BIOLOGY COMPREHENSIVE EXAMINATION REVIEW TOPICS & QUESTIONS- SPRING 2026

Saturday, March 28th, 2026- 9 AM - 12 PM

The exam will be administered in person in EE Just Hall (report to the **first floor**). Please have your HU student ID card ready to display when you check in. Please arrive by 8:30 am. Extra time will not be given for late arrivals.

Please bring your laptop with you, because the exam will be administered electronically. You must be present in person to take the exam, and you must sign up via the Canvas Organization to access the exam. There will be power outlets at each station, so please bring your laptop charger. If you do not have a laptop, a computer will be provided for you. You must be able to use your HU student login credentials to access the computer.

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.

CONTENTS:

*Slight revisions were made to these areas since the Fall 2025 booklet

Department of Biology Guidelines: Comprehensive Examination

1. The Spring 2026 Comprehensive Examination will contain the following sections:

A. Core Requirements (60%): Sixty (60) multiple choice questions from the Biology Core Courses: (From specific pool of questions which will be randomly assigned to each student)

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: For each elective course, **only two** (2) of the five (5) essay questions provided in this Study Guide will appear on the Comprehensive Examination. You may choose to answer up to two essay questions from any elective course.

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 9:00 AM and end at 12 PM (noon). Your will begin at 9AM, and you must be finished by noon.

4. Please note the following:

- **No earphones, earbuds, or headphones** are allowed during the exam.
- **No smart glasses, smartwatches, or wearable technology** of any kind may be used.
- **No notes, textbooks, printed materials, or written aids** are permitted.
- **No electronic devices** other than the one(s) used to take the exam (if applicable) may be present.
- **Use of artificial intelligence tools is strictly prohibited.** This includes—but is not limited to—AI chatbots, AI writing assistants, AI problem solvers, and any automated content-generation tools.
- All work must be completed **independently** and must reflect your own understanding.
- Individuals found to break this rule shall be given a grade of zero percent (0%) for the examination. You should also turn off your cell phone and disable chatting applications on your computer and/or other devices.

5. We strongly encourage everyone to take care of biological needs before the exam

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

7. Students who wish to review their scored examinations should make arrangement to do so by emailing Dr. Rachelle Allen-McFarlane (email address: rachelle.allen@howard.edu), ***within three days*** 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.

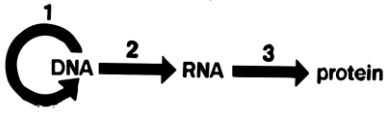
Biology 101

Cell Structure and Physiology

- Small Molecules and the Chemistry of Life
    - Types of chemical bonds: Strong bonds: covalent bonds. Weak bonds: hydrogen bonds, hydrophobic interactions, ionic bonds, and Van der Waals interactions.

    - The biological polymeric macromolecules and their structures: Nucleic acids (DNA, RNA), proteins, carbohydrates, and lipids.

    - The Central Dogma of Molecular Biology.



      Steps: 1) **DNA Replication** (2) **Transcription**, and 3) **Translation**
      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.

- 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.

Metabolism

- Function of ATP. Glycolysis, Krebs cycle (a.k.a., TCA cycle or Citric Acid cycle), Photosynthesis, Respiration, and electron transport.
- How enzymes function as catalysts.

The Cell Cycle & Cell Division

- Phases of the Cell Cycle
- Cell Division (Mitosis and Meiosis)

Mendelian Genetics (genetics of diploid organisms)

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

Bacterial and Viral Genetics

- 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
    - **Transformation** - the uptake of DNA from the medium by a bacterial cell.
    - **Conjugation** - the transfer of genetic material from one bacterium to another via pili (a conjugation tube), and
    - **Transduction** - the transfer of DNA from one cell to another mediated by a phage by catalysis.
- Viral reproductive cycles
    - Lytic cycle
    - Lysogenic cycle

Regulation of Gene Expression

- Prokaryotic gene expression: the *lac* and *trp* operons.
- Eukaryotic gene expression:
    - Transcriptional regulation
        - Transcription factors (DNA binding regulatory proteins which activate or repress transcription by binding to the regulatory region of genes).
    - Translational regulation
        - miRNAs
        - siRNAs
        - Translational repressor proteins

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 Diversity
- Vertebrate Diversity
- Animal Physiology: reproduction, homeostasis, circulatory system, and nervous system

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, codominance, 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

- 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.

Essay Questions

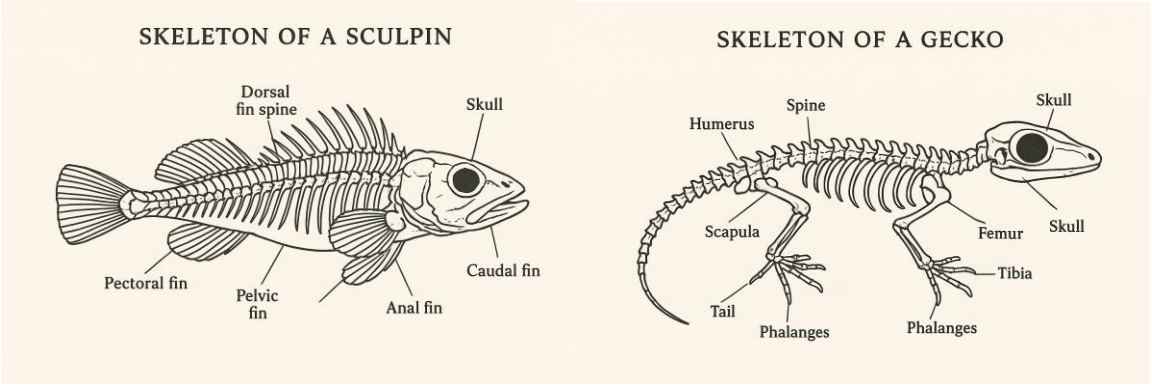
For each of the nine courses covered below, two out of the five possible essay questions will be selected to appear on the exam. Therefore, there will be a total of 18 essay questions to choose from on the exam. You must answer four out of these 18. For help preparing for these essays, please attend the Review Sessions, and for further help, contact professors that teach these courses.

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. Explain the organization, function, and chemical messengers used. Further, Discuss the integration of these two divisions with respect to homeostasis of an example organ function.
4. Compare and contrast the endocrine system with the nervous system. Define each system. discuss the mechanisms of communication, onset and duration of responses, and how they regulate responses to maintain homeostasis. How are responses integrated across the two systems?
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.

Comparative Anatomy:

1. The two most successful living vertebrate groups, in terms of number of species, are Tetrapods and Teleosts, with Tetrapods transitioning to land from their Sarcopterygian ancestors and Teleosts remaining in the water like their Actinopterygian ancestors. Below are two skeletal diagrams generated by ChatGPT-5, one of a teleost and one of a tetrapod. **Describe three errors in each skeleton (totaling six errors) and explain what changes you could make to correct the errors.** For each skeleton, one example should be from the cranial skeleton, one should be from the axial skeleton, and one should be from the appendicular skeleton.



2. Put the following developmental stages in order from earliest (after fertilization) to latest: neurulation, cleavage, and gastrulation; name one anatomical change that happens during each of these three phases of vertebrate development. Additionally, name the three germ layers and for each layer provide one example of a structure that eventually develops from that tissue
3. Compare white matter, gray matter, ganglia, and nerves in the vertebrate nervous system, in terms structure, function, and location.
4. Design a muscle (real or imaginary) that can perform a specific function (realistic or extraordinary). What properties would this muscle have? Include at least the following properties: function of the muscle, muscle strength, muscle speed, cross-sectional area, length of muscle, inlever length, outlever length, insertion point (proximal or distal?), pennation (pennate or not pennate?), and physiological muscle fiber type. When applicable, you can use relative terms such as "high," "intermediate," and "low" (no numbers required). Your essay will be assessed on whether the properties that you assign are consistent with the function of the muscle.
5. Define counter-current exchange, and briefly describe why it is such an effective method of exchange. Give two real biological examples of counter-current exchange, one involving heat exchange and the other involving gas exchange. How do your two examples differ in structure and function?

Cell Biology:

1. **Intracellular Compartments and Protein Sorting**: Compare and contrast protein import into the ER and into the nucleus. List at least two major differences in the mechanisms, and speculate why the ER mechanism might not work for nuclear import and vice versa.

2. **Membranes.** What are the differences between a phospholipid molecule and a detergent molecule? How would the structure of a phospholipid molecule need to change to make it a detergent?

3. **Mitochondria and energy.** (1) Describe 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. (2) Furthermore, 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.** The neurotransmitter acetylcholine is made in the cytosol and then transported into synaptic vesicles, where its concentration is more than 100-fold higher than in the cytosol. When synaptic vesicles are isolated from neurons, they can take up additional acetylcholine added to the solution in which they are suspended, but only when ATP is present. Na+ ions are not required for the uptake, but curiously, raising the pH of the solution in which the synaptic vesicles are suspended increases the rate of uptake. Furthermore, transport is inhibited when drugs are added that make the membrane permeable to H+ ions. Suggest a mechanism that is consistent with all of these observations.

5. **Cell cycle and the cytoskeleton.** The drug taxol, extracted from the bark of yew trees, has an opposite effect to the drug colchicine, an alkaloid from autumn crocus. Taxol binds tightly to microtubules and stabilizes them; when added to cells, it causes much of the free tubule to assemble into microtubules. In contrast, colchicine prevents microtubule formation. Taxol is just as pernicious to dividing cells as colchicine, and both are used as anticancer drugs. Based on your knowledge of microtubule dynamics, suggest why both drugs are toxic to dividing cells despite their opposite actions.

Ecology:

1. a) What are the unique ecological processes or questions that can be examined or explored when ecology is studied at each of these levels: the individual, population, community, and ecosystem?
b) What does it mean when we say that ecological systems are in a dynamic steady state? Explain with at least two examples of ecological systems or processes that are in a dynamic steady state.
c) State the first law of thermodynamics and subsequently explain how it relates to understanding ecology.
d) If the Earth were not tilted on its axis, how would it affect the seasonality of weather at the poles?

2. A) Explain the adaptations that enable
   i. thermophiles to survive in a very high-temperature environment.
   ii. Antarctic fish to survive in very cold, almost icy seawater.
   iii. Cactus to thrive in arid and hot desert environments.
   iv. C_4 plants, like corn, to photosynthesize while minimizing water loss in their hot arid environments.
   v. aquatic plants like waterlilies and duckweed to float and not sink in water where they occur.

B) What are the patterns of survival with age in the three types of survivorship curves?

3. a) What mechanism could cause individuals in a population to be evenly spaced or clustered?
b) If you used a mark-recapture approach to estimate the size of an animal population, but the tags were defective and fell off some percentage of the initially sampled individuals. Would the method tend to underestimate or overestimate the actual population size? Clearly articulate the reason for your chosen answer.
c) Why does the graph of population increase produce a J-shaped curve even though the intrinsic growth rate is constant?
d) What causes a population that is at half its carrying capacity to grow faster than a smaller or larger population size?
e) What factors favor sexual dimorphism in animals? State at least one

4. a) State at least four ways in which prey have evolved to reduce their risk of being killed or eaten by predators.
b) What does the competitive exclusion principle predict about the outcome of two species competing for the same resource or resources?
c) Using the generalized Lotka–Volterra equations, under what conditions do we predict the stable coexistence of two species competing for the same resources?
d) Why do herbivores generally consume larger quantities of food per unit body mass than carnivores?

5. a) Compare and contrast these two terminologies often used by ecologists: species diversity and species richness.
b) What is the fundamental difference between primary and secondary succession?
c) Nitrogen alone makes up about 78% of atmospheric air. However, these are in a form that plants and animals cannot readily use. Describe at least three processes by which nitrogen could be fixed and utilized by organisms in an ecosystem.
d) What are ecosystem services? Explain with at least three examples.
e) What are keystone species in ecology? Explain, citing at least two examples of keystone species.

Evolution:

1. Describe the three modes of natural selection that act on quantitative traits and explain how each mode alters the distribution of phenotypes within a population. Provide one clear biological example to illustrate each mode of natural selection.
2. Discuss the role of gene regulation and the genetic toolkit in evolutionary change and explain how changes in homeotic mutations can result in major morphological transformations.
3. Define evolutionary ecology and explain how life history traits such as life span and the cost of reproduction influence an organism's evolutionary fitness.
4. Define coevolution and explain the difference between specific coevolution and diffuse coevolution, providing two examples of each type of coevolution.
5. Describe horizontal gene transfer and explain how it differs from vertical gene transfer. Also discuss the major mechanisms of horizontal gene transfer in prokaryotes.

Microbiology:

1. Discuss how microbial genetics has shaped modern molecular biology, with specific examples.
2. Justify the statement: "Without microbes, life as we know it on Earth today will cease to exist."
3. Discuss the major historical events in which microbes have influenced human history and culture.

4. In a well-organized essay, justify the statement: "Despite major advances in curtailing infectious diseases, microbial diseases continue to persist."
5. The bacteria provided the basis for the discovery of the polymerase chain reaction, a breakthrough in life sciences that has revolutionized molecular biology, and its broad applications in medicine and forensic science. Starting with the original publications by Brock et al. (1976), Chien et al. (1976), and Mullis et al. (1985), describe the specific role of the bacterium *Thermus aquaticus* in the discovery. (Hint: you must read the three publications for a successful answer)

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 the concept of alternation of generations (you may use a diagram). Include definitions for each generation and describe the transitions between each generation as well. For each plant group (bryophytes, ferns, gymnosperms and angiosperms), define which generation is dominant.

2. *Selaginella* is one of the first lineages of land plants to demonstrate heterospory. Start with the basic life cycle (alternation of generations) and then draw the *Selaginella* plant. Be sure to label**: sporophyte, gametophyte, spore, microsporangium, megasporangium, megaspore, microspore, megagametophyte, microgametophyte, egg, sperm, zygote and embryo.** Draw where they occur in the life cycle**.** List the two important **processes** which transition between the different generations and underline them. Label which **generation** is dominant. For each **bolded** term, indicate the ploidy (n or 2n).

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. Describe the function of each and explain the difference between the stoma, stomata, and stroma

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?