1. (2 pts) Catabolism refers to __d_______, whereas anabolism refers to __a_______.
   a. synthesis of cell structures  b. transfer of electrons
c. uptake of nutrients  d. breakdown of chemicals to yield energy

(5 pts) Choose one of the options to the right for each:
2. halophillic organisms  c  a. grow at very high temperatures
3. psychrophillic organisms  b  b. grow at very low temperatures
4. facultative anaerobes  f  c. grow in high salt concentrations
5. thermophillic organisms  a  d. grow only in the absence of oxygen
6. obligate aerobes  e  e. grow only in the presence of oxygen
   f. grow with or without oxygen

7. (1 pt) Which one of the above types of organisms (#s 2-6) most likely dominated very early earth? 5

8. (1 pt) Which of the following helps prokaryotes survive in the presence of O₂?
   a. H₂O₂  b. superoxide dismutase
d. ATP synthase  e. hydrogenase

9. (1 pt) Which most likely evolved first?
   a. nitrification  b. oxygenic photosynthesis
c. anoxygenic photosynthesis  d. aerobic respiration

10. (1 pt) Which most likely evolved last?
    a. nitrification  b. oxygenic photosynthesis
c. anoxygenic photosynthesis  d. aerobic respiration

11. (1 pt) Evolution of which of the following conferred a huge energetic advantage?
    a. nitrification  b. oxygenic photosynthesis
c. anoxygenic photosynthesis  d. aerobic respiration

(8 pts) Fill in an appropriate C source and energy source for each of the following:

<table>
<thead>
<tr>
<th>Carbon source</th>
<th>Energy source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. organic C such as glucose</td>
<td>organic C such as glucose</td>
</tr>
<tr>
<td>13. <em><strong>CO₂</strong></em>________</td>
<td>sun _________</td>
</tr>
<tr>
<td>14. organic C such as glucose</td>
<td>sun _________</td>
</tr>
<tr>
<td>15. <em><strong>CO₂</strong></em>________</td>
<td>NH₄, CH₄, or H₂S___</td>
</tr>
</tbody>
</table>

16. (1 pt) What is the major source of energy for life on earth?
    a. sun  b. H₂S  c. wind
d. CO₂  e. oceans  f. O₂
17. (1 pt) What is the energy source for tube worms that live next to deep-sea vents?
   a. sun  b. $\text{H}_2\text{S}$  c. wind
   d. $\text{CO}_2$  e. oceans  f. $\text{O}_2$

18. (1 pt) In the following reaction, what is the electron donor? __CH$_4$________

19. (1 pt) What is the electron acceptor? __O$_2$________

20. (1 pt) Which pathway (A, B, or C) is the oxidation? __A________

21. (1 pt) Which pathway (A, B, or C) is the reduction? __B________

22. (1 pt) Which (A, B, or C) is the pathway of electrons? __C________

\[ \text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

23. (1 pt) In respiratory phosphorylation: __b________

24. (1 pt) In substrate level phosphorylation: __a________
   a) ATP synthesis involves the transfer of P from an organic molecule
   b) ATP synthesis is coupled to the transfer of electrons down the electron transport chain
   c) ATP synthesis is coupled to glucose reduction
   d) ATP synthesis depends on substrate concentration

Fill in the most appropriate fermentation product(s) (one answer each; 5 pts):

25. __a__ homofermentation
26. __e__ neutral fermentation (dominant products)
27. __b__ heterofermentation
28. __f__ mixed acid fermentation (dominant products)
29. __c__ fermentation of alanine by the Stickland reaction

a. lactate
b. lactate + ethanol + CO$_2$

c. acetate + NH$_4$ + CO$_2$
d. ethanol + NH$_4$

e. ethanol + butanediol
f. lactate + acetate

(8 pts) Indicate the most likely energy source for each organism (one answer each; use each answer only once)

30. __c__ Beggiatoa
31. __j__ Acidithiobacillus ferrooxidans
32. __e__ Nitrosomonas
33. __d__ Nitrobacter
34. __b__ Methylomonas
35. __a__ Lactobacillus
36. __f__ Clostridium
37. __h__ Cyanobacteria

a. sugars  h. sun
b. methane (CH$_4$)  i. CO$_2$
c. H$_2$S  j. Fe$^{2+}$
d. NO$_2$
e. NH$_4^+$
f. amino acids
g. H$_2$O
(8 pts) Indicate the most likely environment for each organism (one answer each; use each answer only once)

<table>
<thead>
<tr>
<th>Organism</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beggiatoa</td>
<td>a. human intestine</td>
</tr>
<tr>
<td>Acidithiobacillus ferrooxidans</td>
<td>b. fermenting farmyard waste</td>
</tr>
<tr>
<td>Clostridium</td>
<td>c. farm field fertilized with lots of NH₄</td>
</tr>
<tr>
<td>Nitro bacter</td>
<td>d. surface waters of a lake</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>e. deep waters of a lake, near the bottom sediments</td>
</tr>
<tr>
<td>Lactobacillus</td>
<td>f. sulfur spring</td>
</tr>
<tr>
<td>Chlorobium</td>
<td>g. acidic stream</td>
</tr>
<tr>
<td>Korarchaeota</td>
<td>h. hot springs, not necessarily with sulfur</td>
</tr>
</tbody>
</table>

46. (1 pt) What is an example of a terminal electron acceptor in aerobic respiration? **O₂**

47. (1 pt) What is an example of a terminal electron acceptor in anaerobic respiration? **NO₃**, **SO₄**, or **CO₂**

48. (1 pt) Production of propionate from lactate is an example of:
   a. the Stickland reaction  
   b. secondary fermentation  
   c. mixed acid fermentation  
   d. heterofermentation

49. (1 pt) Which of the following organisms ferments the most different types of substrates (polysaccharides, proteins, etc)?
   a. Lactobacillus  
   b. Clostridium  
   c. E. coli  
   d. Acidithiobacillus

50. (1 pt) Beggiatoa cells accumulate:
   a. lipids  
   b. NADH  
   c. magnetite  
   d. sulfur granules

51. (1 pt) What organism carries out the process to the right?
   a. Lactobacillus  
   b. Nitrosononas  
   c. Acidithiobacillus  
   d. Desulfomaculatum

52. (3 pts) Why does fermentation of milk products by *Lactobacillus* prevent spoilage by other organisms?

*Lactobacillus* ferments the sugars in milk, producing acidic by-products. The accumulation of acidic by-products lowers the pH of the fermenting milk to a level that very few other organisms can tolerate.
53. (6 pts) Use arrows to draw (in detail) the path of electrons from glucose to O2 in the diagram below. Include the transfer of electrons to/from all electron carriers in your drawing.

54. (7 pts) Label the above diagram with each of the following:
   a. H2O  e. flavoprotein
   b. O2  f. cytochrome
   c. ADP  g. ATP synthase
d. ATP

55. (1 pt) What do phototrophs use reducing power for?
   a. reduction of O2 to H2O  b. reduction of CO2 to CH4
c. reduction of CO2 to sugars  d. reduction of sun’s energy to ATP

56. (1 pt) What structure enables Chlorobium to photosynthesize at very low light levels?
   a. heterocysts  b. mycelia  c. chlorosomes  d. sulfur granules

57. (3 pts) Why is it not beneficial for Chlorobium, a green sulfur bacteria, to float near the surface of a lake?

   Chlorobium needs light for energy and H2S for reducing power. Light is most abundant at the surface of the lake; however, H2S is typically most abundant near the bottom sediments of a lake. This is because H2S is the product of anaerobic metabolism (SO4 reduction), and the sediments tend to be the only environment in a lake with enough organic C for anoxic conditions to develop. Therefore, Chlorobium would probably lack sufficient H2S near the surface of a lake. Photosynthesis by Chlorobium takes place in structures called chlorosomes, which are extraordinarily efficient at light capture under low light conditions. The chlorosomes allow Chlorobium to get enough light for photosynthesis near the bottom of the lake, in the same environment where H2S is available.
58. (1 pt) Which organism or group of organisms uses H\textsubscript{2}O for reducing power?
   a. purple sulfur bacteria  b. Korarchaeota  c. \textbf{Cyanobacteria}  d. methanogens

59. (1 pt) Which organism or group of organisms uses H\textsubscript{2}S for reducing power?
   a. purple sulfur bacteria  b. Korarchaeota  c. Cyanobacteria  d. methanogens

60. (1 pt) In compost, common mesophillic organisms include:
   a. \textit{Thermus, Bacillus}  b. \textit{Streptomycyes, Bacillus, Psuedomonas, Clostridium}  
c. \textit{Beggiatoa, Lactobacillus, E. coli}  d. \textit{Chlorobium, purple-sulfur bacteria}

61. (1 pt) In compost, common thermophillic organisms include:
   a. \textit{Thermus, Bacillus}  b. \textit{Streptomycyes, Bacillus, Psuedomonas, Clostridium}  
c. \textit{Beggiatoa, Lactobacillus, E. coli}  d. \textit{Chlorobium, purple-sulfur bacteria}

62. (1 pt) The enzyme complex nitrogenase transforms:
   a. \( \text{NH}_3 \rightarrow \text{NO}_3^- \)  b. \( \text{NO}_3^- \rightarrow \text{N}_2\text{O} \)  c. \( \text{NH}_3 \rightarrow \text{amino acids} \)  d. \( \text{N}_2 \rightarrow \text{NH}_3 \)

63. (1 pt) The process of N-fixation requires lots of:
   a. \( \text{NH}_3 \)  b. \( \text{O}_2 \)  c. catalase  d. \textbf{ATP}

64. (1 pt) The genes that encode for the nitrogenase enzymes will be repressed in the presence of lots of:
   a. \( \text{NH}_3 \)  b. \( \text{CO}_2 \)  c. heterocysts  d. \textbf{ATP}

65. (1 pt) Biological oxygen demand refers to:
   a. oxygen tolerance of prokaryotes  
b. the requirement by aerobic organisms for \( \text{O}_2 \)  
c. the quantity of \( \text{O}_2 \) required for biosynthesis  
\textbf{c. the quantity of \( \text{O}_2 \) used by metabolism of organic substrates}

66. (3 pts) Explain \textbf{two} ways in which Cyanobacteria separate the process of N-fixation from a common molecule that will irreversibly inactivate necessary enzymes.

1) Spatially. Photosynthetic cells of Cyanobacteria produce \( \text{O}_2 \) as a by-product of photosynthesis. This \( \text{O}_2 \) irreversibly inactivates the nitrogenase enzyme complex that is responsible for N fixation. Some Cyanobacteria protect nitrogenase from \( \text{O}_2 \) by fixing N only in specialized cells called heterocysts. There is no photosynthesis in heterocysts. Instead, C is transported from photosynthetic cells to heterocysts, and the fixed N is transported in the other direction.

2) Temporally. Some Cyanobacteria fix N only at night. Respiration of photosynthetically fixed C can consume any \( \text{O}_2 \) that would otherwise interfere with the N fixation process, and then fixation can begin once \( \text{O}_2 \) is absent and no longer being produced by the light reactions of photosynthesis.
67. (6 pts) Describe and/or diagram the pathway of C contained in cellulose that has entered the sludge digestor of a wastewater treatment plant. Be sure to specify each process along the pathways leading to the final products.

Cellulose is broken down by anaerobic processes in the digestor. Cellulose is broken into sugar monomers. Sugars are fermented by a variety of pathways. Some of the C from cellulose is lost to the atmosphere as CO$_2$ produced by fermentation. Many other fermentation products result, including acetate and other organic and fatty acids, alcohols, and H$_2$. Many of these compounds undergo secondary fermentation, producing more acetate, CO$_2$, and H$_2$. Finally, methane (CH$_4$) is produced from substrates such as CO$_2$, H$_2$, acetate, and some other simple C compounds. Most of the C from cellulose is lost from the digestor as CO$_2$ and CH$_4$. The rest remains in organic form and is removed and dried as biosolids, which can be disposed of in the landfill or applied to the land.

68. (2 pts) Fill in the blanks to indicate ATP synthesis

69. (2 pts) Fill in the blanks to indicate where oxidation of the substrate is coupled to reduction of NAD

70. (2 pts) Fill in the blanks to indicate where reduction is coupled to oxidation of NADH