

BIOLOGY
COMPREHENSIVE EXAMINATION
REVIEW TOPICS & QUESTIONS
FALL, 2018

Saturday, November 3, 2018, 9 AM - 12 PM

(Please arrive at the E.E. Just Auditorium by 8:30 AM)

The passage of the Comprehensive Examination is a requirement (one of the General Education Requirements of the College of Arts and Sciences) for graduation. The Comprehensive Examination will only be offered once per semester (there will not be any make up examinations for students who fail), therefore, you should take the preparation and passing of this examination very seriously. If you fail, you will not graduate until you pass a subsequently offered Comprehensive Examination in a future semester.

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Department of Biology
Guidelines: Comprehensive Examination

DATE OF EXAMINATION –Saturday November 3, 2018, 9 AM - 12 PM

(Please arrive at the E.E. Just Auditorium by 8:30 AM. **You must have a valid Howard University ID Card to be admitted to the examination**)

1. The Fall 2017 Comprehensive Examination will contain the following sections:

A. **Core Requirements (60%)**: Sixty (60) multiple choice questions from the Biology Core Courses:

- i) Twenty (20) multiple choice questions from Biology 101,
- ii) Twenty (20) multiple choice questions from Biology 102, and
- iii) Twenty (20) multiple choice questions from Genetics (Biology 200).

These sixty (60) multiple choice questions from the Biology Core Courses will constitute 60% of your examination score.

B. **Elective Essays in 200 & 300 Level Courses (40%)**: You are to write four essays (10% each which may be up to two pages long).

Note: **Only two (2)** of the five (5) possible essay questions listed in this Study Guide for the various elective courses will appear on the Comprehensive Examination. You may answer up to two essay questions in any particular elective area.

2. The maximum score on the examination is 100%. The **minimum passing score is 60%**.

3. The time allotted for the examination is **3 hours**. The examination will begin promptly at 9 AM and end at 12 PM (noon). You should arrive at the examination site, the E.E. Just Hall Auditorium, at 8:30 AM to fill out the **data card** that, along with your **Student ID**, is required for you to receive an examination.

4. Students are not permitted to enter the examination area with cell phones [digital/electronic devices], papers, purses, bags, or books. Individuals found to have such items within the examination area shall be given a grade of zero percent (0%) for the examination.

5. Students are permitted to leave the room during the course of the examination only for cases of **dire emergency!** *Take care of biological needs PRIOR to entering the room.*

6. **All essay questions on the examinations are to be written in ink. Multiple choice questions are to be recorded on the answer forms (ScanTron) with a #2 lead pencil. You are required to bring your own ink pen and pencil.**

7. Upon entry, each student will be asked to register for the examination and will receive a numbered examination corresponding to the registration number. The number will represent your

name for this examination. Hence, ***you must not write your name or ID number on any part of the examination.*** This will maintain anonymity during the correction process.

8. Think through your answer before you begin writing. All responses must be restricted to the space provided. ***You may write on both sides of a page but you must answer only one question per page.*** Points will be deducted otherwise! Be certain that the question being answered is placed on the properly designated answer sheets.

9. Test results will be emailed to students after they are submitted to the Office of the Dean.

10. Students who wish to review their scored examinations should make arrangements to do so by emailing Dr. William R.Gordon, wgordon@howard.edu , ***within a 3 day period following receipt of the score.***

REVIEW STRATEGY: BIOLOGY 101 AND 102

General Biology (BIOL 101-102) is probably the most important course offered by the Department of Biology; it contains the basis for all subsequent courses in Biology. It introduces you to many important concepts that every capable and well-prepared Biology major should know. General Biology also presents to you many specific examples that demonstrate these concepts.

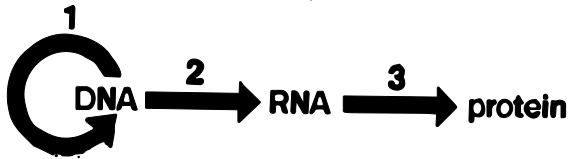
There are certain concepts to which you were introduced in Biology 101-102, that you must retain to perform well in the more advanced courses in Biology at Howard and to perform well in courses you may take in graduate school, medical or dental school. A partial list of some of the basic concepts and facts that you should know are listed below.

Biology 101

The Chemistry of Life

- * Elements, Atomic Number, Atomic Weight, Atomic Structure (Protons [+] Neutrons [0] Electrons [-]), Isotopes (standard, heavy, radioactive), Charged Molecules (anions [-] cations [+])
- * Organic vs. Inorganic molecules, small molecules vs. macromolecules, monomeric molecules vs. polymeric molecules.
- * The chemistry of water: The definition of pH ($\text{pH} = -\log [\text{H}^+]$), the pH scale, the polar nature of water. (You should know what the electronegative atoms that occur in organic compounds are: oxygen and nitrogen).
- * Types of chemical bonds: Strong bonds: covalent bonds. Weak bonds: hydrogen bonds, hydrophobic bonds (or interactions), ionic bonds, and Van der Waals interactions.
- * The biological polymeric macromolecules: Nucleic acids (DNA, RNA), proteins, carbohydrates, and lipids. Monomer subunits and bonds that hold the biological polymeric macromolecules together: Nucleic Acids (DNA, RNA) are made of nucleotide monomers held together by phosphodiester bonds. Proteins are made of amino acid monomers held together by peptide bonds. Carbohydrates or polysaccharides are made of monosaccharides held together by glycosidic bonds. And lipids are frequently triglycerides consisting of glycerol molecules esterified to fatty acid molecules. (There are also other types of lipids).
- * Structure and function of nucleic acids and proteins: Structure of double helical DNA (double stranded DNA = dsDNA). The chemical nature of base pairs (base pairs are hydrogen bonded purine-pyrimidine complexes, GC, AT, or AU). The mechanism of DNA replication (in vivo DNA synthesis involves both leading strand continuous and lagging strand discontinuous DNA synthesis) including the various proteins involved (DNA polymerases, DNA ligase, DNA helicases, primase, and single stranded binding proteins). You should be familiar with and know the function of the origin of replication, primase, the direction of synthesis of nucleic acids, the difference between leading and lagging strand synthesis, and Okazaki fragments.

* **The Central Dogma** also known as the **Information Flow Theory** (DNA → RNA → Protein).



Steps: 1) **DNA Replication** (DNA synthesis catalyzed by DNA polymerases and involves many other enzymes and proteins), 2) **Transcription** (RNA synthesis catalyzed out by RNA polymerase), and 3) **Translation** (Protein synthesis catalyzed by ribosomes, which have 2 subunits each one of which contains at least one major rRNA and many ribosomal proteins. Translation also involves the base pairing of the codons of the mRNA to the anticodons of aminoacylated tRNAs, i.e. tRNA esterified to their specific amino acids).

*The function of reverse transcriptase (a RNA dependent DNA polymerase which synthesizes a complementary DNA, cDNA, from a RNA template) and why it is an exception to the central dogma.

* The proof that DNA is the genetic material (the Griffith Experiment, the Avery, McLeod, McCarty Experiment; The Hersey-Chase Experiment).

* The **mechanism of transcription**, the subunit structure of RNA polymerase, particularly the function of the **sigma factor/subunit** in prokaryotes and the **general transcription factors** among which are **TFIID and other TFIIIs** in eukaryotes and the function of the **promoter site** (the TATA consensus sequence to which RNA polymerase initially binds). The **difference** between prokaryotic and eukaryotic genes: the presence of **introns** in eukaryotic genes. The three steps involved in the **processing of eukaryotic primary RNA transcripts** (i.e., pre mRNAs) into mature mRNAs: 1) 5' capping with m⁷G, 2) 3' polyA tailing, and 3) splicing (excision of introns and religation of exons by spliceosomes made of RNPs [snRNA complexes]).

* The **mechanism of translation**. The structure (ribosomes are complexes of rRNAs and proteins) and function **of ribosomes**, the genetic code, the synthesis of **aminoacyl tRNAs**, the peptidyl transferase reaction, the translocation of ribosomes, the termination of protein synthesis. (You must know how **codons** via base pairing to the **anticodons** of aminoacyl tRNAs specify the next amino acid added by the **peptidyl transferase** reaction which is catalyzed by the **large ribosomal subunit** to the growing polypeptide during the **elongation step** of translation). The involvement of the protein “rho” in the termination of prokaryotic translation.

* Events that occur during posttranslational modification of proteins.

* Factors that contribute to the 2 and 3 dimensional structure of proteins (You should know which **amino acids are hydrophobic and hydrophilic**). Knowledge of the nature of alpha-helices, beta-structure, and disulfide bridges.

Cell Structure

- * Structure of prokaryotic and eukaryotic cells. The differences between pro- and eukaryotic cells. Differences between plant and animal cells. Structure of cell membranes.

Energetics and Metabolism

- * Function of ATP. Synthesis of ATP. Glycolysis, Krebs cycle (a.k.a., TCA cycle or Citric Acid cycle), Photosynthesis, Respiration, and electron transport. Definition of a catalyst. How enzymes function as catalysts.
- *Photosynthesis is the use of the energy from the sun to synthesize carbon compounds (by the Calvin Benson Cycle). The reactants for photosynthesis are CO₂ and H₂O. The products are carbon compounds and oxygen.
- *Photosynthesis in eukaryotes is carried out in chloroplasts.
- *Respiration in eukaryotes results in the synthesis of ATP in the mitochondria by harvesting energy derived from passing electrons down the electron transport (respiratory) chain.
- *Chloroplasts and mitochondria were free living prokaryotes prior to becoming endosymbiots within eukaryotic cells.

Chromosomal Structure, Cell Division (Mitosis and Meiosis)

- * Chromosomes are complexes of DNA and proteins (histones-H1, H2A, H2B, H3, and H4).
- * The “beads on a string model”, nucleosomes, histones, histone core octomers. The nature of non-coding chromosomal DNA: tandemly repetitive DNA (satellite, mini- and microsatellite DNA), interspersed repetitive DNA (transposon-like, retroposon-like repetitive DNA such as *AluI* repeated sequences). Gene families (such as the hemoglobin gene family which arose via gene duplication and reduplication followed by the acquisition of different mutations in the different copies of the gene).
- *Haploid (n) and diploid (2n). An organism with a chromosome number of **2n=16** has a diploid chromosome number of 16 and a haploid chromosome number of 8.
- *During gametogenesis, the **reduction of chromosome number** from diploid to haploid occurs during **Meiosis I**.

Mendelian Genetics (genetics of diploid organisms)

- * DNA and heredity. Mono- and dihybrid crosses.

Phage and Bacterial Genetics (genetics of haploid organisms)

- *Bacteriophages (phages) and bacteria are haploid.
- *Gene can be transferred horizontally from cell to another cell (as versus vertically from parent to progeny or daughter cells during binary fission) by the processes of 1) **transformation**, 2) **conjugation**, and 3) **transduction**
- *Transformation is the uptake of DNA from the medium by a bacterial cell.
- * Conjugation is the transfer of genetic material from one bacterium to another via a pillus (a conjugation tube). This transfer is usually mediated by a F-plasmid (a fertility plasmid).
- * Transduction is the transfer of DNA from one cell to another mediated by a phage by catalysis.
- * Gene Mutations: Types and consequences of mutations (point or substitution mutations and rearrangement mutations, insertions and deletions which may cause frameshifts). The origin (generation) of mutations (spontaneous or caused by mutagens).

Regulation of Gene Expression

- * Prokaryotic gene expression: the *lac* and *trp* operons.
- * Eukaryotic gene expression: Transcriptional regulation, transcription factors (you should be familiar with both general transcription factors, GTFs, which in eukaryotes function similarly to prokaryotic sigma factor, and regulatory transcription factors/proteins which are either activators or repressors), stability of RNAs and proteins.
- * Transcription factors (DNA binding regulatory proteins which activate or repress transcription by binding to the regulatory region of genes).

Recombination DNA and Biotechnology

- * Restriction enzymes, DNA sequencing, synthesis of recombinant molecules. Plasmids and phage cloning vectors
- * Polymerase chain reaction (PCR): in vitro DNA synthesis.

Biology 102

History, Origin, and Evolution of Life on Earth

- * Darwinian & molecular evolution. Population genetics, the Hardy-Weinberg theorem.
- * Origin of life on earth
- * Differential Gene Expression in Development
- * Evolution of Gene and Genomes
- * Speciation
- * Phylogeny, cladistics, & systematics. Characteristics (and differences) of organisms in the phyla. Differences between plants, animals, fungi and protists, between prokaryotes and eukaryotes, between single celled and multicelled organisms, vertebrates and invertebrates, etc.
- * Archea vs. Bacteria: cell wall structure, nucleic acid structure, metabolic characteristics and ecological niches
- * Origin and Diversification of Eukaryotes
- * Fungi: Recyclers, Pathogens, and Parasites
- * Plant diversity, structure, transport, nutrition, and reproduction & development.
- * Invertebrates, vertebrates, reproduction, development, physiology, homeostasis, and behavior.

Review Topics in Genetics:

- * The Nature of the Genetic Material: Chemical composition, experimental evidence that DNA is the genetic material (Experiments of 1) Griffith, 2) Avery, McLeod, and McCarty, 3) Hersey & Chase, Chargaff)
- * Mendelian and the Chromosomal Theory: Mendel's law of segregation, law of independent assortment, monohybrid and dihybrid crosses, applications of probability (Hardy-Weinberg),
- * Modifications of Mendelian Principles: Gene interactions (allelic), incomplete dominance, co-dominance, multiple alleles

- * Genotypic Interactions: Epistasis (recessive and dominant), additive gene action, polygenic inheritance.
- * Sex Determination and Sex Linkage: Sex chromosomes, sex-linked genes.
- * Linkage and Chromosome Mapping (Diploid): Two- and three-point crosses.
- * Cytogenetic: Variation in chromosome number, euploidy, aneuploidy, cytogenetics - variation in chromosome structure, duplications, deficiencies, inversions, translocations
- * Quantitative and Evolutionary Genetics
- * Chemistry of the Gene: Chemical and physical characteristics, the Watson and Crick model of double helical DNA, types of helical forms of DNA.
- * Mechanisms of the genetic synthetic processes of the Central Dogma: The molecular mechanism of 1) DNA replication [synthesis], 2) transcription [synthesis], 3) translation [synthesis].
- * DNA Replication: Semi-conservative replication [Meselson and Stahl Experiment], the origin of replication, the various proteins that constitute the replication machinery, the reason for and difference between leading and lagging strand DNA synthesis, the mechanism of lagging strand synthesis, the multiple enzymatic activities of *E. coli* DNA pol I [1) polymerase, 2) 5'→3' and 3) 3'→5' exonuclease activities].
- * Gene-Phenotype Relationships: Experiment of Beadle, Tatum & Ephrussi (One Gene- One enzyme)
- * Transcription: Promoter recognition in prokaryotes, promoter recognition in eukaryotes, RNA chain elongation and termination.
- * The nature of RNA transcripts (rRNA, tRNA and mRNA) and related ribonucleoproteins: ribosomes (rRNA and protein), spliceosomes (snRNA and protein).
- * The Genetic Code: Triplet nature of the genetic code, experiments that deciphered the genetic code, the Wobble Hypothesis.
- * Protein Structure: The chemical characteristic of amino acid R-groups--particularly their interaction with the solvation shell of water (hydrophobic & hydrophilic R groups) and how that affects the folding of proteins into their ultimate 3 dimensional (tertiary) structure. The levels of macromolecular structure: 1) primary (sequence of monomer units), 2) secondary (structure in two dimensions--in proteins affected by disulfide bonds, alpha helices and beta-structure), tertiary (due to hydrophobic interactions), and quaternary structure (aggregates of subunits--each of which has its own tertiary structure. Example, the tetrameric protein hemoglobin which is made of 4 subunits [2 alpha and 2 beta]).
- * Translation: Initiation mechanisms, elongation mechanisms, and termination mechanisms. ORFs (open reading frames of codons for translation), DNA mutations-- point mutations (silent, missense, nonsense) and insertions and deletions (possibly causing frame shifts).
- *Catalysis of translation by ribosomes (the peptidyl transferase reaction which adds the next amino acid residue to the growing polypeptide and the translocase or translocation reaction which moves the ribosome down (in a 5'→3' direction) the mRNA.

Animal Physiology:

1. Compare and contrast the relationship between the hypothalamus and the anterior pituitary with that of the hypothalamus and the posterior pituitary. Include differences in tissue type, mode of communication with the hypothalamus, and regulation of hormone release.
2. Explain how complex organisms rely on feedback systems to regulate various aspects of bodily functions. Also, provide an example of each type of feedback system, being sure to identify and detail specific mechanisms involved.
3. Identify the two divisions of the autonomic nervous system, and provide an example of how the two divisions have opposing actions on the regulation of a particular bodily function.
4. Compare and contrast the endocrine system with the nervous system, with respect to mode of communication and regulation and integration of bodily functions that maintain homeostasis in humans.
5. The relationship between structure and function is an important principle in physiology. Explain the context of this principle, and relate it to how the intrinsic conduction system supports heart function.

Cell Biology:

1. **Intracellular Compartments and Protein Sorting:** ¹Knowing the hostility of the cytosol, list three distinct reasons for why the cell has organelle sub compartments (as opposed to just doing all the work in the cytosol); in your answer, briefly describe the benefits afforded to the cell? ²What is the unique purpose of vesicular transport methods in comparison to gated transport *and* transmembrane transport; in your answer, list three major benefits afforded to the cell in use of vesicular over gated?
2. **Membranes.** ¹List four reasons that cell would want to modify the fluidity and accessibility of the plasma and organelle membranes; what does this have to do with the diversity of hydrocarbon tails and glycosylation/charged head groups (within the phospholipid)? ²What is the mechanism that automatically drives phospholipids into a semi-permeable bilayer in an aqueous environment; how is the speed of assembly into the bilayer directly related to the balance of positive and negative charged ions in the H-OH environment?
3. **Mitochondria and Energy.** ¹Describe how acetyl-CoA is used in generation of ATP, the purpose of the electron transport chain, coupled transport (i.e. F-type pumps) and the role of an electrochemical gradient. ²Furthermore, discuss how fat stores vs. sugars are differentially used to generate ATP and the amount of energy input vs. gained from the two different sources.

4. **Transport across membranes.** ¹What purpose does coupled transport serve the cell in direct comparison to ATP driven pumps; in your answer, describe how electrochemical potential can serve as both a pro and con of active transport? ²How is V_{max} associated with active transport of molecules by an active transport transmembrane protein; in your answer, compare this to the linear relationship to passive diffusion and explain how this does not have a V_{max} ?

5. **Intracellular Transport and the Cytoskeleton.** ¹Knowing the hostility of the cytosol, list three distinct reasons for why the cell has organelle sub compartments (as opposed to just doing all the work in the cytosol); in your answer, briefly describe the benefits afforded to the cell? ²What are the unique purpose of vesicular transport methods in comparison to gated transport *and* transmembrane transport; in your answer, list three major benefits afforded to the cell in use of vesicular over gated?

Ecology:

1. Discuss the hydrologic cycle. Discuss the following concepts in detail:

- what is the percentage of freshwater and saltwater on earth?
- what is the primary storage reservoir for freshwater on earth?
- the role of solar energy in the hydrologic cycle
- the balance between evaporation and precipitation on land and over the ocean
- transpiration
- runoff
- percolation
- aquifers
- explain two ways that global climate change is changing earth's hydrologic cycle

2. Discuss variations in mating systems in the natural world. Discuss the following concepts in detail:

- What factors are most important for fecundity in males and females?
- Explain monogamy and give an example of one species where this mating system is common. What type of parental care is associated with this mating system? Explain the evolutionary advantages of this mating system.
- Explain polygyny and give an example of one species that exhibits this mating system. What type of parental care is associated with this mating system? Explain the evolutionary advantages of each mating system.
- Explain promiscuity and give an example of one species that exhibits this mating system. What type of parental care is associated with this mating system. Explain the evolutionary advantages of this mating system.

3. What is the competitive exclusion principle? Give a detailed explanation of the classic experiment on competition between two *Galium* species in different soil environments. Define exploitation competition and interference competition and give an example of each.

4. Discuss the co-evolutionary relationship between plants and herbivores. Discuss the following concepts in detail:

- explain specialist vs generalist herbivores
 - explain constitutive vs induced plant defenses against herbivory
 - give two examples of structural defenses in plants
 - give two examples of chemical defenses in plants
 - explain the relationship between herbivory and species diversity in a community
5. Discuss mutualism as a co-evolutionary relationship between species.

5. Discuss the following concepts in detail:

- (a) explain facultative mutualism vs obligate mutualism
- (b) define trophic mutualism and give a detailed explanation of two examples
- (c) define defensive mutualism and give a detailed explanation of two examples
- (d) define dispersive mutualism and give a detailed explanation of two examples

Evolution:

1. Using the two datasets of amino acid sequences provided below construct a phylogenetic tree based on the shared similarities among the 6 species. Note: the 6 species are the same for each data set and you should produce one phylogenetic hypothesis for each set of sequences.

Protein Sequence Set A

Species 5	GNAGYGAEALERM
Species 6	GNAGYGAEALERM
Species 2	NHAAFGEALERM
Species 3	NHSAYGAEALERM
Species 1	AHAGYGAEALERM
Species 4	GHAGYGGEALDRT

Protein Sequence Set B

Species 5	LCNSIGSLFQTF SI
Species 6	LCNSTGSLFQTF AI
Species 2	LCNSTGSLFQTF AI
Species 3	LCNSTGSLFQTF AI
Species 1	LCNSIGSLFQTF SI
Species 4	LCNSIGSLFQTF SI

Using your knowledge of evolutionary processes and patterns provide an explanation for any differences, if any, between the two trees. Explain what additional data you might need to decide which of the trees is closer to the “true” species tree. What criteria could you use to select among the two trees?

2. Compare and contrast the concepts of homology and homoplasy in evolutionary biology. Provide definitions of each, and in addition, A) provide one example (real or hypothetical) of homology, and B) provide one example (real or hypothetical) of homoplasy.

3. What does Hardy-Weinberg Equilibrium describe? What are the genotype frequencies for two alleles under Hardy-Weinberg Equilibrium? Describe the 5 assumptions underlying the Hardy-Weinberg Equilibrium model. Provide an example of how one of these assumptions might be

violated in a population.

4. Describe how historical and ecological processes have shaped biodiversity and its distribution. In your answer be sure to include examples from the various modes of speciation (e.g. allopatric, sympatric, parapatric, and peripatric).

5. List and discuss the 5 major extinctions that have occurred since the Cambrian explosion. Be sure to include the approximate geological time periods of each, the hypothesized causes of the extinctions, and the major groups impacted. Compare and contrast these 5 extinctions events with the current biodiversity crisis in the Anthropocene.

Microbiology:

1. Explain how you would use Robert Koch's postulates to determine that Bacterium HU220 is the causative agent of the disease XYZ. Also, explain why Koch's postulates cannot be fulfilled for some microorganisms.

2. Discuss the role of phages in bacterial pathogenesis

3. The complement system functions as a mediator of both innate and adaptive host defense mechanisms. Given your knowledge of host-defense system, discuss the role played by the complement system in both adaptive and innate immunity.

4. Explain the concept of semiconservative replication and how simultaneous copying of both strands of DNA is accomplished in prokaryotic cells. Include as much detail as you can regarding DNA replication.

5. Explain the differences between defined and complex media, and selective and differential media. Additionally, design an experiment using media to characterize bacteria isolated from soil. Include any laboratory techniques you would use.

Molecular Biology:

1. Define and describe PCR by answering the following questions:

a) What enzyme is employed to carry out PCR?

b) Why is not *E. coli* DNA polymerase I or a viral polymerase used?

c) Why are two oligonucleotide primers required?

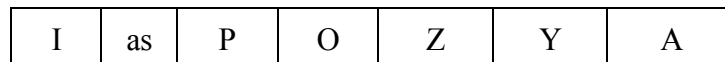
d) What substrates (that is, what reactants) must be provided?

e) What are the three phases of a PCR thermocycle and why are they employed?

and f) After a PCR amplification, how are the products analyzed?

2. Describe the events which occur at the ribosome during the elongation step of translation. Among other things, be sure to define the function of 1) the A- and P-sites of the ribosome, 2) how a particular aminoacyl-tRNA specifically associates with the ribosome and the mRNA, 3) how the amino acid on one tRNA becomes attached to the nascent polypeptide on the peptidyl tRNA, and 4) what translocation is and how it occurs?

3. DNA synthesis on the lagging strand is said to be discontinuous. Describe DNA synthesis in *E. coli* on the lagging strand. Among other things, be sure to include the function(s) of primase, DNA polymerase I, and DNA ligase which are involved in the ultimate synthesis of a continuous piece of DNA. Also, be sure to define what Okazaki fragments are.
4. a) In the regulatory region of a eukaryotic gene, what is an enhancer and how it is involved in the regulation of transcriptional expression.
b) What is the general, basal, or core transcription machinery? Name some of the important components of this complex of molecules. What is the function of this complex of molecules?
5. [A] Below is a sketch of the lactose operon with its component loci and the *lacI* gene. For each locus of this operon and the *lacI* gene, explain what each component **IS**, what **IT DOES**, and/or what **GENE PRODUCT** it expresses.



[B] Explain how the negative regulation of the transcriptional expression (and the relief of the negative regulation) of the genes of the lactose operon is achieved. In your answer, be sure to discuss the role of [1] the ***lacI* gene product** (which you should have named in part [A], [2] the function of the "**P**" and [3] "**O**" loci, [4] the role of **RNA polymerase**, and [5] the role of **inducer** (IPTG or allolactose/lactose). [6] Also be sure to include in your answer where and for what reason does a **conformational change** occur.

[C] Explain how the positive regulation of the transcriptional expression of the genes of the lactose operon is achieved. In your answer, be sure to discuss the role of [1] CRP, [2] cAMP, [3] glucose concentration, [4] adenylyl cyclase, and the function of the [5] "as" and [6] "P" loci.

Plant Diversity:

1. Describe alternation of generations (you may use a diagram). What is the difference between a gametophyte and a sporophyte? For each plant group, bryophytes, ferns, gymnosperms and angiosperms, define which generation is dominant.
2. List the principal characteristics that helped plants adapt to life on land. For each character, explain how it is adaptive. What is sequence of origin of these characters, based on evidence from the fossil record?
3. Where and when were plants first domesticated? Which plants were these? How did the domestication of plants influence other aspects of human culture?

4. Describe the mechanism by which water moves from the soil to the top of a tree- both at the level of the leaves and through the trunk/ stem system.
5. One of the important themes in biology is linking structure to function. Choose either **xylem** or **phloem**. What is the function of the tissue? Be specific. Describe the cell types found in the tissue. For each cell type, explain how the cell structure is linked to the cell function (think cell wall, organelles, living or dead, location).

Plant Physiology:

1. Plant Hormone signal transduction is an exciting field and the mode of signaling for various hormones in the cellular context have been elucidated. Compare and contrast the plant hormone Auxin and ethylene signal transductions mechanisms. (Hint. Begin at the Receptor level)
2. To cope with drought conditions, plants employ a very common mechanism of synthesizing solutes for osmotic adjustment. Describe how solutes help plant cells to cope with drought conditions.
3. Carotenoids comprise a family of orange and yellow pigments present in most photosynthetic organisms. Describe the different types of carotenoids found in photosynthetic organisms pointing to their chemical characteristics and functions.
4. ATP synthesis in chloroplast is based on the stepwise conservation of energy. Trace the conservation of energy from the initial absorption of light by the chlorophyll molecule to the final formation of a molecule of ATP.
5. Trace the path of carbon in a typical C4 type of plants- from its entry through stomata to its export in the vascular tissue. How does this differ from C3 pathway?