This is like when a baseball goes through a window — the energy comes from the baseball and the window just sits there and takes it. For other substances, cells have to use energy to move them.

DIFFUSION THROUGH CELL MEMBRANES

Diffusion is the movement of substances by their kinetic energy, which is the energy of motion. Most molecules are light enough to move about in air. You notice this if a skunk goes by. The scent from the skunk consists of molecules given off by the skunk that move about and find their way to your nose. When the air temperature is higher, the average velocity of the air molecules is faster. The motion of individual molecules is said to be **random**, meaning it is unpredictable. The concept of random depends upon your concept of reality. To some, it means that things just happen and there is no plan or control. To others, that are aware of God's role in the universe, it is under His sovereign control — it is just that we do not know how to predict where any given molecule will be at any given time. But we know that there is control because using the laws that govern the motion of gas molecules, we can predict where most of the molecules will be at any given time. We just

WORDS TO UNDERSTAND

- active transport
- aquapores
- concentration gradient
- crenated
- diffusion
- electrical gradient
- hypertonic (hyperosmotic)
- hypotonic (hyposmotic)
- isotonic (isosmotic)
- membrane pumps
- osmosis
- permeable
- physiological saline
- random
- solute
- turgor pressure

cannot predict where any individual molecule will be. If we can predict where the bulk of the molecules will go, which we can, the individual molecules have to be controlled. Molecules diffuse from where they are more concentrated to where they are less concentrated. This aspect of diffusion is predictable. Perfume will diffuse out of a bottle into a room and not from the room into a bottle.

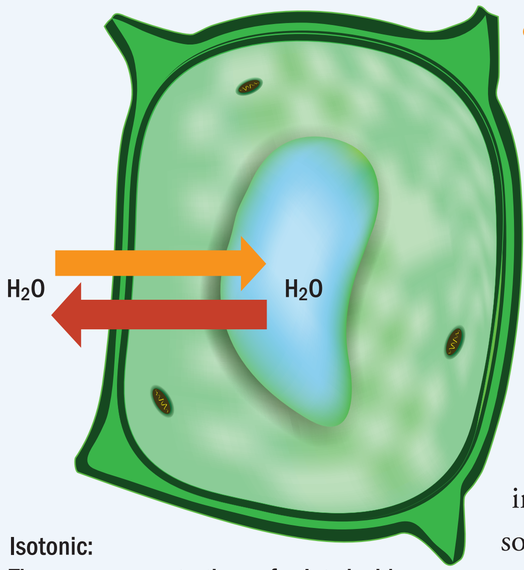
Some molecules diffuse in and out of cells because they are small enough to go through pores if they collide with the opening at the right angle and velocity. Water molecules diffuse through **aquapores**, which are protein-lined channels through cell membranes. Otherwise, water molecules would be repelled by the hydrophobic phospholipids in the middle of the membranes.

When a substance is at the same concentration on both sides of a membrane, it will diffuse in and out of the cell at the same rate. They are at equilibrium.

Because diffusion is caused by the movement of the molecules themselves, there is no cost to the cell. Even though there is no net change in the concentrations of the substance at equilibrium, the individual molecules are still moving just as much as before. When the concentration of the substances is not the same on both sides of the membrane, a **concentration gradient** exists. This is where molecules of the same kind are more concentrated on one side of a membrane than the other.

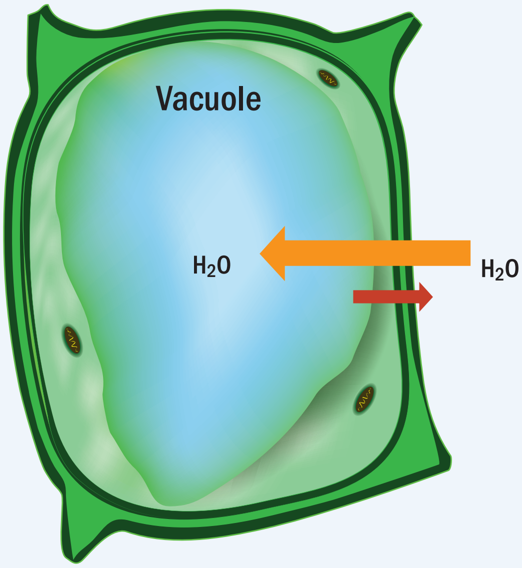
PROCESS OF OSMOSIS

The most abundant molecule that diffuses across a cell membrane is water. The diffusion of water across a cell membrane is called **osmosis**. Water is a solvent (other molecules will dissolve into it) and what dissolves into it is called the **solute**. When salt (sodium chloride, NaCl) is added to water, the Na^+ ions and the Cl^- ions separate and become dispersed between the water molecules. The term ion refers to an atom or molecule that is + or – charged. Positive-charged Na^+ (sodium) ions are attracted to the negative-charged side of water molecules and the negative-charged Cl^- (chloride) ions are attracted to the positive-charged side of water molecules. When the NaCl solutions are the same concentrations on both sides of the cell membrane, they are called **isotonic** or **isosmotic**. The prefix iso- means same. The NaCl concentration inside of a living cell is 0.9%. When a cell is placed in a 0.9% NaCl solution, it will not absorb too much water or lose too much water. This is called **physiological saline**.



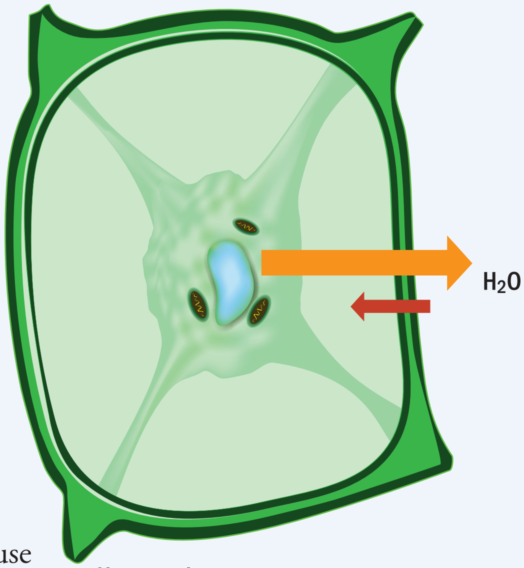
Isotonic:
The same concentrations of solute inside and outside the cell

In distilled water, the NaCl concentration is 0% and the water concentration is 100%. When cells are placed in distilled water, water will diffuse from a region of greater concentration to a region of lesser concentration; so more water will diffuse from outside of the cell to the inside of the cell. Inside the cell, the NaCl is 0.9% and the water concentration is 99.1%. So the water diffuses down the concentration gradient from 100% to 99.1%. This may not seem like a big difference but in this case it is. The cell will swell up and burst, or if it is a plant cell it will swell and push out on the outer cell wall. The 0% NaCl concentration outside the cell is called **hypotonic** or **hyposmotic** to the solution in the cell. The prefix hypo- means under or less, so it refers to a solution with a lower solute concentration.



Hypotonic:
Greater concentrations of solute inside the cell than outside the cell

When water enters a cell by osmosis, the additional water molecules in the confined space of a cell produce pressure against the inside walls of the cell called **turgor pressure**. It can burst animal cells and stiffen plant tissues because the cell membranes of plant cells push out against their outer cell walls. This is why well-watered plants do not wilt.



Hypertonic:
Greater concentrations of solute outside the cell than inside the cell

If a cell is placed in a solution of 10% NaCl (90% water), water will diffuse out of the cell faster than it will diffuse into the cell. This is from 99.1% water in the cell to 90% water outside of the cell. The cell will lose water and shrivel up. The cell is said to become **crenated**. The 10% NaCl is called **hypertonic** or **hyperosmotic** when contrasted to the solution inside the cell.

Sugar acts as a preservative in jelly. As a solute, sugar in jelly is hypertonic to bacteria and mold (fungus) cells. Water molecules diffuse at a greater rate from bacteria and mold cells into the jelly, causing the bacteria and mold cells to shrivel up and die.

The predictability of the process of osmosis is another example of the overall predictability of the movement of molecules that are said to move randomly. This is a great demonstration that even the physical processes that govern living organisms appear to be part of an intelligent design. It is a form of worship to recognize and give God the credit for what He has so wonderfully provided by His grace. As a result of osmosis, water moves from soil into root cells supplying water to thirsty plants. As well, osmosis transports water from one cell to another within animal tissues and from plant cells within leaves to neighboring cells.

ACTIVE TRANSPORT ACROSS CELL MEMBRANES

In many situations, molecules are moved against a concentration gradient at the expense of cellular energy. This is **active transport** because the cell is active in moving molecules from where they are less concentrated to where they are more concentrated. This would be like catching perfume molecules in the room and stuffing them back into a bottle. Well, maybe not quite as difficult, but that is the idea. This process involves specialized proteins in the cell membrane that can physically catch molecules on one side of a membrane and deposit them on the other side where they are more concentrated. Active transport can be detected by adding poison to cells blocking the transport proteins by cutting off their energy supply. If the process is stopped by the poison, it is active transport and not diffusion.

Some of the proteins imbedded in the two phospholipid layers of the cell membrane are called **membrane pumps**. The most extensive studied system of membrane pumps is the sodium–potassium exchange pumps in neurons (nerve cells). Sodium (Na^+) ions are pumped out of the cell faster than they can diffuse back in. This results in the Na^+ ions being more than 10 x more concentrated outside of the membrane than in the cytoplasm. The protein pumps are highly selective as to what they move across the membrane. At the same time, potassium (K^+) ions are pumped into the cytoplasm from outside of the cell, with 3 Na^+ ions pumped out for every 2 K^+ ions pumped in. This results in more positive charges being outside of the membrane than in the cytoplasm. This is a concentration gradient and an **electrical gradient** (more positive charge on the outer part of the cell membrane than inside the cell). This prepares the membrane of the neuron for a nerve impulse. When the pump ceases and the Na^+ gates (also formed by proteins in the membrane) open, Na^+ ions rush into the cytoplasm. This is called a nerve impulse, which is going on in your brain right now.

Energy from the energy storage molecules adenosine triphosphate (ATP) is required for the membrane pumps. When energy is released from ATP molecules they lose their third phosphate ion, becoming adenosine diphosphate, phosphate, and energy.

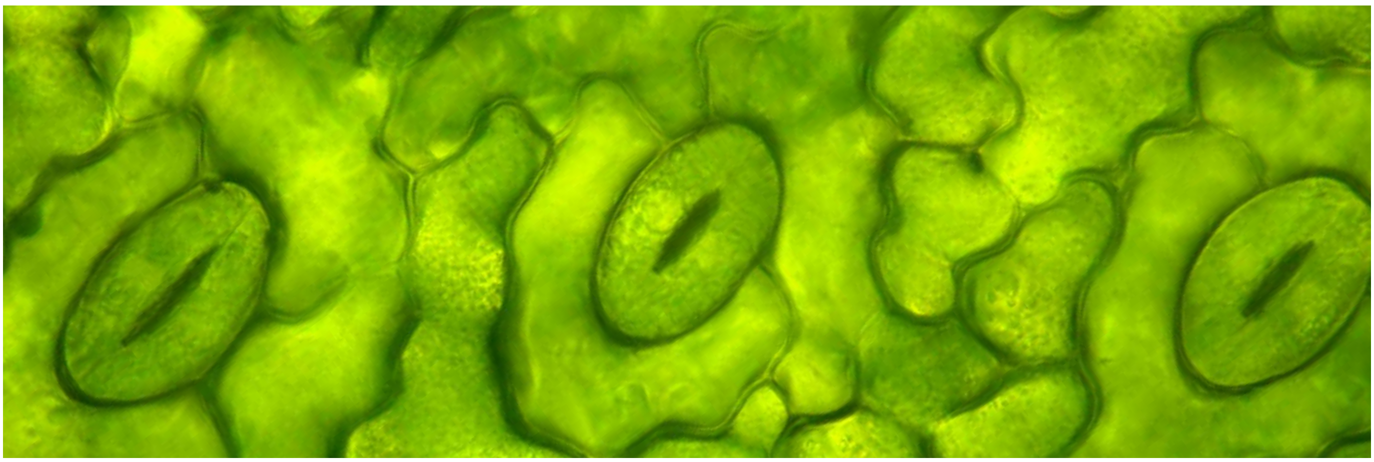
$$\text{ATP} \rightarrow \text{ADP} + \text{Phosphate} + \text{Energy}$$

This energy-releasing process is universal among living organisms. This happens in most cases where a cell uses energy. This consistent pattern would not be expected from constantly changing evolutionary processes, but would be expected with the same Designer creating all life forms.

Other examples of membrane pumps include the movement of Ca^{++} (calcium) ions across cell membranes within cells involved in muscle contraction, the filtration processes in the kidneys, uptake of salts by the gills of freshwater fish, and the transport of salts out of the gills of salt water fish.

Life processes of cells involve moving materials in and out of cells through their outer membranes. The dominant role of the cell membranes is to control the movement of water in and out of cells. This is mainly carried out by the diffusion of water molecules from regions of greater water concentration to regions of lower concentration which is osmosis. This is a huge example of God's grace because it does not cost the cell any energy – it is driven by the energy of motion of the water molecules. It is like opening the door on a windy day and using the energy of the air molecules to move it into a room. All you have to do is open the door. You do not have to push the air into the room. It is like saying that most of the necessary things in life are free. For the health of our cells, it is huge to keep the water balance. I trust that you can see God's design and grace throughout this study which should encourage and strengthen your faith. Life does not depend on us – God has already abundantly provided.

Osmosis



REQUIRED MATERIALS

- Fresh apple
- Fresh potato
- Distilled water (available from grocery store)
- NaCl (salt from grocery store)
- Knife to cut the potato and apple
- Teaspoon
- 100 ml beakers (3) (from the supply kit)
- Metric ruler (from the supply kit)
- 50 ml graduated cylinder (from the supply kit)
- Wax pencil (from the supply kit) or a non-permanent marker

INTRODUCTION

Water diffuses into and out of cells through pores (called aquapores) in cell membranes. Diffusion occurs from a region where molecules are more concentrated to where they are less concentrated. The concentration of water in distilled water is 100% because there is nothing besides water. A 10% NaCl (salt) solution has a water concentration of 90%. The fluid inside of cells is 99.1% water, so if a cell is placed in a 10% NaCl solution, water will diffuse out of the cell more than will diffuse into the cell (from 99.1% to 90%) and the cell will shrivel up.

If cells are placed in distilled water (100% water), it will diffuse more into the cell with (99.1% water) than out of the cell and the cell will swell and perhaps burst.

PURPOSE

To observe a practical example of osmosis.

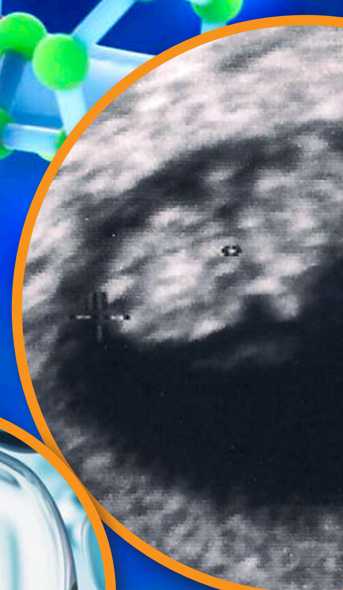
PROCEDURE

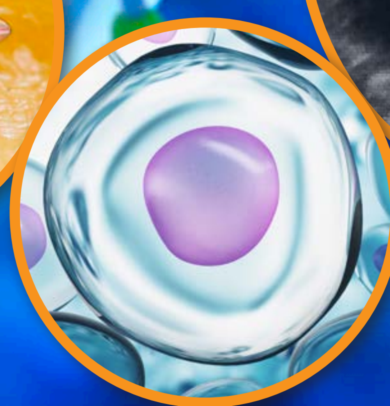
1. Label a beaker as distilled water, another beaker as 1.0% NaCl, and a third beaker as 10.0% NaCl.
2. Measure out a 50 ml (milliliter) portion of distilled water with a graduated cylinder and pour it into each of the three beakers.
3. Add 0.5 gram of NaCl to the 50 ml of distilled water in the second beaker — 0.5 gram is the amount on the tip of a table knife. This is accurate enough for this procedure. This beaker should be labeled as 1.0% NaCl.
4. Add 5 grams of NaCl to the water in the third beaker. One teaspoon of NaCl is 5 grams. This beaker should be labeled as 10.0% NaCl.
5. Cut 3 rectangles of potato and 3 rectangles of apple about 2 cm (centimeters) long, 1 cm tall, and 1 cm wide. Use the metric ruler from your supply kit.
6. Dry each of the potato and apple rectangles by blotting them with a paper towel.
7. Place a potato and apple rectangle in each of the 3 beakers.
8. After 30 minutes, remove the rectangles and place them on a paper towel. Blot each one with paper towel. Keep track of which pieces came from which beaker. Describe the appearance of each rectangle. Are they swollen, shriveled, or the same as before?
9. Write a complete sentence describing how the potato and apple pieces compare to their appearance before they were placed in the beakers.
10. **Osmosis** is the diffusion (movement) of water across a cell membrane from the side of the membrane where it is more concentrated to the other side of the membrane where it is less concentrated. Distilled water is 100% water. The beaker with 0.5 grams of NaCl in 50 ml of water is 1.0% NaCl and 99% water (100 – 1 = 99). The beaker with 5 grams of NaCl in 50 ml of water is 10% NaCl and 90% water (100 – 10 = 90).
    A. For the first beaker, the potato and apple pieces with 99% water are place in distilled water (100%). Would you expect the water to move more into or more out of the potato and apple cells? From your observations what do you think happened? If more water moved into the potato and apple cells, they would swell up. If more water moved out of the potato and apple cells, they would shrink. If the same amount of water entered the cells as came out of them, they would stay pretty much the same. Did it happen the way you thought it would?
    B. For the second beaker, the potato and apple pieces with 99% water are placed in 1% NaCl (99% water). The fluid within the cells is 99.1% water to begin with. Would you expect the water to move more into or out of the potato and apple cells? From your observations, what do you think happened? Did it happen the way you thought it would?
    C. For the third beaker, the potato and apple pieces with 99% water are placed in 10% NaCl (90% water). Would you expect the water to move more into or more out of the potato and apple cells? From your observations what do you think happened? Did it happen the way you thought it would?
11. Answer the questions in this lab in your lab report with complete sentences.

Osmosis is a simple concept (that many make confusing), which is very predictable when the basics are understood. Hopefully, this lab helps you to visualize its effects and understand it much better.

CHAPTER 14

Chromosomes and Genes

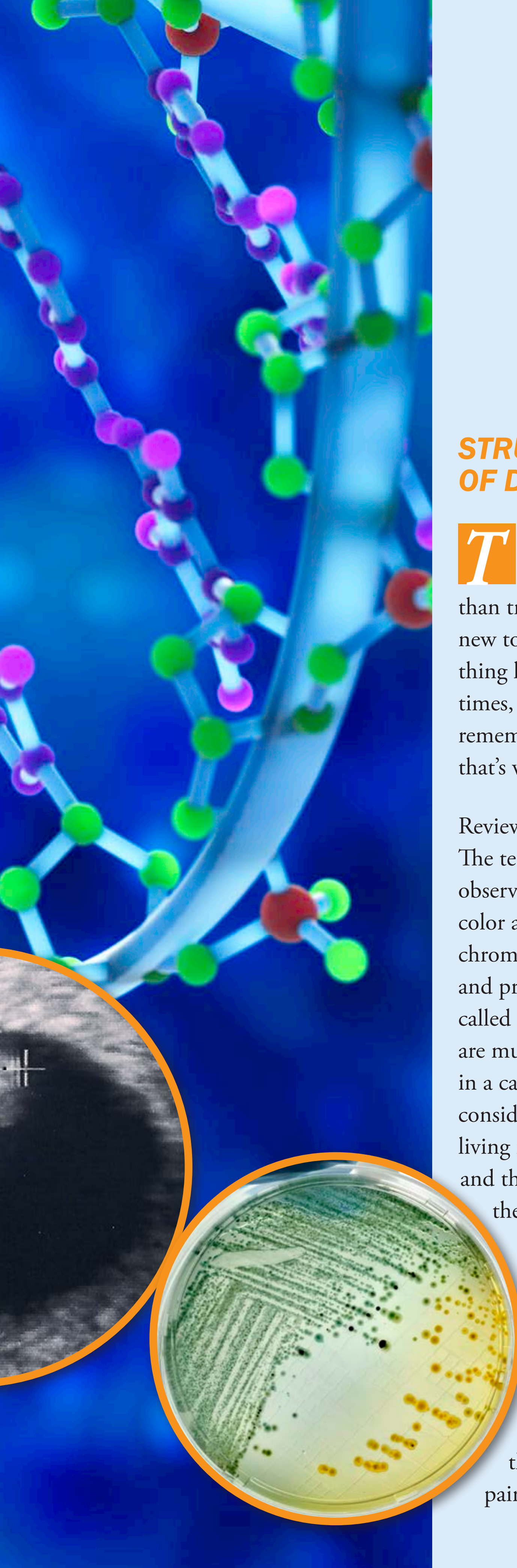




OBJECTIVES

At the conclusion of this lesson students should have an understanding of...

- The structure and replication of DNA and chromosomes
- The role of genes in life processes



STRUCTURE AND REPLICATION OF DNA AND CHROMOSOMES

The subject matter of this chapter can be a difficult one. For that reason, it is suggested that you read to follow the discussion rather than trying to memorize everything. Most of this material is probably new to you. Instead of a list of things to memorize, it is a story where one thing leads to another. You may want to read through the chapter several times, and then use the practice exercises to show you what you need to remember. They are simply that, practice exercises and not a quiz, and that's why the answers are provided for you.

Review the material on nucleic acids (DNA and RNA) in chapter 4. The term chromosome came about because in the 1800s objects were observed in the nuclei of cells that absorbed dark stains. *Chromo* means color and *soma* means body — so they were called colored bodies or chromosomes. Today we know that chromosomes are composed of DNA and proteins. Bacteria cells that lack nuclear membranes have regions called nucleoids where a single circular chromosome is located. Viruses are much smaller than bacteria cells. They consist of DNA or RNA in a capsule. Biologists debate about whether or not viruses should be considered alive because they lack several important characteristics of living forms. They do not carry out cellular respiration, they do not grow, and they do not reproduce. All of these functions are carried out by using the cellular mechanisms of host cells that they infect.

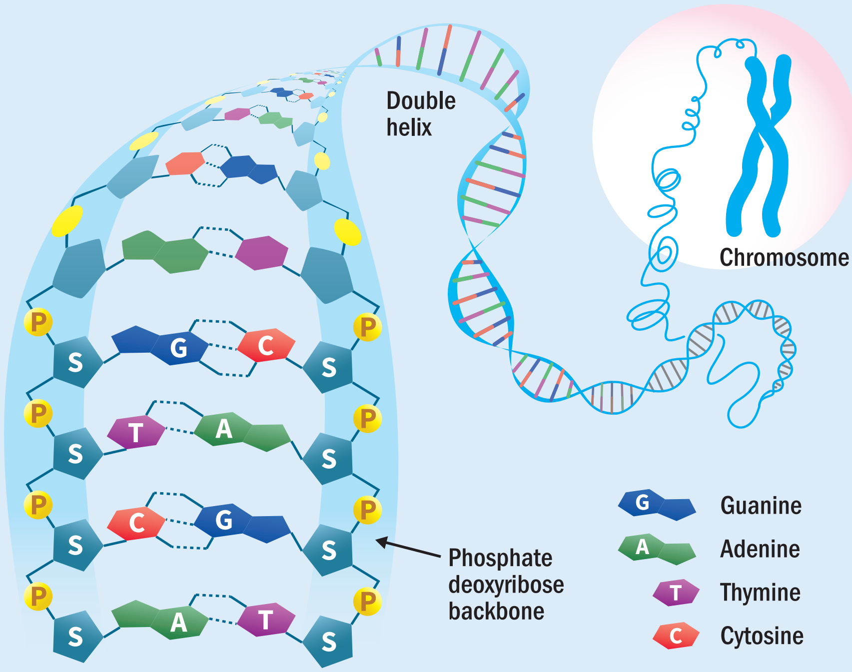
The nuclei of eukaryotic cells are covered with a nuclear membrane and contain the DNA that is the genetic code of a cell. You can think of the nucleus as the safety deposit box protecting the DNA without which the cell would die. Most eukaryotes are diploid, meaning that they have 2 copies of each chromosome. That way if one chromosome has DNA with mutations, meaning that they code for defective proteins, the other chromosome in the pair could have healthy DNA that codes for properly functioning

WORDS TO UNDERSTAND

- haploid
- regulator gene

proteins. The symbol 2n means that the cell has 2 of each chromosome. The fruit fly *Drosophila melanogaster* has 4 different chromosomes, so 2n = 2 x 4 = 8, meaning that they have a total of 8 chromosomes or 4 pairs. Corn, *Zea mays*, has 10 different chromosomes, so 2n = 20. As humans, we have 23 different chromosomes, giving 2n = 46.

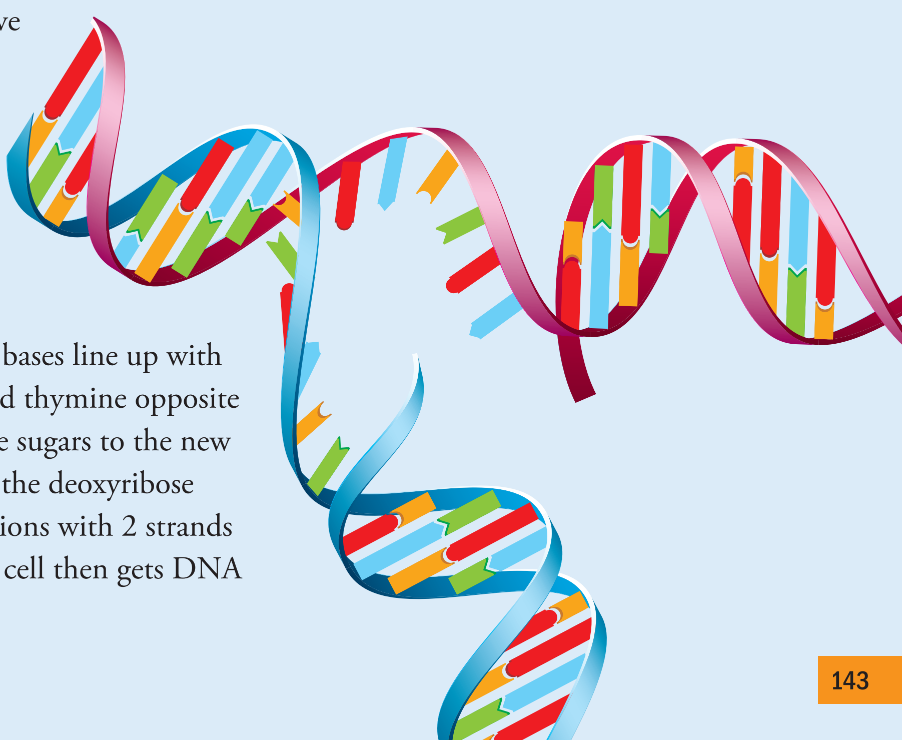
A chromosome consists of DNA that is a double helix (as described in chapter 4). Picture a ladder that twists like a spiral as it goes up. The DNA strands are like the sides of the ladder and the rungs of the ladder are the hydrogen bonds between the bases (guanine, cytosine, adenine, and thymine).



The strands going up the sides of the DNA molecule are alternating deoxyribose (5 carbon sugar) and phosphate. The bases (G, C, T, and A) are attached to the sugar molecules and face inward toward each other. The sugar, phosphate, and base together is called a nucleotide. As the bases face each other on DNA, you always find guanine opposite cytosine, and thymine opposite adenine. The cytosine and guanine pairs form 3 hydrogen bonds between them, and the adenine thymine pairs form 2 hydrogen bonds between them. To have a hydrogen bond you have to have an oxygen or nitrogen atom opposite a hydrogen atom on the opposite base. A thymine and cytosine would not match to form hydrogen bonds. The adenine and guanine molecules are longer than the cytosine and thymine molecules. When they are properly paired up they form hydrogen bonds with the appropriate distances between the strands. A ladder with some short and some long rungs would not work and would be rather dangerous to climb. That would be like having 2 long bases or 2 short bases opposite each other. For proper spacing, you have to have a long base opposite a short base.

Before cells divide, the DNA is replicated during interphase. In cell division, a parent cell gives rise to 2 daughter cells. Each of the daughter cells has the same amount of DNA and number of chromosomes as the original parent cell. For this to happen, the DNA has to be replicated before cell division.

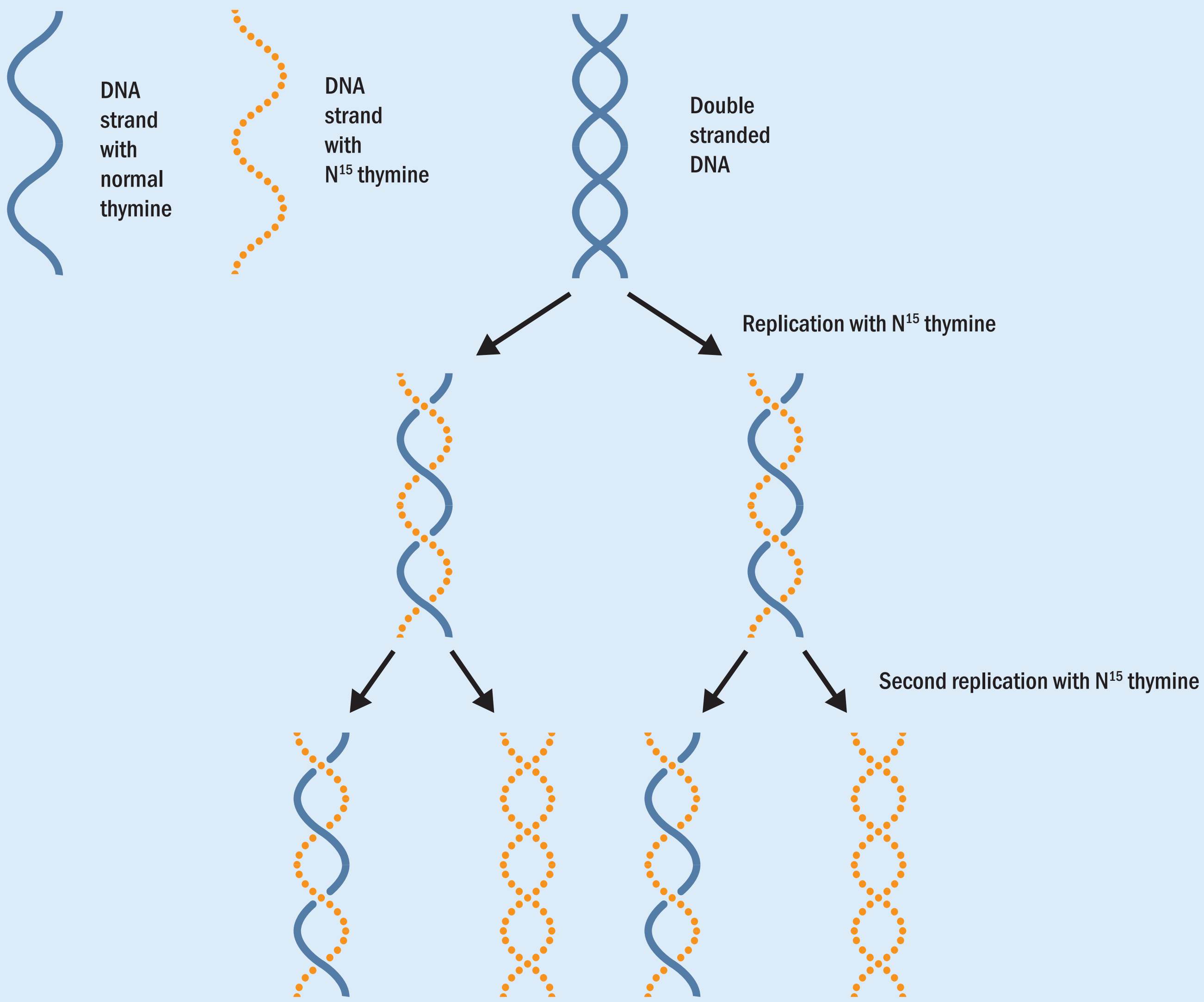
In 1958, Matthew Meselson and Franklin Stahl performed a very cleverly designed experiment demonstrating that the DNA of a chromosome is replicated in a semiconservative fashion — the resulting DNA molecules each have a new strand and an old strand. The 2 strands of the original DNA separate over part of their length and new strands are made next to each of the old strands as shown in the following diagram.



After a section of the DNA is unraveled, new bases line up with the old bases — guanine opposite cytosine and thymine opposite adenine. Then enzymes attach the deoxyribose sugars to the new bases and phosphates are attached to connect the deoxyribose sugars to each other. Then the 2 resulting sections with 2 strands each separate from each other. Each daughter cell then gets DNA with a new strand and an old strand.

In Meselson and Stahl's experiment, the original DNA had the isotope ^{14}N in the thymine bases. The new bases included thymine with the nitrogen isotope ^{15}N, which is heavier than the ^{14}N isotope. They demonstrated that the new DNA had a weight in between that with all ^{14}N and that with all ^{15}N. This meant that the new DNA had a strand with ^{14}N and a strand with ^{15}N. You might need to review chapter 1 to understand the symbolism used here for the isotopes of N.

This experiment was done with the bacteria *Escherichia coli* (abbreviated *E. coli.*). They extracted the DNA from *E. coli* before the DNA replicated, and after it replicated with ^{15}N thymine (this is thymine molecules that have the heavier ^{15}N instead of ^{14}N). They placed the DNA from the *E. coli* into a centrifuge in a test tube containing a cesium chloride solution. The spinning centrifuge pulled the DNA down through the cesium chloride solution. The DNA with a strand with ^{14}N thymine and a strand with ^{15}N thymine moved quicker and farther through the cesium chloride because of its greater weight. If DNA that had both strands with ^{15}N thymine were spun it would



Meselson and Stahl Experiment

go faster and farther down the test tube. This is a good example of demonstrating experimentally what you cannot see directly.

THE ROLE OF GENES IN THE LIFE PROCESS

The understanding that every new cell receives just as much DNA as the original parent cell is a very important realization. Cells in different parts of the body turn out differently because of which part of their DNA is expressed and how it is regulated. The cells of your big toe all have the same DNA as cells of your nose, but that does not mean that your nose looks and smells like your big toe (I hope not).

Charles Darwin, in his day, thought that children inherited "inheritance factors" that came from every cell of the parent's body. We know today that only the DNA in the egg cell from the mother and the sperm cell from the father are inherited. A process of cell division called meiosis produces cells that become egg and sperm cells for reproduction. This is called a reduction division because it reduced the number of chromosomes to one of each instead of two of each. Each of the resulting cells with one of each chromosome is called **haploid** instead of diploid. The DNA of a chromosome is divided into sections such that each section (gene) has the genetic code to produce a protein chain.

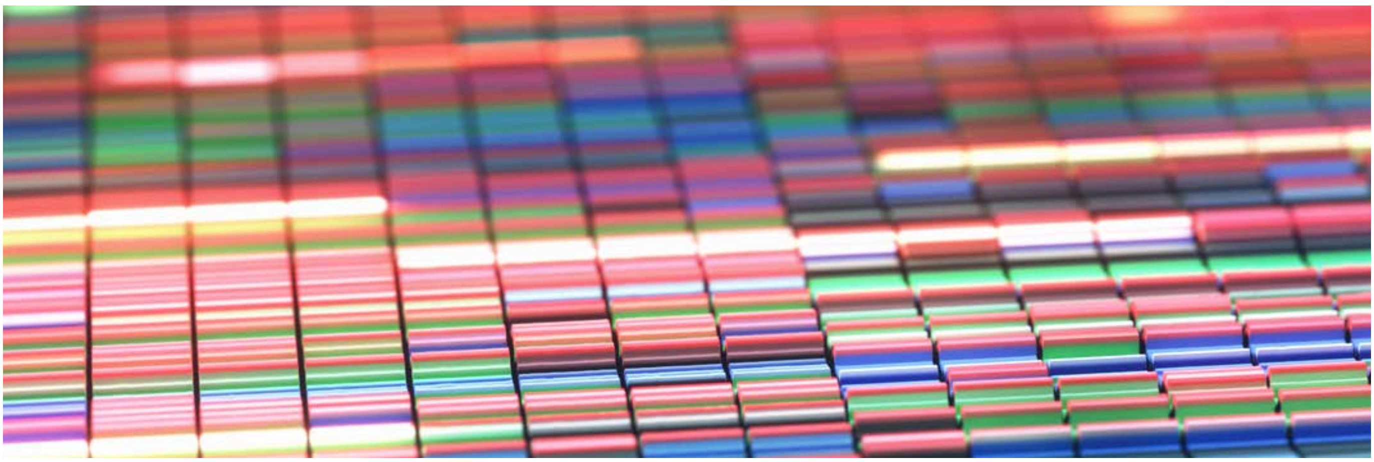
When a cellular process, like Krebs cycle, has several enzymes that function in sequence, the genes that code for the enzymes are usually in the same order in a chromosome. There is usually a **regulator gene** at the beginning of the sequence that determines if they are all to be turned on or off.

The famous artist Salvador Dali stated that the announcement of Watson and Crick about the structure of DNA "is for me the real proof of the existence of God."

The molecular biologist G.S. Stent wrote in the scientific journal, "I think that Dali has sized up the situation quite correctly: the achievements of molecular biology have furnished proof for the existence of God."

Artist Salvador Dalí 1939

Chromosomes and Genes



REQUIRED MATERIALS

- Microscope (from the supply kit)
- Microscope Prepared Slide Onion Root Tip Mitosis (from the supply kit)
- Microscope Prepared Slide Roundworm *Ascaris* (from the supply kit)
- 3 lengths of thick string 30 inches long
- 81 paper clips
- 14 strips of red colored paper ½ inch x 1 inch
- 16 strips of blue colored paper ½ inch x 1½ inch
- 14 strips of green colored paper ½ inch x 1 inch
- 16 strips of yellow colored paper ½ inch x 1½ inch
- 16 strips of white paper ½ inch x 1 inch
- Other colors of paper can be used, as long as you have 5 different colors

INTRODUCTION

Chromosomes are long lengths of double-stranded DNA with attached proteins. Genes are sections of DNA that contain the information to direct the formation of a protein (or protein subunit). There are many genes connected end to end making up a chromosome. As humans, we have at least 25,000 genes on 23 chromosomes. DNA is structured like a twisted ladder with 2 alternating supports on the outside and rungs in between. The outside supports are made up of alternating 5 carbon sugar molecules (deoxyribose) and phosphates (PO_4^{-3}). The rungs of the ladder are the bases (adenine, thymine, guanine, and cytosine) that are attached to the deoxyribose molecules.

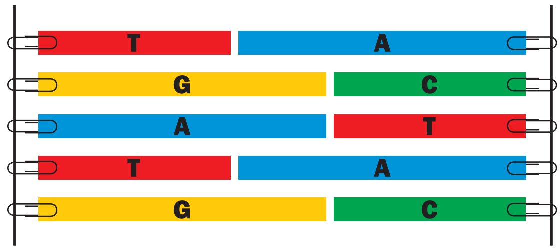
Along the length of a DNA strand, every group of 3 bases is called a **codon**. Each codon codes for an amino acid. In the process called *transcription* a single-stranded length of RNA is made by copying part of one of the strands of the DNA. This RNA strand called messenger RNA (mRNA) leaves the nucleus and goes out into the cytoplasm where it is "read" to construct a protein which is a length of amino acids.

PURPOSE

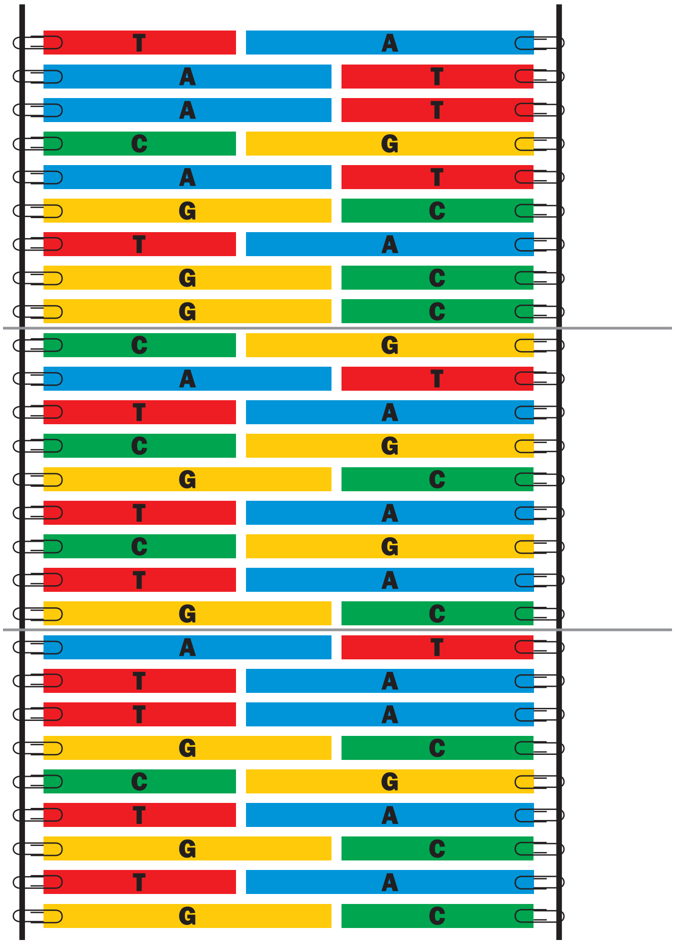
You are constructing a model to visualize the structure of a chromosome. When you read a description like that of the structure of a chromosome, the imagination is a tricky thing and can come up with different ideas. This exercise is designed to help you have an accurate image of the chromosome structure. This is essential to understand the following chapters.

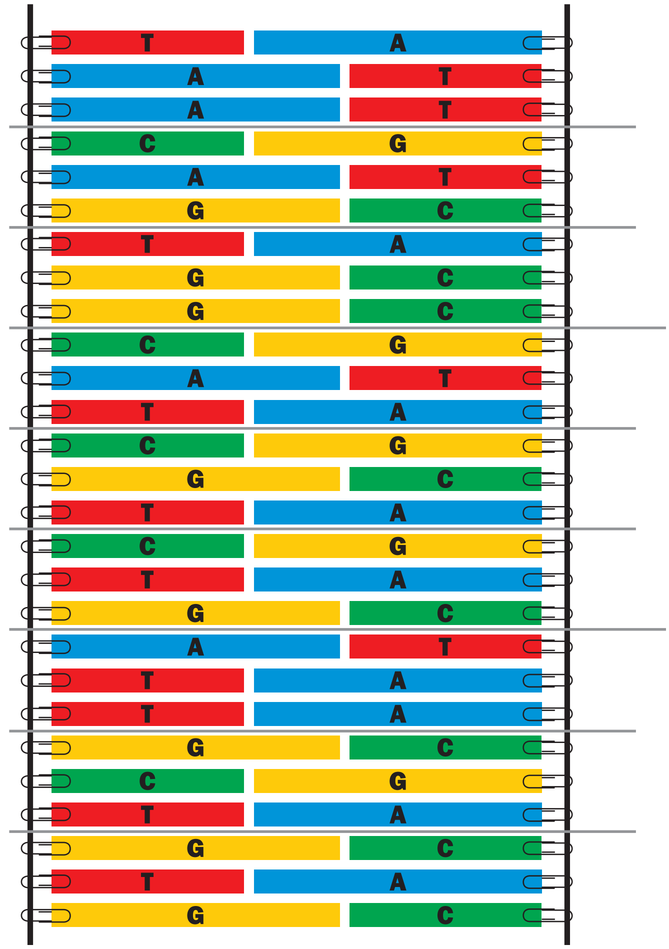
PROCEDURE

1. Look at the prepared slide with the metaphase stage of mitosis of the onion root tip. Start with the low power objective lens and shift to the medium and then to the highest power objective lens. The darkly stained "stringy"-looking structures that you see in the middle of the cell are chromosomes. These are composed of extremely long strands of DNA. Look for chromosomes on the *Ascaris* slide as well. Point out the chromosomes on the onion root tip slide and the *Ascaris* slide to your teacher.
2. Put a capital letter A (adenine) on each of the blue (1½ inch long) strips of paper. Set two of these aside for next week.
3. Put a capital letter G (guanine) on each of the yellow (1½-inch-long) strips of paper. Set two of these aside for next week.
4. Put a capital letter T (thymine) on each of the red (1-inch-long) strips of paper.
5. Put a capital letter C (cytosine) on each of the blue (1-inch-long) strips of paper.
6. Put a capital letter U (uracil) on each of the white (1-inch-long) strips of paper. Set two of these aside for next week.
7. Attach the paper clips to each length of string at 1-inch intervals with 27 on each length of string.
8. Lay 2 of the lengths of string on a flat surface parallel to each other with their paper clips facing each other. To each paper clip on one string connect one of the paper strips. Mix up the colors.
9. Connect paper strips to each of the paper clips on the parallel string so that A is opposite T and C is opposite G between the 2 strings.
10. Draw the "double stranded DNA" that you constructed.



11. On your diagram, draw a line after every 9 bases. This should give you 3 sections with 9 bases on each string.





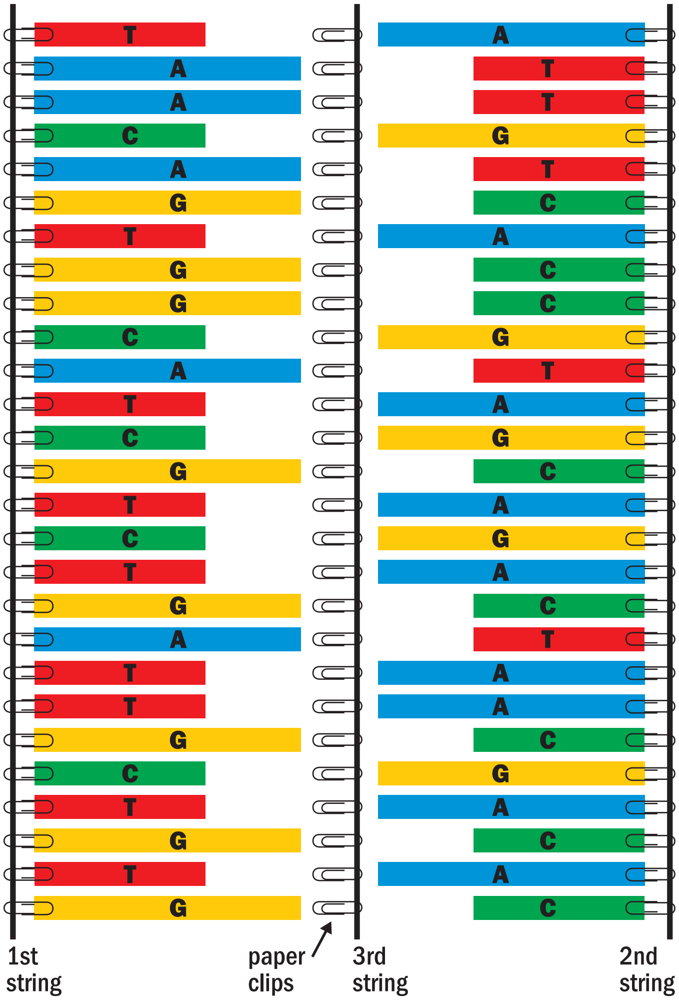
12. Draw a line after each group of 3 bases within the groups of 9 bases.

13. Each group of 9 bases represents a gene that codes for 3 amino acids.

14. Each group of 3 bases represents a codon that codes for an amino acid.

15. In your DNA, each group of 3 bases is a codon and each group of 9 bases is a gene that codes for a protein consisting of 3 amino acids. Real proteins may have over 100,000 amino acids — that would take a lot of string and paper clips.

16. Separate the strings and place the third string with paper clips between the two original strips with its paper clips facing the left-hand string.



17. Attach strips of paper to the paper clips on the third string so that A (third string) faces T (first string); U (third string) faces A (first string); G (third string) faces C (first string) and C (third string) faces G (first string).

18. Notice that the third string has U instead of T. RNA has uracil instead of thymine.

19. Slide the third string out from between the first and second strings and bring the first and second strings back together again.

20. The third string represents a single stranded messenger RNA (m-RNA) molecule that leaves the nucleus of the cell to direct the amino acid sequence of a new protein formed in the cytoplasm of the cell. This process is called **transcription,** which comes from the word *transcribe*, which means to write out a copy. The original double-stranded DNA (represented by the first and second strings) remains protected in the nucleus of the cell.

21. Your lab report is oral, consisting of pointing out and describing the chromosomes on the onion root tip slide and your model of DNA and the process of transcription.

22. Save the 3 strands (strings with paper clips and bases attached to them) that you made for the next lab.

This lab is designed to visualize the structure of DNA in genes and how mRNA is produced from DNA. It is amazing how it works this way in all life forms showing God's wisdom in the details. The DNA in the originally created life forms has been replicated from one generation to the next. This DNA produces the enzymes that replicate DNA and the mRNA that is used to produce proteins — including these same enzymes.

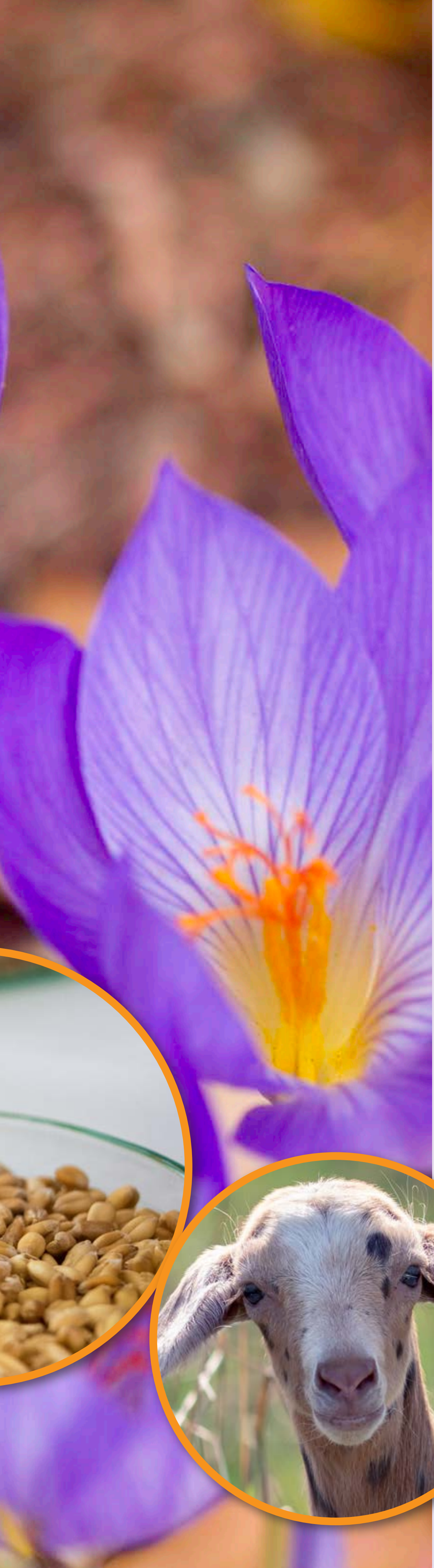
CHAPTER 21

Genetic Mutations and Variations

OBJECTIVES

At the conclusion of this lesson students should have an understanding of...

- Species and kinds of creation
- Kinds of mutations
- Speciation and polyploidy
- Natural selection and artificial selection



SPECIES AND KINDS

The idea of genetic variation has been a difficult topic for many years. Aristotle taught that there were different levels of complexity in living forms. He also taught that they all fit into groups and could not change from one group to another. Later, evolution became popular with the idea that all living organisms came from a simple beginning life form that evolved from non-living materials. This is very different from the creation account in Genesis where God created all living things in groups called kinds (the English translation). It has been thought for several years that species represented these kinds, so the idea of "**fixity of the species**" came about. In recent years there have been observed many cases where animals and plants of different species mated and formed hybrid offspring that could have offspring. If they could breed and have offspring, they should be in the same kinds, even though they were in different species. So what are the kinds that Genesis introduced?

Aristotle used the terms *genus* and *species* to mean generic and specific categories for classification. In 1686, John Ray was the first to give the term *species* a biological definition. In the 1700s, the Swedish biologist Carolus Linnaeus placed organisms that were similar in the same species and those that were different from each other in separate species. This took place many years after Moses wrote Genesis, and was developed by studying organisms rather than trying to understand the created kinds. This means that the word species many times may not be the same thing as the kinds of creation. The test of seeing which organisms can breed and have offspring has been the best test to tell which are in the same kinds. In Genesis, God told those in the same kinds to be fruitful and multiply over the earth. Some have gotten confused with this issue and thought that it was an open door to allow for evolution. But it sets distinct limits as to which organisms can interbreed. From the creationist perspective, a limited amount of variation can help us understand how we have

WORDS TO UNDERSTAND

- allopolyploid
- artificial selection
- chromosomal mutations
- deletion
- duplication
- fixity of the species
- inversion
- natural selection
- point mutations
- polyploidy
- translocation
- transposon

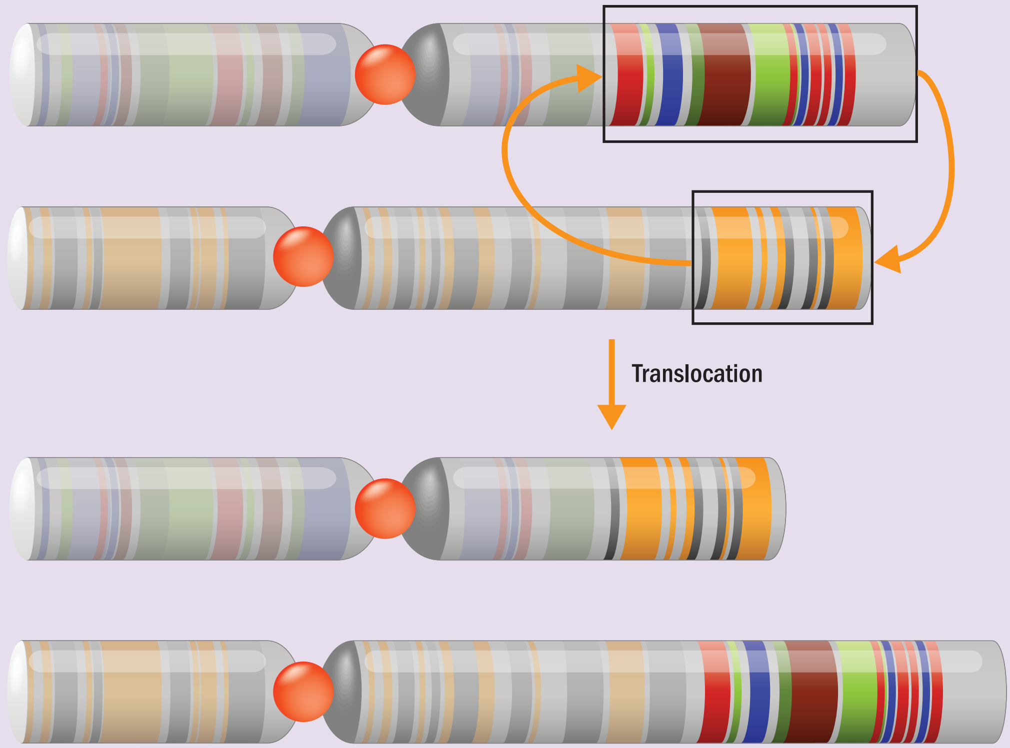
more variation today than was present right after the flood. An example is that bulldogs, German shepherds, greyhounds, and cocker spaniels all came from the same breed of dog. In fact, all forms of dogs, including wolves and coyotes, can interbreed and have pups. So what are the ways that there can be genetic variations within the created kinds? That is the purpose of this chapter. It is interesting that the amount of variation has specific bounds and cannot be used to justify an evolutionary model.

KINDS OF MUTATIONS

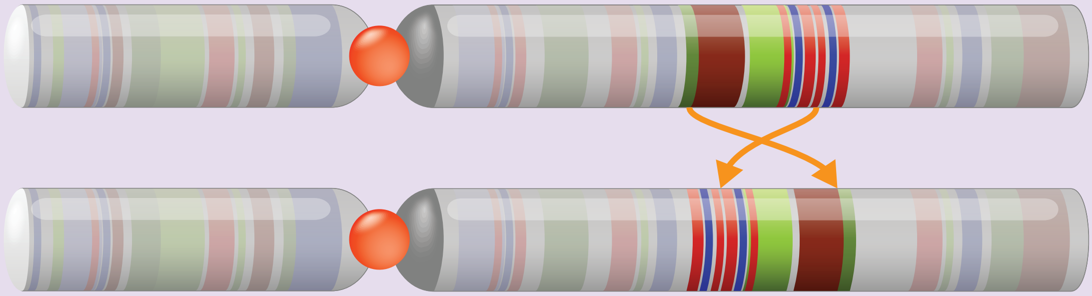
Mutations are alterations of the genetic material. Sometimes they produce variations in phenotypes and sometimes they produce disease and death. Some are called **point mutations** that alter a base pair in the DNA. Look back at the chart in chapter 15 (Genetic Code) showing the bases in the codons of mRNA that code for their respective amino acids. Some of the codons are redundant, meaning that more than one codon combination codes for the same amino acid. If GAA becomes GAG by the third adenine becoming a guanine, it still codes for glu (glutamine). This is by God's mercy, not a mistake of evolution. But if GAA becomes GAU by the third base adenine becoming uracil, it codes for the amino acid asp (aspartic acid). Sometimes it makes little or no difference when this happens because the amino acid is not in a critical position in the protein. Sometimes the slight modification of a protein can produce a protein that can survive and function in hotter or colder conditions. At times, this is God's grace in allowing organisms to handle changing environments that would otherwise be very harmful to them. But if the amino acid is critical to the protein, the effects can be quite severe. This is a result of sin entering the world, and disease and death being the result. But in spite of this, it is reduced by God's grace, and death is conquered by the shed blood of our Lord. This way we do not have to spend eternity in a body of disease and pain.

Other types of mutations are called **chromosomal mutations**. Examples are translocations, inversions, duplications, or deletions. **Translocations** are the exchanging of sections of chromosomes within chromosomes or between chromosomes. The researcher Barbara McClintock found that sections of chromosomes (called **transposons**) moved around between parts of chromosomes of corn cells. Like crossing over, it was found that this is a very natural enzyme directed process. Sometimes, sections of chromosomes are swapped between entirely different chromosomes. It produces healthy variations that can account for quite a bit of the variation that we see today that arose since the animals came off the Ark after the Flood of Noah.

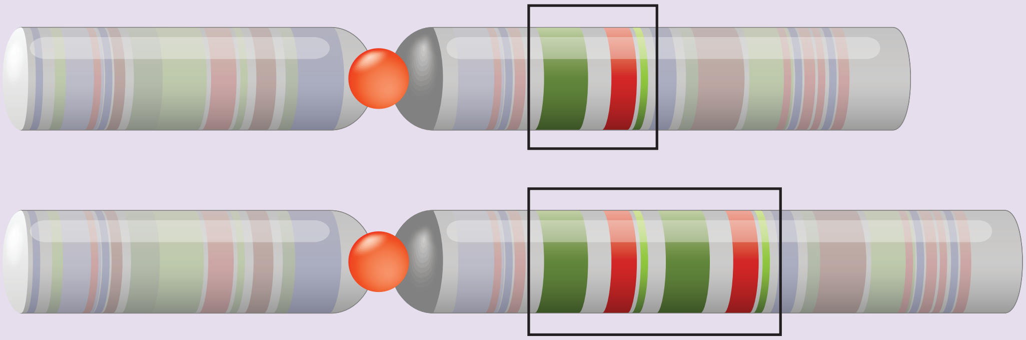
Sometimes it is possible for the interior portion of a chromosome to be broken and reattached in the inverse order, as shown here.



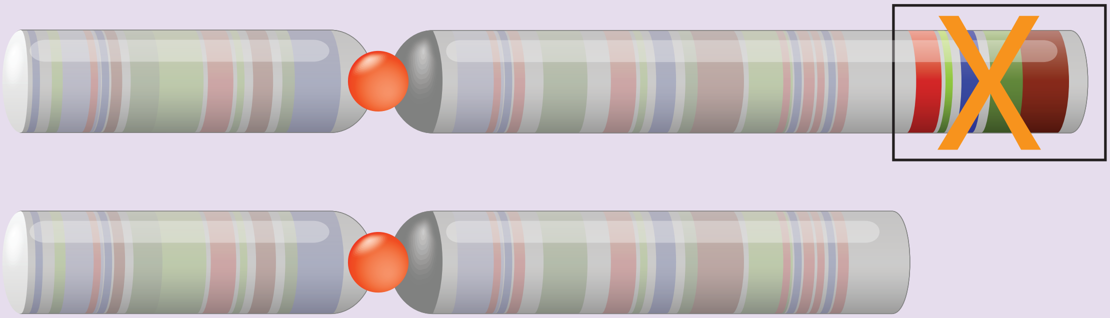
An **inversion** usually does not affect the individual adversely, but it can make them sterile so that they cannot have offspring. This is because in meiosis the homologous chromosomes cannot synapse properly because the bases will not match up to each other in the right order to produce a tetrad.



A **duplication** can produce more than one copy of a gene in a chromosome. Sometimes when duplication occurs, one copy is changed by point mutations while the other one is not. If one of the genes were to be changed enough, a new gene could result. Many cite this as the chief means of the evolution of new life forms. But research has not demonstrated that enough changes ever occur to produce a new gene. Usually the duplication can have a few different amino acids but nothing too significant.



Sometimes a **deletion** occurs where a gene or part of a gene is eliminated. This is always harmful because it results in a missing protein in a cell.



These chromosomal mutations usually result in the individual not surviving or surviving very poorly. Sometimes crossing over, transposons and gene duplications can result in some natural variations. These processes do not produce the kind of variation that Charles Darwin expected. They possibly account for some of the variation within the kinds of creation. Beneficial variations would be expected to be formed by enzymes coded for in the DNA and repair enzymes.

SPECIATION AND POLYPLOIDY

Because the term *species* is often different from the term *kind*, some biologists have called some organisms by different species names that were originally the same species. They call this developing of a new species speciation. But it is just a modified form within the same created kind. Theodosius Dobzhansky called a group of fruit flies a new species after repeated inversions and translocations. Some have called this microevolution. Darwin said that very small changes over millions of years would produce large changes and all of the biological diversity that we see today. That is just based upon his own ideas and not scientific evidence. Some plants (like the Jimson weed) have been known to be called different species because of a number of inversions and translocations. The inversions and translocations do not result in the loss of DNA but rather a change in the regulation of the DNA transcription because the genes are in different positions in the chromosomes.

Another important source of genetic variation is **polyploidy**. This is more common in plants, but has been observed in a few animals. This is where there is more than two of each chromosome. It can be caused in some plants by spraying them with a compound called "colchicine" that comes from a European flowering plant called the autumn crocus (*Colchicum autumnale*). If there is a cross between 2 similar plant species and the hybrid (usually sterile) has all of the chromosomes from both parent plants, it is called an **allopolyploid**. An example is the attempt to produce a plant that had the top of a cabbage and the root of a radish. But instead a plant with the top of a radish and the root of a cabbage resulted. God has a sense of humor.

Polyploidy plants often have larger flowers and fruit. Some examples that were produced with colchicine are the large flowered chrysanthemums, Bartlett pears, and navel oranges. Sometimes this is how some of the seedless varieties (such as seedless watermelons) are produced because they tend to be sterile (produce very few seeds). The wheat that is used to make bread here in the United States is a polyploidy. It has produced a mixed blessing. The bread made from this wheat holds together better, making thin sliced bread possible. It is also high in the protein gluten (that holds the bread together) which in its high concentration has resulted in celiac disease in many individuals. This is why you can find gluten-free foods being produced.

Some say that the Bible was written so long ago that it has errors that the authors were ignorant of because of their lack of knowledge of genetics and technology. This could be the case if it was just written by humans. But the Bible was written as the all-knowing God directed human authors. Of course God has a better understanding of genetics than we do because He created it. Second Samuel 21:20 states that in the Philistine army was a huge man with six fingers on each hand and six toes on each foot. In recent years, a gene change was discovered (called a polydactyly mutation) that causes this condition. In Genesis 30, it appears that Jacob produced many speckled and spotted goats by placing speckled and

A variety of jimson weed flowers

spotted rods in front of the goats that would breed with each other. We know that the rods that the goats looked at could not cause them to have speckled and spotted offspring. Genesis 31: 10 – 13 is where God explains to Jacob that He controlled the breeding of the goats so that most of the offspring were speckled and spotted. God prospered Jacob because those were the ones that his father in-law Laban told him that he could take with him from Laban's flocks. That is interesting because these traits are produced by recessive mutations.

NATURAL AND ARTIFICIAL SELECTION

Natural selection is where some genetic variations survive better than others because of the environment. For example, some may survive better in colder regions and some may survive better in hot, dry regions. Some state that natural selection is the driving force of evolution. But natural selection does not produce the variations. Many variations are produced as described above, including the process of crossing over. Without a Creator Designer it is hard to explain the many DNA enzyme–directed processes, and that there are extensive enzyme-directed repair mechanisms to correct harmful mutations.

Artificial selection is a similar process, where humans deliberately cross certain organisms with each other to produce offspring with specifically selected alleles. An example is the work of the late Dr. Walter Lammerts (Horticulture Professor at UCLA) who produced the many varieties of roses that we have today by selectively breeding them (similar to the work of Gregor Mendel). He was also one of the founders of the Creation Research Society.

Charlotte Armstrong

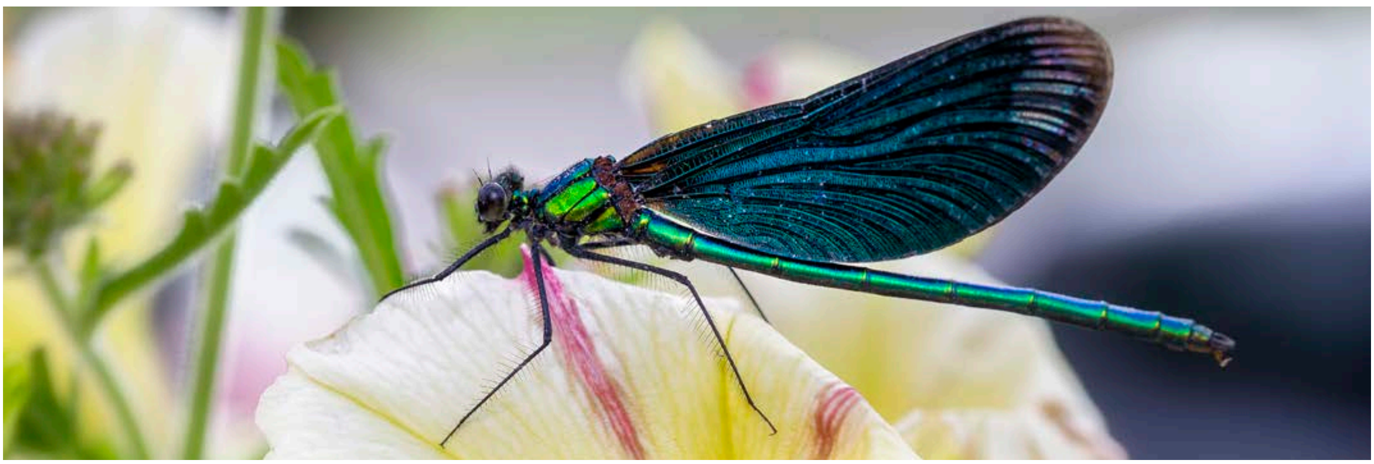
Dean Collins

Many have wondered how there could be so much variation in humans today if we all came from just 2 parents – Adam and Eve. We all started out with the DNA that Adam and Eve passed on to their offspring. This has caused many to question whether God meant the early chapters of Genesis to be read as history or figurative poetry. In studying this chapter you saw a number of ways that the variation could be possible. These processes do not produce DNA from non-DNA as evolution would require. Rather they modify already existing DNA. These modifications produce small changes – not enough to get an orangutan from a chimpanzee. Remember that they are controlled by enzymes that were originally coded for in the original DNA from Adam and Eve. God predestined the modifications, when they would occur and how they would occur. He did this by designing enzymes coded for in the DNA that would produce these modifications. An important principle is that something may look different from the Scriptures at first but as objective research is carried out, the picture becomes clearer and the Scriptures hold true. Genesis can be trusted fully as history.

Minuette

Queen Elizabeth

Genetic Variation



REQUIRED MATERIALS

- Paper and pencil
- Access to insects or pictures of insects

INTRODUCTION

This chapter is about a number of ways that modifications of DNA can occur that bring about variations in the genotypes of the next generation. There are limits as to the nature and amount of variations of DNA that can take place. If the DNA is changed such that critical proteins are produced that cannot function, the organism dies.

You have certainly noticed that you have some differences from your parents and siblings. What if your parents told you that you were going to have a baby brother who would be hairy like a monkey and have webbed feet? That is silly because it does not happen.

Can a German shepherd give birth to a collie? This does not happen. But a German shepherd can mate with a collie and have puppies that look like part German shepherd and part collie. The German shepherd does not have some of the alleles that are needed to produce a collie — but a collie does. It appears that the dogs that were released from Noah's

Ark became all of the other dogs. That was thought to be impossible at one time, but after the mechanisms introduced in this chapter and some others were better understood, it seemed reasonable. This is not the same as evolution because it is making subtle changes in DNA that was already there. In spite of these variations, they are still all dogs. There is no new information that is added.

In this lab exercise, you are going to look at a number of insects and see some similarities and some differences. In the Book of Genesis, God commanded the life forms to reproduce after their kinds. This created distinct groups that could not cross over between each other to produce offspring. But then God allowed for very limited variations within each kind so that as they spread out over the earth they could survive in very different environments.

Biological classification is based upon a system of dividing organisms down into smaller and smaller groups based upon their similarities and differences. This is the system for insects.

DOMAIN EUKARYA
(have true nuclear membranes)
KINGDOM ANAMALIA
PHYLUM ARTHROPODA
CLASS INSECTA

The class Insecta is broken down into orders which are studied in this exercise. To complete the classification levels, orders are broken down into families, which are broken down into genera (plural of genus), which are broken down into species.

PURPOSE

This exercise will give you experience looking at insects that appear to be in very distinct groups and insects that are very similar to each other that could possibly be the same kind.

PROCEDURE

1. What you do here will depend upon your access to insect specimens. If you are doing this exercise in a region where it is spring with many insects hatching out, you should go out and see how many you can find that are listed below. If you have snow on the ground and spring seems like it will never come, then you will need to look up pictures of the insect. You will probably have to look up some, no matter where you are. If available, you should be able to find some in a pet shop.
2. Find pictures (the Internet should be very helpful) or specimens of insects in the following orders.
   A. Lepidoptera — butterflies and moths
   B. Diptera — flies
   C. Ephemeroptera — mayflies
   D. Hymenoptera (winged) — winged ants, wasps, and bees
   E. Odonata — dragonflies and damselflies
   F. Isoptera — termites (I hope you do not find these specimens)
   G. Hymenoptera — ants
   H. Coleoptera — beetles
   I. Orthoptera — cockroaches, walking sticks, grasshoppers, crickets
   J. Hemiptera — true bugs
3. For each of these orders, try to find several examples that you can look at. For each order, try to list those together that you think could have been in the same kind of creation. This means that you would expect that they are similar enough to each other where they could interbreed and produce offspring that could again produce offspring. Each order is going to have insects that would not be in the same kind. Some think that in some cases, perhaps those in the same family or genus may be in the same kind. You could only tell for sure if you did breeding experiments with them. The purpose of this exercise is to gain experience dealing with this concept rather than to actually identify which are in the same kind. This is difficult even for well-trained and experienced entomologists (insect specialists).

4. Prepare your report in an orderly fashion so that someone else looking at it will understand it. It is your option whether you include pictures in your report or not. That will depend on what resources you have available.

A biology course is not complete without an insect collection. The diversity in insects is a good indicator that God created many different insect kinds at creation. Someone asked why God created mosquitoes. Contrary to what we would suspect, mosquitoes do not use blood as a food source. They get their food from nectar in flowers like many other insects. However, female mosquitoes need mammalian blood for the development of their eggs. There are probably mutations in mosquitoes that damage a protein needed for their eggs to develop and they must rely on blood to supply that protein. When Christ returns and makes all thing right, He will correct that mutation and mosquitoes will no longer bite. The Bible states that lions will not have to eat lambs then either.

Lepidoptera


Common blue butterfly


Common tiger butterfly


Magpie moth


Drury's jewel moth

Diptera


Band eye drone fly


Mosca equilibrista

Ephemeroptera


Mayfly (Baetidae)


Small minnow mayfly

Hymenoptera


Carpenter ant


Winged bulldog ant


Paper wasp


European Beewolf


Honeybee


Red-tailed bumblebee

Odonata


Blue-fronted dancer


Eastern forktail damselfly


Skimmer Dragonfly


Cretan dragonfly

Isoptera


Giant forest termite


Nasute termite

Hymenoptera


Pharaoh ant


Inchman

Coleoptera


Blister beetle


Fogstand beetle

Orthoptera


Domino cockroach


Common shining cockroach


Walking stick


Golden-eyed stick insect


Spotted grasshopper


Malaysian grasshopper


Oak bush-cricket


Golden cricket

Hemiptera


Cicada


Shield-backed bug