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Running out of time

Part I

Pre-case Reading:
The Antibiotic Resistance Crisis (Part 1: Causes and Threats)
By C. Lee Ventola
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4378521/

Introduction to case: Getting to Structure

Maria was recently given an internship at the local Pharmaceutical company in her metropolitan area, and this is a big break for her. Maria hopes to make some connections and perhaps apply for a job when she graduates from college. After a week of getting her feet wet, her advisor in the lab asks Maria to pick a project on which to work over the next 3 months of her internship.

The same day Maria started at the pharmaceutical company, her little brother Javier was playing in the park and cut his leg on one of the playground slides. He and his parents did not think anything of it and put a Band-Aid on the cut. In the next few days, Javier began to feel lethargic and developed a fever. Maria's parents decided to take Javier to the doctor and after a few tests they were told he had a bacterial infection. He was prescribed penicillin G (standard penicillin prescription) but after a week, Javier is weaker and is still feverish. Upon their second visit to the pediatrician, Maria's parents were told that her brother tested positive for an antibiotic resistant infection and they were sent to the hospital downtown. Unfortunately, they had to admit little Javier into the ICU because his condition was deteriorating.

Questions
1) Maria thought penicillin was effective and would stop any infection. What do you think has happened to Javier?
2) List any enzymes, DNA, and structures found in bacteria that would help us understand what has happened to Javier? In general, would you describe the inside of these bacteria to be hyperosmotic or hypoosmotic compared to the outside? In such a case which way would you predict water would want to move (into or out of the cell)? Which part of the cell is applying osmotic pressure?
3) Give a complete description of how penicillin works (what is the enzymatic target of penicillin) and how bacteria become resistant to penicillin. In your description, you should include information about which molecules are passed between bacteria and how this contributes to acquiring antibiotic resistance.

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Part II
Exploring the Structure

Maria's brother Javier is still sick in the ICU at the local hospital. Maria decided to study beta-lactam (penicillin like) antibiotics to figure out how bacteria become resistant to them. One of the key types of enzymes that break down penicillin antibiotics are beta-lactamases. Class A beta-lactamases are found in several organisms including *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, *Streptomyces albus G*, and *Bacillus licheniformis*. The structure for these enzymes can be found in the Protein Database (https://www.rcsb.org/). The PDB designations for the beta-lactamases discussed above are:

Species	PDB designation
Staphylococcus aureus	3BLM
Escherichia coli	1BTL
Bacillus cereus	6W33
Streptomyces albus G	1BSG
Bacillus licheniformis	2BLM

As a first step to design a beta-lactam drug that is resistant to beta-lactamases, Maria decides to identify the most important amino acids in these beta-lactamases by comparing these sequences.

How to compare protein sequences:
1) In RSCB-PDB website, search the PDB designation.
2) Select "Display Files" near the top of page and select FASTA Sequence.
3) Go to Clustal Omega (https://www.ebi.ac.uk/Tools/msa/clustalo/) and enter FASTA Sequences.
4) After you have entered all sequences (separated by a blank lines) select: ClustalW with character counts for step 2 – this is the default so you can skip this step if already selected.
5) Submit job.
6) In the output, select "show colors" button.

Questions

1) Now that you have completed your multiple sequence alignment, write out which amino acids are exclusively conserved by using the 2BLM numbering scheme and listing the specific amino acid at that location. For example, if you see S at position 75 in 2BLM, you can list it as: Ser at 75. Exclusively conserved amino acids are starred in this output format.
2) What role do these exclusively conserved amino acids likely play in the enzyme?
3) How can this information be used in designing research projects to study this enzyme?

Based on her studies of beta-lactamases, Maria has identified 3 exclusively conserved amino acids found in the active site of Class A beta-lactamases. She believes these amino acids are playing specific roles in the enzyme mechanism of these enzymes. These are labelled A, B, and C in the model of penicillin G bound into the active site of the *E. coli* beta-lactamase in the ready-made scene http://www.callutheran.edu/BioDev/marcey/BetaLac/ALEX_FINAL.html.

4) Identify the amino acids A, B, and C based on their structure.
5) Which amino acids from your list in question 1 could be A, B or C? List all possibilities for each. For example, A could be: ?, ?, or ?

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Part III

Modeling

After testing several antibiotics for effectiveness, Javier has continued his slow recovery from a near fatal bacterial infection. Maria, his older sister, recently read the CDC report titled "Antibiotic Resistance Threats in the United States". She learned that 2.8 million antibiotic-resistant infections occur each year in the United States and over 35,000 people die from these infections yearly.

Moreover, Maria has learned that the natural target of penicillin antibiotics is the enzyme transpeptidase. By reacting with transpeptidases, penicillin is able to inhibit these enzymes.

Questions
1) What is the mechanism for this transpeptidase with its natural substrate the cell wall? Describe the specific parts of the cell wall substrates that react with transpeptidase.
2) Take a look at the 3D representation of penicillin. What is it about this structure that allows it to bind the active site of the transpeptidases?
3) What role does the serine residue of the transpeptidase active site play in catalysis.

Take another look at Maria's model. Use this model to answer the following questions.

Questions

4) What is the mechanism for the hydrolysis of penicillin G by beta-lactamases?
5) Given this mechanism and Maria's model, can you propose a function for the three highly conserved amino acids that Maria has identified.
6) If you were to design a new beta-lactam drug, what kind of features would you want to include in the structure of you new drug?

Additional Resources
Part I Sites:
https://www.news-medical.net/health/What-are-Superbugs.aspx