1. (2 pts) Catabolism refers to ___D____, whereas anabolism refers to __A_____.
   (be sure to fill in the blanks!)
   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

3. (1 pt) Which one of the above types of organisms (#s 2-6) most likely dominated very early earth? 5

4. (1 pt) Which of the following helps prokaryotes tolerate O2?
   a. H2O2  b. superoxide dismutase
d. ATP synthase  e. hydrogenase

5. (1 pt) Which of the following most likely evolved first?
   a. nitrification  b. oxygenic photosynthesis
c. anoxygenic photosynthesis  d. aerobic respiration

6. (1 pt) Which of the following most likely evolved last?
   a. nitrification  b. oxygenic photosynthesis
c. anoxygenic photosynthesis  d. aerobic respiration

7. (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. (1 pt) In respiratory phosphorylation: ___B____

9. (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

10. (1 pt) O2-, OH-, and H2O2 are:
    a) essential to the growth of obligate aerobes  b) high energy intermediates
c) toxic O2 byproducts  d) fixed electron carriers
The following is a list of nutritional types of prokaryotes:

chemoorganoheterotroph  chemolithoautotroph  photoheterotroph
chemolithoheterotroph  photoautotroph

Fill in the most appropriate nutritional type for each of the following. You may use one type more than once. If you think that more than one type is possible, pick only one and be sure to explain your answer.

11. (1 pt) Responsible for introducing O₂ to the earth's atmosphere
   _____ phototroph________________________

12. (1 pt) An organism that oxidizes NH₄⁺ and uses CO₂ for a carbon source
   _____ chemolithoautotroph________________________

13. (1 pt) Purple bacteria that get energy from the sun and electrons from organic acids
   _____ phototroph (could be auto or hetero)___________________________

14. (1 pt) An organism that oxidizes sugars and uses NO₃⁻ as an electron acceptor
   _____ chemoorganoheterotroph________________________

15. (1 pt) A member of the Korearchaeota that is finally cultured, when provided with H₂ and organic acids. The organisms did not grow when provided either H₂ or organic acids alone.
   _____ chemolithoheterotroph________________________

16. (1 pt) An organism growing in an atmosphere containing CH₄⁺ and CO₂ and on a medium containing no organic nutrients
   _____ chemolithoautotroph________________________

17. (1 pt) Give an example of a chemolithotroph (genus) Beggiatoa, Acidithiobacillus, Methylomonas, etc
   __________

18. (1 pt) Give an example of a terminal electron acceptor used in aerobic respiration
   _____ O₂_____

19. (1 pt) Give an example of a terminal electron acceptor used in anaerobic respiration
   _____ NO₃, SO₄, CO₂_____

20. (1 pt) In the following reaction, what is the electron donor?
   _____ NH₄_____  _____ O₂_____

21. (1 pt) What is the electron acceptor?
   _____ O₂_____

22. (1 pt) Which pathway (A, B, or C) is the oxidation?
   _____ A_____

23. (1 pt) Which pathway (A, B, or C) is the reduction?
   _____ B_____

24. (1 pt) Which (A, B, or C) is the pathway of electrons?
   _____ C_____

\[ \text{NH}_4^+ + O_2 \rightarrow \text{NO}_2^- + H_2O \]
25. (2 pts) What is $\mu_{\text{max}}$ on the following graph? __about 0.7______

26. (2 pts) Is substrate concentration limiting to growth rates at point A? ___yes, because addition of more substrate results in higher growth rates______

At point B? ___No, addition of substrate does not further increase growth rates. At this point the organism’s ability to take up substrate is saturated______

27. (1 pt) The dominant product(s) of mixed acid fermentation is/are:
   a. pyruvate  b. lactate  c. lactate + acetate  d. ethanol + NH$_4$  e. lactate + acetate + CO$_2$

28. (1 pt) The dominant product(s) of neutral fermentation is/are:
   a. pyruvate  b. lactate  c. lactate + acetate  d. ethanol + NH$_4$  e. lactate + butyraldehyde + CO$_2$

29. (1 pt) The dominant product(s) of heterolactic fermentation is/are:
   a. pyruvate  b. lactate  c. lactate + acetate  d. ethanol + NH$_4$  e. lactate + acetate + CO$_2$

30. (1 pt) Production of propionate from lactate is an example of:
   a. the Stickland reaction  b. secondary fermentation  c. mixed acid fermentation  d. heterofermentation

31. (1 pt) Which of the following organisms ferments the widest diversity of substrate types (polysaccharides, proteins, etc)?
   a. Lactobacillus  b. Clostridium  c. E. coli  d. Acidothiobacillus

32. (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.
(6 pts) Indicate the most likely energy source for each organism (one answer each; do not use an answer more than once)

33. __C___ Beggiatoa
   a. sugars
   b. methane (CH₄)
   c. H₂S
   d. H₂O
   e. NH₄⁺
   f. Fe²⁺
   g. sun

34. __F___ Acidithiobacillus ferrooxidans
   a. sugars
   b. methane (CH₄)
   c. H₂S
   d. H₂O
   e. NH₄⁺
   f. Fe²⁺
   g. sun

35. __E___ Nitrosomonas
   a. sugars
   b. methane (CH₄)
   c. H₂S
   d. H₂O
   e. NH₄⁺
   f. Fe²⁺
   g. sun

36. __G___ Cyanobacteria
   a. sugars
   b. methane (CH₄)
   c. H₂S
   d. H₂O
   e. NH₄⁺
   f. Fe²⁺
   g. sun

37. __B___ Methylomonas
38. __A___ Lactobacillus

(7 pts) Indicate the most likely environment for each organism (one answer each; use each answer only once)

39. __F___ Beggiatoa
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

40. __G___ Acidithiobacillus ferrooxidans
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

41. __C___ Nitrosomonas
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

42. __D___ Cyanobacteria
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

43. __E___ Chlorobium
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

44. __A___ Lactobacillus
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

45. __B___ Korarchaeota
   a. human intestine
   b. hot springs, not necessarily with sulfur
   c. farm field fertilized with lots of NH₄⁺
   d. surface waters of a lake
   e. deep waters of a lake, near the bottom sediments
   f. sulfur spring
   g. acidic stream

46. (1 pt) What organism carries out the process to the right?
   a. Lactobacillus
   b. Nitrosomonas
   c. Acidithiobacillus
   d. Desulfomaculatum

47. (1 pt) Biological oxygen demand refers to:
   a. oxygen tolerance of prokaryotes
   b. the requirement by aerobic organisms for O₂
   c. the quantity of O₂ required for biosynthesis
   d. the quantity of O₂ used for metabolism of organic substrates

48. (1 pt) The storage of huge amounts of organic C that we now use as a source of fossil fuels resulted because:
   a. global temperatures were far lower than normal
   b. consumers (dinosaurs) became extinct and so ceased consuming plant matter
   c. reduction of C far exceeded oxidation
   d. oxidation of C far exceeded reduction
49. (6 pts) Use arrows to draw (in detail) the path of electrons from glucose to O_2 in the diagram below. Include the transfer of electrons to/from all electron carriers in your drawing.

50. (7 pts) Label the above diagram with each of the following:
   a. H_2O   c. ADP   e. flavoprotein   g. ATP synthase
   b. O_2   d. ATP   f. cytochrome

51. (1 pt) Phototrophs use reducing power for:
   a. reduction of O_2 to H_2O   b. reduction of CO_2 to CH_4
   c. reduction of CO_2 to sugars   d. reduction of sun’s energy to ATP

52. (1 pt) In anoxygenic photosynthesis, the electrons in chlorophyll pigments that are energized by light:
   a. pass through an electron transport chain and return to the chlorophyll pigment
   b. pass through an electron transport chain and reduce NADP
   c. reduce NADP and then return to the chlorophyll
   d. are used to reduce SO_4^{2-} to H_2S

53. (1 pt) What structure enables Chlorobium to photosynthesize at very low light levels?
   a. heterocysts   b. mycelia   c. chlorosomes   d. sulfur granules

54. (1 pt) Which organism or group of organisms uses H_2O for reducing power?
   a. purple sulfur bacteria   b. Korarchaeota   c. Cyanobacteria   d. methanogens

55. (1 pt) Which organism or group of organisms uses H_2S for reducing power?
   a. purple sulfur bacteria   b. Korarchaeota   c. Cyanobacteria   d. methanogens
56. (4 pts) Why do nitrifiers have folded membranes? Be sure to explain: a) the significance of folded membranes and b) why this benefits the nitrifiers in particular.

Metabolic processes, essential for transformation of energy to useable forms, take place in or on membranes. Therefore, more membrane surface area allows for more potential for the organism to gain energy. The process of nitrification yields relatively little energy. Folded membranes maximize the amount of nitrification an organism can carry out and therefore increase the chance that nitrifiers will be able to get enough energy for growth.

57. Methanogenesis produces CH₄, which can be used as an energy source in the process of methane oxidation.

a. (4 pts) Outline both processes (methane production and oxidation), in terms of electron donors, electron acceptors, and final products. One example of methane production is sufficient.

b. (2 pts) Draw a picture of where you might find these two processes in relation to one another, in nature. Specify any relevant environmental conditions.

c. (2 pts) Explain why these two processes do not typically co-occur in exactly the same environment.

a.
Methanogenesis: H₂ (donor) + CO₂ (acceptor) → CH₄ + H₂O
Methane oxidation: CH₄ (donor) + O₂ (acceptor) → CO₂ + H₂O

b. c. methanogenesis requires the absence of O₂; methane oxidation requires the presence of O₂
58. (2 pts) Fill in the blanks to indicate ATP synthesis

59. (2 pts) Fill in the blanks to indicate where oxidation of the substrate is coupled to reduction of NAD

60. (2 pts) Fill in the blanks to indicate where reduction of the substrate is coupled to oxidation of NADH

61. (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 the processes and intermediate products 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 CO₂ produced by fermentation. Many other fermentation products result, including acetate and other organic and fatty acids, alcohols, and H₂. Many of these compounds undergo secondary fermentation, producing more acetate, CO₂, and H₂. Finally, methane (CH₄) is produced from substrates such as CO₂, H₂, acetate, and some other simple C compounds. Most of the C from cellulose is lost from the digestor as CO₂ and CH₄. 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.