

## Guidelines for Ph.D. Written Qualifying Exam

- The Qualifying Exam in Biological Sciences consists of two parts -- a written portion (Part-I), followed by an oral portion (Part-II, taken only after passing the written portion). The written portion of the Qualifying Exam must be taken by the end of the 5th semester of study.
- Students select topics from 'Core Topic Areas'. The topics should be a good test of student's general knowledge, knowledge learned from graduate classes, and reading of the literature.
- The student's capacity for systematic review of relevant literature and conducting rigorous analyses of data, are evaluated. This can be thought of as "fact based". This exam will help evaluate the student's future ability to write a scholarly paper suitable to peer review publication and a dissertation.
- The student's ability to understand, critically think and communicate ideas and concepts are evaluated. This can be thought of as "concept based". The student should be able to present hypotheses, alternative scenarios, and implied connections between concepts. Questions are generally open-ended to provide significant latitude for presentation of these. This exam will help evaluate the student's future ability to write a scholarly paper suitable to peer review publication and a dissertation.
- In the written exam, the student will answer a total of 5 questions over 4 hours for an average of 40 minutes per question. To demonstrate both breadth and depth of knowledge about a topic answer, 40 minutes of should fill at least 1 to 1 ½ pages of single-spaced standard sized text. If a detailed schematic or diagram is used, then one could have only ¾ of a page of text. During the written exam, if a student answers a question with only one or two standard length paragraphs, then the student must immediately consider what additional related information can and should be provided.
- Students should be careful that a diagram/flow chart of a process does not replace text. Students should be certain that text supplements information in a diagram. For instance, in the example answer and diagram below, the role or activity of the proteins are shown, and the text clearly provides their role in the pathway.
- This is one of the milestones students have to achieve before they become a 'true expert' in their very specific subject, therefore this process is rigorous and the expectations are higher than general class/course written exams.

- Here are several pointers for successfully passing the written exams:

Plan	Evaluate	Practice	Deliver
<ul style="list-style-type: none"> <li>• Start 3-4 months prior to written exam</li> <li>• Reach out to your committee with an outline of what you know about your 5 areas and ask what else you need to know or reference papers to study.</li> <li>• Make a plan and organize your class notes, reference papers and other resources relevant to your topics.</li> <li>• Talk with your advisor to see how much time off (daily or weekly) they're willing to give you to study.</li> </ul>	<ul style="list-style-type: none"> <li>• Start 2-3 months prior to exam</li> <li>• Pick the topics you want to focus on and inform your advisor</li> <li>• Make a list of resources available: book chapters, references and cross-references</li> <li>• Make a study plan and stick to it (2-3 days for each topic)</li> <li>• Identify possible questions</li> <li>• Identify weak areas/topics and seek out other graduate students to help you study.</li> </ul>	<ul style="list-style-type: none"> <li>• Start 1-2 months prior to exam</li> <li>• Advisor will collect all questions from committee members and ensure that at least 2 or more choices within each topic are available to the student. Select one question for each topic.</li> <li>• Select the questions you need practice with. Focus on the ones you're less confident about.</li> <li>• Challenge yourself with follow-up questions.</li> <li>• Let another graduate student or your advisor give feedback to your answer.</li> </ul>	<ul style="list-style-type: none"> <li>• Start 2 weeks prior to exam</li> <li>• Dedicate studying in depth.</li> <li>• Practice multiple sections/questions of each topic, synthesize and/or memorize the questions several times over.</li> <li>• Remember, some questions may not have just "the "right" answer, rather intelligent and informed response is acceptable in most cases. Therefore, be thoughtful and improve answers.</li> <li>• Take sample test/answer sample questions</li> </ul>

### Examiner's Guidelines:

- 1) Make sure you answer the questions explicitly and clearly.
- 2) Take the time to think through and outline your argument and its structure before you write.
- 3) Provide a clear introduction and conclusion that can help you summarize your central point.

Note: No one can know everything about everything. You will see in this collection of sample questions and answers that it is relatively rare for a question to demand knowledge of a complex mechanism or process. Rather, you will also see that you are often called upon to identify and describe critical mechanisms, with examples, that are relevant to biology, evolution, adaptation or disease processes. You will be expected to evince in-depth knowledge of some issues or areas. Effective in-depth knowledge can help you convince reviewers/examiners your effort, preparation and understanding of the broad topic of interest.

## Core Topic Areas for Written Qualifier

### Cellular Biology

- (1) **Cell structure and function:** cell culture, cell visualizing, organelles, nuclei, cell function
- (2) **Biomembrane structure and vesicular trafficking:** lipid-bilayer membranes, membrane protein structure and function, phospholipids, vesicular budding, fusion and trafficking
- (3) **Trans-membrane transport of small molecules:** overview, diffusion, facilitated transport, active transport
- (4) **Cell organization and movement:** microfilaments and actin filaments, cell movement, microtubule structure and organization, divisome
- (5) **Cell cycle and its regulation:** model organisms and methods, mitosis, meiosis, cell cycle regulation, cell cycle checkpoints, stem cells
- (6) **Signal transduction:** signal transduction from extracellular signal to intracellular response, G-protein-coupled receptor structure and mechanism, two-component regulatory system
- (7) **Signaling pathways and gene expression control:** Tyrosine receptor kinases, Ras/MAP kinase pathway, Phosphoinositide signaling pathway, Wnt/catenin signaling pathway
- (8) **Cell death and apoptosis:** apoptosis, cell death and regulation
- (9) **Cellular homeostasis:** how cells maintain homeostasis through their unique organelles such as mitochondria, chloroplasts, lysosomes, and endocytosis, in response to environmental stress such as pollutants or other types of treatments such as chemotherapy drugs.
- (10) **Integrating cells into tissues:** cell-cell and cell-matrix adhesion junctions, extracellular matrix, motile and non-motile cells

### Molecular Biology

- (11) **Chromosomes:** chromosome morphology, chromosome functional elements, kinetochore, centromere, telomere, extra chromosomal elements
- (12) **Genome organization and structure:** genome structure, genome organization, histone code, epigenetics, genome sequencing and information, personal genome and medicine
- (13) **Gene organization and function:** operon, exon and intron, alternative splicing, mobile elements
- (14) **DNA Replication, DNA Repair, DNA Recombination:** DNA replication, DNA damage, Damage repair, DNA recombination
- (15) **DNA transcription:** operons, transcription initiation, elongation, and termination, transcription machinery, RNA polymerases, transcription factors
- (16) **Transcriptional and post-transcriptional regulation:** control elements, transcription factors (activators and repressors), epigenetics for transcriptional regulation, techniques for transcription studies
- (17) **Translation and post-translational modifications:** translation machinery and process, ribosome structure and function, post-translational modifications including adenylation, phosphorylation, methylation, acetylation and ubiquitination.
- (18) **Protein structure and functions:** structure and motifs, folding, functions (such as multi-drug transporters and detoxification, hemoglobin and other respiratory proteins, aquaporins, Zinc-finger proteins), regulation (such as oxidative stress and antioxidants), proteomics, methods for protein function studies

## Hypothesis Testing

### (19) **Statistical Methodology and Experimental Interpretation**

## Evolutionary Biology

- (20) **Genes and Mutation:** gene structure, types and rates of mutation, pseudogenes, transcribed genes
- (21) **Genome Evolution:** genome size, gene duplication, nongenic sequences, chromosomal evolution
- (22) **Hardy-Weinberg Principle and Population Genetics:** allele frequencies, genetic drift, fixation, stasis, neutral theory of molecular evolution
- (23) **Natural Selection:** Principles and Mechanisms: criteria, types of selection, mechanisms of selection, statistical and comparative analyses for evidence of selection.
- (24) **Mechanisms of Speciation:** genetic isolation, divergence, hybridization, loci of speciation
- (25) **Evolution of Sex and Life History:** ploidy, recombination, origin and costs of sex, cytoplasmic inheritance, alteration of generations
- (26) **Evolution of Development:** genetic switches, origins and consequences of novelty, gene regulatory networks, modularity, and evolutionary constraint
- (27) **Molecular Phylogenetics:** homology, gene and protein families, principles of phylogenetic inference and reliability, molecular clock hypothesis
- (28) **Co-evolution:** Red Queen effect, symbioses, role in emerging pathogens (antigen switching, host jumping, etc.), arms race, disease evolution
- (29) **Bioinformatics and Quantitative Genetics:** databases, BLAST, molecular modeling, sequence homology and structure inferences, QTL mapping, linkage, genome wide association studies
- (30) **Origin and Diversity of Life:** RNA world, extant domains of life, horizontal gene transfer, role of endosymbiosis in eukaryotic evolution
- (31) **Evolutionary Epigenetics:** transgenerational inheritance of non-coding loci, mutation bias, role in phenotypic plasticity, role in cancer
- (32) **Human Evolution:** origins, migration, genetic differentiation, pedigree analysis, emergence of novel mutations in recent human history
- (33) **Metagenomics:** microbial diversity and environmental association, speciation by symbiosis, host-associate co-evolution

## Environmental Biology

- (34) **Climate and Global Warming:** The Atmosphere, Solar Radiation, Ocean/Atmosphere Circulation, The Earth's Climate and Climate Variation, The Earth's Climate and Climate Variation, Greenhouse Gases, Climate Feedbacks, Past Climate Change, Anthropogenic Climate Change Causes, Anthropogenic Climate Change Consequences
- (35) **Biological Productivity and Energy Flow:** Autotrophy and Primary Production, Constraints on Primary Production, Chemosynthesis, Heterotrophy and Secondary Production, Energy Flow and Food Webs
- (36) **Nutrient Cycles:** Nutrient Cycles Overview, The Nitrogen Cycle, The Phosphorus Cycle, Carbon Reservoirs, The Long Term Carbon Cycle, The Marine Carbon Cycle, Ocean Acidification, The Terrestrial Carbon Cycle, Human Alterations to the Carbon Cycle, Fossil Fuel Use
- (37) **Environmental Impact on Population Biology:** Abundance and Distribution of Organisms, Coping with Environmental Variation, Population Growth and Dynamics, Isle Royale Wolves, Human Population Growth

- (38) **Ecosystems and Communities:** Ecological Interactions, Ecological Interactions, Multispecies Interactions, Community Structure, Community Changes
- (39) **Environment and Biological Diversity:** What is Biodiversity?, Biogeography, What Determines Biodiversity?, Does Biodiversity Matter?, Loss of Biodiversity, Conservation Biology
- (40) **Pollution, Toxicology, and Environmental Health:** Air Pollution, Stratospheric Ozone Depletion, Water Pollution and Treatment, Basic Toxicology, Heavy Metal Pollutants, Organic Pollutants, Ecology of Infectious Disease

### **Biochemistry, Biological Pathways, and Metabolism**

- (41) **Proteins:** structure and function, protein-protein interactions
- (42) **Enzymes, catalysis, and kinetics:** Mechanisms of catalysis, control flow through pathways, allosteric regulation.
- (43) **Membrane proteins including channels and receptors:** Structure/ principles of membrane proteins, receptor binding specificity, regulation of information flow by membrane proteins.
- (44) **Nucleic acids structure and biochemical synthesis:** Purine and pyrimidine synthesis and catabolism, de novo synthesis and salvage pathways
- (45) **Hormones and Hormone receptors:** Evolution of hormone signaling, hormone / receptor binding specificity and kinetics, Downstream signaling pathways, Information signaling via hormones.
- (46) **Antibodies and Antigens:** Antibody structure and specificity, Antibodies as experimental tools.
- (47) **Redox signaling and cell defense mechanisms:** Chemistry of reactive oxygen and nitrogen species, Pleiotropic effects of free radicals,
- (48) **Energy metabolism:** Alternative pathways of energy transduction, evolutionary and functional diversity of energy metabolism, Aerobic / anaerobic metabolism, alternate electron acceptors, control of energy flow
- (49) **Carbohydrate/lipid metabolism:** Evolutionary aspects of carbohydrate/ lipid metabolism, regulation of substrate utilization in response to nutritional state, Energy production/ storage, biosynthesis of carbohydrate/ lipid.
- (50) **Adenylates and other high-energy phosphates:** Energy conservation in the form of “high energy phosphates”, Thermodynamics of cellular energy storage/ transfer, Mechanisms of conversion of ATP to physical or chemical work.