Question 1

Describe how a plasmid can be genetically modified to include a piece of foreign DNA that alters the phenotype of bacterial cells transformed with the modified plasmid. Describe a procedure to determine which bacterial cells have been successfully transformed.

Describe plasmid modification (8 points maximum):

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasmid vector</td>
<td>Describes plasmid as small circular DNA</td>
</tr>
<tr>
<td>Cut (cleave) DNAs</td>
<td>Use of restriction endonucleases (RE)</td>
</tr>
<tr>
<td></td>
<td>Plasmid and inserted DNA must have same RE cut ends or be cut by same RE</td>
</tr>
<tr>
<td>Sticky ends</td>
<td>Ends of DNA should be sticky, wanting to bond with matching ends</td>
</tr>
<tr>
<td></td>
<td>Generate ends for attachment using endonucleases</td>
</tr>
<tr>
<td>Ligase</td>
<td>For joining of sticky ends</td>
</tr>
<tr>
<td>Orientation</td>
<td>Correct orientation of insertion to ensure expression</td>
</tr>
<tr>
<td>Gene of interest</td>
<td>DNA cut should be a complete sequence of gene</td>
</tr>
<tr>
<td></td>
<td>Attach piece with a promoter or insert next to promoter</td>
</tr>
<tr>
<td>Reporter gene</td>
<td>Gene used to identify insertion of desired DNA</td>
</tr>
<tr>
<td></td>
<td>Insert DNA with a gene that produces a new phenotype</td>
</tr>
<tr>
<td>Selective marker</td>
<td>Inserted to help identify the DNA insertion (e.g., antibiotic resistance)</td>
</tr>
<tr>
<td>AUG in place</td>
<td>Ensure proper start codon</td>
</tr>
<tr>
<td>Uptake of plasmid</td>
<td>Calcium chloride and heat shock, electroporation to make competent</td>
</tr>
<tr>
<td>Alternative procedures</td>
<td>Blunt cuts; T4 ligase; add terminal transferase to add poly (A) to 3’ end</td>
</tr>
</tbody>
</table>

Describe plasmid uptake and how transformation is determined (6 points maximum):

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformation</td>
<td>Defined process of transformation of a plasmid</td>
</tr>
<tr>
<td>Isolation</td>
<td>Isolate plasmids/agar plate that grows only colonies of resistance gene</td>
</tr>
<tr>
<td>Antibiotic</td>
<td>Use of antibiotic resistance/sensitivity genes</td>
</tr>
<tr>
<td></td>
<td>Detailed description of antibiotic resistance lab procedure</td>
</tr>
<tr>
<td>Gel electrophoresis</td>
<td>Isolate plasmid using electrophoresis</td>
</tr>
<tr>
<td></td>
<td>Detailed description of gel electrophoresis for isolation</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Retrieve altered plasmid</td>
</tr>
<tr>
<td>Protein</td>
<td>Identification of new protein, possible glowing marker protein</td>
</tr>
<tr>
<td></td>
<td>Detailed description of retrieval or protein method</td>
</tr>
<tr>
<td>Tag</td>
<td>Fluorescent marker, etc.</td>
</tr>
<tr>
<td></td>
<td>Detailed description of alternate method</td>
</tr>
</tbody>
</table>
Question 2

Discuss the patterns of sexual reproduction in plants. Compare and contrast reproduction in nonvascular plants with that in flowering plants. Include the following topics in your discussion:

(a) alternation of generations
(b) mechanisms that bring female and male gametes together
(c) mechanisms that disperse offspring to new locations

Four points per part. Student must write about all three parts for full credit. Within each part it is possible to get points for comparing and contrasting. Also, specific points are available from details provided about nonvascular and flowering plants.

Discuss the patterns of sexual reproduction in plants (4 points maximum):

(a) Alternation of generations (4 points maximum):

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternating generations</td>
<td>Haploid stage and diploid stage.</td>
</tr>
<tr>
<td>Gametophyte</td>
<td>Haploid-producing gametes.</td>
</tr>
<tr>
<td></td>
<td>Dominant in nonvascular plants.</td>
</tr>
<tr>
<td></td>
<td>Double fertilization in flowering plants.</td>
</tr>
<tr>
<td></td>
<td>Gametangia; archegonia and antheridia in nonvascular plants.</td>
</tr>
<tr>
<td>Sporophyte</td>
<td>Diploid-producing spores.</td>
</tr>
<tr>
<td></td>
<td>Heterosporous in flowering plants.</td>
</tr>
<tr>
<td></td>
<td>Flowering plants produce seeds; nonvascular plants do not.</td>
</tr>
<tr>
<td></td>
<td>Flowering plants produce flower structures.</td>
</tr>
<tr>
<td></td>
<td>Sporangia (megasporangia and microsporangia).</td>
</tr>
<tr>
<td></td>
<td>Dominant in flowering plants.</td>
</tr>
</tbody>
</table>

(b) Mechanisms that bring female and male gametes together (4 points maximum):

<table>
<thead>
<tr>
<th>Nonvascular Plants (1 point each)</th>
<th>Flowering Plants (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic—requires water for motile sperm</td>
<td>Terrestrial—pollination by wind, water, or animal</td>
</tr>
<tr>
<td>Micropyle in ovule for pollen tube to enter</td>
<td>Pollen tube to carry sperm nuclei</td>
</tr>
<tr>
<td>Self- or cross-pollination</td>
<td></td>
</tr>
<tr>
<td>Antheridia produce sperm</td>
<td>Gametophytes; no antheridia or archegonia</td>
</tr>
<tr>
<td>Archegonia produce egg</td>
<td>Ovules produce female gametophytes/gametes</td>
</tr>
<tr>
<td>Pollen: male gametophyte that produces gametes</td>
<td></td>
</tr>
</tbody>
</table>
(c) Mechanisms that disperse offspring to new locations *(4 points maximum)*:

<table>
<thead>
<tr>
<th>Nonvascular Plants (1 point each)</th>
<th>Flowering Plants (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersal of spores by wind</td>
<td>Dispersal through seeds</td>
</tr>
<tr>
<td>or Carried by wind, water, or animal</td>
<td>Detailed animal description: fur, etc.</td>
</tr>
<tr>
<td>Dispersal of spores in water</td>
<td>Detailed wind description: winged seeds, etc.</td>
</tr>
<tr>
<td>Protection of seeds/seeds protect young sporophytes</td>
<td>Fruits used to lure animals</td>
</tr>
</tbody>
</table>
Water is essential to all living things.

(a) **Discuss** THREE properties of water.

(b) **Explain** each of the following in terms of the properties of water. You are not limited to the three properties discussed in part (a):

- the role of water as a medium for the metabolic processes of cells
- the ability of water to moderate temperature within living organisms and in organisms’ environments
- the movement of water from the roots to the leaves of plants

(a) **Discuss** THREE properties of water (**6 points maximum)**:

Name of property **and** correct description (**2 points**). Points **MUST** provide both property and description.

<table>
<thead>
<tr>
<th>Property</th>
<th>Description (2 points jointly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity of water</td>
<td>Polar covalent bonds created by unequal sharing of electrons between O and H within the molecule</td>
</tr>
<tr>
<td>Specific heat/high heat capacity</td>
<td>Heat absorption without temperature change</td>
</tr>
<tr>
<td>High heat of vaporization</td>
<td>Water molecules absorb energy as it changes state/breaking of bonds by absorbing energy</td>
</tr>
<tr>
<td>Adhesion</td>
<td>Attraction to other molecules that are polar or have charge</td>
</tr>
<tr>
<td>Cohesion</td>
<td>Attraction to other water molecules due to polar nature of water/surface tension</td>
</tr>
<tr>
<td>Three states of matter</td>
<td>Ice–liquid–gas (vapor)</td>
</tr>
<tr>
<td></td>
<td>Kinetic energy differences</td>
</tr>
<tr>
<td></td>
<td>Expands at 4°C to become less dense</td>
</tr>
<tr>
<td>Repels hydrophobic material</td>
<td>Moves aside nonpolar substances</td>
</tr>
</tbody>
</table>

(b) **Explain** each of the following in terms of water properties (**6 points maximum; 2 points for each part**). To earn 10 points, students must get at least 1 application point for each area.

**Water’s role as a medium** for the metabolic processes of cells (**2 points maximum**):

- Diffusion—allows for movement of materials through an aqueous solution down the concentration gradient
- Osmosis—movement of water across membranes due to water potential differences (down the gradient)
- Solvent—dissociation/ionization of materials
- Buffer—explanation of role water plays in formation of bicarbonate ion
Water’s ability to moderate temperature within living organisms/environments (2 points maximum):

- Specific heat—moderates climates, maintains stable temperature in cells, constant internal environment
- High heat of vaporization—perspiration cooling, evaporative cooling
- Ice forming and acting as insulator for lakes, keeping water in liquid state

Water from the roots to the leaves of plants (2 points maximum):

- Transpiration—moving water away from leaves due to water potential differences/evaporation through stomata
- Capillary action of water due to adhesion and cohesion
- Root pressure—driven by osmosis/movement of water into roots
- Negative pressure potential—caused by surface tension of water as it is pulled up xylem
Question 4

Many organisms require a continuing source of oxygen for respiration. Discuss important structural and physiological adaptations for oxygen uptake in THREE of the following:

- a paramecium
- a tree
- a fish
- a mammal

Each structural and physiological adaptation earns 1 point. Student must mention at least one structural and one physiological area to earn 10 points. Only the first three organisms mentioned earn points.

- **Paramecium (4 points maximum):**

<table>
<thead>
<tr>
<th>Structural (1 point each)</th>
<th>Physiological (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane surface area/volume small</td>
<td>Utilizes diffusion</td>
</tr>
<tr>
<td>Wet habitat</td>
<td>Cytoplasmic streaming</td>
</tr>
<tr>
<td>Membrane permeable to oxygen</td>
<td>Ventilation of surface with cilia</td>
</tr>
</tbody>
</table>

- **Tree (4 points maximum):**

<table>
<thead>
<tr>
<th>Structural (1 point each)</th>
<th>Physiological (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomata/guard cells</td>
<td>Stomatal regulation</td>
</tr>
<tr>
<td>Large wet internal surface area in mesophyll</td>
<td>Surface for gas exchange</td>
</tr>
<tr>
<td>Lenticels</td>
<td>Cohesion, transport</td>
</tr>
<tr>
<td>Pneumatophores</td>
<td>Pressure flow/source to sink</td>
</tr>
<tr>
<td>Root hairs</td>
<td></td>
</tr>
<tr>
<td>Epidermis permeable to oxygen</td>
<td>Photosynthesis production of oxygen</td>
</tr>
</tbody>
</table>

- **Fish (4 points maximum):**

<table>
<thead>
<tr>
<th>Structural (1 point each)</th>
<th>Physiological (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gills</td>
<td>Countercurrent exchange</td>
</tr>
<tr>
<td>Operculum</td>
<td>Operculum movement/gill slit movement</td>
</tr>
<tr>
<td>Vascularization/gill capillaries</td>
<td>Ram ventilation (swimming)</td>
</tr>
<tr>
<td>Increase surface area/diffusion</td>
<td>Blood flow—heart pumping</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>Iron molecules holding oxygen</td>
</tr>
<tr>
<td>Lungfish lungs</td>
<td></td>
</tr>
</tbody>
</table>
Question 4 (continued)

Mammal (4 points maximum):

<table>
<thead>
<tr>
<th>Structural (1 point each)</th>
<th>Physiological (1 point each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lungs</td>
<td>Homeostatic adjustments via medulla</td>
</tr>
<tr>
<td>Vascularization of alveoli</td>
<td>Capillaries increase surface area/diffusion</td>
</tr>
<tr>
<td>Hemoglobin/RBC</td>
<td>Iron molecules holding oxygen</td>
</tr>
<tr>
<td>Diaphragm/ventilation (breathing) mechanisms</td>
<td>Ventilation physiology</td>
</tr>
<tr>
<td>Four-chambered heart</td>
<td>Separate pulmonary and systemic blood</td>
</tr>
<tr>
<td></td>
<td>Blood flow—heart pumping</td>
</tr>
</tbody>
</table>