Teaching Cell Biology: Experimental Format

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There are perhaps as many curriculum concepts and ways of organizing a given course as there are biologists teaching today. Faced with this and with the problem of teaching numerous classical courses at small enrollments, the biology department at Biola College initiated a core curriculum in 1967. The biology courses were organized hierarchically—population, organismic, cellular, and molecular biology—with introductory courses in biology survey and systematics. In addition, various elective courses were offered.

The course in cell biology was organized to introduce sophomore and junior students to cytology, microbiology, histology, and microtechnique. It became obvious during the first year that a survey would not acquaint the students with these subjects in any depth, give them the skills of experimentation, or convey the excitement of these fields of biology. I also suspected that the students would not appreciate "cookbook" laboratories; therefore an inquiry-based course was introduced.

Organization of the Course

Such a course has been taught for the past two years; see table 1. The table outlines a 15-week-semester, four-unit course having three hours of lecture and two two-hour labs a week. The three general sections are broad enough to allow teachers much freedom of choice as to topics and format; at the same time they are inclusive enough to insure breadth and depth of coverage in cytology, heredity, and histology.

The lecture sections have continuity, in that plant and animal cell structure and function—including chromosome biology—can be integrated with histology through the treatment of tissue types as differentiated cells. Histology is slighted for a particular reason: the basic tissue types presented are the epithelial, the connective, and the irritable (nerve and muscle), with the recognition that laboratory experimentation in histology (see below) will lead the student on to greater depth in histology plus demonstrating to him the fact that most tissues and organs are but composites of these three elemental types.

The lectures make use of several audiovisual methods. The instructor must be sensitive to the method that most efficiently communicates the subject; for example, he might use models in chemistry, flow diagrams to explain metabolism, and the oscilloscope in nerve biology. In tissue studies I have the students look at microscope slides while they listen to my lecture; at times they are asked to give their attention to projections on a screen.

The laboratory work is correlated with the lectures. It emphasizes research techniques and experimentation: approximately half the semester is devoted to two open-ended, inquiry based research projects (table 1). The student, working in team with another student, is required to formulate, experiment with, analyze, and formally report on a problem of his choosing. Before he undertakes the tissue-culture project the student has been exposed to methods of culture, counting, staining, and the like; that is, he has some confidence in attempting the project. In this laboratory, tissue culture is vital: from its practice the student learns cytology, microscopy, and photography, and he develops proficiency in aseptic culturing techniques, counting, staining, and making permanent slides. In addition, the student becomes aware of the cells' needs (nutrition, pH, temperature) and learns to recognize causal environmental relationships. He observes that a strain of cancer cells may be polynuclear and divide twice as fast as do normal cells. He has at his disposal at all times graphic instruments such as the camera lucida, microprojectors, microscope closed-circuit television, and bright-field, dark-field, and phase microscopes. The student is encouraged to use 35-mm, polaroid, and 16-mm time-lapse microphotographic techniques of analysis and recording.

In addition to tissue-culture experimentation the student is exposed to other cellular concepts and techniques through the experiments in cell fractionation by differential centrifugation and autoradiography. The student is also introduced to the study of cell development through experiments dealing with nuclear transplantation (attempted) and with enzyme induction in a microorganism.

The student, again as part of a team of two, must also formulate a plant or animal histology project

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involving preparation and analysis of tissue slides. The student learns the joys and pitfalls of histologic microtechnique and acquires experience in recognizing cell, tissue, and organ structures.

Complementary Projects

The projects complement and reinforce each other in terms of experimental technique and conceptual information. For example, the student is expected to reach a certain proficiency in the recognition of tissue slides, and this is reinforced by analysis of his own project. The student has access at all times to a complete reference collection of slides in cytology and histology and is encouraged to study them and include comparative aspects in his research notebook and formal reports. A corollary experience is the self-tutorial use of Super 8 film loops that emphasize laboratory techniques. Film-loop content is coded to the laboratory outlines; however, viewing is optional.

Students are required to summarize and evaluate 10 journal or review articles in this field during the semester. The journal articles selected by the student usually relate to lectures or laboratory work—allowing him to focus on current research developments.

The requirement that the student keep a research notebook is necessary in a course of this nature. It forces the student to organize his time and his experimental procedures so that raw data and chronologic observations can be entered directly without "dry-labbing." He is also encouraged to organize results in graph or table form, caption his pictures, label his diagrams, discuss problems of method or theory, and include a bibliography. Theoretically, if all these things are faithfully entered the project report can be a summary of notebook research information rather than a formidable obstacle. Two or three checkings of the notebook (with grading) during the course will insure full participation by the student as well as allow the instructor to correct and comment on format errors.

Evaluation; Equipment

Evaluation in the course is by means of objective and subjective hour-long exams, daily quizzes, take-home problems, work sheets, oral reports, laboratory practicals, and the formal project reports. Cytogenetics and principles of microscopy are sections conducive to take-home problems. It has been observed that students tend to perform for a grade when only objective testing is used, whereas take-home exams more directly help students consolidate and conceptualize information; and this technique appears to provide stronger motivation for learning.

What equipment is needed and what textual material is used? Table 2 is a list of specialized equipment that could be used in a course of this nature. This list is suited to the open laboratory design; that is, student groups follow experimentation timetables that are not necessarily concurrent with the formal

Table 1. Topical summary of the cell-biology course.

General subject	*Lecture*	*Time (hours)*	*Laboratory*	*Time (weeks)*
Cell structure and function	History, survey of structure, cellular chemistry	6	Introduction to microscopy, bacteriologic and cytologic culture, counting, staining, and mounting techniques	2
	Microscopy and cytologic techniques	3	Cell fractionation by centrifugation and staining analyses	1
	Cytoplasm, membrane systems, cell organelles	7	Plant and animal tissue culture project	3
Nuclear and cytogenetics	Nucleus and chromosomes, reproduction	4	Plant root-tip, animal mitosis, and *Drosophila* chromosome preparations, mammalian chromosome culture, chromosome cytology (prepared slides), cell autoradiography	3
	Mendelian genetics (review), cytogenetics and radiation biology	6	Nuclear transplantation in *Amoeba proteus* and β-galactosidase enzyme induction in *E. coli*	1
	Cell differentiation	2		
Functional histology	Epithelial and connective tissues	7	Whole-mount and histologic techniques, histology project experimentation	3
	Irritable tissues (nerve and muscle biology)	5	Glycerinated muscle preparation and frog nerve-muscle electrophysiology experiment	1
	Plant-cell types	2	Histology review (prepared slides), student discussion of histology research projects, laboratory practical exam	1
	Tests	3		
	Total	**45**	**Total**	**15**

Table 2. Specialized equipment used in the cell-biology course. Projection based on a laboratory enrollment of 10 to 15 students. The estimates can be doubled for every 15 additional students in laboratory concurrently.

Category *Item*	*Use*	*Cost (approx.)*
Laboratory equipment		
1 inverted microscope with phase optics	Tissue culture, photography	$ 900+
1 ciné and 35-mm microphotography attachments with camera drive and time-lapse control	Tissue culture, photography	2,000
2 trinocular microscopes (phase optional) with polaroid and other photography attachments	Photography, cytology	2,000
1 sterile transfer hood with germicidal lights (open front)	Tissue culture	400+
1 high-speed centrifuge	Cytology	1,500+
2 rotary microtomes	Histology	1,800
1 sliding clinical microtome with freezing attachment (cryotome preferable)	Histology	300+
1 stereoscopic disserting microscope with trinocular head and camera assembly	Histology, photography	600+
1 vacuum oven	Histologic wax infiltration	400+
Other equipment (optional)		
1 microprojector	Microscope-slide visualization	300+
1 closed-circuit TV, attachable to trinocular microscope	Microscope-slide visualization	variable
1 automatic tissue-processor	Histology	1,500+

laboratory time. This allows the most efficient use of the equipment. Other, standard equipment needed would be compound medical microscopes (four objectives), dissecting microscopes, incubators, water baths, a dry-heat sterilizing oven, an autoclave, a laboratory fume hood, a refrigerator, and miscellaneous equipment for making cultures. Specialized glassware is needed for tissue culture, and histology demands a complete stock of dyes and stains as well as a large volume of histologic solvents. Reference slides in cytology, cytogenetics, and plant and animal histology should be available for study.

A textbook that is organized in keeping with this course is *Cell Biology,* by de Robertis *et al.* (1970). It would be possible, however, to use other recent cytology textbooks if proper supplementation were made in the subjects of microtechnique, cytogenetics, and histology. Because of the open-ended nature of the laboratory investigations, our students depend on a fairly complete library reference section in histology and tissue culture; however, textbooks by P. Gray (1964) and G. Humason (1967) provide a good grounding in procedures. Two inexpensive softback outlines giving good diagrammatic representations of animal and plant tissue types are, respectively, by H. Rowett (1957) and by A. Lee and C. Heimick (1962). Students are also encouraged to purchase a book on photographic technique, such as Eastman Kodak's *Photography Through the Microscope* (1970), and to write for biology supply house catalogues.

Advantages of the Format

Several objectives are actualized in a cell-biology course of this format. First of all, consolidation of several traditional branches of biology is realized through experimentation. For sophomores, the inquiry method of learning certainly provides the conceptual and experimental tools needed in the study of modern biology. Students' evaluation of the course affirms this conclusion. The open-laboratory format encourages students to think independently and to work together closely as research teams; it also gives the instructor more time for personal contact with each student. Many students become vitally interested in cell biology and put in more time on research than a more traditional course would require.

REFERENCES

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