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Alabama High School Science Exit Examination

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## Question: 1

In biological experiments, which of the following is the best and safest way to heat samples?

- A. A methane burner.
- B. A hot plate.
- C. A space heater.
- D. A heating blanket.

**Answer: B**

Explanation:

In biological experiments, precise temperature control and safety are paramount. Among the options provided—methane burner, hot plate, space heater, and heating blanket—the best and safest method to heat samples is utilizing a hot plate. This choice is due to several key factors that prioritize both the integrity of the samples and the safety of the laboratory environment.

Firstly, a hot plate provides a stable and controllable source of heat, with the ability to set specific temperatures necessary for various biological reactions and processes. This level of control is crucial in experiments where even slight temperature variations can lead to significant differences in outcomes. Unlike open flames from a methane burner, which can fluctuate and are harder to control precisely, hot plates maintain a consistent temperature, ensuring experimental reliability.

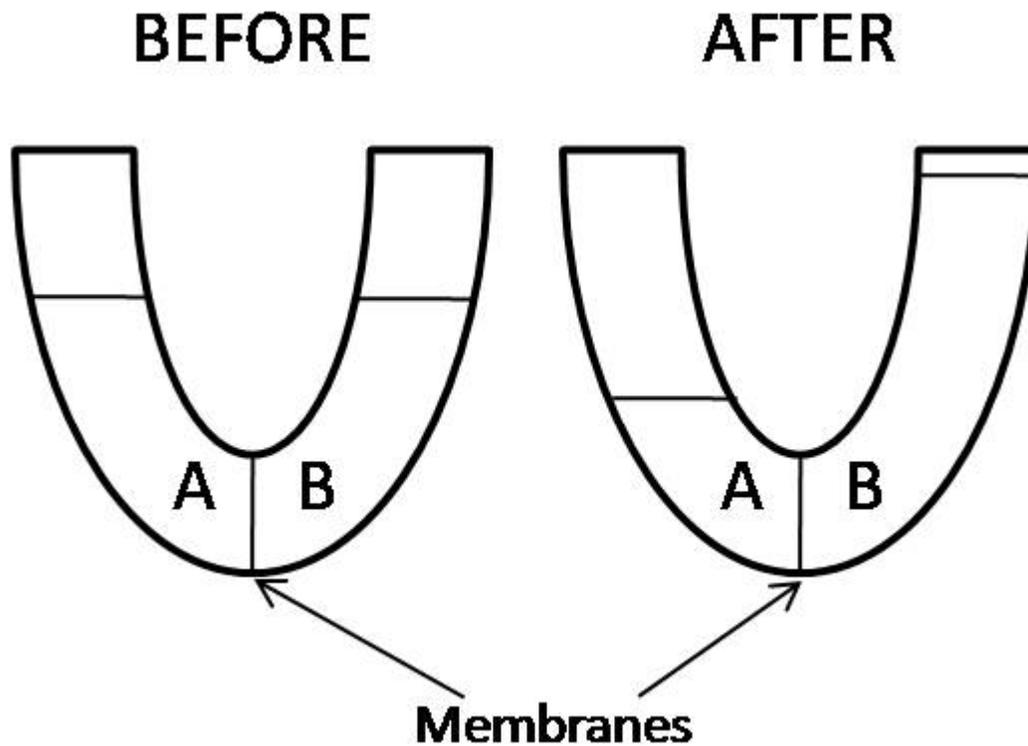
Moreover, safety in the laboratory is another critical consideration. A hot plate, unlike a methane burner, does not involve open flames. Open flames can present a significant hazard, especially in environments where flammable materials, such as solvents or volatile chemicals, are used. These substances can easily ignite, posing a risk of fire or explosion. Additionally, open flames can also lead to accidental burns to personnel.

Comparatively, space heaters and heating blankets are generally not suitable for laboratory experiments involving heating samples. Space heaters are designed to warm environments and are not typically used for direct heating of experimental samples due to their imprecise temperature control and safety risks. Heating blankets, while useful for maintaining temperature in certain contexts, do not offer the necessary precise temperature adjustment needed for most biological experiments.

In conclusion, a hot plate stands out as the safest and most effective method for heating samples in biological experiments. It combines the essential elements of safety, precision, and reliability, thereby facilitating accurate experimental results while minimizing risk in the laboratory setting.

## Question: 2

Two salt solutions are separated by a semi-permeable membrane. Water can pass freely between the A and B sides, but salt cannot. The figures show the water levels on each side before and after the body is allowed to get to equilibrium. What can be said about the figure and the water in the curved tube above?



- A. In the BEFORE figure, the concentration of salt is higher in A than in B.
- B. In the BEFORE figure, the concentration of salt is higher in B than in A.
- C. In the AFTER figure, the concentration of salt is higher in B than in A.
- D. The arrangement is not physically possible.

**Answer: B**

Explanation:

The scenario described is a classic example of osmosis, which is the movement of water across a semi-permeable membrane from a region of lower solute concentration to a region of higher solute concentration. In this context, the solute is salt, which cannot pass through the membrane, whereas the solvent (water) can move freely.

Initially, if the concentration of salt is higher on side B than on side A, it implies that side B is more hypertonic relative to side A, which is more hypotonic. In response to this concentration gradient, water molecules will naturally move through the semi-permeable membrane from side A (lower salt concentration) to side B (higher salt concentration). This osmotic movement of water continues until the osmotic pressure equilibrates the solute concentrations on both sides of the membrane, or until another physical limit is reached, such as the volume capacity of the container.

As water moves from side A to side B, the water level on side B will rise while it decreases on side A. This change in water levels is a direct result of the osmotic flow of water. The water in the curved tube typically acts as a manometer, indicating the pressure or level changes due to the movement of water. An increase in water level on side B visually confirms the net movement of water to that side, supporting the conclusion that side B had a higher salt concentration initially.

This understanding of the osmotic process not only confirms the correct answer but also highlights the fundamental principles of semi-permeable membranes and osmosis in maintaining concentration balances in various biological and chemical systems.

### Question: 3

A diploid human cell contains 46 chromosomes. At the end of meiosis I, how many chromosomes are present in each cell?

- A. 46 chromosomes
- B. 23 chromosomes
- C. 23 chromatids
- D. None of the above

**Answer: B**

Explanation:

Meiosis is a type of cell division that reduces the number of chromosomes in the parent cell by half and produces four gamete cells. This process is divided into two stages: meiosis I and meiosis II. It is essential for sexual reproduction and contributes to genetic diversity.

In humans, each body cell normally contains 46 chromosomes, organized into 23 pairs. These pairs consist of one chromosome from each parent, making the cell diploid. At the start of meiosis I, each chromosome duplicates itself, resulting in two copies of each chromosome, called sister chromatids, which remain attached at a point called the centromere.

During meiosis I, the cell undergoes several phases, starting with prophase I, where homologous chromosomes (one from each parent) pair up in a process called synapsis. This pairing is crucial as it allows for crossing-over, a process where homologous chromosomes exchange segments of DNA, enhancing genetic diversity. Following synapsis, during metaphase I, these pairs line up at the cell's equator. In anaphase I, the spindle fibers pull each homologous chromosome pair towards opposite poles of the cell. This step is pivotal as it halves the chromosome number. Finally, telophase I and cytokinesis conclude the division, resulting in two daughter cells.

Each of these two daughter cells at the end of meiosis I contains 23 chromosomes. However, it's important to note that each chromosome still consists of two sister chromatids. Therefore, although the chromosome number is halved (from 46 to 23), each chromosome is still duplicated. The cell at this point is considered haploid because it contains only one set of chromosomes, one from each original homologous pair, but each chromosome still consists of two chromatids.

Following meiosis I, meiosis II occurs in each of the two haploid cells. Meiosis II resembles a typical mitotic division, where the 23 chromosomes (each with two chromatids) line up, and the sister chromatids are then separated and pulled to opposite poles by the spindle fibers. This results in four haploid cells, each with 23 single chromatids. These cells are the gametes - in males, they develop into sperm cells, and in females, into oocytes.

Therefore, at the end of meiosis I, each cell has 23 chromosomes, each consisting of two chromatids. This setup is crucial for the subsequent phase, meiosis II, where these chromatids will be separated, leading to the formation of gametes with genetically distinct single-chromatid chromosomes.

### Question: 4

During which stage of meiosis would you expect to find the least amount of DNA in a cell?

- A. Prophase I
- B. Anaphase I
- C. Prophase II
- D. Telophase II

**Answer: D**

Explanation:

The correct stage of meiosis where you would expect to find the least amount of DNA in a cell is Telophase II. To understand why, it is important to review the process of meiosis, particularly focusing on the changes in chromosome and DNA content throughout the stages.

Meiosis is a type of cell division that reduces the chromosome number by half, resulting in four genetically unique daughter cells, each with half the chromosome number of the original cell. This process is crucial for sexual reproduction and occurs in two successive stages: Meiosis I and Meiosis II. During Prophase I, the first stage of Meiosis I, each chromosome pairs with its corresponding homologous chromosome to form a tetrad. This is followed by Metaphase I, where tetrads align at the cell's equator, and then Anaphase I, where the homologous chromosomes are pulled apart to opposite poles of the cell. By the end of Telophase I and the subsequent cytokinesis, the cell has divided into two daughter cells, each with half the original number of chromosomes, but each chromosome still consists of two chromatids.

Meiosis II resembles a typical mitotic division. It begins with Prophase II, where the chromosomes, each still consisting of two chromatids, condense again. The cells enter Metaphase II, where chromosomes line up at the equator, followed by Anaphase II, where the sister chromatids finally separate and move to opposite poles.

Telophase II is the final stage of meiosis. At this point, the sister chromatids have already been separated and are now considered individual chromosomes. They decondense and are enclosed in newly formed nuclear envelopes. As the chromosomes decondense, they are less compact, and thus, the total DNA content appears reduced compared to earlier stages where DNA was tightly packed. Moreover, since these chromosomes are now divided among four cells (as cytokinesis follows quickly after Telophase II), each cell contains only a quarter of the DNA of the original parent cell. Therefore, during Telophase II, each of the four resulting cells from meiosis has the least amount of DNA because the DNA content per cell is only a quarter of that in the original cell. This makes Telophase II the stage with the least DNA content per cell in the process of meiosis.

## Question: 5

The union of two gametes (in humans, a sperm and egg) during sexual reproduction immediately forms what?

- A. Zygote
- B. Germ cell
- C. Blastocyst
- D. Embryo

**Answer: A**

Explanation:

The correct answer to the question "The union of two gametes (in humans, a sperm and egg) during sexual reproduction immediately forms what?" is a zygote. A zygote is the initial cell formed when a sperm cell from the male and an egg cell from the female fuse during fertilization. This process marks the beginning of a new organism's development.

Gametes, the reproductive cells involved in sexual reproduction, are haploid, meaning they each contain only one set of chromosomes. In humans, each gamete carries 23 chromosomes. When these gametes unite during fertilization, they form a zygote, which is diploid. This means the zygote contains a complete set of chromosomes (46 in humans), half contributed by the sperm and half by the egg. This genetic material will guide the development of the organism.

The zygote undergoes rapid cell divisions through a process called mitosis, increasing in cell number and eventually forming different structures as development progresses. Approximately five days after fertilization, the zygote has divided multiple times and forms a structure known as a blastocyst, which is comprised of an outer layer of cells, and an inner group of cells that will develop into the embryo.

The term "embryo" is used to describe the developing organism after the zygote stage and until the end of the eighth week of gestation, where it is then referred to as a fetus. However, the transition from a zygote to an embryo occurs after several rounds of cell division when distinct cellular structures begin to form. The term "embryo" is particularly reserved for the developing organism after it has implanted in the uterus wall, which occurs after the blastocyst stage.

In summary, immediately after the fusion of sperm and egg, the resultant cell is called a zygote. This single cell represents the earliest stage of embryonic development and holds all the genetic information necessary to develop into a complete organism. The stages that follow include the blastocyst and embryo as the cells continue to divide and differentiate.

## Question: 6

The concept of differential expression of the same genetic trait in different individuals is known as which of the following?

- A. Transduction.
- B. Translocation.
- C. Transmission.
- D. Variable expressivity.

**Answer: D**

Explanation:

Variable expressivity is a genetic concept that refers to the varying degrees to which a particular genetic trait can manifest in different individuals. Even when individuals share the same genotype (the same set of genes), the phenotype (the observable characteristics) can differ due to variable expressivity. This variance in expression can range from mild to severe and is influenced by numerous factors, including environmental influences, interactions with other genes, and random developmental events.

For instance, consider a genetic disorder caused by a specific mutation. Even among family members who all have the same mutation, the severity and specifics of how the disorder manifests can differ significantly. One family member might have a severe form of the disorder, another might show moderate symptoms, and yet another might exhibit only mild symptoms or even appear to be symptom-free. This diversity in the manifestation of genetic traits, despite having an identical genetic basis, exemplifies variable expressivity.

Variable expressivity should not be confused with penetrance, which is another important concept in genetics. Penetrance refers to the likelihood that a person carrying a particular genotype will actually show the phenotype associated with that genotype. In cases of complete penetrance, every individual with the mutant genotype will display the phenotype. In contrast, incomplete penetrance means that some individuals will not express the phenotype at all, despite carrying the genotype.

Understanding variable expressivity is crucial in genetics and medicine as it helps predict the range of possible outcomes in genetic counseling, anticipates prognosis in genetic diseases, and guides research in genetic and developmental biology. It underscores the complexity of genetic expression and the challenges in predicting exactly how genetic traits will manifest in individuals.

### Question: 7

For any particular trait, the pair of alleles of each parent separate and only one allele from each parent passes to an offspring. This idea is known as Mendel's Principle of which of the following?

- A. Regular distribution.
- B. Parental inheritance.
- C. Transmission.
- D. Segregation.

**Answer: D**

Explanation:

The question refers to one of the foundational concepts in genetics, derived from the experiments and subsequent conclusions of Gregor Mendel, a 19th-century Augustinian monk who is often referred to as the "father of modern genetics." Mendel's research primarily involved experimenting with pea plants in his monastery's garden, where he meticulously tracked the inheritance of various traits. Through his observations, Mendel concluded that traits were inherited in specific, predictable patterns.

Mendel's Principle of Segregation is one of these patterns. This principle states that every individual possesses pairs of alleles (variants of a gene) for any particular trait and that these alleles segregate (separate) during the formation of gametes (sperm and eggs). Consequently, each gamete receives only

one allele from each pair. During fertilization, when the gametes from two parents unite, the offspring then receives one allele from each parent, restoring the pair. This principle is a cornerstone of the inheritance patterns observed in sexually reproducing organisms and explains why offspring may exhibit one of two traits carried by their parents.

This principle was groundbreaking because it challenged the blending theory of inheritance prevalent at the time, which suggested that offspring merely exhibited a blend of parental traits. Instead, Mendel's findings indicated that traits are inherited as discrete units, and these units remain unchanged as they pass from parent to offspring. This understanding laid the groundwork for the establishment of the laws of heredity and the later development of modern genetics.

The correct answer to the question is hence "Segregation." This choice directly refers to Mendel's Principle of Segregation, which accurately describes the process by which alleles for a trait separate during gamete formation and only one allele from each parent is passed on to the offspring. This principle is critical for understanding genetic inheritance and has implications in fields ranging from agriculture to medicine.

### Question: 8

Which of the following is true about the Phylum Annelida?

- A. They only live in damp earth.
- B. They have a single pore that acts as mouth and anus.
- C. They have an open circulatory system.
- D. They have various specialized types of tissue.

**Answer: D**

Explanation:

The correct answer, that annelids have various specialized types of tissue, reflects the complexity and evolutionary advancement of the Phylum Annelida. Annelids are a diverse group of segmented worms, including earthworms, leeches, and marine polychaetes. They demonstrate a high degree of organization with specialized tissues and internal structures that perform distinct functions. This specialization is a significant step above more primitive organisms that might exhibit more generalized structures.

In terms of their anatomy, annelids are known for having a segmented body plan. Each segment, or metamere, can contain elements of various organ systems, such as the nervous system, circulatory system, and excretory structures. This segmentation leads to a more efficient and flexible body structure, allowing for complex movements and functions. The digestive system of annelids is a prime example of specialization; it includes different regions like the esophagus, crop, gizzard, and intestine, each performing specific roles in the processing of food.

Annelids also possess a closed circulatory system, which is more advanced compared to the open systems found in many other invertebrates. In a closed circulatory system, blood is enclosed within vessels, allowing for more efficient transport of nutrients and gases throughout the body. This system includes a heart-like structure and blood vessels that extend into each body segment, ensuring that all tissues receive adequate blood supply.

Moreover, the nervous system in annelids is well-developed and centralized, featuring a pair of cerebral ganglia, or brain-like structures, at the anterior end, which connect to a ventral nerve cord running the

length of the body. This configuration supports complex behaviors and responses to environmental stimuli.

To address the incorrect options, it is important to clarify that while many annelids, such as earthworms, are commonly found in damp soil, the phylum as a whole inhabits a variety of environments. Annelids are not restricted to terrestrial habitats; numerous species thrive in marine and freshwater ecosystems, demonstrating the phylum's adaptability and ecological diversity.

In conclusion, the diversity of specialized tissues and advanced organ systems in annelids underscores their evolutionary success and adaptability to various environments. This specialization enables them to perform complex functions and maintain efficient physiological processes, distinguishing them from simpler organisms and highlighting their significance in the study of biology and evolution.

## Question: 9

Identify the person who invented dynamite and also used his wealth to institute one of the most prestigious prizes awarded each year to those who have excelled in their field.

- A. Sir Isaac Newton
- B. Alfred Nobel
- C. Albert Einstein
- D. Nicolaus Copernicus

**Answer: B**

Explanation:

The correct answer to the question is Alfred Nobel.

Alfred Bernhard Nobel, born on October 21, 1833, in Stockholm, Sweden, was a prolific inventor, scientist, and businessman. He is best known for inventing dynamite, a discovery that revolutionized the construction and demolition industries. Nobel's invention was a safer way to handle the highly unstable nitroglycerin by absorbing it in a porous substance, making it less volatile and easier to handle. Despite his success as an inventor, Nobel was often troubled by the use of his inventions in warfare and was deeply concerned about how he would be remembered. This concern was further fueled when, in 1888, a French newspaper erroneously published his obituary instead of his brother's and condemned him for making a fortune from the sales of arms and explosives. The obituary famously bore the headline "The merchant of death is dead" which profoundly affected him.

Motivated by a desire to leave a positive legacy, Nobel decided to allocate the bulk of his wealth to establish the Nobel Prizes. He drafted a will specifying that his fortune be used to create a series of prizes for those who confer the "greatest benefit on mankind" in the fields of Physics, Chemistry, Medicine, Literature, and Peace. Later, the Nobel Memorial Prize in Economic Sciences was added in 1968 by Sweden's central bank.

The Nobel Prizes, first awarded in 1901, have become highly prestigious and are awarded annually in recognition of academic, cultural, or scientific advances. The Peace Prize, in particular, is awarded in Oslo, Norway, in accordance with Nobel's wishes, while the other prizes are awarded in Stockholm, Sweden. These prizes not only honor Alfred Nobel's name but also reflect his hope for a better world through science, literature, and peace.

Through his invention of dynamite and the establishment of the Nobel Prizes, Alfred Nobel created a lasting impact that continues to resonate across various fields around the world, demonstrating a profound transformation from a man of industry to a benefactor of humanity.

## Question: 10

A spring of force constant  $k$  is cut into two pieces so that the one piece is double the length of the other. What will be the force constant of the longer of the two pieces?

- A.  $2k/3$
- B.  $3k/2$
- C.  $3k$
- D.  $6k$

**Answer: B**

Explanation:

To understand the change in the force constant of a spring when it is cut, it is vital to recall the relationship between the force constant ( $k$ ) of a spring and its length. The force constant of a spring is defined by Hooke's Law, which states that the force  $F$  exerted by a spring is directly proportional to the distance  $x$  it is stretched or compressed, expressed as  $F = -kx$ . The negative sign indicates that the force exerted by the spring is in the opposite direction of its displacement.

When a spring is cut into pieces, the force constant of each piece changes. This change is inversely proportional to the length of the spring. If the original spring has a force constant  $k$  and is of length  $L$ , cutting it into pieces of different lengths will result in each piece having a different force constant. The relationship can be described by the formula  $k' = k(L/L')$ , where  $L'$  is the length of the new spring segment.

In the given problem, a spring with an original length  $L$  and force constant  $k$  is cut into two pieces such that one piece is double the length of the other. This results in one piece being  $L/3$  long and the other being  $2L/3$  long. According to the formula for the force constant of a cut spring, the force constant  $k'$  for the longer piece (length  $2L/3$ ) can be calculated as:  $k' = k(L/(2L/3)) = k(3/2) = 3k/2$ .

This calculation shows that the force constant of the longer piece is  $3k/2$ , which means it is 1.5 times the force constant of the original spring. This increase makes the longer piece stiffer compared to the original spring. The physics behind this is that with a shorter relative length ( $2L/3$  compared to the original  $L$ ), each segment of the spring needs to handle a greater proportion of the load for the same amount of stretch, hence the increase in the force constant.

Therefore, the answer to the question is that the force constant of the longer of the two pieces, which is  $2L/3$  of the original length, becomes  $3k/2$ . This spring is stiffer and harder to compress compared to its original configuration, reflecting the inverse relationship between the force constant and the length of a spring.



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