19 September 1996

Biology colleagues:

At the SI meeting this morning, we agreed that the members of each subgroup would develop a conception of the principal concepts and skills that ought to be taught in their fields; for biologists, particularly, this requires sharing of ideas between SI and ES. For your consideration, I'm submitting my list of the concepts (and some skills) that would be developed in an ideal general biology course, recognizing that no course might have time to include all of this. Without apology, I've taken the list from the topics covered in my new general biology book; I couldn't do this otherwise. Of course, I'm not implying that the topics must be covered in the sequence listed; I actually would prefer a sequence starting with ecology. The division into numbered items is quite arbitrary; I could have bunched many major ideas differently, and I just did it this way to emphasize what I think are the most important points. Thus, I might have made the list of plant topics look longer and the list of animal topics look shorter. (This is always a point of contention between plant and animal biologists.) In any case, these are the ideas that an ideal student would understand--*or at least would have studied one time*--before going on to more advanced subjects in biology. In other words, they are the topics that I would like to assume a student has been exposed to when she or he comes into a junior-level program. I am not naive enough to assume that students would have really *assimilated* all these concepts, of course.

The attached page with four boxes is a handout for this year's FONS program, modified somewhat from boxes about the four overriding themes of our new book.

I am much less confident about skills, and so I've only started a list. (These are lab skills; I subsume the skills of applying the concepts and solving problems with them under the concepts themselves.) I expect others to criticize this whole document, but I hope, particularly, that you will add to the list of skills.

With my neck stuck *waaaay* out,

Burt Guttman

CONCEPTS AND SKILLS FOR GENERAL BIOLOGY

Part 1: Concepts

I. Overriding themes or general concepts (see attached Box sheet)

1. Organisms are genetic systems.
2. Organisms live in ecosystems.
3. Evolution, operating primarily through genetic diversity and natural selection.
4. Organisms function through molecular interactions.
5. Cell Theory: the cell as the "atomic unit" of biology.

II. Specific concepts

A. General overview

1. General diversity of the biological world; general concept of domains and kingdoms.
2. General concept of evolution and natural selection; evidence for evolution; homology; phylogeny, macroevolution, and the fossil record; geological time and age of the earth.
3. General concept of ecosystem, biological community, and ecological niche.
4. Threefold concepts of selection, adaptation, and niche.
5. Organism as structure that operates on the basis of a genome.
6. Populations: exponential growth and genetic diversity.
7. Natural selection as differential reproduction and survival

B. Biological structure

8. Basic chemical concepts, especially types of bonds, water, pH, hydrophilicity and hydrophobicity, organic structure, stereoisomerism
9. Polymers and principle of polymeric construction
10. Structures of polysaccharides, nucleic acids, and proteins.
11. Major protein structures.
12. Enzymes and stereospecificity
13. Importance of weak interactions and equilibrium
14. Protein dynamics and allostery
15. Link between protein structure and the genome
16. Shaping of protein structure through evolution; protein homologies
17. General cellular structure and cell theory; procaryotic and eucaryotic cells.
18. Conception of major organelles and their functions

C. Metabolism (with additional structural and ecological concepts)

19. General conception of free energy; exergonic and endergonic processes.
20. Need for coupling between exergonic and endergonic processes in organisms.
21. ATP and NAD.
22. Metabolic pathways.
23. Energy relationships within the ecosystem; food chains and webs; roles of organisms within a community (producers, consumers, etc.); chemotrophy and phototrophy; autotrophy and heterotrophy.
24. Lipids and membrane structure
25. Types of membrane proteins and their functions
26. Transport processes: diffusion, facilitated diffusion, active transport, etc.
27. Overall view of metabolism; cellular respiration, photosynthesis, and the carbon cycle.
28. Overall understanding of respiration; glycolysis and Krebs cycle
28. Chemiosmotic coupling and phosphorylation
29. Overall understanding of photosynthesis; light-dependent and light-independent processes; photophosphorylation.
30. Types of photosynthesis: C_3 and C_4 plants.
31. General concepts of cell growth and regulation; transducers and negative feedback.
32. Homeostasis and steady-state conditions
33. Receptor proteins and signal ligands
34. The general intracellular signal pathways: G-proteins, second messengers, etc.

35. The cytoskeleton and functions of microtubules and microfilaments

D. Genomic structure and function

36. General genomic structure and function
37. Relationship between genes, proteins, and metabolism; the use of mutants
38. DNA structure; general function and replication
39. Chromosome structure
40. The cell cycle, mitosis, and DNA replication
41. Information transfer: DNA to RNA to protein
42. General process of protein synthesis; function of eucaryotic organelles in the process
43. Epigenetic information
44. Sexual cycles and meiosis
45. Mendelian principles and analysis of Mendelian inheritance
46. General concepts of genetic mapping and complementation
47. Genetic processes in bacteria and viruses
48. Principles of recombinant-DNA techniques
49. Operon concept and genetic regulation; eucaryotic regulatory mechanisms
50. Applications to human genetics; genetic engineering, gene therapy, and ethical considerations.
51. Overview of early embryonic development in animals and plants
52. Major processes of morphogenesis
53. Genetic regulation of development; gene hierarchies, spatial information, and homeotic genes.

E. Evolution

54. Genetic structure of populations; polymorphism
55. Hardy-Weinberg equilibrium; effects of mutation, selection, and genetic drift
56. Fitness and geographic variation
57. Speciation and genetic isolating mechanisms
58. Macroevolution: extinction, phyletic evolution, punctuated speciation

F. Ecology

59. Geophysical constraints on ecosystems: sunlight, winds, ocean currents, etc.
60. Survey of ecosystems (biomes): oceanic, freshwater, terrestrial
61. Biogeographic realms; tectonic plates and biogeography
62. Ecosystem efficiencies and trophic levels
63. Cycling in ecosystems; turnover and residence times; biogeochemical and nutrient cycles
64. Ecological succession and species turnover
65. General population structure, habitat, and range
66. Population limitation; regulation from above or below; density-dependent and -independent factors
67. Resource allocation and behavioral strategies; ideal free distribution; territoriality
68. Opportunistic and equilibrium species; r- and K-selection; survivorship
70. Niche concept; Gause's Principle
71. Interspecific competition, niche differentiation, and speciation
72. Allelochemic interactions in ecosystems
73. Binary interactions: predation, parasitism, symbiosis, etc.
74. Predator-prey relationships; mimicry, camouflage, etc.

G. Classification and the variety of organisms

75. Classification, nomenclature, and Linnaean taxonomy; cladistics
76. The species concept and its problems
77. Origin of biological systems and early evolution
78. Monera: the variety of bacteria

79. Protista: the variety of algae, protozoans, and molds
80. Fungi: survey of the kingdom
81. Plantae: survey of divisions and the evolution of plant reproduction and structure
82. Animalia: survey of major phyla and animal body plans
83. Some commonalities of plant and animal biology: unitary or modular structure, water relations, gas exchange, respiration, surface/volume and mass/area considerations.

H. Plant biology

84. Plant tissues; structure and growth of roots, stems, and leaves in vascular plants
85. Plant nutrition; nitrogen fixation
86. Xylem structure and water transport
87. Phloem structure and transport; problems of water and gas exchange
88. Plant hormones and growth; gene expression in plants
89. Photoperiodism and phytochromes

I. Animal biology

90. General chemical regulation: endocrine, paracrine, and nervous
91. Nervous system structure and evolution
92. Neurons: membrane potential, action potential, nerve impulse, synapses
93. Principal endocrine glands and hormones
94. Structure and function of principal receptors
95. Skeleton, connective tissues, and musculo-skeletal structure
96. Muscle structure and contraction
97. Circulatory systems, open and closed; vertebrate circulatory system and heart function
98. Blood; gas transport and exchange (internal and external respiration)
99. Excretory systems; transport by epithelia; kidney function
100. Digestive system structure and function; distribution and assimilation of principal nutrients
101. Animal defense systems and acute inflammation
102. Immunity, cellular and humoral; antibody synthesis
103. Behavior: fixed-action patterns and releasers; the role of learning
104. Social behavior and structure of animal societies
105. Reproductive behavior and mating; sex hormones and cycles; fertilization

Part 2. Skills

1. Use of a light microscope; knowledge of the optical system and ability to adjust a microscope for maximum clarity.

2. Chemical glassware and solutions; ability to correctly use chemical glassware and to make solutions of designated concentration, including calculations of molarity.

3. Understanding of pH and buffers; ability to make solutions of designated pH and to properly use a pH meter.

4. Spectroscopy. Understanding the optical system of a spectrophotometer and ability to obtain absorption spectra, to measure the absorbance of solutions and determine concentrations on this basis.

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