

Honors Seminar 259 — cheat sheet for 9/10/2008 — Andrew Baker

Benner et al. (2004)

You should spend more time on this article than on Sismour & Benner (2005). Some questions to think about as you are reading: Why do the authors argue that life has each of a number of general biochemical requirements? What are the three categories of explanations for why life on Earth has any given aspect of its observed biochemistry? Could other worlds besides the earth be *more* hospitable for different kinds of life than the Earth is for ours?

Below is a partial list of the scientific terminology that appears in the paper. Although the list is long, keep in mind that not all of the entries are *important* in the sense that they connect to the authors' main ideas; one of your goals as a reader is to recognize which terms are central and which are more peripheral.

- **aerosol** = liquid droplet or small solid particle that is suspended in a gas (typically, the atmosphere).
- **alkyl** = chain of carbon and hydrogen atoms that can be attached to another molecule.
- **anion** = negatively charged ion (the opposite is “cation”).
- **biotin** = vitamin B₇, required for metabolism of fatty acids.
- **chiral** = adjective describing something (molecule, crystal, hand, etc.) that cannot be superimposed on its mirror image. In the case of molecules, the two mirror images are known as *enantiomers* of each other.
- **cofactor** = a substance that must be present, supplementing an enzyme, for a particular chemical reaction to occur.
- **conjugated system** = molecule in which the electrons involved in covalent bonding are not uniquely attached to a particular bond, but are delocalized.
- **covalent bond** = type of chemical bond formed when two atoms share one or more pairs of electrons; covalent bonds are stronger than “hydrogen bonds” (like those linking complementary nucleotides in a strand of DNA).
- **cytidine** = molecule formed by the combination of cytosine (the “C” base in RNA and DNA) and ribose.
- **deamination** = removal of an amine group (ammonia with one or more substitutions) from a molecule.
- **denaturation** = process by which a protein, RNA, or DNA unfolds and loses its preferred three-dimensional shape (a shape often required if it is to do what it's supposed to).
- **deoxyribose** = a sugar containing five carbon atoms that provides part of the “backbone” of DNA.

- **dihydrogen** = hydrogen that is bound together into H_2 molecules. (Beware of anyone who tries to alarm you with the news that the drinking supply has been contaminated with “dihydrogen monoxide”!)
- **formamide** = a particular example of an *amide* (a compound featuring a $C=O$ group bonded to a N atom) that has the formula $HCONH_2$.
- **Gibbs free energy** = Gibbs energy = the amount of useful work that can be extracted out of a thermodynamic system with uniform temperature and pressure. The *change* in Gibbs energy ΔG associated with a chemical reaction is negative if the reaction releases energy and positive if the reaction requires energy.
- **guanosine** = molecule formed by the combination of guanine (the “G” base in RNA and DNA) and ribose.
- **halogen** = an element from the next-to-last column of the periodic table (F, Cl, etc.).
- **homochiral** = adjective describing molecules that have the same chirality.
- **hydrolysis** = partial or complete breakdown of a molecule due to reactions driven by the H and OH that result from the splitting of a water molecule.
- **hypersurface** = the analog of a surface in more than three dimensions. In the context of this article, suppose that the sequence of a protein is described by exactly two parameters (call them x and y — granted, this is not very realistic!), and the ability to “confer fitness” is a function of these parameters $z = f(x, y)$. If we plot (x, y, z) , then we’ll have a landscape of peaks, dips, ridges, valleys, and ripples. A hypersurface is the generalization of this landscape to more than two parameters.
- **isosteres** = two molecules with the same numbers of atoms and “valence” electrons (electrons in the outer shell that are important for chemical bonding).
- **liposome** = bubble whose surface is a double layer of lipid molecules, with their hydrophilic “heads” pointing outward and their hydrophobic “tails” pointing inward.
- **micelle** = sphere whose surface is a single layer of lipid molecules with their hydrophilic “heads” pointing outward and their hydrophobic “tails” pointing inward (unlike a liposome, a micelle does not enclose anything).
- **oligosilane** = a small number of silicon atoms chained together with hydrogen atoms attached to every other available bonding site. Silane (SiH_4) is analagous to methane (CH_4).
- **oxidant** = a substance that gains electrons in oxidation-reduction reactions (more on this later in the semester)
- **phenol** = carboic acid = compound consisting of an OH group bonded to a phenyl ring (i.e., benzene with OH tacked on).

- **phosphorylation** = addition of a phosphate group (PO_4) to an existing molecule.
- **pKa** = negative logarithm of the acid dissociation constant K_a . Since K_a is higher when an acid (e.g., HCl) is more easily dissociated into its constituents (e.g., H and Cl^-), an acid with a *larger* value of pKa is *weaker*.
- **polar** = a molecule with an asymmetric distribution of charge (water is polar; methane is not).
- **pyridoxal** = vitamin B₆.
- **racemic** = adjective describing a mixture that contains equal amounts of left-handed and right-handed enantiomers of a chiral molecule.
- **reductant** = a substance that loses electrons in oxidation-reduction reactions (more on this later in the semester)
- **ribose** = a sugar containing five carbon atoms that provides part of the “backbone” of RNA (most compounds whose names end in “ose” are sugars/carbohydrates).
- **ribosome** = one of many RNA/protein complexes within a cell that “translates” the instructions from a DNA sequence (conveyed via a “messenger RNA” molecule) into a protein.
- **sulfone** = chemical compound containing a $\text{O}=\text{S}=\text{O}$ group attached to two carbon atoms.
- **thermodynamic equilibrium** = the state of a system whose temperature, pressure, and chemical composition don’t change, and which (for constant temperature and pressure) has a minimum Gibbs free energy.
- **thioester** = one of a family of chemical compounds that include sulfur atoms.

Sismour & Benner (2005)

You should spend less time on this article than on Benner et al. (2004)– in fact, I would recommend reading only the abstract, the introduction, and the discussion (the last paragraph of the “Results” section describing Figure 7 is also tractable). Some questions to think about as you are reading: What is the immediate objective of the work that the authors describe? What are the criteria they are using to determine whether this work has been successful? What is a hypothesis related to extraterrestrial life that the results of their work *disproves* (even if they don’t state it explicitly)?

A partial list of the scientific terminology appearing in this paper, mostly from its first and last sections (see also the list for Benner et al. (2004) above):

- **dNTP** = deoxyribonucleotide triphosphate, i.e., a generic term for one of the complete nucleotides in DNA (base + deoxyribose + triphosphate). Specific examples would be abbreviated according to the base as dGTP (deoxyguanosine triphosphate), TTP (thymidine triphosphate– in this case, “thymidine” includes deoxyribose), dATP (deoxyadenosine triphosphate), and dCTP (deoxycytidine triphosphate).

- **duplex** = a double-helix DNA strand.
- **major groove** = wider of the two helical gaps between the two strands of the DNA double helix (i.e., the one through which access to the base pairs is easier).
- **minor groove** = narrower of the two helical gaps between the two strands of the DNA double helix.
- **nucleotide** = the basic rung of the ladder in a nucleic acid: one base plus one sugar plus one phosphate group (the latter two comprising the “backbone” of the DNA or RNA molecule)
- **oligonucleotide** = a short segment of a nucleic acid, with only a “few” ($\leq 20?$) bases.
- **PAGE** = polyacrylamide gel electrophoresis, a technique used to separate proteins or nucleic acids by applying an electric field through a polyacrylamide gel. (Polyacrylamide is a polymer built up from smaller units of acrylamide, which is unfortunately a neurotoxin!) In this paper, for the “nucleotide competition” test, the authors included a mercury-containing compound in the gel that was known to have a braking effect on compounds including sulfur (e.g., 2-thipTTP). Figure 4 shows the result of this test, with the molecules having been driven from the top to the bottom of the plot.
- **PCR** = polymerase chain reaction. This is a technique that biologists use to make large numbers of copies of (i.e., “amplify”) a fragment of DNA, using an enzyme known as a DNA polymerase.
- **polymerase** = an enzyme that makes one or more copies of a nucleic acid (substances whose names end in “ase” are generally enzymes).
- **purine** = a molecule containing a pyrimidine ring attached to an imadizole (three carbon plus two nitrogen atoms) ring, or one of its derivatives; the bases guanine (G) and adenine (A) are purines.
- **pyrimidine** = a molecule containing a ring of four carbon and two nitrogen atoms, or one of its derivatives, which include the bases cytosine (C), thymine (T), and uracil (U). C pairs with guanine (G); T and U pair with adenine (A) in DNA and RNA, respectively.
- **RT = reverse transcriptase** = enzyme that copies an RNA sequence into the corresponding DNA double helix.
- **steric complementarity** = when the bonding between two complex molecules is enhanced by the fact that they have the right sizes and shapes for a good “lock and key” fit. Steric “bulk” and “exclusion” also relate to the size and shape of a molecule.
- **tautomers** = two molecules that are equivalent apart from the switch of a single hydrogen atom or proton.
- T_m = temperature at which a given molecule will melt.

- **Thermus aquaticus** = (abbreviated *Taq*) a bacterium that thrives at the high temperatures found in hot springs.
- **thione** = type of molecule including a C=S bond.
- **thymidine** = the combination of thymine (the “T” base in DNA) plus deoxyribose.