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7.013 Spring 2005 Problem Set 3

FRIDAY March 11, 2005

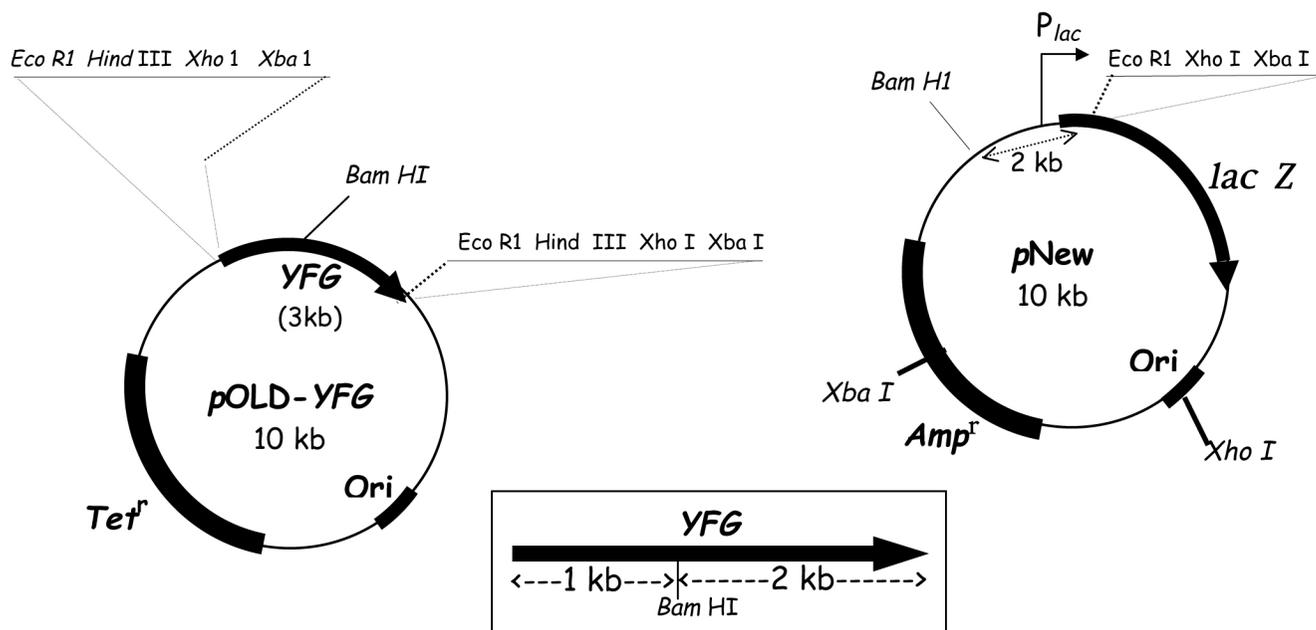
Problem sets will NOT be accepted late.

Question 1

You'd like to clone the 3 kb *YFG* gene from the 'pOld-YFG' plasmid into the 'pNew' plasmid. The pNew plasmid carries the *lac Z* gene encoding β -Galactosidase that can cleave a substrate, X-gal, into a blue colored compound. When grown on medium with X-Gal, cells without β -Galactosidase form white colonies, while cells with β -Galactosidase form blue colonies.



Below are drawings of the plasmids and the inset shows the linear *YFG* gene.



a) Of the following enzymes, which would or would not be useful for cloning the *YFG* gene from pOld-YFG to the pNew plasmid. Assume that each of the cut restriction sites can only ligate with the same kind of cut restriction site (ex: *Bam* HI with *Bam* HI, *Xho* with *Xho* I, etc.)

- i) Would *Eco* RI be useful? Why or why not?
- ii) Would *Hind* D III be useful for cloning? Why or why not?
- iii) Would *Bam* HI be useful cloning? Why or why not?

iv) Would *Xba* I be useful for cloning? Why or why not?

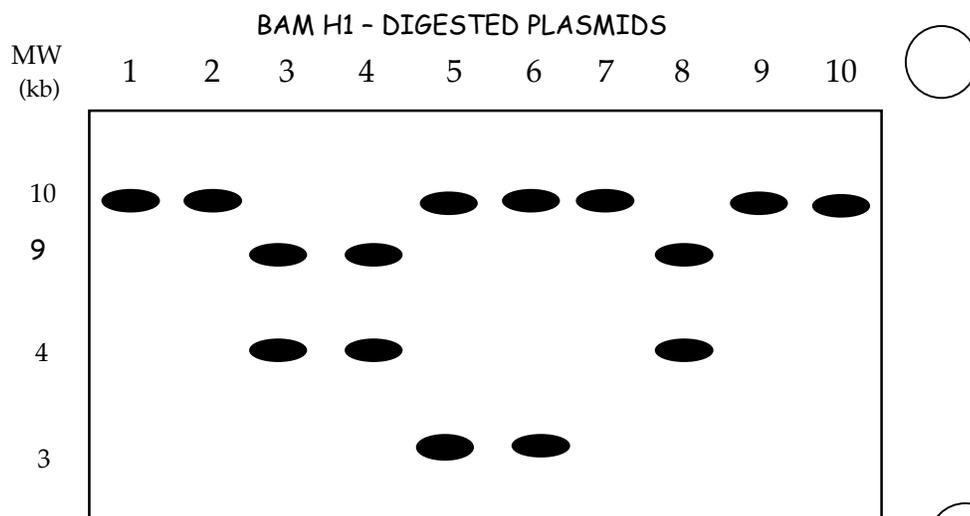
v) Would *Xho* I be useful cloning? Why or why not?

You digest both plasmids with the appropriate restriction enzyme(s) and combine digests in a single tube and add DNA Ligase. You transform appropriate bacteria with this ligation mix.

b) How would you identify transformants that have taken up *pNew* but not *pOld-YFG*? (Hint: 2 steps)

Now that you have colonies that have taken up *pNew*, you realize that the *YFG* gene could have inserted in either orientation. You take 10 transformants, isolate plasmid DNA from them, and perform restriction digestion using *Bam* H1. You get the following results after running the digests out on an agarose gel.

c) Fill in the electrode charges in the circles depicting how the gel was run.



d) Which plasmids have no inserts?

e) Which plasmids have *YFG* inserted?

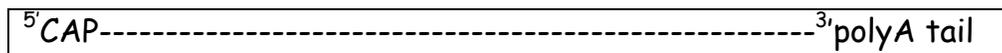
f) Of the plasmids in e) which colonies have *YFG* inserted in a way that it will be expressed off P_{lac} ?

g) How could you have avoided choosing colonies harboring plasmids without inserts? How could you have screened the transformants for ones that had plasmids with the *YFG* gene?

Question 2

You want to study protein targeting in yeast, but first you need to construct a strain that will help you with your research. Your goal is to clone the gene encoding the Fructose Receptor (FruR), a plasma membrane protein, and fuse it with a gene encoding Green Fluorescent Protein (GFP).

a) You first make a cDNA library from yeast that is able to grow fructose. This is done by using the enzyme Reverse Transcriptase (RT) to make a DNA copy of each of the messenger RNA molecules in this yeast strain. RT, like other DNA polymerases, needs a primer to initiate elongation. You recall from earlier lectures that eukaryotic mRNA has a cap at the 5' end and is polyadenylated (A_n) at the 3' end.

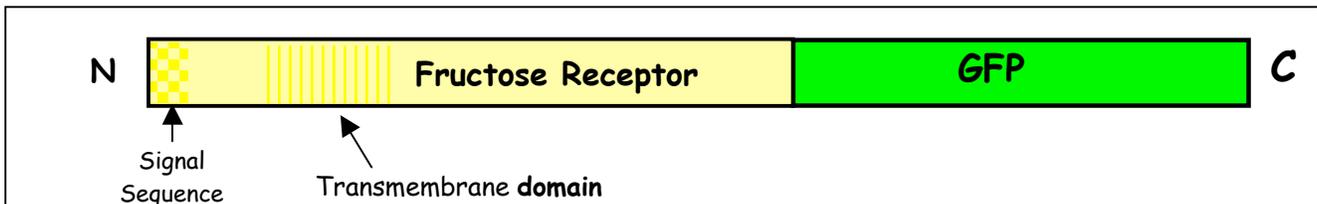


- i) Which end of an RNA molecule (**5'** or **3'**) would you use as a template to design a primer? Circle one.
- ii) Given what you know, as stated above, what would be a good 'universal' primer for an RT reaction? (Assume 10 nucleotides long is sufficient.)
- b) Using the primer you just designed you've synthesized millions of cDNA molecules but only a few encode the fructose receptor gene.
- i) First you need to clone these cDNAs into vectors. What needs to be upstream of your cDNA in the vector to insure strong expression of the fructose receptor?
- ii) You consider expressing the protein in bacteria. Why would this plan make it critical to have made a cDNA library rather than making genomic DNA library?
- iii) You decide to transform your library into yeast. How would you isolate the plasmid clone expressing the fructose receptor? What yeast strain would you transform into?
- | | |
|-----------------|--------------------------------|
| Wild-type Yeast | Fructose Receptor Mutant Yeast |
|-----------------|--------------------------------|
- iv) What medium could you use to plate the transformants that would select for the correct plasmid clone.

Question 3

You are pleased to discover that this is indeed a sequence of *gfp*. Your goal is to make a fusion protein where the N-terminus of Green Fluorescent Protein is replaced by Fructose Receptor (FruR). Green Fluorescent Protein (GFP) is a protein isolated from jellyfish that fluoresces green when exposed to blue light (It has been demonstrated that some proteins do not require their extreme C terminus or their N terminus to function.)

In this case, the first half of the fusion protein (the NH₃ end) will be a fully functional Fru R protein, and the second half (the COOH end) will be a fully functional GFP protein.



The sequence for the extreme 3' end of *fruR* and the 5' start of *gfp* is shown below. For both, the underlined indicates an in frame codon. For *gfp*, it corresponds to the start codon.

3' end of *fruR*



5' end of *gfp*



<i>Afl</i> III:	<i>Avr</i> II	<i>Stu</i> I	<i>Nhe</i> I	<i>Kpn</i> I
C [^] TTAAG	C [^] CTAGG	AGG [^] CCT	G [^] CTAGC	GGTAC [^] C
GAATT [^] C	GGATC [^] C	TCC [^] GGA	CGATC [^] G	C [^] CATGG

Determine what enzyme(s) you would use to fuse the 5' end of *gfp* with the 3' end of *fruR* such that the resulting gene fusion would result in the expression of an in-frame hybrid protein. Remember it's ok to fuse the genes in a way that they are missing a bit off the ends or even adding some nucleotides between them. The goal is to make an in-frame fusion protein.

Question 4

After successfully making your in-frame GFP fusion, you are ready to use this construct to elucidate new genes involved in protein targeting in the yeast cell. To identify new targeting genes, you create a collection of temperature sensitive yeast mutants. Temperature-sensitive mutations produce functional protein products at low (permissive) temperatures but do not produce functional protein at high (restrictive or nonpermissive) temperatures. This allows a rapid switch from a wild type to a mutant phenotype by a temperature shift from permissive to restrictive. Thus temperature sensitive mutations allow one to study genes whose products are essential for the strain because one can grow and maintain the strain at the permissive temperature.

To determine if any of your temperature sensitive mutations have an effect on protein targeting you introduce your newly constructed gene fusion to each mutant strain to examine the localization of FruR-GFP hybrid protein. The GFP tag allows you to visualize that localization of FruR in the cell using fluorescence microscopy.

Below are the observations from the fluorescence microscopy for the **wild type** yeast strain. Note that all fusion proteins are bound to the plasma membrane as seen in picture below.

Photomicrograph removed due to copyright reasons.

You identify 5 temperature sensitive mutations that are defective in protein targeting at the restrictive temperature and name them dpt1-5.

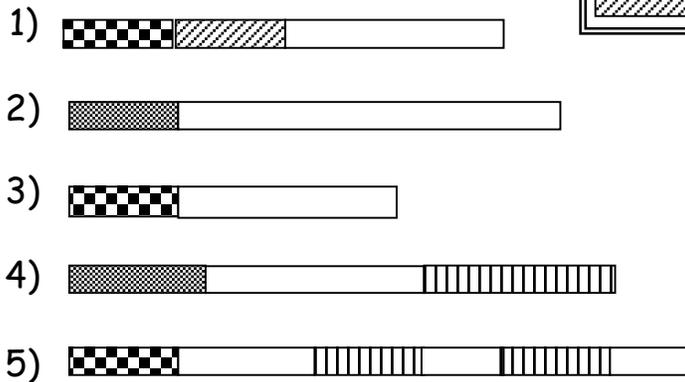
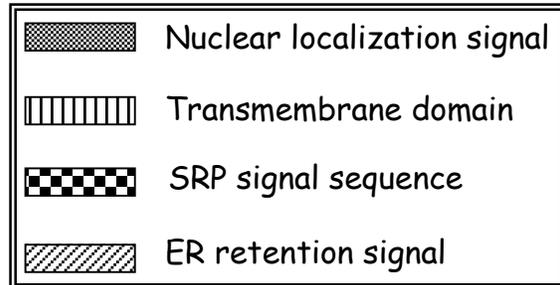
dpt1: All ER localized
dpt2: Found in small vesicles
dpt3: Found in the cis Golgi
dpt4: Cytoplasmic
dpt5: No GFP detected

a) For each of the mutants identify which step of the secretory pathway is blocked. (Assume all mutations are in proteins other than FruR.)

Mutant	Step of Secretory Pathway Affected
dpt1	
dpt2	
dpt3	
dpt4	
dpt5	

b) Which of the above mutations could be a result of an internal mutation in FruR? Explain what the mutation would be.

You are interested in determining the effect of some of the above mutations on the localization of other cellular proteins. Below are the domain structures of the cellular proteins you are interested in (labeled 1-5).



c) In a wild type cell where would each of these proteins be found?

Protein	Cellular Location
1	
2	
3	
4	
5	

d) Where would each protein be localized a *dpt1* mutation?

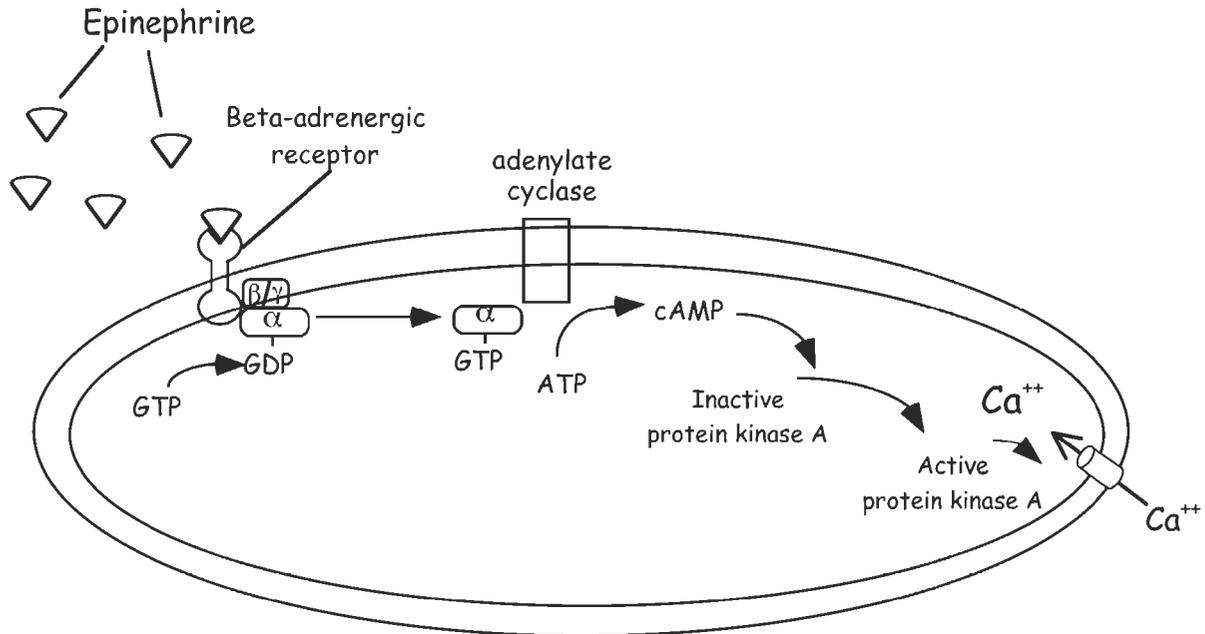
Protein	Cellular Location
1	
2	
3	
4	
5	

e) Where would each protein be localized a *dpt3* mutation?

Protein	Cellular Location
1	
2	
3	
4	
5	

Question 5

Many signaling pathways make use of heterotrimeric *G* protein coupled receptors. One such pathway is the adrenalin or epinephrine pathway. Production of epinephrine leads to many downstream effects that are part of the "fight or flight" response. Epinephrine binds to β -adrenergic receptors which leads to the activation of adenylate cyclase, cAMP production and the activation of Protein kinase A. In the cell depicted below the net result of epinephrine binding is Calcium influx to the cell.



a) List two advantages of having multiple steps in a signal transduction pathway.

b) Once the *G*-protein is active why doesn't it continually activate adenylate cyclase?

c) Some cells have surface adenosine receptors that are also *G*-protein coupled receptors like the adrenergic receptor depicted above. However, unlike the adrenergic receptor above, the affect of adenosine receptors is to **inhibit** the enzyme adenylate cyclase, decreasing cAMP levels, through an inhibitory *G*-protein subunit. Draw the adenosine receptor, the ligand, and its downstream pathway in the figure above.

Caffeine is similar in chemical structure to the adenine portion of adenosine. Caffeine is similar enough to adenine to fit into adenosine receptors, but is not similar enough to stimulate those receptors. So the main action of caffeine is to block adenosine from binding to its receptor. Thus caffeine is an adenosine receptor "antagonist."

Interestingly, caffeine ingestion also leads to the production of epinephrine.

d) Given the information above, what would the end result be in the cell above if it has both the β -adrenergic receptor and the adenosine receptor described, in an animal that has been fed caffeine?