**Appendix One.** The hierarchical level of each concept, its coverage in the pre-workshop version of the course (1=covered; 0=not covered), its coverage in the Spring 2008 version of the workshop course (1=covered; 0=not covered), and a description of each concept is listed in this appendix.

<table>
<thead>
<tr>
<th>Level</th>
<th>Pre</th>
<th>Post</th>
<th>Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>1</td>
<td>1</td>
<td><strong>Scientific knowledge</strong> is based on the evaluation of tentative hypotheses through systematic observation of nature.</td>
</tr>
<tr>
<td>2nd</td>
<td>1</td>
<td>1</td>
<td><strong>Hypotheses</strong> are claims which can be scientifically tested, and potentially disproved.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Exploration of initial observations and related knowledge contributes to hypothesis generation.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td><strong>Hypotheses-testing</strong> includes using the hypothesis to generate a prediction, then making observations and comparing the prediction of the hypothesis to the observations.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Hypotheses can be tested with <em>controlled experiments</em> which have independent and dependent variables or through <em>natural experiments</em> which do not include the controlled manipulation of independent variables.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Quantitative patterns in observed results are often illustrated with <em>graphs</em>.</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>1</td>
<td>All experiments make <em>assumptions</em> which may or may not be true.</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>1</td>
<td><em>Null hypotheses</em> can be disproved but not proved.</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>1</td>
<td><em>Inferential statistics</em> estimate the probability that the variation between the observations and prediction are simply due to chance.</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>1</td>
<td><em>Model systems</em> are often used in controlled experiments.</td>
</tr>
<tr>
<td>4th</td>
<td>0</td>
<td>1</td>
<td>Some hypotheses are represented with <em>mathematical models</em>.</td>
</tr>
<tr>
<td>2nd</td>
<td>1</td>
<td>1</td>
<td>The level of acceptance of hypotheses varies greatly as a result of the number and quality of tests of the hypothesis that have supported it.</td>
</tr>
<tr>
<td>2nd</td>
<td>1</td>
<td>1</td>
<td><strong>Scientific facts</strong> are observations or hypotheses that have been supported so many times that they are assumed to be true.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Examples of scientific facts: cells exist; genes are coded into the structure of DNA; evolution happens.</td>
</tr>
<tr>
<td>2nd</td>
<td>1</td>
<td>1</td>
<td><strong>Theories</strong> are major concepts which link together many observations and hypotheses.</td>
</tr>
<tr>
<td>1st</td>
<td>1</td>
<td>1</td>
<td><strong>Evolution</strong> is the change in the frequency of heritable traits of a population across generations.</td>
</tr>
<tr>
<td>2nd</td>
<td>1</td>
<td>1</td>
<td><strong>Natural selection</strong> can result in adaptive evolution.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Natural selection is <em>differential survival</em> of individuals within a population based on a variation in trait.</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>1</td>
<td>Natural selection is an interaction between individuals and their environment.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Natural selection results in evolution if the selected trait is <em>heritable</em>.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td><em>Populations not individuals</em> evolve.</td>
</tr>
<tr>
<td>3rd</td>
<td>1</td>
<td>1</td>
<td>Evolution cannot occur unless there is <em>heritable variation</em> for the trait in the population.</td>
</tr>
</tbody>
</table>
| 4th   | 1   | 0    | Natural selection can result in *directional, stabilizing, or disruptive*
changes in phenotypes.

Natural selection against a dominant allele can result in rapid fixation of the recessive.

Natural selection against a recessive allele does not result in fixation.

Natural selection favoring heterozygous genotypes maintains a balance of the frequency of alleles in the population and maintains genetic diversity.

Genetic Drift is a random pattern of evolution due to bottlenecks and founder effects.

Genetic drift is due to random sampling error of a trait in association with mortality or dispersal.

Genetic (or demographic) Bottlenecks are random mortality relative to a trait.

Founder effects are random dispersal relative to a trait.

Genetic drift reduces genetic diversity.

Reduced genetic diversity can result in inbreeding depression.

Genetic drift and inbreeding depression are problems for endangered species.

Sexual selection is due to differences in fitness due to variation in traits which influence mating success.

Sexually dimorphic traits are more pronounced in the sex which invests less energy in producing gametes and caring for offspring (typically males).

Sexually dimorphic traits function as armaments and/or ornaments.

Mate choice can be influenced by pre-existing sensory bias, non-genetic benefits to offspring or female, genetic benefits to offspring.

Speciation occurs when gene flow between diverging populations is blocked.

Microevolutionary processes (natural selection, genetic drift, mutation, gene flow) contribute to speciation.

Secondary contact reinforces speciation if hybrids are less fit.

Adaptive Radiations are characterized by relatively rapid speciation and diversification within a taxa.

Adaptive radiations are triggered by opportunities resulting from environmental or genetic change.

Heritable variation associated with adaptive radiations is often associated with regulatory genes.

Extinction is the permanent loss of a species.

Mass extinctions are times of widespread and relatively rapid extinction rates.

The K-T mass extinction resulted in reduced dominance of reptiles and gymnosperms and triggered the adaptive radiations of angiosperms, insects, birds, and mammals.

The K-T mass extinction was due to an asteroid impact.

Some mass extinctions may have been influenced by the effects of the arrangement of continental plates on climate.

We are entering a mass extinction due to climate change, habitat
destruction, and invasive species.

**Biodiversity** is a result of historic patterns of speciation and extinction.

**Phylogenies** are hypotheses about speciation and extinction within a taxa.

*Domains* indicate that 2/3 of the diversity of life is prokaryotic.

The wide range of habitats colonized by *prokaryotes* is associated with their *diverse metabolism*.

The phylogenetic history of *plants* is associated with adaptation to terrestrial environments.

The fundamental life history difference between plants and animals is mitotic growth during the haploid stage of plant life cycles to produce *gametophytes*.

*Fungi* are more closely related to *animals* than to plants.

*Fungi* differ from animals in that they secrete enzymes, *externally digest* molecules including cellulose, and then absorb the nutrients.

*Animal Phyla* are associated with morphological, mobility, & perceptual adaptations

*Exo-* and *endo-*skeletons enable precise muscle control of appendages

Insect pollinators & herbivores co-evolved with angiosperms

Phenotypes are determined by *genotypes* and the *environment*.

Genes are *discrete units* on information passed unchanged, except for rare mutations, from parents to offspring.

The genetic code is a result of the structure of *DNA* within chromosomes.

*Alleles* are versions of genes.

Mutation produces new alleles.

Mutations can occur at many levels: point mutations, chromosomal rearrangements, and changes in ploidy.

*Genotypes* describe an individual's alleles.

*Phenotypes* describe observable traits of individuals.

Meiosis, fertilization, and gene expression underlie *Mendelian patterns of inheritance*.

Somatic cells are *diploid*.

*Meiosis* randomly separates homologs into haploid gametes.

Genes on nonhomologous chromosomes sort independently resulting in genetic variation among gametes.

*Crossing over* increases genetic variation by rearranging alleles of genes between homologs.

*Fertilization* combines haploid gamete genotypes into diploid zygotes.

*Dominance relationships* describe the phenotypic expression of heterozygotes.

*Pleiotropic* genes influence more than one phenotypic trait.

*Epistatic* interactions between gene products influence the expression of genotypes into phenotypes.

*Quantitative traits* are influenced by polygenic genes.

In humans, X-linked genes are hemizygous in males.

Males inherit these genes from their mothers.
Multiplicative probability describes the increased expression of recessive X-linked genes in males.

While mutation is the ultimate source of new alleles, recombination produces new combinations of alleles.

In eukaryotes, crossing over, independent assortment, and fertilization contribute to recombination.

In prokaryotes, horizontal gene transfer results in recombination.

Behavioral traits evolve in response to natural selection.

Behavior is a response to a stimulus.

Behaviors range from innate fixed action patterns to complex learned behaviors.

Behaviors can be learned through a variety of processes (e.g. operant, habituation, classical conditioning, imprinting).

Populations have dynamic spatial and temporal structures.

The spatial boundaries of populations are influenced by abiotic factors, as well as species interactions; both of these factors change through time.

Invasive species have moved out of their native region and are disturbing natural and human communities.

Population size and density varies through time.

Populations with a constant and positive per capita growth rate grow exponentially.

All species have a positive biotic potential.

Birth rate, death rate, and migration determine r.

Birth rate is determined by fecundity and age structure.

Death rate is determined by life span and age structure.

Age structure causes demographic momentum.

Density-dependent mortality can regulate N at K.

The global human metapopulation has increased global K, reduced d through agricultural, medicinal, and scientific innovations, and reduced b through birth control but is still growing exponentially.

Species interactions influence the evolution of traits, population growth, and community structure.

Parasitism, predation, and herbivory are + -.

Competition is - -.

Intraspecific competition results in density-dependent mortality and contributes to K.

Strong intraspecific competition can contribute to coexistence.

Interspecific competition can result in competitive exclusion, niche differentiation, and habitat partitioning.

Inter- and intra-specific competition can occur through exploitation or interference.

Keystone predators can reduce interspecific competition and increase species diversity of prey species.

Mutualism is + +.

Mutualism can promote coexistence and expand niches.

Communities change in response to biotic and abiotic factors.

Primary succession initially favors species with high dispersal and
tolerance.  
2nd  1  1 *Secondary succession* is promoted by facilitation; slowed by inhibition.  
3rd  1  1 *Intermediate disturbance* can increase species diversity and productivity  
2nd  1  1 *Species diversity* increases with decreasing *latitude*.  
1st  1  1 Energy flows through *ecosystems*; nutrients cycle within ecosystems.  
2nd  1  1 Atmospheric *nitrogen* is common, but nitrogen is often *limiting*.  
3rd  1  1 Nitrogen fixation, nitrification, and denitrification depend on *bacteria*.  
2nd  1  1 *Photosynthesis & cellular respiration* are important components of energy flow and carbon cycling.  
3rd  1  1 Deforestation and burning fossil fuels influence carbon cycling, energy flow, and result in climate change.  
4th  1  1 There are direct and indirect measures of increasing atmospheric carbon dioxide.  
4th  1  1 There is theoretical and empirical evidence of the link between carbon dioxide and climate change.  
4th  1  1 Climate change, along with invasive species and habitat destruction, is resulting in the disruption of natural communities.