Biology MSc program – Final exam questions – 2019

Molecular Genetics, Cell and Developmental Biology Specialization

Molecular Cell Biology

1. Structure of the plasma membrane. Plasma membrane transport processes. Co- and post-translational modifications of proteins and its role in protein sorting, transport and regulation of protein functions.
2. Compartmentalisation of the eukaryotic cell, characterisation of the endomembrane system (endoplasmic reticulum, Golgi apparatus, endosomes, lysosomes), its function in vesicular traffic and in cell communication pathways.
3. The structure and function of nucleus: the chromosomes and the complexity of eukaryotic genome, histones and nucleosomes. The nuclear membrane and chromosomal cycle. Transport of macromolecules between the nucleus and the cytoplasm.
4. Cell-cell junctions and their role in multicellular organisms. Basic tissue types. Cellular communication on the molecular level: signal and receptor molecules. Molecular mechanisms of cell signalling, presentation of some types upon examples of exact signalling pathways.
5. Dynamics of cytoskeleton, role of components of cytoskeleton in the life of a cell. The features of cell cycle and cell cycle control. Examples of failures in cell cycle control in tumours.

Developmental Biology

6. Antero-posterior polarity and axis formation in the oocyte of *Drosophila* and of an Anamnia species.
7. Developmental steps leading from fertilization to blastula stage and their molecular background on the example of *C. elegans* and *X. laevis*.
8. Mechanism of gastrulation in *Drosophila* and birds: morphogenesis and molecular regulation.
9. Determination of segmentation in *Drosophila*.
10. Examples of determination and development of the central nervous system of an Anamnia and Aminote species.

Programmed Cell Death and Autophagy

11. Mechanism and control of apoptosis.
12. The role of ubiquitin-proteasome system in apoptosis.
13. Mechanism and control of autophagy.

Biology of Cancer

14. Mechanism of malignant transformation, characteristics of malign cell population.
15. Mechanism of multiple steps carcinogenesis and its evidences, mutagenic and carcinogenic agents.

16. Cell signalling background of carcinogenesis: oncogenes and tumour suppressors. The role of viruses in the development of cancer.

Genetics and population genetics

1. Gene and mutation: genes in prokaryotes and eukaryotes; the definition cistron, gene and ORF; rules of Mendelian inheritance; sex-based inheritance; gene interactions; the molecular nature of mutations; functional mutation types (Muller morphs); mutations of genes and chromosomes; chemical and physical mutagens; tests for detecting mutagens.
2. DNA repair: common repair pathways (*direct reversal*, base excision repair, nucleotide excision repair, *mismatch repair*, repair through homologous recombination, error-prone repair); human diseases of DNA repair.
3. Mobile genetic elements: the experiments of Barbara McClintock on maize (Ds, Ac elements); polar mutations; DNA transposons; IS elements; retrotransposons; the mechanism of transposition; gene transfer with transposons ("Sleeping Beauty"); hybrid dysgenesis; transposon-induced mutations.
4. The organization of the genetic material in prokaryotes and eukaryotes: epigenetics; chromatin organization; modification of chromatin structure on DNA and protein level and its role in gene expression regulation; X chromosome inactivation and genomic imprinting.
5. Sex determination and dosage compensation: sex determination in *C. elegans*, in *Drosophila*, and in mammals. Mechanisms for dosage compensation. X chromosome inactivation, changes in the number of sex chromosomes and its consequences in humans.
6. Recombination: linkage; the relation between gene conversion and crossing over; tetrad analysis; the Holliday model; the double strand breakage model; the molecular mechanism of recombination; genetic mapping; Haldane's mapping function, LOD analysis.
7. Genomics: genome programs; gene libraries; cloning systems; genetic polymorphisms and their detection; genome-wide "omics" studies; genetic diseases; forensic genetics; relationship between gene number and complexity; the reduction of organellar genomes; ENCODE projects.
8. Microbial genetics: chromosomal organization; options for gene transfer; genetic mapping in bacteria; gene technology (vectors, enzymes); regulation of prokaryotic gene expression (*lac* operon, *trp* operon, positive and negative regulation, attenuation, phage genetics, rII locus of the T4 phage, λ phage and regulation of lysogeny.

Biology MSc program – Final exam questions – 2018
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Regulation of eukaryotic gene expression

9. Eukaryotic transcription: cis- and trans-regulation; recruitment of regulatory proteins; combinatorial regulation of gene expression; chromatin-level regulation; transcription factors; enhancers and silencers; insulator sequences; transcription; mRNA maturation (splicing); translation.
10. Post/transcriptional regulation: RNA interference; si-, mi- and piRNA pathways (structure and function), reverse genetics with gene silencing, nonsense-mediated decay (NMD) and other RNA degradation pathways.

Developmental and molecular genetics

11. Developmental Genetics: cell fate determination; cell-cell communication; major signaling pathways and their roles in development; epistasis analysis; the difference between genetic and biochemical pathways; genetic interactions (recessive and dominant epistasis, complementary inheritance).
12. Early development in *Drosophila*: maternal effect genes, gap genes, segmentation genes, *Hox* genes. Differentiation and apoptosis.

Gene technology and genetic analysis

13. Molecular cloning and transgenic organisms: cloning systems (vectors and enzymes); expression systems; observation of expression patterns; genome editing techniques (zinc-finger nucleases, TALE nucleases, CRISPR/Cas9 system).
14. Gene knockout systems: Cre-loxP; PCR-based methods for isolating deletion mutants; transposon insertion and remobilization; mutations induced with genome editing techniques (e.g. CRISPR/Cas9), genetically modified organisms (GMOs).

Bioinformatics

15. Sequence alignment: alignment algorithms (paired – multiple, global – local) and their application; the logic of similarity searches; similarity searching algorithms; molecular phylogeny; methods for molecular phylogeny (distance and character-based), the reliability of phylogenetic trees.