CHAPTER 8 - BIOLOGY PART 2 - CELL BIOLOGY

Visual #8-1

Biology is the study of life in general. So-called *historical* biology has to do with untestable ideas about how living things might have acquired their features in the prehistoric past. Many rule out the possibility of creation and treat historical biology as synonymous with evolution.

Empirical or *operational* biology, on the other hand, has nothing to do with the origin of biological features but instead deals with processes going on in the present that can be observed, repeated, and tested. Empirical biology can be divided into many specialized areas such as botany, zoology, bacteriology, microbiology, genetics, and so on.

All known types of living things have the following characteristics in common.

Visual #8-2

- They take in nutrients. These furnish the raw material needed to keep them functioning as well as allowing them to grow and reproduce. Cellular respiration, in which cells take in substances such as oxygen or carbon dioxide, is involved in this process.
- They excrete wastes into the surrounding environment. If they did not, they would quickly become sacks filled with materials useless to them. Transpiration, in which plants release water into the environment, is involved with this process.
- They reproduce. As part of this process, they pass along some or all of their traits to their offspring.
- They exhibit *homeostasis*, that is, they maintain fairly stable internal conditions.
- They grow and develop.

  One celled organisms often simply get larger with little change in their overall structure until they divide into two "daughter" cells. Each of the daughters repeats the process.

  Multi cellular organisms develop specialized organs and systems as they grow.
- They react to their environment. (This characteristic is sometimes known as *irritability*.)

Though there are many different areas of biology, the basic unit of life is the cell. Our focus will therefore be on the biology of the cell.

I. BIOLOGICAL CLASSIFICATION SYSTEMS.

Visual #8-3

Though there are several classification systems in biology, one of the most commonly used has three Domains at the highest level: Archaea, Bacteria, and Eukarya. Other systems have two: Archaea and Bacteria, including Eukarya as part of Archaea.

Archaea and Bacteria are prokaryotes (cells without nuclei), and Eukarya are eukaryotes, cells that have a central nucleus. "Karyote" in the name is from the Greek word for "kernel." The "pro" prefix means "early" or "first" and was assigned in the 1930s based on the assumption that evolution between categories had occurred. "Eu" is the Greek prefix for "good" and was assigned based on the assumption that the eukaryotic cells had evolved to a higher level.

Some systems divide Eukaryotes into five Kingdoms: Plantae, Protozoa, Animalia, Chromista, and Fungi or Animalia, Plantae, Fungi, Protista and Monera. Others use six kingdoms, with Monera divided into Archaea/Archaebacteria, and Bacteria/Eubacteria.

Visual #8-4

Each Kingdom is divided into Phyla. These may be grouped in Subphyla. The next level is the Class, which may be divided into Subclasses. Next are Orders, which may be divided into Suborders. The next level, the Family, may be divided into Subfamilies. Genera (plural of Genus) may be divided into Subgenera. Finally, Species may be divided into Subspecies.

II. CELL THEORY.

Visual #8-5

In order for an idea to be considered a scientific theory, it must be well tested by experimentation. It also must meet the following criteria:

- First, it explains a number of observations.
- Second, it has the potential to be falsified.

- Third, it enables us to make accurate predictions about future observations.

Cell theory has three main parts, and meets all the above qualifications.

1. All life is composed of cells. If even a single organism were ever discovered that did not meet the criteria of cell theory, we would have to admit that the theory was wrong.

   Some organisms such as amoebae and bacteria are composed of a single cell, whereas others are composed of trillions.

2. The cell is the basic structural unit of both single celled and multi celled organisms.
3. Cells arise from preexisting cells.

A. HOW CELL THEORY DEVELOPED.

Before the invention of the microscope, we could only speculate about the way life was organized. Cells are too small to see with the naked eye.

Visual #8-6

- Though ancient people may have found ways to make lenses, the first *documented* record of anyone making a magnifying glass was Roger Bacon (1214-1292).
- In the late 16th century, Dutch lens makers Hans and Zacharias Janssen came up with the idea of using two lenses to examine small objects. They developed the first compound microscope, but were not able to obtain a magnification of more than nine times the object's size. (Meanwhile, another Dutch lens maker, Hans Lipperhey, developed an early telescope which became the basis for Galileo's improved version.)
- Microscope lenses were gradually improved until they could magnify the object by several hundred times.
- In 1667 Robert Hooke (1635-1703) published his book *Micrographia,* which contained drawings of objects he saw under a microscope. He called them cells because they reminded him of the cells that monks occupied in a monastery.
- In 1674 Anton (Antonie) van Leeuwenhoek (1632-1723) looked at cloth under microscope and observed bacteria for the first time. He also observed wriggling sperm cells and called them "animalcules."
- In 1833 Scottish botanist Robert Brown (1773-1858) first observed the nucleus in plant cells.

Visual #8-7

- In 1838 Matthias Schleiden (1804-1881) observed that the simpler type of plant life were composed of single cells, whereas more complex ones were made of many cells.
- Soon afterward, Schleiden's physiologist friend Theodor Schwann (1810-1882) reached the same conclusion about animals.

  Schleiden and Schwann recognized that there were three features common to all the cells they had observed: a membrane, nucleus, and cell body. (Alberts, 2022) Schwann is often considered the founder of cell theory.
- In 1855 Rudolf Virchow (1821-1902) postulated the "biogenetic law," that all cells come from previously existing cells. (Underwood, 2022) This is the basis of cellular pathology, which says that diseases do not arise when defective new cells spontaneously come into existence but instead when something goes wrong with previously existing ones. The previously existing ones may even have been healthy.
- The French scientist Louis Pasteur (1822-1895) is considered the father of the germ theory of disease.

Visual #8-8

  Previously, many thought that rotting meat produced flies, dirty rags produced mice, and similar ideas. In the 1850s, Pasteur did experiments to disprove this idea. He boiled broth in flasks with bent necks. Broth would normally spoil if left out in the open, but the curved necks prevented it from being contaminated by particles carried by the air. When he opened the flasks to allow air in, things began to grow. Pasteur concluded that there must be microorganisms floating in the air that were contaminating the material.

This was strong confirmation for Virchow's conclusion that life comes only from life.

Pasteur also developed vaccines used to prevent rabies, anthrax and cholera. (Prior to his work, the mortality rate of rabies was 100%.) He originated the process now called pasteurization, in which milk is heated enough to kill the bacteria in it but not enough to destroy its food value.

Visual #8-9

- In 1882 German biologist Walther Flemming (1843-1905) published a book whose title in English would be *Cell-Substance, Nucleus, and Cell-Division* He reported that he had seen cells divide for the first time, in a process now known as mitosis. (Britannica, "Walther Flemming," 2022)

Since Schwann and Schleiden introduced cell theory, there have been three additions: (1) DNA is passed between cells during reproduction; (2) The cells of organisms belonging to the same species are very similar to each other, and (3) Energy flows within the cell.

B. LIMITATIONS OF MICROSCOPY.

Visual #8-10

Visible light has a wavelength between 380-760 nm, or about 0.38 - 0.76 micrometers (μm). By comparison, the smallest cells are about 0.1 micrometers, smaller than the wavelength of light. It is difficult to see details of these cells with a light microscope. Even medium size cells of 5 - 10 μm have internal parts that are too small to resolve with an optical microscope. The only cells whose internal structure we can see with a light microscope are the larger ones, on the order of 100 μm.

Since even the best optical microscopes are limited to about 1000 times magnification, how can we see what goes on inside a cell? Most of the techniques that allow higher magnification are not used with living samples.

1. ***Super-resolution fluorescence microscopy*** is powerful enough to allow us to track single proteins as they develop within cell. However, it is so sensitive that any motion by the observed object causes it to be so blurred and thus useless. It generally cannot be used with living samples.
2. ***Electron Microscopes.*** For higher magnification, scientists usually use some variation of *electron microscope*. Instead of sending visible light through an object as in an optical microscope, an electron microscope uses a beam of electrons.
   - A Scanning Electron Microscope (SEM) bounces a beam of electrons off an object as it scans the surface under the control of computer circuitry.
   - A Transmission Electron Microscope (TEM) sends a beam through a very thin slice of the material being examined.
   - A Scanning Tunneling Microscope (STM) uses a *quantum tunneling* effect to scan the surface of a material at the level of atoms.

   In all types of electron microscope, sensors record the behavior of the electron beam and send the data to a computer that uses it to generate a digital image.

   Note: electron microscopes require a vacuum to prevent air molecules from interfering with the electron beam. See an example at https://www.youtube.com/watch?v=GY9lfO-tVfE.
3. ***Atomic Force Microscope.*** An AFM does not use electrons but instead uses an extremely small computer-controlled probe to scan a surface, also furnishing data for a computer generated image.

There are two reasons these devices are not used for living cells. First, a beam of electrons would immediately kill a cell. Second, any internal motion would result in a blur and render the image useless.

Many of the still pictures we see are composites of multiple electron microscope images. The beautiful animations of the inside of a cell are not the result of observation through optical microscopes; instead, they are actually the result of a great many images put together

by computers using AI (Artificial Intelligence) technology.

4. ***X-ray crystallography.***

Visual #8-11

If scientists want to get a picture of the overall shape of crystals and molecules without needing the details of the rest of the cell, they can send a beam of X-rays (wavelength smaller than an atom) through them. The beam is scattered as it goes through the material and the resulting output is collected by sensors and interpreted by computer processing. This is how the three dimensional shapes of molecules as small as H_2O and proteins were discovered, as well as the double helix structure of DNA.

A note of caution: proteins are generally removed from their normal environment before being subjected to X-rays. This may allow them to change shape. Since a great deal of drug design depends on producing molecules that match the shape of receptor proteins on the cell membrane, even a slight change may produce inaccurate results. (Harkey et al., 2019)

C. HOW WE KNOW WHAT WE KNOW ABOUT HOW CELLS OPERATE.

As noted in Chapter One, we can legitimately "know" things (1) through our senses, (2) through trusting the word of an authority, or (3) through logic. (Intuition is not part of scientific methodology.)

1. Present Processes.

Most of us will never personally look at the image from an electron microscope, but we read books and articles written by those who say they have. The more articles written, the greater the confidence we can have in the reported results. Many researchers have applied logic and computer technology to their observations to put together models and animations. The greater the number of reports that agree with other, the more we decide to trust them.

2. Past Processes - origins of everything.

All these things have to do with the present. As to how the processes began in the prehistoric past, though, we should always remember that no human being actually saw it happen. We can choose to believe humans who were not there, or God, Who was.

III. STRUCTURE OF CELLS.

Visual #8-12

Every known living cell has certain features in common. Many take this to indicate evolution from a common ancestor. However, we will later note many *differences* that are hard to reconcile with the idea of evolution.

A. BASIC STRUCTURE.

Cells are made up of thousands of different kinds of proteins. The proteins are in turn made of twenty very specific amino acids (all in the left-handed form) in precise sequences.

Visual #8-13

All cells are completely surrounded by a membrane made up of a double layer of compounds known as *phospholipids*, arranged tail-to-tail. The heads on the outer and inner sides are known as hydrophilic ("water-loving"), but the tails between the heads are hydrophobic ("water-hating"). This makes it difficult for water to get in and out through the membrane and almost impossible for many other important materials such as phosphates. However, there are gateways known as permeases, ion channels, or protein channels through the membrane at appropriate locations to allow specific materials in and out of the cell where needed.

Plants, fungi, algae, and bacteria have an additional outer layer known as the cell wall around the membrane. Cell walls are made primarily of carbohydrates rather then the phospholipids used in the cell membrane. They furnish structure and rigidity, while allowing signaling chemicals to pass though pores to other plant cells.

B. MAIN TYPES OF CELLS.

Cells are often divided into two major types: *prokaryotes* and *eukaryotes*.

1. Prokaryotes.

Visual #8-14

Prokaryotes have no nucleus. Their DNA forms a single loop. They range in size from about 0.1 - 15 μm, or 100-1500 nm.

2. Eukaryotes.

Eukaryotes include plants and animals. They have a clearly defined nucleus surrounded by a nuclear membrane. Needed substances get in and out through the nuclear pore complexes. The DNA is not a continuous loop, but is divided into chromosomes (colored bodies). Normal human DNA, for instance, has 46 chromosomes.

Though they are still too small to be seen without a microscope, eukaryotic cells are considerable larger than prokaryotes, typically ranging from about 10 - 100 μm. (One exception is the fertilized egg of an ostrich, which starts as a single cell over 14 cm in diameter before it splits into billions of cells.)

C. INTERNAL STRUCTURE OF THE CELL.

Visual #8-15

Most living things (e.g., bacteria) consist of a single cell. With the single exception of the seven-celled Myxozoa (Morris, 2010), others are composed of anywhere from thousands (nematode worms) to trillions of cells. No known life forms consist of in between numbers such as two, four, eight, sixteen, and so on. (”Colonial protozoans” are not multi celled organisms, but large numbers of single celled ones that live in clusters.) There are no known fossil or living transitions showing how single celled organisms could have evolved into multi celled.

A single celled organism is not simple. It has to perform all the functions of life: taking in nutrients, excreting wastes, growing and reproducing, maintaining homeostasis, and reacting to its environment. By contrast, in multi celled organisms, the cells specialize. Some become heart cells, some lung, some brain, some blood, and so on. Each of its cells has the same DNA, but only the segments of DNA needed by that cell are switched on. Other segments remain dormant. (The potential to produce other types of cells remains, leading to stem cell research in an attempt to cure diseases from the individual’s own cells.)

Visual #8-16

A cell relies on a great many ***organelles*** (“little organs”) of various types. Those on the inside of the cell membrane float around in the liquid *cytoplasm*, while those on the outside are attached to it. Some of the organelles used in cells are:

- *Ribosomes* are the framework used to hold together amino acids in the manufacture of proteins.
- *Endoplasmic reticulum* is a network of tubular membranes.

  Rough endoplasmic reticulum furnishes the framework to which ribosomes attach.

  Smooth ER produces materials such as phospholipids, cholesterol, and hormones, as well as storing and releasing calcium ions needed for muscle and nerve function.
- *Golgi bodies*, named after discoverer Camillo Golgi, help process and package proteins and lipid (fatty) molecules (Golgi Body, 2022) to prepare them for delivery to the appropriate places.
- *Vesicles* are self-contained storage sacs inside the cell surrounded by a double walled membrane. They are often used for storage or transport. Several important types:

  Visual #8-17

  Lysosomes, or “suicide sacs,” contain digestive enzymes that break down nutrients into manageable size particles. Lysosomes are surrounded by their own membranes in the interior of the cell. When the cell dies, they rupture and digest it from the inside out. In a multi celled organism, this allows waste materials to be removed.

Peroxisomes are also membrane-bound organelles that help to manufacture lipids and carbohydrates, recycle carbon dioxide, and process materials such as fatty acids and amino acids. (Cooper, 2020)

Visual #8-18

Vacuoles are membrane-bound sacs mostly containing water, used for temporary storage. Their membranes can attach to the outer membrane of the cell and form an opening so as to allow the entry of material to be digested or allow the excretion of wastes. They also serve as storage areas in which digestion can occur and often act as safety valves to expel excess water from inside the cell. (Vacuole, 2020).

- *Mitochondria* are known as the "powerhouses" of many eukaryotic cells. They release energy to be used elsewhere in the cell by changing the phosphate molecules adenosine monophosphate (AMP), adenosine diphosphate (ADP), and adenosine triphosphate (ATP), back and forth in a process called the Krebs Cycle. (Rogers, 2022)

Visual #8-19

- *Chloroplasts* are found in plants and algae that perform a process called photosynthesis. They extract radiant energy directly from sunlight and convert that energy into chemical potential energy as they build up their structures one atom or molecule at a time.

Most types of organisms are *heterotrophs*, that is, they have to digest previously living things to obtain their nutrients. Photosynthetic plants and algae, on the other hand, are *autotrophs*. They build up their structures from elements found on the periodic table. They often become food for the heterotrophs.

Visual #8-20

- *Centrosomes* (*centrioles*) are next to the nuclei of eukaryotic cells. They are part of the cytoskeleton and contain *microtubules*, which extend through out the cell and furnish a framework on which the parts of the cell are transported to the location they need to be. (Rogers, 2019).
- *Kinesin* and *dynein* are "motor proteins" that "walk" along the microtubules throughout the cell to carry materials wherever they need to go. See computer animation at https://www.youtube.com/watch?v=y-uuk4Pr2i8 .

Visual #8-21

- *Cilia* are microscopic hairlike structures on the surface of many animal cells. For some, they are primarily a means of propulsion. On others, they also beat like tiny paddles and create currents that carry nutrients and oxygen along the surface of the cell and also push away wastes (Augustyn, 2019), as for example when they help to propel mucus away from the lungs.

  Cilia are also important pasts of hearing and balance mechanisms in the inner ear.
- *Flagella* are somewhat like cilia in structure, though their principal function is often locomotion. In eukaryotes, they tend to be whip-like structures that wave back and forth. In many bacteria, though, they have a helical structure and function like rotary propellers. (Rogers, 2016)

  Flagella are driven by microscopic electric motors and are able to swivel through 360 degrees and reverse direction (Behe, 1996). Both the flagellum and the motor are composed of dozens of proteins in precise sequence. If any one of the parts is missing, they do not work.
- *Microvilli* are small protrusions from the surface cells of multi celled organisms. Microvilli are shorter and thicker than cilia. They increase the surface area and thus increase the cell's ability to take in nutrients.

None of these structures develops or arrives in its proper place by random chemical action. Every one of them is the result of information programmed into the cell's DNA.

D. FUNCTIONS OF DNA.

A cell spends most of its life getting ready to reproduce, while also maintaining its normal functioning in order to stay alive. It has to take in enough raw materials to duplicate its

Visual #8-22

DNA and all the other parts of the cell. In addition, it contains the genetic information needed to produce an unlimited number of descendants. Most of the genes in eukaryotes such as humans do not produce visible results. That is, they are *unexpressed*. If you believe the Bible, you should realize that that God, Who knows the end from the beginning, had you in mind when He put unexpressed genes in Adam's DNA that would recombine thousands of years later and produce YOU.

DNA stands for *deoxyribonucleic acid*. It stores the information needed to produce and maintain a living cell. DNA sounds similar to RNA (ribonucleic acid), but the difference in names is because the former is centered around a sugar called deoxyribose, which has one less oxygen atom than the ribose sugar that forms the framework for RNA. (Hence the *deoxy-* in DNA.) Various types of RNA perform many of the practical functions of cell operation as they follows the instructions programmed in the DNA.

- Eukaryotic cells have a nucleus housing the DNA in multiple smaller segments known as *chromosomes*. The word means "colored body" and was assigned because chromosomes accept dyes fairly easily and become easy to see during cell duplication. (Humans, for example, have 46 chromosomes).
- Prokaryotes do not have a nucleus. Their DNA forms a single loop, usually containing only a single chromosome. However, in some there are two or more chromosomes (*Prokaryotic chromosome structure*, 2022). The chromosome(s) is divided into smaller segments called plasmids.

Regardless of the difference, every cell has DNA.

Visual #8-23

DNA has three obvious functions: (1) Maintaining and repairing the cell, (2) Duplicating every part of the cell including itself, and (3) Furnishing the genetic information to produce a potentially unlimited number of descendants.

1. Manufacture of Cell Components.

Cells are made mainly of proteins, which in turn are made of twenty specific left-handed amino acids. The amino acids do not just line up into the correct order according to any inherent chemical properties, though. They are forced to line up in precise sequences by the information contained in DNA.

a. Chromosomes.

Visual #8-24

DNA contains the *genotype* (the genetic instructions) for the cell. (By contrast, the *phenotype* is the visible structure produced by the DNA.) DNA has a double helix structure, like the threads on a screw. As noted above, it is subdivided into *chromosomes*.

b. Genes.

Each chromosome is divided into thousands of *genes*, which contain information needed to produce the structures of the cell. *Homeotic* genes (e.g., those that produce hearts, lungs, and so on) are crucial to life and are the same in every individual of a particular type. *Alleles* are genes that exist in multiple forms, such as the genes for hair and eye color. Some alleles are *dominant* (visibly *expressed*) while others are *recessive* (no visible results, but available for future use).

- Many genes contain the instructions to produce specific parts of the cell such as proteins.
- Others do not seem to directly produce proteins. Some who believe in evolution have proposed that some of the parts of DNA had specific functions millions of years ago but have lost those functions through the accumulation of random *mutations* (copying mistakes). These are called "pseudogenes" ("false genes").

However, as time goes on scientists have discovered more and more of the

functions of the so-called pseudogenes. They have learned that especially in multi celled organisms, the "pseudogenes" contain structural information or the information to switch certain functions on and off. For instance, some of your cells become heart cells, brain cells, liver cells, skin cells and so despite the fact that every one of them contains the same DNA.

Visual #8-25

Genes are made up of large groups of four molecules called *nucleotides*. (They occur in pairs, so the term *base pairs* is also used.) The nucleotides are adenine, cytosine, guanine, and thymine, represented by the letters A, C, G, and T. Each nucleotide consists of a base, a phosphate (PO_4), and a 5-carbon-atom sugar known as *deoxyribose*.

The nucleotides are used over and over in different sequences, which are unique to each type of organism. The arrangement of A, C, G, and T conveys instructions to the cell, in a way similar to Morse code, which can spell out any message using dots, dashes, and pauses. (For example, dot-dot-dot dash-dash-dash dot-dot-dot is Morse Code for "SOS").

A strand of DNA can contain dozens of chromosomes, thousands of genes, and hundreds of billions of base pairs.

c. Triplets.

The genes that contain the coding to produce proteins are in turn divided into *triplets*, i.e., groups of three. Each triplet contains the information needed to fasten one specific amino acid in place to attach to the next one in the process of manufacturing any specific protein.

i. Universal genetic code.

Scientists have discovered that the same genetic code is used to assemble the correct amino acids into proteins in every call ever studied, from the "simplest" to those considered the most complex.

Since four nucleotides are used in each of the three positions on a triplet, there are sixty-four (four times four times four) possible triplet combinations. These code for the twenty left-handed amino acids used in living things. Scientists have discovered that DNA triplets code for the results as shown below:

Visual #8-26

TGG - Tryptophan	ATG - Methionine
TTT or TTC - Phenylalanine.	TAT or TAC - Tyrosine
TGT or TGC - Cysteine	CAT or CAC - Histidine
CAA or CAG - Glutamine	AAT or AAC - Asparagine
AAA or AAG - Lyseine	GAT or GAC - Aspartic acid
GAA or GAG - Glutamic acid	ATT, ATC, or ATA - Isoleucine
CCT, CCC, CCA, or CCG - Proline	ACT, ACC, ACA, or ACG - Threonine
GTT, GTC, GTA, or GTG - Valine	GCT, GCC, GCA, or GCG - Alanine
GGT, GGC, GGA, or GGG - Glycine	
CGT, CGC, CGA, CGG, AGA, or AGG - Arginine	
TAA, TAG, and TGA - "stop" codes indicating the end of a coding section	
AGT, AGC, TCT, TCC, TCA, or TCG - Serine	
TTA, TTG, CTT, CTC, CTA, or CTG - Leucine	(Black, 1998)

Some have criticized this system as being inefficient, noting that triplets have the potential to code for 64 amino acids rather than just 20. However, the fact that more than one combination may code for the same amino acid allows the same segment of DNA to produce more than one structure, depending where the process of decoding starts. And since the two halves of the unzipped DNA strand are read in opposite directions during reproduction, the redundancy also

allows the manufacturing apparatus to copy the DNA in opposite directions yet produce the same results.

Evolution would lead us to believe that living things underwent tremendous changes from the simplest early cells to the most complex. The fact that every organism known, no matter how "simple" or "complex" uses exactly the same genetic code is difficult to reconcile with this idea. Why would the information storage system remain the same while the rest of the cell went through such drastic changes?

ii. Universal manufacturing mechanism.

Visual #8-27

DNA resides in the interior of the cell, whether in the cytoplasm of prokaryotes or in the nucleus of eukaryotes. When some part of the cell needs more of a specific protein in order to grow, reproduce, or repair itself, it sends a message to the DNA by means of some sort of signal molecule such as a hormone. This activates specific types of enzymes known as *ligases* and *helicases* that interact with DNA. Scientists are not certain how the enzymes "know" which section contains the blueprint for that protein (some pattern of the nucleotides A, C, G, and T), yet they find it.

- The ligases break the hydrogen bonds and the helicases temporarily unzip the DNA segment into its two halves.
- Various enzymes such as *RNA polymerases* use the exposed DNA segment to manufacture a special form of ribonucleic acid known as *messenger RNA*. mRNA consists of a chain of nucleotides that match with the exposed segment, except that Uracil substitutes for Thymine. (For example, if a section of DNA contains the pattern GAGCTA its corresponding mRNA contains CUCGAU.) When completed, the mRNA molecule is hundreds or thousands of nucleotides long.

  In DNA we can use "base pairs" and "nucleotides" synonymously. RNA, on the other hand, does not use pairs. It is a single-stranded molecule rather than a double helix.
- The newly formed mRNA is transported along microtubules by little-understood mechanisms from the area where the DNA is located to the *endoplasmic reticulum* area where the manufacturing is actually done.
- Once there, the mRNA attaches to special bodies called *ribosomes* to maintain its orientation while each triplet of its nucleotides matches up with one *transfer* RNA (tRNA) molecule, also made up of a triplet of nucleotides.
- Each tRNA molecule serves a dual function: on one side it attaches to a specific triplet on the mRNA, and on the other it physically attaches to a specific amino acid.

Visual #8-28

  As the first tRNA molecule attaches to the triplets on the mRNA, it precisely positions the first amino acid. As the second tRNA attaches it allows its amino acid to link up with the first. The first tRNA molecule is then released so it can go get another amino acid and get back in line. The third tRNA allows its acid to link with the second, releasing the second tRNA, and so forth.

- In order to function, a protein cannot just go in a straight line, but has to have a specific three dimensional shape. Once the sequence of amino acids is complete the protein is folded into a specific shape by other little-understood processes involving yet more enzymes. (Englander & Mayne,

2014) When incorrect folding occurs, the protein is unfolded and refolded. Once in its correct shape, it is taken wherever the cell needs it.

In summary: DNA contains the stored information telling the cell how to make more of what it needs, but it does not directly interact with the manufacturing apparatus. Specific segments of the DNA are copied to produce mRNA, which is then transported to the location where the manufacturing is done. The mRNA then fastens to the ribosomes to furnish a template to which tRNA molecules will match. Each tRNA molecule brings a specific amino acid to the correct place to link with other amino acids and form a protein chain. Once the amino acid is linked to its neighbors, the tRNA is free to go get another amino acid. Once the chain is complete, it is folded by enzymes to the shape it needs to be in order to function. The mRNA and tRNA nucleotides can be reused indefinitely.

Once again, the fact that every organism known, no matter how "simple" or "complex" uses exactly the same protein manufacturing apparatus is difficult to reconcile with the idea of evolution from the simplest early cells to those considered the most complex. How could the rest of the cell undergo such a vast number of alterations while leaving the manufacturing apparatus completely unchanged?

2. Self-replication of DNA.

Visual #8-29

DNA guides the reproduction of every part of the cell, including itself, in meticulous detail. The process of cell reproduction occurs in one of two ways:

(1) *Mitosis*, in which the cell divides into two "daughter" cells that each contain the same number of chromosomes as the parent cell. Most cell reproduction follows this pattern, in which the proteins of the parent cell are divided between the daughters. If one gets less, it manufactures what it needs by using the information in its DNA. Unless a mutation (a copying mistake) occurs, the DNA of each daughter is identical to that of its parent.

(2) *Meiosis*, in which there are two different parents. Each furnishes a *gamete*, a special reproductive cell containing only half the number of chromosomes found in the rest of the parent's cells. When two gametes unite during sexual reproduction a new single-celled organism (a *zygote*) is formed. It has some DNA from each of its parents. This cell then reproduces by mitosis. Its daughters and their daughters repeat the process over and over until the organism develops into a recognizable specimen of the same kind as its parents. It exhibits some visible characteristics of each of them, and perhaps a few from grandparents and earlier ancestors.

During the process of sexual reproduction, the new organism receives all the homeotic genes from its parents. It also receives many of their alleles. Some of these may be dominant (for instance, the gene for brown eyes), while others may be recessive (blue eyes). If the organism receives at least one dominant allele in any of the variable areas, that trait is visibly expressed. Only if it receives a recessive gene from both its parents does it express the recessive characteristic. (For example, a child has blue eyes only if it gets the blue-eye allele from both parents.) Thus, many recessive genes may be present but not expressed in the individual. They may show up in future generations as "throwbacks."

a. Operation of Enzymes.

Cells require a great many continual chemical processes, but it is not enough for these processes to occur at the rate they would if left to themselves. In order for the

cell to stay alive, the reactions need to take place far faster. There must be some sort of *catalyst*, a substance that speeds up chemical reactions with out being changed itself. (Like a matchmaker who keeps getting her friends together yet never gets married herself.) Some catalysts such as platinum work passively by simply furnishing a surface for other chemicals to come together and react. Other catalysts actively capture the atoms or molecules they need and then force them to do a specific action. The types of catalyst used most often in cells are special protein molecules called enzymes, some of which make reactions occur millions of times faster than they do on their own. There are thousands of different types of enzymes. Each is present because the information to produce it is coded into DNA, but DNA is only present because enzymes manufacture it.

Visual #8-30

Enzymes serve one of two functions, either putting things together or else taking them apart. Each enzyme is extremely specific in its operation, usually speeding up only a single chemical reaction.

Enzymes are so small - only a few millionths of an inch across - that they can manipulate individual atoms as needed. An enzyme is able to perform such a specialized function because, like all protein molecules, it has a precise 3-dimensional shape determined by the arrangement of the amino acids that compose it. It reacts only with substances that have shapes which complement its own at certain key contact points.

As an example of how enzymes work, consider the enzyme chymotrypsin. This molecule consists of about 4,000 atoms, all in specified position, arranged into 241 amino acid links. Dressler and Potter describe the way it operates:

> "The fitting portion has a kind of springy atomic jaw that aligns the target link; the process is referred to as a lock-and-key mechanism. Chymotrypsin usually catches the charged end of the protein thread and severs the long thin chain. The parts move off, the spring resets and the unchanged enzyme molecule can act again." (Morrison, 1992, 114)

This is only one of the thousands of enzymes in living organisms. Some help manufacture proteins and other parts of the cell, including copies of themselves. For instance, when DNA needs to reproduce the double helix is first "unzipped" by *helicases*. Then *Type 1 topoisomerase* cuts one of the DNA strands into shorter pieces to prevent tangling of the twin strands. It untwists, then *Type 2 topoisomerase* prevents the two halves from winding around each other. DNA *Ligases* reconnect the separate strands which are no longer coiled (Sarfati, 2018, 24-26). A number of other enzymes known collectively as *DNA polymerases* then use the two halves to make two complete new copies of the DNA. These enzymes maintain at least three levels of error-checking and ensure amazing accuracy in the copying process.

Visual #8-31

b. Nucleotide Selection.

The double strands of DNA are complementary to each other, much like a film negative and the photograph made from it. They both contain the same information, but one is the opposite of the other. Wherever an "A" occurs on one half of the DNA, a "T" is found on the other, and vice versa; likewise, "C" matches with "G."

These types are complementary because of matching numbers of *hydrogen bond* sites. A hydrogen atom consists of a proton with an electron free to move around it. This arrangement changes when the atom attaches to other elements to form compounds. In many cases the electron is drawn strongly to the other atoms, leaving hydrogen's proton exposed and resulting in the compound having a positive end.

Visual #8-32

The exposed proton can then be attracted to other atoms that have an excess of electrons, forming a hydrogen bond.

In DNA, "C" and "G" link up with each other because of hydrogen bonds at three matching positive and negative sites, while "A" and "T" link together at two sites. (In RNA, "U" takes the place of "T," but still matches with "A".) The hydrogen bonds between the paired nucleotides keep the two halves of the DNA strand together. However, during cell reproduction helicase enzymes (tiny motors) overcome these bonds and "unzip" the two halves of the DNA. Each half then acts as a template for one of the DNA polymerase enzymes to make two complete DNA strands out of the one that split in two. It selects the appropriate nucleotide from those available nearby and inserts it into the proper place on the newly forming strand. Because of the complementarity of A to T and C to G, the enzyme is usually able to select the appropriate nucleotide. The wrong one is inserted only about 1 in 100,000 times.

Since the two halves of the DNA strand are complementary, they must be readable in both directions to allow correct protein manufacture. If there were not a redundant genetic code as seen earlier in this chapter, this would be difficult or impossible.

c. Preliminary Proofreading.

Visual #8-33

The next step of DNA reproduction uses an enzyme known as *proofreading exonuclease*, named by discoverers Douglas Brutlag and Arthur Kornberg of Stanford University (1972, 241). Because of the physical structure of each nucleotide, the linked pair of "C" and "G" are the same distance across as the "A" and "T" pair. This ensures that a correctly formed DNA strand is a constant diameter. However, if an enzyme detects a mismatched nucleotide in the newly forming strand (an "A" with an "A," "C," or "G," a "C" with an "A," "C," or "T" and so on), it changes the diameter of the strand at that point and slows down the addition of the next nucleotide. When this occurs, the proofreading exonuclease removes the offending nucleotide and tries again to insert the one that fits. This reduces the frequency of errors to about one in 10 million.

d. Final Error Detection and Correction.

Visual #8-34

Finally, other DNA polymerases reread the new double strand of DNA to make sure there are no mismatches. If they find one, they remove the defective segment on the new half, then repair it by rereading the segment on the original and remanufacturing and inserting a corrected, properly matched segment on the copy. This brings the rate of copying errors down to about one in 10 billion (Radman & Wagner, 1988, 40-46).

The method by which enzymes determine which half of the double strand is new and which is old is not well understood. If various groups evolved from common ancestors, they should all use similar systems, yet it seems to vary from one major type of organism to another. Different types "know" in different ways and make corrections only on the defective newly formed half.

e. Summary of Error Correcting Mechanisms.

Visual #8-35

Those who believe life has gone from simple to complex believe that the enzymes and error correcting mechanisms are the result of nothing more than a long string of accidents.

- Since the first living things are supposed to have used some unknown information storage system far less complicated than DNA, the DNA and all its features

would have had to evolve later through copying mistakes. Those who believe that life evolved through purely natural processes must believe that the mechanisms that serve to prevent and correct errors are the result of a series of thousands or millions of errors that were *not* prevented and corrected.

- DNA reproduction and error correction work the same in every type of cell ever studied, from the simplest bacteria to the most advanced higher organisms. They all seem to have had this complex system from the beginning, rather than developing it gradually as they went from simple to complex.
- Those who believe that God directed a process whereby life gradually developed from simple to complex (evolution) may believe that (1) He created life then added the error-correcting mechanisms later, or else (2) He placed the mechanisms in living things from the beginning then overrode those same mechanisms millions of times to make them evolve from simple to complex.
- The elaborate mechanisms in every cell do not ***cause*** evolution. They ***prevent*** it by almost totally eliminating copying mistakes.

The whole system works because DNA produces the enzymes needed to produce correct DNA, but it requires the enzymes to be present from the beginning in order to make the DNA that makes them. This is an irreducibly complex system, all of whose parts have to be present at the same time for it to work at all.

3. Effects of Mutation.

Visual #8-36

Since DNA is an information storage system, a simple analogy can illustrate the effect mutations have on it. Suppose we arrange some letters to say

In the beginning God created.

Could we replace one letter or space at a time to change this phrase to make it say

For God so loved the world ?

Of course we could. Many believe that copying mistakes in DNA produced new information in this way, one "point mutation" at a time. However, let us add a reasonable constraint. Starting with the first phrase we will replace one letter or space at a time, but the whole thing *has to make sense*, that is, it has to have at least minimal function, every step along the way. How far will we get now? Not very. We may get something that makes a little less sense such as "In the beginning God c*h*eated" - the equivalent of a mutation in a nonessential part of the DNA - but before long, we will have a nonsense phrase corresponding to a mutation in a homeotic gene and will be unable to go any farther.

In a similar way, if we start with a functional organism and make changes in its DNA, we have to have something that makes biological sense every step of the way. Mutations in non-critical alleles may produce unusual characteristics (a new color of rose, for instance) or may not be visibly expressed, but a mutation in a homeotic gene will cause the DNA not to make sense. It will produce a corpse instead of an evolving organism.

Visual #8-37

Suppose that a copying mistake slips through the error correcting mechanism. Depending when and where it occurs, its effects may be trivial or they may be fatal. Even a single mutation in a key gene may cause extremely deleterious or lethal effects, e.g., sickle cell anemia, Tay-Sachs disease, muscular dystrophy, cystic fibrosis, congenital deafness, familial hypercholesterolemia, hemochromatosis, Huntington's disease, and so on (Genetic Alliance, 2010).

- *Mutation in an adult.* Only those cells descended from a mutated cell inherit its altered DNA. If a mutation occurs in a non critical area in an adult, it may either not

have much of an effect on the organism (neutral), or else it may lead to a disease such as cancer. However, if the mutation occurs in a reproductive cell it may be passed on to offspring.

- *Mutation in early stages.* A mutation in a homeotic gene during meiosis in the parent, or in the early stages of embryonic development, will almost certainly be harmful or fatal because it will be copied throughout the organism. A mutation in a nonessential gene may produce an odd characteristic or may have no visible effect, though it may be expressed in future generations.

Why do we not see a great many more mutations than we do? Because of the previously noted elaborate mechanisms in the cell that serve to prevent mistakes and correct them on the occasions when they do happen.

a. No mutations known to increase genetic information.

Visual #8-38

We noted earlier that (1) information in a closed system has never been seen to increase spontaneously, and (2) information in an open system increases only when more is inserted from outside. Random changes do not increase organization and information, they decrease it.

All a mutation can do is *change* preexisting information. However, in order to produce new structures in an evolving line of organisms, new information would need to be *added* periodically. If the idea of simple-to-complex is correct there should be a continually increasing amount of information in DNA from the simplest organisms all the way up to humans. This is not the case.

b. No mutations known to benefit a species.

Evolution is supposed to occur not at the level of individuals but of species. Despite occasional benefits to individuals or small groups, no one has documented a single mutation that gave a ***species*** an overall survival advantage. Nevertheless, there are a few mutations that convey an advantage to affected individuals.

(1) A certain mutation in the millimeter-long worm *Caenorhabditis elegans* (*C. elegans* for short) lengthens its life span from the normal 18 days to about 42. However, its rate of reproduction is less than its unmutated relatives, so it is questionable whether the change gives an overall benefit to the species (Van Voorhies et al., 2006)

(2) Some of the aquatic birds on the Galapagos Islands have small, poorly developed wings. This is believed to be the result of a mutation. The change allows the affected individuals to be better swimmers and divers, but they are unable to fly. Their underdeveloped wings are an advantage only in this one environment. Anywhere else in the world, they would be at an extreme *dis*advantage (Cross et al., 2017).

(3) The best known seemingly beneficial mutation in humans is sickle cell anemia, which gives its human victims immunity to malaria. However, this is just a side effect. The mutation brings about a change in the shape of hemoglobin, the substance that enables blood to carry oxygen throughout the body. The result is sickle cell anemia (Sickle Cell Anemia, Mayo Clinic, n.d.).

Visual #8-39

Each red blood cell contains millions of hemoglobin molecules. Since the sickle cell mutation changes the shape of each one, the normally round blood cell assumes a sickle shape. The blood cells clump together in the blood vessels, cutting off oxygen to many parts of the body and killing millions of other cells.

Visual #8-40

An individual who inherits the sickle-cell mutation from both parents will likely die a slow, painful death. If he gets a sickle-cell gene from one parent and

a normal hemoglobin gene from the other, he will have only a mild case of sickle-cell and need not worry about catching malaria. At what price? Sickle cell is incurable. As dangerous as malaria is, it can be cured. Sickle cell is passed on to the next generation. Malaria is not.

This is not raw material for evolution. The individual may receive a slight benefit, but the species suffers.

c. "Mutations" in bacteria and insects

Visual #8-41

There is a common misconception that some bacteria and insects are examples of "evolution in action." Some bacteria have supposedly become "superbugs" by evolving a resistance to antibiotics, and some insects have evolved an immunity to pesticides. This is not evolution and it is not the result of mutations.

Suppose you have a barnyard with machinery set up to automatically care for 1,000 chickens. You put in 950 white chickens and 50 brown ones. Now suppose that someone tampers with the feeding apparatus by putting in a special poison that kills only white chickens. Soon only 50 chickens are left, all of them brown. Since the farm is equipped to feed a thousand, they quickly multiply. Before long the barnyard is populated by 1,000 brown chickens. (The occasional white descendants continue to die out until all the white genes are gone.) The brown chickens did not evolve. They survived because they were resistant to the poison all along. Nothing has been added to the chickens' gene pool; instead, the ability to produce white chickens has been lost.

This is similar to what happens with bacteria and insects. We humans introduce antibiotics or poisons, to which most of them quickly succumb. Those that have a greater immunity survive and multiply until only the resistant strain is left. Nothing has been added; some of them were resistant from the start. If they had acquired this resistance by random mutations there would be many different strains in different geographic areas, each resistant to a different kind of poison. However, some bacteria thawed out after being frozen for over a hundred years have the same resistance as the supposedly new "superbugs" (e.g., Struzik, 1990). They have been here all along. Likewise, "mutated" insects or bacteria show immunity to the same poisons in widely different areas. This shows that their immunity is not the result of mutation but was present in some of them all along. It has nothing to do with evolution.

4. Storage of Genetic Information.

DNA stores all the genetic information for the cell. If it were the result of evolution, it would be expected to show an increate in contents form the simplest early cells to the most highly evolved.

a. Unpredictability of numbers of base pairs.

Visual #8-42

The simplest known living cells have one or two million nucleotides in their DNA; many creatures considered simple have many millions or a few billion; insects have hundreds of millions; birds have about a billion; reptiles have one or two billion; most plants have anywhere from hundreds of millions to several billion; humans have more than three billion. Since humans are believed to be the most highly evolved species, we might expect the numbers to stop there. They do not. Sharks and frogs have about four billion; newts and some varieties of beans have about thirty billion; and some lilies have almost a hundred billion. There is no pattern of simple to complex.

A question of interest in biology classes is whether all this additional genetic

information could have come from mere substitution of one nucleotide for another during reproduction. Something would have had to repeatedly insert large numbers of additional nucleotides into the DNA of evolving organisms, resulting in tens of thousands of times as much genetic information in some creatures as in their hypothetical primitive ancestors.

b. Excess capacity of information storage.

Visual #8-43

Single celled organisms of any particular type are almost identical to each other. However, many multi celled types exhibit a great deal of variability. Humans, for instance, all have the same basic instructions in their homeotic genes (the genotype), but a great deal of variability in their individual features (the phenotype) due to alleles in the DNA. We inherit far more of them from our parents than we need to survive, for instance, alleles that determine skin color, eye color, hair color, height, and so on.

If an allele happens to be *dominant* it is visibly *expressed*. The genes that are present in DNA but do not usually produce visible results are called *recessive*. If we do not inherit any dominant genes for some particular feature, the visible result (e.g., red hair) will be due to the combination of the recessive alleles.

Human DNA has so much information storage potential that if one individual had every one of the alleles, the alleles could eventually recombine to produce every individual that has ever lived. The Bible would lead us to conclude that this happened with Adam.

c. Duplication of genes and chromosomes.

Visual #8-44

Every so often during cell reproduction, an extra copy of a functional gene may be inserted into the DNA. Since the original gene was working properly, the new one is not needed. Some believe that new features evolved over hundreds of millions of years as the duplicates underwent copying mistakes that produced radically new features such as. Of course, the process would have to repeat countless times to produce the rest of the circulatory system as well as the lungs, brain, skin, eyes, ears, bones, fins, arms, legs, wings, claws, kidneys, glands, and so on.

Such a belief requires that duplication must have introduced a great deal of new genetic information in the course of damaging what was already there. However, medical science has found that duplicate DNA segments are harmful rather than beneficial, as in Down syndrome (extra copy of chromosome 21), Warkany syndrome (chromosome 8), Patau syndrome (chromosome 13), and Edwards syndrome (chromosome 18) (Clancy & Shaw, 2008).

Remember also that at minimum, living things require carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorous. While mutations were producing new structures, they would also have to modify the affected organisms to require other elements such as iron, calcium, sodium, copper, molybdenum, manganese, magnesium, silver, and many others. Since members of the animal kingdom are unable to extract these elements from the soil, there had to be parallel mutations in plants to make them go out and get the elements the animals needed out of the ground so that they could use them.

Scientific observation through the centuries shows that copying mistakes do not produce new structures for the first time. They damage what was there already.

d. Coding - e.g., antibody production

DNA is a digital information storage system that contains instructions to produce all parts of the cell including itself. The way the instructions are programmed are

far beyond anything humans have been able to devise. For instance, consider the markers known as antibodies, used to notify the body that an invading substance needs to be destroyed.

At the microscopic level, it's a dangerous world. Our bodies are under constant attack from bacteria, viruses, chemicals, and who knows what else. Fortunately, our immune system protects us from such threats. When functioning properly, it can identify and destroy almost any invader imaginable.

In order to defend the body, the immune system needs first to identify invaders, then to mark them as targets, and finally to destroy them. While all these operations are important, we will here consider only the identification and marking systems. (Those who want to know more about the destruction mechanism should read Michael Behe's book *Darwin's Black Box*.)

Visual #8-45

How does the immune system mark objects that constitute a threat? It uses *antibodies*, tiny Y-shaped molecules composed of two "heavy" and two "light" chains of amino acids, to identify foreign substances as targets. Because of the three-dimensional shapes of amino acids, the ends of the chains form fingerlike protrusions with billions of possible shapes. When one of the combinations matches the shape of an invader, the antibody attaches to it. Whenever the immune system detects an object with an antibody attached, it "knows" that it must destroy it.

Since there are billions of possible types of invaders, how can the body produce antibodies to identify them all? After all, there are only about 3 billion nucleotides in our DNA. If every one of them were used to code for antibodies, they would constitute about one billion triplets, coding for perhaps a few million types of antibodies. Yet our cells have the ability to produce over ten billion distinct types.

The key is in the programming. Only a small portion of DNA codes for antibodies, but it does so in an astonishingly efficient way. Researchers have discovered that the genes coding for an antibody do not need to all come from the same segment of the DNA strand, but can come from different ones. Thus, the antibody coding genes function like a biological dictionary. Just as we can form a complete sentence by taking a word out of the dictionary, skipping some, taking another, skipping more, taking another, and so on, likewise the cell takes a piece of a gene, skips some, takes another, skips more, takes another and so on, until it assembles the complete gene needed to produce a desired antibody. (Some researchers are beginning to consider the possibility that at least a few so-called pseudogenes may also include noncontiguous coding segments.)

According to our present understanding, the "dictionary" is quite small, consisting of four gene clusters. The first cluster contains about 250 gene segments, the second has ten, the third has six, and the fourth has eight. If we take one from segment one, one from two, one from three, and one from four, there are about 120,000 possible combinations producing distinct types of heavy amino acid chains. Since the light chains need not come from the same segments, the number of possible combinations of heavy and light chains is tens of thousands of times greater. This enables the immune system to produce more than ten billion different types of antibodies.

When the body is invaded by a foreign substance such as a virus, it is not enough to have a large number of antibodies floating in the bloodstream. The immune system needs to be able to rapidly manufacture billions more of the appropriate ones. This requires at least three steps:

Visual #8-46

(1) There needs to be a mechanism to attach each of the billions of types of antibodies to the outside of the cells that produced them so that those cells can serve as factories to produce many more.
(2) There needs to be a manufacturing apparatus inside the cell to duplicate only the desired antibody.
(3) It would be wasteful if the body manufactured billions of copies of billions of unneeded antibodies. There needs to be a "messenger" from the antibody on the outside of the cell to notify the manufacturing apparatus that it has captured a prisoner (the virus). Only when the messenger goes to the nucleus of the cell and notifies it to begin mass production does the cell begin its work in earnest.

Where did this amazing mechanism come from? Nobody knows. There is nothing in any known invertebrate from which it might have evolved.

The important point is that all the parts of this system have to be present in order for it to work. If the antibody is floating free it is useless; if there is no duplicating apparatus nearby it is useless; and if there is no messenger between the two it is useless. It is extremely unlikely that the antibody manufacturing system is the product of random chance. It would be reasonable to conclude that it is the product of design.

IV. CONCLUSION.

Visual #8-47

The Bible says that "The heavens declare the glory of God; and the firmament sheweth his handywork." (Psalms 19:1) Anyone who studies the way living things work would have to conclude that we serve a God of unimaginable wisdom and intelligence. The book of Romans tells us, though, that many refuse to acknowledge the Creator:

> "For the wrath of God is revealed from heaven against all ungodliness and unrighteousness of men, who hold the truth in unrighteousness; Because that which may be known of God is manifest in them; for God hath shewed it unto them. For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead; so that they are without excuse: Because that, when they knew God, they glorified him not as God, neither were thankful; but became vain in their imaginations, and their foolish heart was darkened. Professing themselves to be wise, they became fools…" (Romans 1:18-22)

Don't be a fool. Give the Creator the glory that is due Him.

CHAPTER 8 REVIEW QUESTIONS

1. What are the characteristics of a scientific theory that make it more than just a guess?

   a. _____

   b. _____

   c. _____

2. What is the first main point of cell theory as put forth by Schleiden, Schwann, and Virchow?

_____

_____

_____

3. How could this idea be falsified?

_____

_____

4. What are the second and third main points of cell theory as put forth by Schleiden, Schwann, and Virchow?

   b. _____

   c. _____

5. How did Pasteur prove that life would not arise spontaneously from decaying material?

_____

_____

6. What is there about the wavelength of visible light as compared to the size of cells that limits the usefulness of microscopes in observing cells? _____

_____

_____

7. Why can we not observe living cells by using electron microscopes?

_____

_____

8. How do scientists obtain animated views of processes inside cells? _____

_____

_____

9. What protective layer surrounds every type of cell known? _____

_____

10. What extra structure not present in animal cells surrounds the cells of plants, fungi, algae, and bacteria? _____

11. What does this structure do for plant cells? _____

_____

12. What is the difference between prokaryotic and eukaryotic cells?

_____

_____

13. What are the small structures (e.g., ribosomes, golgi bodies) inside a cell called?

_____

14. What is one of the main mechanisms used to transport materials such as proteins inside a cell?

_____

_____

15. Identify three main functions of DNA in the life of a cell.
    1. _____
    2. _____
    3. _____
16. Why were certain segments of DNA formerly called “pseudogenes” by evolutionists?

_____

_____

_____

17. How many different types of amino acids are used to manufacture proteins? _____
18. Triplets of nucleotides can combine 64 ways but only produce 20 amino acids. How is this helpful in manufacturing proteins?
    1. _____

    _____

    2. _____

    _____
19. How does the fact that all known cells use exactly the same genetic code and exactly the same manufacturing apparatus cause problems for the idea of evolution? _____

_____

_____

20. What is the difference between mitosis and meiosis? _____

_____

_____

21. How do enzymes make it possible for DNA to be rapidly duplicated? _____

_____

_____

22. What do atheists believe to be the source of the error correcting mechanisms in DNA reproduction? _____

_____

_____

23. What do theistic evolutionists believe to be the source of the error correcting mechanisms in DNA reproduction? _____ _____

_____

_____

24. What is a mutation? _____

_____

25. How many mutations have ever been observed that add to the genetic information in DNA?

_____

26. In the cases where mutations have given individuals a survival advantage, what effect have they had on the DNA of the affected species? _____

_____

27. Why are the claims that bacteria have become resistant to drugs not evidence for evolution?

_____

_____

28. What pattern is there in the number of base pairs in DNA from the "lowest" to "highest" organisms? _____

29. What usually happens to individuals whose genes and chromosomes are duplicated during cell reproduction? _____

_____

30. How is human DNA, with only three billion base pairs, able to produce ten billion distinct types of antibodies? _____

_____

_____

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