Name: __________KEY______________

7.012 Exam One -- 2006 KEY

Exam starts at 10:05 am and ends at 10:55 am.

There are 10 pages including this cover page.

Please write your name on each page.

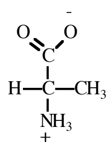
Only writing on the **FRONT** of every page will be graded.
(You may use the backs, but only as scratch paper.)

Question 1	**21 pts________**
Question 2	**35 pts________**
Question 3	**14 pts________**
Question 4	**30 pts________**

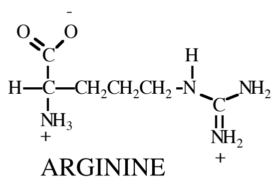
TOTAL out of 100_______

Name: __________KEY_____________

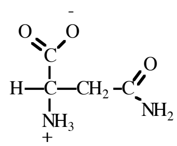
at pH 7.0



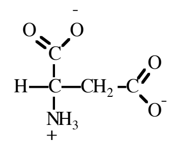
ALANINE
(ala)



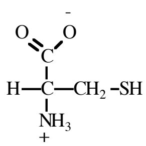
ARGININE
(arg)



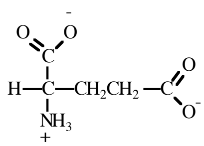
ASPARAGINE
(asN)



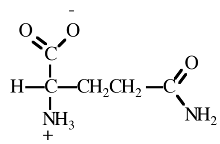
ASPARTIC ACID
(asp)



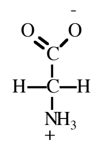
CYSTEINE
(cys)



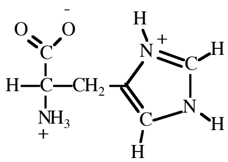
GLUTAMIC ACID
(glu)



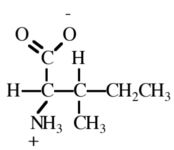
GLUTAMINE
(glN)



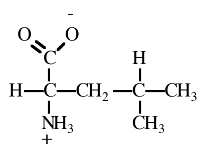
GLYCINE
(gly)



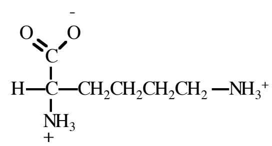
HISTIDINE
(his)



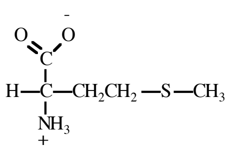
ISOLEUCINE
(ile)



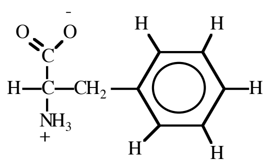
LEUCINE
(leu)



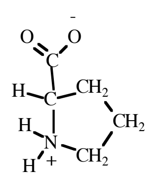
LYSINE
(lys)



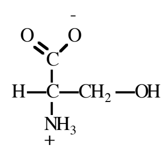
METHIONINE
(met)



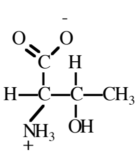
PHENYLALANINE
(phe)



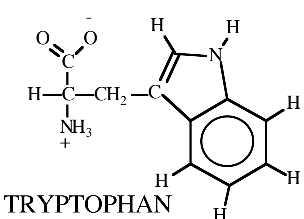
PROLINE
(pro)



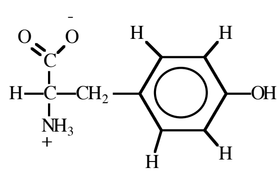
SERINE
(ser)



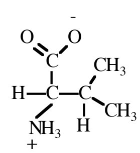
THREONINE
(thr)



TRYPTOPHAN
(trp)



TYROSINE
(tyr)

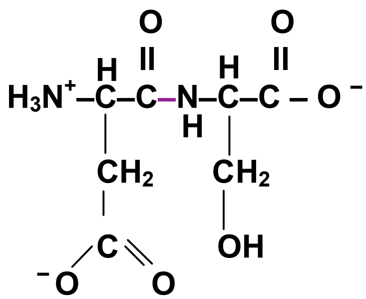


VALINE
(val)

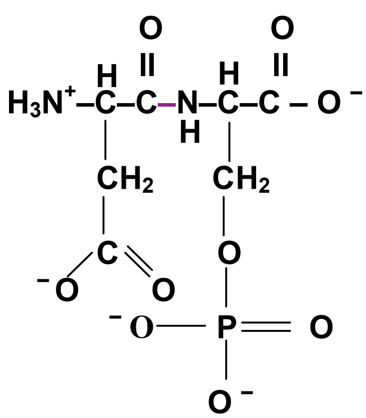
Name: __________KEY______________

Question 1. **(21 pts)** You are studying a di-peptide with the sequence N-asp-ser-C.

(a, 4 pts) Draw the structure of this di-peptide at pH7.

N-terminus  C-Terminus

(b, 4 pts) Draw the structure of this di-peptide at pH7 if it had been phosphorylated on one of its R groups.

N-terminus  C-Terminus

Name: __________KEY______________

(c, 8 pts) If an interaction occurred between two proteins via each pair of the following amino acids, what is the strongest type of bond that would form between the amino acids of each pair? Your choices are: Hydrogen bond, ionic bond, hydrophobic effect, covalent bond, and van der Waals force.

(i) Cys and cys

Covalent bond. Two cysteines can form disulfide bonds togther, which are a type of covalent bond.

(ii) Tyr and his

Hydrogen bond or van der Waals were accepted here.

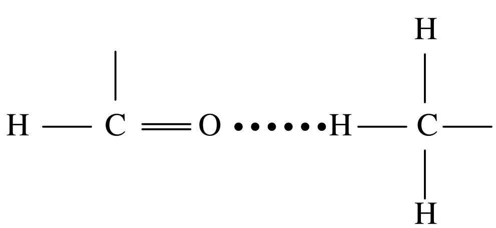
(iii) Phe and arg

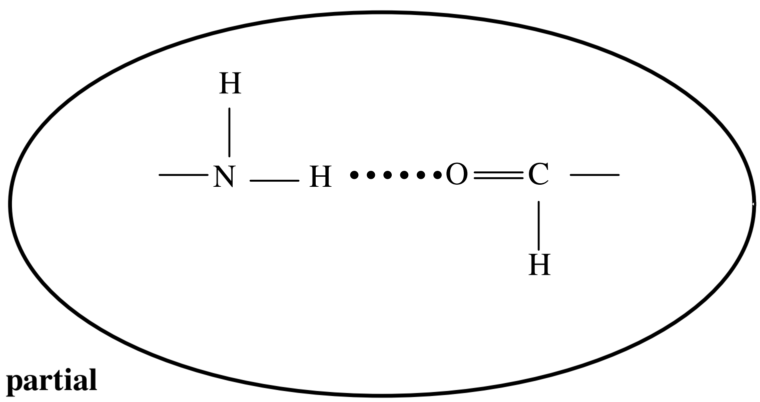
Van der Waals. Phe is hydrophobic and arg is charged so there are no other bonds between them.

(iv) Phe and val

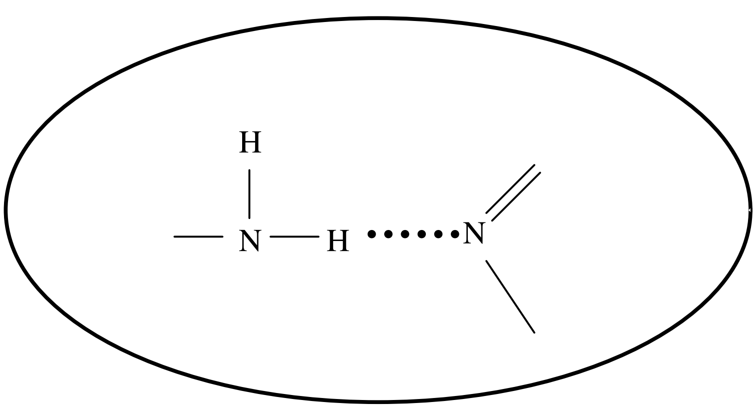
Hydrophobic. The R groups of phe and val are both non-polar hydrocarbons.

(d, 5 pts) Which of these is a Hydrogen bond that is correctly drawn? Of the four options below, circle **all** that are correctly drawn. The series of dots (••••••) indicate hydrogen bonds.

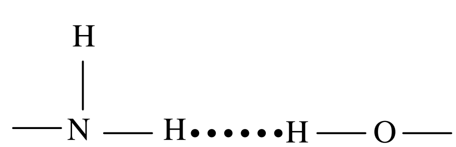




The one above doesn't work because carbon is not electronegative enough for there to be a partial charge on the C and the H that are bonded together.



The one below doesn't work because both Hs have a partial partial positive charge on them so they wouldn't attract each other.



Name: __________KEY______________

Question 2. **(35 pts)** You imagine that not all life forms (if you include viruses and aliens) must have double-stranded DNA molecules as their genetic material. Theoretically, a life form could have a genome made of:
single-stranded DNA, single-stranded RNA, double-stranded DNA, double-stranded RNA, or a hybrid of one strand of RNA with one strand of DNA. Which type of genome is each of these life forms most likely to have?
(a, 3 pts) genome = 26%G, 6%T, 26%C, 18%U, 24%A

A hybrid of one strand of RNA with one strand of DNA. It must have both RNA and DNA in it because there are both Us and Ts.

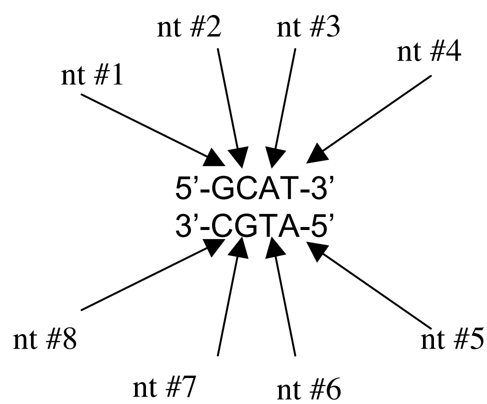
(b, 3 pts) genome = 15%G, 0%T, 15%C, 35%U, 35%A

Double-stranded RNA. This genome has Us but not Ts, so it must be RNA, and the %Gs = the %Cs whereas the %As = the % Us.

(c, 3 pts) genome = 31%G, 19%T, 19%C, 0%U, 31%A

Single-stranded DNA. This genome has Ts but not Us, so it must be DNA, and the %Gs does NOT equal the %Cs and the %As does NOT equal the % Ts.

In the following sequence:



(d, 3 pts) Which of these nucleotides would have a free triphosphate group extending from one of the carbons of their sugar? List the nucleotides by the numbers (nt #1 – nt #8) with which they have been labeled.

Nucleotides #1 and #5, because the 5' end of each DNA strand has a triphosphate group.

(e, 3 pts) Which of these nucleotides would have a free hydroxyl group extending from one of the carbons of their sugar? List the nucleotides by the numbers (nt #1 – nt #8) with which they have been labeled.

Nucleotides #4 and #8, because the 3' end of each DNA strand has an OH group.

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You discover a new protein in *E. coli* that you believe has both a transmembrane domain and a domain that binds to DNA. Below is shown part of this protein's sequence:

N… Ala-Leu-Phe-Ala-Gly-Ile-Val-Glu-Asn-Ser-Thr-Ala-Asp-Trp-His-Arg-Lys-His-Arg…C

(f, 5 pts) List the continuous set of amino acids that would be most likely be a part of the transmembrane domain. State why you chose that stretch of amino acids.

Ala-Leu-Phe-Ala-Gly-Ile-Val. This stretch is a continuous stretch of non-polar hydrophobic amino acids, which are the only amino acids that can insert themselves into the hydrophobic core of the cell membrane.

(g, 4 pts) You discover experimentally that your hypothesis that this protein is a transmembrane protein is not correct; it is a protein that resides in the cytoplasm. Where in the 3-dimensional structure of this protein do you think you would find the amino acids you listed in part **(f)**?

They would be buried in the inside core of the protein, where they would be hidden from water.

(h, 5 pts) List the continuous set of amino acids that would be most likely to bind and interact with DNA. State why you chose that stretch of amino acids.

His-Arg-Lys-His-Arg. These amino acids have R groups that are positively charged at pH7. Therefore they would form ionic bonds with the sugar-phosphate backbone of DNA, which is negatively charged.

(i, 3 pts) Do you think those amino acids are more likely to interact with the bases of the DNA or the backbone?

The backbone. This is the part of DNA which is exposed (the bases are hidden inside), and is also the part of DNA that is negatively charged. (The phosphate groups are negatively charged but the sugar deoxyribose and the bases are uncharged.)

(j, 3 pts) What is the strongest bond that would form between this protein and the DNA to which it can bind? Your choices are: Hydrogen bond, ionic bond, hydrophobic effect, covalent bond, and van der Waals force.

Ionic bonds.

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Question 3. (14 pts) The following is a biochemical pathway involved in converting tyrosine (an amino acid) into melanin (the pigment that colors our skin). Humans who lack melanin have albinism and thus lack pigment. The pathway is shown with the compounds in lowercase, and three of the enzymes that operate in this pathway in **UPPERCASE**.

TYROSINASE

tyrosine → dopaquinone → dopachrome

↓ **DOPACHROME TAUTOMERASE**

5-dihyroxyindole carboxylic acid (5-dhica)

↓ **TRP-1**

quinone

↓

melanin

(a, 4 pts) Albinism is always recessive. Why do you think it is recessive?

Albinism results from a lack of one of the three enzymes listed above. Let's take tyrosinase as an example. If we call "T" an allele of the gene encoding tyrosinase that encodes for functional tyrosinase and "t" an allele of the gene that encodes non-functional tyrosinase, then a "TT" indivdual would have functional tyrosinase and thus would not have albinism, but a "tt" individual would have non-functional tyrosinase and thus would have albinism. A "Tt" individual would have functional tyrosinase, and would thus not have albinism. Therefore albinism is recessive because a heterozygote still makes tyrosinase, just at 50% levels (which is virtually always enough for any biochemical step to occur), and thus can successfully complete this pathway for making melanin.

There are different forms of albinism; all are very rare. People with albinism who accumulate tyrosine have a form of albinism that is autosomal. People with albinism who accumulate dopachrome have a form of albinism that is autosomal. People with albinism who accumulate 5-dhica have a form of albinism that is sex-linked.

(b, 5 pts) Given this information, what can you conclude regarding the genes encoding **TYROSINASE** and **TRP-1**, in terms of linkage? Are they linked, unlinked, both, neither, or is it inconclusive?

Unlinked. Tyrosinase is encoded by an autosomal gene, which would lie on one of the chromosomes #1-#22, and TRP-1 is encoded by a sex-linked gene, which would lie on the X chromosome. Since these two genes are not on the same chromosome, they must be unlinked.

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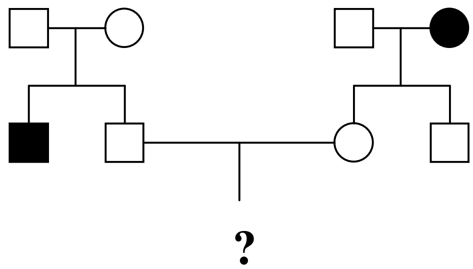
Answer part **(c)** using the following pedigree.



(c, 5 pts) Assume that the two families that join at the bottom of this pedigree are unrelated. The family on the left has a son who has albinism and accumulates **tyrosine**. (Assume this son contains a defect in only one enzyme in the pathway shown above.) The mother of the family on the right has albinism and accumulates **dopachrome**. What is the chance that the child indicated by a question mark will have albinism?

Zero. This is a human complementation test. The family on the left only carries mutations in the gene encoding tyrosinase. The family on the right only carries mutations in the gene encoding dopachrome tautomerase. Therefore the father and mother who are shown joining at the bottom of the pedigree will have children who get a wild-type copy of the gene for dopachrome tautomerase from their dad and a wild-type copy of the gene encoding tyrosinase from their mom. Albinism is recessive, so none of these kids will have albinism.

Question 4. **(30 pts)** The following is a biochemical pathway involved in producing a pigment that makes a particular animal's fur green. Gene A encodes Enzyme A. Gene B encodes Enzyme B. Gene C encodes Enzyme C. A^- or B^- or C^- indicates a mutant allele that eliminates function of the gene and causes a recessive phenotype.

$$\text{Blue precursor} \xrightarrow{\text{Enzyme A}} \text{Red precursor} \xrightarrow{\text{Enzyme B}} \text{brown precursor} \xrightarrow{\text{Enzyme C}} \text{green pigment}$$

(a, 2 pts) What would the phenotype of a B^-B^- animal be?

Red, because then you wouldn't be able to get past the step that Enzyme B normally does.

(b, 2 pts) What would the phenotype of a C^-C^- animal be?

Brown, because then you wouldn't be able to get past the step that Enzyme C normally does.

(c, 2 pts) What would the phenotype of a B^-B^- C^-C^- animal be?

Red, because then you wouldn't be able to get past the step that Enzyme B normally does.

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(d, 6 pts) If you mated an $B^+B^-\ C^-C^-$ animal to an $B^+B^-\ C^+C^-$ animal, what classes of offspring would you get out, and in what ratio? Answer using a phenotypic ratio. Assume Gene B and Gene C are on different autosomes.

3 brown: 3 green: 2 red

The first animal will make $B^-\ C^-$ gametes 50% of the time and B^+C^- gametes 50% of the time.
If B and C are on different autosomes, then they are unlinked and will assort independently from each other. Thus second animal will make:

$B^-\ C^+$ gametes 25% of the time — **B^+C^- gametes 25% of the time**
$B^-\ C^-$ gametes 25% of the time — **B^+C^+ gametes 25% of the time**

So there will be 8 genotypic classes of offspring, each occurring 1/8 of the time:

Gamete from animal #1:	Gamete from animal #2	Phenotype
	25% $B^-\ C^+$	red = 12.5%
	25% B^+C^-	brown = 12.5%
50% $B^-\ C^-$	25% $B^-\ C^-$	red = 12.5%
	25% B^+C^+	green = 12.5%
	25% $B^-\ C^+$	green = 12.5%
	25% B^+C^-	brown = 12.5%
50% B^+C^-	25% $B^-\ C^-$	brown = 12.5%
	25% B^+C^+	green = 12.5%

(e, 8 pts) If you mated an $B^+B^-\ C^-C^-$ animal to an $B^+B^-\ C^+C^-$ animal (named Scruffy), which phenotypic classes of offspring would you get out, and how many offspring would be in each class if there were 1000 total offspring? In this part, now assume Gene B and Gene C are 10cM apart on the same autosome. Also assume that the parents of Scruffy were true-breeding; one was brown and the other was red.

475 brown, 275 green, 250 red

The first animal will make $B^-\ C^-$ gametes 50% of the time and B^+C^- gametes 50% of the time.
Scruffy's parents were true-breeding brown and red and Scruffy is $B^+B^-\ C^+C^-$, so Scruffy's parents must have been $B^+\ C^-/\ B^+\ C^-$ and $B^-C^+/\ B^-C^+$. Therefore Scruffy must be $B^+\ C^-/\ B^-C^+$ because he received one chromosome from each parent. Since the B and C genes are 10cM apart, Scruffy will make 10% recombinant gametes and 90% parental gametes. Therefore the gametes Scruffy will make are:

$B^-\ C^+$ gametes 45% of the time — **B^+C^- gametes 45% of the time**
$B^-\ C^-$ gametes 5% of the time — **B^+C^+ gametes 5% of the time**

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So there will be 8 genotypic classes of offspring, each occurring at the following frequencies:

Gamete from animal #1:	**Gamete from Scruffy**	**Phenotype**
	45% $B^- C^+$	**red = 22.5%**
	45% $B^+ C^-$	**brown = 22.5%**
50% $B^- C^-$	**5% $B^- C^-$**	**red = 2.5%**
	5% $B^+ C^+$	**green = 2.5%**
	45% $B^- C^+$	**green = 22.5%**
	45% $B^+ C^-$	**brown = 22.5%**
50% $B^+ C^-$	**5% $B^- C^-$**	**brown = 2.5%**
	5% $B^+ C^+$	**green = 2.5%**

Therefore the offspring will be:
Green = 2.5% + 22.5% + 2.5% = 27.5% X 1000 = 275

Red = 22.5% + 2.5% = 25% X 1000 = 250

Brown = 22.5% + 22.5% + 2.5% = 47.5% X 1000 = 475

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A1⁻ and A2⁻ are two different mutant alleles of the same gene (gene A), and that gene lies on the X chromosome. (Assume this animal's gender is determined in the same way as humans.) Each mutation alone eliminates the function of the gene and causes a recessive phenotype.

Blue precursor $\xrightarrow{\text{Enzyme A}}$ Red precursor $\xrightarrow{\text{Enzyme B}}$ brown precursor $\xrightarrow{\text{Enzyme C}}$ green pigment

(f, 2 pts) What would the phenotype of an $X^{A1-}X^{A1-}$ animal be?

Blue, because then you wouldn't be able to get past the step that Enzyme A normally does.

(g, 2 pts) What would the phenotype of an $X^{A2-}X^{A2-}$ animal be?

Blue, because then you wouldn't be able to get past the step that Enzyme A normally does.

(h, 6 pts) If you mated an $X^{A1+}X^{A1-}$ animal to an $X^{A2-}Y$ animal, what classes of offspring would you get out, and in what ratio? Answer using a phenotypic ratio. State a separate phenotypic ratio for sons and for daughters.

Sons would be 1 blue: 1 green
Daughters would be 1 blue: 1 green

If you mate these two animals, you can get sons that are either
$X^{A1+}Y$ or $X^{A1-}Y$
The son with the wild-type allele of A will be green and the son with the mutant allele will be blue.

If you mate these two animals, you can get daughters that are either
$X^{A1+}X^{A2-}$ or $X^{A1-}X^{A2-}$
The daughter with one mutant allele and one wild-type allele will be wild-type (green) and the daughter with two mutant alleles will be blue.