Supplemental Lecture **(98/03/28 update) by** Stephen T. Abedon **(**abedon.1@osu.edu**)**

1. **Chapter title: Procaryote Extracellular Appendages**
    a. A list of vocabulary words is found toward the end of this document
2. **Glycocalyx (gli-ko'ka-liks)**
    a. A substance that surrounds cells.
3. **Bacterial glycocalyx**
    a. "A viscous (sticky), gelatinous polymer that is external to the cell wall and is composed of polysaccharide, polypeptide, or both." (p. 47, Tortora et al., 1995)
    b. All bacteria probably have at least some *glycocalyx*.
    c. A *glycocalyx* can serve a number of functions including:
        i. bacterial attachment to surfaces
        ii. protection against desiccation
        iii. nutrient trap
        iv. protection from phagocytosis
        v. protection from viruses
        vi. protection from certain toxins (e.g., detergents)
4. **Capsule**
    a. **Well organized glycocalyx:**
        i. A well organized bacterial glycocalyx that is firmly attached to the bacterial cell wall.
        ii. "When the layer is well organized and not easily washed off, it is called a capsule." (p. 58, Prescott *et al.*, 1996)
    b. **Marker for virulence:**
        i. Note that the *capsule* can be associated with the virulence displayed by a bacteria.
        ii. This at least in part is because bacteria displaying *capsules* can resist phagocytosis.
    c. "Although capsulues are not required for bacterial growth and reproduction in laboratory cultures, they do confer several advantages when bacteria grow in their normal habitats. They help bacteria resist phagocytosis by host phagocytic cells. . . (In addition) capsules contain a great deal of water and can protect bacteria against desiccation. They exclude bacterial viruses and most hydrophobic toxic materials such as detergents. The glycocalyx also aids bacterial attachment to surfaces of solid objects in aquatic environments or to tissue surfaces in plant and animal hosts." (p. 58-59, Prescott *et al.*, 1996)
5. **Slime layer**
    a. **Loose capsule:**
        i. Equivalent to a capsule except this glycocalyx is not firmly attached to the cell wall.
        ii. "A slime layer is a zone of diffuse, unorganized material that is removed easily." (p. 58, Prescott *et al.*, 1996)
    b. **Attachment to surfaces:**
        i. Despite their looseness, *slime layers* nevertheless play important roles in the attachment of bacteria to surfaces.

ii. For example, bacteria can attach to teeth via *slime layers*.
iii. *Slime layers* can also bind cells together.

c. *Slime layers* can trap nutrients and water, acting, for example, as a seal over a nutritious substrate, thus allowing a bacteria to use exoenzymes (extracellular enzymes) in a limited area containing high concentrations of substrate.

6. **Flagella [sing. Flagellum]**
   a. String-like (or whip-like) appendages attached to the cell envelope of bacteria and which are twisted (spun) to propel bacteria.
7. **Motility [motile]**
   a. The ability to move under one's own power, particularly in a directed fashion.
   b. About half of all known prokaryotic species are *motile*
   c. Bacteria with functional flagella (one or more) are *motile*.
   d. See text figure 1080.1
   e. Other only quasi-flagellar-like mechanisms of movement are employed by sprirochetes (corkscrew shaped bacteria) as well as by various gliding bacteria.
8. **Run**
   a. The act of bacterial forward movement via flagellar action is called a *run*.
   b. *Runs* are bracketed by tumbles.
9. **Tumble [twiddle]**
   a. The spinning of flagella in reverse results in a at first seemingly maladaptive *tumbling*, whereby bacteria cells stop moving "forward" and instead randomly reorient themselves via a literally *tumble*-like action.
   b. This *tumbling*, however, actually plays a key role in the directed movement by bacteria called taxis.
10. **Taxis**
    a. Movement toward or away from a stimulant.
    b. **Directed random motion:**
       i. Flagellar movement occurs in a given direction, but the direction a bacterium faces is not under the bacterium's control.
       ii. Instead, a bacteria will tumble (a consequence of reversal of flagellar motion), then resume motion in a random forward direction via flagellar motion.
       iii. Net directional movement ultimately results from tumbling occurring less frequently when movement is in the appropriate direction. Thus, movement in the proper direction occurs simply as a consequence of merely biasing movement more in that direction than not.
       iv. "A bacterium travels in a straight or slightly curved line, a run, for a few seconds; then it will stop and tumble or twiddle about. The tumble is followed by a run in a different direction. When the bacterium is exposed to an attraction gradient, it tumbles less frequently (or has longer runs) when traveling up the gradient, but tumbles at normal frequency if moving down the gradient. Consequently the bacterium moves up the gradient. Behavior is shaped by temporal changes in chemical concentration: the bacterium compares its current environment with that

experienced a few moments previously; if the attractant concentration is higher, tumbling is suppressed and the run is longer." (p. 63, Prescott *et al.*, 1996)

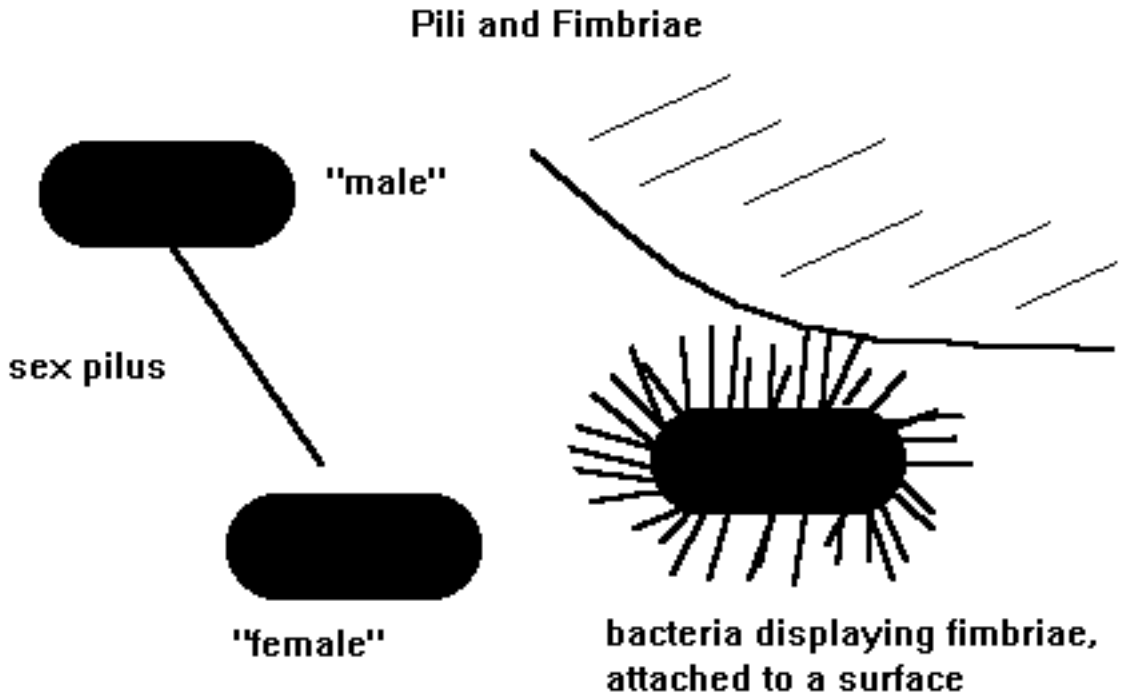
v. Thus, directed movement is accomplished without aiming, and concentration gradients may be sensed without measuring differentials down only a single cell length.

vi. See text figure 1080.1

11. **Chemotaxis**
    a. Taxis toward (positive *chemotaxis*) or away (negative *chemotaxis*) from a chemical stimulant.
12. **Phototaxis**
    a. Taxis toward (positive *phototaxis*) or away (negative *phototaxis*) from a light stimulant.
13. **-trichous**
    a. Suffix of terms referring to the number and location (and other characteristics?) of bacteria flagella:
        i. atrichous
        ii. monotrichous
        iii. amphitrichous
        iv. lophotrichous
        v. peritrichous
14. **Atrichous**
    a. Lacking in flagella.
15. **Monotrichous**
    a. Having a single flagellum at one end of the cell.
16. **Amphitrichous**
    a. Having two flagella, one at either end of a cell.
17. **Lophotrichous**
    a. Having two or more flagella at a polar attachment point. (p. 47, Tortora et al., 1995)
    b. A tuft of polar flagella. (Boyd, 1984 and Webster, 1986)
18. **Peritrichous**
    a. Having a large number of flagella located various (many) places about the cell.
19. **Axial filaments [endoflagella]**
    a. "Spirochetes have *axial filaments*, or *endoflagella*, instead of flagella that extend beyond the cell wall. Each filament is attached at one of its ends to an end of the cytoplasmic that forms the body of the spirochete. Axial filaments cause the rigid spirochete body to rotate like a corkscrew when they twist inside the outer sheath." (p. 87, Black, 1996)
20. **Pili [sing. Pilus]**
    a. Protein "poles" (sticks, whatever) arrayed perpendicular to the surface of bacteria and projecting out into the extracellular space.
    b. "Pili (singular: pilus) are tiny, hollow projections. They are used to attach bacteria to surfaces and are not involved in movement. A pilis is composed of subunits of the protein pilin. Bacteria can have two kinds of pili: (1) long conjugastion pili, or F pili (also called

sex pili), and (2) short attachment pili, or fibriae." (p. 87-89, Black, 1996)

21. **Fimbria [pl. fimbriae] ['fim-bre-a, 'fim-bre-I] [attachment pili]**
    a. *Fimbria* are short pili found in large numbers (up to hundreds) and used to attach bacteria to surfaces.
    b. See illustration below.
    c. *Fimbria* can be important contributers to the ability of a bacteria to cause disease since they can secure the attachment of the bacteria to the host.
22. **F (conjugation, sex) pili**
    a. *F pili* are long pili found in low numbers and used to attach one bacteria to a another, typically of the same species.
    b. *F pili* are involve in the transfer of plasmids from one bacteria to the other, a process called conjugation. These plasmids code for the expression of F pili.
    c. See illustration below.
23. **Illustration, pili and fimbriae**



24. **Vocabulary**
    a. Amphitrichous
    b. Amphitrichous
    c. Axial filaments
    d. Flagella
    e. Bacterial glycocalyx
    f. Capsule
    g. Chemotaxis

h. Fimbria
i. Glycocalyx
j. Lophotrichous
k. Monotrichous
l. Motility
m. Peritrichous
n. Phototaxis
o. Pili
p. Pili and fimbriae, illustration
q. Run
r. Slime layer
s. Taxis
t. Tumble
u. See also Lecture: Procaryotic Cellular Anatomy I

25. **Practice questions**
    a. The root -trichous refers to what bacterial structure? [PEEK]
    b. Draw an amphitrichous bacilli with sufficient detail to define these terms, and then label key components. [PEEK]
    c. Name three ways that a glycocalyx might be beneficial to a bacterium which excretes one. [PEEK]
    d. A bacteria is attracted to light, is repelled by hydrogen ions, and is able to move toward the former and away from the latter via a series of random tumbles plus flagellar-mediated directed movement. These processes in general may be considered to be examples of _____. (note, I am looking for the technical term so "movement" and other non-technical equivalents will not be considered correct answers) [PEEK]
    e. With respect to movement toward a specific stimulant (e.g., toward sugar), bacteria get to a specific here from a less specific there as a consequence of _____ only when moving up concentration gradients (choose best answer) [PEEK]
        i. tumbling
        ii. flagellar action
        iii. extended runs
        iv. random search
        v. photoelectric effect
        vi. rudder action
    f. In positive chemotaxis (i.e., toward a chemical signal), describe the movement of a bacterium in terms of runs, tumbles, and concentration gradients. [PEEK]
    g. Name two "virulence factors." That is, two components of bacteria cells which, if present, allow the bacteria to cause disease, but if absent result in bacteria which can successfully reproduce (e.g., in the laboratory), but are nevertheless either unable or less able to cause disease. [PEEK]
    h. Draw a peritrichous bacillus such that I am convinced that you know what these terms

mean. [PEEK]

i. What two substances are bacterial glycocalyx made of? [PEEK]
j. A bacilli has one flagellum at each pole. This is an example of what? [PEEK]
k. What is the generic term describing a bacterial structure potentially involved in (i) attachment to surfaces, (ii) protection against desiccation, (iii) nutrient trap (iv) protection from phagocytosis, (v) protection from viruses, and (vi) protection from certain toxins?. [PEEK]
l. Tumbles occur less frequently during movement *up* a salt concentration gradient. This is an example of what? (be sure that your answer takes into account the described direction of travel) [PEEK]

26. **Practice question answers**
    a. Degree of flagellation as in amphitrichous, lophotrichous, monotrichous, peritrichous.
    b. A rod with a single flagellum at either end.
    c. attachment, resistance to desiccation, resistance to phagocytosis, resistance to viruses, resistance to toxins such as detergents, trappping of nutrients.
    d. taxis.
    e. iii, extended runs.
    f. The bacterium will display longer runs (fewer tumbles) when heading up the concentration gradient (i.e., toward the signal) than when heading down the concentration gradient.
    g. capsules and attachment pili. "Plasmids expressing R-factors" is also a reasonable answer.
    h. i, bacillus with numerous flagella located all about the cell envelope.
    i. polypeptide (protein) and polysaccharide (carbohydrate)
    j. amphitrichous flagellar placement (an amphitrichous bacterium)
    k. bacterial glycocalyx
    l. bacterial positive chemotaxis
27. **References**
    a. Black, J.G. (1996). *Microbiology. Principles and Applications***.** Third Edition. Prentice Hall. Upper Saddle River, New Jersey. pp. 78-82, 84-90.
    b. Prescott, L.M., Harley, J.P., Klein, D.A. (1996). *Microbiology***.** Third Edition. Wm. C. Brown Publishers, Dubuque, IA. pp. 40-72.
    c. Tortora, G.J., Funke, B.R., Case, C.L. (1995). *Microbiology. An Introduction.* Fifth Edition. The Benjamin/Cummings Publishing, Co., Inc., Redwood City, CA, pp. 70-90.