In lecture we discussed the possibility that the first cells may have been formed in boiling mud puddles, which have been shown (in the lab) to produce fatty acids, carbohydrates, and primitive RNA. When conditions are right (or so it is hypothesized) fatty acids assembled to form a micelle that just so happen to encapsulate RNA. Voila! Life! Questions 1–16 concern the molecules involved in this origin-of-life hypothesis.

In a recent paper it was shown that melamine (M) and barbituric acid (BA) (both of which can be formed via the boiling mud scenario) self-assemble into hydrogen-bonded structures resembling DNA nucleobase pairs.

1. (4) DNA (as we know it) requires nucleobase pairing via hydrogen bonding. Complete this statement by writing no more than six words in each space. A hydrogen bond donor requires a hydrogen atom...

...whereas all hydrogen bond acceptor atoms have...

2. (3) In the M-BA base pair, M and BA are joined by three hydrogen bonds. Complete this drawing of the M-BA base pair. Note that a portion of the BA structure is already drawn. Hint: Practice your drawing elsewhere before writing your answer here.

3. (4) Melamine is an aromatic molecule whereas barbituric acid is not. List all of the noncovalent molecular forces that cannot be operating when M and BA associate with each other in a base pair, or in any other way.

4. (2) Which molecule has the weakest London dispersion forces? Write a letter in the box. Answer choices: (a) melamine; (b) barbituric acid; (c) water; (d) all about equal; (e) none of these answers.

5. (4) Solubility in water is important for our origin-of-life hypothesis. Rank the solubility of barbituric acid (BA) in the solvents listed below by writing one solvent name in each blank. Solvent name choices: Water, methanol (CH₃OH), and propanol (CH₃CH₂CH₂OH). BA is most soluble in _____________ and least soluble in _____________.

6. (2) Considering your answer to question 5, write the letter of the statement which best describes the water solubility of melamine:
   (a) Melamine and barbituric acid have nearly identical solubility properties.
   (b) Melamine is soluble in solvents in which barbituric acid has poor solubility, and vice-versa.
   (c) No prediction can be made about the relative solubility of melamine and barbituric acid.
7. (5) Complete the following statement by writing 'is' or 'is not' in the blank. If you write 'is' you are done with this question. If you write 'is not' complete the explanation by adding no more than ten words. Barbituric acid (BA) __________ a lipid because...

8. (2) Complete this sentence by writing one word in the blank. ______________ can be used interchangeably with lipophilic.

9. (2) The boiling mud puddle hypothesis uses molecules such as water, urea, and carbon dioxide as precursors to melamine, barbituric acid, and ribose. It is important that these molecules do not evaporate quickly from the boiling mud. Rank the relative ease of evaporation of these precursor molecules by writing 'most', 'middle', and 'least' in the ease of evaporation boxes. There are no ties.

<table>
<thead>
<tr>
<th>Precursor molecule:</th>
<th>Water</th>
<th>Urea</th>
<th>Carbon dioxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of evaporation:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. (3) In the box write the name or draw the structure of a molecule whose boiling point is clearly less than the boiling point of any of the precursor molecules shown in question 9.

11. (3) In the space below write the name of one noncovalent molecular force absent in your molecule of question 10 that explains why its boiling point is less than any of the precursor molecules of question 9.

12. (6) Acidity of a hydrogen bond donor is critical. If the donor is too acidic it will function as an acid and protonate the acceptor instead of just forming a hydrogen bond. Complete this sentence by writing 'greater than', 'equal to', or 'less than' in the blank:

(a) The acidity of melamine's NH bond is ______________ the acidity of aniline's NH bond.
(b) $K_a$ for melamine is ______________ $K_a$ for aniline.
(c) The p$K_a$ of melamine's NH bond is ______________ the p$K_a$ of aniline's NH bond.
13. (6) So when melamine is protonated, which nitrogen gets the proton? Complete the following sentence by writing either 'NH\textsubscript{2}' or 'ring' in the blank, and then complete the explanation by adding no more than twenty words: When melamine is protonated, the proton becomes bonded to the \underline{\hspace{2cm}} nitrogen because...

14. (2) Capacity as a hydrogen bond acceptor is related somewhat to basicity. Complete this sentence by writing 'stronger', 'equal', or 'weaker' in the blank: Melamine is a \underline{\hspace{2cm}} base than barbituric acid.

15. (2) Barbituric acid gets its names from its acidic properties. Consider this equilibrium:

\[
\text{Barbituric acid} + \text{H}_2\text{O} \rightleftharpoons \text{Barbituate anion} + \text{H}_3\text{O}^+
\]

\[
pK_a = 4.0 \quad pK_a = 15.7 \quad pK_a = 20.0 \quad pK_a = -1.8
\]

Complete this statement by writing 'greater than', 'equal to', or 'less than' in the blank: For the equilibrium shown \(K_{eq}\) is \underline{\hspace{2cm}} 1.

16. (6) By adding, subtracting, or changing into another element exactly one atom, redraw in the box the structure of barbituric acid to make its C–H bond obviously more acidic. In the space below write the name of one structural feature such as resonance that is the most significant reason your new molecule is more acidic.

\[
\begin{align*}
\text{O} & \quad \text{COOH} \\
\text{HO} & \quad \text{OH}
\end{align*}
\]

\[\text{Miscellaneous questions: These questions are not part of our barbituric acid/melamine origin of life hypothesis.}\]

17. (2) In the box write the strongest acid. Answer choices: HOF, HOCl, HOBr, H\textsubscript{2}O, and HOCH\textsubscript{3}.

18. (4) The definition of 'lipid' contains two key ideas. List these ideas using one word for each idea: \underline{\hspace{2cm}} and \underline{\hspace{2cm}}.

19. (2) In the box write the general lipid category (fatty acid, etc.) to which the molecule belongs. If the molecule is not a lipid write 'none'.

Page 3 score = \underline{\hspace{2cm}}
20. (2) In the box draw the basic molecular structure that is characteristic of all steroids.

21. (4) In the space below write the names of two general lipid categories whose members always contain a carbonyl group.

22. (2) Write a letter in the blank. Of the pictures shown below ______ is the best representation of a micelle.

A  B  C  D

23. (5) By adding any number of any atoms except carbon, complete this drawing of a standard amino acid having a hydrophobic, nonacidic side chain.

24. (4) Complete this sentence by writing one number in each blank: A tripeptide contains _______ amino acids and _______ peptide bonds.

25. (2) Write an amino acid name in the blank. ________________ is the only amino acid that can form a disulfide bridge.

26. (3) Make a drawing that clearly shows the structure of a disulfide bridge. More detail is better than less detail.
27. (2) Complete this sentence by writing 'primary', 'secondary', 'tertiary', or 'quaternary' in the blank. A disulfide bridge is an example of the __________ level of protein structure.

28. (2) Write the symbols for the element(s) (i.e., Ag, U) for the atom(s) covalently bonded to hydrogen in the hydrogen bond donor(s) in DNA base pairs.

29. (6) Complete each statement by writing one nucleobase letter in each the first two blanks, and then a number in the third blank.
   (a) One DNA base pair occurs between nucleobases _____ and _____, and it involves ______ hydrogen bonds.
   (b) The other DNA base pair occurs between nucleobases _____ and _____, and it involves ______ hydrogen bonds.

30. (2) Complete this statement by writing element symbol(s) (U, Ag, etc.) in the blank. In DNA, phosphorus is bonded to ________.

31. (2) The DNA double helix is stabilized by hydrogen bonding. Write the name of another noncovalent molecular force that operates elsewhere within the DNA double helix.

---

Work area. Nothing below this line will be graded.