

# Workbook



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# The Foundation of BioChemistry

## Cellular Foundation

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### Questions

- 1) Given the following statement, determine which one is false:  
Eukaryotes are characterized by
  - a. Presence of a nucleus
  - b. Presence of membrane bound organelles
  - c. Presence of a cell wall
  - d. Presence of the Golgi apparatus
  
- 2)
  - a. What is the commonly used unit used to measure biological cells and what is the size of a cell?
  - b. Can a unicellular organism be only 1-2  $\mu\text{m}$  long?
  
- 3) The smallest living biological structure unit is a/an
  - a. Tissue
  - b. Organelle
  - c. Molecule
  - d. Cell
  
- 4) A membrane-enclosed nucleus is a characteristic of
  - a. All living organisms
  - b. Prokaryotic cells
  - c. Eukaryotic cells
  - d. Bacteria and viruses

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5) a. Given the following statement, determine which one is true:

A plasmid

- a. Is circular DNA found in Eukaryotes
- b. Cannot replicate independently of the chromosome
- c. Allows for lateral transfer of genetic information
- d. Is found in 1 type of bacteria

b. For the statements of 1a that are incorrect, please correct the sentence so that it is true:

A plasmid

- e. Is circular DNA found in bacteria that are a type of Prokaryotes
- f. Replicates independently of the chromosome
- g. Allows for lateral transfer of genetic information
- h. Is found in several types of bacteria

6) Define the following terms:

- a. Plasma membrane
- b. Cytoplasm
- c. Nucleus vs. nucleoli
- d. Cytoskeleton

7) How many distinct domains do organisms belong to and what are they?

8) Give an example of an organism that lives in an extreme environment and what domain does it belong to?

9) What are aerobic vs. anaerobic organisms, and what 2 types of anaerobic organisms are there?

10) a. Name the 2 categories based on energy sources and define them:

b. Into what 2 further classifications can Phototrophs and Chemotrophs be divided into, and explain these.

11) Within the classification based on energy source utilization, what are humans?

12) The 4 major biological molecules include:

- a. Carbohydrates, saccharides, lipids, proteins.
- b. Carbohydrates, lipids, proteins, amino acids.
- c. Carbohydrates, fatty acids, amino acids, nucleotides.
- d. None of the above.

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**13)** The building block of proteins is?

- a. Nucleotides.
- b. Disaccharides.
- c. Amino acids.
- d. tRNA.

**14)** Which molecule/s are monosaccharides?

- a. Fructose
- b. Glucose
- c. Ribose
- d. All of the above

**15) a.** What are the 5 nucleotide bases?

**b.** Which bases are exclusive to either DNA/RNA and specify:

- a. Adenine (A)
- b. Guanine (G)
- c. Cytosine (C)
- d. Thymine (T)
- e. Uracil (U)

**16)** Which is not a component of an amino acid?

- a. A central carbon.
- b. An amino group.
- c. A carboxyl group.
- d. A phosphate group.
- e. An R group or side chain.

**17)** What are the 3 types of fatty acids?

- a. Saturated, polysaturated and unsaturated
- b. Saturated, unsaturated and polyunsaturated
- c. Saturated, polysaturated and polyunsaturated
- d. None of the above.

**18)** What is another term for macromolecule and what does it mean?

**19)** What are the 4 major classes of biological macromolecules, and which of these are the most abundant polymers in cells?

## Answer Key

1) The answer is C

2) a. The commonly used unit to measure biological cells is the micrometer/micrometre =  $\mu\text{m}$ , also known as a micron. This unit is equal to  $1 \times 10^{-6}$  meter.

The size of a cell depends on the type:

- Prokaryotic cell size ranges from 0.1 to  $10\mu\text{m}$
- Eukaryotic cell from either 5 or 10 to  $100\mu\text{m}$  in diameter

b. Yes. As in the example given of the Prokaryote E. coli, a rodlike shaped bacterium, which is  $2\mu\text{m}$  by  $1\mu\text{m}$  in size

3) The answer is D

4) The answer is C

5) a. The answer is C

b.

a. is circular DNA found in bacteria that are a type of Prokaryotes

b. replicates independently of the chromosome

c. allows for lateral transfer of genetic information

d. is found in several types of bacteria

6) a. Plasma membrane - is composed of lipid and protein molecules that form a flexible hydrophobic barrier around the cell, separating its contents from the surrounding.

b. Cytoplasm - includes an aqueous solution (the cytosol) and various particles that have specific functions all enclosed by the plasma membrane

c. Nucleus vs. nucleoid - the nucleus is where the eukaryotes' genome – DNA is found and replicates. It is enclosed within the nuclear envelope and contains a region called the nucleolus, which is where ribosomes are assembled. The nucleoid is found in prokaryotes (bacteria and archaea), and is not separated from the cytoplasm by a membrane.

d. Cytoskeleton - a network of intracellular filaments consisting of protein assemblies that maintains the eukaryotic cell structure.

7) 3 domains: Bacteria (Eubacteria), Archaea (Archaeobacteria), and Eukarya.

8) Any of these Archaea can be given as an example:

- Methanogens – organisms that produce methane –  $\text{CH}_4$
- Halobacteria - organisms that thrive in concentrated brine solutions
- Thermophiles - organisms that inhabit hot springs

9) Aerobic organisms live in environments with plentiful supply of oxygen.

Anaerobic organisms live in environments devoid of oxygen and are either obligate anaerobes which die when exposed to oxygen, or facultative anaerobes that are able live with or without oxygen.

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- 10)** a. Phototrophs – use sunlight, Chemotrophs – derive their energy from oxidation of a chemical fuel  
b. Autotrophs - those that can synthesize their biomolecules directly from CO<sub>2</sub>,  
Heterotrophs - those that require some preformed organic nutrients made by other organisms
- 11)** Humans are Chemoheterotrophs – since they derive their energy from a chemical source and they rely on an organic source of “fuel”, nutrients, or in other words – food.
- 12)** The answer is C
- 13)** The answer is C
- 14)** The answer is D
- 15)** a. Adenine (A), Guanine (G), Cytosine (C), Thymine (T), Uracil (U).  
b. Thymine (T) – DNA, Uracil (U) - RNA
- 16)** The answer is D
- 17)** The answer is B
- 18)** Polymer is another term for macromolecule, and it stems from the Greek words for “many parts” (poly -many, mer- part). Each of those parts is a monomer (mono which in Greek means “one part”). These are large organic molecules that are necessary for life. In other words, a polymer is a molecular structure consisting of a large number of similar units bonded together.
- 19)** Carbohydrates, Lipids, Proteins, Nucleic acids (DNA and RNA).

# The Foundation of BioChemistry

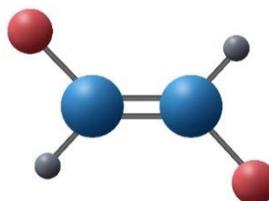
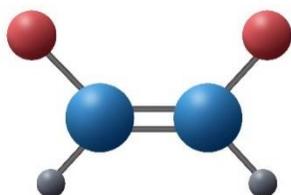
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## Chemical Foundation

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### Questions

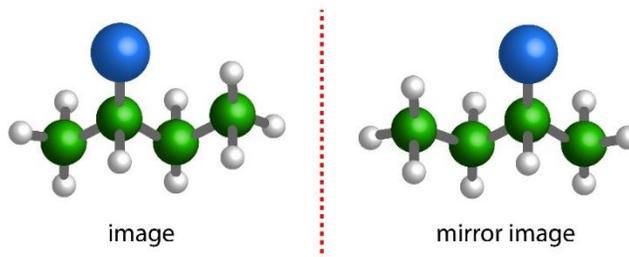
- 1) Define Biochemistry.
- 2) The “plant and animal world” are rich in what 4 elements?
- 3) Describe the phenomena known as “biochemical unity.”
- 4) a. Of the ~90 naturally occurring chemical elements, how many are essential to organisms, and what can be said of most of them?  
b. What are the 4 most abundant elements in living organisms (in terms of percentage of total number of atoms), and what chemical attribute do they have?
- 5) What are trace elements?
- 6) Which statement about Carbon is false?
  - a. It can form single bonds with hydrogen atoms
  - b. It can form single and double bonds with oxygen and nitrogen atoms
  - c. It can form very stable single bonds with up to 2 other carbons
  - d. Two carbon atoms can share two (or three) electron pairs – forming double (or triple) bonds
- 7) What can you say about the flexibility and length of single bonds vs. double bonds?
- 8) a. What is the term for a collection of different small organic molecules dissolved in the cell’s cytosol?  
b. What is their role in the cell?
- 9) What is the difference between primary and secondary metabolites and give examples of each?
- 10) What is stereochemistry and what are stereoisomers?
- 11) a. Define Geometric isomers (aka cis-trans isomers).  
b. Indicate which figure depicts a cis isomer and which a trans isomer.



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12) What type of isomers are these biomolecules?



13) What term defines the importance of the configuration and conformation to chemical interactions between biomolecules and explain this?

14) Give at least 2 examples of biomolecules that have stereospecific interactions.

15) What can you say about chiral molecules that are present in living organisms?

### Answer Key

- 1) Biochemistry is the study of biological forms and function in chemical terms.
- 2) Carbon, Oxygen, Nitrogen, Phosphorous
- 3) The answer is in the video.
- 4) a. Less than 30. Most have low atomic number, only 4 have a higher atomic number than 30.  
b. Hydrogen, Oxygen, Nitrogen, Carbon.
- 5) The answer is in the video.
- 6) C
- 7) The answer is in the video.
- 8) a. Metabolites  
b. Either an intermediate or an end product of metabolic reactions - generally catalyzed by enzymes that naturally occur within cells and are part of metabolism.
- 9) The answer is in the video.
- 10) The answer is in the video.
- 11) The answer is in the video.
- 12) The answer is in the video.
- 13) The answer is in the video.
- 14) Enzyme and its substrate, Hormone and its receptor, Antigen and its specific antibody.
- 15) The answer is in the video.

# The Foundation of BioChemistry

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## Physical Foundation

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### Questions

- 1) Define the term dynamic steady state.
- 2) What is required in order to maintain a steady state?
- 3) What happens when a cell is no longer able to obtain and utilize energy?
- 4) What are Photosynthetic organisms?
- 5) a. Define reduction and oxidation and the reaction known as redox.  
b. How are redox reactions relevant to the energy cycle?
- 6) Energy conversion in living systems is required for what three types of work?
- 7) What is the term used to define a highly ordered steady state, which requires energy, and is maintained by living organisms, and what does it stem from?
- 8) What can you say about an organism that is in equilibrium with its environment?
- 9) Define System, surrounding and universe in the context of biochemistry.
- 10) **Part I:** What are the 3 types of systems?
  - a. Open, Closed, Combined
  - b. Open, Closed, Universal
  - c. Open, Closed, Isolated
  - d. Internal, External, Combined**Part II:** Describe what each system means, and label each of the containers as the correct system.
- 11) What type of system is a biological system?
- 12) List and describe the two main laws that biochemists use to describe biological processes in thermodynamic terms.
- 13) Name and define the 3 measures that were used by Gibbs to establish the free-energy constant,  $G$ , and the formula used to calculate it.



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14) State what type of reaction occurs in the different states of  $\Delta G$ .

15) Which of the following comparisons or contrasts between endergonic and exergonic reactions is false?

- Endergonic reactions have a positive  $\Delta G$  and exergonic reactions have a negative  $\Delta G$ .
- Endergonic reactions consume energy and exergonic reactions release energy.
- Both endergonic and exergonic reactions require a small amount of energy to overcome an activation barrier.
- Endergonic reactions take place slowly and exergonic reactions take place quickly.

16) What is the common source of free energy in the cell?

17) Which is true?

- The amount of energy available to do work is equal to the theoretical amount of energy released.
- The amount of energy available to do work is equal to the theoretical amount of energy released.
- The amount of energy available to do work is less than the theoretical amount of energy released.
- The amount of energy available to do work is not related to the theoretical amount of energy released.

18) Please explain the formula for the equilibrium constant and how does this translate to  $K_{eq}$

in relation to 1: 
$$K_{eq} = \frac{[C]_{eq}[D]_{eq}}{[A]_{eq}[B]_{eq}}$$

19) The magnitude of the standard Gibbs free energy  $\Delta G^\circ$  is a measure of how \_\_\_\_\_ the standard state is from \_\_\_\_\_.

20)  $\Delta G^\circ = -RT \ln K_{eq}$

The formula for The standard Gibbs free energy shows its direct link to a reaction's equilibrium constant:

- The equilibrium constant is thus a measure of the directionality of the reaction under standard conditions.
- Thus  $\Delta G^\circ$  is another way [besides  $K_{eq}$ ] of expressing the driving force on a reaction.

Considering this, which statement is correct?

- When  $K_{eq} \gg 1$ ,  $\Delta G^\circ$  is large and negative
- When  $K_{eq} \ll 1$ ,  $\Delta G^\circ$  is small and negative
- When  $K_{eq} \gg 1$ ,  $\Delta G^\circ$  is large and positive
- When  $K_{eq} \ll 1$   $\Delta G^\circ$  is small and positive
- None of these are correct

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- 21) What important general role to enzymes have in an organism?
- 22) What is the activation barrier and **activation energy,  $\Delta G^\ddagger$**  ?
- 23) Which of the following is the best way to judge the relative activation energies between two given chemical reactions?
- Compare the  $\Delta G$  values between the two reactions.
  - Compare their reaction rates.
  - Compare their ideal environmental conditions.
  - Compare the spontaneity between the two reactions.
- 24) How do enzymes contribute and catalyze reactions?
- 25) Which of the following is not true about enzymes:
- They are usually made of amino acids.
  - They lower the activation energy of chemical reactions.
  - Each one is specific to the particular substrate(s) to which it binds.
  - They increase  $\Delta G$  of reactions.
- 26) Name at least 2 characteristics of cellular catalysts – enzymes in context of cellular reactions.
- 27) What can you explain about how the many (thousands) of enzyme-catalyzed reactions in cells are organized?
- 28) How would you define metabolism?
- 29) What are the 3 main roles of metabolism?
- 30) List the 2 major types of metabolism and define them.
- 31) How do enzymes contribute to metabolism?

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**32)** Select the proper one to complete the statement:

The pathways that act on the main components of cells such as proteins, fats, sugars, and nucleic acids, are essentially identical in all living organisms in that \_\_\_\_\_.

- a. this activity occurs through stepwise biochemical reactions.
- b. some of the reactions in these pathways are spontaneous and release energy, while others require energy to proceed.
- c. they require the continuous production of energy to refill the energy being used.
- d. all of the above is correct.

**33) a.** What can you explain about how the many (thousands) of enzyme-catalyzed reactions in cells are organized?

b. Describe the definitions:

- i. Metabolism
- ii. Catabolism
- iii. Anabolism

### Answer Key

- 1) The answer is in the video.
- 2) The continuous investment of energy is required by the organism in order to maintain the dynamic steady state.
- 3) It dies and begins to decay toward equilibrium with its surroundings.
- 4) The answer is in the video.
- 5) The answer is in the video.
- 6) Osmotic work, Chemical work, Mechanical work.
- 7) Homeostasis.
- 8) The organism is no longer alive.
- 9) The answer is in the video.
- 10) Part I: C, Part II: The answer is in the video.
- 11) Biological systems are open systems, as both matter, such as nutrients and waste products, and energy -mainly heat, are exchanged with the surroundings.
- 12) The answer is in the video.
- 13) Enthalpy H, Entropy S, Absolute temperature T.
- 14) The answer is in the video.
- 15) D – what type of reaction does not indicate the rate at which the reactions take place.
- 16) The answer is in the video.
- 17) C.
- 18) The answer is in the video.
- 19) The magnitude of the standard Gibbs free energy  $\Delta G^\circ$  is a measure of how **far** the standard state is from **equilibrium**.
- 20) D.
- 21) The answer is in the video.
- 22) The answer is in the video.
- 23) B.
- 24) The answer is in the video.
- 25) D.
- 26) The answer is in the video.
- 27) The answer is in the video.
- 28) The chemical processes that occur within a living organism in order to maintain life.
- 29) 1. The conversion of food to energy to run cellular processes. 2. The conversion of food/fuel to building blocks for proteins, lipids, nucleic acids, and some carbohydrates. 3. The elimination of metabolic wastes.
- 30) Anabolic pathways, Catabolic pathways.
- 31) The answer is in the video.
- 32) D.
- 33) The answer is in the video.

## Genetic Foundation

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### Questions

- 1) While records of historical civilizations have rarely survived for thousands of years, a clue-in to the evolution is what type of biological evidence?
- 2) What encodes the instructions for forming all other cellular components, as well as provides a template for the production of identical DNA molecules to be passed along to progeny when cells divide?
- 3) Part I: What is true and crucial for the continuation of biological species?
  - a. That its genetic information be maintained in a stable form.
  - b. That the genetic information be expressed accurately in the form of gene products.
  - c. That the genetic material is copied with a minimum of errors.
  - d. All of the answers above.Part II: What maintains distinction between species is:
  - a. Effective storage of genetic material
  - b. Consistent and precise expression of genetic material
  - c. Accurate reproduction/replication of genetic material
  - d. All of the answers above
- 4) When the properties of a chemical species is described, typically the average behavior of a very large number of identical molecules is actually represented. We mentioned an exception of this, what is it and what example did we mention to illustrate this?
- 5) What are the covalently linked subunits which encode the genetic message?
- 6) a. What specialized human eggs carry the hereditary information and transmit it to the next generations in the form of DNA molecules?  
b. What occurs when these 2 cells unite?
- 7) The structure of DNA allows its replication and repair with near-perfect fidelity – mention 2 factors that contribute to this as well as describe two aspects of the replication and its fidelity.
- 8) State the 2 phases in which the change from 1-dimensional DNA to 3-dimensioned proteins occurs.
- 9) Mention 2 facts about a protein's native conformation.
- 10) What affects both native conformation of proteins and self-assembly of supramolecules?

### Answer Key

- 1) Genetic information in bones and other such remains as well as in living organisms serve as historical evidence of evolution. Genetic information has remained virtually unchanged over great periods of time.
- 2) The sequence of the monomeric subunits – the nucleotides in the linear polymer - in eukaryotes and most prokaryotes the subunits are deoxyribonucleotides, that make up the polymer DNA.
- 3) Part I+II: D.
- 4) The Answer is in the video.
- 5) Nucleotides are covalently linked in a linear sequence to encode the genetic message.
- 6) The Answer is in the video.
- 7) The Answer is in the video.
- 8) The Answer is in the video.
- 9) The Answer is in the video.
- 10) Both are affected by the cellular environment (such pH, metal ion concentrations, etc.), which in essence means that it contributes, along with the DNA sequence to maintain cell continuity and function.

## Evolutionary Foundation

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### Questions

- 1) Small mutations that confer a selective advantage to an organism in some ecological niche resulted in what?
  
- 2) Which statement is false?
  - a. Earth was formed about 4.6 billion years ago and the first evidence of life dates to more than 3.5 billion years ago.
  - b. The first simple organism arose during Earth's first billion years.
  - c. Lipid vesicles containing organic compounds and self-replicating RNA gave rise to the first cells, and the cells with the greatest capacity for self-replication became more abundant.
  - d. The first organism will have had the ability to replicate from a template that was the first genetic material.
  - e. All of the above.
  
- 3) Define the term evolution, and what is the evolutionary theory.
  
- 4) Complete the sentences below - fill in the blanks
  - a. Genetic replication has near-perfect \_\_\_\_\_.
  - b. In the rare occasion an unrepaired mistake in DNA replication results in a change to the \_\_\_\_\_ sequence of the DNA, producing a genetic \_\_\_\_\_.
  - c. A genetic mutation can affect the \_\_\_\_\_ for a cellular component, for example a specific protein will be affected.
  - d. It is \_\_\_\_\_ for one strand to have an unrepaired error and result in a genetic mutation.
  - e. Mutations in the \_\_\_\_\_ cells can be particularly harmful or even lethal to the \_\_\_\_\_.
  - f. Occasionally a mutation is \_\_\_\_\_ to the organism's survival in its environment.
  
- 5) a. Explain how a mutation can be beneficial to the organism's survival in its environment and what are these mutations called?  
b. What is the term that describes this driving force of evolution?
  
- 6) Explain how an extra copy [a second copy] of a gene that is introduced into the chromosome as a result of defective replication can confer a role in evolution.
  
- 7) How is the frequency of errors in DNA replication important for evolution and survival?

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- 8) a. Describe the Big Bang Theory.  
b. What are possible powerful environmental forces that contributed to the formation of the compounds that compose the first living organism based on the The Big Bang Theory?
- 9) a. Describe how Stanley miller in Harold Urey's lab tested the Big Bang Theory in 1953.  
b. What did this experiment show?
- 10) What additional evidence corroborated the Big Bang Theory and Miller's findings?
- 11) Prebiotic evolution may have begun with what type of molecule, and what facts supports this idea?
- 12) **Part I:** Which of the following are part of the possible steps of biological evolution?  
a. Chance formation of an RNA molecule that is catalytic.  
b. A self-replicating RNA.  
c. The self-replication of RNA would result in "errors".  
d. Limitation in supply of nucleotides.  
e. All of the above.  
**Part II:** How does this step contribute to the idea of evolution – how is it significant?
- 13) What molecules with sequences complementary to the self-replicating RNA molecules took over the role of conserving the "genetic" information, and what role did RNA molecules evolve to fulfill?
- 14) Explain and describe the metabolism-first hypothesis.
- 15) List a number of facts that support the RNA World Hypothesis for biological evolution.
- 16) Complete the sentence:  
The earliest cells arose in an atmosphere lacking \_\_\_\_\_, thus they most likely obtained \_\_\_\_\_ from \_\_\_\_\_ and compounds in their environment, which were abundant on the early earth. For example, this reaction:  $\text{FeS} + \text{H}_2\text{S} \longrightarrow \text{FeS}_2 + \text{H}_2$ .  
They used that energy to \_\_\_\_\_ precursor molecules needed for the cells' functioning.
- 17) What is photosynthesis and why is it significant?
- 18) a. What 3 major changes must have occurred for the eukaryotic cell to develop?  
b. What further evolution led to the plethora of complex organisms?

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19) Which of the following is true?

- a. Only sequencing of full genomes of organisms enables thorough and quantitative comparisons between species.
- b. Molecular phylogeny derived from gene sequences is consistent yet less precise than the classical phylogeny based on macroscopic structures.
- c. Organisms continuously diverged at the level of gross anatomy, yet at the molecular level there is basic unity between them.
- d. All of the above.

20) What are homologs, paralogs and orthologs?

21) Which type of homologous genes are best described as such:

**Part I:** \_\_\_\_\_ genes are likely derived from gene duplication followed by gradual changes in their sequences, and they tend to be similar in their 3-d structure as well as their sequences, yet they typically have different functions.

**Part II:** \_\_\_\_\_ genes are found in different species, yet have similar sequences and typically have the same function in both organisms.

22) How are the degree of evolutionary divergence of 2 homologous genes associated with their sequence similarities?

## Answer Key

- 1) Speciation.
- 2) E.
- 3) The answer is in the video.
- 4) a. fidelity                      b. nucleotide, mutation                      c.instructions  
    d. enough/sufficient        e. reproductive/sex, offspring              f. beneficial
- 5) The answer is in the video.
- 6) The answer is in the video.
- 7) The answer is in the video.
- 8) The answer is in the video.
- 9) The answer is in the video.
- 10) The answer is in the video.
- 11) An RNA-like molecule was plausibly where prebiotic evolution began, and the fact that RNA molecules can act as catalysts in their own formation supports this.
- 12) E.
- 13) DNA molecules took over the role of conserving the “genetic” information, while RNA molecules evolved to play roles in protein synthesis.
- 14) The answer is in the video.
- 15) The answer is in the video.
- 16) Oxygen, energy, inorganic fuels, synthesize.
- 17) The answer is in the video.
- 18) The answer is in the video.
- 19) C.
- 20) The answer is in the video.
- 21) Part I: Paralogous              Part II: Orthologs.
- 22) The answer is in the video.