1. 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.

STANDARDS:

STRUCTURE: Max. = 8 points
__ Seed coat (protection)
__ Embryo (new plant)
__ Cotyledons (store food)
__ Epicotyl (new shoot)
__ Hypocotyl (new stem/root)
__ Radicle (1st root)
__ Plumule (1st leaves)
__ Hilum scar (attachment)
__ Micropyle (pollen tube entry)

GERMINATION DISCUSSION: Max. = 12 points
__ Imbibition of water (increases metabolism)
__ Correct temperature (enzymes)
__ Oxygen (for respiration)
__ Radicle emerges 1st (establishes root)
__ Subsequent shoot (photosynthesis when stored food gone)
__ Formation of hook/arch (pulls epicotyl)
__ Epigeal germination

a. Hormonal Control
   -- Auxin in geotropism (+ or -)
   -- More auxin, lower 1/2 axis
   -- Stem/root affected differently
   -- Gibberellins stimulate length growth
   -- Cytokinins stimulate cell division
   -- Abscisic acid inhibits root cell elongation

b. Structural Changes (Note: some germination discussion is structural change)
   -- Formation of root cap
   -- Dropping spent cotyledons
   -- Change, dark-to-light-growth
   -- Branch root production
   -- Leaf primordia
   -- Two different foliage leaves

c. Tissue differentiation
   -- Cell division, elongation, maturation
   -- Xylem, phloem (elaboration)
   -- Apical meristem
   -- Protoderm, ground meristem, procambium
   -- Several vascular strands, stem; one, roots
   -- Collenchyma, sclerenchyma
   -- Mesophyll, epidermis, guard cells
   -- Endodermis pericycle
   -- Root hair formation

2. 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.

**ANSWER:**

**Question Overview.**

This question is composed of two discrete parts in which Part A has two components. It was the decision of the readers that a perfect score of ten could not be obtained unless at least one point was earned for each component (i.e., one point for naming three variables, plus at least one point for developing an experiment linked to some variable mentioned, plus at least one point for results expected, and at least one point for a discussion of physiology linked with the same variable.)

Variables - need 3 for 1 pt

Experiment/results - 6 pts max

Physiology - 4 pts max

**Variables:**

- Light (Intensity-duration-wavelength)  
- Water
- Temperature
- CO2
- Humidity
- Wind
- Carbon of CO2 incorp in carbon chains
- Soil Chemistry (Adj) - (pH-fertilizers
- Soil Type (Adj) - (Sand-vermiculite)
- Competition
- Hormones (added
- Predation

**Experiment/results:**

- Control - Constants
- Results - linked to experiment
- Manipulation of variable
- Physiological function affected (how manipulated - linked to variable)
- Measurement of growth (measured as [mass-length-dry-wet initial vs final - % change - duration
- Elaboration (of Results or Physiology)
- Verification (sample size - repetition)
- Elaboration (of any one of above)
- Overall exceptional experimental design
- Hypothesis - includes measurable predictions and clearly states experimental conditions

**5. STANDARDS:**

**A. GRAPH:**

(Max of 3 points)

Correct Orientation of X (independent) and Y (dependent) axes

Scale and proper labels

Group I - properly graphed (3.5/7.7/10.6)

**B. BIOLOGICAL/PHYSICAL PROCESSES FOR DIFFERENCES:**

(Max of 5 points)

- Control (I) - function of
- Transpiration / Photosynthesis (description of)
- Humidity (II) - thus increase water potential surrounding leaf - thus curve will be BELOW control (inside constant/ outside increased)
Fan (III) - water potential decreased surrounding leaf - therefore curve will be ABOVE control (inside constant/outside decreased)

Fan (III) - wind shear (fan close) stomates closed - therefore curve BELOW control

Fan (III) - cools because of evaporation (decreases kinetics) - therefore curve BELOW control

(Max of 2 points for Fan)

Light (IV) - stomates open (or) increase water usage via photosynthesis - curve ABOVE control

Light (IV) - heat - physical (increased kinetic energy) - curve ABOVE control

Light (IV) - heat - stomates closed - therefore curve BELOW control

Max of 2 points for Light)

Curves (graphs) - all correspond to description (hypothesis testing)

Mechanism of stomates close/open (CO2 / K+ flux / etc.)

C. CONCEPT OF WATER POTENTIAL: FROM STEM - LEAF - ATMOSPHERE:

(Max of 4 points)

Concept of water potential (high to low)- (diffusion/osmosis)-relationship to solute

Water movement (Cohesion-Tension Theory)

Properties of water (adhesion, cohesion, hydrogen bonding, capillary action) Tension "transpirational pull" - gradient xylem to outside

Negative pressure

Pressure potential/Osmotic potential

Air space of leaf has higher water potential than air outside leaf

Water moves out through stomata

Mesophyll cells higher water potential than surrounding air spaces of leaf Water moves out into leaf air spaces

Solute in mesophyll cells becomes more concentrated when less water present - therefore, less water potential (Mesophyll hypertonic to xylem)

Xylem has higher water potential than mesophyll cells - water moves out of xylem into mesophyll cells