

Spring 2017

BIOL241 – Introduction to Genetics
and Molecular Biology

Final Exam (110 points)

5/2/2017

Please use scantron sheet for Question A (1-36).

Name: _____

Purdue ID: _____

Question A: _____ (72)

Question B: _____ (4)

Question C: _____ (6)

Question D: _____ (10)

Question E: _____ (10)

Question E: _____ (8)

Total: _____

A. Multiple-choice questions (72 points; 2 points each; please use scantron sheet).

1) Comparing genomes from various prokaryotic species, which of the following statements is incorrect?

- a. Prokaryotic organisms contain mostly circular chromosomes.
- b. Genes in prokaryotic organisms are always expressed as single-gene mRNAs.
- c. Different prokaryotic organisms contain different amount of genomic DNA.
- d. Genes in prokaryotic organisms do not contain introns.
- e. Prokaryotic genomes contain less repetitive sequences than eukaryotic genomes.

2) The genome size of *Vibrio cholerae*, a bacterium, is 4.03mb (10^6 bases). Based on the comparison of prokaryotic genomes, the number of genes in *Vibrio cholerae* is expected to be around:

- a. 40000.
- b. 20000.
- c. 8000.
- d. 4000.
- e. 2000.

3) Which of the following statements best explains horizontal gene transfer?

- a. Transposon-mediated DNA movement from one chromosome to a non-homologous chromosome.
- b. The transfer of DNA from agarose gel onto nitrocellulose membrane.
- c. The detection of clones containing specific DNA on nitrocellulose membrane with radioactively labeled probes.
- d. The mating between F^+ and F^- bacterial strains.
- e. The transformation by DNA from closely related species.

4) Which of the following statements is a good example of synteny?

- a. α and β globin genes show similarities in their amino acid sequences.
- b. α and β globin genes show similarities in the intron positions.
- c. α and β globin genes exhibit different temporal regulations of their respective expressions.
- d. *E. coli* and *B. subtilis* exhibit similar gene density.
- e. Mouse and human Hox gene complexes show similarities in the order of genes along the chromosomes.

5) Comparing human and *C. elegans* genomes, which of the following features is similar?

- a. The amount of DNA.
- b. The number of genes.
- c. The number of introns per gene.
- d. The average size of introns.
- e. The number of identified protein domains.

6) When using 2D gels to separate the cellular proteins, the proteins are first separated by:

- a. Their molecular weights.
- b. Their ability to bind to DNA.
- c. Their mass-to-charge ratios.
- d. Their electric charges.
- e. Their ability to form disulfide bonds.

7) Which of the following terms best describes the condition that a human cell has mitochondria of different genotypes?

- a. Homoplasmy.
- b. Heterozygous.
- c. Synteny.
- d. Maternal inheritance.
- e. Heteroplasmy.

8) Regarding prions, which of the following statements is correct?

- a. Prion proteins are coded by mitochondrial genomes.
- b. Transmission of prions is sensitive to UV light treatment.
- c. Mutant prion proteins cause diseases by inducing the transcription and expression of additional prion proteins.
- d. Transmission of prions is resistant to treatment of protease.
- e. Mice with cellular PrP genes deleted are resistant to mutant prion infection.

9) When a haploid *petite* mutant mates with haploid normal yeast, the resulting diploid zygote exhibits the petite phenotype. After sporulation (meiosis), all haploid progeny are petite. This pattern of inheritance describes:

- a. Segregational petite.
- b. Neutral petite.
- c. Suppressive petite.
- d. Haploinsufficient.
- e. Dominant negative.

10) A different yeast *petite* mutant is isolated. To determine the type of mutation causing this phenotype, the haploid *petite* and wild type strains are crossed. The diploid zygotes are normal, and half the haploid ascospores after sporulation are normal. The explanation for this mutation is that:

- a. It disrupts a nuclear gene that participates in mitochondrial function.
- b. The inheritance of mitochondrial genome in yeast is strictly maternal.
- c. The inheritance of mitochondrial genome in yeast is strictly paternal.
- d. It affects mitochondrial genes, which disrupt mitochondrial function, but gives normal mitochondria proliferation advantage.
- e. It affects mitochondrial genes, which disrupt mitochondrial function, but gives defective mitochondria proliferation advantage.

11) Which of the following observations supports the notion that the *eye/less* gene is a master regulatory gene?

- a. The *eye/less* protein contains a homeobox domain and regulates gene expression.
- b. Mutations in fly and mouse *eye/less* homologs both disrupt eye formation.
- c. The *eye/less* protein forms a gradient and acts as a morphogen for eye formation.
- d. The *eye/less* gene acts cell autonomously during eye formation.
- e. Expression of *eye/less* in developing fly legs causes the formation of ectopic eyes.

12) A tissue from the leg bud during chick development is transplanted into the wing bud. Later on, the transplanted tissue forms structures of leg origin. Based on this, you can conclude that:

- a. The cell fate of cells in the transplanted tissue responds to inductive signaling from the surrounding host cells.
- b. The cell fate of cells in the transplanted tissue responds to lateral inhibition from the surrounding host cells.
- c. The cell fate of cells in the transplanted tissue has not been determined.
- d. The cell fate of cells in the transplanted tissue has been determined.
- e. The cells in transplanted tissue undergo mitotic recombination.

13) Bicoid protein is capable of specifying more than one cell type by forming a concentration gradient. Based on this, Bicoid can be described as:

- a. A homeotic gene.
- b. A juxtacrine gene.
- c. A morphogen.
- d. An inductive signaling gene.
- e. A paracrine gene.

14) As discussed in class, which of the following descriptions best characterizes the molecular event distinguishing germ cells from the somatic cells during *C. elegans* embryogenesis?

- a. Regulating translocation of transcription factors into the nucleus.
- b. Activation of Ras small GTPase.
- c. Lateral inhibition mediated by the Notch pathway.
- d. Segment-specific expression of homeobox-containing transcription factors.
- e. Partitioning cytoplasmic factors in asymmetric cell division.

15) To pinpoint the determinants for *bicoid* and *nanos* mRNA localization, you have generated several chimera constructs (fusions) using the lacZ gene. After transgenic wild type flies expressing these constructs are established, you perform RNA in situ hybridization on the embryos using lacZ as a probe. Which of the following constructs will yield lacZ-positive signal at the posterior pole?

- a. lacZ 5'UTR – lacZ coding region – lacZ 3'UTR.
- b. bicoid 5'UTR – lacZ coding region – lacZ 3'UTR.
- c. nanos 5' UTR – lacZ coding region – lacZ 3' UTR.
- d. lacZ 5'UTR – lacZ coding region – bicoid 3'UTR.
- e. lacZ 5'UTR – lacZ coding region – nanos 3'UTR.

16) Which of the following patterns best describes the expression of *engrail*, a segmental polarity gene, during *Drosophila* embryogenesis?

- a. Uniform throughout the entire embryo.
- b. Localized to either anterior or posterior pole.
- c. A broad stripe at a specific region.
- d. 7 stripes.
- e. 14 stripes.

[Questions 17-20 deal with *C. elegans* vulva formation.]

17) What is the phenotype when the Pn.p cells are homozygous for a loss-of-function *let-23* allele and carry one copy of *let-60*^{V12} mutation?

- a. Wild type.
- b. Two anchor cells.
- c. Two uterine cells.
- d. Vulvaless.
- e. Multiple vulva structures.

18) In *C. elegans*, *let-60* is a target of microRNA *let-7*. Based on this, what is the effect of *let-7* over-expression on the phenotype of Pn.p cells expressing *let-60*^{V12}?

- a. The *let-7* over-expression enhances the phenotype associated with *let-60*^{V12} because the *let-60*^{V12} protein level is higher when more *let-7* is present.
- b. The *let-7* over-expression suppresses the phenotype associated with *let-60*^{V12} because the *let-60*^{V12} protein level is higher when more *let-7* is present.
- c. The *let-7* over-expression enhances the phenotype associated with *let-60*^{V12} because the *let-60*^{V12} protein level is lower when more *let-7* is present.
- d. The *let-7* over-expression suppresses the phenotype associated with *let-60*^{V12} because the *let-60*^{V12} protein level is lower when more *let-7* is present.
- e. The *let-7* over-expression will have no effect on the phenotype associated with *let-60*^{V12} because the *let-60*^{V12} mutation is no longer sensitive to *let-7*.

19) In *C. elegans* vulva formation, which of the following genes contains a tyrosine kinase domain?

- a. Lin-3.
- b. Lin-12.
- c. Lin-45.
- d. Let-23.
- e. Let-60.

20) A transcription factor *hlh-2* has been found to activate *lin-3* expression. Based on our discussion of *C. elegans* vulva formation, which of the following statements is most likely to be correct?

- a. The function of *hlh-2* is required cell autonomously in the Pn.p cells.
- b. Loss-of-function mutations in *hlh-2* are epistatic to gain-of-function *let-23* mutations.
- c. Gain-of-function mutations in *hlh-2* are epistatic to loss-of-function *let-23* mutations.
- d. Gain-of-function mutations in *hlh-2* are epistatic to loss-of-function *lin-3* mutations.
- e. The function of *hlh-2* is required non-cell autonomously in the anchor cell.

[Questions 21-24 deal with *Drosophila* R7 formation]

In *Drosophila*, two genes, *Sevenless (sev)* and *bride-of-sevenless (boss)*, are involved in forming the R7 photoreceptor cells. The Boss proteins are expressed on the surface of R8 cells, whereas Sev is expressed in the R7 precursor cells.

21) During development, R8 cells are evenly spaced. This spacing of R8 cells is achieved by lateral inhibition. Based on this information, which of the following molecules likely participates in the specification of R8?

- a. Delta.
- b. Sev.
- c. Boss.
- d. Bicoid.
- e. Ras.

22) If the R8 cell is genotypically *boss*⁻ and the R7 precursor cells are genotypically *boss*⁺, what will the phenotype be?

- a. One R7 cell.
- b. No R7 cell.
- c. Multiple R7 cells.
- d. No R8 cell.
- e. Multiple R8 cells.

23) If the R8 cell is genotypically *sev*⁺ and the R7 precursor cells are genotypically *sev*⁻, what will the phenotype be?

- a. One R7 cell.
- b. No R7 cell.
- c. Multiple R7 cells.
- d. No R8 cell.
- e. Multiple R8 cells.

24) The function of GTPase-activating protein (GAP) is to accelerate the rate of GTP hydrolysis of small GTPases. Based on this, what is the expected phenotype of R7 precursor cells over-expressing GAP?

- a. One R7 cell.
- b. No R7 cell.
- c. Multiple R7 cells.
- d. No R8 cell.
- e. Multiple R8 cells.

25) Like hereditary retinoblastoma, the inheritance of Li-Fraumeni syndrome is autosomal dominant. This is because:

- a. One copy of functional p53 is insufficient to properly regulate cell proliferation.
- b. Mutations in p53 that cause abnormal cell proliferation are dominant-active mutations.
- c. The normal function of p53 is to promote cell proliferation.
- d. Mutations in p53 that cause abnormal cell proliferation are dominant-negative mutations.
- e. The remaining wild type p53 being mutated during heterozygous individuals' lifetime is likely.

[26-30 deals with the cell cycle checkpoint discussed in class]

26) Regarding RB and E2F functions, which of the following statements is correct?

- a. E2F functions as a transcription activator for genes required for DNA synthesis.
- b. E2F binds to RB and prevents RB from entering the nucleus.
- c. Both copies of E2F gene need to be mutated to cause deregulated cell proliferation.
- d. Phosphorylated RB enters the nucleus and regulates the expression of S phase genes.
- e. The expression of RB proteins oscillates with cell cycle.

27) In this system, a decrease in cyclin-dependent kinase function is likely to:

- a. Increase the presence of Rb proteins in the nucleus
- b. Decrease the presence of Rb proteins in the nucleus
- c. Increase the level of E2F proteins in the nucleus.
- d. Decrease the level of E2F proteins in the nucleus.
- e. Decrease the expression of p21 proteins.

28) Which of the following statements accurately describes PUMA function?

- a. PUMA promotes cell proliferation by binding to Rb.
- b. PUMA inhibits cell proliferation by binding to the promoters of S-phase genes and repressing their expression.
- c. PUMA inhibiting the cell cycle progression by inhibiting the activity of cyclin/CDK complex.
- d. PUMA promotes cell death by binding to Bcl2 and releasing BAX.
- e. PUMA promotes apoptosis by binding to BAX and releasing Bcl2.

29) Which of the following scenarios is likely to cause DNA replication even in the presence of DNA damage?

- a. A mutation in one copy of the Rb that disrupts its ability to bind E2F.
- b. A mutation in one copy of the cyclin that disrupts its ability to bind CDK.
- c. A mutation in one copy of p53 that disrupt its ability to activate transcription.
- d. Mutations in both copies of E2F that disrupt its ability to activate transcription.
- e. Loss-of-function mutations in both copies of the p53 gene.

30) In this context, which of the following genes is an example of proto-oncogene?

- a. p21.
- b. p53.
- c. PUMA.
- d. Cyclin-dependent kinase.
- e. Rb.

31) Which of the following terms best describes a process of cancer cells acquiring invasive capabilities?

- a. Genomic instability.
- b. Angiogenesis.
- c. Epithelial-mesenchymal transition.
- d. Extravasation.
- e. Loss of heterozygosity.

32) Which of the following descriptions likely represents an oncogenic mutation?

- a. A mutation in Ras that accelerates its GTPase activity.
- b. A duplication of the p53 gene.
- c. A mutation in Rb that over-expresses the Rb proteins.
- d. A mutation in CDK that activates its kinase activity, even when this CDK is not bound to a cyclin.
- e. A deletion that removes the entire locus of a receptor tyrosine kinase.

33) Allelic exclusion ensures:

- a. Each B cell expresses only one type of successfully rearranged Ig molecule.
- b. Different B cells express different types of Ig molecules.
- c. Each B cell expresses multiple types of Ig molecules, generated by gene rearrangement of different chromosomes.
- d. Each B cell expresses an antibody with two heavy chains, one κ and one λ chain.
- e. Each B cell expresses an antibody that is made from one single polypeptide.

34) Regarding T cell receptor, which of the following statement is incorrect?

- a. T cell receptor recognizes free antigens and induces expression of cytokines.
- b. T cell receptor consists of α and β chains.
- c. T cell receptor recognizes antigens presented by MHC molecules.
- d. Each T cell expresses only one type of T cell receptor.
- e. T cell receptor locus undergoes somatic gene rearrangement.

35) Regarding synonymous substitutions, which of the following statements is correct?

- a. These are nucleotide changes that alter amino acid sequence.
- b. The rates of synonymous substitutions are lower than those of non-synonymous substitutions.
- c. Synonymous substitutions are typically found in coding sequences.
- d. Synonymous substitutions are typically found in 5'- and 3'UTRs, whereas non-synonymous substitutions are found in introns.
- e. Synonymous substitutions are typically found in 5'- and 3'UTRs, whereas non-synonymous substitutions are found in exons.

36) Which of the following statements best describes over-dominance?

- a. Heterozygous individuals have fitness advantages over homozygous individuals.
- b. Homozygous individuals have fitness advantages over heterozygous individuals.
- c. Evolution of reproductive isolation within a population in the absence of a geographical barrier.
- d. Evolution of reproductive isolation within a population in the presence of a geographical barrier.
- e. Beneficial alleles are maintained by natural selection.

B) The coiling of snail shell is controlled by a single maternal-effect locus, where D (dextral) is dominant and d (sinistral) is recessive. If a dextral male of Dd genotype is mated with a sinistral female of dd genotype, predict the genotypic and phenotypic ratios of F₁ progeny (**2 points**).

Genotypic ratio (indicate the genotypes):

Phenotypic ratio (indicate the phenotypes):

If the F₁ heterozygous progeny are interbred, predict the genotypic and phenotypic ratios of F₂ progeny (**2 points**).

Genotypic ratio (indicate the genotypes):

Phenotypic ratio (indicate the phenotypes):

C) In mouse, κ light chain locus has 85 V segments and 4 J segments, whereas λ light chain locus has 2 V segments and 3 J segments. Based on this, how many different immunoglobulin (Ig) light chains can be generated by somatic DNA recombination alone (**2 points**)?

On a different chromosome, the heavy chain locus contains 134 V segments, 13 D segments, 4 J segments, and 8 C segments. How many different Ig heavy chains can be generated by somatic DNA recombination alone (**2 points**)?

How many different Ig's can be generated by somatic DNA recombination alone in mouse (**2 points**)?

D) In a large herd of cattle, three different traits showing continuous distribution are measured, and the variances in the following table are calculated:

	<i>traits</i>		
Variance	<i>Shank length</i>	<i>Neck length</i>	<i>Fat content</i>
Phenotypic	310.2	730.4	106.0
Environmental	248.1	292.2	53.0
Additive genetic	46.5	73.0	42.4
Dominance genetic	15.6	365.2	10.6

- a. Calculate the broad- and narrow-sensed heritabilities for each trait (**6 points**).

- b. In the population of animals studied, which trait would respond best to selection (**1 point**)? Please briefly explain your answer (**1 point**).

- c. The mean fat content is currently 10.5 percent. To decrease mean fat content in the herd, animals with a mean of 6.5 percent fat content are interbred as parents of the next generation. What mean fat content can be expected in the descendants of these animals (**2 points**)?

E) Erma and Harvey were two highly inbred pigs with different tail lengths. While Harvey's tail was only 6 cm long, Erma's was 30 cm. Their F_1 piglet offspring all grew tails that were 18 cm. After F_1 sibling mating, an F_2 generation resulted in many piglets, whose tails ranged in 4-cm intervals from 6 to 30 cm (6, 10, 14, 18, 22, 26, 30).

a) How many genes are involved in the tail length determination in these piglets (**2 points**)?

b) What proportion of F_2 piglets would have 26-cm tails (**2 points**)?

c) What proportion of F_2 piglets would have 18-cm tails (**2 points**)?

d) If a F_1 18-cm-tail pig were mated with one of the 6-cm F_2 pigs, what phenotypic ratios would be predicted in the offspring (**4 points**)?

F) In a population of *Drosophila* reared in the laboratory, the mean wing length is 0.55 mm, and the range is 0.35 to 0.65. A geneticist selects a female with wings that are 0.42 mm in length and mates her with a male that has wings that are 0.56 mm in length.

- What is the selection differential of this cross (**3 points**)?
- What is the expected wing length of their offspring if wing length has a narrow-sensed heritability of 0.8 (**3 points**)?
- If the phenotypic variance of the original population is 0.2 mm^2 , what is the additive variance (**2 points**)?