Hormonal Regulation of Cotyledon Senescence

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Senescence is defined as changes which lead sooner or later to the death of an organism or some part of an organism. Senescent processes are encountered in all parts of a plant at all stages of the plant's life cycle (Woolhouse, 1978). All cells, tissues and organs of a plant undergo senescence throughout the entire life of the plant. Figure 1 is a schematic diagram of a plant which illustrates the principal organs and the factors which are known to alter the rate of senescence of various organs. A wide range of growth substances and other internal and external factors are involved in promotion or inhibition of senescent processes. But the dogmatic generalization which is presented in most textbooks states that senescence in plants tissue is promoted by ethylene and inhibited by cytokinins.

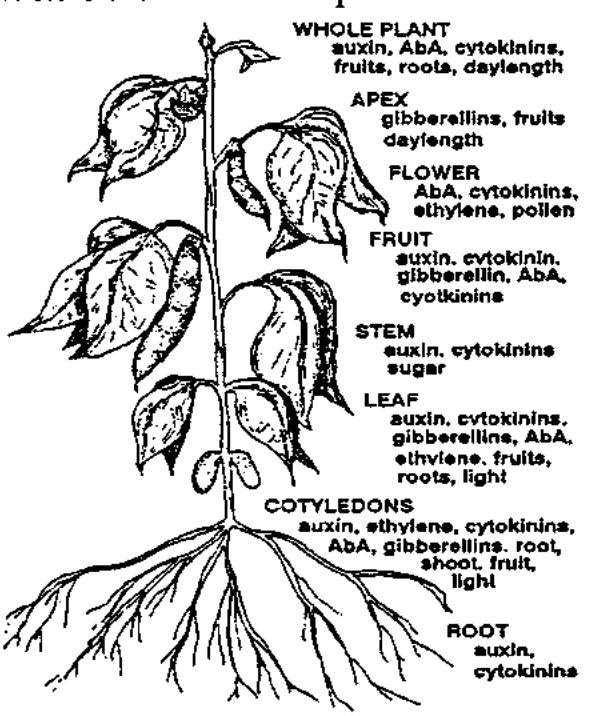

Figure 1. Factors which regulate the senescent processes in various tissues and organs of a plant (adapted from Sexton and Woolhouse, 1984).

Cytokinins are recognized as the plant growth regulators with primary control over the promotion of cell division. Cytokinins are required in plant cell culture systems to induce cell division. Cells which have undergone terminal differentiation can revert to a meristematic, parenchymatous cell type under the influence of cytokinins.

Point application of cytokinins to the surface of detached leaves results in the region of application remaining green while surrounding tissue turns yellow. This phenomena results from the induction of metabolic activity in the region where cytokinins are applied. The treated tissue functions as a metabolic sink which drains the surrounding tissue of nutrients. Thus the regions of a detached leaf which are exposed to exogenous cytokinins appear to have a retarded rate of senescence when compared to surrounding regions. Thus cytokinins have been referred to as "fountain of youth" hormones in plants.

Fruit ripening, one of the best documented forms of senescence, was the first plant response which was clearly shown to be regulated by ethylene. Ethylene is produced at very high levels by many ripening fruit. Application of ethylene in gaseous or liquid form (ethephon; Figure 2) hastens the ripening of many fruits. Sufficient quantities of ethylene are produced by fruit to allow vacuum extraction of internal gases for quantification by

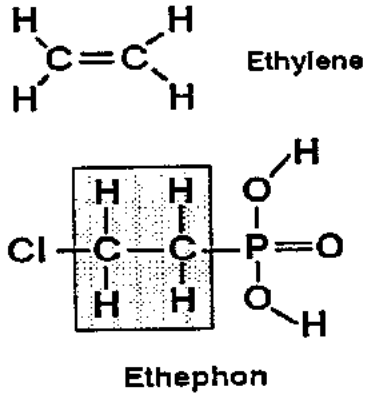

Figure 2. Structure of ethylene and the ethylene releasing agent ethephon. The shaded region of the ethephon molecule is released as ethylene under neutral or weakly acidic conditions.

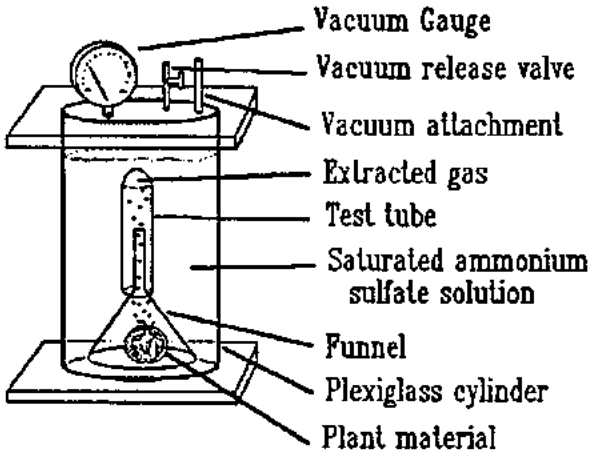

Figure 3. Apparatus for extraction of endogenous ethylene from plant tissues. Plant tissue is placed inside the Plexiglas cylinder in a saturated solution of degassed ammonium sulfate. A vacuum is used to remove ethylene from the tissue gaseous and liquid phases. The extracted gases and ethylene content are quantitated using flame ionization gas chromatography.

flame ionization gas chromatography (Figure 3). Similar alterations in ethylene levels and rates of senescence can be observed during flower fading, and during leaf and cotyledon degreening and senescence.

Cytokinins can alter the rate of ethylene biosynthesis. Lau and Yang (1976) observed stimulation of ethylene biosynthesis by excised mung bean hypocotyl segments treated with cytokinin. Ethylene biosynthesis is synergistically enhanced with the application of cytokinin and calcium. Stimulation of ethylene biosynthesis by cytokinin is thought to result from enhancement of Ca^{2+} uptake by cytokinin into cells and specifically into the Pacemaker Reaction of the ethylene biosynthetic pathway (Yang *et al.*, 1980). The stimulation of ethylene biosynthesis (which promotes senescence) by cytokinins (which inhibit senescence) illustrates the complexity of hormonal interactions which occur during physiological processes.

The stimulation of ethylene biosynthesis by cytokinin is only one example of the interactions which occur between the plant hormones. Many interactions have been documented (Letham *et al.*, 1978). Figure 4 illustrates the relationship between the five major classes of

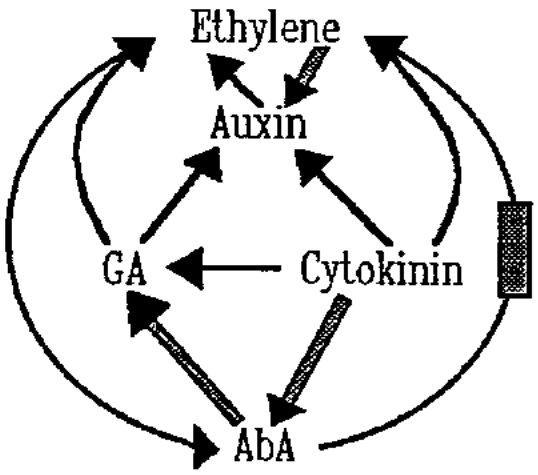

Figure 4. Hormonal interactions in plant tissues. Solid lines indicate hormones which increase the level of another hormone. Shaded lines indicate hormones which reduces the level of another hormone (adapted from Letham *et al.*, 1978).

plant hormones. When examining the effect of any single plant growth regulator, it is important to consider possible interactions and involvements of other

hormones. A response to a hormone may result from enhancement or suppression of the synthesis or activity of another hormone.

This laboratory exercise explores the process of cotyledon senescence as a model system for examining the complexity of hormonal interactions in a physiological process. The effects of the five major classes of plant hormones on cotyledon senescence are examined. This laboratory exercise requires minimal equipment and is presented in a form which can be used in an introductory level course. Modifications are suggested at the end of this exercise which increase the complexity of data analysis and interpretation for use in advanced courses.

Goals of the Experiment

1. Observe the process of senescence in detached cotyledons.
2. Determine the effect of plant hormones on the rate of senescence in detached cotyledons.

Time Requirements

0.5 hr approximately 4 days prior to the experiment to plant seed
1.0 hr prior to the experiment to prepare test solutions
1.0 hr to prepare humidified chambers, excise cotyledons and setup the experiment
0.1 hr every other day for two weeks to make and record observations or photograph results.

Materials and equipment

Seed [radish, turnip, Chinese cabbage, Fast Plant (*Brassica rapa*) or almost any *Brassica* sp.]
Plastic 35mm film cans (Four cans per student)
Osmocote fertilizer pellets
Nail punch
Soil mixture (1:1 peat: vermiculite)
Unwaxed cotton cord
Plastic storage box or plastic shoe box
Pellon fabric
Scott brand household paper towel
Disposable plastic petri plates, 100x15 mm (Minimum of six petri plates per student)
Filter paper (Whatman No. 1)
Indole-3-acetic acid; Benzyladenine; Gibberellic acid; Abscisic acid; Ethephon
0.1 N HCl; 0.1 N NaOH
pH meter
Single edge razor blades
Various glassware; Distilled water
Optional: Micrometer, Spectronic 20 or color print charts, Photographic equipment (camera with macrolense and color film)

Methods

Seedling Preparation. This step should be done in advance of the experiment by the students or instructor. Seeds are planted in plastic film cans as illustrated in Figures 5 and 6. Plant five seeds per film can. Each student should prepare four film cans. Students can prepare the film cans during the laboratory period a week prior to the experiment; the instructor will add water to initiate the germination approximately 4 days before the next laboratory period. For optimal growth, place the seeds/seedlings under a fluorescent light bank to maintain constant illumination of < 350 foot candles and 22° C. Seedlings are used when the cotyledons are fully expanded; this should require 3-4 days, depending on the species which is selected.

Solution Preparation. Solutions should be prepared of the five hormones which will be used in the experiment. Optimal concentrations for the hormones are: 0.1 mM indole-3-acetic acid (0.0175 g/L), 0.1 mM gibberellic acid (0.0346 g/L), 10 mM abscisic acid (0.00264 g/L), 1 mM benzyladenine (0.000225 g/L), 250 ppm ethephon (250 mL/L), and distilled water for the control treatment. The pH of all solutions should be adjusted to 6.2. Twenty milliliters of each solution will be required initially for each replicate of each treatment. An additional 3-5 ml of each solution will be required every two days by each replicate.

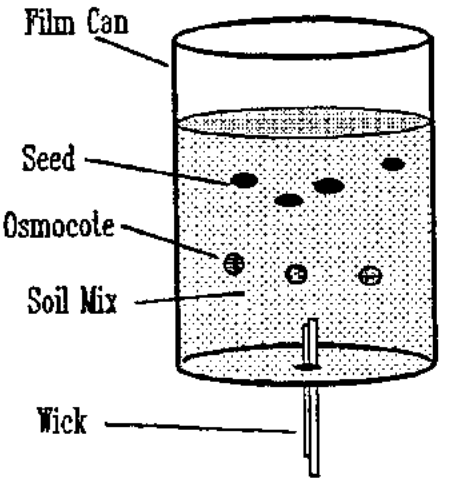

Figure 5. Diagrammatic representation of the use of plastic 35 mm film cans to germinate and grow seedlings and plants. Hole in bottom of can is made using a nail punch. Unwaxed cotton cord is used as a wick. The soil is peat:vermiculite (1:1). Three or four pellets of Osmocote are placed in each can as fertilizer.

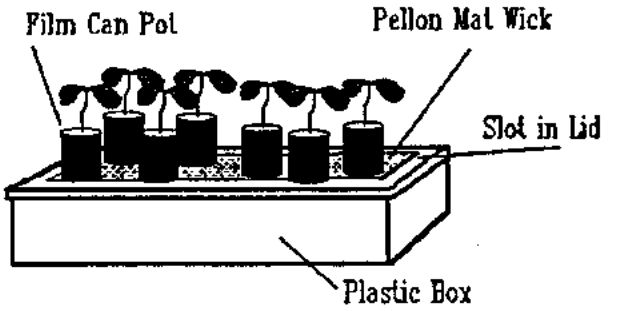

Figure 6. Planting trays for use with the film can system. Plastic boxes are used as water reservoirs. A slot is cut into the lid of the box. A rectangle of bleached Pellon covers the top of the box and extends through the slot into the reservoir. The Pellon mat serves as a wick.

Humidified Chambers. Each student should prepare a minimum of six chambers (1 replicate). Each chamber consists of a petri plate labeled on the top and bottom with the treatment. Two filter paper disks are placed in the bottom half and 2 filter paper disks are placed in the upper half of each petri plate. The filter paper disks are moistened by adding 10 ml of the hormone solution to each half of the petri plate. After 0.5 to 1.0 minutes the excess solution is drained from both halves of the petri plates. The tops of the plates are placed on the bottoms; the filter paper in the top halves should remain adhered to the top inside surface of the petri plates.

Cotyledon Preparation. Excise 30 cotyledons from the seedlings using a single edge razor blade. Place the excised cotyledons in pairs from the same seedling on a moist paper towel. Cotyledons should be fully expanded and bright green at this stage.

Experimental Procedure

1. Select 5 cotyledons and place the lower surface of the cotyledon against the filter paper in the bottom half of each of the 6 petri plates (5 treatments and 1 control). From those excised, cotyledons should be selected randomly except that care should be taken not to select both cotyledons from a single plant for a single treatment; this could bias the results.

2. If results are recorded using photographs, take an initial 0 hr photo. Replace the cover on each plate.

3. Observe or photograph each plate at 48 hr intervals for a two week period. After recording the observations, dampen the filter paper in the upper and lower halves of each plate with the appropriate test solution.

Observations and Questions

What changes occur in the color of the cotyledons during the experiment? Is degreening delayed or promoted by any of the treatments?

Do changes occur in the total surface area of any of the cotyledons? Do changes occur in the thickness of the cotyledons?

Observe the cut surface where the cotyledons were excised from the seedlings. Do you observe any response to the various hormone treatment by these cells? Develop a hypothesis to account for these changes. How would you design an experiment to test your hypothesis?

Do any of the treatments develop fungal or bacterial contamination during the course of the experiment? How could one account for the occurrence of contamination in particular treatments? Why is it not advisable to include antibiotics or antifungal agents in the solutions to control contamination? What is the mode of action of most antibiotic and antifungal agents? What effects might be expected if antibiotic or antifungal agents were used? How would the experiment need to be redesigned if antibiotic or antifungal agents were included? Could you design a protocol which would control contamination without the use of antibiotics or antifungal agents?

Suggestions and Modifications for Additional Experiments

1. The basic experiment relies on qualitative observations of senescence. Several types of quantitative measures of senescence can be performed.

A. Surface area measurements can be obtained by tracing the outline of the cotyledons onto index card stock, cutting out and weighing the tracingsor by digital image analysis.

B. Micrometers can be used to measure changes in thickness of the cotyledons. Inexpensive micrometers can be purchased at any hardware or building supply store.

C. Degreening can be quantified by chopping one or two of the cotyledons into fine pieces and placing the material in 5 ml of 95% acetone. After 30 min the chlorophyll within the tissue is removed by the acetone solution. The acetone solution can be decanted and the chlorophyll content quantified using a Spectronic 20. A time course of degreening can be prepared if sufficient replicates are available or measurements can be made at the end of the two week period.

D. A less time consuming measure of degreening is the use of a color comparison chart. A number of different color charts are available commercially but custom color paint charts can be found at most hardware and paint stores. These charts will allow students to match the paint chip color to cotyledon color. It is recommended that the instructor assemble one or more color charts using only the greens to yellows to light browns from the paint charts. Use of the chart allows students to observe subtle changes in degreening which might be overlooked or forgotten between the observations.

E. Changes in protein, reducing sugars, lipids, and starch can be measured using the simple tests which are described in most biology laboratory manuals.

F. An indication of changes in the "leakiness" of membranes can be determined if a conductivity meter is available. The five cotyledons of a treatment replicate are placed in a test tube containing 5 ml of distilled water. After 30 minutes the cotyledons are removed from the tube and placed back in the petri dish. The conductivity of the solution in the tube is measured. Changes in conductivity are most dramatic during the later stages of senescence.

2. Students can vary the hormone concentrations. Decreasing the concentration from the optimum by up to 4 orders of magnitude or increasing the concentration by up to 2 orders of magnitude will significantly alter the rate of senescence.

3. Several antagonists of the plant hormones can be used to allow students to further examine the role of the hormones in senescence. Since many antagonists have indirect modes of action, the students are required to perform additional library research in order to interpret some of the unusual effects these compounds produce. Malic hydrazide, napthalphlamic acid, and the morphactins are auxin antagonists available from most scientific chemical supply catalogs. The compound 4-cyclopentylamino-2-methyl thiopyrrolo [2,3-d]pyrimidine is a potent "anti"cytokinin. AMO1618 is a

commonly available inhibitor of GA3 synthesis. The herbicide fluoridone is an inhibitor of abscisic acid synthesis which produces interesting effects due to an inhibition of carotenoid biosynthesis. A large group of compounds are available which alter ethylene biosynthesis or activity. L-canaline, mimosine, cobalt chloride, aminoethyoxyvinylglycine, and acetylsalicylic acid inhibit ethylene biosynthesis. Silver ions in the form of silver nitrate (very toxic to tissues) or silver thiosulfate (used to delay flower fading in the floral industry) are effective in blocking the action of ethylene.

Use of antagonists of the hormones allow a student or group of students within a laboratory section to design unique variations of the experiment and provides a more realistic research environment within the setting of a teaching laboratory.

These variations present a greater challenge for the student in experimental design and interpretation and should be used only with more advanced students.

Potential Problems and Considerations

One variable which must be considered when using cotyledons in hormone treatment experiments is that young cotyledons which have not fully expanded can exhibit other types of responses to hormones. Radish cotyledon expansion is a commonly used bioassay for cytokinins (Letham, 1971). Gibberellins can also induce expansion of young cotyledons of many species.

During the later stages of senescence, tissues "leak" solutes and other nutrients. Thus, fungal and bacterial contamination may become significant. Students may use this as an indicator of a stage of senescence; it does not have to be considered to be a problem with the experiment. Incorporation of antibiotics or antifungal agents are not recommended. These compounds generally alter tissue metabolism and effect hormone activity. If contamination becomes an major issue, the solutions can be filter sterilized, filter paper and other materials can be autoclaved, and the cotyledons can be surface sterilized in a 4% household bleach solution.

One observation which students often make is the presence of "growths" on the cut surface of the cotyledons in the cytokinin treatment. The "growths" are undifferentiated cells (callus) which form at the point of excision. These student observations can be used to supplement discussions of plant tissue culture and hormonal involvement in cell division.

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Botany Students as Scientists

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Recent criticisms of science education in the United States, along with suggestions on improving science teaching (e.g., Moore, 1990), make it seem that there is not much sciene nor excitement in most science teaching. However, many professors at public and private universities have long been quietly teaching various biological disciplines, like botany, as if they were the sciences which textbooks and critics suggest they should be. Indeed, Seago (1992) even presented a pedagogical rationale for the role of undergraduate student research, i.e., science, in college courses. Such pedagogy does more than provide students the excitement and discovery of science; the critical thinking it fosters can be integrated not only into a course, but into a student's academic program and life.

The formal communications of research are, of course, the culmination of science and thus of great importance to students.

Commentaries by well-known journal editors claim that there is a lack of excitement in biological disciplines, a lack of active participation by students in science or the educational processes, a lack of commitment to science by its teachers, and a lack of research by undergraduates (e. g., Goldberg, 1993; Moore, 1993). Such commentaries reveal that some editors may not be aware that many faculty have engaged students in research for years: teaching botany as science.

Nevertheless, it can be argued that students need many courses with traditional lecture/lab approaches with professors giving lectures and presenting ideas and facts, along with standard labs of experiments or observations and even such devices as problem-solving or hands-on-learning. In other words, there is some support for the concept that botany professors teach best when disseminating the fundamentals of essential botanical knowledge that students should know by standard lecture/lab formats. We disagree. If there is anything such as a unit of essential botanical knowledge, it is surely, in large part, that knowledge which derives from current scientific research and literature. In that context, what Moore stated has profound meaning (1986, p. 420): science makes its advances by "studying what is not known rather than what is . . . .known." Further, Seago (1992) argued that students probably generate a better and lasting framework of knowledge when they develop it within the context of science as research and with their own memory and learning systems, not when it is imposed.

Rather than review all the literature on this topic, we will present some of the ways students can participate more actively in coursework and concurrently get the excitement of a science course or program like botany. The arguments for a participatory approach are generally those put forth by Seago (1992): students should be generating and directing research in formal courses. In order for students to understand botany as science, not just the results of botany, it is necessary for them to participate in botany as science. We believe that students learn more botany by addressing research questions during a course.

While there are other elements of formal coursework in which students can actively participate in generating ideas and facts

Table 1. Elements of student participation in botany lecture/lab courses.

RESEARCH PROJECT	Proposal	1 page: general problem and methods	
	Project	lab and/or field work	
	Talk	10-15 min.; in class; like talk at annual meeting	
	Poster	during class time; paper format; high visibility; location	
	Paper	draft and manuscript reviews; literature retrieval; American Journal of Botany format	
JOURNAL ARTICLE	Talk	5-10 min.	summary of refereed research article
REVIEWS	Paper	1 page	general nature of problem, methods and results, meaning, and relation to course
COURSE SUBTOPICS	Talk	15-30 min.; specific course subtopics	
LABORATORIES	Experiments	student-generated work;	
	Observations	in conjunction with formal labs	
EXAMINATIONS	Essay	including work from student talks and labs	

(Table 1), research should be the most important element of science courses. To generate and direct a research project within the framework of formal courses, a student should produce a research proposal, usually after some discussion with the professor. This proposal should outline the problem, the materials to be used, and the methods to be followed. It may be presented in oral or written form, or both. The proposal must be approved before research can be begun.

Lab and/or field research should be conducted within the limitations of the facilities and the course, such as subject matter, credit units, time, supplies, instrumentation, etc.; students can be very imaginative at overcoming limitations. Students should try to overcome problems that invariably arise and that may cause unsatisfactory results. Even long projects that seem to fail can be useful to a student's understanding of scientific process in the discipline; rather than repeat such a project, the student should analyze the problems carefully for the paper and report what he/she did.

The formal communications of research are, of course, the culmination of science and thus of great importance to students. In many courses, student talks can be presented near the end of a term; talks of 10-15 minutes are presented like research talks at a scientific society's annual meetings. Students can also present posters in a paper format at a poster session arranged at class time in a location of high visibility, like a union lounge or main foyer of a science building. Talks or posters allow dialogue with others learning about the research projects. If a talk or poster precedes a paper, it can be used by the student to develop a better concept of the project before the paper is completed and submitted. Appendix 1 has project/paper titles for some botany courses.

The research paper should follow standard format as in the *American Journal of Botany* or other well-known journals: title, author, abstract, introduction, materials and methods, results, discussion, and literature cited. Titles may not be as precisely stated as they should be (see Table 2), because they

Table 2. Selected titles of student research projects in recent botany courses.

PLANT KINGDOM:
Diatoms of the SUNY Oswego campus littoral zone of Lake Ontario.
Tree Identification of a limited section of the SUNY Oswego lakeside.
The effects of IAA on *Vicia faba* growth.
Classification and identification of common Basidiomycetes in and around Oswego NY area.
The effects of cadmium on the progagtion of spider plants.
Collection of northeastern fungi.
Fall swamp flora identification of a swamp in Oswego County.
A study of *Ambrosia artemisifolia* pollen.
Phosphate uptake in *Oedogonium.*
An evaluation of autotoxic capabilities of *Typha angustifolia.*

DEVELOPMENTAL PLANT BIOLOGY:
The effects of GA3 on *Avena* coleoptile sections.
Propogation of geranium plants by shoot apical meristem tissue culture.
The effects of high cadmium levels on the root hair development of *Arabidopsis.*
The effects of GA3 and IAA on elongation of morning glory hypocotyls.
Light effects on the germination of light sensitive lettuce seeds and light insensitive lettuce seeds.

MORPHOLOGY OF NON-VASCULAR PLANTS:
A study of algae in Glimmerglass Pond.
An investigation of the microstructure and macrostructure of *Ustilago zeae..*
Fungi of New York's coniferous forests.
Algal sexual reproduction.
Different algae in Lake Ontario in the fall of 1986.

PLANT ANATOMY AND MORPHOLOGY:
Geotropism in roots.
Investigations on the chilling stress effects on *Phaseolus vulgaris.*
Water conditions in relation to plant stem anatomy and physical appearance.
Wood identification.
Leaf anatomy of *Aloe barbadensis* and the significance of the inner bundle sheath parenchyma.

CYTO-HISTO-TECHNIQUES:
A study of the stem of *Tradescantia sp.* plants.
A comparison of conifer needles using *Pinus strobus* and *Picea glauca.*
Structural differences in the mesocarp of different varieties of *Pyrus malus.*
Oil gland comparisons in *Citrus sinensis.*
An observation of calcium oxalate crystals in *Diffenbachia.*

PROBLEMS IN BIOLOGY: PLANTS AND ACID RAIN:
Acidic effects on cattail bud and root growth.
Acid rain effects on root hairs of radishes.
Acid deposition effects on carbohydrate mobility during germination of pea seeds.
Decreased growth of balsam fir in the uplands and wetlands of the Adirondack Mountains, NY.
Effects of acidic precipitation on the structure of chloroplasts and concentrations of B-carotene in *Spinacia oleracea* over given time intervals.

are sometimes not submitted when student manuscripts are reviewed and proofed. The abstract must be a paragraph with a succinct statement of the problem and the results. The introduction must contain a clear, concise statement of the research problem, question, hypothesis, or however the student presents the nature of the research pursued. Background, especially for advanced undergraduates or graduate students, may help lead to the statement of the problem.

Science requires that students participate in their own acquisition of knowledge and experience the excitement and the processes of science, especially through research and the scientific literature.

The materials and methods section must completely describe and list the organisms, supplies, techniques, procedures, instruments, sampling methods, and any statistical techniques employed. This descriptive section is hard for many students because they are accustomed to having had this section written for them in lab manuals. In the results section, students present their findings. At the undergraduate level, it is helpful to keep students from interweaving discussion into results so that they can focus on their own findings, observations, and data. Tables, graphs, drawings, photographs, and verbal descriptions are all important features of the results.

In the discussion section, the students should analyze whether or not their findings are properly based upon the problem posed and the materials and methods used. Then, they should make a comparison to the work of others from the literature; the amount of literature discussed may vary greatly with the level of the course. Botanical literature is cited in the various sections, especially the discussion, and needs to be referenced completely in a literature cited section which follows the rules for authors of the selected style; we recommend the practice in the *American Journal of Botany*. Referral to botanical literature is a very important feature of the research.

Students entering basic botany courses may have had very little exposure to library use and may, in fact, think of acceptable library research as using an encyclopedia and the *Reader's Guide to Periodical Literature*. Good literature retrieval, however, is critical. Most libraries are equipped with indices to the technical literature. These indices are found in hard-copy or book format, in databases stored on CD-ROM within the library itself, or in databases at remote locations that can be accessed "on-line" over telephone or data cables at most institutions. *Biological Abstracts* and *Science Citation Index* are among many such indices that students will find invaluable. There are also sources, such as *Biosis*, which allows access to many remote databases. Interlibrary loans may also be necessary and helpful in retrieving literature.

If professors also have students present short, narrowly prescribed topics or design labs (experimental or observational), students must prepare more deeply for one or more areas of the course and become more integrally involved in the course and its teaching. Thus, we can enhance a student's acquisition of knowledge, including the essential botanical knowledge of the discipline.

We think that having students read and report on refereed research articles from current scientific journals of the campus library is pedagogically sound and exciting. Students can present short, 5-10 minute talks in class and/or submit short, often one page summaries of recent research articles from current journals; these can cover any aspect or subtopic of a course's subject matter. The students should present a brief account of the objective of the research problem, the general methods used and results obtained, the overall meaning of the research, and the relation of the research in the article to the subject matter of the course.

Scientific literature conveys some of the excitement that cannot be done effectively and timely in texts. As soon as students start delving into the abstract or introduction to a paper, they are reading current science, seeing what scientists think is important today, and learning what scientists think is essential knowledge. Even if the articles are

difficult to read and understand, students often get the gist of them, and suddenly the scientific world is so much larger and more interesting. Scrutinizing the works of modern scientists is a wonderful learning device and an important complement to the conduct of research. The authors of such works can serve as models for the student.

Incorporating material from the various student presentations into examinations deepens the participation of students in formal botany courses and heightened their attention to the work of others. We find this easier to do with essay-type examinations that permit students to explore the relation between student contributions and teacher expectations.

We recognize that there are many effective pedagogical methods in college education, but the use of undergraduate student research and participatory learning in courses can only enhance student interest in and understanding of science. Science requires that students participate in their own acquisition of knowledge and experience the excitement and the processes of science, especially through research and the scientific literature. Involvement of students in research and research communications produces essential botanical knowledge and must receive a high-

Scientific literature conveys some of the excitement that cannot be done effectively and timely in texts. . . . they are reading current science, seeing what scientists think is important today, and learning what scientists think is essential knowledge.

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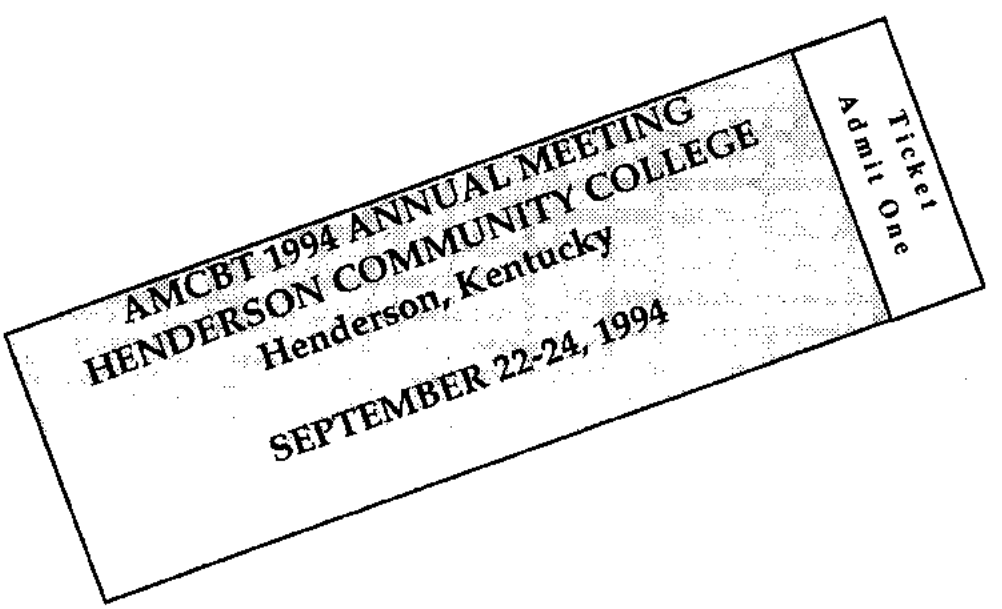

The Scientific Attitude

by Frederick Grinnell
New York: Guilford, 1992 (2nd ed.)

Book Review

by
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Examining the processes of science is presently the favorite sport of many sociologists and philosophers of science, so it's refreshing to read a book on the subject by a practicing scientist, by someone who speaks from experience. Frederick Grinnell is a cell biologist, and his book is an examination of the "scientific attitude" from the viewpoint of someone who has obviously done a great deal of self examination to be able to write so perceptively on what it is to do science. By "scientific attitude," Grinnell means something different from what C. H. Waddington did when he wrote a book with the same title in 1941. Discussing the cultural impact of science, Waddington argued that the scientific attitude could be a valuable moral force for good in the political and cultural realm.

Grinnell, on the other hand, focuses directly on science rather than the larger culture and emphasizes the idea that "understanding science means understanding it as something that people do," as a human endeavor. By scientific attitude, Grinnell means not an approach to solving the world's problems, but a way of viewing the world. He sees this attitude, as opposed to other ways of looking at the world, as "radically intersubjective," meaning that observations and hypotheses are intersubjectively valid such that they can be confirmed by anyone. He writes: "My assumption as an individual scientist is that other investigators could adopt a similar scientific attitude and confirm my observations and hypotheses." This seems terribly obvious, but it cuts to the essence of science, and, therefore, it is important that this aspect of science is appreciated by everyone, scientist and nonscientist alike.

Grinnell's intended audience would seem to be young people who are considering, or have recently decided upon careers in science. While those interested in any scientific field will profit from reading the book, it would seem most useful to those interested in biology, since most of Grinnell's examples are drawn from this science. This is a very personal book since the author writes freely of the mistakes he has made and of what he has learned from them. Those who are interested in the deeper issues in the philosophy of science will be disappointed, since much of the discussion is at a very practical level: how do you choose a field of study; how do you become part of a "scientific collective;" how do you get grants? This type of information is obviously very important to young researchers, and is often neglected in books on the process of science, so its coverage here is welcome. This approach, however, reduces the general appeal of the book, since some of this material is of little interest to the seasoned researcher or to the lay person seeking a better understanding of the workings of science. But there is still a great deal here that is of value to all readers. One major change in this second edition is that Grinnell has expanded his discussion of scientific misconduct, which is now the focus of much more attention than it was in 1983, when he started writing the first edition.

One thing I found mildly annoying in the book is the diversity of topics Grinnell covers in a single chapter. For example, in Chapter Three: *Experimental Design and Interpretation*, he manages to include not only the expected material on hypothesis formation and reproducibility, but such topics

as luck in science and the levels of structure in biological organisms. I can appreciate Professor Grinnell's problem: he is trying to give the beginning biologist a look at all facets of the profession, from its philosophical underpinnings to its most practical aspects, and to do all this, he must pack a lot into each chapter. Yet despite the difficulties involved, I think he could have chosen a slightly tighter organization.

But I don't want my fault-finding to discourage you from reading this book; it is really a worthwhile volume, not only for young biologists, but for those who teach them. It reminds us of all the aspects of our science that we must present to students, including many aspects we tend to take for granted. This is especially true of our role in initiating new biologists into a "thought collective," a term which can be used to mean many things from the collective of the science in general to the small collective of researchers involved in a particular problem, using particular techniques, and viewing the problem from a particular perspective.

In Chapters Four and Five, Grinnell discusses scientific collectives and argues that it is best for students to appreciate the variety of styles and approaches in science. While reading these chapters, I was reminded of Jonathan Harwood's *Styles of Scientific Thought* (University of Chicago Press, 1993) in which he discusses the scientific styles of German geneticists in the first three decades of this century. In his brilliant analysis, Harwood shows how educational, cultural, and psychological factors contributed to a biologist's scientific style. Grinnell's approach is much more practical than Harwood's; he takes ideas similar to those Harwood uses and looks at their practical rather than their philosophical aspects: how do you enter a thought collective by choosing a thesis advisor; how the thought style is transmitted from senior to junior workers; and how research reports, journal articles, and funding contribute to the maintenance of a thought style.

Why this emphasis on thought style? Grinnell sees it at the heart of science and as the most fundamental thing which a young researcher learns from a thesis advisor. He quotes an unnamed Nobel Prize winner as saying of this person's advisor, also a Nobel Laureate, that the most important thing he had learned was style rather than information: "It's the contact: seeing how they operate, how they think, how they go about things. (Question: Not the specific knowledge?) No, not at all. It's learning a style of thinking, I guess."

This is probably the most important message that this books imparts: science is a process, a style of thought, as much as it is a body of knowledge. Most young scientists have spent their time learning the body of knowledge and this other aspect of science is foreign territory to them. Grinnell's book is a very useful map of this territory of style.

News and Views

CONGRATULATIONS TO THE NEWLY ELECTED AMCBT OFFICERS:

President
Harold Wilkinson, Millikin University, Illinois

Secretary
Dorothy May, Park College, Missouri

Members-at-Large
Marc Roy, Beloit College, Wisconsin
Karen Klyczek, U. of Wisconsin-Park Falls, Wisconsin

AMCBT FINANCIAL REPORT - 1992

INCOME

160 renewals (146 Regular[31 new]; 14 Retired

Full Dues	$2,900.00
$15 Advance Special (91 payment)	135.00
1991 Dues payments	430.00
Miscellaneous collections	50.00
Contributions	40.00
Subtotal	$3,555.00
Deposits from 1992 Meeting-St. Xavier University	$4,104.75
Checking Account Balance--1/1/92	$1,340.99
Total Income	**$9,000.74**

EXPENSES

Steering Committee Meeting--Spring 1992	$1,059.36
ASM-CELS Meeting--John Jungck	250.00
Mailing Supplies	49.74
Miscellaneous Postage	81.31
Bioscene publication	1,852.00
Mailing Costs: Bioscene, Directory, Fall Programs	302.67
Printing Costs: Directory, Fall Programs	118.27
Fall Meeting Costs--Sr. Marion	617.17
Fall Meeting Costs--Canteen Corp.	2,035.00
Total Expenses	**$6,365.52**

Total Income:	$9,000.74
Total Expenses:	$6,365.52
Net Balance:	$2,635.22
Present Checkbook Balance:	$2,649.77

AMCBT INTERIM FINANCIAL REPORT - 1993

INCOME (to date)

141 renewals @ $25.00	$3525.00
22 New Members @ $25.00	550.00
7 Retired Members	70.00
23 Members--Back Dues	1020.00
1 Sustaining (carried from 92)	50.00
Total Income	**$5215.00**

EXPENSES (to date)

Steering Committee Planning Meeting	$1630.48
Bioscene Publication (2 issues)	1159.00
Publication of Meeting Materials	108.17
Mailing of all materials	325.63
Total Expenses	**$3223.28**

SAVINGS ACCOUNT (9/30/93):	$1,388.68
CHECKING ACCOUNT (10/18/93):	$4,735.40

AMCBT TENTATIVE BUDGET - 1994

1.	Steering Committee Expenses	$1,500.00
2.	Bioscene Publication and Mailing	2,500.00
3.	Executive Secretary--Postage, Printing	650.00
4.	1994 Meeting Expenses	950.00
	TOTAL:	$5,600.00

AMCBT Honorary Life Member: Laddie J. Bicak

Professor Emeritus, University of Nebraska at Kearney, Laddie Bicak has been a member of AMCBT for 22 years. He was a Steering Committee Member 1978-1980. Professor Bicak has authored over a dozen publications as well as several books in Science Education.

Professor Bicak served as Dean of the Graduate School at Kearney, 1969-1978, was President of the Nebraska Academy of Sciences, 1978-1979, and was also a member of the executive committee for several years.

Previously Unpublished Abstracts from 1993 AMCBT Meeting at Millikin University, 28-30 October 1993

Sessions

II.4. Using Automated Technology Systems in Undergraduate Microbiology Courses

Dorothy May, Park College, Parkville, MO

A demonstration/workshop will be presented on the preparation, inoculation, and interpretation of BIOLOGY Microplates, a rapid automated identification system. The test plate consists of a matrix of wells containing 95 different carbon sources which, when oxidized, turn color. The resultant pattern of purple and colorless wells produces a "metabolic fingerprint" of the test organism. The prepared Microplates can be inoculated by inexpensive means and read manually or automatically. Interpretation is made by way of a software demonstration disk, which is available at no cost to teachers.

II.4. Hydrothermal Vent for Midwesterners: Deep Sea as the Largest Habitat on Earth

Nancy Sander, NorthEast Nissouri State

The presentor's film from aboard the Alvin while diving the Galapagos hydrothermal vent will be used to focus educational discussion of this recently discovered ecosystem.

Posters

P.1. Problem Solving Sets and Clinical Case Studies: A Nontraditional Approach to the Undergraduate Biochemistry Experience

Joyce Kaleta, Sharon Rose and Melissa Vought, Purdue University North Central, Westville, IN 46391

A nontraditional educatioaln approach to an undergraduate biochemistry course has been initiated on an experimental basis at PU/NC. This approach utilizes problem solving sets and clinical case studies as the central learning tool for evaluating biochemical phenomena, as opposed to the traditional pursuit of memorizing biochemical structures and pathways for the purpose of examination. Under the direction of and with assistance from the instructor, students work on and discuss the problem sets and case studies, enhancing their understanding of biochemical concepts and applicaitons, while fostering problem solving and critical thinking skills. The process and outcome assessment of this educational endeavor are presented by the undergraduates involved.

P.3. Some Mathematical Interpretations for Elementary Presentations of Cell Structure

Norman Woldow, Maryville University, St. Louis, MO 63141

There is no need for introductory presentations of cell structure to be non-mathematical. By explor-

ing some ideas of topology, tessellations and some interesteing recreational puzzles, we can enrich the contexts both of biology and mathematics for our students.

A mathematical interpretation of cell structure depends on finding corresponding topics that are meaningful both in mathematics and cell theory. (1) Topology is an area of modern mathematics whose abstractions are general enough to avoid contradicting many of the observations of cell structure. At the same time, topology provides concepts that can simplify some of the complex detail of cell structure without compromising the integrity of the biological abstractions: simplification without over-simplification. (2) Tessellations can be used to study how sets of discrete shapes can "fit" together to "cover" a surface. The individual shapes are called "Tiles" in a productive analogy for the highly complex "fitting together" of diverse molecules in three dimensional cell structures. A "contact puzzle" and the "hexa-flexagon" are two topics from recreational mathematics that are highly descriptive of cell structure and function.

P.4. Teaching Invertebrate Biology by Constructing Alien Life Forms

K. A. Grimnes, Alma College, Alma, MI 48801

The incredible diversity of invertebrate form and function as well as the difficulties of terminology and taxonomy tend to reduce invertebrate groups to vocabulary lists, character tables and species memorization. Students can easily lose sight of the fact that diverse animals must solve the same basic problems to remain alive. The Alien Life Project entices students to adopt a more integrative approach toward morphology and physiology of the invertebrates they are studying. In the project, students "discover" and "report" on three alien life forms (a parasitic, an inactive and an active species). These reports include drawings and explanations of body form, internal systems and reproductive behavior. Special attention must be paid to integration of the systems with form and lifestyle; successful integration on paper generates "life" for the animal. Extensive revision is allowed since students may encounter substantial design flaws and often must rework their entire animal. Student-reported outcomes include an increased subject interest, a greater appreciation of the biological complexities of adaptation and evolution, as well as a certain pride in their application of higher order decision-making skills.

P.5. Measurements of Light Quality and Other Factors on the Rate of Photosynthesis

K. L. Rukes and T. J. Mulkey, Life Sciences Department, Indiana State University, Terre Haute, IN 47809

The study of photosynthesis in a teaching laboratory often involves specialized equipment which is expensive to purchase and maintain as well as being too difficult to be mastered in the limited time available for the students in the laboratory. Thus, photosynthesis is often a topic which is demonstrated or even ignored in the general biology laboratory. A simple, inexpensive technique for hands-on exploration of the effect of light quality on the rate of photosynthesis in leaf disks will be presented. The laboratory can be easily modified to allow examination of the effects of light quality (determination of light compensation point), CO_2 levels (carbon dioxide compensation point), herbicides, and environmental pollutants on photosynthetic rates. The simplicity of the techniques allow modification of the protocol for examination of many aspects of photosynthesis including the physiological differences between C3 and C4 photosynthesis.

P.6. Hormonal Regulation of Cotyledon Senescence

K. L. Rukes and T. J. Mulkey, Life Sciences Department, Indiana State University, Terre Haute, IN 47809

The dogma which is presented in textbooks states that senescence in plant tissue is a process of aging which is under the control of cytokinins. In reality senescence which includes degreening, fruit ripening, flower fading, abscission, etc. is a complxs set of physiological processes which involve several plant hormones and interactions between the hormones. This laboratory exercise explores one senescent process, cotyledon degreening. Slight modifications in the protocol by different students or groups of students allows a class to examine the effects and interactions of auxins, gibberellins, cytokinins, abscicic acid, and ethylene on a well defined system. Discussion of

class data provides a basis for the introduction of the complexity of the interaction of plant hormones which is required for physiological and developmental control in plants.

P. 7. Hormones and the Motor Response of Root Gravitropism

S. Y. Kim and T. J. Mulkey, Life Sciences Department, Indiana State University, Terre Haute, IN 47809

Gravitropism is a growth movement which results from the response of roots and shoots to gravity. The motor response of gravitropism is the asymmetric growth which occurs on the opposing sides of a plant organ which results in curvature. Two theories are presented by current textbooks concerning the hormones involved in the motor response of roots during gravitropism. The Cholodny-Went hypothesis proposes that auxin is the regulatory hormone. The Root Cap Inhibitor model proposes that abscisic acid is the regulatory hormone. This simple, inexpensive laboratory exercise allows students to examine the involvement of auxin and abscisic acid or any of the hormones/growth regulators in the motor response. From this laboratory experiment, students are able to determine which theory should be discarded.

P. 8. Calcium Movement During Root Gravitropism

S. Y. Kim and T. J. Mulkey, Life Sciences Department, Indiana State University, Terre Haute, IN 47809

Plants which are reoriented in a gravitational field exhibit differential growth rates of opposite sides of plant organs. The initial event of gravitropism is sensing the change in the orientation of the gravity vector. The sensor mechanism of shoots is diffuse, but the sensor mechanism of roots is localized inthe root cap. This laboratory exercise allows students to examine the redistribution of calcium ions, a key trigger event, during the graviresponse of roots. This exercise can be used to introduce students to concepts associated with radioisotopes, tracer techniques, active transport and diffusion, as well as the sensory mechanism of gravitropism.

P.9. Auxin and Protein Phosphorylation in Plants

S. Y. Kim and T. J. Mulkey, Life Sciences Department, Indiana State University, Terre Haute, IN 47809

Many physiological and developmental processes in plants and animals require protein phosphorylation as a post-translational reversible covalent modification which is central to the regulatory control of the processes. Auxin controls many physiological processes such as cell elongation, cell division, and differentiation in plants and elicits rapid responses in orgnaelles such as the plasma membrane, golgi apparatus, endoplasmic reticulum and the nucleus as well as in the cell wall. This laboratory exercise allows students to examine protein phosphorylation in cytoplasmic and membrane components associated with hormonal regulation in plants. This exercise presents students with hands-on experience with electrophoresis and autoradiography, two common techniques which are widely used in current research laboratories. The equipment which is required is normally available in most biology departments. The techniques are simple and easily mastered. Slight modifications in the protocol and biological specimens allows students to investigate a wide array of regulatory mechanisms in both plants and animals.

Application For Membership

ASSOCIATION OF MIDWESTERN COLLEGE BIOLOGY TEACHERS

NAME:_____ DATE:_____

TITLE:_____

DEPARTMENT:_____

INSTITUTION:_____

STREET ADDRESS:_____

CITY:_____STATE:_____

ZIP CODE:_____

ADDRESS PREFERRED FOR MAILING:_____

CITY:_____STATE:_____

ZIP CODE:_____

WORK PHONE:_____ FAX NUMBER:_____

HOME PHONE: _____ E-MAIL ADDRESS:_____

MAJOR INTERESTS:

( ) 1. Biology
( ) 2. Botany
( ) 3. Zoology
( ) 4. Microbiology
( ) 5. Pre-professional
( ) 6. Teacher Education
( ) 7. Other_____

SUB DISCIPLINES: (Mark as many as apply)

( ) A. Ecology
( ) B. Evolution
( ) C. Physiology
( ) D. Anatomy
( ) E. History
( ) F. Philosophy
( ) G. Systematics
( ) H. Molecular
( ) I. Development
( ) J. Cellular
( ) K. Genetics
( ) L. Ethology
( ) M. Neuroscience
( ) N. Other_____

RESOURCE AREAS:

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RESEARCH AREAS:

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How did you find out about AMCBT? _____

Have you been a member before?_____ If so, when?_____

PLEASE MAIL

MEMBERSHIP APPLICATION

FORMS TO:

Edward S. Kos
Executive Secretary, AMCBT
AMCBT Central Office
Department of Biology
Rockhurst College
1100 Rockhurst Road
Kansas City, MO 64110-2561

CURRENT DUES ARE **$25.00**