Essay Writing Tips:

Each essay question is worth no more than 10 points. Credit is given for an answer that contains:
- Terms
- Examples
- Facts
- Applications
- Links to other information
- Definitions

If the essay has 2 parts, each part is probably worth 6 points.
If the essay has 3 parts, each part is probably worth 4 points.
If the essay has 4 parts, each part is probably worth 3 points.
Make sure to answer all parts of the question to maximize the potential for points.

Beginning in 2004, a ten-minute reading period will be given to students to allow time for preparing to write comprehensive essays. Students are encouraged to use this time to outline their answer on the green question sheet. Please note that any writing on the green sheet will not be graded. Only the answers written in the essay booklet will be graded. After the ten-minute reading period, ninety minutes will be allowed for you to answer all four essay questions.

1. Answer only what is asked. Carefully read each section of the question and make certain that you are answering the specific question that is being asked. No points are given for restating the question or extra information that is unrelated to the question.

2. Write complete sentence answers. (No credit is given for outlines)

3. Pay special attention to numbers in the question. Ex. Give three examples of homeostasis in living systems. Extra examples beyond three receive no extra credit. Only the first three examples will be considered for grading. It is important that students follow through with the examples if asked to continue discussions in part B and C.

4. The exam requires that all four essays be answered. Each exam question will be rated the same, however within an exam question; sections will be weighted differently. Ex. If a question has three parts A, B, and C, the value of each section can differ.

5. Lab-based questions may require creating graphs or charts. It is important to properly label the graph or chart with a title and also label the axes of graphs with correct labels including units of measurements.

6. Experimental design questions must be answered with attention to:
   1. a clearly defined testable hypothesis
   2. a controlled experiment with a description of the control and IV
3. many subjects should be included in the sample sizes- never just one
4. a clear description or what is to be measured, how it is to be measured and how frequently observations and measurements will be made (DV)
5. an explanation of how data will be analyzed if appropriate
6. the need for repetition of the experiment to prove results or the need for revision of the hypothesis

7. Students are encouraged to write clearly using black or blue pen. If student penmanship is hard to read they can print if it is easier to read. Write large enough for the reader to be able to read what you have written.

8. It is easier for the grader if students answer the question sections in order, labeling each section. Ex. 1A, 1B, 1C.

9. It is suggested that students allocate sufficient time (22 minutes) for each of the four essay answers. Bringing a watch into the exam setting may be helpful to student’s time management. Students may go back during the essay writing section if time allows, to add more information to their answer, but they are encouraged to write succinctly and use their time carefully to answer all sections of each of the four questions. Remember that writing outlines on the green question sheets will give you no points as green sheets are not graded.

**Scientific Method**

1) (2) The activities of organisms change at regular time intervals. These changes are called biological rhythms. The graph depicts the activity cycle over a 48-hour period for a fictional group of mammals called pointy-eared bombats, found on an isolated island in the temperate zone.

```
Time of Day

High

Bomb Activity Level

Low

Midnight 4 A.M. 8 A.M. Noon 4 P.M. 8 P.M. Midnight 4 A.M. 8 A.M. Noon 4 P.M. 8 P.M. Midnight
```

a) Describe the cycle of activity for the bombats. Discuss how three of the following factors might affect the physiology and/or behavior of the bombats to result in this pattern of activity.

- temperature
- food availability
- presence of predators
- social behavior

b) Propose a hypothesis regarding the effect of light on the cycle of activity in bombats. Describe a controlled experiment that could be performed to test this hypothesis, and the results you would expect.
2) (99) The rate of photosynthesis may vary with changes that occur in environmental temperature, wavelength of light, and light intensity. Using a photosynthetic organism of your choice, choose only ONE of the three variables (temperature, wavelength of light, or light intensity) and for this variable
   a) design a scientific experiment to determine the effect of the variable on the rate of photosynthesis for the organism;
   b) explain how you would measure the rate of photosynthesis in your experiment;
   c) describe the results you would expect. Explain why you would expect these results.

1) (2) The following experiment was designed to test whether different concentration gradients affect the rate of diffusion. In this experiment, four solutions (0% NaCl, 1% NaCl, 5% NaCl, and 10% NaCl) were tested under identical conditions. Fifteen milliliters (mL) of 0% NaCl were put into a bag formed of dialysis tubing that is permeable to Na+, Cl-, and water. The same was done for each NaCl solution. Each bag was submerged in a separate beaker containing 300 mL of distilled water. The concentration of NaCl in mg/L in the water outside each bag was measured at 40-second intervals. The results from the 5% NaCl solution are shown in the table below.

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>NaCl (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>130</td>
</tr>
<tr>
<td>80</td>
<td>220</td>
</tr>
<tr>
<td>120</td>
<td>320</td>
</tr>
<tr>
<td>160</td>
<td>400</td>
</tr>
</tbody>
</table>

a) On the axes provided, graph the data for the 5% NaCl solution.

b) Using the same set of axes, draw and label three additional lines representing the results that you would predict for the 0% NaCl, 1% NaCl, and 10% NaCl solutions. Explain your predictions.

c) Farmlands located near coastal regions are being threatened by encroaching seawater seeping into the soil. In terms of water movement into or out of plant cells, explain why seawater could decrease crop production. Include a discussion of water potential in your answer.

2) (80) Discuss the lock-and-key theory of enzyme-substrate interaction giving a specific example to illustrate the theory. Include in your discussion the effects of each of the following:
   a. Substrate concentration
   b. pH shifts
   c. Temperature shifts
   d. Competitive inhibition

3) (81) Discuss the biological importance of each of the following organic compounds in relation to cellular structure and function in plants and animals.
   a. Carbohydrates
   b. Proteins
   c. Lipids
   d. Nucleic acids

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4) (85) Describe the chemical composition and configuration of enzymes and discuss the factors that modify enzyme structure and/or function.

5) (88) After an enzyme is mixed with its substrate, the amount of product formed is determined at 10-second intervals for 1 minute. Data from this experiment are shown below.

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product formed (mg)</td>
<td>0.00</td>
<td>0.25</td>
<td>0.50</td>
<td>0.70</td>
<td>0.80</td>
<td>0.85</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Draw a graph of these data and answer the following questions.

a) What is the initial rate of this enzymatic reaction?
b) What is the rate after 50 seconds? Why is it different from the initial rate?
c) What would be the effect on product formation if the enzyme were heated to a temperature of 100°C for 10 minutes before repeating the experiment? Why?
d) How might altering the substrate concentration affect the rate of the reaction? Why?
e) How might altering the pH affect the rate of the reaction? Why?

6) (91) Carbon is a very important element in living systems.

a) Describe the various characteristics of the carbon atom that make possible the building of a variety of biological molecules.
b) Explain how reactions involving carbon-containing compounds can contribute to the greenhouse effect.
c) The following structures are examples of two different categories of biological compounds. Describe how each category of compounds is important of the structure and function of living systems.
7) A laboratory assistant prepared solutions of 0.8M, 0.6M, 0.4M, and 0.2M sucrose, but forgot to label them. After realizing the error, the assistant randomly labeled the flasks containing these four unknown solutions as Flask A, Flask B, Flask C, and Flask D.

Design an experiment, based on the principles of diffusion and osmosis, that the assistant could use to determine which of the flasks contain each of the four unknown solutions. Include in your answer:

   a) a description of how you would set up and perform the experiment;
   b) the results you would expect from your experiment;
   c) an explanation of those results based on the principles involved. (Be sure to clearly state the principles addressed in your discussion.)

8) Enzymes are biological catalysts.
   a. Relate the chemical structure of an enzyme to its specificity and catalytic activity.
      a) b. Design a quantitative experiment to investigate the influence of pH or temperature on the activity of an enzyme.
      b) c. Describe what information concerning the structure of an enzyme could be inferred from your experiment.

9) The unique properties (characteristics) of water make life possible on Earth. Select three properties of water and:
   a) for each property, identify and define the property and explain it in terms of the physical / chemical nature of water.
   b) For each property, describe one example of how the property affects the functioning of living organisms.

10) The effects of pH and temperature were studied for an enzyme-catalyzed reaction. The following results were obtained.

   a) How do (1) temperature and (2) pH affect the activity of this enzyme? In your answer, include a discussion of the relationship between the structure and the function of this enzyme, as well as a discussion of how structure and function of enzymes are affected by temperature and pH.
   b) Describe a controlled experiment that could have produced the data shown for either temperature or pH. Be sure to state the hypothesis that was tested here.
11) (3B) Water is important for all living organisms. The functions of water are directly related to its physical properties.
   
   (a) Describe how the properties of water contribute to TWO of the following.
   
   • transpiration
   • thermoregulation in endotherms
   • plasma membrane structure
   
   (b) Water serves as a reactant and a product in the carbon cycle. Discuss the role of water in the carbon cycle.
   
   (c) Discuss the impact of one human activity on the water cycle.

12) (5B) Water potential in potato cells was determined in the following manner. The initial masses of six groups of potato cores were measured. The potato cores were placed in sucrose solutions of various molarities. The masses of the cores were measured again after 24 hours. Percent changes in mass were calculated. The results are shown below.

<table>
<thead>
<tr>
<th>Molarity of Sucrose in Beaker</th>
<th>Percent Change in Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 M</td>
<td>18.0</td>
</tr>
<tr>
<td>0.2</td>
<td>5.0</td>
</tr>
<tr>
<td>0.4</td>
<td>-8.0</td>
</tr>
<tr>
<td>0.6</td>
<td>-16.0</td>
</tr>
<tr>
<td>0.8</td>
<td>-23.5</td>
</tr>
<tr>
<td>1.0</td>
<td>-24.0</td>
</tr>
</tbody>
</table>

   a) Graph these data on the axes provided. From your graph, find the apparent molar concentration (osmolarity) of the potato core cells.
   
   b) What are the components of water potential, and why is water potential important for the movement of water in plants?
   
   c) Predict what would happen to typical animal cells placed in 0.0 M and 1.0 M sucrose solutions, and explain your prediction.

Cell Biology

1) (81) Describe the structural arrangement and function of the membranes associated with each of the following eukaryotic organelles.
   
   a. Mitochondrion
   b. Endoplasmic reticulum
   c. Chloroplast
   d. Golgi apparatus

2) (83) Describe the fluid mosaic model of the plasma membrane. Discuss the role of the membrane in the movement of materials through it by each of the following processes.
   
   a. Active transport
   b. Passive transport

3) (84) Describe the structure of a generalized eukaryotic plant cell. Indicate the ways in which a non-photosynthetic prokaryotic cell would differ in structure from this generalized eukaryotic plant cell.
4) (93) Membranes are important structural features of cells.
   a) Describe how membrane structure is related to the transport of materials across a
      membrane.
   b) Describe the role of membranes in the synthesis of ATP in either cellular respiration or
      photosynthesis.

5) (94) Discuss how cellular structures, including the plasma membrane, specialized endoplasmic
      reticulum, cytoskeletal elements, and mitochondria, function together in the contraction of
      skeletal muscle cells.

6) (98) Cells transport substances across their membranes. Choose THREE of the following four
      types of cellular transport.
      • Osmosis
      • Active transport
      • Facilitated diffusion
      • Endocytosis/exocytosis
      For each of the three transport types you choose:
      a) describe the transport process and explain how the organization of cell membranes
         functions in the movement of specific molecules across the membrane; and
      b) explain the significance of each type of transport to a specific cell (you may use
         different cell types as examples.)

7) (99) Communication occurs among the cells in a multicellular organism. Choose THREE of the
      following examples of cell-to-cell communication, and for each example, describe the
      communication that occurs and the types of responses that result from this communication.
      • Communication between two plant cells
      • Communication between two immune-system cells
      • Communication either between a neuron and another neuron, or between a neuron and a
        muscle cell
      • Communication between a specific endocrine-gland cell and its target cell

8) (2B) The physical form of cells and organisms is often influenced by special structural polymers.
    Choose one polymer from each of the following three pairs of polymers:
    Pair 1: tubulin…myosin
    Pair 2: cellulose…chitin
    Pair 3: messenger RNA…transfer RNA
    For each of the three polymers you have chosen, describe its
    (a) structure, and
    (b) role in a cell or organism.

9) (4B) Prokaryotes are found throughout the biosphere. Answer two of the following.
   a) Provide three examples of adaptations found in various prokaryotes. Explain how these
      three adaptations have ensured the success of prokaryotes.
   b) Discuss how prokaryotes early in Earth’s history altered environments on Earth.
   c) Discuss three ways in which prokaryotes continue to have ecological impact today.
10) A major distinction between prokaryotes and eukaryotes is the presence of membrane-bound organelles in eukaryotes.
   a) Describe the structure and function of TWO eukaryotic membrane-bound organelles other than the nucleus.
   b) Prokaryotic and eukaryotic cells have some non-membrane-bound components in common. Describe the function of TWO of the following and discuss how each differs in prokaryotes and eukaryotes.
      • DNA
      • Cell wall
      • Ribosomes
   c) Explain the endosymbiotic theory of the origin of eukaryotic cells and discuss an example of evidence supporting this theory.

11) The relationship of structure to function is one of the major themes in biology. For three of the following structure/function pairs, describe the structure and then explain how the function is related to the structure.
   a) Enzyme structure/catalysis
   b) mRNA structure/protein synthesis
   c) Cell membrane structure/signal transduction
   d) Membrane protein structure/active transport or facilitated diffusion

12) Membranes are essential components of all cells.
   (a) Identify THREE macromolecules that are components of the plasma membrane in a eukaryotic cell and discuss the structure and function of each.
   (b) Explain how membranes participate in THREE of the following biological processes:
      • Muscle contraction
      • Fertilization of an egg
      • Chemiosmotic production of ATP
      • Intercellular signaling

Energetics

1) Explain what occurs during the Krebs (citric acid) cycle and electron transport by describing the following.
   a) The location of the Krebs cycle and electron transport chain in the mitochondria.
   b) The cyclic nature of the reactions in the Krebs cycle.
   c) The production of ATP and reduced coenzymes during the cycle.
   d) The chemiosmotic production of ATP during electron transport.
2) (90) The results below are measurements of cumulative oxygen consumption by germinating and dry seeds. Gas volume measurements were corrected for changes in temperature and pressure.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>22°C Germinating Seeds</strong></td>
<td>0.0</td>
<td>8.8</td>
<td>16.0</td>
<td>23.7</td>
<td>32.0</td>
</tr>
<tr>
<td><strong>Dry Seeds</strong></td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>10°C Germinating Seeds</strong></td>
<td>0.0</td>
<td>2.9</td>
<td>6.2</td>
<td>9.4</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Dry Seeds</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

a) Using the graph paper provided, plot the results for the germinating seeds at 22°C and at 10°C.
b) Calculate the rate of oxygen consumption for the germinating seeds at 22°C, using the time interval between 10 and 20 minutes.
c) Account for the differences in oxygen consumption observed between:
   (1) germinating seeds at 22°C and at 10°C;
   (2) germinating seeds and dry seeds.
d) Describe the essential features of an experimental apparatus that could be used to measure oxygen consumption by a small organism. Explain why each of these features is necessary.

3) (95) Energy transfer occurs in all cellular activities. For 3 of the following 5 processes involving energy transfer, explain how each functions in the cell and give an example. Explain how ATP is involved in each example you choose.
   • Cellular movement
   • Active transport
   • Synthesis of molecules
   • Chemiosmosis
   • Fermentation

4) (5) Yeast cells are placed in an apparatus with a solution of sugar (a major nutrient for yeast metabolism). The apparatus detects bubbles of gas released by the yeast cells. The rate of respiration varies with the surrounding temperatures as indicated by the data below.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bubbles of gas produced per minute</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

a) **Graph** the results on the axes provided. **Determine** the optimum temperature for respiration in the yeast.
b) **Respiration** is a series of enzyme-catalyzed reactions. Using your knowledge of enzymes and the data above, **analyze and explain** the results of this experiment.
c) **Design** an experiment to test the effect of varying the pH of the sugar solution on the rate of respiration. Include a prediction of the expected results.
Photosynthesis

1) (86) Describe the light reactions of photosynthesis and, for both a C3 and a C4 plant, trace the path of a carbon dioxide molecule from the point at which it enters a plant to its incorporation into a glucose molecule. Include leaf anatomy and biochemical pathways in your discussion of each type of plant.

2) (04) A controlled experiment was conducted to analyze the effects of darkness and boiling on the photosynthetic rate of incubated chloroplast suspensions. The dye reduction technique was used. Each chloroplast suspension was mixed with DPIP, an electron acceptor that changes from blue to clear when it is reduced. Each sample was placed individually in a spectrophotometer and the percent transmittance was recorded. The three samples used were prepared as follows.
   - Sample 1 – chloroplast suspension + DPIP
   - Sample 2 – chloroplast suspension surrounded by foil wrap to provide a dark environment + DPIP
   - Sample 3 – chloroplast suspension that has been boiled + DPIP

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Light, Unboiled % Transmittance</th>
<th>Dark, Unboiled % Transmittance</th>
<th>Light, Boiled % Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>28.8</td>
<td>29.2</td>
<td>28.8</td>
</tr>
<tr>
<td>5</td>
<td>48.7</td>
<td>30.1</td>
<td>29.2</td>
</tr>
<tr>
<td>10</td>
<td>57.8</td>
<td>31.2</td>
<td>29.4</td>
</tr>
<tr>
<td>15</td>
<td>62.5</td>
<td>32.4</td>
<td>28.7</td>
</tr>
<tr>
<td>20</td>
<td>66.7</td>
<td>31.8</td>
<td>28.5</td>
</tr>
</tbody>
</table>

   a) On the graph provided, construct and label a graph showing the results for the three samples.
   b) Identify and explain the control or controls for this experiment.
   c) The differences in the curves of the graphed data indicate that there were differences in the number of electrons produced in the three samples during the experiment. Discuss how electrons are generated in photosynthesis and why the three samples gave different transmittance results.

Photosynthesis & Cellular Respiration

1) (82) Describe the similarities and differences between the biochemical pathways of aerobic respiration and photosynthesis in eukaryotic cells. Include in your discussion the major reactions, the end products, and energy transfers.

2) (97) Photosynthesis and cellular respiration recycle oxygen in ecosystems. Respond to TWO (and only two) of the following:
   a) Explain how the metabolic processes of cellular respiration and photosynthesis recycle oxygen.
   b) Discuss the structural adaptations that function in oxygen exchange between each of the following organisms and its environment: a plant; an insect; a fish.
   c) Trace a molecule of O₂ from the environment to a muscle cell in a vertebrate of your choice.
1) (80) Describe in detail the process of meiosis as it occurs in an organism with a diploid chromosome number of 4 (2n = 4). Include labeled diagrams in your discussion. Indicate when and how each of the following occurs in meiosis.
   a. Crossing over
   b. Nondisjunction

2) Discuss the process of cell division in animals. Include a description of mitosis and cytokinesis, and of the other phases of the cell cycle. Do NOT include meiosis.

3) (96) An organism is heterozygous at two genetic loci on different chromosomes.
   |   |   |   |   |
   |   |   |   |   |
   |   |   |   |   |
   |   |   B   b |
   |   |   |   |   |
   |   |   |   |   |
   A   a

   a) Explain how these alleles are transmitted by the process of mitosis to daughter cells.
   b) Explain how these alleles are distributed by the process of meiosis to gametes
   c) Explain how the behavior of these two pairs of homologous chromosomes during meiosis provides the physical basis for Mendel’s two laws of inheritance.

   Labeled diagrams that are explained in your answer may be useful.

4) (4) Meiosis reduces chromosome number and rearranges genetic information.
   a) Explain how the reduction and rearrangement are accomplished in meiosis.
   b) Several human disorders occur as a result of defects in the meiotic process. Identify ONE such chromosomal abnormality; what effects does it have on the phenotype of people with the disorder? Describe how this abnormality could result from a defect in meiosis.
   c) Production of offspring by parthenogenesis or cloning bypasses the typical meiotic process. Describe either parthenogenesis or cloning and compare the genomes of the offspring with those of the parents

5) (6b) Sexual reproduction requires that half of the chromosomes in a zygote come from one parent and the other half from the second parent.
   a) Describe the process by which a germ cell's complement of chromosomes is halved in the formation of gametes.
   b) Choose one organism or group of organisms that reproduce asexually. Describe the mode of asexual reproduction in that organism and explain the advantages to the organism of asexual reproduction.
   c) Choose one organism or group of organisms that reproduce sexually. Describe the mode of sexual reproduction in that organism and explain the advantages to the organism of sexual reproduction.
1) (83) State the conclusions reached by Mendel in his work on the inheritance of characteristics. Explain how each of the following deviated from these conclusions.
   a. Autosomal linkage
   b. Sex-linked (X-linked) inheritance
   c. Polygenic (multiple-gene) inheritance

2) (88) Discuss Mendel’s laws of segregation and independent assortment. Explain how the events of meiosis I account for the observations that led Mendel to formulate these laws.

3) (97) In a laboratory population of diploid, sexually reproducing organisms a certain trait is studied. This trait is determined by a single autosomal gene and is expressed as two phenotypes. A new population was created by crossing 51 pure breeding (homozygous) dominant individuals with 49 pure breeding (homozygous) recessive individuals. After four generations, the following results were obtained.

   \[
   \begin{array}{ccc}
   \text{Generation} & \text{Dominant} & \text{Recessive} & \text{Total} \\
   1 & 51 & 49 & 100 \\
   2 & 280 & 0 & 280 \\
   3 & 240 & 80 & 320 \\
   4 & 300 & 100 & 400 \\
   5 & 360 & 120 & 480 \\
   \end{array}
   \]

   a) Identify an organism that might have been used to perform this experiment and explain why this organism is a good choice for conducting this experiment.
   b) On the basis of the data, propose a hypothesis that explains the change in the phenotypic frequency between generation 1 and generation 3.
   c) Is there evidence indicating whether or not this population is in Hardy-Weinberg equilibrium? Explain.

4) (3) In fruit flies, the phenotype for eye color is determined by a certain locus. \( E \) indicates the dominant allele and \( e \) indicates the recessive allele. The cross between a male wild-type fruit fly and a female white-eyed fruit fly produced the following offspring.

   \[
   \begin{array}{ccccc}
   \text{Wild-type} & \text{Wild-type} & \text{White-eyed} & \text{White-eyed} & \text{Brown-eyed} \\
   \text{Male} & \text{Female} & \text{Male} & \text{Female} & \\
   \text{Fl} & 0 & 45 & 55 & 0 & 1 \\
   \text{F2} & 23 & 31 & 22 & 24 & 0 \\
   \end{array}
   \]

   The wild-type and white-eyed individuals from the Fl generation were then crossed to produce the following offspring.

   a) Determine the genotypes of the original parents (P generation) and explain your reasoning. You may use Punnett squares to enhance your description, but the results from the Punnett squares must be discussed in your answer.
   b) Use a Chi-squared test on the F2 generation data to analyze your prediction of the parental genotypes. Show all your work and explain the importance of your final answer.
c) The brown-eyed female in the F1 generation resulted from a mutational change. Explain what a mutation is, and discuss two types of mutations that might have produced the brown-eyed female in the F1 generation.

<table>
<thead>
<tr>
<th>Degrees of Freedom (df)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>3.84</td>
<td>5.99</td>
<td>7.82</td>
<td>9.49</td>
<td>11.1</td>
</tr>
</tbody>
</table>

The formula for Chi-squared is:

\[ \chi^2 = \sum \left( \frac{(o - e)^2}{e} \right) \]

where \( o \) = observed number of individuals
\( e \) = expected number of individuals
sigma = the sum of the values (in this case, the differences, squared, divided by the number expected)

**Molecular genetics**

1) (1) Proteins—large complex molecules—are major building blocks of all living organisms. Discuss the following in relation to proteins.
   a) The chemical composition and levels of structure of proteins.
   b) The roles of DNA and RNA in protein synthesis.
   c) The roles of proteins in membrane structure and transport of molecules across the membrane.

2) (02) The human genome illustrates both continuity and change.
   a) Describe the essential features of two of the procedures/techniques below. For each of the procedures/techniques you describe, explain how its application contributes to understanding genetics.
      • The use of a bacterial plasmid to clone and sequence a human gene
      • Polymerase chain reaction (PCR)
      • Restriction fragment length polymorphism (RFLP) analysis
   b) All humans are nearly identical genetically in coding sequences and have many proteins that are identical in structure and function. Nevertheless, each human has a unique DNA fingerprint. Explain this apparent contradiction.

3) (82) A portion of a specific DNA molecule consists of the following sequence of nucleotide triplets.

**TAC GGA CTT GGG TCC**

The DNA sequence codes for the following short polypeptide.

**methionine -- leucine -- glutamic acid -- proline -- arginine**

Describe the steps in the synthesis of this polypeptide. What would be the effect of a deletion or an addition in one of the DNA nucleotides? What would be the effect of a substitution in one of the nucleotides?
4) (84) Experiments by the following scientists provided critical information concerning DNA. Describe each classic experiment and indicate how it provided evidence for the chemical nature of the gene.
   a. Hershey and Chase -- bacteriophage replication
   b. Griffith and Avery, MacLeod, and McCarty -- bacterial transformation
   c. Meselson and Stahl -- DNA replication in bacteria

5) (85) Describe the operon hypothesis and discuss how it explains the control of messenger-RNA production and the regulation of protein synthesis in bacterial cells.

6) (86) Describe the biochemical composition, structure, and replication of DNA. Discuss how recombinant DNA techniques may be used to correct a point mutation.

7) (87) Describe the production and processing of a protein that will be exported from a eukaryotic cell. Begin with the separation of the messenger RNA from the DNA template and end with the release of the protein at the plasma membrane.

8) (90) Describe the steps of protein synthesis beginning with the attachment of a messenger RNA molecule to the small subunit of a ribosome and ending with the release of the polypeptide from the ribosome. Include in your answer a discussion of how the different types of RNA function in this process.

9) (93) Assume that a particular genetic condition in a mammalian species causes an inability to digest starch. This disorder occurs with equal frequency in males and females. In most cases, neither parent of affected offspring has the condition.
   a) Describe the most probable pattern of inheritance for this condition. Explain your reasoning. Include in your discussion a sample cross(e(s) sufficient to verify your proposed pattern.
   b) Explain how mutation could cause this inability to digest starch.
   c) Describe how modern techniques of molecular biology could be used to determine whether the mutant allele is present in a given individual.

10) (95) The diagram below shows a segment of DNA with a total length of 4,900 base pairs. The arrows indicate reaction sites for two restriction enzymes (enzyme X and enzyme Y).

   DNA Segment Length (base pairs) 0 400 500 1,200 1,300 1,500
   Enzyme X Enzyme Y Enzyme X Enzyme X

   a) Explain how the principles of gel electrophoresis allow for the separation of DNA fragments.
   b) Describe the results you would expect from the electrophoretic separation of fragments from the following treatments of the DNA segment above. Assume that the digestion occurred under appropriate conditions and went to completion.
   I. DNA digested with only enzyme X
   II. DNA digested with only enzyme Y
   III. DNA digested with enzyme X and enzyme Y combined
   IV. Undigested DNA
c) Explain both of the following.
   (1) The mechanism of action of restriction enzymes.
   (2) The different results you would expect if a mutation occurred at the recognition site for enzyme Y.

11) (98) By using the techniques of genetic engineering, scientists are able to modify genetic material so that a particular gene of interest from one cell can be incorporated into a different cell.
   • Describe a procedure by which this can be done.
   • Explain the purpose of each step of your procedure.
   • Describe how you could determine whether the gene was successfully incorporated.
   Describe an example of how gene transfer and incorporation have been used in a biomedical or commercial application.

12) (99) Scientists seeking to determine which molecule is responsible for the transmission of characteristics from one generation to the next knew that the molecule must (1) copy itself precisely, (2) be stable but able to be changed, and (3) be complex enough to determine the organism's phenotype.
   • Explain how DNA meets each of the three criteria stated above.
   • Select one of the criteria stated above and describe experimental evidence used to determine that DNA is the hereditary material.

13) (0) Information transfer is fundamental to all living organisms. For two of the following examples, explain in detail how the transfer of information is accomplished.
   a) The genetic material in one eukaryotic cell is copied and distributed to two identical daughter cells
   b) A gene in a eukaryotic cell is transcribed and translated to produce a protein
   c) The genetic material from one bacterial cell enters another via transformation, transduction, or conjugation

14) (2B) Bacteria were cultured in a system that allowed for the continual addition of fresh nutrients and the removal of waste products. Bacteriophage (virus) were added at the time shown and the following population changes were observed.
   a) Describe and explain the observed results.
   b) Discuss the infection cycle of a DNA virus from attachment to lysis.
   c) Describe how the genome of a retrovirus like HIV (Human Immunodeficiency Virus) becomes incorporated into the genome of the host cell.
15) (3B) A difference between prokaryotes and eukaryotes is seen in the organization of their genetic material.
   a) Discuss the organization of the genetic material in prokaryotes and eukaryotes.
   b) Contrast the following activities in prokaryotes and eukaryotes:
      • Replication of DNA
      • Transcription or translation
      • Gene regulation
      • Cell division

16) (5B) Protein synthesis is vital for cell growth and metabolism.
   a) Describe transcription and translation.
   b) Identify similarities between transcription and translation.
   c) Identify differences between transcription and translation.
   d) Describe structural changes that can occur to a protein after translation to make it function properly.

17) (5) The unit of genetic organization in all living organisms is the chromosome.
   a) Describe the structure and function of the parts of a eukaryotic chromosome. You may wish to include a diagram as part of your description.
   b) Describe the adaptive (evolutionary) significance of organizing genes into chromosomes.
   c) How does the function and structure of the chromosome differ in prokaryotes?

18) (7B) A molecule of messenger RNA (mRNA) has just been synthesized in the nucleus of a human cell.
   a) What types of modifications may occur to this RNA before it leaves the nucleus?
   b) Once in the cytoplasm, how is the mRNA translated to a protein?
   c) If the cell is a secretory cell, how is the protein from part (b) eventually targeted, packaged, and secreted to the exterior of the cell?

Evolution

1) (80) Discuss the significance of each of the events listed below in the evolution of living organisms.
   a) Primordial reducing atmosphere
   b) Origin of photosynthesis
   c) Increase in atmospheric oxygen and the development of the ozone layer.
   d) Origin of eukaryotes

2) (81) Define, discuss, and give an example of how each of the following isolating mechanisms contributes to speciation in organisms.
   a) Geographic barriers
   b) Ecological (including seasonal) isolation
   c) Behavioral isolation
   d) Polyploidy

3) (82) Describe the special relationship between the two terms in each of the following pairs.
   a) Convergent evolution of organisms and Australia
   b) Blood groups and genetic drift.
   c) Birds of prey and DDT
4) Describe the modern theory of evolution and discuss how it is supported by evidence from two of the following three areas.
   a) Population genetics
   b) Molecular biology
   c) Comparative anatomy and embryology

5) Describe how the following adaptations have increased the evolutionary success of the organisms that possess them. Include in your discussion the structure and function related to each adaptation.
   a) C4 metabolism
   b) Amniotic egg
   c) Four-chambered heart
   d) Pollen

6) Describe the processes of speciation. Include in your discussion the factors that may contribute to the maintenance of genetic isolation.

7) Do the following with reference to the Hardy-Weinberg model.
   a) Indicate the conditions under which allelic frequencies (p and q) remain constant from one generation to the next.
   b) Calculate, showing all work, the frequencies of the alleles and the frequencies of the genotypes in a population of 100,000 rabbits, of which 25,000 are white and 75,000 are agouti. (In rabbits the white color is due to a recessive allele, w and agouti is due to a dominant allele, W.)
   c) If the homozygous dominant condition were to become lethal, what would happen to the allelic and genotypic frequencies in the rabbit population after two generations?

8) Discuss how each of the following has contributed to the evolutionary success of the organisms in which they are found.
   a) Seeds
   b) Mammalian placenta
   c) Diploidy

9) Evolution is one of the major unifying concepts of modern biology.
   a. Explain the mechanisms that lead to evolutionary change.
   b. Describe how scientists use each of the following as evidence for evolution.
      (1) Bacterial resistance to antibiotics
      (2) Comparative biochemistry
      (3) The fossil record

10) Genetic variation is the raw material for evolution.
    a) Explain three cellular and/or molecular mechanisms that introduce variation into the gene pool of a plant or animal population.
    b) Explain the evolutionary mechanisms that can change the composition of the gene pool.
11) (94) Select two of the following three pairs and discuss the evolutionary relationships between the two members each pair you have chosen. In your discussion include structural adaptations and their functional significance.
   PAIR A: green algae – vascular plants
   PAIR B: prokaryotes – eukaryotes
   PAIR C: amphibians – Reptiles

   The problems of survival of animals on land are very different from those of survival of animals in an aquatic environment. Describe four problems associated with animal survival in terrestrial environments but not in aquatic environments. For each problem, explain an evolutionary solution.

12) (3B) Biologists are interested in preserving the diversity of living organisms on the planet.
   a) Explain THREE of the following processes or phenomena, using an appropriate example for each.
      • mutation
      • adaptive radiation
      • polyploidy
      • population bottlenecks
      • growth of the human population
   b) For each process or phenomenon you selected in (a), discuss its impact on the diversity of life on Earth.

13) (4) Darwin is considered the “father of evolutionary biology.” Four of his contributions to the field of evolutionary biology are listed below.
   • The nonconstancy of species
   • Branching evolution, which implies the common descent of all species
   • Occurrence of gradual changes in species
   • Natural selection as the mechanism for evolution
   a) For EACH of the four contributions listed above, discuss one example of supporting evidence.
   b) Darwin’s ideas have been enhanced and modified as new knowledge and technologies have become available. Discuss how TWO of the following have modified biologists’ interpretation of Darwin’s original contributions.
      • Hardy-Weinberg equilibrium
      • Punctuated equilibrium
      • Genetic engineering

14) (1) Charles Darwin proposed that evolution by natural selection was the basis for the differences that he saw in similar organisms as he traveled and collected specimens in South America and on the Galapagos Islands.
   a) Explain the theory of evolution by natural selection as presented by Darwin.
   b) Each of the following relates to an aspect of evolution by natural selection. Explain three of the following.
      i. Convergent evolution and the similarities among species (ecological equivalents) in a particular biome (e.g. tundra, taiga, etc.)
      ii. Natural selection and the formation of insecticide-resistant insects or antibiotic-resistant bacteria.
      iii. Speciation and isolation.
      iv. Natural selection and behavior such as kinesis, fixed-action-pattern, dominance hierarchy, etc.
      v. Natural selection and heterozygotes advantage.
15. (5B) In the evolution of organisms, major adaptations arose in certain groups, opening new evolutionary possibilities. For two of the following types of organisms, discuss the evolutionary significance of the features listed.
   a) Flowering plants: flowers, fruits and seeds, and broad leaves
   b) Flatworms: three germ layers, bilateral symmetry, and cephalization
   c) Segmented worms: segmentation, coelom, and digestive system
   d) Reptiles: amniotic eggs, waterproof skin, and well-developed lungs

16. (95) The problems of survival of animals on land are very different from those of survival of animals in an aquatic environment. Describe four problems associated with animal survival in terrestrial environments but not in aquatic environments. For each problem, explain an evolutionary solution.

17. (6)

According to fossil records and recent published observations, two species of leaf-eating beetles (species A and B) have existed on an isolated island in the Pacific Ocean for over 100,000 years. In 1964 a third species of leaf-eating beetle (species C) was accidentally introduced on the island. The population size of each species has been regularly monitored as shown in the graph above.
   a) Propose an explanation for the pattern of population density observed in species C.
   b) Describe the effect that the introduction of beetle species C has had on the population density of species A and species B. Propose an explanation for the patterns of population density observed in species A and in species B.
   c) Predict the population density of species C in 2014. Provide a biological explanation for your prediction.
   d) Explain why invasive species are often successful in colonizing new habitats.
Classification

1) (99) Scientists recently have proposed a reorganization of the phylogenetic system of classification to include the domain, a new taxonomic category higher (more inclusive) than the Kingdom category, as shown in the following diagram.

- Describe how this classification scheme presents different conclusions about the relationships among living organisms than those presented by the previous five-kingdom system of classification.
- Describe three kinds of evidence that were used to develop the taxonomic scheme above, and explain how this evidence was used. The evidence may be structural, physiological, molecular, and/or genetic.
- Describe four of the characteristics of the universal ancestor.

2) (4B) Organisms differ from one another and yet share characteristics.
   a) Select two kingdoms and briefly describe three characteristics used to distinguish between members of one kingdom and members of the other.
   b) Describe three characteristics (at least one molecular and one cellular) that members of these two kingdoms share.
   c) Propose an explanation for the existence of similarities and differences between the two kingdoms.

Animals Physiology

1) (80) In humans, discuss the transport of gases (oxygen and carbon dioxide) by the blood and the exchange of these gases between the blood and cells of the body. Include in your discussion the cellular and fluid composition of the blood.

2) (81) Describe the structure and function of the mammalian kidney. Include a discussion of the regulation of water balance by kidney and hormonal interaction.

3) (81) Describe the structure and function of the reflex arc in higher vertebrates. Include a description of the cell types and a discussion of the mechanism of transmission of the impulse.

4) (82) Describe the following mechanisms of response to foreign material in the human body.
   a. The antigen-antibody response to skin graft from another person.
   b. The reactions of the body leading to inflammation of a wound infected with bacteria.

5) (83) Describe the structure of a mammalian respiratory system. Include in your discussion the mechanisms of inspiration and expiration.

6) (84) Discuss the sources and actions of each of the following pairs of hormones in humans and describe the feedback mechanisms that control their release.
   a. Insulin … glucagon
   b. Parathyroid hormone … calcitonin
   c. Thyrotropin (TSH) … thyroxine (T4)
7) (85) Describe the anatomical and functional similarities and differences within each of the following pairs of structures.
   a. Artery … vein
   b. Small intestine … colon
   c. Skeletal muscle … cardiac muscle
   d. Anterior pituitary … posterior pituitary

8) (85) Describe releasers, imprinting, and communication, as each of these terms relates to animal behavior. You may include in your answer a discussion of the classical studies of Nikolaas Tinbergen, Konrad Lorenz, and Karl von Frisch.

9) (86) Beginning at the presynaptic membrane of the neuromuscular junction, describe the physical and biochemical events involved in the contraction of a skeletal muscle fiber. Include the structure of the fiber in your discussion.

10) (86) Describe the processes of fat and protein digestion and product absorption as they occur in the human stomach and small intestine. Include a discussion of the enzymatic reactions involved.

11) (87) Discuss the processes of exchange of O2 and CO2 that will occur at the alveoli and muscle cells of mammals. Include in your answer a description of the transport of these gases in the blood.

12) (88) Discuss the processes of cleavage, gastrulation, and neurulation in the frog embryo; tell what each process accomplishes. Describe an experiment that illustrates the importance of induction in development.

13) (89) Describe negative and positive feedback loops, and discuss how feedback mechanisms regulate each of the following.
   a. The menstrual cycle in a nonpregnant human female.
   b. Blood glucose levels in humans.

14) (90) a. Describe the differences between the terms in each of the following pairs.
       (1) Coelomate versus acoelomate body plan
       (2) Protostome versus deuterostome development
       (3) Radial versus bilateral symmetry
   b. Explain how each of these pairs of features was important in constructing the phylogenetic tree shown below. Use specific examples from the tree in your discussion.

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15) (91) The graph below shows the response of the human immune system to exposure to an antigen. Use this graph to answer part a and b of this question.
   a) Describe the events that occur during period I as the immune system responds to the initial exposure to the antigen.
   b) Describe the events that occur during period II following a second exposure to the same antigen.

   c. Explain how infection by the AIDS virus (HIV) affects the function of both T and B lymphocytes.

16) (92) Biological recognition is important in many processes at the molecular, cellular, tissue, and organismal levels. Select three of the following, and for each of the three that you have chosen, explain how the process of recognition occurs and give an example.
   a. Organisms recognize others as members of their own species.
   b. Neurotransmitters are recognized in the synapse.
   c. Antigens trigger antibody responses.
   d. Nucleic acids are complementary.
   e. Target cells respond to specific hormones.

17) (93) Many physiological changes occur during exercise.
   a) Design a controlled experiment to test the hypothesis that an exercise session causes short-term increases in heart rate and breathing rate in humans.
   b) Explain how at least three organ systems are affected by this increased physical activity and discuss interactions among these systems.

18) (96) Structure and function are related in the various organ systems of animals. Select two of the following four organ systems in vertebrates:
   • Respiratory
   • Digestive
   • Excretory
   • Nervous

   For each of the two systems you choose, discuss the structure and function of two adaptations that aid in the transport or exchange of molecules (or ions). Be sure to relate structure to function in each example.
19) The survival of organisms depends on regulatory mechanisms at various levels. Choose THREE from the following examples. Explain how each is regulated

- The expression of a gene
- The activity of an enzyme
- The cell cycle
- The internal water balance of a plant
- The density of a population

20) A scientist working with Bursatella leachii, a sea slug that lives in an intertidal habitat in the coastal waters of Puerto Rico, gathered the following information about the distribution of the sea slugs within a ten-meter square plot over a 10-day period.

**DISTRIBUTION OF SLUGS WITHIN A TEN-METER SQUARE PLOT**

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Average Distance Between Individuals (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midnight</td>
<td>8.0</td>
</tr>
<tr>
<td>4 A.M.</td>
<td>8.9</td>
</tr>
<tr>
<td>8 A.M.</td>
<td>44.8</td>
</tr>
<tr>
<td>Noon</td>
<td>174.0</td>
</tr>
<tr>
<td>4 P.M.</td>
<td>350.5</td>
</tr>
<tr>
<td>8 P.M.</td>
<td>60.5</td>
</tr>
<tr>
<td>Midnight</td>
<td>8.0</td>
</tr>
</tbody>
</table>

a) For the data above, provide information on each of the following.

- Summarize the pattern.
- Identify THREE physiological or environmental variables that could cause the slugs to vary their distance from each other.
- Explain how each variable could bring about the observed pattern of distribution.

b) Choose ONE of the variables that you identified and design a controlled experiment to test your hypothetical explanation. Describe results that would support or refute your hypothesis.

21) The evolutionary success of organisms depends on reproduction. Some groups of organisms reproduce asexually, some reproduce sexually, while others reproduce both sexually and asexually.

a) Using THREE different organisms, give an example of one organism that reproduces sexually, one that reproduces asexually, and one that reproduces BOTH sexually and asexually. For each organism given as an example, describe two reproductive adaptations. These adaptations may be behavioral, structural, and/or functional.


22) To survive, organisms must be capable of avoiding, and/or defending against, various types of environmental threats. Respond to each of the following.

a) Describe how adaptive coloration, mimicry, or behavior function as animal defenses against predation. Include two examples in your answer.

b) Describe how bacteria or plants protect themselves against environmental threats. Include two examples in your answer.

c) Compare the human primary immune response with the secondary immune response to the same antigen.
23) (1) In biological systems, structure and function are related. Choose three of the following components of organ systems.

- alveolus
- villus
- sarcomere
- capillary
- nephron
- neuron

  a) For each component, describe the structure of the component and explain how that structure is responsible for the function of that component.
  
  b) For the three components that you chose in part a, explain how the structure of the component contributes to the functioning of the organ system to which it belongs.

24) (2) The complexity of structure and function varies widely across the animal kingdom. Despite this variation, animals exhibit common processes. These include the following:

- transport of materials
- response to stimuli
- gas exchange
- locomotion

  a) Choose two of the processes above and for each, describe the relevant structures and how they function to accomplish the process in the following phyla:

      Cnidaria (e.g. hydra, jellyfish)
      Annelida (e.g. earthworm)
      Chordata (e.g. mouse)

  b) Explain the adaptive (evolutionary) value(s) of the structural examples you described in part a.

25) (2B) In mammals, heart rate during periods of exercise is linked to the intensity of exercise.

  a) Discuss the interactions of the respiratory, circulatory, and nervous systems during exercise.
  
  b) Design a controlled experiment to determine the relationship between intensity of exercise and heart rate.
  
  c) On the axes provided below, indicate results you expect for both the control and the experimental groups for the controlled experiment you described in part B. Remember to label the axes.

26) (2B) A triploblastic animal is one in which three germ layers form during embryonic development. Triploblastic animals include acoelomate, pseudocoelomate, and coelomate (eucoelomate) organisms.

  a) Identify the three germ layers of a triploblastic embryo and discuss the fates of these germ layers in embryonic development.
  
  b) Describe acoelomate, pseudocoelomate, and coelomate body plans. Identify an animal that is representative of each of these types of body plan.
  
  c) Compare and contrast the digestive systems of an acoelomate and a coelomate organism.

27) (3) Death is a natural and necessary part of life cycles at all levels or organization.

  a) Discuss TWO examples of how cell death affects the development and functioning of a multicellular organism.
  
  b) Discuss ONE example of how substances are degraded and reused in cells.
  
  c) Discuss the evolutionary significance of death.

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28) (5) An important defense against diseases in vertebrate animals is the ability to eliminate, inactivate, or destroy foreign substances and organisms. **Explain** how the immune system achieves THREE of the following:

- Provides an immediate nonspecific immune response
- Activates T and B cells in response to an infection
- Responds to a later exposure to the same infectious agent
- Distinguishes self from non-self

29) (6) The evolution of circulatory systems allowed larger and more-complex animals to arise.

a) Describe the respiratory and digestive systems' specialized structures that facilitate the movement of oxygen and glucose into the circulatory system of mammals.

b) Explain how oxygen and glucose are transported within the circulatory system of mammals.

c) Explain the transfer of oxygen and glucose from the blood and into the active cells of mammals.

30) (7) Cephalization and the development of a brain were important steps in animal evolution.

a) **Discuss** the evolutionary origin and adaptive significance of cephalization in animal phyla.

b) **Describe** the development of the nervous system in the vertebrate embryo.

c) At the sound of shattering glass, people quickly turn their heads. **Discuss** how the human nervous system functions to produce this type of response to an external stimulus.

31) (7B) The defenses of the human body to the entry and establishment of a pathogen (disease-causing organism) can be divided into nonspecific responses and specific responses.

a) Explain how THREE types of nonspecific defenses can prevent the entry and/or establishment of a pathogen in a person's body.

b) Discuss how the immune system responds to an initial pathogenic exposure, and how this initial exposure can lead to a quicker response following a second exposure to the same pathogen.

c) Explain the biological mechanisms that lead to the rejection of transplanted organs.

**Plants**

1) In flowering plants, describe in detail the transport of water, carbohydrates, and inorganic solutes (nitrates, for example). Discuss the theories that have been proposed to explain how these substances are transported.

2) In the life cycles of a fern and a flowering plant, compare and contrast each of the following.
   a. The gametophyte generation
   b. Sperm transport and fertilization
   c. Embryo protection

3) (83) Relate the structure of an angiosperm leaf to each of the following.
   a. Adaptations for photosynthesis and food storage.
   b. Adaptations for food translocation and water transport.
   c. Specialization adaptations to desert environment.
4) (84) Define the following plant responses and explain the mechanism of control for each. Cite experimental evidence as part of your discussion.
   a. Phototropism
   b. Photoperiodism

5) (85) Describe the structure of a bean seed and discuss its germination to the seedling stage. Include in your essay hormonal controls, structural changes, and tissue differentiation.

6) (87) Describe the effects of plant hormones on plant growth and development. Design an experiment to demonstrate the effect of one of these plant hormones on plant growth and development.

7) (88) Trace the pathway in a flowering plant as the water moves from the soil through the tissues of the root, stem, and leaves to the atmosphere. Explain the mechanisms involved in conducting water through these tissues.

8) (90) Discuss the adaptations that have enabled flowering plants to overcome the following problems associated with life on land.
   a) The absence of an aquatic environment for reproduction
   b) The absence of an aquatic environment to support the plant body
   c) Dehydration of the plant

9) (91) A group of students designed an experiment to measure transpiration rates in a particular species of herbaceous plant. Plants were divided into four groups and were exposed to the following conditions.
   Group I --- Room conditions (light, low humidity, 20°C, and little air movement)
   Group II --- Room conditions with increased humidity
   Group III --- Room conditions with increased air movement (fan)
   Group IV --- Room conditions with additional light
   The cumulative water loss due to transpiration of water from each plant was measured at 10-minute intervals for 30 minutes. Water loss was expressed as milliliters of water per square centimeter of leaf surface area. The data for all plants in Group I (room conditions) were averaged. The average cumulative water loss by the plants in Group I is presented in the table below.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Average Cumulative Water Loss (mL H₂O / cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3.5 x 10⁻⁴</td>
</tr>
<tr>
<td>20</td>
<td>7.7 x 10⁻⁴</td>
</tr>
<tr>
<td>30</td>
<td>10.6 x 10⁻⁴</td>
</tr>
</tbody>
</table>

   a) Construct and label a graph using the data for Group I. Using the same set of axes, draw and label three additional lines representing the results that you would predict for Groups II, III, and IV.
   b) Explain how biological and physical processes are responsible for the differences between each of your predictions and the data for Group I.
   c) Explain how the concept of water potential is used to account for the movement of water from the plant stem to the atmosphere during transpiration.
10) Survival depends on the ability of an organism to respond to changes in its environment. Some plants flower in response to changes in day length. Some mammals may run or fight when frightened. For both of these examples, describe the physiological mechanisms involved in the response.

11) Angiosperms (flowering plants) and vertebrates obtain nutrients from their environment in different ways.
   a) Discuss the type of nutrition and the nutritional requirements of angiosperms and vertebrates.
   b) Describe 2 structural adaptations in angiosperms for obtaining nutrients from the environment. Relate structure to function.
   c) Interdependence in nature is evident in symbiosis. Explain two symbiotic relationships that aid in nutrient uptake, using examples from angiosperms and/or vertebrates. (Both examples may be angiosperms, both may be vertebrates, or one may be from each group.)

12) Numerous environmental variables influence plant growth. Three students each planted a seedling of the same genetic variety in the same type of container with equal amounts of soil from the same source. Their goal was to maximize their seedling’s growth by manipulating environmental conditions. Their data are shown below:

<table>
<thead>
<tr>
<th>Plant Seedling Mass (grams)</th>
<th>Day 1</th>
<th>Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student A</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Student B</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>Student C</td>
<td>4</td>
<td>64</td>
</tr>
</tbody>
</table>

   a) Identify three different environmental variables that could account for differences in the mass of the seedlings at day 30. Then choose one of these variables and design an experiment to test the hypothesis that your variable affects growth of these seedlings.
   b) Discuss the results you would expect if your hypothesis is correct. Then provide a physiological explanation for the effect of your variable on plant growth.

13) Regulatory (control) mechanisms in organisms are necessary for survival. Choose THREE of the following examples and explain how each is regulated.
   - Flowering in plants.
   - Water balance in plants
   - Water balance in terrestrial vertebrates
   - Body temperature in terrestrial vertebrates
14) (3B) Hormones play important roles in regulating the lives of many living organisms.  
a) For TWO of the following physiological responses, explain how hormones cause the 
response in plants.  
- increase in height  
- adjustment to change in light  
- adjustment to lack of water  
b) For TWO of the following physiological responses, explain how hormones cause the 
response in animals.  
- increase in height  
- adjustment to change in light  
- adjustment to lack of water  
c) Describe TWO different mechanisms by which hormones cause their effects at the 
cellular level.

15) (5) Angiosperms (flowering plants) have wide distribution in the biosphere and the 
largest number of species in the plant kingdom.  
a) Discuss the function of FOUR structures for reproduction found in 
angiosperms and the adaptive (evolutionary) significance of each.  
b) Mosses (bryophytes) have not achieved the widespread terrestrial success of 
angiosperms. Discuss how the anatomy and reproductive strategies of mosses limit their 
distribution.  
c) Explain alternation of generations in either angiosperms or mosses.

16) (6) The movement of water through vascular plants is important to their survival.  
a) Explain the mechanism of water movement through vascular plants during 
transpiration. Include a discussion of how the anatomy of vascular plants and the 
properties of water contribute to this process.  
b) Explain how gas exchange affects transpiration.  
c) Describe TWO adaptations that affect the rate of transpiration in desert plants.

17) (6b) While studying transpiration, a scientist used a dendrometer to record 
the small daily changes in the diameter of a tree trunk at two different heights (2 
meters and 3 meters) above the ground at the same time. The diameter 
decreased in the daytime. This decrease 
happened first at the higher location. Discuss the following in relation to 
water movement in plants.  
a) Identify how two different 
environmental factors could 
be involved in the daily fluctuations shown above.  
b) Discuss the mechanisms involved in the uptake and transport of water by vascular 
plants.  
c) Discuss the role of water in the normal functioning of plants.
1) (80) Many areas of North America that were once covered with many small lakes and ponds have undergone succession and are now continuously covered with forests. Give a detailed description of the events (biotic and abiotic factors) that lead to the establishment of a climax forest.

2) (81) Define, discuss, and give examples of each of the following close interactions of species.
   a. Predator-prey relationships
   b. Commensalism
   c. Mutualism
   d. Parasitism

3) (82) Define and explain the role of each of the following in social behavior.
   a. Territoriality
   b. Dominance hierarchies
   c. Courtship behavior

4) (83) Describe the trophic levels in a typical ecosystem. Discuss the flow of energy through the ecosystem, the relationship between the different trophic levels, and the factors that limit the number of trophic levels.

5) (83) Describe and give an example of the following. Include in your discussion the selective advantage of each.
   a. Pheromones
   b. Mimicry
   c. Stereotyped behavior (instinct)

6) (85) Describe the process of ecological succession from a pioneer community to a climax community. Include in your answer a discussion of species diversity and interactions, accumulation of biomass, and energy flow.

7) (86) Describe the biogeochemical cycles of carbon and nitrogen. Trace these elements from the point of their release from a decaying animal to their incorporation into a living animal.

8) (89) Using an example for each, discuss the following ecological concepts.
   a. Succession
   b. Energy flow between trophic levels
   c. Limiting factors
   d. Carrying capacity

9) (93) Living organisms play an important role in the recycling of many elements within an ecosystem. Discuss how various types of organisms and their biochemical reactions contribute to the recycling of either carbon or nitrogen in an ecosystem. Include in your answer one way in which human activity has an impact on the nutrient cycle you have chosen.
10) Interdependence in nature is illustrated by the transfer of energy through trophic levels. The diagram below depicts the transfer of energy in a food web of an arctic lake located in Alaska.

a) Choosing organisms from four different trophic levels of this food web as examples, explain how energy is obtained at each trophic level.

b) Describe the efficiency of energy transfer between trophic levels and discuss how the amount of energy available at each trophic level affects the structure of the ecosystem.

c) If the cells in the dead terrestrial plant material that washed into the lake contained a commercially produced toxin, what would be the likely effects of this toxin on this food web? Explain.

11) The rate of photosynthesis may vary with changes that occur in environmental temperature, wavelength of light, and light intensity. Using a photosynthetic organism of your choice, choose only ONE of the three variables (temperature, wavelength of light, or light intensity) and for this variable

- design a scientific experiment to determine the effect of the variable on the rate of photosynthesis for the organism;
- explain how you would measure the rate of photosynthesis in your experiment;
- describe the results you would expect. Explain why you would expect these results.
12) (1) A biologist measured dissolved oxygen in the top 30 centimeters of a moderately eutrophic (mesotrophic) lake in the temperate zone. The day was bright and sunny, and the wind was calm. The results of the observations are presented below.

<table>
<thead>
<tr>
<th>Hour</th>
<th>[O₂]</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00 am</td>
<td>09. mg/L</td>
</tr>
<tr>
<td>8:00 am</td>
<td>1.7 mg/L</td>
</tr>
<tr>
<td>10:00 am</td>
<td>3.1 mg/L</td>
</tr>
<tr>
<td>12:00 am</td>
<td>4.9 mg/L</td>
</tr>
<tr>
<td>2:00 pm</td>
<td>6.8 mg/L</td>
</tr>
<tr>
<td>4:00 pm</td>
<td>8.1 mg/L</td>
</tr>
<tr>
<td>6:00 pm</td>
<td>7.9 mg/L</td>
</tr>
<tr>
<td>8:00 pm</td>
<td>6.2 mg/L</td>
</tr>
<tr>
<td>10:00 pm</td>
<td>4.0 mg/L</td>
</tr>
<tr>
<td>12:00 midnight</td>
<td>2.4 mg/L</td>
</tr>
</tbody>
</table>

a) Using the graph paper provided, plot the results that were obtained. Then, using the same set of axes, draw and label an additional line/curve representing the results that you would predict had the day been heavily overcast.

b) Explain the biological processes that are operating in the lake to produce the observed data. Explain also how these processes would account for your prediction of results for a heavily overcast day.

c) Describe how the introduction of high levels of nutrients such as nitrates and phosphates into the lake would affect subsequent observations. Explain your prediction.

13) (3) Many populations exhibit the following growth curve:

a) Describe what is occurring in the population during Phase A.

b) Discuss THREE factors that might cause the fluctuations shown in Phase B.

c) Organisms demonstrate exponential (r) or logistic (K) reproductive strategies. Explain these two strategies and discuss how they affect population size over time.
14) (4) Organisms rarely exist alone in the natural environment. The following are five examples of symbiotic relationships.

- Plant root nodules
- Digestion of cellulose
- Epiphytic plants
- AIDS (acquired immune deficiency syndrome)
- Anthrax

Choose FOUR of the above and for each example chosen.

a) identify the participants involved in the symbiosis and describe the symbiotic relationship, and

b) discuss the specific benefit or detriment, if any, that each participant receives from the relationship.

15) (4B) In most aquatic environments, primary production is affected by the light available to the community of organisms. Using measurements of dissolved oxygen concentration to determine primary productivity, design a controlled experiment to test the hypothesis that primary productivity is affected by either the intensity or the wavelength of light. In your answer, be sure to include the following.

- A statement of the specific hypothesis that you are testing.
- A description of your experimental design (Be sure to include a description of what data you would collect and how you would present and analyze the data using a graph.)
- A description of results that would support your hypothesis.

16) (5B) Survival of organisms depends on adaptive behavior and species interactions. (2005B)

a) Behaviors of organisms may be influenced by environmental factors. Select two of the following types of behavior. For each type, explain

i. how the environment affects the behavior, and (ii) why this behavior increases the survivorship of individuals of a species.

- Taxis/Kinesis
- Migration
- Courtship

b) Interactions among populations may have an effect on densities of the species that interact. Predation represents an important interaction among populations. The curves below depict the population densities of three species: a small herbivore, a larger herbivore, and a carnivore.

[Graph showing population densities over time]

Identify which curve represents which of the species listed, and justify your answer by describing the changes in the population densities of these three species over time.
17) (6b) In many ways, all organisms in a food web can be said to be solar-powered. The producer level of the food web is responsible for the transformation of the solar energy into a form that can be used by other living organisms.
   a) Discuss the role of green plants in transforming the Sun's energy into a form that can ultimately be used by heterotrophs.
   b) Discuss the flow of energy from producers through top carnivores in a food web in terms of the laws of thermodynamics.

18) (7) Compared with other terrestrial biomes, deserts have extremely low productivity.
   a. Discuss how temperature, soil composition, and annual precipitation limit productivity in deserts.
   b. Describe a four-organism food chain that might characterize a desert community, and identify the trophic level of each organism.
   c. Describe the results depicted in the graph. Explain one anatomical difference and one physiological difference between species A and B that account for the CO2 uptake patterns shown. Discuss the evolutionary significance of each difference.

![CO2 UPTAKE FOR TWO SPECIES OF DESERT PLANTS OVER 24 HOURS](image)

19) (7B) Without adaptive behaviors, animals would not survive.
   a. Describe what innate and learned behaviors are. Explain the adaptive value of each of these two categories of behavior to an individual animal.
   b. During mating season, male snakes exhibit tracking behavior when they follow chemical pheromone trails deposited on the ground by females. Design a controlled experiment to determine whether a male garter snake will track only a female of his species or will also follow the female of a related species.

20) (7B) The energy flow in ecosystems is based on the primary productivity of autotrophs.
   a) Discuss the energy flow through an ecosystem and the relative efficiency with which it occurs.
   b) Discuss the impact of the following on energy flow on a global scale.
      - Deforestation
      - Global climate change
1) (3B) Regulatory (control) mechanisms in organisms are necessary for survival. Choose THREE of the following examples and explain how each is regulated.
   i. Flowering in plants
   ii. Water balance in plants
   iii. Water balance in terrestrial vertebrates
   iv. Body temperature in terrestrial vertebrates

2) (99) Communication occurs among the cells in a multicellular organism. Choose THREE of the following examples of cell-to-cell communication, and for each example, describe the communication that occurs and the types of responses that result from this communication.
   ○ Communication between two plant cells
   ○ Communication between two immune-system cells
   ○ Communication either between a neuron and another neuron, or between a neuron and a muscle cell
   ○ Communication between a specific endocrine-gland cell and its target cell

3) (0) Feedback mechanisms are used by organisms to maintain the steady-state physiological condition known as homeostasis. Choose three of the following and for each, explain how feedback mechanisms maintain homeostasis.
   ○ Blood glucose concentration.
   ○ Calcium ion concentration in blood.
   ○ Body temperatures in mammals.
   ○ Osmolarity of the blood.
   ○ Pulse rate in mammals

4) (4B) Homeostasis, maintaining a steady-state internal environment, is a characteristic of all living organisms. Choose three of the following physiological parameters and for each, describe how homeostasis is maintained in an organism of your choice. Be sure to indicate what animal you have chosen for each parameter. You may use the same animal or different animals for your three descriptions.
   • Blood-glucose levels
   • Body temperature
   • pH of the blood
   • Osmotic concentration of the blood
   • Neuron resting-membrane potential