1.

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.

Hypothesis (1 point)

- A statement of the specific hypothesis that you are testing (reasonable, testable and measurable)

Note: No points for just stating which independent variable (IV) they are choosing
Explanations provided in hypothesis may apply to last bullet

Experimental design (1 point each, **Maximum 8 points**)

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)

Note: to get max. must earn at least one graph point

- identify/define control
- identify independent variable (IV)
- specify IV levels/range
- identify dependent variable (DV)
- explain how to measure DV
- identify constant (only one needed to earn point)
- identify appropriate aquatic organism (not limited to species name, e.g. phytoplankton ok)
- specify length of experiment or frequency of measurements
- specify number of replications
- specify statistical analysis
- graph - correct possible line graph setup (axis, labels-units not necessary)
- graph - correct line(s) (must imply comparison)

Results (1 point)

- A description of results that would support your hypothesis/explanation that relates to primary productivity

2.

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. **(7 points maximum)**

* Each dash = 1 point

Mechanism (in correct context)	**Anatomy** (related to how anatomy contributes to transpiration)	**Water Properties** (related to how property contributes to transpiration)
• Movement of water - water evaporates or leaves the plant - transpiration pull **OR** cohesion-adhesion tension theory - continuous column of water - capillarity - root pressure - ψ (water potential differences) - osmosis/diffusion/tonicity • Energy driving transpiration - environmentally powered (sun, wind, humidity) - passive on part of plant	- Stomata/guard cells - Spongy mesophyll - Xylem, tubes, tracheids, vessel elements - Any specific root structure (root hairs, Casparian strip)	- Polarity/hydrogen bonding - Cohesion - Adhesion/capillarity - High heat of vaporization (H_2O vapor exiting leaf)

* Each dash = 1 point

(b) **Explain** how gas exchange affects transpiration. **(2 points maximum)**

- Stomata
  - Open stomata → increased transpiration
    OR
  - Closed stomata → decreased transpiration
- Gas identification
  - CO_2 in and O_2 and/or H_2O out of the plant
    (gas exchange must be in correct direction)
- Consequence of gas exchange
  - tradeoff of more gas exchange (for more photosynthesis)
    resulting in more transpiration (and possible dehydration, wilting, flaccidity)
- Environmental factors such as:
  - humidity
  - air movement
  - evaporative cooling
  - wind stress
  - intense light/heat (factor must be tied to effect on transpiration)

* Each dash = 1 point

(c) **Describe** TWO adaptations that affect the rate of transpiration in desert plants.
(2 points maximum)

- Reduced surface area
  - small leaves
  - loss of leaves/other parts
- Leaf modifications
  - thick cuticle (not just "waxy")
  - thicker epidermis
  - reflective surfaces
  - epidermal hairs "trap" water vapor
  - leaf wilting/curling
  - leaf orientation
- Stem modifications
  - thick cuticle (not just "waxy")
  - thicker epidermis
  - have stomata
- Stomata
  - concentrated on lower/shady surface
  - in pits, furrows, depressions
  - fewer stomata
- Metabolism
  - stomata open at night (CAM plants)
  - stomata closed when arid/not open as long (C_4 plants) (no points for photorespiration)
  - hydraulic lift
- Water storage/uptake
  - in fleshy stems
  - roots (large, shallow system for maximum water capture; deep taproots, etc.)
- Dormancy

3.

(a) Discuss the role of green plants in transforming the Sun's energy into a form that can ultimately be used by heterotrophs. **(6 points maximum)**

Required (Student cannot earn the maximum of 6 points without earning these 3 points)

- Energy transformation (photosynthesis -> chemical energy/glucose/G3P/ PGAL/starch/carbohydrate/chemical bonds)
- Chlorophyll or chloroplast required ("green pigment" not credited)
- Function of chlorophyll—light/energy capture concept

Parts of photosynthesis (in context or with explanation) (3 points maximum)

- Photolysis (splitting of water)—oxygen and/or electrons released
- Chemiosmosis (or explanation)
- ATP production
- NADPH production/reduction
- Photosystems II and I in correct order
- Calvin Cycle
- CO_2 fixation
- Products of light-dependent reactions used in light-independent (dark) reactions

(b) Discuss the flow of energy from producers through top carnivores in a food web in terms of the laws of thermodynamics. **(6 points maximum)**

Required (Student cannot earn the maximum of 6 points without earning these 2 points)

- Statement/definition of 1st Law of Thermodynamics
- Statement/definition of 2nd Law of Thermodynamics (definitions must be correct, but students are not penalized for misnumbering the laws)

Concepts of energy flow (in context or with explanation) (4 points maximum)

- 10 percent rule/Not all energy transferred to next level/Very little energy transferred to next level/energy lost at each level
- Explanation of energy loss (e.g., used in metabolism, locomotion, etc.)
- Lost energy as heat/entropy/2nd law illustrated as heat loss or inefficiency
- Energy pyramid (explained)
- More energy at producer level than at consumer levels
- Scarcity of energy at higher trophic levels
- Limited number of consumer levels
- Very few top carnivores
- 1st law illustrated as conversion of solar energy to chemical energy or as conversion of chemical energy to chemical energy (e.g., Glucose to ATP)

4.

(a) **Discuss** how temperature, soil composition, and annual precipitation limit productivity in deserts. **(3 points maximum)**

Abiotic factor (description)	**How abiotic factor limits productivity (must be linked) (1 point per factor)**
Temperature	
Increase in transpiration/evaporation	Lowers photosynthetic rate
Desiccation	Lowers plant growth
Loss of water from tissues/guard cells	Lowers biomass production
Not optimal temperatures	PS/metabolic enzymes/proteins hindered
Soil composition	
Low organic content/nutrients	Lowers photosynthetic rate/plant growth
Low water retention	Lowers photosynthetic rate/plant growth
Sandy	Poor root anchorage limits plant growth
Compacted soil	Root limitations decrease photosynthesis
Annual precipitation	
Low rainfall	Little water available for photosynthesis
Seasonal rainfall	Lowers plant growth
	Period of high productivity/wildflowers

Clear definition/discussion of productivity: e.g., a measure of the amount of biomass produced by autotrophs/photosynthetic organism/plants…amount of light energy converted to chemical energy by autotrophs per unit time...reduced community productivity **(1 point)**

(b) **Describe** a four-organism food chain that might characterize a desert community, and **identify** the trophic level of each organism. **(2 points)**

- **Written description** of a minimum of 4 organisms (must include a producer/plant) **(1 point)**
- **Clear identification** of 4 distinct trophic levels of the organisms discussed **(1 point)**
  (producer → primary consumer → secondary consumer → tertiary consumer
  or top carnivore or decomposer or scavenger)

(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 CO_2 uptake patterns shown. **Discuss** the evolutionary significance of each difference. **(6 points maximum)**

Graph interpretation (3 points)

- Describe graph (plant *A* takes up CO_2 during day AND plant *B* takes up CO_2 at night) **(1 point)**
- Species *B* as CAM **(1 point)**
- Species *A* as C_3 or species *A* as C_4 **(1 point)**

Anatomical difference (1 point)

- Species *A* is C_4 with bundle sheath/wreath/Kranz anatomy
- Stomata location (pits/crypts, underside stems) linked to CO_2 uptake
- Stomata density linked to CO_2 uptake
- In species *B*/CAM vacuole/mesophyll of organic acids (malate)

Physiological difference (1 point)

- Species A stomata open during day
- CAM/species *B* stomata open at night/closed during day
- Species *A* uses C_3 pathway; CAM/ species *B* uses C_4 pathway
- C_3 uses Rubisco/ C_4 uses PEP Carboxylase
- Organic acids synthesis for CO_2 storage
- Carbon fixation during day vs. night

Evolutionary significance (2 points)

Discuss the evolutionary significance linked to each difference **(2 points, 1 point per difference)**
e.g., increased evolutionary success due to decrease in water loss in the desert environment
e.g., C_4 pathway circumvents the problem of photorespiration

5.

(a) **Describe** THREE types of chemical bonds/interactions found in proteins. For each type, **describe** its role in determining protein structure. **(6 points; 1 point for bond/interaction description, 1 point for description of role)**

Bond/interaction	Description	Role associated to bond/interaction
Covalent/ peptide	sharing electrons **OR** linking amino acids together	amino acid sequence **OR** primary structure (no credit for chain or polypeptide alone)
Disulfide/ covalent	disulfide, S–S bond (bridges); sulfur-containing R group bonding	tertiary or quaternary structure
Hydrogen	H–O or H–N interactions	α helix, β sheet; secondary, tertiary, or quaternary structure
van der Waals	unequal electron clouds in R group; dipole moments	tertiary or quaternary structure
Hydrophobic	nonpolar R groups	tertiary or quaternary structure
Ionic	charged R groups	tertiary or quaternary structure

(b) **Discuss** how the structure of a protein affects the function of TWO of the following. **(3 points maximum)**

Muscle contraction **(1 point for each bullet; 2 points maximum)**

- Actin (thin filaments) and myosin; cross-bridges OR filamentous proteins slide past each other.
- Troponin/tropomyosin interaction blocks binding of myosin to actin.
- Ca^{2+} changes troponin shape/binding of troponin-tropomyosin to actin altered.
- ATP/ADP changes myosin structure.

Regulation of enzyme activity **(2 points maximum)**

- Shape change caused by **(1 point for each bullet)**
  - Binding of allosteric or noncompetitive inhibitor.
  - Binding of allosteric activator.
  - Feedback control.
  - pH or temperature changes.
  - Cleavage of pre-enzyme (e.g., zymogen).
  - Cooperativity; coenzymes; cofactors.
  - Covalent modification (e.g., phosphorylation).
- Competitive inhibitors binding in the active site prevent substrate binding.

NOTE: The active site regulating enzyme activity is not enough to earn a point.

Cell signaling **(2 points maximum)**

- Receptor-ligand binding **(1 point for each bullet)**
  - Event: Ligand binds specifically to receptor.
  - Result: Receptor structure altered by binding, transducing signal through membrane.

  Examples may include hormones, neurotransmitters.
- Enzyme-linked receptors: binding of ligand causes enzyme to catalyze reaction.
- Gap junctions: shape of junctions allows for passage of regulatory ions or molecules.
- Ligand-gated channel: binding of ligand opens channel.
- Immune signaling: leads to activation of cells.

(c) Abnormal hemoglobin is the identifying characteristic of sickle cell anemia. **Explain** the genetic basis of the abnormal hemoglobin. **Explain** why the sickle cell allele is selected for in certain areas of the world. **(3 points maximum)**

Genetic basis **(2 points maximum)**

- Point mutation in DNA; base substitution leading to a different amino acid in the hemoglobin.
- Changing glutamate (glutamic acid) to valine (in β-globin).

Selection **(2 points maximum)**

- Sickle cell condition protects against or resists malaria.
- Changed hemoglobin leads to oxygen-deprivation minimizing malarial infection.
- Heterozygotes maintain a reproductive advantage/success.

NOTE: Stating that sickle cell confers immunity to malaria does not earn a point.

6.

For THREE of the following complex structures, describe the smaller units, their assembly into the larger structures, and one major function of these larger, organized structures.

For each:

Unit Structure (with description) **1 point**	**Organization/Assembly** **2 points maximum* (*1 may be general, second specific to larger structure)**	**Function/Benefit** **1 point maximum**

Structures → Emergent properties **(4 points maximum each, only grade first 3)**

(a) A eukaryotic chromosome

Unit Structure—Organization/Assembly (must demonstrate organization to a chromosome):

- Describe nucleotides (or later structure in the sequence)
  → DNA → nucleosomes* → chromosome
  *around histones (non-DNA)
- Describe levels of folding
  → heterochromatin → condensed chromosome
- Describe DNA (or later structure in the sequence)
  → functional sequences (introns/exons/spacers) → genes → regulatory elements → chromosome

Function/Benefit:

- Package DNA
- Make for efficient cell division
- Juxtaposition of coding elements
- Gene regulation
- Storage/protection of genetic information

(b) A mature angiosperm root

Unit Structure—Organization/Assembly (must demonstrate organization to a functional root):

- Describe organelles (or later structure in the sequence)
  → cells → tissues→ layer → root

Function/Benefit:

- Storage
- Transport H_2O (absorption only via root hairs)
- Symbiotic relationships
- Secondary growth

- Anchorage
- Mineral uptake

(c) A colony of bees

Unit Structure—Organization/Assembly (must demonstrate organization to a colony):
- Individual bee (or component later in sequence) (this is usually the unit)
- → organization into castes (workers, drones, queen) → colony
- Elaboration on roles of castes

Function/Benefit:
- Survival of colony—specialization maintains colonial "homeostasis"
- Preservation of genetic makeup through altruism
- Communication for food/enemies
- Role in ecosystem, e.g., pollination

(d) An inner membrane of a mitochondrion

Unit Structure—Organization/Assembly (must demonstrate organization to inner membrane):
- Phospholipids and proteins (or component later in sequence)—describe at least one
- → organization of proteins (specific respiratory molecules together) → folding → membrane (cristae must be uniquely mitochondrial)

Function/Benefit:
- Impermeable to H+ forming gradient
- Proximity of Kreb's Cycle to the membrane
- Electron transport

(e) An enzyme

Unit Structure—Organization/Assembly (must demonstrate organization to enzyme):
- Amino acid (or component later in the sequence) described
- → polypep (1° structure, etc.) → protein + modification
- Uniquely enzymatic modifications: cofactor/coenzyme/prosthetic group/allosteric modulators

Function/Benefit:
- R-group interactions forming active site
- Lowers activation energy
- Increases reaction rate (cannot simply say "catalyzes reactions")

7.

ATP and GTP are primary sources of energy for biochemical reactions.

(a) **Describe** the structure of the ATP or the GTP molecule. **(1 point each; 2 points maximum)**
- Adenosine + 3 phosphates or guanosine + 3 phosphates.
- Elaborating on the phosphate bonds, e.g., unstable, negatively charged. Mentioning without explaining "high-energy bonds" is insufficient.
- Adenosine or guanosine described as adenine or guanine bound to ribose.

Note: adenine + ribose + 3 phosphates earns 2 points.

(b) **Explain** how chemiosmosis produces ATP. **(1 point each; 3 points maximum)**
- Electron transport, e.g., linked to proton pumps, coenzymes, NADH.
- H+ pumped to one side of the membrane, photosynthesis—inside thylakoid, respiration—outside cristae.
- Proton gradient established, has potential energy or capacity to do work.
- ATP synthases or channel proteins generate ATP.

(c) **Describe** TWO specific cell processes that require ATP and explain how ATP is used in each process. **(4 points maximum)**

	Description of process **(1 point per process; 2 points maximum)**	**How ATP is used** **(1 point per process; 2 points maximum)**
Mechanical	Muscle, sliding filament; cilia or flagella, propulsion; chromosome movement in mitosis or meiosis	ATP → ADP + P connected to process or energy coupling, e.g., conformational change in myosin head
Transport	Active transport or transport against gradient; sodium-potassium pump; endocytosis or exocytosis	ATP → ADP + P connected to process, e.g., phosphorylating the transport protein
Chemical	Hydrolysis or synthesis; specific chemical reaction, e.g., photosynthesis or glycolysis; kinase activity	ATP → ADP + P connected to process or energy coupling, e.g., phosphorylating glucose in glycolysis or PGA in Calvin cycle

(d) An energy pyramid for a marine ecosystem is shown below. **Label** each trophic level of the pyramid and provide an example of a marine organism found at each level of this pyramid. **Explain** why the energy available at the top layer of the pyramid is a small percentage of the energy present at the bottom of the pyramid. **(3 points maximum)**

	Explanation **(1 point per box; 3 points maximum)**
Label trophic levels	Producer or autotroph → 1° consumer or herbivore → 2° consumer or carnivore → 3° consumer; no point for mentioning detritivores or decomposers
Examples of marine organisms	Algae → zooplankton → small fish → shark Type of plankton must be specified if used above producer level; "fish" can be used once if unspecified; top level may include terrestrial organisms
Energy transfer	Energy transferred due to metabolic activities, heat, work, entropy Mentioning without explaining 10% energy transfer between trophic levels is insufficient

Note: Students must receive points in all four sections to earn a score of 10.

8.

Organisms utilize a diversity of methods to obtain proper nutrition.

(a) Some organisms digest food intracellularly, while others digest food extracellularly.
(4 points maximum)

- **Identify** ONE nonvertebrate organism that digests food intracellularly and **describe** the process.
- **Identify** ONE nonvertebrate organism that digests food extracellularly and **describe** the process.

	Organisms include, but are not limited to (1 point each)	**Identify process (1 point each)**
Intracellular	Protozoa, sponges, flatworms, Cnidaria	Breakdown/hydrolysis of food inside the cell.
Extracellular	Fungi, bacteria, invertebrates with a gut, Cnidaria, carnivorous plants, flatworms	Breakdown/hydrolysis of food in the gastrovascular cavity, gut, or outside of the organism.

(b) **Describe** TWO structural features of the human stomach and/or small intestine. For each, **explain** how the structure relates to the function.
(4 points maximum)

	Structural feature	**Description (1 point each)**	**Explanation of structure/function relationship (1 point each)**
Stomach	Lining	Mucus layer	Protection from acid damage.
	Wall	Muscular	Mechanical digestion/churning/movement.
	Shape	Saclike	Food reservoir/storage.
		Rugae	Expansion/increase of surface area and secretions.
	Sphincter	Muscular ring	One-way movement through the system.
Small intestine	Villi	Fingerlike or hairlike	Increases surface area to increase absorption.
	Microvilli	Fingerlike or hairlike	Increases surface area to increase absorption.
	Duodenum	Tubular passageway	Enzyme-mediated digestion or nutrient absorption.
	Length/size	Long or folded	More area and time for absorption.

(c) Plants have a variety of mechanisms for obtaining nutrients. **Describe** TWO plant structures and **explain** how each structure is utilized in nutrient uptake.
(4 points maximum)

	Description of plant structure (1 point each)	**Explanation of mechanism (1 point each)**
Root	Branched or fibrous	Increases surface area for absorption.
	Taproot	Increases soil penetration to reach deep nutrients.
	Nodules	Nitrogen uptake.
Root hairs	Hairs, thin extensions	More surface area for water/mineral absorption.
Leaf	Stomata/pores/openings in leaf	Carbon dioxide uptake, transpiration drives water/mineral uptake.
Trap	Chamber for catching/digesting prey	Breakdown of prey into nutrients absorbed through chamber wall.