Midwest Bioscene

Volume 14 Number 3
November 1988

Midwest Bioscene Volume 14(3) November 1988

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Midwest Bioscene is published by the Association of Midwest College Biology Teachers

Interfacing with Microcomputers in the Physiology Laboratory

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My memory goes back to the time when spring-powered kymographs with recording paper smoked over a sooty flame were state-of-the-art in many undergraduate laboratories. Next came kymographs driven by electric motors which were considered quite an advance at the time. Electronic equipment with greatly increased efficiency, accuracy and versatility has largely replaced kymographs. I still have fond (?) memories of the kymograph. Every now and then I have students attempt to record some physiological event with the kymograph so that they more fully appreciate today's equipment.

Multichannel chart recorders such as the Physiograph enable students to simultaneously record several physiological events. These events can then be analyzed and correlated; for example, recording the atrial and ventricular contractions of the pulsating turtle heart along with its electrical activity (EKG) on three channels. In our labs, both the Physiograph and Thornton recording equipment are used with good success by students. In this report, I make no attempt to describe the whole array of such equipment, but only some representative types with which I am familiar.

By the 1980's, programs for physiological simulations utilizing microcomputers became available. "Physiological Simulations" (1980) is one that I have used successfully in the lab with the Apple computer, was developed by James E. Randall of Indiana University. Another recently developed simulation program we now use is on the "Mechanical Properties of Active Muscle" by Richard A. Meiss, also of Indiana University, and is available from QUEUE of Bridgeport, Ct. This program utilizes the IBM PC computer. Both simulation programs allow students to set up experimental conditions and observe the results on the screen. This stimulates the interest of many students.

Another development of the 1980's that we now use in the lab is the Physiogrip by Intelitool of Wheaton, Illinois. This consists of a specially designed displacement transducer connected to an Apple computer along with software that enables display, recording and rapid analysis of human muscle contractions by stimulating the flexor digitorum superficialis muscle through the surface of the forearm.

Another system now available utilizing existing electronic equipment and microcomputers is the Sensor-Processor Interface (SPI) system by Thornton Associates, Inc., of Waltham, Massachusetts. Apple and IBM PC computers can be used with this system. The following are some examples of the use of the SPI system that are suitable for a biology or introductory physiology laboratory. Thornton electronics were interfaced with an Apple IIc computer, color monitor and an Imagewriter printer. The SPI unit does not occupy much space, as it measures only 9.25" x 8.5" x 2.5". The VOLT1 program, supplied with the system, plots voltage against time, with time on the X axis. The X and Y axis parameters can be set by the user, the settings depending on the event being recorded.

Figure 1 is a copy of a segment of an electrocardiogram made with a Type 400 Bio-Amplifier/Supply and a Type 410 Isolated

Preamplifier. The time between the data points was 0.02 second. The SPI memory configuration allows 8000 data points to be collected. When the sampling rate is set, the time per screen and the total time will be displayed. In this recording with sample points every 0.02 second, the total time is 160 seconds with the time per screen being 2.14 seconds. The data points are displayed as they are collected. At the end of the time period (160 sec. in this case), several options are presented. LOG will present the data in tabular form on the screen and on the printer. FILE will store the data to disk.

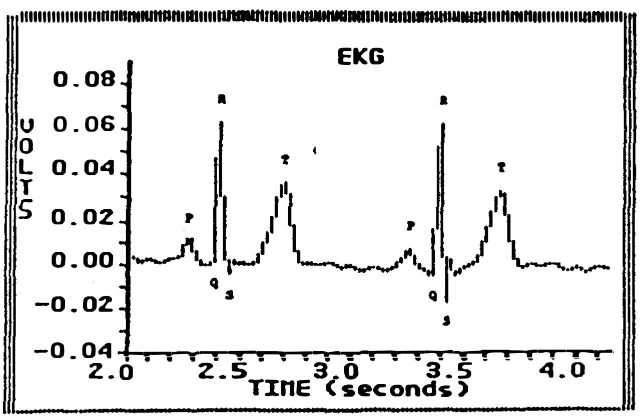

Figure 1. Electrocardiogram with data points connected. P, QRS and T added.

One can also scan each screen from the beginning or select any point during the total time period and begin scanning at that point. If something particularly interesting happens at a certain time, say at 60 seconds during the recording, one can begin scanning at about 58 seconds and save the time of scanning all the preceding screens. A hardcopy of any screen can be obtained by pressing P. One can RESTART the program with the X and Y parameters remaining as set. RESTART, however, will erase the current data so a decision must be made before doing this whether or not to save the data.

Figure 1 shows a 2.14 second segment of the EKG beginning at 2.0 seconds. An option of whether or not to connect the data points is available by simply pressing C when scanning the screens. Whether or not to do this depends on the nature of the data. By viewing it both ways, or making copies both ways, one can decide which way appears best on paper. In Figure 1, the data points are connected. Two complete cardiac cycles are shown, with the P, QRS, and T components labeled by me.

Figure 2 shows a screen of the recording of the volume pulse in the fingertip of a 22 year-old subject using a Type 428 Photoplethysmograph. The time between data points is 0.04 second with a total recording time of 320 seconds. In this copy, the data points are not connected. A prominent dicrotic notch is

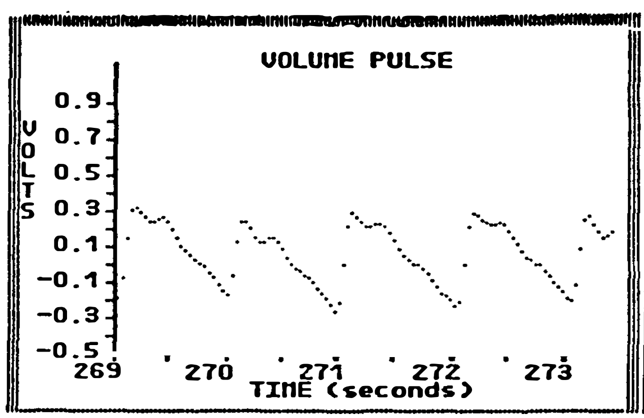

Figure 2. Fingertip volume pulse. Data points not connected. Note dicrotic notch following each volume peak.

visible, caused by the elastic recoil of the large arteries after ventricular systole.

The SPI system has two analog imputs and one or both can be used at the same time. In Figures 1 and 2, only one channel is used, but in Figure 3, both channels were used to show the relationship between the volume pulse and the electrocardiogram. The time between samples is the same as in Figure 1 (0.02 sec.). The EKG is not as clearly defined as in Figure 1 because the voltage parameters for a volume pulse are not the same as for an EKG. Only one set of voltage parameters can be used for both channels. Nevertheless, P, QRS, and T can be identified and the time delay between QRS (ventricular excitation) and the peak of the volume pulse in the fingertip can be easily seen. The prominent dicrotic notch seen in Figure 2 is

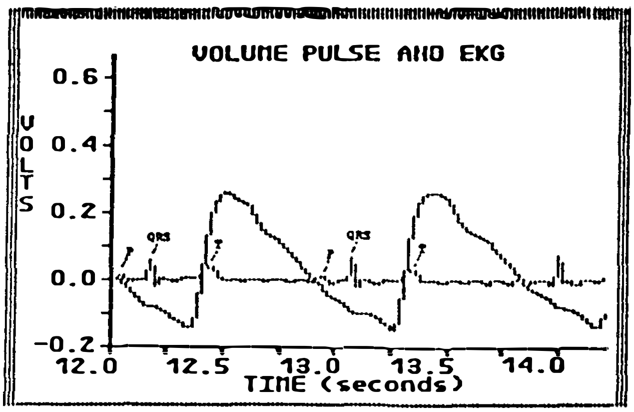

Figure 3. Relationship of volume, pulse and EKG. Data points connected. P, QRS and T have been added.

considerably diminished in Figure 3 because the volume pulse and EKG in this recording are of a 64 year-old individual. The diminished dicrotic notch is very likely the result of the aging process with the large arteries being less elastic than those of a 22 year-old individual.

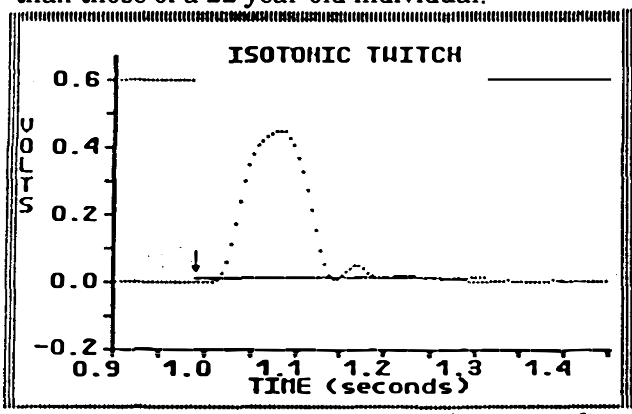

Figure 4. Frog gastrocnemius muscle. Data points not connected. Arrow indicates point of stimulus followed by latent period.

The form curve of a single isotonic twitch of the frog gastrocnemius muscle is shown in Figure 4. The twitch was produced by a single pulse from a stimulator of six milliseconds duration and four volts in amplitude. The time between data points is 0.005 second with the time per screen at 0.55 second. A type 424 Displacement Transducer and a Type 450 Stimulator were used. The displacement transducer was connected to Channel 1 and the event output of the stimulator was connected to Channel 2. In this way, the stimulator served as a signal marker for the stimulus to the muscle. This is shown as the upper line in the screen. As the stimulator button is pressed, the line drops to the base line of the muscle lever. This allows the latent period of the muscle twitch to be measured, which in this case is 0.021 second. The time of the complete twitch at room temperature, including the latent period, is about 0.155 second. The form curve of the muscle twitch is comparable to any which can be produced on an oscilloscope screen and by utilizing the computer-driven printer which makes it a simple matter to obtain a copy of the

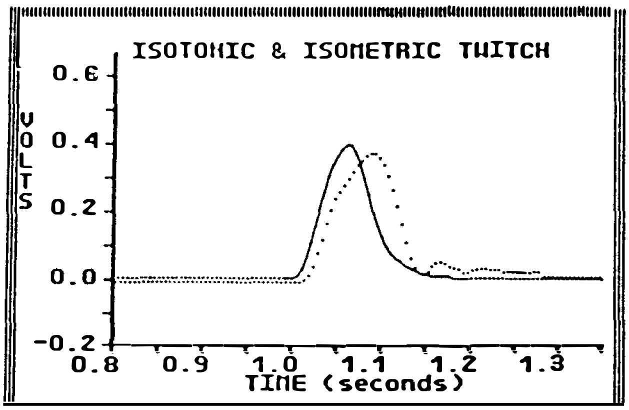

Figure 5. Superimposed twitches of two frog gastrocnemius muscles. Data points connected on isometric twitch.

twitch.

Figure 5 shows an isotonic twitch and an isomeric twitch of the right and left gastrocnemius muscle of a frog. The isotonic twitch was produced by connecting one muscle to a Type 424 Displacement Transducer and the isometric twitch was produced by connecting the other muscle to a Type 422 Force Transducer. The muscles were simultaneously stimulated with a Type 450 Stimulator. The time between data points is 0.005 second (same as in Fig. 4). The two twitches can easily be distinguished on the monitor screen because they appear in two colors, orange and blue. In Figure 5, the data points of the isometric twitch are connected (by hand) to distinguish it in the absence of color.

The characteristics of the two contractions can be compared by examining the superimposed tracings. In Figure 5, the isometric twitch is the upper line beginning on the left side of the screen. The most noticeable differences are the shorter latent period and peak tension produced in the isometric twitch before the isotonic twitch reaches maximum contraction. In the isometric twitch, the force transducer responds immediately to an increase in tension resulting from stimulation, whereas in the isotonic twitch, enough tension must be produced to overcome the inertia of the muscle lever and attached weight before there is any movement.

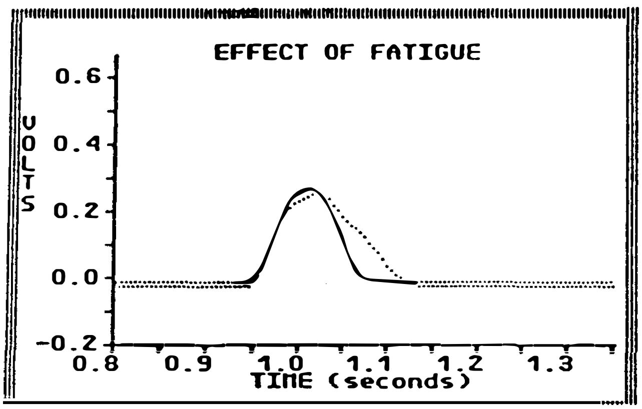

Figure 6. Isontonic twitches of two frog gastrocnemius muscles. Data points not connected on twitch showing fatigue.

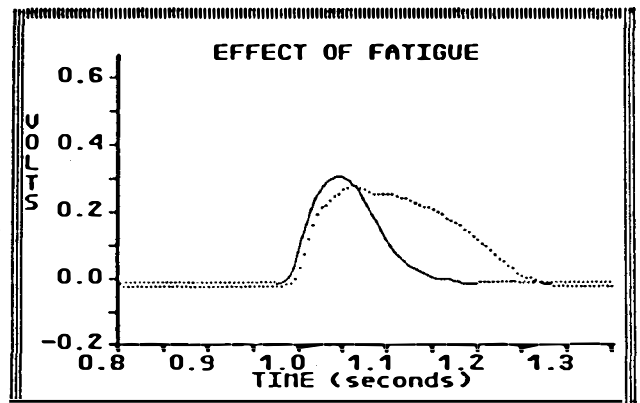

Figure 7. Isontonic twitches of two frog gastrocenemius muscles. Data points not connected on twitch showing a more advanced state of fatigue.

Figures 6 and 7 show the effect of fatigue on the frog gastrocnemius muscle. Both muscles of a frog were connected to Type 424 displacement transducers producing isotonic twitches. The conditions for both muscles were the same except one muscle had performed more work than the other before the twitches were recorded. On the screen, the two muscle contractions appeared as orange and blue. To distinguish them in these copies, the data points on the fatigued muscle are not connected.

In Figure 6, one muscle lifted a ten-gram weight 40 times more than the other. Some evidence for fatigue is visible in the longer relaxation period in the twitch. In Figure 7, the same muscle lifted the ten-gram weight 100 times more than the other. The effect of fatigue is more pronounced as shown by the slight delay in responding to the stimulus, not contracting to the same degree as the other muscle, and the considerably longer relaxation period.

Microcomputers are now an integral part of the physiology laboratory, whether they are used for physiological simulations, with special transducers or interfaced with components of other recording equipment.

In these examples of interfacing with microcomputers, Thornton equipment was used, but other analog sensors and transducers can also be used. Real-time data acquisition and analysis is simplified and enhanced. The Thornton SPI system adds another dimension to the laboratory and allows greater use of your existing electronic equipment and microcomputers. The extent of this depends on the ingenuity of the user.

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The Cloning of Humans:
CAN WE? WILL WE? SHOULD WE?

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Introduction

Technology, science, and society intertwine at every turn of events, often leading to vigorous controversies. Social implications stemming from advances made in the discipline of genetics may head the list. Many liberal arts colleges and universities, including Saint Mary's College of Minnesota, are presenting scientific explanations, spelling out social ramifications, and considering ethical aspects of these genetic advances through courses offered in a variety of academic departments (Kowles, 1985). This paper will consider one of these issues; specifically, the technological, biological, and ethical stances concerning the prospects of human cloning. Cloning is the growth of one or more individuals each from a single cell taken from another existing individual. Cloned progeny are genetically identical to each other and to their one parent. In other words, a cloned child would be a twin of the donor; that is, a perfect example of the "chip off of the old block" expression. Usually, a clone implies a population of organisms in which all of the descendants are derived from a single original cell by asexual means. In the human population, identical twins, triplets, etc. come as close as we can to comprising a true clone.

Cloning is theoretically possible because every cell of the body supposedly has the same set of genes.

During the development of an organism from a fertilized egg to an adult, a number of different tissues are produced by a very little understood process called differentiation. The phenomenon whereby any cell of the body other than sex cells, for example skin, cartilage, intestinal, or white blood cells, can differentiate into another complete organism is known as totipotency. Such a feat, if possible, might obviate the need for sex.

Can We Clone?

Many plants, and some animals, undergo asexual reproduction naturally. An asexual mode of reproduction is taken to mean any reproductive event that does not involve the union of genetic material from two sexes or mating types. Resulting progeny, therefore, have exactly the same genetic constitution of their one parent. Parthenogenesis (meaning virgin birth) is the situation in which an unfertilized egg, or any other cell, develops into an individual. Although somewhat rare, parthenogenesis has been observed in certain insects, lizards, and even one variety of turkeys (Cole, 1984; Cuellar, 1987). Researchers have also found ways to induce it in other species (Markert, 1982). Parthenogenesis in humans, although often claimed, has never been documented. Some women who have claimed "virgin birth" had given birth to a son which is, of course, not genetically possible. Research on cloning has produced some precedents in a number of species. The wild carrot was probably the first plant to be differentiated and cloned from a single cell through scientific manipulation in the laboratory (Steward *et al.*, 1958). Similar successes followed with other plant species. Among animals, frogs were cloned using a different strategy (Briggs and King, 1952; 1953; 1959). Because these researchers believed that something in a fertilized egg's cytoplasm promoted totipotency, they replaced the fertilized egg's nucleus with a nucleus from an embryo cell. The newly constructed cell then developed sequentially into a larva, tadpole, and normal adult frog. It is important to note that abnormal growth resulted when the transplanted nucleus came from an adult frog.

In 1962, J. B. Gurdon performed a remarkable experiment. Gurdon used ultraviolet light to inactivate the nuclei of unfertilized eggs of a toad. He then transplanted a diploid nucleus from a tadpole intestinal cell into each of the enucleated eggs. Some of these manipulated cells developed into adult toads. The impact of these experiments emerges from the fact that the intestinal cells of the tadpole are highly differentiated cells; still their nuclei could show totipotency when placed into the cytoplasm of an egg.

Some of the cloning experiments in mice have been somewhat of a scientific controversy, mostly because of a low amount of success in repeating them. An experiment similar to that of the toad was reported by Illmensee and Hoppe (1981). A different procedure, called the half-clone technique, was previously reported by Hoppe and Illmensee in 1977. In this latter case, one of the two nuclei in a fertilized egg is removed before they unite ... either the female or the male nucleus. The remaining nucleus is induced to double by chemical treatment. This latter step is necessary because two complete sets of chromosomes must be present for normal development, and the sperm or egg nucleus by itself has only one set of chromosomes. The egg cell, now containing two sets of chromosomes (either both male or both female), is implanted into a female mouse. Recognize that the resulting progeny is not a clone in a true sense. The donor nucleus, although doubled, constitutes only one-half of the genetic information of the organism from which it came.

Cloning of cattle is often mentioned in both scientific literature and the popular press. This agricultural advance consists of still another procedure. The cow is artificially inseminated, and an eight-celled embryo is removed, separated into two- or four-celled embryos, and each implanted into other cows for gestation. The calves born will be genetically identical to each other, but not to the cow serving as the donor. Regardless, quality traits of the donor cow and/or the bull providing the sperm can be highly propagated among the progeny at a faster than usual rate. The cows used for gestation purposes can practically be any old herd of cows since they only serve as "incubators."

In 1951, a young woman in Baltimore died of a very fast-growing cancer of the cervix. A biopsy of this tissue was performed, and the resulting cells were distributed and successfully grown in research laboratories around the world. These cells are called *HeLa* cells as a shortened version of Henrietta Lacks, the woman's name. The cells are fairly easy to culture within flasks under laboratory conditions; they never die out if maintained properly; and researchers have performed a myriad of experiments with them. Although the cells of Henrietta Lacks technically can live forever within pyrex which tempts one to call the phenomenon a sort of immortality, the undefined aggregations of cells remain just that ... undefined aggregations of cells.

No scientist knows how to induce these cells to differentiate into another Henrietta Lacks. Assume that some Monday morning upon returning to the laboratory, Henrietta appeared to be back with us. After fully developing into an adult, how would this Henrietta compare to the 1951 Henrietta?

First of all, cells grown through tissue culture techniques often change over time; that is, relative to their genetic material, the genes and the chromosomes. Secondly, even if her genetic material did not change, how similar would she be to the original Henrietta Lacks? The environment is certainly going to play a role, and sometimes it can be a highly significant role. Would a cloned cell of Hitler develop into another Hitler as we knew the first one? Would a cloned cell of Einstein be another Einstein? Would a cloned cell of Clark Gable ... and so forth?

A shocking book was published on March 31, 1978 by the J. B. Lippincott Co. The title of the book was *In His Image: Cloning of Man*, written by a freelance writer, David M. Rorvik. Although the book was published as a true story, science researchers have labeled it a hoax and a fraud. Supposedly a rich millionaire, called Max, had a single cell removed from his body and implanted into a surrogate mother; ultimately this cell grew into another perfect "Max." The news of such a possibility alarmed even Congress to the extent of their calling a special hearing with some of the country's foremost experts on the subject. Fully aware of the present state of the art, these scientists were in agreement; that is, it is impossible to accomplish a sophisticated feat such as the cloning of a human being with a "basement operation." Good reasons exist for publishing fiction as fiction. The great concern that erupted among the public was indeed an interesting response. It directs us to the question of whether humans should be cloned, even if we are able to solve the biological riddles that thus far set barriers to such an achievement.

Should We?

Should research involving the cloning of humans be conducted? Many hard questions are being asked about this technological possibility, some based upon ethical grounds and some simply as common sense.

Proponents might point out that the study of cloning and cell differentiation can provide valuable insights into cellular physiology, growth, and development.

It may improve our ability to cope with cancer and other cellular diseases. The technology may also aid in our ability to heal wounds, and it could make the regeneration of lost limbs a distinct reality. Cloning may even further our understanding of the aging process. If we ever do grow adult clones, we will obviously learn a great deal about the interaction between heredity and environment in the development of organisms. Serious thought given to cloning allows one to extend the list of possibilities, albeit they begin to become more remote. For example, we could clone organs for the body from one or more cells taken from the same body. Immediately one sees the advantage of this technique because of the elimination of the constant threat of tissue rejection. Maybe we could clone endangered species before the last member of their population dies resulting in an extinction (Benton, 1985). Even more bizarre, one might think about removing a cell from a well-frozen pre-historic animal and regenerating the creature in the laboratory via cloning techniques. Some people undoubtedly have entertained thoughts about having their own cells and nuclei preserved in a frozen condition for cloning subsequent to their death. Who should we recreate if it were possible? geniuses? great musicians? homerun kings?

Many arguments have been presented in opposition to human cloning. People assert that there is simply no good reason for cloning. Certainly the world is not in need of more people. We seem to generate more than enough in the old fashioned way.

The question about who should and who should not be cloned is a valid consideration. And who will make these important decisions?

I think that everyone of us can produce a lengthy list of persons who should not be cloned. But who are we to make that judgement? A cloned army would probably be a terrible army. Good armies have diversity, and clones do not have diversity. Still, many people are concerned about such a possibility, especially in conjunction with tyrants of international powers; or worse yet, the cloning of the tyrants. Other people (mostly men) become upset over cloning because men would not be needed. A woman can donate the body cell with its nucleus to be cloned, and, of course, a woman will be the one to donate the egg to receive the nucleus and the uterus to provide for the gestation.

Technicalities aside, the prospects of cloning humans greatly disturb ethicists. Cries have frequently been heard that the xerox of life will be impersonal; that humans will become a "man-made thing;" that humans will become dehumanized. A multitude of ethical questions springs up. How do we define "parent" for clones? What happens to the unused embryo clones? What should we do with the monstrosities if they occur? Should the disposal of unwanted embryo clones be construed as murder? Does every person have a right to a unique set of genes, rather than a set which is identical to someone else; that is, the cell donor. Identical twins share all of the same genes, but the situation is not the result of an intentional act. Another possible predicament relates to the psychological aspects. The individuals resulting from cloned donor cells would know their precursor's accomplishments, ills, and failures. Coping with this information could be very difficult.

Will we?

Many investigations of the cell are constantly taking place around the laboratories of the world due to our interests in cancer, genetic diseases, regeneration, aging, and other facets of human well-being. Could researchers stumble onto the secret of cloning? Some scientists have predicted success in the cloning of humans by the next decade. On the other hand, others are cautious in their predictions.

The improbability of effecting such a technology needs to be considered. A biological assessment can begin by recalling that the cloning successes in animals, thus far, have required cells from embryos or at least immature organisms; and conversely, a complete lack of success occurs with cells and nuclei from adult organisms.

The most spectacular result was the cloning of frogs with intestinal cells from a tadpole. Researchers have never been able to clone frogs from cells of an adult frog, or anything comparable to these conditions. Cells become very specialized as development proceeds, and evidently the program in the cell is extremely difficult to change. Of course, scientists could attempt to clone human embryo cells much like they do frog embryo cells. Even if possible, however, it defeats the purpose of knowing exactly who we are cloning at that early point in the organism's development. Speculating on gene combinations is such a game of roulette.

A severe difficulty from the outset relates to the senescence of cells. Most cell types undergo senescence during growth and proliferation under in vitro (in glass) conditions; that is, they literally age and eventually die out (Hayflick and Moorhead, 1961; Hayflick, 1965; 1975; 1976; 1980). If the starting cells of such a population of cells are taken from a human embryo, they will divide approximately fifty times before dying, regardless of how well we take care of them. A series of fabulous experiments have been performed with these cells by Hayflick and his colleagues. There exists a controlling program in each of our cells ... a program to die. Nonetheless, beginning with one cell, fifty doublings will generate enough cells to form an entire adult human being.

Cells taken from adults and grown in vitro, however, do not undergo nearly as many doublings as do embryo cells. In fact, the number of doublings possible under these laboratory conditions is somewhat dependent upon the age of the cell donor. The previously discussed Hela cells, along with a few other unique cell strains, are extraordinary exceptions. How is the "program to die" overcome? Half of the genetic material of a person's cell is placed into a specialized cell called a sperm. Half of the genetic material of another person's cell is placed into a specialized cell called an egg. These two cells combine by a process called fertilization, also known as sex. The result is a developing organism, differentiation, and the formation of another human being; and this human being is now granted the opportunity for the same number of cell doublings and life span as all the other members of the species. And it makes little difference whether the mother is forty-eight years of age and the father sixty years of age, relatively old by parental standards. But again this is not cloning; rather, this is conventional reproduction. In a sense, one can look upon the perpetuation of successive generations through sexual reproduction as a kind of immortality. The salient point is that the union of genetic material from two different organisms seems to be obligatory, even for this kind of immortality. Cell senescence may prove to be a formidable obstacle to the cloning of humans. The half-clone technique, discussed earlier with regard to mouse experiments, also has its problems. Firstly, it technically is not cloning. Secondly, recall that this procedure required the doubling of the genetic material provided by one nucleus. Almost everyone has three to five very deleterious genes in their genetic material; deleterious to the extent of being lethal. Our salvation lies in their being mostly recessive; that is, these genes will not express unless homozygous. Consequently, making the genes homozygous will, in most cases, produce deleterious effects and lethality in the resultant cell, embryo, or subsequent stage of development. Besides that, only the cloning of females could even be attempted through this scheme. In order to be a male, the cell must have one Y chromosome along with an X chromosome. Cells with a YY chromosome constitution as a result of the doubling step do not survive. Doubling the genetic material with an X chromosome results in an XX situation which is the normal chromosome makeup needed for the development of females. We have in this technique, even if it did work in humans, another situation in which males become dispensable. Related experiments in mice are thus far showing a need for both moms and dads (McGrath and Solter, 1984; Barton et al., 1984; Anderegg and Markert, 1986; Surani, 1987). In order to have proper development, the fertilized egg must have one set of chromosomes from a mother and another set from a father. Researchers have replaced the male nucleus of the fertilized egg with another female nucleus, or the female nucleus with another male nucleus. The end result is a fertilized egg with either two female nuclei or two male nuclei; that is, a zygote with two mothers or two fathers. In these trials, embryonic development does not occur. The genetic contribution from the male and the female are not equivalent with regard to developmental function. Their differences influence the role of the genes during embryo development. These differences between male and female nuclei may be subtle, but obviously important. When two female nuclei are brought together, the various extraembryonic tissues are deficient, and these tissues are essential to development. When two male nuclei are brought together, the embryo itself does not develop properly. The phenomenon is called imprinting. Imprinting is the persistent influence of parentage at the gene and chromosome levels. Paternal and maternal chromosomes undergo imprinting during egg and sperm formation. The chromosomes are somehow conditioned or programmed. This is sex-related conditioning required for normal embryonic development. At any rate, a male and a female parent seems to be absolutely necessary in this species. Imprinting is still another obstacle for human cloners.

Conclusions

From a strictly biological standpoint, human cloning may not be as imminent as some seem to think. This review has outlined a number of impediments to developing such a system of technology. We all know, however, that unsurmountable problems today are often surmounted tomorrow, especially with the advent of a racing biotechnology. With that possibility in mind, students of today should continue to confront questions such as cloning, among the many other issues. After all, they are eventually going to be pressed with the critical decisions and charged with developing the appropriate regulations. Considering the historical record of scientific progress, numerous writers from all walks of life, including cell researchers, have seriously questioned whether biologists should even pursue human cloning (McKinnell, 1985). Their concerns always relate to the many other pressing problems that beg for solutions, and consequently, a higher priority of funding. Solutions to the problems of clean air, adequate water, over population, starvation, quality of food, aging, epidemics, cancer, genetic diseases, radioactive waste disposal, human relationships, and many more. Who can disagree?

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New Honorary Life Member

At the Annual Meeting in Beloit this year, a long time member of AMCBT, George Garoian of Southern Illinois University at Carbondale was awarded Honorary Life Membership status by AMCBT. George was elected to At-Large Membership on the Executive Committee of AMCBT, and to the Presidency, directly serving the membership for a six-year period. He was appointed to serve for one year on the Honorary Life Membership Nominating Committee and currently is serving on the Editorial Board of Bioscene. George has served AMCBT long and well and we welcome him to the roster of our distinguished Honorary Life Members. Congratulations George, well deserved.

Clarence Darrow and Critical Thinking

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Critical thinking, in the realm of science, is essentially analogous to logical reasoning. Max Black of Cornell University explains the analogy in this way: "LOGIC can be briefly defined as the study of reasoning. The study of any subject calls for thought, and every student is, or ought to be, a thinker; but he is not a student of logic unless he thinks about reasoning" (Black, 1952).

One of the objectives in the teaching of biology, or the sciences in general, is to develop within the student the ability to reason, to effectively use the element of abstraction in the solution of problems. The involvement of inductive thinking in the derivation of knowledge is fundamental to critical thinking, and much of inductive reasoning may rely on an ability to enter into abstraction. Very little scientific discovery is purely inductive; many solutions to problems are founded on a great store of information. Deductively, we seek available information to assist us in designing investigations which will lead to new or novel solutions.

Critical thinking is not something we can teach or learn from a text; nor is it something that can be told to a student. Students must be actively involved in the process. Consequently, we may ask. Is our teaching of biology such that the activities lend themselves to enhancing the desired outcome of a logical thought process? To answer this question we must each evaluate our biology curriculums with regard to content, laboratory and field experiences and methods of teaching. What provisions are made for---student designed investigations; inquiry activities in the laboratory, in lecture and discussion sessions?...in contrast to straight lecture, verification laboratory exercises; and, few if any field assignments.

We will need to sacrifice some sacred content of biological knowledge to provide time to exercise those kinds of practices which will enhance the opportunities of the student to become as critical a thinker as possible.

All of us have attempted to foster inductive thinking in our classes. It is interesting to note that it is not only in recent years that we have been admonished to do so. We may reflect on the teaching of Socrates for evidence to support the premise; but, it is interesting to examine the writings of persons apart from teaching who have made observations about the process of critical thinking. As a result of his contribution to gaining for teachers the freedom of expression, through the John Scopes trial, it is relevant to look at the work of Clarence Darrow. It is revealing to discover how he viewed education and how we may establish analogies with Darrow's insights into learning.

Clarence Darrow's career in law is marked with many noteworthy cases involving among others, the struggle for equity in the labor forces of the United States; the evaluation of legislation at the federal level (the NRA: National Recovery Act); and cases involving individual clients. Two trials which drew international attention were the Leopold and Loeb case and the Dayton Case or Scopes Trial. From a brief review of these cases we immediately develop a feeling for the character and the nature of the thinking process of Darrow.

Of the Leopold and Loeb case, Darrow states,

> "I endeavored in my address to make a plain, straightforward statement of facts on the case, and I meant to apply such knowledge as we now have of the motives that move men. The argument took the longest part of two court days and was printed almost word for word in some of the Chicago papers, and very extensively by the press outside the city, so that people at the time were fairly familiar with the facts in the case, and certainly of the outcome" (Darrow, 1932).

This quotation is in reference to a tragedy which occurred in 1924; the tragedy involved a boy named Robert Franks. Robert, who was 14 years of age, had not come home from school and his disappearance alarmed his parents. The next day Robert's father received a ransom note demanding $10,000.00 be delivered to a specific site in Chicago. Robert had been kidnapped by Richard Loeb and Nathan Leopold, the sons of wealthy Chicago families. These young men who were 17 and 18 years old, had out of want for something exciting to do, conceived what they thought would be the perfect crime.

Robert Franks lived in the same neighborhood and had accepted a ride home from school from Loeb and Leopold. During the ride, Franks was hit on the head with a chisel and he died. Loeb and Leopold left the naked body in a railroad culvert where it was discovered. Discovered, too, was a pair of spectacles which were traced to Leopold. Eventually, Loeb and Leopold told their terrible story and were charged with kidnapping and murder (Darrow, 1932).

Clarence Darrow was asked to defend Loeb and Leopold and he consented to take the case knowing full well the public bias and outrage against the defendants. Darrow was opposed to capital punishment and his objective for the case was to keep Loeb and Leopold from the gallows.

Darrow's insight into human nature and how man thinks under a given set of circumstances illustrates his ability to analyze a problem and how to apply the analysis to a solution. Darrow was very aware of bias and emotion as they enter the decision making process. Relative to the Loeb-Leopold case, Darrow stated,

> "Everyone who thinks knows how common it is for men to set aside their views. Most men never had but one or two ideas, anyhow, and to these they hang like grim death. How often do people set aside their beliefs on politics, on religion, or any other question if in conflict with something they want to do? To set aside an opinion without evidence is not only psycho-logically impossible, but is phy-sically absurd" (Darrow, 1932).

To confirm Darrow's reference to setting aside beliefs when conflict arises we need only to refer to fraud in science reported by Broad and Wade (1982). It was Mark Spector, a 24 year old graduate student, who consistently and deliberately altered data derived from gel electrophoresis to confirm preconceived ideas about the nature of cancer cells. Spector knowingly deceived his advisor and the scientific community. Another case of fraud in medical research is cited by Roman (1988), in the use of tranquilizers known as neuroleptics; a case in which data were deliberately falsified and misleading. In each of these cases the nature of the research was oriented away from acquiring data objectively; this was accomplished by arranging the investigation to produce data which would confirm preconceived ideas.

Having preconceived ideas about the possible solution to a problem is quite acceptable; we call these ideas hypotheses to be tested. But, manipulating investigative procedures to produce the desired data which would permit the acceptance of a hypothesis is quite unethical and may be unlawful.

For most biologists, the name Clarence Darrow is nearly synonymous with "the Dayton Case," or the trial of John T. Scopes. This was the only case for which Darrow volunteered his services because he "really wanted to take part in it" (Darrow, 1932). Darrow was an advocate of a free-flow of knowledge, of information, and he was dismayed that legislatures would pass laws forbidding such practice. So it was in some Southern states, including the State of Tennessee, that a bill was passed which prohibited the teaching of "...any doctrine in conflict with the Genesis story" (Darrow, 1932).

John T. Scopes was a biology teacher in Dayton, Tennessee, where the textbook Hunter's Biology was used and where John Scopes taught the students that it was conceivable that life on earth may have originated or evolved from the sea. Scopes was arrested for violating the law and his arrest set the stage for the Scopes Trial, which in reality placed the validity of the law on trial rather than Scopes. Darrow was the attorney for the defense while William Jennings Bryan, the noted fundamentalist, was the attorney for the prosecution.

Bryan's background in the sciences was summed in his comment that he was, "...not so much interested in the age of rocks as in the Rock of Ages" (Darrow, 1932). Darrow had been reared on books of science and some of his favorite subjects while in school and after he left school, were in the natural sciences. He came well prepared to argue both science and religion.

One of the chief precepts which the world learned from this famous case in 1925, was that we cannot and should not legislate the free exchange of knowledge. All through his career Darrow was a proponent, a fighter, for the dissemination of facts and the right of the individual to express his ideas. Certainly, this has been one of the underlying strengths which has enabled science to make the advances it has. However, we need only to look at the history of science to determine that this has not always been so.

Darrow must be given much credit for tearing down the curtain that shielded the student from ideas. Unfortunately, this issue has not been completely resolved and even today we continue to battle for the cause of a free exchange of ideas and scientific information.

The first Darrow to reach America from England arrived in about 1680 (Gurko, 1965). One of the descendents of the first Darrows was Amirus Darrow who graduated from the Meadville Theological Seminary and had been offered a parish by the Unitarian Church. His religious belief had been strong, but as he progressed through seminary, he began to have doubts; there were questions neither he nor his teachers could answer. Upon graduation he rejected the life of a minister. Amirus had married Emily Eddy whom he had met while a student in Ellsworth Academy in Amboy, Ohio, and together they set off on life's journey. After working at many jobs, Amirus became a carpenter and began making various kinds of furniture for the people of Kinsman, Ohio, where he and Emily had settled. Kinsman was a small village of 400-500 persons and it was here, on April 18, 1857, where their fifth child, Clarence Seward, (for William Henry Seward) was born and grew up (Gurko, 1965).

The one great passion of Darrow's parents was books, and Amirus who spent endless scholarly hours with his hundreds of books, tried to imbue his eight children with this same love. Clarence's father constantly pursued the cause of learning and reading with his children. Clarence stated that he did not remember when he could not read. Much of his father's motivation came from citing other people as examples of scholarliness...his reference to John Stuart Mill's study of Greek at the age of three was a particular annoyance to Clarence, since he would rather have been playing baseball than learning Greek or Latin or studying mathematics (Gurko, 1965). Darrow had mastered the multiplication tables and he had spent endless hours on memorizing the weights and measures, but he was dismayed to learn that these tables were conveniently located in the dictionary and were at hand when needed.

He makes a valid point in stating that school books were filled with notable precepts and seemed not to have any application to real life.

Because teachers tried so hard to get them to learn, the students viewed them as natural enemies who could not see that a child's life depended on activity and exercise, the law of life. "The mistake of maturity," he claimed, "is that maturity lives in the present and forgets the lessons of the past, that life is mostly illusions and the illusions of childhood are more alluring than those of later years" (Darrow, 1932).

Darrow points to the futility of schools relying almost entirely on rote learning. His observation is in line with the thinking of today, that science at all levels must actively involve the student through inquiry and challenging activities; we cannot assume that lectures and readings alone will motivate students in biology.

In reference to the study of grammar, Darrow states, "The longer I live the surer I am that the chief trouble of writers and speakers is the lack of interesting thoughts, and not of proper words" (Darrow, 1932).

One might say too, that in biology we do not lack for concepts to be learned, but rather a shortcoming may be our lack of exercises which promote inductive thinking and problem solving based on these fundamental concepts.

In general, Darrow found his school study to be too moralistic, too filled with idealistic stories and not enough focused on the real world of the person. Publishers, he thought, were hypocrits...to publish books which promoted honesty and moral and ethical values, yet they themselves practiced less than this. Honesty, he felt, was espoused by parents and teachers alike, yet he maintained, the child is fundamentally truthful and has no need to lie or cheat. This lesson in straying from the truth he contends, comes by example from parents and teachers and ultimately a child wanders from the truth out of fear of punishment or reprimand. Darrow states, "Children tell the truth as naturally as they breathe, and it is only the stupidity and brutality of parents and teachers that drive them to tell lies. In high society and low, parents lie to children much oftener than children lie to parents; it would not occur to a child to lie unless someone made him feel the need of doing so" (Darrow, 1932).

Here one may cite a relevance to teaching, that

by example we as teachers must display the virtues we wish our students to possess. If we desire students to be involved with experimentation and inquiry, we must engage in these activities ourselves. Science must be visible in our classroom and laboratory environments.

If students are to foster good reading habits in science, if students are to use the language of science properly (or for that matter, grammar in general) then biology teachers must be conscious of these objectives and make concerted efforts to assist the student to achieve acceptable levels of learning.

Darrow was not a psychologist but he was astute enough to recognize that success in school and elsewhere in life depended on some extrinsic motivation and reinforcement. Rewards in Sunday School (to which his parents sent him) took the form of colorful cards; yet his father for all of his emphasis in the classics, was remiss in not providing a word of encouragement when Clarence did well in school or on the baseball field. So disappointed was Darrow in the methods of teaching and learning that he said he, "...used to beg my father to throw away my stupid books and apprentice me to learn the blacksmith trade" (Darrow, 1932). His father guided him, but Clarence was not sure that his father was right. How easy it can be for teachers to provide the appropriate word at the appropriate time which may well send a student on to greater successes. Compassion, understanding and respect for the dignity of the student need not be viewed as weaknesses in the teacher. Darrow comments on the worth of the individual in this way..."After much reflection I have reached the conclusion that all people are envious to a greater or less degree, and of course each one's goodness and importance increased in proportion as those of others are made to grow less" (Darrow, 1932).

Darrow had a high regard for nature, for life. His favorite subjects in school were biology and the natural sciences. When Darrow was practicing law in Chicago, a large room in his apartment was devoted to weekly meetings of the Biology Club, whose members lectured on and discussed scientific topics (Gurko, 1965). Darrow comments about his school science:

"We were given certain rules as to our treatment of animals, (and) we were told to be kind to them, but no effort was made to awaken the imagination of the child so that in a way he might put himself in place of the helpless beings with whom he lived" (Darrow, 1932).

All through Darrow's long and distinguished career as an attorney, one is able to discern this attitude toward his clients; he placed himself in the position of the client and then constructed a defense in keeping with the virtues of the person he was defending. Would not this be appropriate for teachers of science, to put ourselves in the place of the student and ask...If I were this student, how would I like to have this course taught? There is a great deal to be learned from placing ourselves in the other person's position to develop more than one perspective on any issue, whether the issue is scientific, political or aligned with teaching method.

Darrow was not known to be the epitome of sartorical splendor. His wife would buy fine suits of clothing for him; silk shirts; and appropriate ties. Yet, when he dressed in these well-chosen items, Darrow had a knack for making even the most expensive suits look rumpled and ill-kept. It is important that we look behind the facade which may clothe a person.

In the final analysis, we may have to look at ourselves and make a more concentrated effort to help students learn science, rather than losing our perspective of teaching through trying to impress students with our "vast" knowledge of science. For the most part, telling a student, or dispensing information, may not be teaching.

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Dear Members:

Please send all resolutions to the Chairman of the Resolutions Committee:

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LOUIS AGASSIZ:"FATHER OF AMERICAN BIOLOGY"

by
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One of the greatest naturalists and biology teachers of the 19th century was the Swiss-born scientist, Louis Agassiz. More than any one man, Agassiz was responsible for bringing science to the general public. William James, the philosopher, gives us an insight into the popular feeling about Agassiz when he said: "He was of so commanding a presence, so curious and inquiring, so responsive and expressive, and so generous of himself and of his own, that everyone said of him: 'Here is no musty savant, but a man, a great man... '". Agassiz also made outstanding contributions to the study of natural history and geology and achieved lasting fame through his innovative teaching methods which changed the direction of science education in the United States.

Louis Agassiz was born May 28th, 1807, in the small village of Motier, Switzerland, the son of a local protestant minister. He was educated first at home and studied later at the academy of Lausanne. His collegiate studies were conducted at the universities of Zurich, Heidelberg and Munich. In 1829, at the age of twenty-two, the degree of Doctor of Philosophy was awarded to him by the University of Munich, and a year later in 1830, the Doctor of Medicine degree.

Even as a young boy the world of biology fascinated him. He spent many hours studying the freshwater fish of his native Switzerland. His interest in ichthyology continued throughout his college studies, and prior to his second graduation from the University of Munich in 1830, he edited an important work on the freshwater fishes of Brazil. The specimens for this study were largely collected from the Amazon River and had been brought back to Germany by two eminent naturalists, one of which died in 1826. Thereupon the collection was turned over to the young Agassiz for description and classification. He threw himself into this work, and in the year 1829 the task was completed and culminated in the publication Selecta Genera et Piscium.

After graduation in 1830, Agassiz moved to Paris, France, where he worked in the Museum of Natural History. He soon became the protege of French paleontologist and anatomist Baron Cuvier. After Cuvier's death in 1832, Agassiz obtained a professorship in natural history at the University of Neuchatel, Switzerland. Here he began his monumental study of fossil fish which resulted in his five volume work entitled Studies on Fossil Fish. Using the principles of comparative anatomy learned from Cuvier, he was able to describe more than 1,700 species of fossil fish, 300 of which were previously unknown. Agassiz's work gave impetus to the study of extinct life and laid the foundation for the new science of paleichthyology.

In 1836, Agassiz began his study of glaciers. He had a hut constructed on one of the glaciers and lived in it during the summer months. After charting glacier movements, Agassiz was soon convinced that at one time vast areas of the earth were covered with sheets of ice (glaciers) resembling those now found in Greenland. His findings contradicted the then held belief that only uniform and gradual changes in the earth's geological history had occurred. In 1840, his work on glaciers resulted in the publication of his book Studies on the Glaciers. This work brought him widespread fame as the originator of the concept of ice ages and gave fresh impetus to the study of glacial phenomena worldwide.

In 1846, Agassiz was invited to give a series of lectures in Boston. He immediately fell in love with America and was enthusiastically received by the audiences he spoke before. While lecturing, Agassiz would draw chalk diagrams of the various forms of life he was talking about. Ernest Longfellow, son of the poet and an artist himself, said, "It was a real treat to see a perfect fish or a skeleton develop under his hand with extraordinary sureness and perfect knowledge, without any hesitation or correcting." He decided to remain in America.

In 1848, Harvard University offered him a professorship in natural history. It soon became apparent that Agassiz was quite different from the other professors of his day. As the Boston Transcript reported, Agassiz "smashed all the traditions of correctness of demeanor and chilly aloofness.... He wore a soft hat and smoked like a steam engine." While at Harvard he founded the Museum of Comparative Zoology (later named in his honor) and served as its first curator. His scientific works during this period consisted of the following: Lake Superior (1850), Contributions to the Natural History of the United States (1857-62), and Essay on Classification (1859) which failed to take into account the fact that science was moving away from the idea of creationism toward that of Darwin's theory of evolution. A deeply religious man, Agassiz believed that evolutionary change was brought about by God, who in order to make a new design would first destroy the original living thing. Besides his major contributions to biology, there were many papers written on various topics in the field of natural history and especially on fishes.

Ichthyology continued to fascinate him, and so in 1868, Agassiz organized an expedition to Brazil, primarily to study the fish life of the Amazon River. He and his wife co-authored an interesting account of this expedition entitled A Journey to Brazil (1868). In 1871, he furthered his study of ichthyology by taking a trip to California to study the coastal surf fishes.

Agassiz's method of teaching was to emphasize the observation of nature over that of learning from books. He discouraged the use of textbooks and was often quoted as saying, "Read nature not books." The purpose of study was not to memorize facts but rather to observe the natural world in order to gather the needed facts.

At times he would give his students specimens for observation while he lectured. He did this because as he said, "My intention is not, however, to impart information, but to throw the burden of study on you. If I succeed in teaching you to observe, my aim will be attained." Agassiz felt the best source for these specimens were the students themselves. They were encouraged to collect specimens from the natural habitat.

In the laboratory Agassiz emphasized the inductive approach to learning. He felt it was his responsibility as a teacher to define a problem but the students' responsibility to solve the problem. A laboratory session in Agassiz's class was often a strenuous situation. He would leave the laboratory for hours at a time looking in every so often to ask the students what they had learned from their specimens. If Agassiz was not satisfied with the students' answers, he would tell them that it was not enough and leave the students to observe for a while longer.

In the interest of better science teaching, Agassiz founded the first summer school for biology teachers on the island of Penikese in Buzzards Bay, MA in 1873. This school was named after John Anderson, a wealthy New York merchant, who upon reading of Agassiz's proposal for a summer school in the New York newspapers, donated the island and fifty thousand dollars in cash. The Anderson School of Natural History opened July 8, 1873, with 58 students in attendance.

As a result of his teaching activities, it has been said that every notable biology teacher of the latter half of the nineteenth century was either a pupil of Agassiz at one time or had been taught by one of Agassiz's former students. Because of this fact, Agassiz is considered to be the "Father of American biology." When asked what his greatest accomplishment in life was, Agassiz replied, "I have taught men to observe." And so he had in that his teaching methods let students discover for themselves.

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TWENTY POINTS FAVORING UNDERGRADUATE RESEARCH

by
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1. Lets undergraduates experience joy and challenge of doing science -- lets them work on something that is not fully understood.
2. Reveals student attributes (independence, perseverance, creativity, ingenuity) that courses often fail to reveal -- attributes that are often more important than those that courses reinforce.
3. Lets student test depth of personal interest in field vis a vis a career; mentor also observes this depth of interest.
4. Lets student develop practical skills.
5. Gives student opportunity to develop and take pride in personal, specific expertise -- expertise that may sustain him or her during adjustment to graduate school.
6. Encourages elevation of personal standards and greater degree of commitment to field -- motivates more mature view of coursework as means to end rather than ends in themselves.
7. Lets student stand taller among peers and members of scientific community; student ceases to be pure student but instead becomes junior member of scientific community.
8. Gives student something of his or her own to write and talk about.
9. Improves prospects for gaining admission and support in graduate school; many graduate schools want student to describe undergraduate research experience.
10. Exposes student to original literature; breaks textbook syndrome.
11. Develops strong, lasting relationship between student and mentor -- one that continues and possibly later reverses, whereby mentor becomes primary receiver.
12. Puts faculty on spot. Stimulates faculty research activity, even leads to redirection of faculty research. Fosters writing of proposals, etc.
13. Strong student/mentor bond produces stronger allegiance and support among graduates. Latter want to repay debt.
14. Ongoing faculty/student research sustains pride in alma mater among graduates. Paves way for continuing, fruitful interaction with alumni.
15. Prepares and favorably predisposes next generation of collegiate faculty, who will know from firsthand experience that research is possible and important in colleges.
16. Demonstrates that courses are only part of the educational delivery system.
17. Students produce valuable results! Students often bring superior pre-existing skills to project.
18. Collaborative venture broadens student/faculty relationship.
19. Fill in from your experience.
20. Goto 19.

Kudos and Future Plans

Kudos to John Jungck of Beloit and Kathy Hunt of Henderson Community College for putting together a fine meeting. The format was excellent, and the feedback on the sessions, the field trips, the food and the fellowship was all glowing. Next year we meet at **Quincy College** from September 28-30. The theme will be **"The Values of Biology."** We want to focus on those intangible aspects of biology we prize: honesty, integrity, aesthetics, the beauty of life, the sense of rightness or order, etc. This sense is well captured by Judith Wechsler in the Introduction to On Aesthetics of Science.[1].

> "Scientists talking about their own work and that of other scientists use the terms "beauty," "elegance," and "economy" with the euphoria of praise more characteristically applied to painting, music and poetry. Or there is the exclamation of recognition - the "Aha" that accompanies the discovery of a connection or an unexpected but utterly right realization in art and science. These are epithets of the sense of "fit" - of finding the most appropriate, evocative and correspondent expression for a reality heretofore unarticulated and unperceived, but strongly sensed and actively probed. The right formulation or model which "capture" this reality seems almost magical in its potency. Both art and science evoke the previously ineffable in making ideas and concepts clear, cogent and manipulable."

For some of us the first attraction of biology was the outdoors, for others the desire to know how things work; but for each of us living things caught not just our rationality but our aesthetic senses. For all of us, the sometimes hidden objective in each course we teach is the transmission of that sense of joy and wonder. At the same time, we seek to transfer the ethics of the field: the need for honesty, accuracy and integrity in both the plan and the process.

As you plan to come to the next meeting, take a minute or two to think about sharing your expertise with the membership. Enclosed in the packet that covered this journal issue is a program planning sheet. Anyone willing to contribute please send the form to next year's program planner, Sr. Jeanene Yackey of Fontbonne College in St. Louis.

Also remember to make a pitch to your colleagues to join the organization for there are increases in services planned and we hope to give the organization more exposure. A summary of the executive planning session will appear in the next Midwest Bioscene.

1. Wechsler, Judith. ed. 1978. On Aesthetics in Science. The MIT Press, Cambridge, Massachusetts.