(4) The Second Law of Thermodynamics states that organisms tend to run down without an external source of energy. If an animal stops eating or green plants are placed in the dark they die. Creationists tend to ignore external sources of energy and say that evolution from simple to complex organisms could not occur. The only energy required by the living world is the sum of that necessary for the individual organisms for growth and maintenance. There is a great increase in complexity as an organism grows from an embryo to an adult. If this can be done in spite of the Second Law, evolution will be possible. Energy is required only for living—not for evolving.

(5) The theory of evolution is science and not metaphysics. The central biological concept of evolution is scientific. The creationists base their attack on a statement made by philosopher Karl Popper: "Darwinism does not really predict the evolution of variety." They have taken great comfort in Popper's point of view. However, their infallible philosopher has changed his mind: "It does appear...that some people think that I have denied scientific character to the historical sciences such as paleontology or the history of life on earth...This is a mistake and I wish here to affirm that these and other historical sciences have in my opinion scientific character: their hypotheses can in many cases be tested."

Many individuals have no problem with cosmic evolution or evolution of organisms other than man, but the moment that man is mentioned in the evolutionary process all sorts of difficulties seem to arise in their thinking. While procedures of evolutionary science allow us to explain much about this natural world, the creationists stress that we cannot explain everything. This is true, but it would be as foolish to discard the theory of evolution with the overwhelming evidence as it would be ridiculous to disband the medical profession because there is not cure for the common cold.

BIBLIOGRAPHY


CREATION OF THE EVOLUTION LABORATORY

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Evolutionary biologists continue to receive criticism from many sides; but primarily from creationists and antisociobiologists. While academicians in Ivy League or very large state universities may be isolated from this fray, those of us who teach in small colleges are frequently on the line because we may be the only evolutionist on campus. Furthermore, we may be ill prepared to deal with the onslaught from several directions because we feel that evolutionary thinking is so reasonable that any intelligent individual would obviously be convinced. Therefore, we certainly have not developed efficacious strategies to counter
the well-organized political movements which are challenging our basic academic freedoms. This has frequently resulted in many an academic evolutionist being artfully dissected by the smooth rhetoric of a national spokesperson with a spate of out-of-context quotes which have been carefully selected for their emotional appeal to their solicited audience. Needless to say those evolutionists who have scored evenly or even come out on top in this oratory battles have returned to the roundtable to share their dragon slayer stories; somehow such exercises seem counterproductive. While we may be doing excellent science in basic research and while our lecture-discussion courses may be very well prepared, **one large disservice which we may have done ourselves is the lack of consistently offering evolution laboratories in conjunction with our courses.** One reason for the perpetuation of this tradition may be that we have not sufficiently shared appropriate, workable laboratories with one another. I herein share with you some resources which may be useful in a variety of courses which emphasize evolutionary thinking.

It is surprising that there seem to be no published lab books purely devoted to evolution. On the other hand, a variety of lab books include individual exercises on evolution and several commercial vendors sell kits to illustrate evolutionary processes. In addition, the recent revolution in microcomputers has led to a large number of portable simulations at modest price. Furthermore, our own educationally oriented biology journals are a rich resource for seeing what some of our ingenious colleagues have developed to illustrate important concepts and processes in evolution. Hence, I do not feel that there is sufficient reason to hide any longer behind the set of excuses for not offering evolution labs: evolutionary experiments could never be done in a single semester, much less a year, because the time frame is too short to witness anything significant, since evolution is the unifying principle of biology, we already teach enough evolution in other courses, so there is no need for a whole separate course and lab devoted solely to it, simulations are cookbook and gedanken exercises only, etc.

On July 2nd, 1981, Professor Frank Price of Hamilton College in Clinton, New York presented the syllabus for his evolution lab to the participants in a educational workshop sponsored by the Society for the Study of Evolution and the American Society of Naturalists after their combined annual meeting at the University of Iowa. He feels that biology students are insufficiently exposed to mathematics and modeling. Therefore, he has combined his primary interest in evolution with a complete laboratory experience in computer simulations and data analysis. He takes his students through deterministic models of changes in gene frequencies due to mutation, migration, genetic drift, and selection, through stochastic models of the same processes, and then through both descriptive and inferential statistical analyses of the classic Bumpus data on stabilizing selection in sparrows. (Bumpus's 1899 article is reprinted in Carl Jay Bajema, editor, *Natural Selection Theory, Benchmark Papers in Systematic and Evolutionary Biology*, Volume 5, Hutchinson Ross Publishing Co.: Stroudsburg, PA, (1983), pp. 348-365.)

Professor Price's stochastic simulations have been accepted by CONDUIT so they probably become available in less than a year. His models are thoroughly researched and their use in his laboratory seems pedagogically and scientifically effective. He reports student growth and satisfaction with this laboratory experience. He is a recent recipient of the National Science Teacher's OHMEN Outstanding College Science Teachers' Award. In terms of the vogue use of "evolutionary stable strategies" (ESS), I would characterize Dr. Price's model as a pure strategy. For the sake of those of us who prefer diversity, let us explore some components of a more mixed strategy.

Since my own professional background is in chemical evolution and molecular evolution, I have enjoyed using a variety of experiments on the origin of life in my class labs. They frequently have the advantage of being classic experiments which intrigue students because
they have already heard or read something about them. The best collection of experiments which are well presented (which I am aware of) is Biology of the Cell: Laboratory Explorations by William DeWitt and Eleanor R. Brown (W.B. Saunders Company, 1977). Their experiments involve the synthesis of organic compounds from a simulated primordial atmosphere, polymerization of amino acids to form proteinoids, preparation of proteinoid microspheres and coacervates, microscopic comparison of cellular universalities and differences in the five kingdoms, and experiments on metabolism. Unfortunately, the experiments on catalysis do not employ proteinoids nor do the experiments on permeability make use of proteinoid microspheres or black thin film membranes; both of which have been widely explored in the chemical evolution literature.

When Luria and Delbruck won the Nobel Prize, I was extremely disappointed that the press did stress the impact of one of their first collaborative efforts as one of the finest experiments in the history of evolutionary research. The fluctuation test which they reported in 1942 was a significant test of teleology. While the experiment is easy to perform, many textbooks do not discuss it because the analysis of the data employs Poisson statistics. One fine discussion of the experiment is in William Stansfield's The Science of Evolution (Macmillan, 1977): A good lab write-up of the experiment is by B.W. Glover, "Luria & Delbruck Fluctuation Test," pp. 22-26 in R.C. Clowes & W. Hayes, eds., Experiments in Microbial Genetics, Blackwell Scientific Publs. (1968). Besides ruling out an environmentally directed origin of adaptations, the experiment was one of the first to yield accurate estimates of a gene's mutation rate. Most texts have supplanted this test of teleology with the Lederberg and Lederberg replica plating experiment which uses no mathematical analysis, but clearly demonstrates the existence of pre-adaptive mutations in the absence of the selective agent.

Along with many other evolutionists, I believe that every phylogenetic tree is an evolutionary hypothesis. Thus, any experimental analysis of taxonomic relationships seems perfectly appropriate for the evolutionary laboratory. A commercial kit entitled "Immunology and Evolution" allows students to stimulate the immunological cross-reactivity between man, chimpanzee, monkey, orangutan, and pig. If appropriate experiments are chosen, the construction of a dissimilarity matrix should be possible. An extensive computer package available from Professor Joseph Felsenstein at the University of Washington (Seattle) allows students to investigate a large variety of clustering algorithms for generating phylogenetic trees, phenograms or cladograms. Each tree developed from data which students have collected in a laboratory could be examined for reasonableness when compared with traditional classifications.

Besides employing antisera to explore phylectic distances, I have used paper chromatography of plant pigments and thin layer chromatography of essential oils to make chemotaxonomic comparisons. The Artemesias are quite good specimens which show considerable differences in their essential oils; some of the plants which store well include Dusty Miller, Silver King, Silver Plume, sage brush, wormwood, and a commercial variety just labelled as "artemesia." Extracts such as "Absorbine, Jr." contain sufficient material to make some inferences as to the plants employed in the commercial preparation. Care should be taken not to concentrate too much on some of the essential oils such as chamazulene, because some students (and I) react strongly to the odors. If you have a good gas chromatograph available, it will allow you to compare these specimens with much smaller samples, greater safety, and much more quantifiable results.

The use of gel electrophoresis to examine polymorphism and heterozygosity in natural populations has been extremely popular ever since the 1966 experiments of Lewontin and Hubby. Results from such experiments have revolutionized the way we have looked at the roles of selection and genetic drift ala the neutralists. In addition to classic work with
Two frequently employed labs involve the classification of imaginary organisms. I have used Joseph Camin's caminalcules for years. Robert R. Sokal, "Numerical Taxonomy" in Scientific American 215(6):106-116 (December, 1966), for more pictures of Caminalcules, see Robert r. Sokal, "A Phylogenetic Analysis of the Caminalcules. I. The Data Base", Systematic Zoology 32(2):154-184 (1983). I have delighted in reading the imaginative scenarios which students have constructed to account for their differences. A colleague recommends the game "Hardvaria." He brings in a large number of washers, screws, nuts, bolts, cotter pins, nails, etc. and tells the students to pretend these are artifacts brought back from another planet by a NASA team. Their goal is to construct a meaningful classification. In either case, the students will tackle some very real decision-making problems in deciding upon groups and characteristics to be considered. I have students use these data as well as protein and nucleic acid sequence data with Felsenstein software to develop better ideas about classification and phylogenetic inference.

In class, we frequently discuss rapid speciation through allopolyploidy or simple polyploidy. Thomas R. Mertons in "Student Investigations of Speciation in Tragopogan," Journal of Heredity 63 (1): cover, 39-42 (January-February, 1972), discusses a laboratory examination of the chromosomes of T. porsifolius L., T. pratensis L., and T. dubius Scop. and the two amphidiploid species T. mirus and T. miscellus which have twenty-four chromosomes instead of the twelve of the original stocks. He uses a vital stain to select pollen which is likely to be viable. Meiosis is studied in pollen mother cells. The interesting relationships between cauliflower, broccoli, rutabaga, mustard, and a variety of related plants is nicely discussed in the second edition of the genetics book by Suzuki, Lewontin, and Griffiths.

Directional selection for geotaxis and phototaxis in drosophila set up easily, "A Circular Countercurrent-Distribution Behavioral Genetic Maize, J. Heredity 68:123-125 (1977) (Kordek, Jungck, etc.) and easily illustrate the principles in a reasonable period of time. However, not all students seem to have the patience required for these experiments. Thus, classical population cages may be readily employed in larger classes. Chemostat experiments are perhaps best for most rapid illustrations.

Variation can also be studied morphologically in a nice commercial kit employing common sunflowers, Helianthus annus. Students can easily construct a histographic assortment which looks quite Gaussian (we have found that sunflower seeds sold as commercial bird food works just as well as the kit). A similar effective display at Harvard's Agassiz Museum of Comparative Zoology employs snail shells with different banding patterns.

One of the questions asked by evolutionists relates to why there are so many different kinds of organisms. In an interesting twist, Professors Raup and Michelson (Science, '65) "Theoretical Morphology of the Coiled Shell", was able to generate shell morphologies on both analog and digital computers with striking resemblance to most of the contemporary and extinct gastropods. One of the questions they asked is: since our simple model could account for so many other forms which seem to never have existed, why didn't those other forms ever evolve?

I usually include four field trips amongst my evolution labs. First, we are close to a number of excellent quarries and road cuts which are good for fossil collecting. Second, we make one all day trip to Milwaukee and fit in the Milwaukee Public Museum with its excellent dinosaur diorama, the Mitchell Dome Conservatory with its superb diversity of flora, and the Zoo. Third, we travel to Chicago to the Museum of Science and Industry which has an
excellent display on the evolution of hemoglobin and of Raup's coiled shell simulation and the Shedd Aquarium. Finally, the last trip is again to Chicago to the Field Museum of Natural History for their annual systematics symposium which focuses on evolution.

My students usually begin the lab course in evolution with a confidence approaching arrogance that they know what evolution is all about. Part of the way into the course, they have tried enough labs that they question not only their confidence, but also the ability of evolutionists to make any sense of all the material they are being presented: especially they have difficulty in constructing phylogenies and in understanding the regularities of stochastic processes. Delightfully, before the course is half over they acquire a new sense of confidence which is seemingly developed out of the competence of performing labs rather than just reading or listening. Therefore, labs will remain an important part of my evolution class. If you have other ideas for evolution labs, please share them with me.

UNDERGRADUATE OPPORTUNITIES IN SCOTLAND FOR BIOLOGISTS
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Why should the humanities and social science majors have all of the fun? Traditionally, few undergraduate science majors have felt free to consider a year abroad for a number of reasons: (1) few study abroad programs offer options permitting science students to take science courses; (2) those programs which do offer science may not measure up to the quality of science courses taught at the home institution, and thus advisors have been reluctant to promote those programs; (3) the curriculum for science majors is generally highly structured, and students think that they must not leave campus because they fear missing particular courses required for the major; and (4) science majors often take the MCAT during the junior year, and they fear postponing that test until senior year when they are back on campus.

We think we have an answer to those problems. The Great Lakes Colleges Association (GLCA) is a consortium of colleges in Indiana, Michigan, and Ohio. Included are Albion College, Antioch College, Denison University, DePauw University, Earlham College, Hope College, Kalamazoo College, Kenyon College, Oberlin College, Ohio Wesleyan University, Wabash College, and the College of Wooster. Seven biology majors from those colleges have studied abroad at the University of Aberdeen, Scotland, in the past five years. All have had a successful experience, and all have taken one, or more than one, science course at Aberdeen.

The University of Aberdeen is an old British university with approximately 5,000 students. Offering both undergraduate and graduate degrees, it is also the center for much geological, biological and chemical research in Scotland because of its ties to both the petrochemical industry (the North Sea oil production has created a real boom in Aberdeen) and to the historically productive agricultural region in northeastern Scotland. Because of these factors, the undergraduate science departments at Aberdeen are generally well staffed and well equipped, and the research programs of the faculty there provide many interesting opportunities for students.

Students enrolling in the GLCA Scotland Program for 1984-85 will attend regular university classes, live in university dormitories and immerse themselves in Scottish student activities. The academic year goes from October 1 through May 15 for American students, with two three week vacations at Christmas and during spring. Cost of the program will be $6,850 for tuition, student activity fee, orientation and group activities, and round trip transportation. Room and board is approximately $1,500 per year. Although the