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TASC

TASC's mission is to rebuild and strengthen the foundation of the Christian faith by increasing awareness of the scientific evidence supporting the literal biblical account of creation and refuting evolution.

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Book Review: *Miracle of the Cell* by Michael Denton

By Dan W Reynolds, PhD

Miracle of the Cell (Discovery Institute Press, 2020)[1] is the most recent in a series of books on evolution and intelligent design by Michael Denton.[2,3,4] Denton is best known for his books *Evolution: A Theory in Crisis* and *Nature's Destiny*. Denton holds a PhD in biochemistry and is also a medical doctor. He grew up in England but has also lived and worked in Canada, New Zealand, and Australia. He is a Senior Fellow at the Discovery Institute's Center for Science and Culture. Many of the leading proponents of the intelligent design movement, including Michael Behe and Philip Johnson, have said Denton inspired their work.

Although Denton is an agnostic, his analysis of the biological world is insightful and honest. He believes there is strong evidence for intelligent design in nature. He accepts the secular cosmological and biological evolutionary stories, but he concludes that the observed fine-tuning in chemistry and physics necessary for organic life must have been planned by an intelligence. He is somewhat deistic in his view. He believes that the initial conditions of the universe and the laws of physics were precisely planned, but that the universe then unfolded to its present state on its own. He says that abiogenesis is the greatest mystery facing science. The origin of life, he says, can only be explained by yet-undiscovered physical laws or an intelligent designer.

In *Miracle in the Cell*, Denton examines the "fitness" of the chemical elements for biochemistry. He discusses the chemical properties of carbon, hydrogen, nitrogen, oxygen, phosphorous, sulfur, calcium, potassium, sodium, and some of the transition metals in this context. He explores the elements' electronegativities, bonding geometries, and covalent bond strengths. He discusses Van Der Waals forces, hydrogen bonding, chemical reactivities, and the unique properties of water. He shows how the unique chemical properties of these elements are just what they must be to facilitate the formation and properties of lipids, proteins, and nucleic acids (DNA/RNA).

In this review, I'll cover the aspects of Denton's book that reveal the fine-tuning of chemistry for life.[5] The book will be covered chapter by chapter. I will not delve deeply into his speculations about cosmic and biological evolution. All quotes are of Michael Denton taken from the Kindle edition of the book, which does not have page numbers.

Introduction

Denton lays out his plan to discuss the fine-tuning of the chemical elements for life. He reveals his deistic view. He explains that the properties of water determine the diffusion rates of compounds in the cell and are critical to cell size and function. These diffusion rates ultimately allow cells to crawl, change shape, follow chemical gradients, and selectively adhere to other cells—capabilities critical for the embryogenesis of higher organisms.

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1 Denton M (2020) *The Miracle of the Cell*, Kindle Edition, Discovery Institute, Seattle, WA

2 Akins J (2014 Mar 18) Michael Denton Interview, <https://successfulstudent.org/dr-michael-denton-interview/> Accessed 2021 Apr 19

3 Wikipedia (2020 Dec 29) Michael Denton <https://en.wikipedia.org/wiki/Michael_Denton> Accessed 2021 Apr 19

4 Discovery Institute, Michael Denton, <https://www.discovery.org/p/denton/> Accessed 2021 Apr 19

5 Denton's book and this review will be most accessible to those with some chemistry and biochemistry background. For interested readers, there is a free biochemistry book available on the web: https://bio.libretexts.org/Bookshelves/Biochemistry/Book%3A_Biochemistry_Free_For_All_(Ahern_Rajagopal_and_Tan)

Chapter 1: The Amazing Cell

Denton begins by inviting the reader to view a short video of a leukocyte (white blood cell) chasing a bacterium.[6] Denton remarks:

> What one witnesses there seems to transcend all our intuitions: A tiny speck of matter, invisible to the naked eye, so small that one hundred of them could be lined up across the top of a pin, is seemingly endowed with intention and agency.

Denton continues:

> A cell consists of trillions of atoms, representing the complexity of a jumbo jet and more, packed into a space less than a millionth of the volume of a typical grain of sand. But unlike any jumbo jet, unlike any nano-tech, or indeed unlike even the most advanced human technology of any kind, this wondrous entity can replicate itself. Here is an "infinity machine" with seemingly magical powers.

Denton says that the cell has the greatest known complexity packed in the smallest volume. We have only scratched the surface of what there is to know about cells. Cells occur in great diversity of form, function, and means of movement. Cells can count molecules of sugars and amino acids; trigger all or nothing responses; assemble into patterns; survive extreme conditions (desiccation for hundreds of years, high salinity, extreme temperatures, etc.); measure the passage of time; sense electrical and magnetic fields; communicate with each other via electrical and chemical signals; self-replicate; selectively attach to other cells; build diverse multicellular organisms; covert light into chemical energy, etc.

Chapter 2: The Chosen Atom

Denton explains how people once believed in a mysterious vitalist force that was uniquely capable of generating the molecules of life. Denton observes:

> In the early modern period right up to the first decades of the nineteenth century, many biologists were vitalists, believing that the unique behavior, characteristics, and abilities of living things that were not shared by non-living things—including sentience, agency, and the capacity for self-replication—were the result of a nonmaterial, indwelling vital spirit.

However, properties once thought attributable to a vital force have been found to be due to the properties of matter and certain elements in particular. People thought that organic compounds could only be made by living things until the synthesis of urea by Friedrich Wohler in 1828, which showed a biochemical compound could be made by nonbiochemical means.

Soon many compounds found in living things were made synthetically. Most of the compounds contained carbon, hydrogen, nitrogen, and oxygen. Soon the chemicals of life were seen as special because of the unique properties conferred upon them by their elemental makeup, especially carbon, and not because they were the product of a vital life force. The atoms that make up biochemicals are specifically suited to form compounds that make life possible. Once the uniqueness of carbon was recognized, the field of organic chemistry (the study of the compounds of carbon) was born. Denton remarks:

> By the beginning of the twentieth century, more than 100,000 organic compounds had been documented. And all the basic compounds of living organisms—the twenty common amino acids used in proteins and the four nucleotides used in DNA, as well as many of the sugars and fats and fatty acids found in living organisms—had been synthesized in the lab.

There are more than 20 million organic compounds known today.[7]

Carbon can form a wide variety of compounds. Carbon can bond with itself to form stable molecules with huge molecular weights (1 million or greater). Carbon can bond to many other elements to form an almost endless variety of stable compounds. The diversity of compounds based on carbon make construction of complex cells possible. Elemental carbon takes the forms of diamonds, graphite, fullerenes, and graphene (100 times stronger than steel, conducts electricity, conducts heat). Some of the biochemically relevant types of organic compounds include hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, amines, carbohydrates, amino acids, cellulose, proteins, nitrogenous bases, DNA, RNA, organophosphates, etc. The diversity of carbon compounds made from carbon, hydrogen, oxygen, and nitrogen is immense. These compounds are found throughout biochemistry. Without this diversity, life as we know it could not exist.

Only carbon can form chains of itself of almost any length. Carbon forms stable and large molecules consisting of millions of atoms. No other element can form this

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[6] Hill MA (2018 Jul 4) Embryology *Movie - Neutrophil chasing bacteria* <https://embryology.med.unsw.edu.au/embryology/index.php/Movie_-_Neutrophil_chasing_bacteria> Accessed 2021 Apr 19

[7] LibreTexts, 25.1 Organic Chemistry <https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Book%3A_Introductory_Chemistry_(CK-12)/25%3A_Organic_Chemistry/25.01%3A_Organic_Chemistry> Accessed 2021 Apr 19

diversity or molecular size. The unique ability of carbon to form large molecules facilitates the existence of DNA, RNA, proteins, carbohydrates, and lipids without which there would be no life. Only DNA, RNA, and proteins are large enough to carry the information required to build and regulate a cell.

A carbon atom typically forms four bonds. If the four bonds are single bonds, carbon's bonding orbitals point towards the four corners of a tetrahedron. Carbon can also form double and triple bonds with itself and other elements. When carbon forms a double bond, its bonding geometry is trigonal planar,[8] and when it forms a triple bond, its bonding geometry is linear. It is the geometries of the bonding of carbon with itself and other elements that facilitate the three-dimensional (3D) structures of large molecules (proteins, DNA, RNA, carbohydrates, lipids, etc.). And it is the 3D structures of the large molecules that facilitate their functions in the cell. The strengths of the chemical bonds that carbon makes with itself and other elements facilitate the formation of biochemicals that are stable to ambient conditions but weak enough to be broken by enzymes. Enzymes are proteins that serve as specific reaction catalysts which lower the energy barriers (energies of activation) to chemical transformations. A particular enzyme will typically only perform one reaction on only one specific compound. Enzymes are capable of performing specific reactions under ambient conditions at rates that are orders of magnitude greater than abiotic (nonbiological) chemistry and in essentially 100% yield (no side reactions). An enzyme has an "active site" where the reactant molecule fits like a key in a lock and is transformed into another compound before being released. Denton explains the significance of the fine-tuning of the stabilities of organic compounds:

> If organic bonds were substantially stronger in the ambient temperature range, say as strong as in many inorganic compounds which may be two to three times as strong (and which can only be broken by heating to very high temperatures), protein movements [in enzymes] could not significantly weaken particular bonds, i.e., decrease the activation barrier for particular reactions. Consequently, the sorts of controlled chemical reactions carried out in living cells would be greatly constrained. Moreover, not only would proteins be unable to exert sufficient conformational strain to significantly weaken particular bonds, but molecular collisions in the ambient temperature range would only very rarely impart sufficient energy to overcome energy barriers and cause bonds to break. On the other hand, if organic bonds were substantially weaker in the ambient temperature range, disruption via molecular collisions would dominate and no controlled chemistry [via enzymes] would be possible.[9]

And as it turns out, the bond energies of bonds made from carbon bound to various elements are similar. The result is that these bonds have similar stabilities under ambient conditions and similar reactivities when transformed by an enzyme; carbon is unique in this.

Biochemistry is known to work from –20°C up to possibly 130°C. This is a narrow temperature range when compared to the range of temperatures found in our universe: near absolute zero (–273°C) up to millions of degrees inside stars. And the temperature range friendly to life overlaps with the temperatures water is in the liquid state. Denton says the correspondence of the stabilities and reactivities of organic molecules with the temperatures at which water is a liquid is miraculous.

Chapter 3: The Double Helix

Proteins, not DNA, were originally thought to be the carrier of genetic information. Proteins are made from twenty different amino acids, but DNA consists of just four nucleotides. We now know that DNA codes for proteins—three adjacent nucleotides (a codon) code for one amino acid—and that the sequence of nucleotides in DNA therefore codes for the amino acid sequences in proteins. Some amino acids are hydrophilic (water loving), and some are hydrophobic (water fearing). The sequence of amino acids in a protein determines how the protein will fold in an aqueous environment through the various hydrophilic, hydrophobic, and intramolecular (see below) interactions and hence what 3D shape the protein will ultimately assume. The 3D shape of a protein determines its function. The specificities of a protein's amino acid sequence and consequent 3D architecture are required for specific enzymatic activity and DNA replication. Science has no explanation for the origin of the sequence information in DNA and proteins.

There are two types of chemical bonds involved in biochemistry: covalent and noncovalent. Covalent bonds involve the sharing of electrons between atoms and are relatively strong. Noncovalent bonding includes hydrogen bonds, dipole-dipole interactions, dipole-ion interactions, and Van Der Walls forces. These noncovalent bonds, interactions, and forces (1) do not involve the

[8] Biochemistry 1.1: Geometry of carbon bonds, <https://www.youtube.com/watch?v=C9_RYP5gQ54> Accessed 2021 Apr 20

[9] The bracketed words were added to clarify Denton's intended meaning.

sharing of electrons between atoms and (2) are usually 10 to 20 times weaker than covalent bonds (making them easier to break). These weaker noncovalent bonds and interactions play a major role in determining the 3D shape and hence function of proteins and the formation of the DNA helix.

Weak noncovalent bonds can form reversibly. For example, pulling DNA strands apart for transcription or replication mainly involves the breaking of many weak hydrogen bonds. The specificity and catalytic power of protein enzymes are largely determined by the weak bonds formed within the protein. Denton says,

> Selective bonding between two molecular surfaces [for example, the active site of an enzyme and a reactant molecule] can only be achieved by using a number of [weak noncovalent] bonds which collectively form a unique, complementary lock-and-key pattern of electrostatic interactions linking the two surfaces together.

Covalent bonds are too strong for this purpose. Several weak, 3D specific, reversible, noncovalent bonds are needed to facilitate the function of an enzyme. If only relatively strong covalent bonds were possible, enzymes would work much more slowly because they would have to make and break strong covalent bonds between the active site and the reactant and product molecules over the course of a chemical transformation. Weak bonds must be weak enough to allow rapid reversibility (capture of the reactant, performance of the reaction, and release of the product) yet strong enough to form specific 3D interactions with the surfaces of other molecules to facilitate the chemistry. The fact that there is a balance of the strength of these weak bonds with the strength of covalent bonds at the temperatures water is a liquid is more evidence for fine-tuning.

The elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur—the key atoms for biochemistry—make covalent compounds with carbon that have defined 3D structures. These same elements facilitate the formation of the weak noncovalent bonding interactions critical to the DNA helix and enzyme function. Transition metals (for example: iron, copper) can form covalent bonds with many of the same atoms. Transition elements, often associated with proteins, confer special activities to these proteins.

The molecular biochemical revolution has erased all vitalist thought but has also revealed the fine-tuning of the chemistry of life.

Chapter 4: Carbon's Collaborators

The elements hydrogen, oxygen, nitrogen, and carbon form covalent bonds in order to have the noble gas electron configurations. Hence hydrogen makes one covalent bond to be like helium, oxygen makes two covalent bonds to be like neon, nitrogen makes three covalent bonds to be like neon, and carbon makes four covalent bonds to be like neon. Covalent bonds between hydrogen, oxygen, nitrogen, and carbon are tight, strong, and stable. Carbon, nitrogen, and oxygen regularly form multiple bonds. The chemical properties of oxygen, nitrogen, and hydrogen help determine the 3D structures fit for life. They facilitate formation of strong directional bonds. Oxygen and nitrogen allow the formation of organic acids and bases which help determine pH. The diversity of compounds available from combinations of carbon, oxygen, hydrogen, and nitrogen is enormous. Period 2 elements are different from their period 3 neighbors and can't be replaced by them.[10]

The relative electronegativities of the elements play a crucial role in determining the polarity of the bonds between two atoms. Electronegativity is a measure of an atom's affinity for electrons: the higher the electronegativity, the greater the affinity for electrons. The electronegativities of some of life's key elements decrease in the series oxygen, nitrogen, carbon~sulfur, carbon, hydrogen~phosphorus. Covalent bonds between elements with significantly different electronegativities will tend to be *polar,* having greater electron density around the atom with the greater electronegativity. Such a polar bond will have a partially negatively charged end around the most electronegative atom and a partially positively charged end around the atom with the lower electronegativity. For example, an O–H bond has greater electron density (partial negative charge) around the oxygen atom and less electron density (partial positive charge) around the hydrogen atom. Such polar bonds can act as tiny bar magnets (dipoles) and will be attracted to charged atoms or other polar bonds and molecules. This is one of the causes of reversible noncovalent weak bonds discussed above. Polar bonds are attracted to polar water molecules and are hence hydrophilic. If an organic molecule has enough polar bonds, it may have significant water solubility. Examples of polar bonds include O–H, N–H, and C–O. When one end of a polar bond involves

[10] The inadequacy of period 3 elements to serve as replacements, despite having similar chemical properties to their period 2 counterparts, emphasizes the uniqueness and fine-tuning of the elements in period 2 for biochemistry.

hydrogen such as with an O–H bond, the partially positively charged hydrogen atom may be attracted to the partially negatively charged end of another polar bond. Such an interaction is called *hydrogen bonding*. For example, a hydrogen bond can be formed between the hydrogen atom of one hydroxyl group and the oxygen atom of another hydroxyl group and is written as H–O···H–O, where the dotted line between the O and H represent the hydrogen bond. Hydrogen bonds are what hold the two strands of DNA together in the double helix. On the other hand, atoms with similar electronegativities such as C and H form covalent bonds with a more even electron distribution between the atoms. These covalent bonds are relatively *nonpolar* and hence do not attract polar bonds and molecules. Compounds consisting of primarily nonpolar bonds tend to have low water solubility. This is the case for the organic compounds know as hydrocarbons, which consist of carbon and hydrogen. These compounds have very poor water solubility because their nonpolar bonds make them hydrophobic. As we will see, polar and nonpolar groups of atoms play essential roles in the formation of the cell membrane's lipid bilayer and the 3D structure and hence function of proteins.

Water is polar and capable of dipole–dipole interactions, hydrogen bonding, and proton transfer. Water forms a sphere of solvent molecules, a hydration shell, around charged species. Most biochemicals have significant polarity and are therefore water soluble (sugars, proteins, carboxylic acids, nucleotide bases, amino acids, etc.). In water, nonpolar molecules are forced into insoluble clusters. Cell membranes are made from phospholipids. Phospholipids are molecules that have a very polar and electrically charged phosphate end and a very nonpolar long-chain hydrocarbon end. The polar end is hydrophilic while the nonpolar end is hydrophobic. When phospholipids are placed in water, they spontaneously form lipid bilayers. The two surfaces of the lipid bilayer have the polar ends of the phospholipids directed towards the water while the nonpolar hydrocarbon ends are directed away from the water and towards the nonpolar portion of other phospholipids.

Many proteins are found inserted into cell membranes. How proteins fold is critical to the operation of some enzymes. The twenty amino acids that make proteins can be divided into hydrophilic and hydrophobic groups, depending on the nature of their side chains. When a protein is placed into water, the hydrophilic amino acids strive to be on the surface near the water while the hydrophobic amino acids prefer to move away from the water by grouping together. Thus, the protein assumes a shape that maximizes the interaction of the hydrophilic amino acids with water while at the same time moving the nonpolar amino acids together away from the water. The resulting 3D shape is crucial to the proper functioning of the protein. If the electronegativities of carbon, nitrogen, oxygen, and hydrogen had been different, proteins would not fold correctly and life as we know it would not exist.

Cell membranes are semipermeable and protect the chemistry of the cell. Membranes are needed to keep the needed biochemicals in close-proximity so they can react with each other and do the business of the cell. The proteins in the membrane serve as gates for letting nutrients in and waste out. Membranes are self-organizing and to some extent self-repairing. Membranes are flexible and fluid-like, being able to change shape as needed. No other material is known to have all these critical properties. Cells that crawl such as leukocytes need to be able to change their shape. A cell membrane accommodates this need. Lipid bilayers can assume many shapes and form the membranes of various cellular organelles (mitochondria, endoplasmic reticulum, etc.). The overall shape of a particular lipid bilayer depends on the lipid and protein composition. Membranes are relatively thin yet strong. A mammalian cell the size of a pumpkin would have a cell membrane with the thickness of a piece of paper. Folded proteins have about the same width (5 nm) as the thickness of lipid bilayers, a remarkable coincidence needed for ion channels and the regulation of small organic molecules. Some transmembrane proteins are used for signaling, others for cell-to-cell recognition and selective adhesion.

The length of fatty acid chains, the nonpolar hydrocarbon portion of phospholipids, is critical to the required properties of cell membranes. The hydrocarbon fatty acid chains usually consist of 16 or 18 carbon atoms (C16, C18) covalently bound in a linear chain. If the hydrocarbon chains were much longer, they would become wax-like and less flexible. Shorter chains are too mobile and would make the membrane less stable. And the C16 and C18 chains provide a membrane with the same width as folded proteins, another remarkable coincidence that suggests foresight and design.

Cell membranes can have an electrical potential across them caused by the difference in ion concentrations on either side of the membrane. The membrane potential is used to power rapid transport of molecules across the membrane. Sugars and amino acids are transported into a cell by using a sodium cation gradient. Ion gradients facilitate nerve impulses. Ion transport across membranes can be as rapid as 1 million ions per second! Only sodium and potassium cations can function in this crucial role.

Chapter 5: Energy for Cells

The element phosphorus and especially phosphates are uniquely fit for forming the energy currency of the cell: adenosine triphosphate (ATP). A phosphate group is also found in DNA and RNA. Phosphate linkages are much more stable in water than the analogous arsenate linkages;[11] phosphorus is unique in its fitness for its biochemical roles in the cell.

Concerning the energy needs of the cell, Denton observes:

> All cells need energy. They need energy to carry out their varied functional repertoire, including many different enzymatic actions, synthesizing their complement of proteins, lipids and DNA, and pumping ions across the cell membrane. They need energy to move, crawl over the substratum, and transport materials inside the cell, with molecular motors carrying cargoes along microtubules or actin filaments. Most of these activities—from crawling to synthesizing proteins and other polymers such as DNA—can only proceed if chemical energy is put into the system. Generating and using energy is thus basic to all of cell biology.

ATP is the cell's energy currency. A single cell uses 10 million ATP molecules per second, meaning there is roughly a turnover of your body weight in ATP every day. Since there are only 60 g of ATP in our bodies at any given time, each ATP molecule must be used and recharged twice a minute. ATP is thermodynamically unstable but kinetically stable, making it ideal for powering the cell; ATP is stable until it is associated with an enzyme where it releases its thermodynamic energy by being hydrolyzed to adenosine diphosphate (ADP). The negative charges in the phosphate groups make ATP kinetically stable (would have to form a highly charged polyion to form ADP). ATP is universal in all living things—there is no other molecule like it. The chemistry of phosphorus is responsible. If there was no phosphorus, there would be no life.

Cells have two methods for making ATP. Glycolysis, which occurs in the cell's cytoplasm, is an anerobic (without oxygen) process wherein one molecule of glucose [$C_6H_{12}O_6$] is converted into two molecules of pyruvic acid [CH_3COCO_2H] and two molecules of ATP. The second way ATP is formed in cells is through cellular respiration in the mitochondria. Respiration is an aerobic process where pyruvic acid is converted into carbon dioxide (CO_2), water, and 28 ATP molecules. Molecular oxygen (O_2) is used as the terminal oxidant in the respiration that drives ATP formation, but some cells use CO_2 (methanogens) or sulfate (SO_4). Respiration is the process that releases enough energy in the form of ATP for large energy-demanding organisms.

In respiration,[12] food is oxidized, and molecular oxygen is ultimately reduced via the electron transport chain to generate a current that powers the pumping of protons from the outside to the inside of the mitochondria. The potential difference setup by the resulting proton gradient across the mitochondrial membrane is then used to power a molecular machine called ATP synthase, which converts ADP to ATP for use by the cell's myriad reactions.

Chapter 6: No Biology Without Metals

Metals play critical roles in biochemistry. The element iron is needed for hemoglobin, oxidative metabolism, electron transport chains, and larger animal life. One third of all enzymes involve a metal as an essential participant in their function. Iron, copper, sodium, and potassium are critical. Most ribozymes, RNA molecules that function as enzymes, require a metal for function. Iron and copper help transport molecular oxygen. Zinc, magnesium, and calcium stabilize the structures of folded proteins. Metals often serve as catalysts: iron, copper, and manganese are needed for redox reactions involving electron transfer. Sodium, potassium, and calcium help trigger cellular responses. Metals help proteins fold into various shapes, thereby imparting diverse functionality. Magnesium facilitates photosynthesis and the production of molecular oxygen in plants. The cell needs metals to establish transmembrane electrical potentials for powering various cellular activities.

The elements sodium, potassium, magnesium, calcium, cobalt, copper, iron, manganese, molybdenum, and zinc all play essential roles in the cell.

The alkali metal cations of potassium and sodium rapidly move electric charge across lipid bilayers to establish charge gradients used to do work at the cell membrane. Roughly 10^8 potassium ions can move through an ion channel in a cell membrane each second. This is 10^5 times faster than a carrier protein could accomplish the same task. These ions don't bind tightly to organic compounds. This speed is essential for the transmission of nerve impulses in more complex animals. Without potassium and sodium ions, central nervous systems would not be possible.

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[11] Arsenates (AsO_4) are based on arsenic, the next atom in the same family as phosphorus. Although arsenic and phosphorus share some chemical properties, only phosphorus is suitable for its biochemical roles.

[12] For a more detailed discussion of how respiration works as well as other interesting working of the cell, see Reynolds DW (2020) Review of *The Stairway to Life: An Origin of Life Reality Check*. *TASC Newsletter*, July <https://tasc-creationscience.org/sites/default/files/2021-03/jul2020.pdf> Accessed 2021 Apr 19

Calcium triggers rapid conformational changes in proteins such as in muscle contraction. Calcium ions and magnesium ions can move quickly but also may bind to proteins in specific ways that induce conformation changes. Denton says,

> Consequently, in biological systems, calcium is primarily used where chemical information must be rapidly transmitted to a target protein to trigger a particular cellular function. This can be muscle contraction, transmission of nerve impulses across the synapse, hormone release, or changes following fertilization.

Only calcium can transmit chemical signals to proteins rapidly and effectively.

Magnesium is present in all cells. Magnesium is required for the function of over 300 enzymes. Magnesium is necessary for metabolism. Magnesium is essential for the use of ATP for energy in the cell. ATP actually exists as a complex with a magnesium ion, ATP–Mg^{2+}. Magnesium is also required for chlorophyll and thus photosynthesis, a process that splits water into oxygen and generates glucose from carbon dioxide. In chlorophyl, magnesium is situated in a porphyrin ring. The magnesium–porphyrin ring complex has unique light absorbing properties needed for photosynthesis. Chlorophyll's efficiency at converting light into electrical energy is close to 100%.

Various transition metals including manganese, iron, cobalt, copper, zinc, and molybdenum can have various oxidation states which give them various essential properties. Transition metals can channel electrons down gradients efficiently for cellular work. Transition metals have unpaired electrons that can be donated to oxygen to activate it for chemistry. Denton says,

> And for this reason it is always transition metals, most importantly iron and copper, which are used in enzymes involved in oxygen activation, transport, and storage. Without their unique capacity to activate and reduce oxygen, oxidative metabolism would be impossible.

Iron and copper are required for the transport of oxygen for oxidative metabolism. The iron atom, that is in a porphyrin situated in the hemoglobin proteins, can reversibly bind to oxygen without changing it (oxygen) chemically—an essential property. The properties of iron and the attenuation of its reactivity towards oxygen induced by the heme group and the environment of the pocket in which the heme resides are critical to the reversible binding of oxygen. There is a single electron transfer from iron to molecular oxygen which forms an ion pair protected from reacting further by a neighboring histidine amino acid and the pocket in which the heme group resides. The binding of oxygen by hemoglobin is also attenuated in the presence of carbon dioxide and low pH.

Cytochrome c oxidase is an enzyme that transfers electrons to oxygen (reducing it to water) at the end of the electron transfer chain. This enzyme has both iron and copper. No other molecule or other metals are known to be able to play this critical role. Cytochrome c oxidase also contains zinc and magnesium; zinc appears to play a structural role. Magnesium helps in the release of water from the active site.

Manganese is used to oxidize water to molecular oxygen during photosynthesis as a Mn_4Ca cluster.

Zinc is found in enzymes and often functions as a Lewis acid. Denton says,

> Zinc is essential in all forms of life, playing a role in more than 300 enzymes in each of the main fundamental classes: oxidoreductases, transferases, hydrolases, lysases, isomerases, and ligases. All of these roles in turn depend on particular properties of the zinc atom.

Carbonic anyhydrase (which has zinc) is an enzyme that converts carbon dioxide into bicarbonate in the tissues and bicarbonate back to carbon dioxide in the lungs. Zinc is also involved in pH and fluid balance and in producing stomach acid. Zinc is also involved in vision. The carbonic anhydrase can perform 10^6 reactions/enzyme/second. There are many amino acid sequences for carbonic anhydrase in different species, but all have a similar active site where zinc resides. Cadmium, an element in the same family, is substituted for zinc in some cases.

Denton continues:

> To briefly summarize before moving on to the final metal in this chapter: One metal, manganese, gives us oxygen. Two other metals, iron and copper, give us electron transport chains, proton pumping, and ATP. The oxidation of hydrocarbons in the mitochondria gives us H_2O and CO_2. And CO_2 requires another metal atom, zinc, if it is to be excreted from the body in the lungs. Together these provide powerful evidence for a stunning prior fitness in nature for aerobic life.

The last transition metal Denton discusses in this chapter is molybdenum. Molybdenum occurs in four important enzymes. Molybdenum is found in the enzyme nitrogenase, which is responsible for nitrogen fixation (reduction of N_2 to ammonia). Nitrogenases containing vanadium and iron are known.

The fact that all these metals are used in similar ways by all life on earth speaks to their unique fitness for the roles they play. Denton summarizes:

> Of particular interest to us is the special fitness of transition metals for the unique functions on which we advanced aerobic organisms depend. These include the fitness of magnesium for light-capture in photosynthesis, the fitness of iron and copper for the transport and activation of oxygen, and the fitness of zinc for the function of carbonic anhydrase (and consequently for the excretion of CO_2). And of course, the highly mobile atoms sodium and potassium are uniquely fit for generating membrane potentials, which enable nerve impulse transmission. Without them there would be no central nervous system and certainly no carbon-based intelligent beings like humans.

Chapter 7: The Matrix

This chapter is a discussion of the properties of water that make life possible. Denton begins with a high-level view of embryogenesis:

> In the embryo it is not just one cell moving towards a specific target but millions of cells, each moving towards specific targets in an ever-changing kaleidoscope of different embryonic cells and chemical signals, with each cell obeying a strictly choreographed program, a program directing the timing of gene expression and a unique succession of changes in cell shape and cell surface proteins and adhesive properties in different cells in different regions of the embryo.

Development of the human embryo is the most complex phenomenon on earth.

Water, the "matrix of life," has many unique properties. The first property of water Denton discusses is *viscosity*. The viscosity of water determines the diffusion rates of compounds and nutrients through water as well as a property called *viscous drag*.

Only cells with a pliable membrane can change shapes and move in the ways embryonic development requires. The diffusion rates of various substances through water determine the possible size of a cell, and the size of a cell determines how complex a cell can be. For the complex cells of the human embryo, a slower diffusion rate would make the necessary reactions proceed too slowly. The size of cells would then need to be smaller to accommodate the required rates but at the expense of the cytoskeleton needed for the cell to be able to crawl. Also, a smaller cell would have a cell membrane with less surface area, less cell surface adhesion molecules, and fewer ways to form adhesive surfaces for interfacing with other cells. Denton observes:

> In sum, the existence of cells large enough to crawl and morph depends on the diffusion rates of oxygen and other solutes in water being not significantly less than what they are. If these diffusion rates were appreciably lower, active aerobic cells large enough to contain the molecular machinery for crawling and morphing could never have emerged.

Viscous drag is the tendency of a fluid to resist flow and is a result of a fluid's viscosity. Mammals have 1000 capillaries per square millimeter. Capillaries are 40 microns apart. Most cells are one to three cell widths from a capillary. The viscous drag of water when pumped through capillaries causes pressure in the capillaries. If the viscosity of water were much greater, the thin cell walls of capillaries would rupture. The cell walls of the capillaries need to be thin to facilitate the diffusion of oxygen and nutrients. The viscosity of water facilitates the rapid diffusion of oxygen and nutrients by permitting the rapid flow of blood through capillaries. If water were less viscous, the increased mobility of water molecules would make cellular structures less stable. Denton explains:

> That the fitness of the viscosity of water must fall within such a narrow range highlights just how fine-tuned is the natural order for life. The viscosity of common substances varies greatly. Measured in millipascals-seconds, the viscosity of air is 0.017, water 1.0, olive oil 84, glycerin 1420 and honey 10,000. The total range of viscosities of substances on our planet is more than twenty-seven orders of magnitude, from the viscosity of air to the viscosity of crustal rocks. Thus, the range of life-friendly viscosities is a tiny, vital band within the inconceivably vast range of viscosities in nature.

Water, the so called "universal solvent," is able to dissolve a vast array of chemicals, including ions, gases such as oxygen and carbon dioxide, proteins, nucleic acids, carbohydrates and many other biochemicals. And because of water's polarity, water exerts a "hydrophobic force" upon nonpolar molecules. This hydrophobic force is instrumental in the formation of cell membranes (lipid bilayers) and in the folding of proteins. On the other hand, water's polar nature is essential for formation of the double helical structure of DNA and RNA.

Water is also known to form "proton wires." Denton explains:

> One intriguing element of fitness for bioenergetics and proton pumping arises directly out of water's hydrogen-bonded network, which provides so-called "proton wires" consisting of long chains of linked water molecules for moving protons (H ions) around in the cell and across the inner mitochondrial membrane. While, as Alok Jha points out, other charged particles involved in cellular functions have to move themselves physically from one place to another, "protons can pass their energy along a hydrogen-bonded water wire without moving

themselves at all, thanks to the so called Grotthuss mechanism." A proton attaches to one end of the wire, he explains, and in a split second, "each of the hydrogen bonds further along the length of the wire spin around in sequence so that a proton drops off the water molecule at the other end of the wire. The initial proton has not moved any further than the starting end of the wire but its charge and energy have been 'conducted' along the wire's length."

As mentioned previously, the temperature range needed for life's biochemistry is essentially the same as the temperature range at which water is a liquid. Denton calls this coincidence a "miracle." Temperatures below this range makes reactions too slow and temperatures above this range would degrade the organic compounds needed for biochemistry. Also, hydrogen bonding and other weak noncovalent bonds would be disrupted above this narrow temperature range, destroying the 3D shapes critical to the functions of biochemicals. The temperature range for life (–20° to 130°C) is very narrow compared to the range of temperature in nature [absolute zero (–273°C) to millions of degrees in stars].

Chapter 8: The Primal Blueprint

In this final chapter, Denton begins by sharing his views on planned abiogenesis and evolution. Denton thinks the initial conditions of the universe and the laws of physics were designed for the purpose of evolving humans; that there was a primal "blueprint" for human life in place from the beginning of time. Denton acknowledges that the means of assembly of life's building blocks into the first cell are unknown. No one knows how an RNA world could have emerged or how it could have evolved the genetic code and the extant DNA → RNA → protein paradigm. Denton accepts that intelligent design is a possible answer but prefers to think there are yet-undiscovered natural laws that will explain abiogenesis.

Denton summarizes the main conclusions of his book:

1. The unique properties of the carbon atom make life possible. Carbon can form large stable molecules capable of carrying the information for building and maintaining organisms. Carbon can form stable bonds with many other elements resulting in a great variety of organic compounds.
2. The geometries of bonding of carbon and other elements facilitates the formation of the essential 3D structures of proteins, DNA, carbohydrates and other macromolecules.
3. The relative electronegativities of the critical elements of life (carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur and others) create bond polarities which result in various types of weak bonding interactions (hydrogen-bonding, Van Der Walls forces, dipole-dipole interactions, etc.) which are critical to the 3D structures and functions of proteins, DNA, RNA, etc.
4. The non-polar nature of carbon–carbon and carbon–hydrogen bonds facilitates the formation of lipid bilayers (without which there would be no cell membranes) and the proper folding of proteins.
5. Cell membranes (lipid bilayers) are the same thickness as the many proteins embedded within them. Cell membranes protect the chemistry of the cell, are fluid enough to change shape and allow cellular movement, facilitate electrical potential gradients used to power the pumping of ions and other processes, are semipermeable and allow selective transport of molecules into and out of the cell, are self-organizing, and are self-repairing. Cell membranes also facilitate communication with and selective adhesion to other cells.
6. Phosphates, and ATP in particular, are uniquely suited to be the energy currency of the cell. ATP is kinetically stable but thermodynamically unstable. The required properties of ATP trace back to the unique properties of phosphorus.
7. The unique properties of iron and copper facilitate electron transport chains required for respiration and other crucial cellular functions. Also, the properties of iron in hemoglobin are just right for the transport of oxygen. The properties of iron and copper make the reduction of oxygen to water by cytochrome c oxidase possible. Zinc is critical to the transport of carbon dioxide in the cell.
8. The sodium and potassium cations are uniquely suited for rapid transport across cell membranes to establish electrical potentials.
9. The unique properties of water facilitate biochemistry. These properties include its polarity and viscosity. These properties make water an ideal solvent, generate the "hydrophobic force," facilitate the formation of "proton wires," result in the temperature range for liquid water, allow the rapid diffusion of gases and nutrients, allow for rapid circulation of blood cells through capillaries while maintaining cell membrane stability, etc. The temperature range of liquid water is the same as the temperature range required for biochemistry.

The evidences Denton shares point to a designer with creativity, unimaginable intelligence, foresight, and purpose. The evidence from the chemistry of the main elements of life and some of the resulting molecules reveal the fine-tuning of nature by our Creator. It is a shame that Denton for all his brilliance does not conclude that the only explanation for the ubiquitous fine-tuning found in physics, chemistry, biochemistry, and biology is a personal Creator who has a plan involving human beings. But the evidence speaks plainly to anyone willing to accept it. Our universe and our presence in it are no accident. God has a plan for us. He has explained Himself in the Bible. God wants a love relationship with us, His creatures. We have been alienated from Him by our sin, but God has made a Way for us to be reconciled to Him though his son Jesus Christ. If you do not know Him, I invite you to read the gospel of John. John explains God's love for us and His plan of salvation. Seek and you will find. ☙

COMING EVENTS

TASC Zoom Meeting, Thursday, May 13, 7:00 pm EDT

Dan Reynolds, PhD will discuss the book *Miracle of the Cell* by Michael Denton published in 2020. Denton discusses the fine-tuning of the chemical elements that make up the molecules of biochemistry.

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