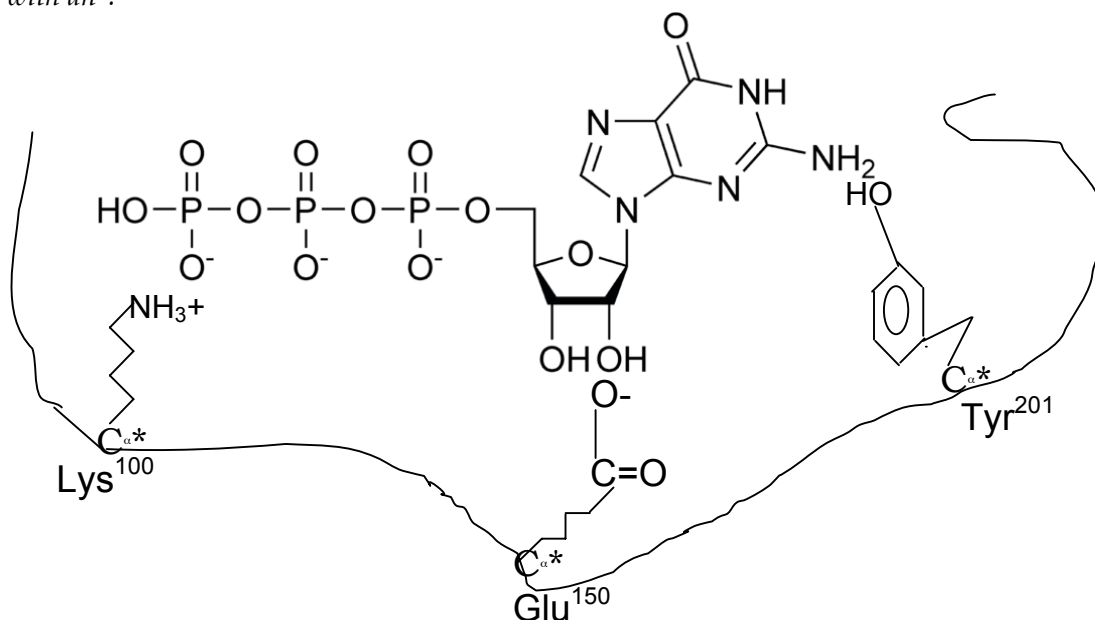


7.013 Practice Exam 1 – Solution Key

Question 1

You are studying a human **membrane protein** that acts as an enzyme and has Guanosine triphosphate (GTP) as its substrate. Binding of GTP to the active site of this protein is shown in the following schematic. For simplicity only the side-chains of the important amino acids in the active site are shown. The alpha C atom of each amino acids is indicated with an*.



a) Circle the **strongest interaction** that exists between.....

- Side-chain of Lys¹⁰⁰ and the phosphate group of GTP.

Hydrogen Ionic Hydrophobic Interaction /Van der Waals forces Covalent

- Side-chain of Glu¹⁵⁰ and the ribose sugar of GTP.

Hydrogen Ionic Hydrophobic Interaction /Van der Waals forces Covalent

- Side-chain of Tyr²⁰¹ and the guanine base of GTP.

Hydrogen Ionic Hydrophobic Interaction /Van der Waals forces Covalent

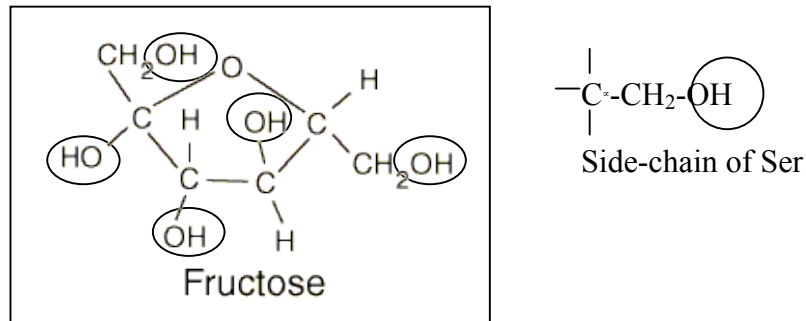
b) You make mutations in the GTP binding pocket of this enzyme and examine the effect of each mutation on the binding of GTP. Give the **most likely** reason why each mutation has the stated effect. **Note:** Consider each mutation independently.

- **Lys¹⁰⁰** mutated to **Arg** results in an enzyme that still binds to GTP.
Both Lys and Arg are positively charged. Therefore the Arg most likely would still form an ionic bond with the phosphate group of GTP.

- **Lys¹⁰⁰** mutated to **Glu** results in an enzyme that cannot bind to GTP.
The amino acid Glu, unlike Arg is negatively charged. Hence, Glu will repel the like charged phosphate group of GTP instead of forming an ionic bond.

Question 1 continued

c) This enzyme is a glycoprotein, and requires addition of the carbohydrate fructose for its function. Fructose (shown below) forms a glycosidic bond with the side-chain of the amino acid serine of this enzyme. Draw the R group of serine and circle its reactive atoms that will form a covalent bond with fructose. Also circle **only one** of the reactive groups on fructose that could participate in the formation of this bond.



d) This enzyme is a membrane protein and has a linear stretch of amino acids that spans the lipid bilayer of the membrane. Below are three different options for the amino acid sequence of this linear stretch of amino acids.

Option 1: lys-cys-ser-trp-tyr-asp-leu-his-gly-arg-leu

Option 2: leu-ala-gly-cys-ala-val-ile-leu-ala-phe-trp

Option 3: gly-thr-tyr-ser-ala-gly-glu-glu-lys-thr-ser

Circle the option that most likely forms a stretch of protein that spans the lipid bilayer? **Explain** briefly why you selected this option.

The stretch of protein that spans the lipid bilayer should be comprised of nonpolar, hydrophobic amino acids such as in option 2. The other options include both polar, uncharged and polar, charged amino acids which are unsuitable for the hydrophobic environment of the lipid bilayer.

e) This enzyme is a glycoprotein, and requires addition of the carbohydrate fructose for its function. Full activity of this enzyme requires both the carbohydrate (fructose) and protein components. You isolate the enzyme and subject it to the following treatments in a test tube and measure its activity. You then return the samples in each tube to the pre-treatment conditions and measure the enzyme activity again. Complete the following table for each treatment. (**Note:** Consider each treatment independently).

Tube	Treatment	Bonds disrupted by treatment	Protein active/inactive when returned to pre-treatment conditions? Explain.
#1	Lactase (hydrolyzes the sugar lactose to glucose and galactose)	None	<i>This enzyme is a glycoprotein that requires addition of carbohydrate fructose and NOT lactose for its activity. Lactase cleaves lactose which is a disaccharide with no fructose. Hence lactase treatment should have no effect on enzyme activity.</i>
#2	Trypsin (cleaves the protein at Lys)	<i>Peptide bonds / covalent bonds</i>	<i>The enzyme Trypsin will cleave the protein at each Lys, including the one that is present in the active site of the enzyme and forms an ionic bond with the phosphate group of GTP. Hence, trypsin treatment will disrupt the active site of the enzyme, an effect that cannot be reversed even by restoring the pretreatment conditions.</i>

Question 2

DNA polymerase is an enzyme that catalyzes the **polymerization** that involves the addition of the incoming nucleotides to a growing strand of DNA. Each polymerization may be regarded as a pair of **coupled reactions** as follows.

- **Reaction 1:** Binding of the incoming **nucleotide triphosphate** to the active site of the enzyme followed by its **hydrolysis** to **nucleotide monophosphate**.
- **Reaction 2:** Formation of a **phosphodiester bond** between the nucleotide monophosphate and the last base of the growing strand of DNA.

a) Based on the information provided, which of these two reactions (reaction 1 / reaction 2) is **most likely** to have a higher free energy change (+ ΔG)? **Explain** why you selected this option.

Reaction 2 most likely has a higher + ΔG since this is an endergonic/ anabolic reaction that involves the formation of the phosphodiester bonds between individual nucleotides.

b) Briefly **explain** why it is important to **couple** reaction 1 with reaction 2 during DNA polymerization.

Reaction 1 is exergonic and the energy released by the hydrolysis of the phosphate bonds in reaction 1 is used to drive reaction 2, which is endergonic.

c) From the choices below, **circle** the reaction parameter(s) that is **reduced** by DNA polymerase and briefly **explain** why this enhances the rate of reaction.

Reaction equilibrium

ΔG

Activation energy

The enzyme can increase the reaction rate by reducing the activation energy that is required by the substrate to reach the transition state.

Question 3

You are studying two traits using a mouse model. The mutant mice are **small** and **lethargic** whereas the normal mice are **large** and **active**. You cross a true breeding **large** and **lethargic** mouse with true breeding **small** and **active** mouse. All of the resulting F1 mice are **small** and **lethargic**.

a) What are the genotypes of the true breeding parental mice? Use the nomenclature outlined below.

- *In each case, use the uppercase letter for the allele associated with the dominant phenotype and the lowercase letter for the allele associated with the recessive phenotype.*
- *For the size (i.e. large or small) use D or d to designate the alleles.*
- *For the activity (i.e. active or lethargic) use G or g to designate the alleles.*

Parent	Genotype
Large and lethargic	<i>ddGG</i>
Small and active	<i>DDgg</i>

Question 3 continued

b) You then cross two of the F1 mice. If these two genes were **unlinked**, based on Mendel's law, about how many **large** and **active** mice do you expect out of a total of 320?

If the two genes are unlinked they should assort independently to give four different phenotypes: Small and lethargic, Small and active, large and lethargic and large and active in the ratio of 9: 3: 3: 1. Therefore if you score 320 mice you would expect $320/16 = 20$ mice to have large and active phenotype.

c) You find that the two genes are **linked**. If the map distance between the two genes is 20 cM, out of a total of 400 offspring, how many will show the **non-recombinant/parental** phenotypes?

A map distance of 20cM corresponds to 20% recombinants and 80% non-recombinants / parental progeny. Hence, out of a total of 400, you would expect 320 to show the parental phenotype i.e. 160 will be large and lethargic with a genotype of dGdg and the other 160 will be small and active with a genotype of Dgdg.

Question 4

Your next experiment involves the fruit fly. In the parental (P) generation, you mate a **true-breeding** female fly that has short antennae and red eyes with a **true-breeding** male fly that has long antennae and white eyes. All of the flies in the F1 generation have long antennae and red eyes.

Note: Assume the genes for these two traits are located on autosomes. For the alleles that regulate antennae length, use the letters "A" and "a" and for the alleles that regulate eye color, use the letters "B" and "b." Use the uppercase letters to represent the alleles associated with dominant phenotypes and lowercase letters to represent the alleles associated with recessive phenotypes.

a) Give the **genotypes** of the flies in the **P generation**.

Genotype of the **female Fly**:

$aaBB$

Genotype of the **male Fly**:

$AAbb$

b) Give the **genotypes of the gametes** produced by the flies in the **P generation**.

iii. Genotype of the **gametes** produced by the **female Fly**: aB

iv. Genotype of the **gametes** produced by the **male Fly**: Ab

c) Give the **genotypes** of the flies that are produced in the **F1 generation**. $AaBb$

d) Assuming that the genes that regulated antennae length and eye color **assort independently**, give **ALL the possible genotypes of the gametes** that are produced by the **F1 flies**.

AB, Ab, aB, ab

e) You mate a female F1 fly with a **true-breeding** male fly that has short antennae and white eyes.

Question 4 continued

- iii. What is the **genotype of the male fly** in this mating experiment? *aabb*
- iv. What is the **genotype of the gametes** produced by the **male fly** in this experiment? *ab*

f) You **mate two F1 flies** and obtain 1600 offspring in the F2 generation. If the genes that regulate antennae length and eye color **assort independently**, complete the table below for each type of progeny in the F2 generation.

Phenotypes of the flies in F2 generation	Corresponding genotypes	Approximate number
Long antennae, red eyes	<i>AABB, AABb, AaBB, AaBb</i>	900
Long antennae, white eyes	<i>AAbb, Aabb, Aabb</i>	300
Short antennae, red eyes	<i>aaBB, aaBb, aaBb</i>	300
Short antennae, white eyes	<i>abab</i>	100

Question 5

a) An error occurs during division of cells that make up the lining of the intestines such that daughter cells inherit an abnormal number of parental chromosomes. Is this more likely to be an error in mitosis or in meiosis? **Explain** briefly.

Mitosis, since meiosis only involves the formation of gametes, not cell division within the intestine

b) A child is born with three copies of chromosome #21 in nearly every cell in its body. This is a disorder commonly called Down Syndrome. Does this disorder most likely reflect an error that occurred during a mitotic cell division or during a meiotic cell division? **Explain** briefly.

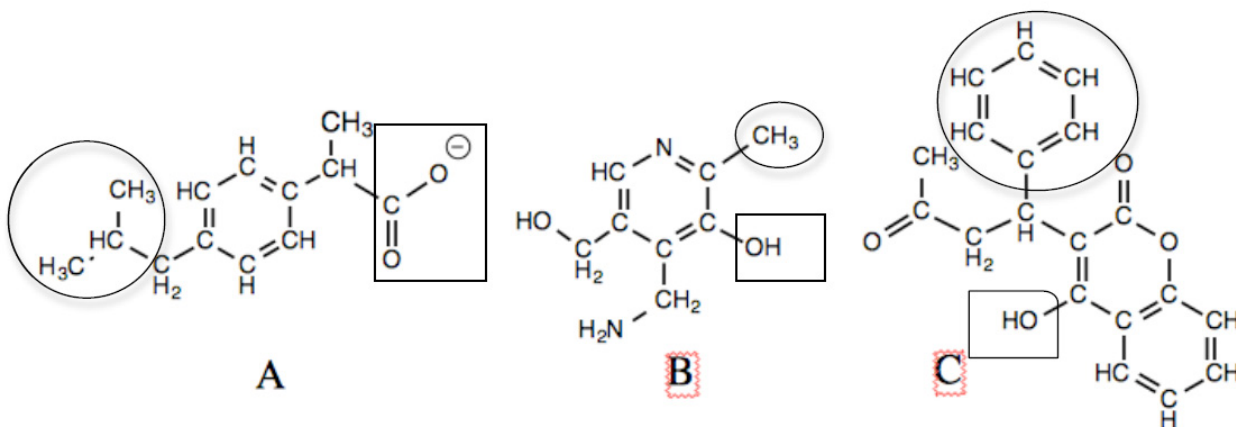
Meiosis, since this reflects an abnormal gamete that gave rise to all other cells

c) During which type of cell division would you expect to see chiasmata? **Explain** briefly.

Meiosis, during which homologous chromosomes align (and cross over/ recombine) during Meiosis 1.

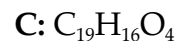
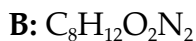
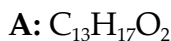
Question 6

The following “line-angle” drawings represent three chemical structures. On each drawing, the hydrogen atoms that should be bonded to the NON-carbon atoms are missing.



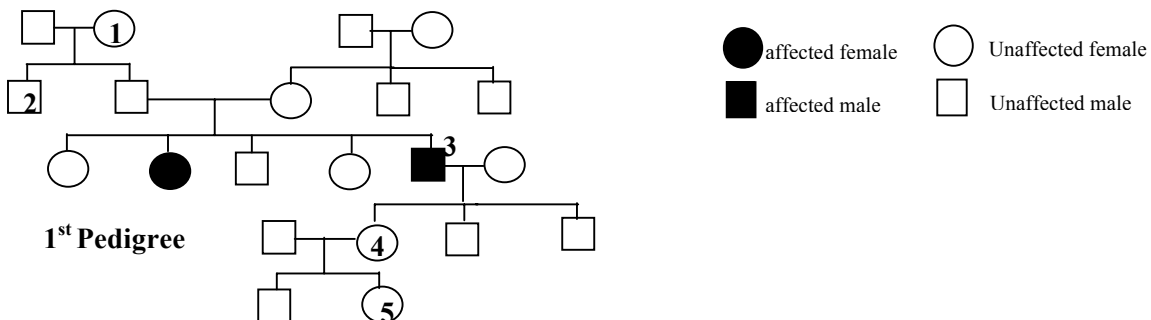
a) For each structure, show the position of **All** carbon (C) and all hydrogen (H) atoms. Note: If there is a charge present make sure you take it into account.

b) Give the **chemical formula** of each of the structures shown by the line angle drawings.



Question 7

The following human pedigree shows the inheritance pattern of a specific disease within a family. Assume that the individuals marrying into the family for all generations (except the parental generation) do not have the allele associated with the disease phenotype and that no other mutation arises spontaneously. Also assume complete penetrance.



a) Circle the **most likely** mode of inheritance for this disease. Choose from: autosomal dominant, **autosomal recessive**, X-linked dominant, X-linked recessive.

b) Write **all possible** genotypes of the following individuals in the pedigree. Use the uppercase “A” or “X^A” for the allele associated with the dominant phenotype and lowercase “a” or “X^a” for the allele associated with the recessive phenotype.

Genotype(s) of Individual 2: AA, Aa

Genotype(s) of Individual 4: Aa

c) What is the probability that Individual 5 will be a carrier? 50%

MIT OpenCourseWare
<http://ocw.mit.edu>

7.016 Introductory Biology
Fall 2014

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.